ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR-
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CTD Data Processing Report

RV POLARSTERN Cruise PS118

Dr. Sandra Tippenhauer and Gerd Rohardt

Contents

1. Introduction

This document reports about the processing of CTD raw data acquired during expedition PS118 by a Seabird SBE 911plus CTD on board RV POLARSTERN.

2. Cruise Details

Vessel	RV POLARSTERN
Cruise	PS118
Region	Weddell Sea
Departure	Punta Arenas, 19 February 2019
Arrival	Punta Arenas, 10 April 2019
Responsible operator	Markus Janout, Alfred-Wegener-Institute, Germany
Responsible for data processing	Sandra Tippenhauer, Alfred-Wegener-Institute, Germany
Number of CTD casts	52
Number of processed casts	52

3. Instrument and Software Configuration

This chapter summarized the configuration of the acquisition software, the rosette assembly, CTD sensors, and salinometer.

Software		
	CTD data acquisition	SBE[1] SeasaveV7, Version 7.23.1
	CTD on board processing	ManageCTD[2]
	Matlab®	Individual tools
Rosette assembly		
	CTD/Deckunit	SBE911 plus; SN 937 (on board system)
	Carousel Water Sampler	SBE32

Sensors

	Type	SN	Pre-calibration	Post-calibration
Pressure	Digiquartz with TC	937	14-Nov-2017	-/-
Primary Temperature	SBE3plus	2929	23-Nov-2017	13-Sep-2019
Primary Conductivity	SBE4c	1198	15-Nov-2017	17-Sep-2019
Secondary Temperature	SBE3plus	5112	29-Jun-2018	13-Sep-2019
Secondary Conductivity	SBE4c	3570	03-Jul-2018	17-Sep-2019
Oxygen	SBE43	1597	06-Jul-2018	25-Sep-2019
Transmisometer[3]	Wetlabs CSTAR	1198	17-Dec-2008	-/-
Fluorometer[3]	Wetlabs EcoFLR	1853	26-May-2010	-/-
Altimeter[3]	Benthos PSA900D	51533	-/-	-/-

Salinometer

OPS	SN 006
Standard Seawater	P160; K15 = 0.99983, expiry date 2019-07-20.

Remarks:
[1] : SBE = Sea Bird Scientific
[2] : AWI software package which includes SBEDateProcessing, Version 7.22.5
[3] : Not calibrated, use relative values only or no required

4. Station list and notes

This chapter contains a station list and the notes made during CTD casts. CTD worked fine without any serious problems.

Tab. 1: List of CTD stations from leg PS118

Station	Cast	Date/Time	Latitude	Longitude	Echo Sounder (m)	Alti-meter (m)	CTD max. Pressure (dbar)	Remark
4	1	22-Feb-2019 18:45:28	63 49.122 S	56 28.626 W	534	8	512	salinity samples
5	1	04-Mar-2019 15:29:50	64 59.022 S	57 45.096 W	445	5	424	
6	1	05-Mar-2019 12:26:09	64 58.806 S	57 46.560 W	440	9	418	Identical with PS118_005_6
8	2	11-Mar-2019 16:38:14	63 59.838 S	55 54.366 W	412	9	404	
10	1	13-Mar-2019 11:55:14	64 0.180 S	55 58.596 W	414	8	407	
11	1	13-Mar-2019 18:33:16	63 53.994 S	55 40.542 W	234	9	233	
12	1	14-Mar-2019 07:04:11	63 48.396 S	55 44.658 W	456	8	449	
13	1	17-Mar-2019 11:31:48	63 4.116 S	54 18.744 W	423	8	415	
15	2	18-Mar-2019 19:00:37	62 1.170 S	54 58.914 W	1506	12	1469	
16	1	19-Mar-2019 00:07:00	61 54.000 S	53 48.162 W	823	8	829	LADCP, salinity samples
17	1	19-Mar-2019 01:55:40	61 55.170 S	53 39.834 W	603	8	581	LADCP
18	1	19-Mar-2019 03:17:49	61 56.322 S	53 31.998 W	1006	8	979	LADCP
19	1	19-Mar-2019 05:02:36	61 58.302 S	53 22.464 W	1484	10	1448	LADCP
20	1	19-Mar-2019 07:10:48	62 0.336 S	53 9.000 W	2217	12	2188	LADCP, salinity samples
21	1	19-Mar-2019 11:03:22	62 2.496 S	52 53.388 W	2468	7	2518	
22	1	19-Mar-2019 14:16:12	62 3.360 S	52 39.972 W	2668	9	2639	
23	1	19-Mar-2019 18:03:52	62 6.798 S	52 23.658 W	2831	10	2814	LADCP, salinity samples
24	1	20-Mar-2019 01:25:00	62 15.210 S	51 28.776 W	3270	9	3259	
24	4	20-Mar-2019 09:55:21	62 14.460 S	51 25.980 W	3286	10	3278	LADCP
26	1	20-Mar-2019 21:17:43	62 22.932 S	52 2.250 W	3061	20	3037	LADCP
27	1	21-Mar-2019 02:31:23	62 31.098 S	52 30.480 W	2917	9	2902	
28	1	21-Mar-2019 07:11:23	62 35.640 S	52 47.622 W	2809	7	2791	LADCP
29	1	21-Mar-2019 11:22:27	62 39.216 S	53 2.124 W	2411	9	2400	LADCP
30	1	21-Mar-2019 14:09:35	62 43.140 S	53 17.370 W	1386	8	1364	
32	1	21-Mar-2019 21:55:19	62 45.780 S	53 26.946 W	860	9	878	LADCP, salinity samples
33	1	22-Mar-2019 00:33:58	62 48.264 S	53 36.036 W	417	6	402	
34	1	22-Mar-2019 01:42:45	62 50.838 S	53 45.588 W	285	8	283	
35	1	22-Mar-2019 03:26:33	62 55.218 S	54 1.890 W	300	9	296	
36	1	22-Mar-2019 05:43:54	62 59.988 S	54 19.566 W	296	8	293	
38	1	22-Mar-2019 11:57:21	63 4.350 S	54 21.432 W	445	9	438	
38	12	23-Mar-2019 03:48:35	63 4.266 S	54 20.184 W	432	10	424	LADCP
41	1	25-Mar-2019 12:27:13	61 19.632 S	51 50.262 W	546	10	536	
42	1	25-Mar-2019 13:57:42	61 23.136 S	51 42.690 W	535	9	528	LADCP
43	1	25-Mar-2019 15:40:07	61 27.252 S	51 32.562 W	627	4	622	LADCP
44	1	25-Mar-2019 17:37:46	61 30.156 S	51 25.278 W	1997	15	1992	LADCP
45	1	25-Mar-2019 20:05:57	61 32.640 S	51 18.540 W	2745	9	2725	LADCP, salinity samples
46	1	25-Mar-2019 23:21:39	61 35.496 S	51 8.574 W	2896	10	2879	LADCP
49	2	26-Mar-2019 18:40:28	61 28.830 S	51 31.086 W	1212	99	1218	

