ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG

CTD Data Processing Report

RV POLARSTERN Cruise PS106

Gerd Rohardt

Contents

1. Introduction

This report describes the processing of CTD raw data acquired by Seabird SBE 911plus CTD on board RV POLARSTERN during expedition PS106.1 and PS106.2. The standard processing procedures are described in the document *AWI CTD Data Processing* .

2. Cruise Details

Vessel	RV POLARSTERN
Cruise	PS106.1
Region	Fram Strait and north of Spitzbergen
Departure	Bremerhaven, May 24. 2017
Arrival	Longyearbyen, Jun. 21. 2017
Responsible operator	Anna Nikolopoulos, AquaBiota Water Research, Sweden
Cruise	PS106.2
Region	North and east of Spitzbergen
Departure	Longyearbyen, Jun. 23. 2017
Arrival	Tromso, Jul. 20. 2017
Responsible operator	Céline Heuzé, University of Gothenburg, Sweden
Responsible for data processing	Gerd Rohardt, AWI
Number of CTD casts	65
Number of processed casts	Leg 1: 34, leg 2: 32

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 485 (on board system)
	Carousel Water Sampler	SBE32
Sensors		
	Primary Temperatur	SBE3plus; SN 2460; cal[3]: 20.Dec.2016. and 28.Oct.2017
	Primary Conductivity	SBE4C; SN 2055; cal: 22-Nov-2016 and 3.Nov.2017
	Secondary Temperatur	SBE3plus; SN 2417; cal: 20.Dec.2016. and 28.Oct.2017
	Secondary Conductivity	SBE4C; SN 2054; cal: 22.Nov.2016. and 9.Nov.2017
	Oxygen	SBE43; SN 880; cal: 03.Aug.2010 and 4.Nov.2017
	Transmisometer[4]	Wetlabs CStar; SN 946; cal: 31.Jan.2006
	Fluorometer[4]	Wetlabs EcoFLR; SN 1670; cal: 11.Dec.2009
	Altimeter	Benthos PSA900; SN 1228; cal:23.Mar.2009
Salinometer		
	Optimare Precision Salinometer OPS	SN 006
	Standard Seawater	P158; K_{15} = 0.99970; valid until: 2018-03-25

Remarks:
[1] : SBE = Sea Bird Electronics
[2] : AWI software package which includes SBEDateProcessing, Version 7.22.5
[3] : Dates of pre- and post-cruise calibration
[4] : Not calibrated, use relative values only

4. Specials

This chapter contains the important notes made during the CTD casts or resulting from the salinity samples.

In general the CTD worked fine without any serious problems, e.g. no broken temperature, conductivity or oxygen sensor. Station 27-2 was canceled at 20 m depth due to a leaking plug. The problem was solved by replacing the belonging cable. Both sensor pairs performed precise; see Figure 1 too.

It was hard to keep the ship on position because the stern thruster was out of order and could not be used during all casts. Therefore the CTD/watersampler was deployed over the sterns big A-frame; during 25-4 to 40-1 and 49-1 to 85-1.

Tab. 1: List of CTD/Water Sampler stations from leg PS106.1. The column “Depth” was taken from the echo sounder reading.

Station	Cast	Date/Time	Latitude	Longitude	Depth (m)	Max. Pres (dbar)
15	1	30-May-2017 17:26:57	77 15.816 N	9 32.340 E	2041	304
15	2	30-May-2017 18:38:03	77 15.798 N	9 31.806 E	2045	1015
17	2	01-Jun-2017 10:35:20	80 26.502 N	7 17.208 E	693	675
18	2	02-Jun-2017 13:16:57	81 17.430 N	9 19.194 E	1337	1307
21	1	04-Jun-2017 05:27:07	81 56.910 N	10 23.286 E	1000	973
21	3	04-Jun-2017 08:39:25	81 57.084 N	10 28.842 E	1014	304
22	2	05-Jun-2017 08:31:26	81 56.256 N	10 56.598 E	1078	1051
22	4	05-Jun-2017 19:29:46	81 55.674 N	10 55.908 E	1076	1051
23	1	06-Jun-2017 05:34:10	81 56.844 N	10 54.126 E	1071	1045
23	3	06-Jun-2017 07:51:30	81 56.910 N	10 53.178 E	1070	304
23	4	06-Jun-2017 18:30:50	81 57.150 N	10 36.600 E	1020	994
24	1	07-Jun-2017 05:34:42	81 56.694 N	10 20.136 E	992	967
24	4	07-Jun-2017 07:44:34	81 56.340 N	10 16.572 E	984	304
24	7	07-Jun-2017 18:25:54	81 54.858 N	9 55.734 E	938	913
25	4	08-Jun-2017 18:47:50	81 53.784 N	9 51.222 E	931	907
26	1	09-Jun-2017 05:50:25	81 54.516 N	9 59.970 E	946	923
27	6	10-Jun-2017 19:21:05	81 52.272 N	10 28.308 E	1066	1040
28	5	11-Jun-2017 18:44:50	81 49.236 N	11 15.684 E	1381	1362
29	1	12-Jun-2017 05:39:47	81 49.734 N	11 31.668 E	1524	1015
29	8	12-Jun-2017 18:55:39	81 48.864 N	11 31.326 E	1563	1537
30	2	13-Jun-2017 14:59:26	81 48.822 N	11 29.814 E	1556	1533
31	1	14-Jun-2017 05:46:29	81 47.940 N	11 17.244 E	1487	1458
31	3	14-Jun-2017 18:40:32	81 44.880 N	10 59.166 E	1502	1475
32	1	15-Jun-2017 05:41:20	81 43.896 N	10 51.204 E	1607	1024
32	5	15-Jun-2017 18:38:19	81 42.360 N	10 41.454 E	1470	1440
33	1	16-Jun-2017 05:40:10	81 42.420 N	10 30.408 E	1408	1013
34	2	17-Jun-2017 13:17:08	80 59.586 N	10 21.846 E	1475	1486
35	1	17-Jun-2017 19:07:15	80 48.342 N	10 55.848 E	1482	1456
36	1	18-Jun-2017 01:15:00	80 36.162 N	11 15.054 E	1057	1034
37	1	18-Jun-2017 04:14:41	80 28.440 N	11 25.548 E	709	691
38	1	18-Jun-2017 07:36:43	80 17.418 N	11 33.996 E	191	177
39	2	18-Jun-2017 11:19:06	80 9.564 N	10 39.204 E	458	448
40	1	18-Jun-2017 14:44:40	80 5.724 N	9 37.302 E	533	519

Tab. 2: List of CTD/Water Sampler stations from leg PS106.2. The column “Depth” was taken from the echo sounder reading.

