

CTD Data Processing Report

RV POLARSTERN Cruise PS109

Gerd Rohardt

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1. Introduction

This report describes the processing of CTD raw data acquired by Seabird SBE 911plus CTD on board RV POLARSTERN during expedition PS109. The standard processing procedures are described in the document *AWI CTD Data Processing*

2. Cruise Details

Vessel	RV POLARSTERN
Cruise	PS109
Region	Fram Strait and in front of the 79N Glacier
Departure	Tromsø, Sep. 12. 2017
Arrival	Bremerhaven, Oct. 14. 2017
Responsible operator	Janin Schaffer, AWI
Responsible for data processing	Gerd Rohardt, AWI
Number of CTD casts	90
Number of processed casts	89 (see chapter 4)

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 (with LADCP)
	Carousel Water Sampler	SBE32
Sensors	Primary Temperatur	SBE3plus; SN 5101; cal ³ : 13.Dec.2016 and 27.Oct.2017
	Primary Conductivity	SBE4C; SN 3290; cal: 13.Dec.2016 and 8.Nov.2017
	Secondary Temperatur	SBE3plus; SN 5112; cal: 13.Dec.2016 and 27.Oct.2017
	Secondary Conductivity	SBE4C; SN 3570; cal: 13.Dec.2016 and 3.Nov.2017
	Oxygen	SBE43; SN 467; cal: 28.Dec.2016 and 14.Nov.2017
		SBE43; SN 2292; cal: 7.Oct.2012 and 14.Nov.2017
	Transmisometer ⁴	Wetlabs CStar;SN 1220; cal: 2.Apr.2009
Salinometer	Fluorometer ⁴	Wetlabs EcoFLR;SN 1853; cal: 26.May.2010
	Altimeter	Benthos PSA900;SN 47768; cal:23.Mar.2009
	Optimare Precision Salinometer OPS	SN 006
	Standard Seawater	P160; K ₁₅ = 0.99983; valid until: 2019-07-20

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 or conductivity sensor. The oxygen sensor was replaced after the first cast and later a second oxygen sensor was installed. No signals were received from this sensor (SN 1834), see Table 1.

The profiles from CStar transmissometer covered a wide range while the ones measured during the previous cruise PS100 varied in a small range only. Therefore these profiles should be used carefully. On the other hand they could still be useful, e.g. showing indications of stronger bottom current.

Winch or wire problems did not occur during the whole cruise. Both sensor pairs performed precise but the secondary conductivity seem to drift more than the primary one; see Figure 1.

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. Extreme ship drift occurred during stations 144-1 and 152-1.

Tab. 1: List of CTD/Water Sampler stations from leg PS109

Station	Cast	Datetime	Latitude	Longitude	NBS Depth (m)	Alti-meter (m)	Pmax from CTD (dbar)	Remark
5	1	15-Sep-2017 03:08:52	78 9.174 N	0 0.480 E	3067		1015	SBE43 sn467 failed
6	1	15-Sep-2017 09:35:44	78 49.008 N	0 0.018 E	2612		1016	SBE43 replaced, sn 2292
7	1	15-Sep-2017 15:43:42	79 28.812 N	0 0.816 E	2835	9	2820	
8	1	16-Sep-2017 00:05:04	80 7.614 N	0 3.750 W	2705		1014	
9	1	16-Sep-2017 07:53:15	80 49.764 N	0 1.968 E	3105		1014	
10	1	16-Sep-2017 12:49:05	80 35.904 N	1 27.114 W	3363		1014	
11	1	16-Sep-2017 16:53:55	80 22.872 N	3 9.006 W	3232	8	3229	
12	1	16-Sep-2017 20:23:08	80 19.806 N	4 0.558 W	2570		1218	
13	1	16-Sep-2017 22:04:36	80 18.498 N	4 32.430 W	2088		1045	
14	1	16-Sep-2017 23:57:02	80 17.484 N	4 59.568 W	1546	9	1534	
15	1	17-Sep-2017 02:37:03	80 15.918 N	5 29.496 W	921	10	895	
16	1	17-Sep-2017 05:03:25	80 14.130 N	6 5.184 W	358	11	339	
17	1	17-Sep-2017 06:59:52	80 13.422 N	6 31.038 W	281	10	283	
18	1	17-Sep-2017 09:09:46	80 12.246 N	7 0.780 W	287	3	290	
19	1	17-Sep-2017 11:37:05	80 8.910 N	7 56.784 W	321	4	328	Samples taken without stop
26	1	18-Sep-2017 07:06:14	80 40.260 N	7 55.674 W	74	10	74	
27	1	18-Sep-2017 09:53:48	80 33.156 N	7 51.918 W	260	4	262	
29	1	18-Sep-2017 12:23:24	80 27.666 N	7 53.844 W	236	9	233	
30	1	18-Sep-2017 14:07:00	80 22.776 N	7 55.968 W	248	9	246	
31	1	18-Sep-2017 16:25:00	80 18.240 N	8 1.578 W	263	10	260	
33	1	18-Sep-2017 21:08:30	80 13.320 N	8 10.722 W	273	9	277	
34	1	18-Sep-2017 23:18:16	80 8.904 N	8 18.744 W	332	15	320	
35	1	19-Sep-2017 01:00:45	80 3.744 N	8 19.788 W	211	10	205	
36	1	19-Sep-2017 05:09:58	80 19.596 N	9 58.398 W	314	10	309	
41	1	20-Sep-2017 03:29:26	79 59.766 N	14 47.766 W	148	9	146	Add a second SBE43, sn 1834
42	1	20-Sep-2017 05:21:27	80 0.936 N	15 7.902 W	214	10	205	
43	1	20-Sep-2017 08:31:41	80 5.724 N	15 36.498 W	431	5	430	
44	2	20-Sep-2017 15:42:19	80 8.874 N	17 23.928 W	165	10	162	
45	1	20-Sep-2017 17:44:04	80 8.094 N	17 41.460 W	204	9	201	
46	1	20-Sep-2017 21:32:57	80 9.264 N	17 21.630 W	176	6	170	
47	1	20-Sep-2017 22:30:11	80 7.890 N	17 25.566 W	152	4	156	
48	1	21-Sep-2017 00:11:48	80 6.192 N	17 24.900 W	92	15	87	
49	1	21-Sep-2017 01:33:00	80 8.244 N	17 5.706 W	196	10	194	
52	2	21-Sep-2017 18:57:29	79 26.382 N	19 46.620 W	321	10	317	