Station	Cast	Date/Time	Latitude	Longitude	Echo Sounder (m)	Alti-meter (m)	CTD max. Pressure (dbar)	Remark
51	1	27-Mar-2019 04:32:23	60 50.808 S	50 11.898 W	1899	8	1881	LADCP
52	1	27-Mar-2019 06:54:45	60 51.024 S	50 0.198 W	2147	10	2137	LADCP
53	1	27-Mar-2019 10:14:51	60 51.108 S	49 45.630 W	2599	11	2612	LADCP, salinity samples
54	1	27-Mar-2019 13:17:02	60 50.436 S	49 35.502 W	2689	7	2671	
55	1	27-Mar-2019 16:10:22	60 50.844 S	49 23.442 W	2553	13	2524	LADCP
56	1	27-Mar-2019 18:44:47	60 50.652 S	49 12.336 W	1903	10	1868	LADCP
57	1	27-Mar-2019 21:00:21	60 50.682 S	49 0.228 W	1122	10	1094	LADCP
58	1	27-Mar-2019 23:59:29	60 51.234 S	48 31.968 W	2090	10	2054	
59	1	28-Mar-2019 03:04:34	60 51.030 S	48 11.790 W	2632	10	2608	LADCP
60	1	28-Mar-2019 06:08:35	60 51.090 S	47 54.054 W	2253	11	2218	LADCP, salinity samples
61	1	28-Mar-2019 09:32:05	60 50.994 S	47 31.032 W	1973	10	1947	LADCP
62	1	28-Mar-2019 13:22:59	60 55.842 S	46 33.516 W	327	7	324	
71	2	31-Mar-2019 20:21:26	61 4.644 S	51 46.458 W	890	12	862	LADCP
82	2	04-Apr-2019 14:39:05	61 13.392 S	52 29.406 W	1002	11	971	LADCP

5. In-situ Salinity Calibration

To monitor the accuracy and precision of the CTD's conductivity sensors, water samples were taken on 23 CTD casts for salinity/conductivity measurements. 22 double samples were taken to increase accuracy. 11 samples where contaminated and are thus not discussed here.
Samples were taken from different depths to investigate the influence of pressure on the conductivity sensor. The sampled water depth with the corresponding bottle data is given in Table 2. During data processing (*CTDdespike*) it was found that the T/S profiles from the secondary sensor pair are noisier than from the primary sensor pair. Therefore, the data from the primary sensor pair was taken for the final data set.
The statistics of the differences between the primary and secondary sensor pair is shown in Figure 1. The general behavior of the sensors was good.
The difference of salinities measured with the Optimare Precision Salinometer (OPS) and salinities measured with the CTD are used to correct for the pressure-effect and for a temporal drift of the sensors. The mean of the difference of salinities measured with the OPS and salinities measured with the CTD primary sensor pair (S0) was -0.0017 with a standard deviation of $7.25e^{-4}$.

Tab. 2: Comparison of CTD measured salinities and salinity samples measured with the OPS. The table gives the station name (Station) and date (Date Time) of each station where samples have been taken, the depth of the sample origin (press), the salinities measured with the CTD primary sensor (s0) and secondary sensor (s1), the salinity measured with the OPS, as well as the differences of the OPS measurements and the primary (OPS-s0) and secondary (OPS-s1) sensor pair of the CTD.

Station	Date Time	press	s0	s1	OPS	OPS-s0	OPS-s1
ps118_004_1	22.02.2019 18:30	404	34,5056	34,5031	34,5086	0,0030	0,0055
		404	34,5056	34,5031	34,5083	0,0027	0,0052
		404	34,5056	34,5031	34,5090	0,0034	0,0059
		404	34,5056	34,5031	34,5088	0,0032	0,0057
ps118_005_1	04.03.2019 15:15	423	34,5760	34,5736	34,5775	0,0015	0,0039
		253	34,5517	34,5490	34,5542	0,0025	0,0052
ps118_013_1	17.03.2019 11:19	415	34,5642	34,5606	34,5638	-0,0004	0,0032
		303	34,5018	34,4986	34,5014	-0,0004	0,0028
		102	34,2020	34,2031	34,2156	0,0136	0,0125
		3	33,8378	33,8356	33,8405	0,0027	0,0049
ps118_015_2	18.03.2019 18:27	1215	34,5741	34,5712	34,5738	-0,0003	0,0026
		809	34,5502	34,5472	34,5504	0,0002	0,0032
		405	34,5305	34,5270	34,5304	-0,0001	0,0034
		20	33,5432	33,5418	33,5457	0,0025	0,0039
ps118_016_1	18.03.2019 23:47	455	34,5417	34,5390	34,5419	0,0002	0,0029

Station	Date Time	press	s0	s1	OPS	OPS-s0	OPS-s1
		455	34,5417	34,5390	34,5423	0,0006	0,0033
ps118_018_1	19.03.2019 02:52	810	34,6301	34,6268	contaminated		
ps118_018_1	19.03.2019 02:52	810	34,6301	34,6268	34,6302	0,0001	0,0034
		530	34,6432	34,6369	contaminated		
		530	34,6432	34,6369	34,6437	0,0005	0,0068
ps118_020_1	19.03.2019 06:22	1827	34,6422	34,6386	34,6414	-0,0008	0,0028
		1827	34,6422	34,6386	34,6410	-0,0012	0,0024
		2	33,4280	33,4260	33,4299	0,0019	0,0039
		2	33,4280	33,4260	33,4310	0,0030	0,0050
ps118_022_1	19.03.2019 13:18	2031	34,6468	34,6431	34,6454	-0,0014	0,0023
		1013	34,6785	34,6748	34,6776	-0,0009	0,0028
ps118_023_1	19.03.2019 17:06	911	34,6773	34,6735	34,6761	-0,0012	0,0026
		911	34,6773	34,6735	34,6754	-0,0019	0,0019
		20	33,3955	33,3947	33,4568	0,0613	0,0621
		20	33,3955	33,3947	33,4552	0,0597	0,0605
ps118_027_1	21.03.2019 01:31	1012	34,6830	34,6792	34,6820	-0,0010	0,0028
		1012	34,6830	34,6792	34,6812	-0,0018	0,0020
		505	34,6841	34,6807	contaminated		
		505	34,6841	34,6807	34,6833	-0,0008	0,0026
ps118_030_1	21.03.2019 13:39	1113	34,6401	34,6366	34,6398	-0,0003	0,0032
		1113	34,6401	34,6366	34,6385	-0,0016	0,0019
		608	34,6609	34,6573	34,6602	-0,0007	0,0029
		608	34,6609	34,6573	34,6592	-0,0017	0,0019
ps118_032_1	21.03.2019 21:31	877	34,6346	34,6313	contaminated		
		877	34,6346	34,6313	34,6351	0,0005	0,0038
ps118_033_1	22.03.2019 00:21	303	34,6087	34,6055	34,6099	0,0012	0,0044
		303	34,6087	34,6055	34,6089	0,0002	0,0034
ps118_035_1	22.03.2019 03:16	278	34,4938	34,4906	34,4960	0,0022	0,0054
		278	34,4938	34,4906	34,4954	0,0016	0,0048
		2	33,9433	33,9404	33,9666	0,0233	0,0262
		2	33,9433	33,9404	33,9662	0,0229	0,0258
ps118_041_1	25.03.2019 12:11	505	34,5760	34,5731	contaminated		
		505	34,5760	34,5731	34,5744	-0,0016	0,0013
		404	34,5745	34,5718	34,5760	0,0015	0,0042
		404	34,5745	34,5718	34,5760	0,0015	0,0042
ps118_043_1	25.03.2019 15:22	557	34,6048	34,6012	contaminated		
	25.03.2019 15:22	557	34,6048	34,6012	contaminated		
		305	34,5560	34,5528	contaminated		
		305	34,5560	34,5528	34,5559	-0,0001	0,0031
ps118_045_1	25.03.2019 19:08	2437	34,6454	34,6416	34,6431	-0,0023	0,0015
		2437	34,6454	34,6416	34,6432	-0,0022	0,0016
		709	34,6877	34,6839	contaminated		
		709	34,6877	34,6839	34,6861	-0,0016	0,0022
ps118_051_1	27.03.2019 03:50	1624	34,6500	34,6462	34,6483	-0,0017	0,0021
		1624	34,6500	34,6462	34,6483	-0,0017	0,0021
		1216	34,6521	34,6484	34,6507	-0,0014	0,0023
		1216	34,6521	34,6484	34,6505	-0,0016	0,0021
ps118_054_1	27.03.2019 12:21	2540	34,6446	34,6406	34,6423	-0,0023	0,0017
		2540	34,6446	34,6406	34,6421	-0,0025	0,0015
		2030	34,6476	34,6440	34,6455	-0,0021	0,0015
		2030	34,6476	34,6440	34,6454	-0,0022	0,0014
ps118_055_1	27.03.2019 15:13	2439	34,6460	34,6422	34,6444	-0,0016	0,0022
		2439	34,6460	34,6422	34,6443	-0,0017	0,0021
		2130	34,6476	34,6439	34,6454	-0,0022	0,0015
		2130	34,6476	34,6439	34,6452	-0,0024	0,0013
ps118_058_1	27.03.2019 23:15	1622	34,6554	34,6518	contaminated		
		1622	34,6554	34,6518	contaminated		
		1318	34,6574	34,6538	34,6547	-0,0027	0,0009
		1318	34,6574	34,6538	34,6541	-0,0033	0,0003
ps118_060_1	28.03.2019 05:21	769	34,6674	34,6654	34,6681	0,0007	0,0027
		769	34,6674	34,6654	34,6683	0,0009	0,0029