Station	Cast	Date/Time	Latitude	Longitude	Depth (m)	Max. Pres (dbar)
43	2	24-Jun-2017 09:47:17	76 10.692 N	19 54.540 E	194	179
44	1	25-Jun-2017 10:22:43	77 53.688 N	30 2.592 E	259	249
46	1	26-Jun-2017 10:19:45	78 33.228 N	33 57.570 E	204	194
47	3	26-Jun-2017 19:22:15	78 24.348 N	34 42.108 E	163	153
48	2	27-Jun-2017 12:41:26	79 48.930 N	34 1.344 E	284	273
49	1	28-Jun-2017 22:52:14	80 31.008 N	30 58.212 E	148	137
53	1	30-Jun-2017 05:30:24	81 34.218 N	33 25.470 E	279	274
56	1	30-Jun-2017 11:17:34	81 41.598 N	32 54.768 E	1628	1613
57	1	30-Jun-2017 16:25:16	81 44.880 N	32 56.394 E	1996	2010
58	1	30-Jun-2017 20:48:01	81 41.556 N	32 37.890 E	1631	1624
59	1	30-Jun-2017 22:49:55	81 40.566 N	32 41.226 E	1356	1355
60	1	01-Jul-2017 00:55:54	81 39.024 N	32 48.138 E	1057	1037
65	1	02-Jul-2017 01:41:03	81 37.428 N	33 21.648 E	608	587
66	2	02-Jul-2017 13:10:55	81 39.876 N	32 14.850 E	1787	202
67	3	03-Jul-2017 14:20:43	81 57.978 N	32 24.672 E	2811	2800
69	4	05-Jul-2017 11:41:31	83 0.288 N	33 11.232 E	3723	3725
71	1	06-Jul-2017 01:09:24	83 19.866 N	33 5.184 E	3899	1017
73	1	06-Jul-2017 20:51:45	83 39.978 N	31 33.798 E	4029	102
73	4	07-Jul-2017 03:09:51	83 39.876 N	31 46.872 E	4025	4042
74	1	08-Jul-2017 08:47:15	83 28.254 N	28 0.576 E	4050	4067
75	1	09-Jul-2017 02:53:33	82 58.812 N	24 52.194 E	4049	4067
76	1	10-Jul-2017 05:41:30	82 29.454 N	18 0.966 E	1904	1013
78	1	10-Jul-2017 22:13:35	82 2.130 N	17 24.468 E	2721	2727
80	1	12-Jul-2017 00:44:46	81 19.590 N	16 55.824 E	1098	102
80	6	12-Jul-2017 23:32:32	81 24.396 N	17 16.986 E	978	967
81	1	13-Jul-2017 01:39:47	81 21.564 N	17 38.418 E	801	774
82	1	13-Jul-2017 05:27:45	81 19.608 N	18 17.934 E	608	587
83	1	13-Jul-2017 09:03:09	81 12.330 N	18 49.398 E	434	424
85	1	14-Jul-2017 19:46:22	80 36.672 N	29 29.364 E	288	304
88	2	15-Jul-2017 18:22:59	79 23.586 N	27 10.362 E	275	268
91	4	16-Jul-2017 16:01:36	78 42.582 N	23 26.976 E	122	122
93	4	17-Jul-2017 10:33:35	78 28.188 N	25 12.318 E	180	178

5. In-situ Salinity Calibration

To monitor the accuracy and precision of the CTD’s conductivity sensors, water samples were taken on 22 CTD casts for salinity/conductivity measurements. Duplicate samples were drawn from the water sampler during leg PS106.1 only (at 9 of 11 stations). No duplicates were taken and measured during leg PS106.2 and salinity were measured from all bottles respectively sampled layers instead, which did not provide the needed accuracy. Only the samples from the very deep casts can be used.

Salinities of the water samples were determined on board using an Optimare Precision Salinometer (OPS). All samples were measured in 11 sessions. Every session started with standardization.

Tab. 3: A subset of the salinity samples from the water sampler and measured with the OPS. The measurements from duplicates with difference less than 0.002 and from the deepest samples were used to determine the salinity correction. OPS measurement from station 32-5 was not taken for correction because the difference of the duplicate was too big.

Station	Date/Time	Press	S0	S1	OPS	S0-OPS	S1-OPS	Diff-Duplicate
22-2	Jun 05 2017 08:31:26	1037	34.9104	34.9101	34.927	-0.0166	-0.0169	
			34.9104	34.9101	34.9269	-0.0165	-0.0168	0.0001
22-4	Jun 05 2017 19:29:46	1037	34.91	34.91	34.9283	-0.0183	-0.0183	
			34.91	34.91	34.9267	-0.0167	-0.0167	0.0016
29-8	Jun 12 2017 18:55:39	1514	34.9158	34.9159	34.918	-0.0022	-0.0021	
			34.9158	34.9159	34.9182	-0.0024	-0.0023	-0.0002
30-2	Jun 13 2017 14:59:26	1511	34.9144	34.9143	34.9198	-0.0054	-0.0055	
			34.9144	34.9143	34.9201	-0.0057	-0.0058	-0.0003
30-2	Jun 13 2017 14:59:26	1000	34.9093	34.9088	34.9164	-0.0071	-0.0076	
			34.9093	34.9088	34.9149	-0.0056	-0.0061	0.0015
32-5	Jun 15 2017 18:38:19	1419	34.9124	34.9126	34.9187	-0.0063	-0.0061	
			34.9124	34.9126	34.9149	-0.0025	-0.0020	0.0038
34-2	Jun 17 2017 13:17:08	1465	34.9108	34.9107	34.9156	-0.0048	-0.0049	
			34.9108	34.9107	34.916	-0.0052	-0.0053	-0.0004
36-1	Jun 18 2017 01:15:00	1020	34.911	34.9111	34.9166	-0.0056	-0.0055	
			34.911	34.9111	34.9164	-0.0054	-0.0053	0.0002
56-1	Jun 30 2017 10:43:53	1589	34.9101	34.9105	34.9147	-0.0046	-0.0042	
67-3	Jul 03 2017 13:23:49	2752	34.9340	34.9340	34.9419	-0.0079	-0.0079	
69-4	Jul 05 2017 10:29:30	3652	34.9374	34.9373	34.9419	-0.0045	-0.0046	
73-4	Jul 07 2017 01:47:59	3960	34.9369	34.9369	34.9409	-0.0040	-0.0040	
74-1	Jul 08 2017 07:25:23	3985	34.9371	34.9370	34.9416	-0.0045	-0.0046	
75-1	Jul 09 2017 01:33:18	3985	34.9371	34.9368	34.9401	-0.0030	-0.0033	
78-1	Jul 10 2017 21:17:21	2680	34.9314	34.9314	34.9348	-0.0034	-0.0034	