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54	1	22-Sep-2017 00:24:35	79 38.430 N	19 7.764 W	421	9	415	
55	1	22-Sep-2017 01:39:21	79 37.902 N	19 13.968 W	402	9	399	
56	1	22-Sep-2017 03:36:25	79 37.044 N	19 17.256 W	352	9	348	
57	1							Cast canceled dui to frozen sensor
58	1	22-Sep-2017 06:52:00	79 35.610 N	19 20.370 W	319	9	316	
63	1	23-Sep-2017 01:09:16	79 34.950 N	19 19.872 W	376	10	211	
Station	Cast	Datetime	Latitude	Longitude	NBS Depth (m)	Alti-meter (m)	Pmax from CTD (dbar)	Remark
64	1	23-Sep-2017 02:30:11	79 34.548 N	19 21.588 W	444	10	440	
65	1	23-Sep-2017 03:21:44	79 34.212 N	19 24.756 W	466	10	460	
66	1	23-Sep-2017 05:13:43	79 34.104 N	19 28.050 W	474	9	469	
67	1	23-Sep-2017 06:10:27	79 34.038 N	19 30.600 W	470	9	464	
77	1	24-Sep-2017 04:23:56	79 33.996 N	19 19.410 W	415	9	409	
78	1	24-Sep-2017 06:08:26	79 33.024 N	19 20.448 W	360	10	354	
79	1	24-Sep-2017 07:11:04	79 31.932 N	19 21.834 W	339	9	331	
80	1	24-Sep-2017 08:49:23	79 30.942 N	19 20.094 W	307	7	303	
82	1	24-Sep-2017 15:27:12	79 30.126 N	19 16.548 W	333	11	326	
87	1	25-Sep-2017 03:37:08	79 31.014 N	18 39.540 W	491	10	485	
89	1	25-Sep-2017 22:27:35	79 12.186 N	17 18.330 W	307	4	308	
90	1	26-Sep-2017 02:03:58	79 14.286 N	16 47.364 W	389	10	384	
91	1	26-Sep-2017 05:44:05	79 13.704 N	16 2.202 W	273	10	270	
92	1	26-Sep-2017 07:48:32	79 14.652 N	16 23.670 W	337	9	329	
93	1	26-Sep-2017 11:27:55	79 11.676 N	17 5.574 W	390	10	385	
94	1	26-Sep-2017 15:02:15	79 11.700 N	17 29.076 W	97	10	90	
100	1	28-Sep-2017 04:53:30	78 26.760 N	18 33.498 W	319	10	311	
101	1	28-Sep-2017 06:21:00	78 28.782 N	18 33.360 W	439	10	430	
102	1	28-Sep-2017 08:03:17	78 28.290 N	18 29.910 W	426	9	417	
103	1	28-Sep-2017 09:11:00	78 27.096 N	18 25.680 W	454	9	429	
104	1	28-Sep-2017 10:52:33	78 25.680 N	18 20.418 W	508	5	507	
114	2	29-Sep-2017 17:31:00	77 55.728 N	17 5.286 W	361	10	358	
115	1	29-Sep-2017 22:07:35	78 1.872 N	16 34.278 W	509	9	504	
116	1	30-Sep-2017 08:01:32	78 25.770 N	17 56.112 W	671	9	664	
119	3	01-Oct-2017 11:00:55	78 54.372 N	17 58.500 W	472	4	471	
123	1	02-Oct-2017 18:33:00	77 53.298 N	13 20.742 W	171	12	166	
124	1	02-Oct-2017 20:37:22	77 52.008 N	13 24.696 W	160	6	305	
125	4	03-Oct-2017 02:55:02	77 47.748 N	13 38.244 W	389	9	385	
126	1	03-Oct-2017 05:36:36	77 49.998 N	13 31.350 W	402	10	397	
128	1	03-Oct-2017 07:51:42	77 54.450 N	13 16.362 W	142	9	146	
130	1	03-Oct-2017 11:52:52	77 54.402 N	12 0.066 W	155	6	156	
131	1	03-Oct-2017 13:37:56	77 54.372 N	11 0.450 W	214	10	210	
132	1	03-Oct-2017 15:20:27	77 54.420 N	10 0.288 W	230	10	228	
133	2	03-Oct-2017 19:59:39	77 29.700 N	9 57.612 W	254	10	251	
134	1	04-Oct-2017 01:19:55	77 54.444 N	7 59.478 W	224	9	223	
135	1	04-Oct-2017 04:52:41	77 54.390 N	9 0.318 W	235	8	235	
136	1	04-Oct-2017 08:11:12	77 42.012 N	10 0.402 W	234	6	235	
137	1	04-Oct-2017 11:04:19	77 16.494 N	10 0.378 W	345	7	347	
138	1	04-Oct-2017 13:07:41	77 4.074 N	9 59.694 W	427	11	421	
140	1	05-Oct-2017 00:49:46	76 50.574 N	8 52.524 W	355	10	353	
141	1	05-Oct-2017 02:49:17	76 44.244 N	8 19.746 W	346	9	344	
142	2	05-Oct-2017 07:11:23	76 29.262 N	7 8.286 W	1163	15	1169	
143	1	05-Oct-2017 09:48:51	76 32.610 N	7 23.064 W	768	9	771	
144	1	05-Oct-2017 11:38:00	76 34.284 N	7 30.102 W	539		88	Cast canceled due to a strong drift
149	1	06-Oct-2017 14:53:00	76 57.408 N	9 25.362 W	371	10	366	
151	1	06-Oct-2017 20:28:51	76 37.902 N	7 45.444 W	327	9	322	
152	1	06-Oct-2017 21:41:33	76 36.246 N	7 37.974 W	330	4	331	Strong drift
153	1	06-Oct-2017 23:38:01	76 34.404 N	7 29.682 W	533	6	536	
156	1	07-Oct-2017 13:05:15	75 49.116 N	4 51.588 W	3339	10	3389	
157	1	07-Oct-2017 21:18:32	75 0.000 N	2 59.988 W	3630	9	3687	