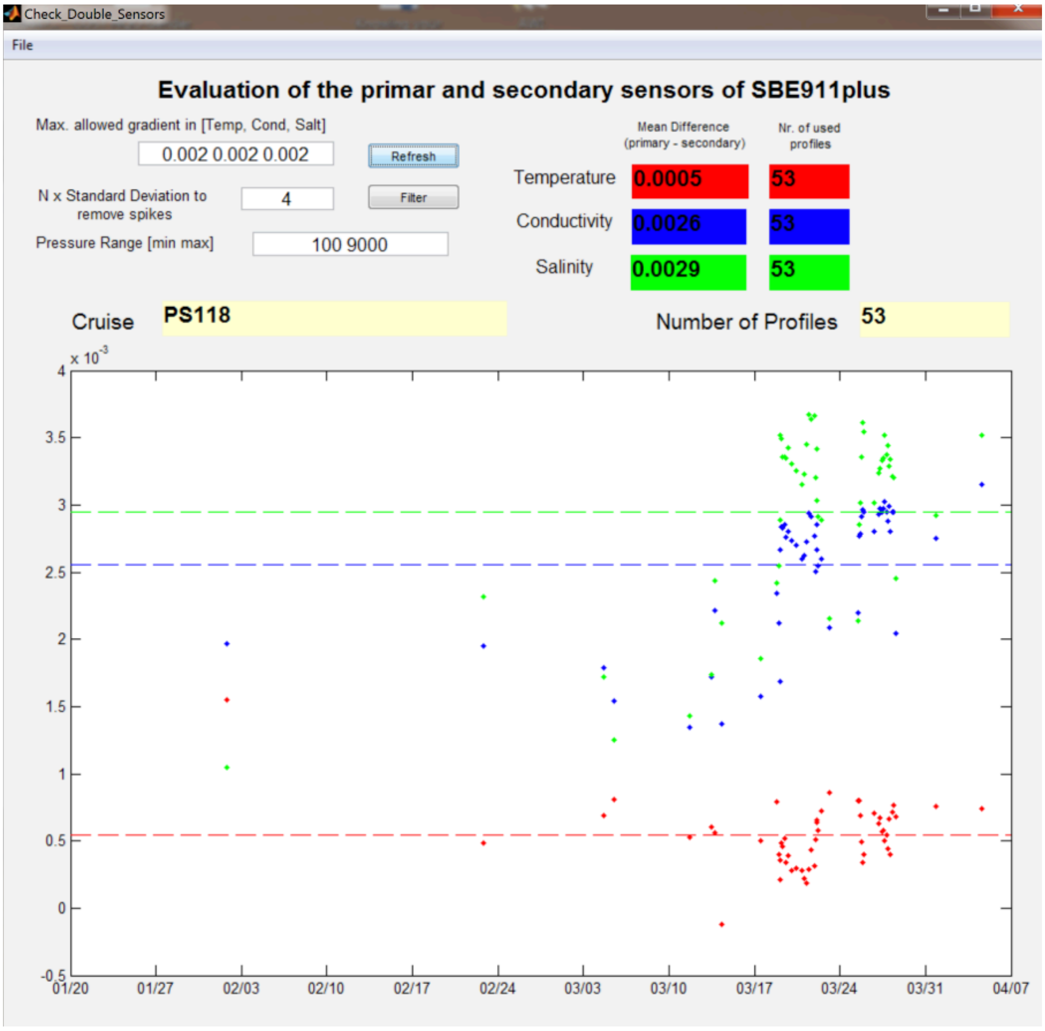

Fig. 1: The statistics of the differences between the primary and secondary sensor pair from layers below 100 m and gradients less than 0.002 (°C/m or mS/m^2).

Determining the pressure effect and temporal drift

To determine a pressure effect or a temporal drift of the sensors, the difference of salinities (S_{diff}) measured with the OPS (S_{OPS}) and salinities measured with the CTD (S_{Senor1} or $S_{Sensor2}$), is fitted against pressure and time using a first order polynomial and the matlab function polyfit.

$$S_{diff} = S_{OPS} - S_{Senor1 \text{ or } 2}$$

Because gradients are strong in shallow water depths, only samples taken from deep layers should be used for the corrections (below 1000m). For this cruise only 10 samples were taken below 1000m. Therefor we use all samples taken below 500m depth, to better constrain the fit for correcting the pressure-effect. Additionally, S_{diff} was set to be zero at the surface, as the pressure effect should vanish there. The resulting pressure-effect-correction has an offset of -8.0797e^{-5} and a slope of -8.8099e^{-7} (Fig. 2 and 3).

After correcting the bottle-data for the pressure effect, we determine the temporal drift using samples taken below 1000m depth. Here we use only the deep samples, as their temporal distribution is such, that we would not cover a lager timeframe by using the shallow samples. We would thus not gain precision by including the shallow and less accurate samples. The resulting correction for the temporal drift has an offset of 66.3881 and a slope of -9.0017e^{-5}.

Figure 4 shows the diference of salinities measured with the OPS and salinities derived from the primary CTD conductivity sensor after applying the correction for pressure effect and temporal drift on the bottle data. The corrections are applied to the data as documented in section 7. The pressure effect and temporal drift where determined without taking the temporal drift of the temperature sensor into account, because it is unknown.