The mean *S0-OPS* is -0.0071 and *S1-OPS* is -0.0072 from all samples shown in Table 3. That means that the internal difference between the sensor pair is small. During the first leg the cast do not reach into deep homogeneous layer. The mean *S0-OPS* and *S1-OPS* from stations 69 to 75, which were deeper than 3500 m, are -0.0040 and -0.0041 with a standard deviation less than 0.001 compared to 0.005 for the overall mean. Therefore salinity was corrected by 0.004 for all stations because the sensors do not show a significant drift, see Figure 1.

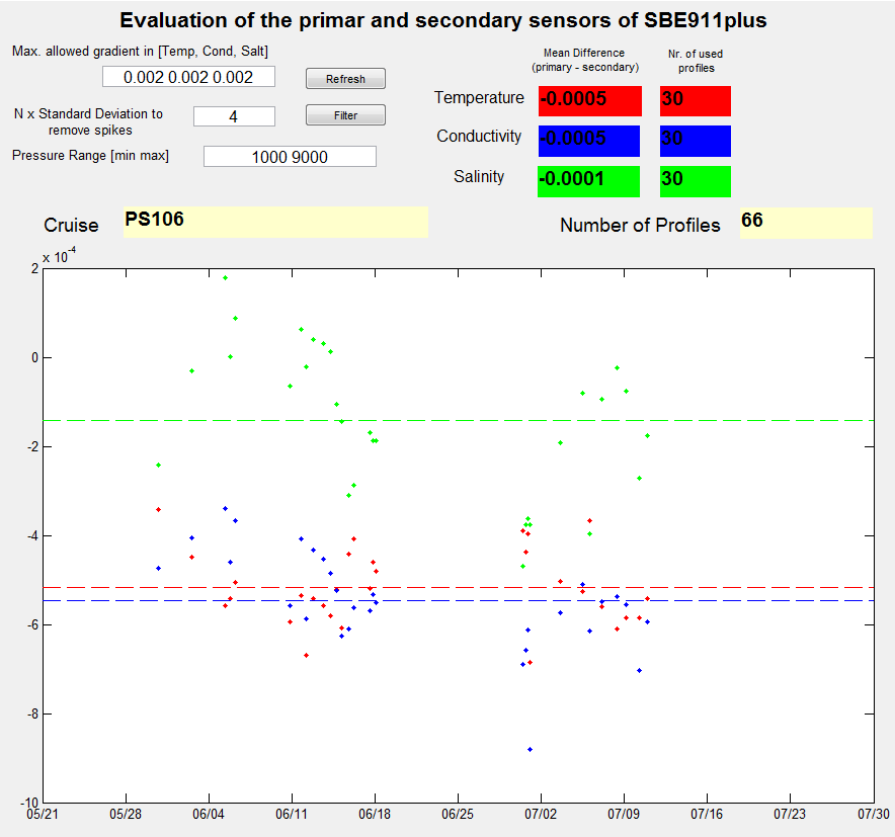

Fig. 1: The statistics of the differences between the primary and secondary sensor pair from layers below 1000 m and gradients less than 0.002 (°C/m or mS/m^2). The record did not indicate a significant sensor drift.

6. Data Processing

The standard processing procedures are described in the document *AWI CTD Data Processing*.

Tab. 4: The number of interpolated/removed spikes from the 1dbar-interval values with the software CTDdespike.

Station	Cast	Records	TEMP	SAL	TEMP2	SAL2	DEN	DEN2
15	1	302						
15	2	1014						
17	2	674		3				
18	2	1306						
21	1	972						
21	3	303						
22	2	1050						
22	4	1049						
23	1	1044						
23	3	302						
23	4	992						
24	1	966		3				
24	4	301						
24	7	911						
25	4	905					3	
26	1	922						
27	6	1038						
28	5	1361						3
29	1	1013		3				
29	8	1536		3				
30	2	1531					4	
31	1	1458						
31	3	1474						
32	1	1023						
32	5	1438					3	
33	1	1012						
34	2	1485						
35	1	1455						
36	1	1032						
37	1	690						
38	1	176						
39	2	448						
40	1	517						
43	2	179						
44	1	248						
46	2	193						
47	3	151						
48	2	271						
50	2	135						
53	1	271						
56	1	1611						
57	1	2007						
58	1	1623						
59	1	1353		6				
60	1	1033						
65	1	585		4				
66	2	197						
67	3	2796		3				
69	4	3720						
71	1	1015						
73	1	98						
73	4	4038						
74	1	4061						
Station	**Cast**	**Records**	**TEMP**	**SAL**	**TEMP2**	**SAL2**	**DEN**	**DEN2**
75	1	4065						

76	1	1010						
78	1	2724						
80	1	100						
80	6	963						
81	1	771						
82	1	572		3				
83	1	423	6					
85	1	286						
88	2	264						
91	4	119						
93	4	173						

Tab. 4: The number of interpolated (column INT) and removed (column NaN) records from the 1dbar-interval during the final processing. Variables are not listed where no records were processed.