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. Duplicate samples were drawn from the water sampler to be measured in Bremerhaven after the cruise for another purpose.

The temperature difference did not indicate a significant drift while the conductivity/salinity difference continuously increased, see Figure 1.

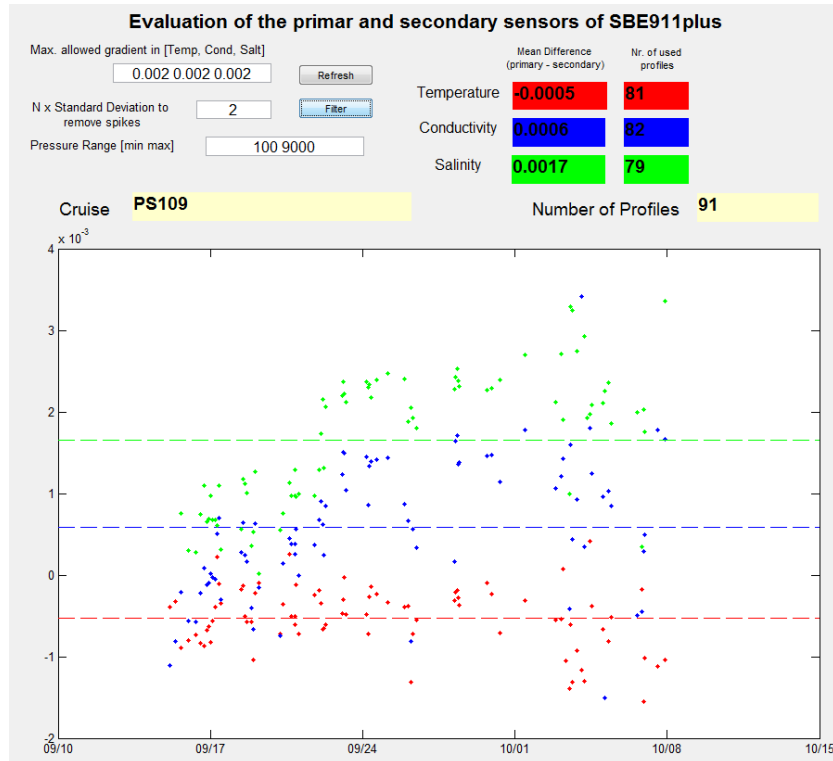


Fig. 1: The statistics of the differences between the primary and secondary sensor pair from layers below 100 m and gradients less than 0.002 ($^{\circ}\text{C}/\text{m}$ or mS/m^2).