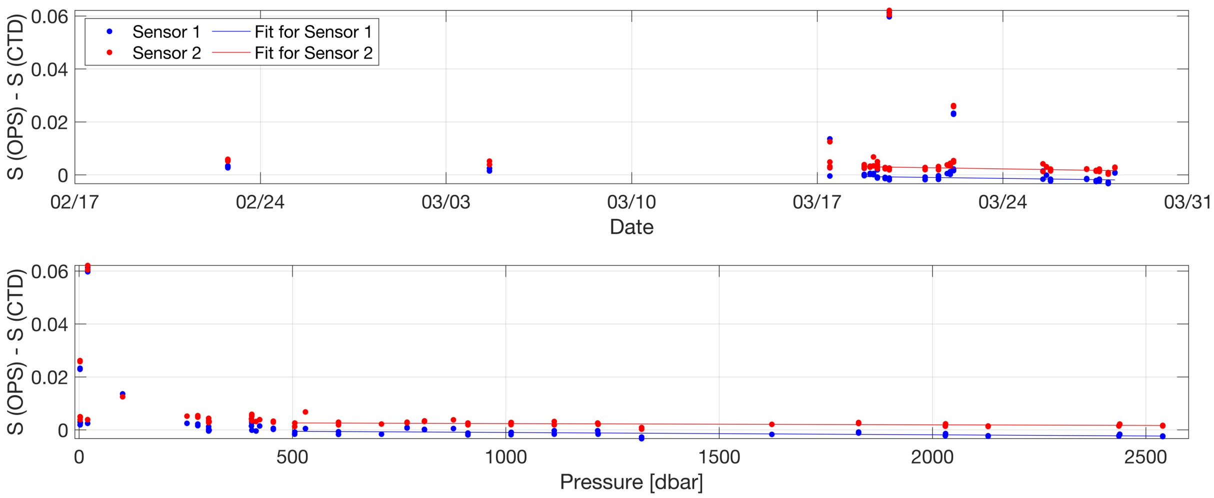

Fig. 2: Differences of salinities measured with the OPS and salinities measured with the CTD (blue – primary sensor pair, red – secondary sensor pair) from all water samples taken. Upper panel shows the temporal evolution, the lower panel shows the pressure dependence.

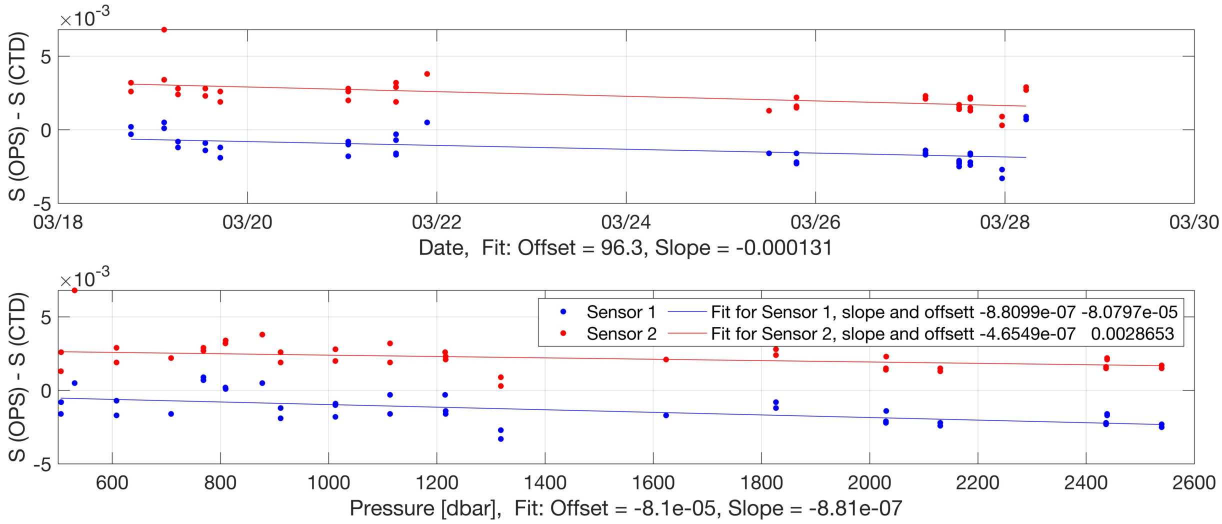

Fig. 3: Same as fig. 2 but zoomed, showing only samples taken below 500m depths. Upper panel shows the temporal evolution, the lower panel shows the pressure dependence with the coefficients of the fit.

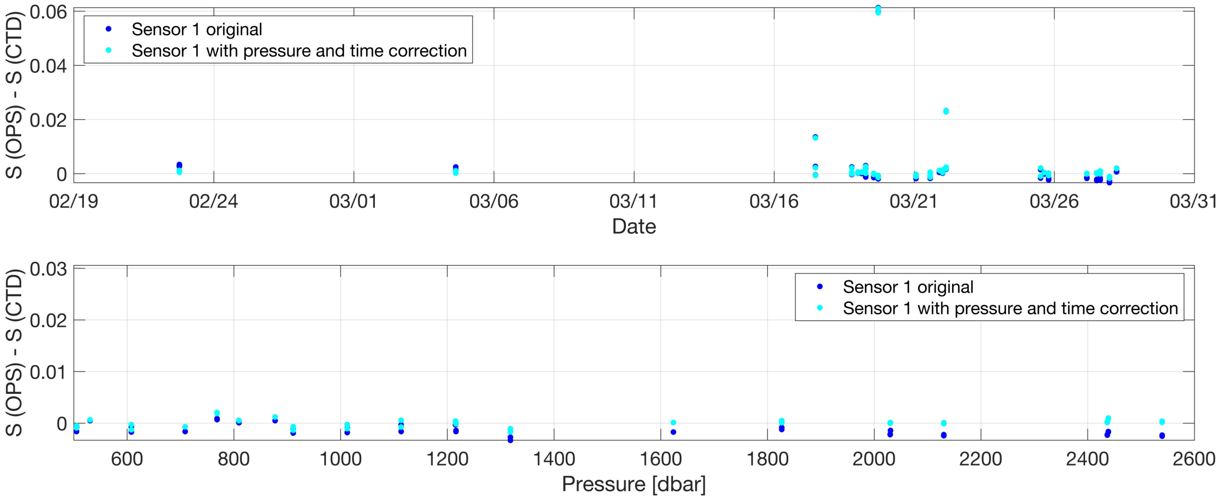

Fig. 4: Differences of salinities measured with the OPS and salinities measured with the CTD primary sensor pair before (dark blue) and after applying the corrections (light blue). Upper panel shows the temporal evolution, the lower panel shows the pressure dependence.

6. In-situ Oxygen Calibration

During this cruise, no oxygen samples were taken, but the same sensor was used as on the cruise before (PS117). On PS117, water samples were taken on 31 CTD casts. Duplicates were taken to verify the results. In total 216 comparisons between SBE43 and measured samples exist. Therefore, the correction used for PS117 was also applied to the data of this cruise. Details of the corrections can be found in the Processing Report of PS117 https://doi.pangaea.de/10.1594/PANGAEA.910663.