	Temperature		Salinity		Oxygen		Transmissometer		Fluorometer	
Station	NaN	INT	NaN	INT	NaN	INT	NaN	INT	NaN	INT
15_01	0	0	0	0	0	0	0	0	0	0
15_02	0	0	0	0	0	0	0	0	0	0
17_02	0	0	0	0	0	0	0	2	0	0
18_02	0	0	0	0	0	0	0	1	0	0
21_01	0	0	0	0	0	0	0	4	0	0
21_03	0	0	0	0	0	0	0	0	0	0
22_02	0	0	0	0	520	5	0	0	0	0
22_04	0	0	0	0	0	0	0	1	0	0
23_01	0	0	0	0	0	0	0	3	0	0
23_03	0	0	0	0	0	0	0	0	0	0
23_04	0	0	0	0	0	0	0	2	0	0
24_01	0	0	0	0	0	0	0	2	0	0
24_04	0	0	0	0	0	0	0	0	0	0
24_07	0	0	0	0	0	0	0	3	0	0
25_04	0	0	0	0	0	0	0	5	0	0
26_01	0	0	0	0	0	0	0	3	0	0
27_06	0	0	0	0	0	0	0	2	0	0
28_05	0	0	0	0	0	0	0	3	0	0
29_01	0	0	0	0	0	0	0	6	0	0
29_08	0	0	0	0	0	0	0	1	0	0
30_02	0	0	0	0	0	0	0	0	0	0
31_01	0	0	0	0	0	0	0	3	0	0
31_03	0	0	0	0	0	0	0	1	0	0
32_01	0	0	0	0	0	0	0	2	0	0
32_05	0	0	0	0	0	0	0	2	0	0
33_01	0	0	0	0	0	0	0	2	0	0
34_02	0	0	0	0	0	0	0	0	0	0
35_01	0	0	0	0	0	0	0	3	0	0
36_01	0	0	0	0	0	0	0	1	0	0
37_01	0	0	0	0	0	0	0	0	0	0
38_01	0	0	0	0	0	0	0	0	0	0
39_02	0	0	0	0	0	0	0	0	0	0
40_01	0	0	0	0	0	0	0	0	0	0
43_02	0	0	0	0	0	0	0	0	0	0
44_01	0	0	0	0	0	0	0	0	0	0
46_02	0	0	0	0	0	0	0	0	0	0
47_03	0	0	0	0	0	0	0	0	0	0
48_02	0	0	0	0	0	0	0	0	0	0
50_02	0	0	0	0	0	0	0	0	0	0
53_01	0	0	0	0	0	0	0	0	0	0
56_01	0	0	0	0	0	0	0	4	0	0
57_01	0	0	0	0	0	0	0	5	0	0

	Temperature		Salinity		Oxygen		Transmissometer		Fluorometer	
58_01	0	0	0	0	0	0	0	1	0	0
59_01	0	0	0	0	0	0	0	3	0	0
60_01	0	0	0	0	0	0	0	3	0	0
65_01	0	0	0	0	0	0	0	2	0	0
66_02	0	0	0	0	0	0	0	0	0	0
67_03	0	0	0	0	0	0	0	1	0	0
69_04	0	0	0	0	0	0	0	3	0	0
71_01	0	0	0	0	0	0	0	0	0	0
73_01	0	0	0	0	0	0	0	0	0	0
73_04	0	0	0	0	0	0	0	3	0	0
74_01	0	0	0	0	0	0	0	1	0	0
75_01	0	0	0	0	0	0	0	2	0	0
76_01	0	0	0	0	0	0	0	0	0	0
78_01	0	0	0	0	0	0	0	1	0	0
80_01	0	0	0	0	0	0	0	0	0	0
80_06	0	0	0	0	0	0	0	0	0	0
81_01	0	0	0	0	0	0	0	0	0	0
82_01	0	0	0	0	0	0	572	0	0	0
83_01	0	0	0	0	0	0	423	0	0	0
85_01	0	0	0	0	0	0	286	0	0	0
88_02	0	0	0	0	0	0	264	0	0	0
91_04	0	0	0	0	0	0	119	0	0	0
93_04	0	0	0	0	0	0	173	0	0	0

Applying the temperature and salinity correction from post-calibration

A difference between the primary and secondary temperature sensor was observed during the data acquisition in the order of about -0.0005 °C (T0-T1). The post-calibration from October 28th 2017 (see appendix) indicated small offsets too, see Table 5.

Tab. 5: Temperature correction based on the post-calibration.

Temperature Sensor	Serial Number	Offset
Primary (T0)	2460	-0.00002 °C
Secondary (T1)	2417	0.00000 °C

The secondary sensor pair was removed. For all profiles the primary temperature it was not necessary to apply a correction.

$$T0_{corr} = T0$$

Salinity was corrected based on the in-situ calibration; see chapter 5.

$$S_{corr} = S + 0.004$$

Oxygen, transmissometer and fluorometer

No in-situ calibration (Winkler titration) was performed for the oxygen sensor SBE43. The post-calibration results in a slope calibration of 0.7980 ml/l. According to the Sea-Birds APPLICATIONS NOTE NO. 64-2 this would reduce e.g. a measured oxygen of 7.5 ml/l by 1.5 ml/l. A comparison with cruise ARK-XXV/1 and PS109, where in-situ calibration was performed, shows **not to apply** a correction based on the post-cruise calibration.

The transmissometer (CSTAR) and fluorometer (ecoFLR) were not calibrated during the cruise. For this reason data from these sensors are given as “relative units”. That means e.g. the chlorophyll can be used for determining the depth of the chlorophyll maximum but do not compare the quantity of the chlorophyll with previous cruises. Same applies for the transmissometer.