Altogether 58 Salinities of the water samples were determined on board using an Optimare Precision Salinometer (OPS). All samples were measured in six sessions. Every session started with standardization. The resulting difference between the salinity measured with the OPS and the salinity S0/S1 measured with the CTD sensor pair T0/C0 and T1/C1 is given in Table 2, see column OPS-S0 and OPS-S0.

Tab. 2: Salinity samples from the water sampler and measured with the OPS. One measure (see *) is obviously a failure, e.g. wrong bottle label or not correct prepared sample.

Station	Date/Time	Press	S0	S1	OPS	OPS-S0	OPS-S1
005_01	15.09.2017 02:45	1013,172	34,9094	34,9084	34,9108	0,0014	0,0024
005_01	15.09.2017 02:45	911,223	34,9063	34,9049	34,9059	-0,0004	0,0010
005_01	15.09.2017 02:45	809,127	34,9163	34,9153	34,9171	0,0008	0,0018
005_01	15.09.2017 02:45	710,84	34,9101	34,9091	34,9111	0,0010	0,0020
006_01	15.09.2017 09:11	1014,812	34,9136	34,9127	34,9148	0,0012	0,0021
006_01	15.09.2017 09:11	911,114	34,9150	34,9140	34,9159	0,0009	0,0019
006_01	15.09.2017 09:11	809,962	34,9179	34,9169	34,9187	0,0008	0,0018
006_01	15.09.2017 09:11	707,804	34,9278	34,9270	34,9290	0,0012	0,0020
007_01	15.09.2017 14:43	2819,177	34,9275	34,9265	34,9270	-0,0005	0,0005
007_01	15.09.2017 14:43	2748,682	34,9255	34,9244	34,9246	-0,0009	0,0002
007_01	15.09.2017 14:43	2542,156	34,9228	34,9218	34,9222	-0,0006	0,0004
007_01	15.09.2017 14:43	2032,599	34,9199	34,9188	34,9193	-0,0006	0,0005
007_01	15.09.2017 14:43	1776,22	34,9188	34,9177	34,9162	-0,0026	-0,0015
008_01	15.09.2017 23:41	1013,775	34,8998	34,8985	34,9006	0,0008	0,0021
008_01	15.09.2017 23:41	910,967	34,8942	34,8929	34,8948	0,0006	0,0019
008_01	15.09.2017 23:41	810,123	34,8876	34,8864	34,8889	0,0013	0,0025
008_01	15.09.2017 23:41	708,993	34,8814	34,8802	34,8825	0,0011	0,0023
011_01	16.09.2017 15:45	3228,414	34,9323	34,9314	34,9293	-0,0030	-0,0021
011_01	16.09.2017 15:45	3053,719	34,9303	34,9295	34,9284	-0,0019	-0,0011
011_01	16.09.2017 15:45	2849,173	34,9279	34,9271	34,9216	-0,0063*	-0,0055*
011_01	16.09.2017 15:45	2643,958	34,9250	34,9242	34,9240	-0,0010	-0,0002
011_01	16.09.2017 15:45	2439,773	34,9233	34,9224	34,9198	-0,0035	-0,0026
011_01	16.09.2017 15:45	2235,216	34,9221	34,9210	34,9211	-0,0010	0,0001
014_01	16.09.2017 23:17	1533,784	34,9154	34,9141	34,9168	0,0014	0,0027