7. Data Processing

CTD data processing at AWI is performed using the software ManageCTD. It consists of several processing steps including:

- conversion of raw data into physical units using the SeaBird Data Processing software
- cutting the profile to start at the surface
- merge meta data from the DShip system into the CTD data
- despike the data
- compare data from primary and secondary sensor pair
- visual inspection of T-S-properties
- export data for Ocean Data View

In the processing step Despike, spikes (suspicious, incorrect values) can be removed from the profile. The respective data point can be set to NAN or the gab can be interpolated. Table 3 gives an overview which profiles where edited.

Tab. 3: Number of interpolated or removed spikes in the respective profile. The table gives the Station number (Station), Cast number (cast), the total length of the profile in number of bins (Record), and the channels that have been edited (Temp – temperature, SAL – salinity, O2 – oxygen, FCHL – Fluorescence Chlorophyll *a*, Trans – Transmissometer). All profiles where checked but the ones not edited, are not listed here.

Station	Cast	Records	TEMP	SAL	O2	FCHL	TRANS
8	2	402	1	0	0	0	0
16	1	826	0	0	0	0	2
17	1	579	1	1	0	0	0
19	1	1447	0	1	0	0	0
23	1	2811	0	1	0	0	0
28	1	2789	0	0	0	0	1
41	1	533	0	1	0	0	0
46	1	2878	0	0	0	0	2
51	1	1879	0	0	0	0	2
58	1	2052	1	2	0	0	0
61	1	1947	0	1	0	0	0
71	2	858	0	0	0	0	3

Applying the temperature and salinity correction from in-situ-calibration

The primary sensor pair was selected for the final dataset because it was slightly less noisy compared to the second sensor pair. The calibration coefficient for temperature, as determined from Seabird in the post-cruise-calibration (Appendix B), was applied with a factor of 0.5, as usually done. This has shown to give the best results in recent years, by comparing the data to other data sets recorded in the same area (personal communication, Gerd Rohardt). The salinity was corrected for the effects of pressure and temporal drift.

$$T0_{corr} = T0 + 0.00087/2$$

$$S0_{corr1} = S0 - (a_p + b_p * PRES)$$

$$S0_{corr2} = S0_{corr1} - (a_t + b_t * time)$$

with a_p = 8.0797e^{-5}, b_p = -8.8099e^{-7}, a_t = 66.3881, and b_t = -9.0017e^{-5}. The mean of the difference of salinities measured with the OPS and measured with the CTD before the corrections, was -0.0017 with a standard deviation of 7.25e^{-4}. After applying the corrections, the mean of salinities measured with the OPS and measured with the CTD was -2.64e^{-14} with a standard deviation of 5.98e^{-4}.
Plots of potential temperature, salinity, potential density (sigma), oxygen, fluorescence, and beam transmission are shown in Figure 8 before the corrections, and in Figure 9, after the corrections have been applied for visual comparison.

Transmissometer and fluorometer
The transmissometer (CSTAR) and fluorometer (ecoFLR) were not calibrated during the cruise. Thus, data is given as “relative units”.

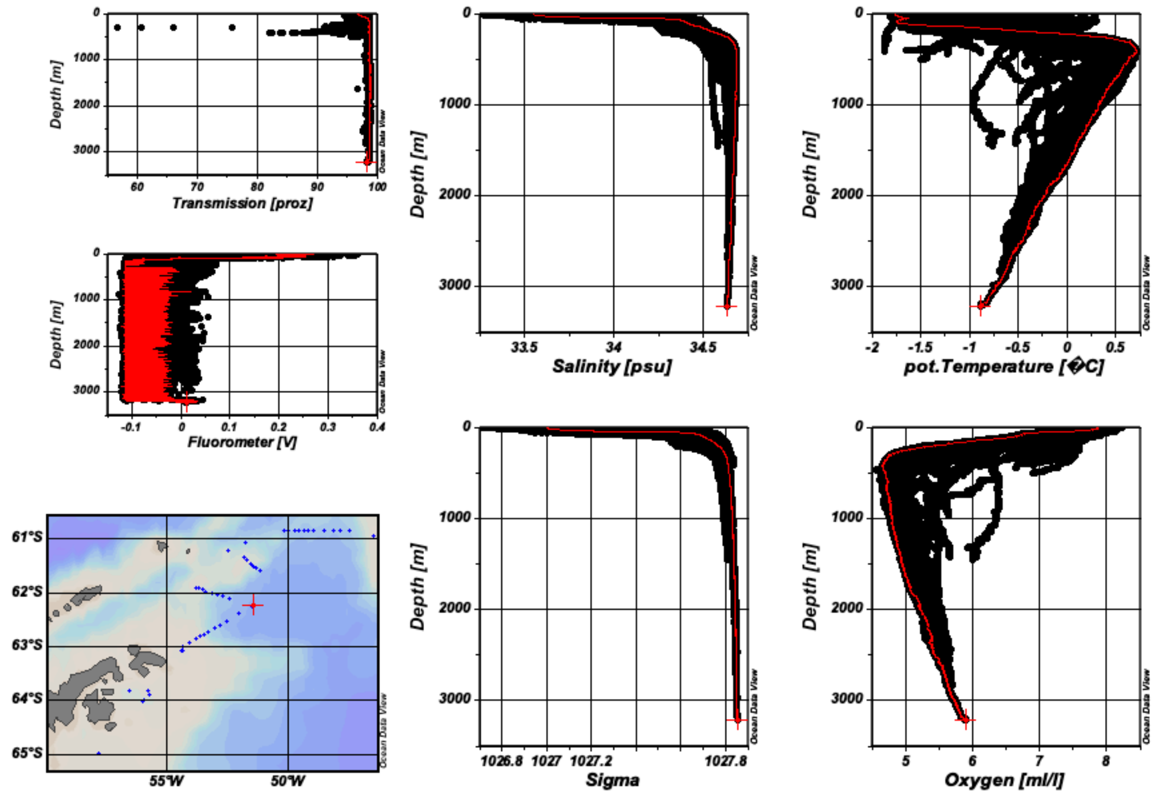

Fig. 8: Scatter plot of potential temperature, salinity, potential density (sigma), oxygen, fluorescence, and beam transmission from the 52 CTD casts before the corrections.