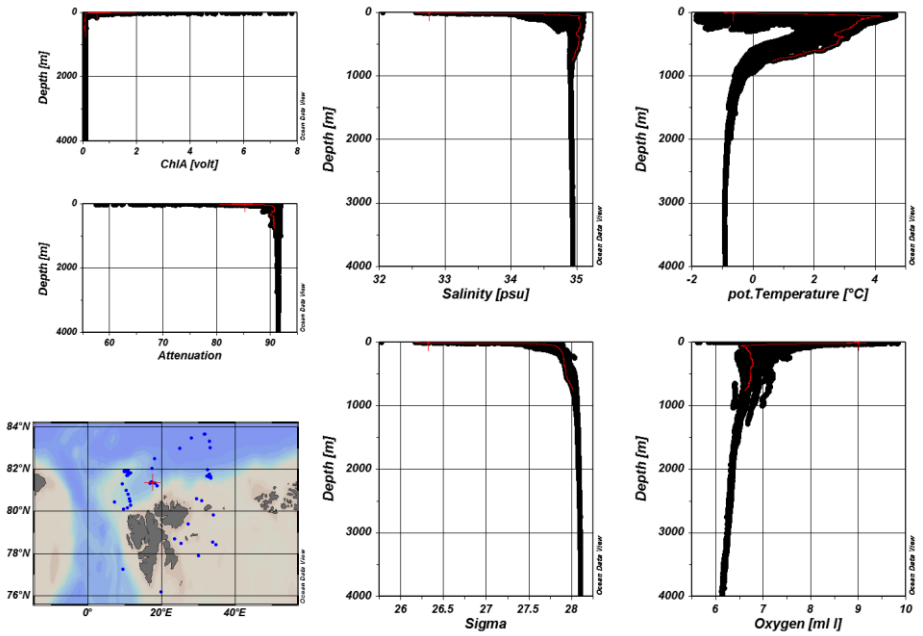

Fig. 2: Scatter plot of all cast from PS106.1+2

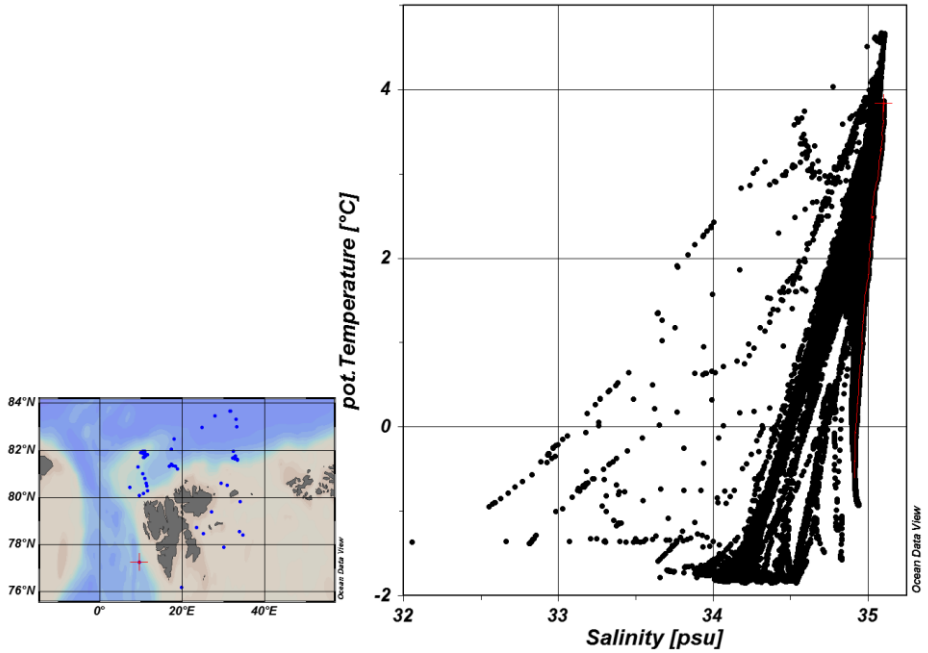

Fig. 3: T/S.plot of all cast from PS106.1+2.

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:\CTD\PS106\SeasavePS106..psa

Date: 05/23/2017

Instrument configuration file: C:\CTD\PS106\CTD-PS106..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               : Yes
NMEA device connected to      : PC
Surface PAR voltage added     : No
Scan time added               : No

1) Frequency 0, Temperature

   Serial number : 2460
   Calibrated on : 20-Dec-16
   G             : 4.37743910e-003
   H             : 6.47399839e-004
   I             : 2.38208049e-005
   J             : 2.24419047e-006
   F0            : 1000.000
   Slope         : 1.00000000
   Offset        : 0.0000

2) Frequency 1, Conductivity

   Serial number : 2055
   Calibrated on : 22-Nov-16
   G             : -9.95652006e+000
   H             : 1.42794866e+000
   I             : -3.90575893e-003
   J             : 3.61897010e-004
   CTcor         : 3.2500e-006
   CPcor         : -9.57000000e-008
   Slope         : 1.00000000
   Offset        : 0.00000

3) Frequency 2, Pressure, Digiquartz with TC

   Serial number : 0485
   Calibrated on : 04-Feb-14
   C1            : -4.853311e+004
   C2            : 5.746510e-001
   C3            : 1.431180e-002
   D1            : 3.777200e-002
   D2            : 0.000000e+000
   T1            : 2.999560e+001
   T2            : -2.287520e-004
   T3            : 4.107500e-006
   T4            : 2.360000e-009
   T5            : 0.000000e+000
   Slope         : 0.99994579
```

```
   Offset        : -0.95173
   AD590M        : 1.280810e-002
   AD590B        : -9.658490e+000

4) Frequency 3, Temperature, 2

   Serial number : 2417
   Calibrated on : 20-Dec-16
   G             : 4.38703138e-003
   H             : 6.48225854e-004
   I             : 2.38663293e-005
   J             : 2.23695811e-006
   F0            : 1000.000
   Slope         : 1.00000000
   Offset        : 0.0000

5) Frequency 4, Conductivity, 2

   Serial number : 2054
   Calibrated on : 22-Nov-16
   G             : -1.01495827e+001
   H             : 1.43780904e+000
   I             : -4.19682568e-003
   J             : 3.83397927e-004
   CTcor         : 3.2500e-006
   CPcor         : -9.57000000e-008
   Slope         : 1.00000000
   Offset        : 0.00000

6) A/D voltage 0, Oxygen, SBE 43

   Serial number : 0880
   Calibrated on : 03-Aug-10
   Equation      : Sea-Bird
   Soc           : 5.15400e-001
   Offset        : -4.88700e-001
   A             : -3.03840e-003
   B             : 1.29700e-004
   C             : -2.40910e-006
   E             : 3.60000e-002
   Tau20         : 1.13000e+000
   D1            : 1.92634e-004
   D2            : -4.64803e-002
   H1            : -3.30000e-002
   H2            : 5.00000e+003
   H3            : 1.45000e+003

7) A/D voltage 1, Free

8) A/D voltage 2, Altimeter

   Serial number : 1228
   Calibrated on : 23-Mar-09
   Scale factor  : 15.000
   Offset        : 0.000

9) A/D voltage 3, Free

10) A/D voltage 4, Fluorometer, WET Labs ECO-AFL/FL

    Serial number : 1670
    Calibrated on : 11-Dec-2009
    Dark output   : 0.0290
    Scale factor  : 2.50000000e+001
```

```
11) A/D voltage 5, Transmissometer, WET Labs C-Star

    Serial number : 946
    Calibrated on : 31-Jan-2006
    M             : 20.9732
    B             : -1.3003
    Path length   : 0.250