014_01	16.09.2017 23:17	1013,329	34,8948	34,8935	34,8954	0,0006	0,0019
043_01	20.09.2017 08:19	429,768	34,8449	34,8443	34,8471	0,0022	0,0028
043_01	20.09.2017 08:19	404,859	34,8445	34,8440	34,8467	0,0022	0,0027
065_01	23.09.2017 03:06	459,322	34,8324	34,8340	34,8332	0,0008	-0,0008
065_01	23.09.2017 03:06	404,385	34,7522	34,7488	34,7503	-0,0019	0,0015
067_01	23.09.2017 05:55	463,434	34,8222	34,8204	34,8254	0,0032	0,0050
067_01	23.09.2017 05:55	404,701	34,7514	34,7502	34,7534	0,0020	0,0032
086_01	25.09.2017 03:20	485,26	34,9162	34,9138	34,9187	0,0025	0,0049
086_01	25.09.2017 03:20	404,547	34,9107	34,9083	34,9135	0,0028	0,0052
090_01	26.09.2017 01:51	384,122	34,9200	34,9180	34,9225	0,0025	0,0045
090_01	26.09.2017 01:51	354,061	34,9211	34,9174	34,9205	-0,0006	0,0031
093_01	26.09.2017 11:15	385,195	34,9219	34,9193	34,9249	0,0030	0,0056
093_01	26.09.2017 11:15	323,588	34,9121	34,9100	34,9160	0,0039	0,0060
103_01	28.09.2017 08:58	429	34,9218	34,9196	34,9236	0,0018	0,0040
103_01	28.09.2017 08:58	404,785	34,9206	34,9188	34,9232	0,0026	0,0044
115_02	29.09.2017 21:53	503,495	34,9345	34,9323	34,9373	0,0028	0,0050
115_02	29.09.2017 21:53	404,606	34,9240	34,9213	34,9252	0,0012	0,0039
116_01	30.09.2017 07:42	663,754	34,9347	34,9322	34,9376	0,0029	0,0054
120_01	01.10.2017 10:46	470,336	34,9154	34,9126	34,9159	0,0005	0,0033
120_01	01.10.2017 10:46	454,772	34,9148	34,9121	34,9141	-0,0007	0,0020
120_01	01.10.2017 10:46	352,227	34,8949	34,8923	34,8958	0,0009	0,0035
126_01	03.10.2017 05:23	395	34,9231	34,9212	34,9305	0,0074	0,0093
126_01	03.10.2017 05:23	302	34,9630	34,9604	34,9666	0,0036	0,0062
137_01	04.10.2017 10:51	345	34,9364	34,9338	34,9401	0,0037	0,0063
142_02	05.10.2017 06:42	1168	34,9073	34,9036	34,9108	0,0035	0,0072
142_02	05.10.2017 06:42	1012	34,9035	34,8998	34,9033	-0,0002	0,0035
143_01	05.10.2017 09:29	770	34,8871	34,8840	34,8915	0,0044	0,0075
153_01	06.10.2017 23:37	496	34,9260	34,9232	34,9297	0,0037	0,0065
156_01	07.10.2017 11:53	3388	34,9152	34,9113	34,9159	0,0007	0,0046
156_01	07.10.2017 11:53	3052	34,9162	34,9125	34,9173	0,0011	0,0048
156_01	07.10.2017 11:53	1013	34,9135	34,9097	34,9165	0,0030	0,0068
157_01	07.10.2017 20:03	3687	34,9154	34,9117	34,9169	0,0015	0,0052
157_01	07.10.2017 20:03	3567	34,9154	34,9118	34,9168	0,0014	0,0050
157_01	07.10.2017 20:03	1012	34,9134	34,9098	34,9162	0,0028	0,0064