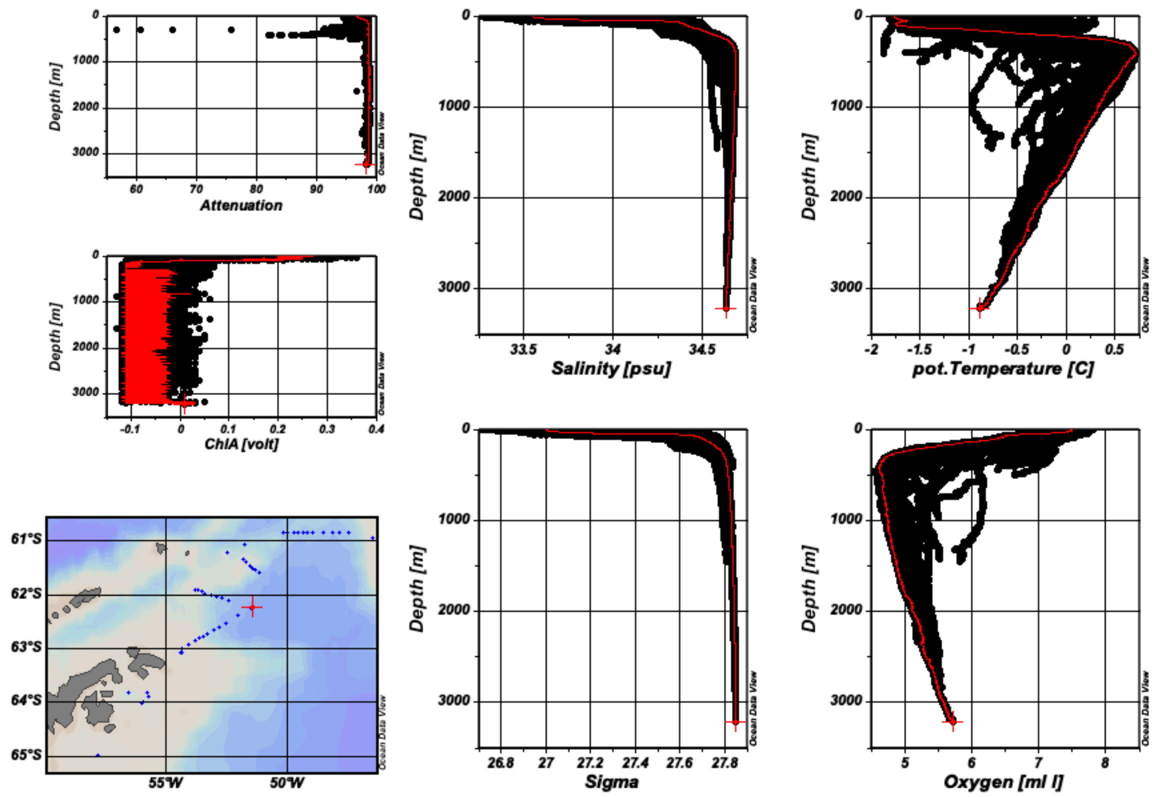

Fig. 9: Scatter plot of potential temperature, salinity, potential density (sigma), oxygen, fluorescence, and beam transmission from the 52 CTD casts after the corrections have been applied.

Appendix

A. Pre-cruise Calibration

The pre-cruise calibration is presented as the copy of the report file create from *SeasaveV7* configuration file.
PSA file: C:\Users\stippenh\AppData\Local\Sea-Bird\Seasave\Seasave_2.psa
Date: 02/03/2020
Instrument configuration file: \\psf\Home\Documents\Data\CTD\PS118\conf1\raw\PS118_082_2.XMLCON
Configuration report for SBE 911plus/917plus CTD

Frequency channels suppressed : 0
Voltage words suppressed : 0
Computer interface : RS-232C
Deck unit : SBE11plus Firmware Version >= 5.0
Scans to average : 1
NMEA position data added : Yes
NMEA depth data added : No
NMEA time added : No
NMEA device connected to : PC
Surface PAR voltage added : No
Scan time added : No

1) Frequency 0, Temperature
Serial number : **2929**
Calibrated on : 23-Nov-17
G : 4.35518269e-003
H : 6.44137593e-004
I : 2.29025545e-005
J : 2.09099434e-006
F0 : 1000.000
Slope : 1.00000000
Offset : 0.0000

2) Frequency 1, Conductivity
Serial number : **1198**
Calibrated on : 15-Nov-17
G : -4.01609586e+000
H : 5.10250929e-001
I : 1.13545511e-004
J : 2.19067195e-005
CTcor : 3.2500e-006
CPcor : -9.57000000e-008
Slope : 1.00000000
Offset : 0.00000

3) Frequency 2, Pressure, Digiquartz with TC
Serial number : **0937**
Calibrated on : 14-Nov-17
C1 : -4.377396e+004
C2 : -6.751446e-001
C3 : 1.352380e-002
D1 : 3.663800e-002
D2 : 0.000000e+000
T1 : 3.012220e+001
T2 : -5.074259e-004
T3 : 3.788210e-006
T4 : 4.207950e-009
T5 : 0.000000e+000
Slope : 1.00001734
Offset : -1.54026
AD590M : 1.281700e-002
AD590B : -9.363100e+000

4) Frequency 3, Temperature, 2
Serial number : **5112**
Calibrated on : 29-Jun-18
G : 4.37936431e-003
H : 6.42094687e-004
I : 2.21867063e-005
J : 2.03044704e-006
F0 : 1000.000
Slope : 1.00000000
Offset : 0.0000

5) Frequency 4, Conductivity, 2
Serial number : **3570**
Calibrated on : 03-Jul-18
G : -9.80508724e+000
H : 1.21366567e+000
I : -1.29509578e-003
J : 1.48863867e-004
CTcor : 3.2500e-006
CPcor : -9.57000000e-008
Slope : 1.00000000
Offset : 0.00000

6) A/D voltage 0, Altimeter
Serial number : **51533**
Calibrated on : 2015
Scale factor : 15.000
Offset : 0.000

7) A/D voltage 1, Free

8) A/D voltage 2, Fluorometer, WET Labs ECO-AFL/FL
Serial number : **1853**
Calibrated on : 26-May-2010
Dark output : 0.0240
Scale factor : 2.50000000e+001

9) A/D voltage 3, Transmissometer, WET Labs C-Star
Serial number : **1198**
Calibrated on : 17-Dec-2008
M : 21.6701
B : -1.1919
Path length : 0.250

10) A/D voltage 4, Free
11) A/D voltage 5, Free
12) A/D voltage 6, Oxygen, SBE 43
Serial number : **1597**
Calibrated on : 06-Jul-18
Equation : Sea-Bird
Soc : 5.14000e-001
Offset : -5.04500e-001
A : -4.30040e-003
B : 1.95920e-004
C : -2.98350e-006
E : 3.60000e-002
Tau20 : 1.10000e+000
D1 : 1.92634e-004
D2 : -4.64803e-002
H1 : -3.30000e-002
H2 : 5.00000e+003
H3 : 1.45000e+003

13) A/D voltage 7, Free

B. Post-cruise Calibration

The post-cruise calibration is presented as the scan from original SBE calibration sheets.

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SENSOR SERIAL NUMBER: 2929
CALIBRATION DATE: 13-Sep-19