12) A/D voltage 6, Free

13) A/D voltage 7, Free

Scan length                  : 41
```

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: 2460
CALIBRATION DATE: 28-Oct-17

SBE 3 TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

COEFFICIENTS:

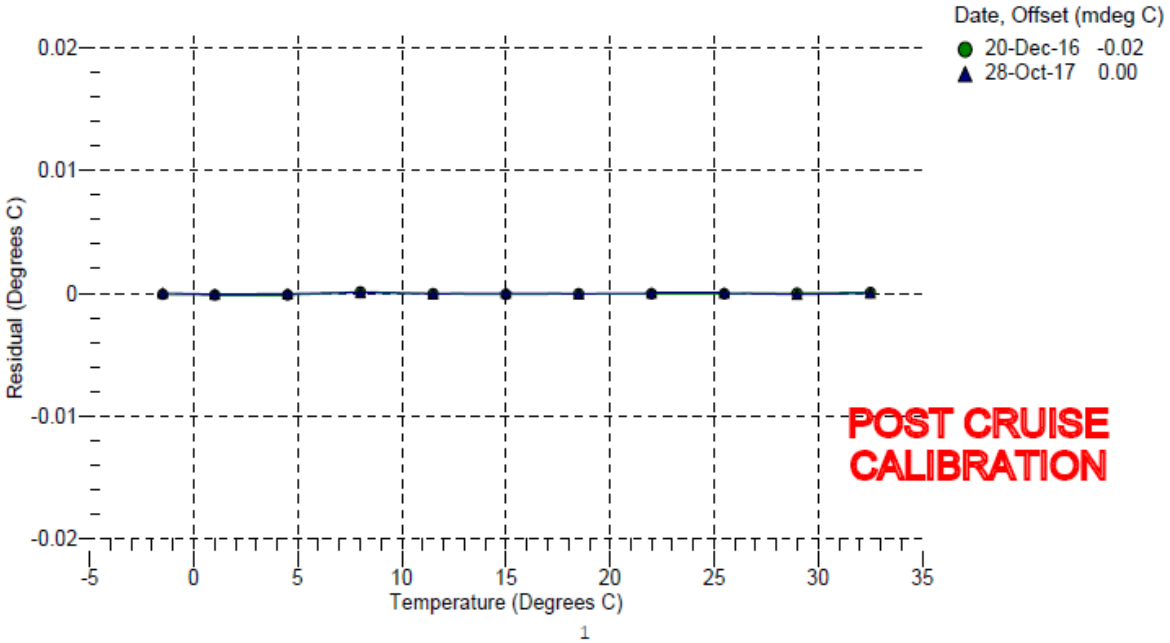
```
g =  4.37759761e-003
h =  6.47727294e-004
i =  2.40452183e-005
j =  2.29512522e-006
f0 =  1000.0
```

BATH TEMP (° C)	INSTRUMENT OUTPUT (Hz)	INST TEMP (° C)	RESIDUAL (° C)
-1.5000	3054.060	-1.5000	0.00005
1.0000	3229.279	0.9999	-0.00006
4.5000	3486.666	4.5000	-0.00003
7.9999	3758.487	8.0000	0.00006
11.5000	4045.134	11.5000	-0.00001
15.0000	4346.977	15.0000	0.00000
18.5000	4664.380	18.5000	-0.00000
22.0000	4997.698	22.0000	0.00002
25.5000	5347.263	25.5000	0.00001
29.0000	5713.394	28.9999	-0.00008
32.5000	6096.433	32.5000	0.00005

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: 2417
CALIBRATION DATE: 28-Oct-17

SBE 3 TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

COEFFICIENTS:

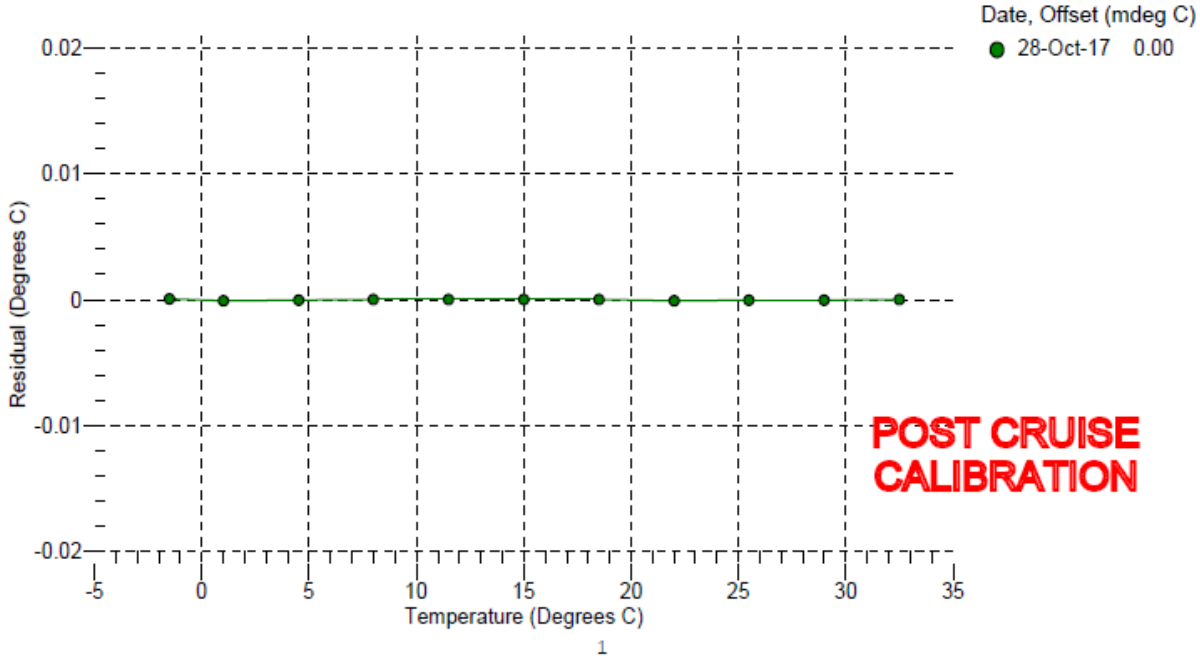
```
g =  4.38719391e-003
h =  6.48551826e-004
i =  2.40888276e-005
j =  2.28706331e-006
f0 =  1000.0
```

BATH TEMP (° C)	INSTRUMENT OUTPUT (Hz)	INST TEMP (° C)	RESIDUAL (° C)
-1.5000	3098.650	-1.4999	0.00006
1.0000	3276.358	0.9999	-0.00007
4.5000	3537.395	4.5000	-0.00003
7.9999	3813.056	7.9999	0.00003
11.5000	4103.749	11.5000	0.00001
15.0000	4409.838	15.0000	0.00004
18.5000	4731.692	18.5000	0.00002
22.0000	5069.662	21.9999	-0.00006
25.5000	5424.110	25.5000	-0.00001
29.0000	5795.346	29.0000	-0.00001
32.5000	6183.693	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: 2055
CALIBRATION DATE: 03-Nov-17

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

COEFFICIENTS:

```
g =  -9.95636136e+000
h =   1.42790083e+000
i =  -3.91063235e-003
j =   3.64104047e-004

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

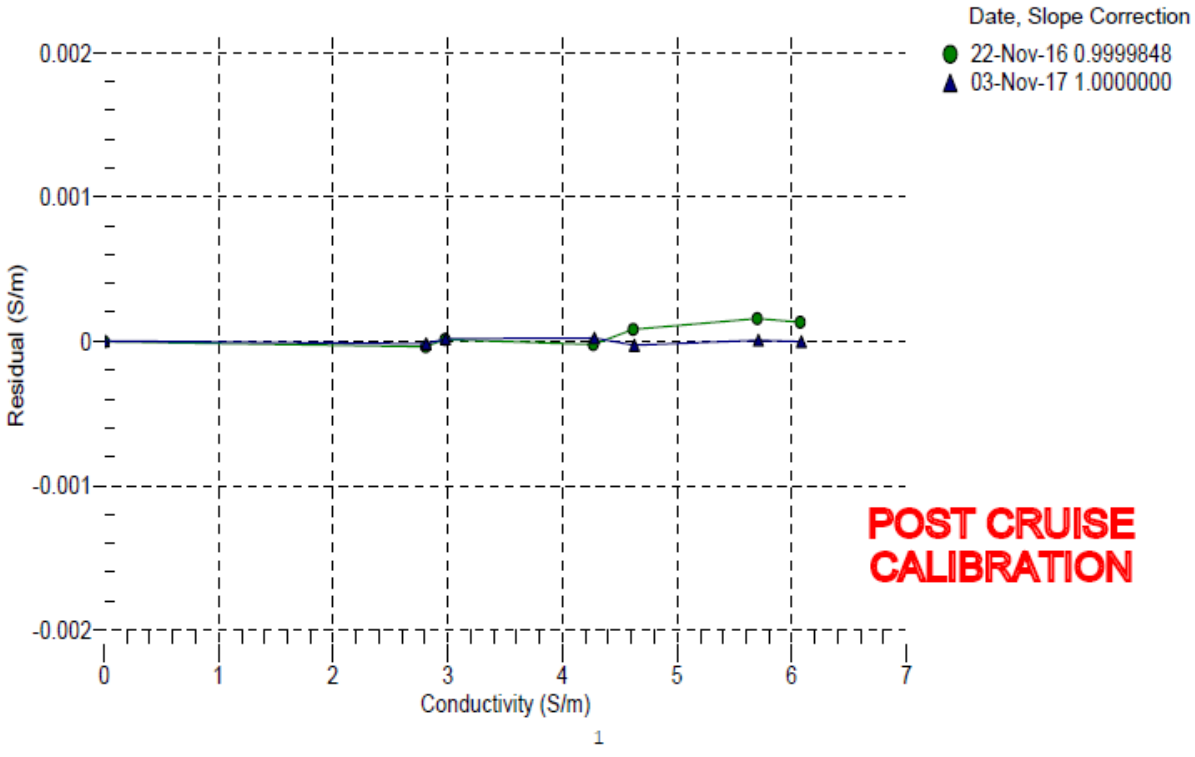
BATH TEMP (° C)	BATH SAL (PSU)	BATH COND (S/m)	INSTRUMENT OUTPUT (kHz)	INSTRUMENT COND (S/m)	RESIDUAL (S/m)
0.0000	0.0000	0.00000	2.64784	0.00000	0.00000
-1.0000	34.8720	2.80864	5.18068	2.80863	-0.00002
1.0000	34.8719	2.98026	5.29630	2.98028	0.00002
15.0000	34.8717	4.27769	6.09924	4.27771	0.00002
18.5000	34.8715	4.62490	6.29658	4.62487	-0.00003
29.0000	34.8690	5.70998	6.87645	5.70999	0.00001
32.5000	34.8651	6.08354	7.06487	6.08353	-0.00000

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: 2054
CALIBRATION DATE: 09-Nov-17