From Table 2 column OPS-S0 and OPS-S1 were plotted vs. date.

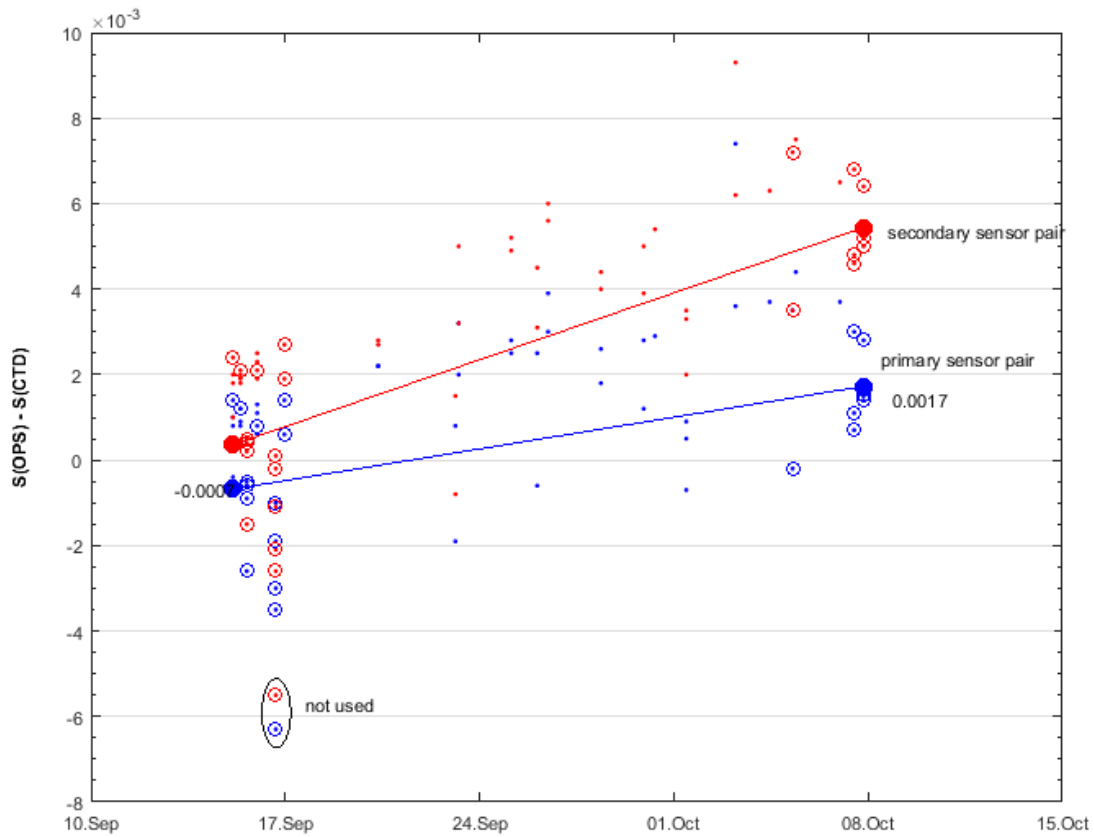


Fig. 2: OPS-S0 (blue) and OPS-S1 (red) vs. date. All measurements indicated by small dots. The circle indicates the measurements from samples taken below 1000 m.

The salinity correction for the primary sensor pair is smaller and the drift is smaller too. The average correction from the beginning of the cruise (deep samples only) is -0.0007 and at the end of the cruise 0.0017 .

6. In-situ Oxygen Calibration

To monitor the accuracy and precision of the CTD's oxygen sensor; type SBE43, water samples were taken on 6 CTD casts for Winkler measurements. Figure 3 shows the resulting correction.

Tab. 3: Oxygen samples from the water sampler. Tow of 36 samples (see *) are obviously a failure e.g. not correct prepared sample.

Station	Date	Pressure (dbar)	Winkler (ml/l)	O ₂ _{CTD} (ml/l)	Winkler – O ₂ _{CTD}
5-1	15.09.2017	1014	7,0005	6,4705	0,5300
		1014	6,9992	6,4705	0,5287
		910	6,9679	6,5259	0,4420
		910	6,9834	6,5259	0,4575
		607	6,9562	6,6613	0,2949*
		607	6,9606	6,6613	0,2993*
7-1	15.09.2017	2819	6,7563	5,942	0,8143
		2748	6,8094	5,9538	0,8556
		2542	6,7697	5,9709	0,7988
		2286	6,7520	5,9903	0,7617
		2033	6,7688	6,0321	0,7367
		1776	6,8164	6,0978	0,7186
11-1	16.09.2017	3228	6,7563	5,9732	0,7831
		3054	6,7778	5,9933	0,7845
		2849	6,7593	6,0043	0,7550
		2644	6,7730	6,0126	0,7604
		2440	6,7480	6,0195	0,7285
		2235	6,7341	6,0284	0,7057
93-1	26.09.2017	385	6,5528	6,0431	0,5097
		385	6,6091	6,0431	0,5660
		354	6,7280	6,1354	0,5926
		354	6,7310	6,1354	0,5956
		324	6,7480	6,1251	0,6229
		324	6,7135	6,1251	0,5884
120-1	01.10.2017	470	6,5935	6,0345	0,5590
		470	6,5986	6,0345	0,5641
		405	6,6132	6,0578	0,5554
		405	6,6048	6,0578	0,5470
		352	6,6126	6,083	0,5296
		352	6,6105	6,083	0,5275
156-1	08.10.2017	3388	6,7258	5,9577	0,7681
		3388	6,7356	5,9577	0,7779
		3052	6,7280	5,9797	0,7483
		3052	6,7625	5,9797	0,7828
		1014	7,4144	6,7464	0,6680
		1014	7,3930	6,7464	0,6466