SBE 3 TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

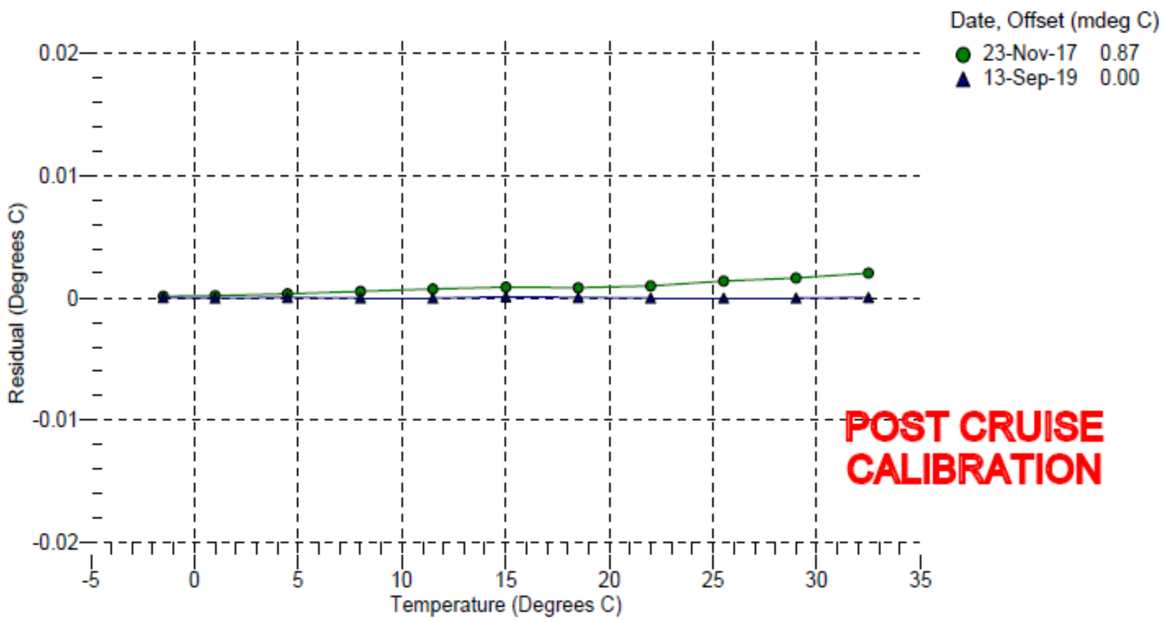
COEFFICIENTS:
g = 4.35545760e-003
h = 6.44721926e-004
i = 2.33159579e-005
j = 2.19144864e-006
f0 = 1000.0

BATH TEMP (° C)	INSTRUMENT OUTPUT (Hz)	INST TEMP (° C)	RESIDUAL (° C)
-1.5000	2956.374	-1.5000	0.00002
1.0000	3126.199	1.0000	-0.00003
4.5000	3375.671	4.5000	0.00001
8.0000	3639.147	8.0000	-0.00001
11.5000	3917.010	11.5000	-0.00003
15.0000	4209.633	15.0001	0.00005
18.5000	4517.354	18.5000	0.00002
22.0000	4840.525	22.0000	-0.00002
25.5000	5179.483	25.5000	-0.00001
29.0000	5534.538	29.0000	-0.00002
32.5000	5906.004	32.5000	0.00002

f = Instrument Output (Hz)

Temperature ITS-90 (°C) = $1/\{g + h[\ln(f0 / f)] + i[\ln^2(f0 / f)] + j[\ln^3(f0 / f)]\} - 273.15$

Residual (°C) = instrument temperature - bath temperature



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SENSOR SERIAL NUMBER: 5112
CALIBRATION DATE: 13-Sep-19

SBE 3 TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

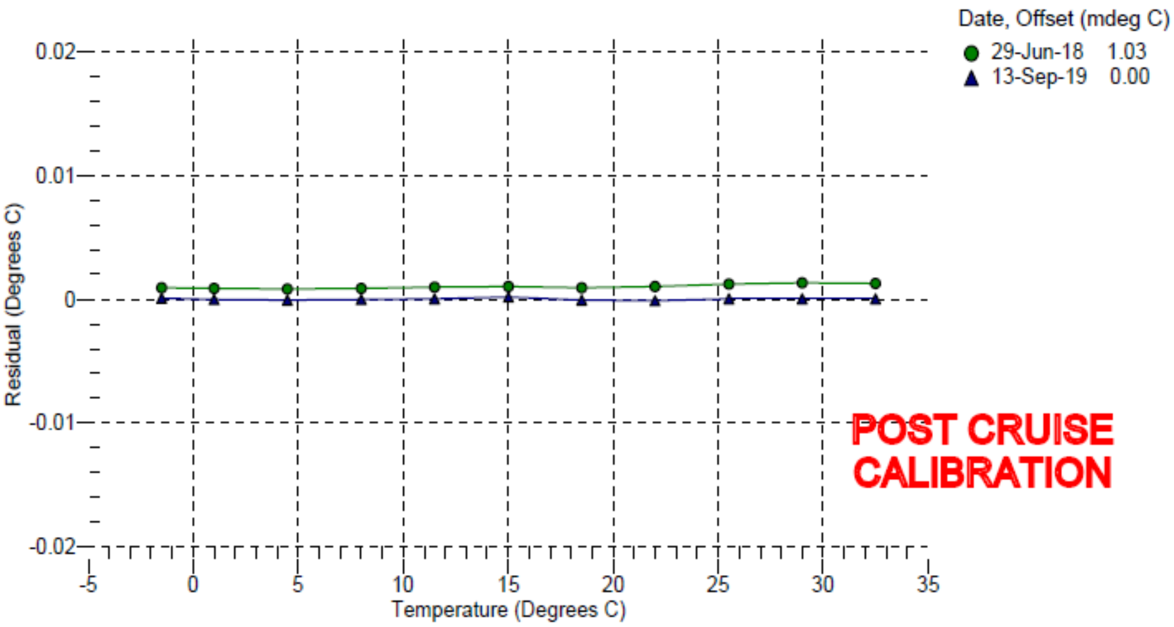
COEFFICIENTS:
g = 4.37924868e-003
h = 6.41890299e-004
i = 2.20569073e-005
j = 2.00398922e-006
f0 = 1000.0

BATH TEMP (° C)	INSTRUMENT OUTPUT (Hz)	INST TEMP (° C)	RESIDUAL (° C)
-1.5000	3085.242	-1.4999	0.00005
1.0000	3263.084	1.0000	-0.00005
4.5000	3524.346	4.4999	-0.00006
8.0000	3800.297	8.0000	-0.00002
11.5000	4091.328	11.5000	0.00003
15.0000	4397.831	15.0002	0.00019
18.5000	4720.129	18.4999	-0.00008
22.0000	5058.641	21.9999	-0.00011
25.5000	5413.706	25.5000	0.00000
29.0000	5785.636	29.0000	0.00004
32.5000	6174.751	32.5000	0.00000

f = Instrument Output (Hz)

Temperature ITS-90 (°C) = $1/\{g + h[ln(f0 / f)] + i[ln^2(f0 / f)] + j[ln^3(f0 / f)]\} - 273.15$

Residual (°C) = instrument temperature - bath temperature



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SENSOR SERIAL NUMBER: 1198
CALIBRATION DATE: 17-Sep-19

SBE 4 CONDUCTIVITY CALIBRATION DATA
PSS 1978: C(35,15,0) = 4.2914 Siemens/meter

COEFFICIENTS:

g = -4.01865941e+000
h = 5.10799451e-001
i = 1.30219401e-005
j = 2.65752364e-005

CPcor = -9.5700e-008 (nominal)
CTcor = 3.2500e-006 (nominal)