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

COEFFICIENTS:

```
g =  -1.01486007e+001
h =   1.43781099e+000
i =  -4.26502092e-003
j =   3.89636941e-004

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

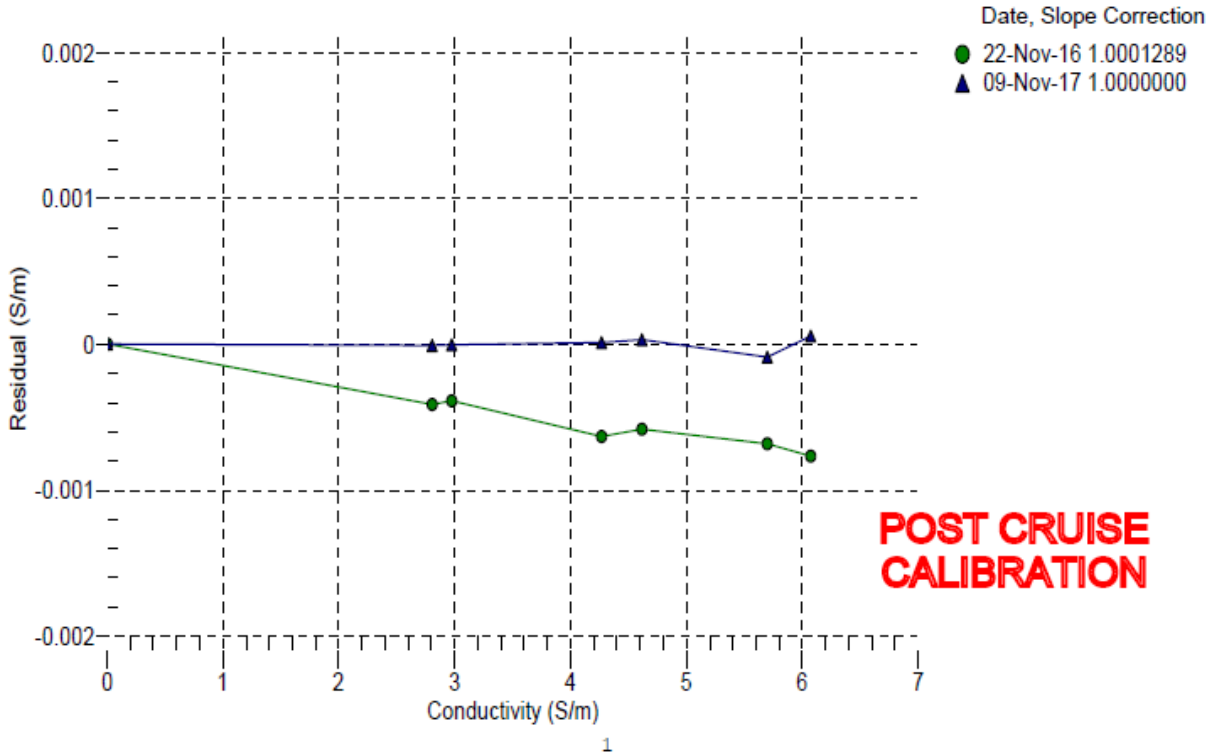
BATH TEMP (° C)	BATH SAL (PSU)	BATH COND (S/m)	INSTRUMENT OUTPUT (kHz)	INSTRUMENT COND (S/m)	RESIDUAL (S/m)
0.0000	0.0000	0.00000	2.66474	0.00000	0.00000
-1.0000	34.8011	2.80347	5.17427	2.80346	-0.00001
1.0000	34.8019	2.97485	5.28918	2.97485	-0.00000
15.0000	34.8026	4.27011	6.08733	4.27012	0.00001
18.5000	34.8019	4.61666	6.28355	4.61670	0.00003
29.0000	34.7970	5.69951	6.85997	5.69942	-0.00009
32.5000	34.7837	6.07095	7.04674	6.07100	0.00006

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: 0880
CALIBRATION DATE: 04-Nov-17

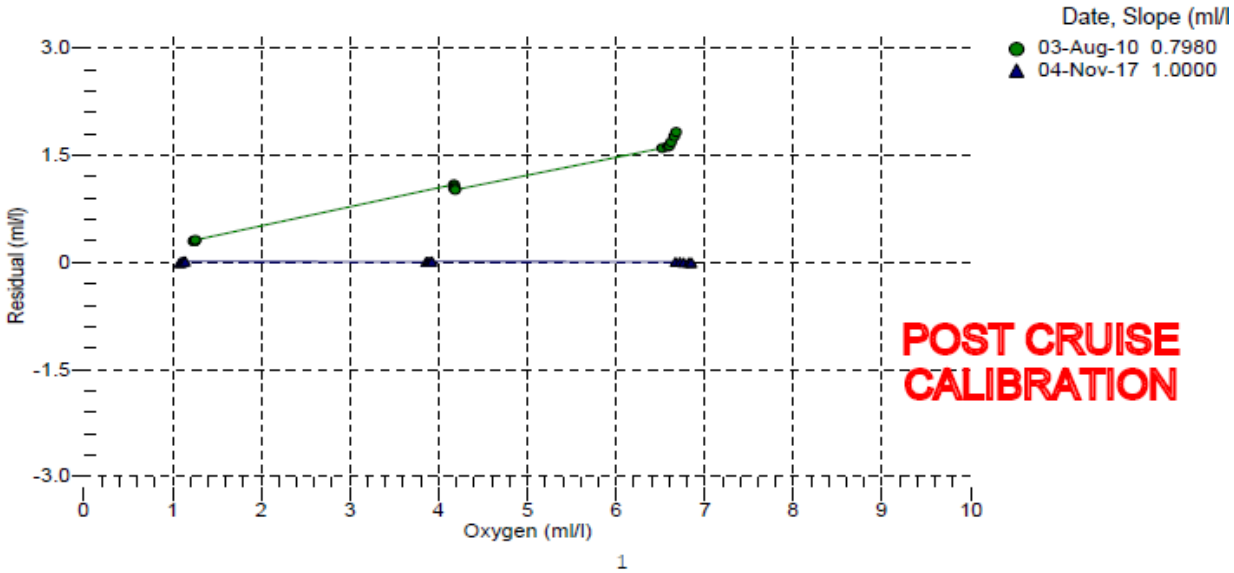
SBE 43 OXYGEN CALIBRATION DATA

COEFFICIENTS:
Soc = 0.6611
Voffset = -0.4953
Tau20 = 2.11
A = -5.1301e-003
B = 1.7352e-004
C = -2.4487e-006
E nominal = 0.036

NOMINAL DYNAMIC COEFFICIENTS
D1 = 1.92634e-4
D2 = -4.64803e-2
H1 = -3.300000e-2
H2 = 5.00000e+3
H3 = 1.45000e+3

BATH OXYGEN (ml/l)	BATH TEMPERATURE (° C)	BATH SALINITY (PSU)	INSTRUMENT OUTPUT (volts)	INSTRUMENT OXYGEN (ml/l)	RESIDUAL (ml/l)
1.08	2.00	0.00	0.664	1.07	-0.01
1.09	6.00	0.00	0.689	1.09	-0.01
1.10	12.00	0.00	0.725	1.10	-0.00
1.12	20.00	0.00	0.777	1.12	0.00
1.13	26.00	0.00	0.818	1.14	0.01
1.14	30.00	0.00	0.848	1.15	0.01
3.86	2.00	0.00	1.105	3.86	0.00
3.87	6.00	0.00	1.185	3.87	0.00
3.89	12.00	0.00	1.310	3.90	0.00
3.91	20.00	0.00	1.477	3.91	0.00
3.92	26.00	0.00	1.609	3.93	0.01
3.93	30.00	0.00	1.697	3.93	0.01
6.67	2.00	0.00	1.549	6.67	0.00
6.72	6.00	0.00	1.692	6.72	0.00
6.76	12.00	0.00	1.908	6.76	-0.00
6.82	20.00	0.00	2.205	6.81	-0.01
6.85	30.00	0.00	2.585	6.84	-0.01
6.85	26.00	0.00	2.434	6.85	-0.00

V = instrument output (volts); T = temperature (°C); S = salinity (PSU); K = temperature (°K)
Oxsol(T,S) = oxygen saturation (ml/l); P = pressure (dbar)
$Oxygen\ (ml/l) = Soc * (V + Voffset) * (1.0 + A * T + B * T^2 + C * T^3) * Oxsol(T,S) * \exp(E * P / K)$
Residual (ml/l) = instrument oxygen - bath oxygen



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