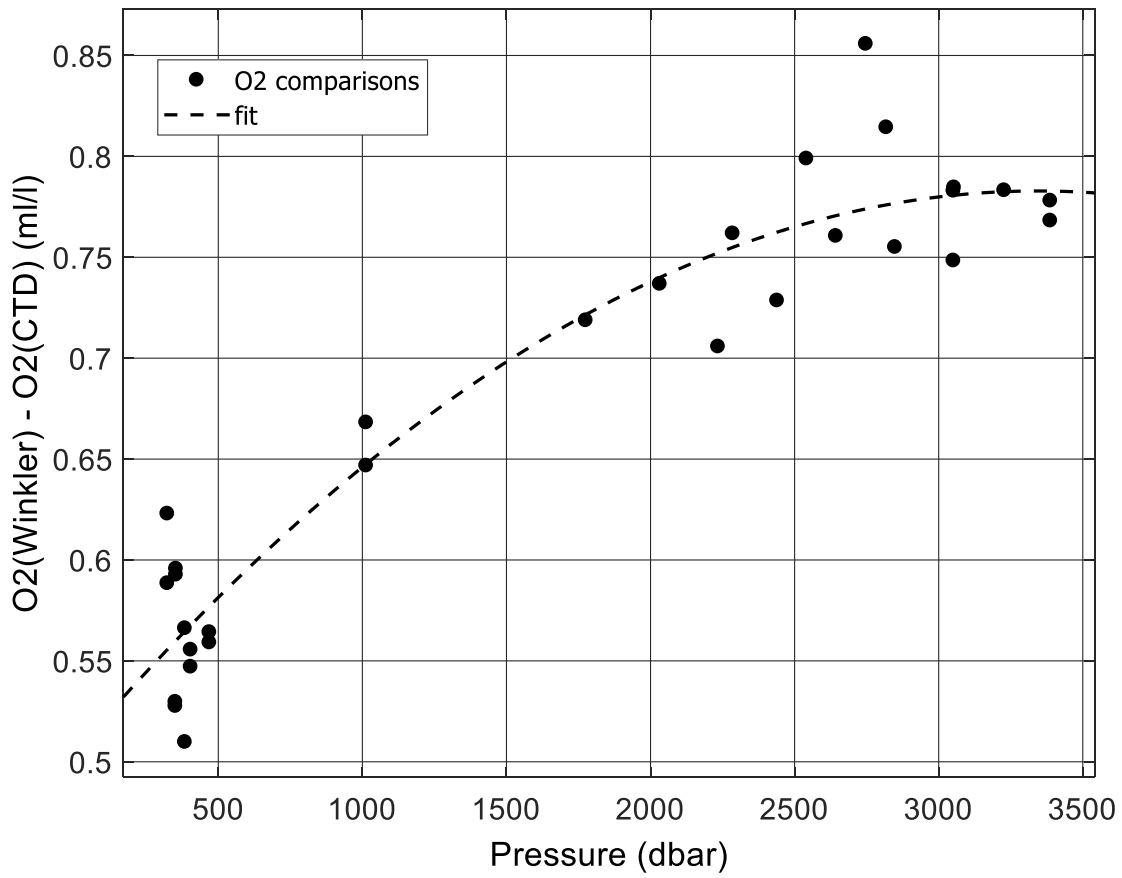


Fig. 3: Oxygen correction versus pressure based on 34 Winkler titrations, see Table 3.

7. Data Processing

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

Typically the chlorophyll (FCHL) becomes very noisy below 200 m. Here large outliers were removed only instead of truncating the whole deep part.

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

Station	Cast	Records	PRES	TEMP	SAL	O2	FCHL	TRANS
5	1	1011	0	0	0	0	0	0
6	1	1012	0	1	2	0	0	4
7	1	2816	0	0	0	0	0	4
8	1	1010	0	0	0	0	0	0
9	1	1010	0	0	0	0	0	0
10	1	1010	0	0	0	0	0	0
11	1	3225	0	0	0	0	98	0
12	1	1216	0	0	0	0	0	0
13	1	1041	0	0	0	0	18	0
14	1	1530	0	0	0	0	0	0
15	1	891	0	0	0	0	13	1
16	1	335	0	0	0	0	0	0
17	1	279	0	0	0	0	0	0
18	1	286	0	0	0	0	0	0
19	1	324	0	0	0	0	7	0
26	1	70	0	0	0	0	0	0
27	1	261	0	0	0	0	0	0
29	1	229	0	0	0	0	0	0
30	1	242	0	0	0	0	6	0
31	1	256	0	0	0	0	0	0
33	1	273	0	0	0	0	0	0
34	1	316	0	0	2	0	0	0
35	1	201	0	0	0	0	0	0
36	1	305	0	0	0	0	0	0
41	1	141	0	0	0	0	0	0
42	1	201	0	0	0	0	0	0
43	1	426	0	0	0	0	2	0
44	2	158	0	0	0	0	0	0
45	1	197	0	0	0	0	0	0
46	1	166	0	0	1	0	0	0
47	1	152	0	0	0	0	0	0
48	1	83	0	1	1	0	0	0
49	1	190	0	0	1	0	0	0
52	2	313	0	0	5	0	0	0
54	1	411	0	0	0	0	0	0
55	1	395	0	0	0	0	0	0
56	1	344	0	0	0	0	0	0
58	1	313	0	2	4	0	0	0
63	1	205	0	0	0	0	0	0
64	1	436	0	0	0	0	0	0
65	1	456	0	0	1	0	0	0
66	1	465	0	1	64	0	0	0
67	1	460	0	0	7	0	0	0
77	1	405	0	0	2	0	0	0
78	1	350	0	0	0	0	0	0
79	1	327	0	0	2	0	0	0
80	1	299	0	0	3	0	0	0
82	1	322	0	0	0	0	0	0
87	1	481	0	0	1	0	0	0
89	1	304	0	0	0	0	0	0
Station	Cast	Records	PRES	TEMP	SAL	O2	FCHL	TRANS