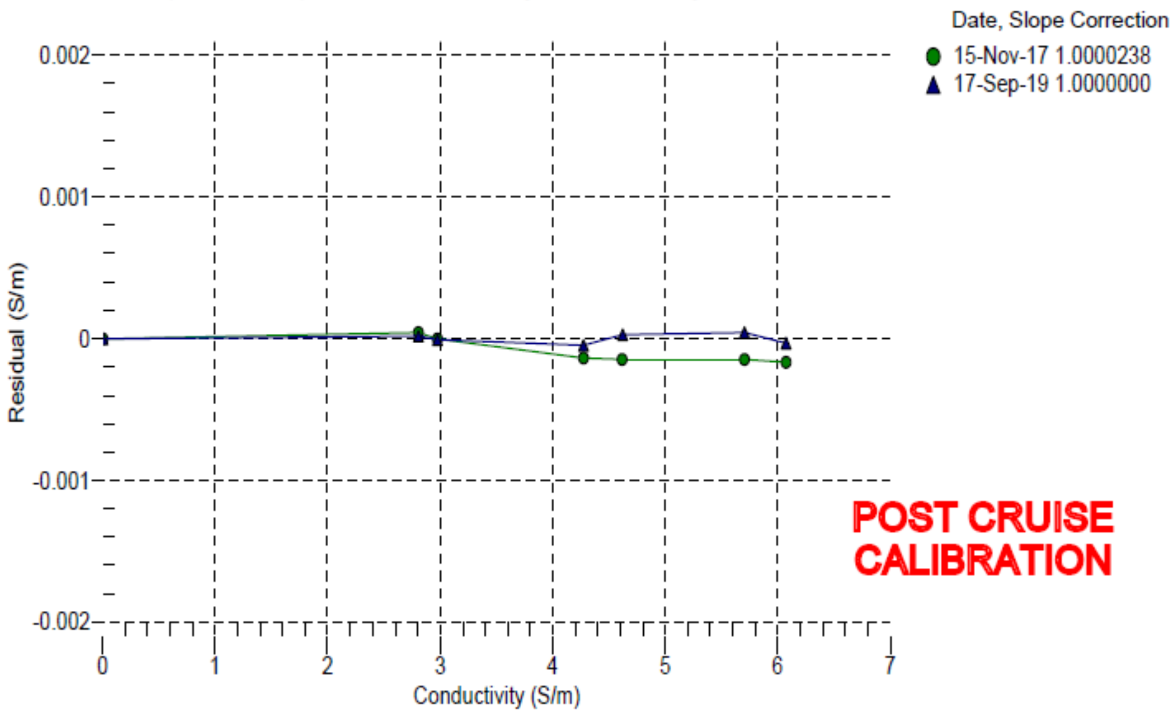
BATH TEMP (° C)	BATH SAL (PSU)	BATH COND (S/m)	INSTRUMENT OUTPUT (kHz)	INSTRUMENT COND (S/m)	RESIDUAL (S/m)
0.0000	0.0000	0.00000	2.80421	0.00000	0.00000
-1.0000	34.8229	2.80506	7.90989	2.80508	0.00002
1.0000	34.8234	2.97651	8.11785	2.97651	-0.00001
15.0000	34.8241	4.27247	9.54252	4.27242	-0.00005
18.5000	34.8230	4.61916	9.88844	4.61919	0.00003
29.0000	34.8194	5.70277	10.89752	5.70281	0.00004
32.5000	34.8078	6.07468	11.22243	6.07464	-0.00003

f = Instrument Output (kHz)

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

Conductivity (S/m) = $(g + h * f^2 + i * f^3 + j * f^4) / 10 (1 + \delta * t + \varepsilon * p)$

Residual (Siemens/meter) = instrument conductivity - bath conductivity



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SENSOR SERIAL NUMBER: 3570
CALIBRATION DATE: 17-Sep-19

SBE 4 CONDUCTIVITY CALIBRATION DATA
PSS 1978: C(35,15,0) = 4.2914 Siemens/meter

COEFFICIENTS:

g = -9.81435640e+000
h = 1.21561666e+000
i = -1.64660992e-003
j = 1.71094168e-004

CPcor = -9.5700e-008 (nominal)
CTcor = 3.2500e-006 (nominal)

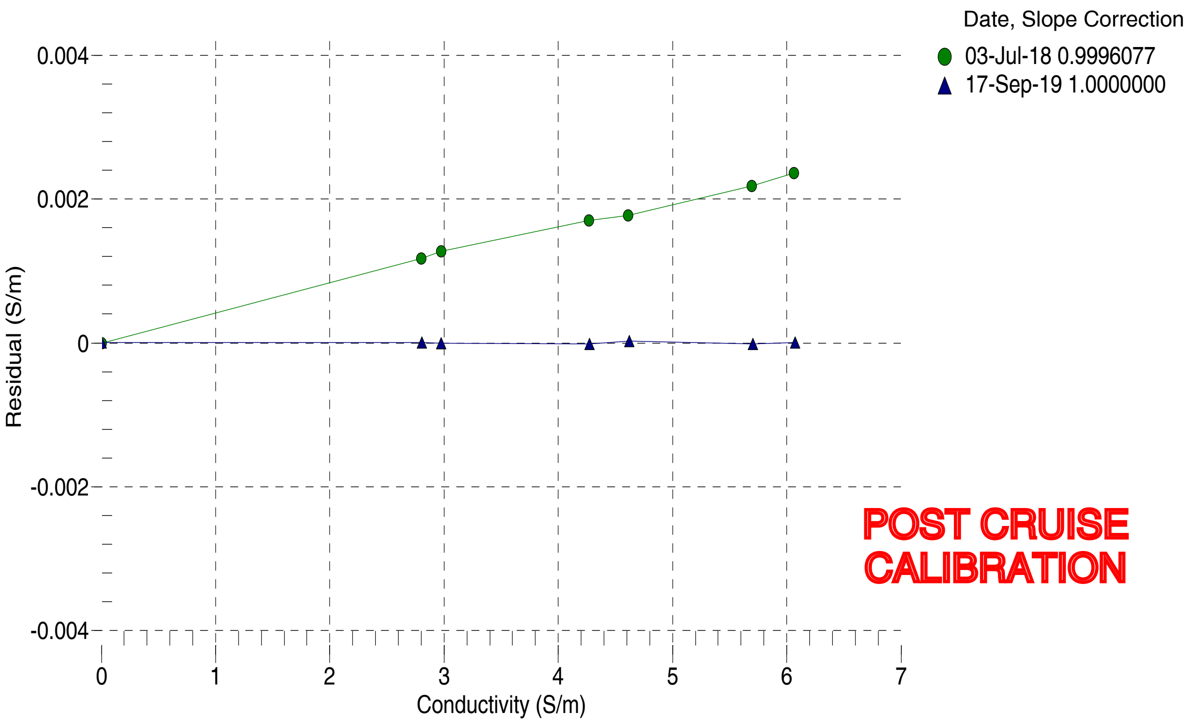
BATH TEMP (° C)	BATH SAL (PSU)	BATH COND (S/m)	INSTRUMENT OUTPUT (kHz)	INSTRUMENT COND (S/m)	RESIDUAL (S/m)
0.0000	0.0000	0.00000	2.84527	0.00000	0.00000
-1.0000	34.8229	2.80506	5.58998	2.80506	0.00000
1.0000	34.8234	2.97651	5.71506	2.97651	-0.00000
15.0000	34.8241	4.27247	6.58360	4.27245	-0.00002
18.5000	34.8230	4.61916	6.79702	4.61918	0.00002
29.0000	34.8194	5.70277	7.42409	5.70275	-0.00002
32.5000	34.8078	6.07468	7.62729	6.07468	0.00001

f = Instrument Output (kHz)

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

Conductivity (S/m) = $(g + h * f^2 + i * f^3 + j * f^4) / 10 (1 + \delta * t + \varepsilon * p)$

Residual (Siemens/meter) = instrument conductivity - bath conductivity



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