CTD Data Processing Report



90	1	379	0	1	1	0	0	0
91	1	266	0	1	1	0	0	0
92	1	325	0	0	0	0	0	0
93	1	381	0	0	1	0	0	0
94	1	86	0	0	0	0	0	0
100	1	307	0	0	0	0	0	0
101	1	428	0	1	2	0	0	0
102	1	413	0	0	4	0	0	0
103	1	427	0	0	4	0	0	0
104	1	503	0	0	4	0	0	0
114	2	353	0	0	3	0	0	0
115	1	500	0	0	2	0	0	0
116	1	660	0	0	1	0	9	0
119	3	467	0	0	3	0	0	0
123	1	162	0	1	10	0	0	0
124	1	301	0	0	5	0	0	0
125	4	381	0	1	1	0	0	0
126	1	393	0	0	1	0	0	0
128	1	142	0	1	0	0	0	0
130	1	152	0	0	10	0	0	0
131	1	206	0	0	4	0	0	0
132	1	224	0	0	2	0	0	0
133	2	246	0	2	16	0	0	0
134	1	218	0	1	18	0	0	0
135	1	231	0	1	20	0	0	1
136	1	231	0	1	11	0	0	0
137	1	343	0	0	2	0	0	0
138	1	417	0	2	7	0	0	0
140	1	349	0	2	4	0	0	0
141	1	335	0	0	9	0	0	0
142	2	1166	0	6	7	0	30	0
143	1	767	0	1	7	0	0	0
144	1	81	0	1	2	1	1	1
149	1	362	0	2	4	0	0	362
151	1	318	0	4	6	0	0	0
152	1	327	0	0	2	0	0	0
153	1	532	0	1	1	0	0	532
156	1	3385	0	1	3	0	0	3385
157	1	3626	0	0	1	0	3626	3626

Tab. 5: The number of interpolated (column INT) and removed (column NaN) records from the 1dbar-interval during the final processing.

Station_Cast	Temperature		Salinity		Oxygen		Transmissometer		Fluorometer	
	NaN	INT	NaN	INT	NaN	INT	NaN	INT	NaN	INT
005_01	0	0	0	0	1011	0	0	0	0	0
006_01	0	0	0	0	56	0	0	0	0	0
007_01	0	0	0	0	13	0	0	0	0	0
008_01	0	0	0	0	9	0	0	0	0	0
009_01	0	0	0	0	8	0	0	0	0	0
010_01	0	0	0	0	8	0	0	0	0	0
011_01	0	0	0	0	8	0	0	0	0	0
012_01	0	0	0	0	11	0	0	0	0	0
013_01	0	0	0	0	8	0	0	0	0	0
014_01	0	0	0	0	9	0	0	0	0	0
015_01	0	0	0	0	10	0	0	0	0	0
016_01	0	0	0	0	12	0	0	0	0	0
017_01	0	0	0	0	11	0	0	0	0	0
018_01	0	0	0	0	11	0	0	0	0	0
019_01	0	0	0	0	11	0	0	0	0	0
026_01	0	0	0	0	10	0	0	0	0	0
027_01	0	0	0	0	13	0	0	0	0	0
029_01	0	0	0	0	10	0	0	0	0	0
030_01	0	0	0	0	11	0	0	0	0	0
031_01	0	0	0	0	10	0	0	0	0	0
033_01	0	0	0	0	11	0	0	0	0	0
034_01	0	0	0	0	11	0	0	0	0	0
035_01	0	0	0	0	10	0	0	0	0	0
036_01	0	0	0	0	13	0	0	0	0	0
041_01	0	0	0	0	0	0	0	0	0	0
042_01	0	0	0	0	0	0	0	0	0	0
043_01	0	0	0	0	0	0	0	0	0	0
044_02	0	0	0	0	0	0	0	0	0	0
045_01	0	0	0	0	0	0	0	0	0	0
046_01	0	0	0	0	0	0	0	0	0	0
047_01	0	0	0	0	0	0	0	0	0	0
048_01	0	0	0	0	0	0	0	0	0	0
049_01	0	0	0	0	0	0	0	0	0	0
052_02	0	0	0	0	0	0	0	0	0	0
054_01	0	0	0	0	0	0	0	0	0	0
055_01	0	0	0	0	0	0	0	0	0	0
056_01	0	0	0	0	0	0	0	0	0	0
058_01	0	0	0	0	0	0	0	0	0	0
063_01	0	0	0	0	0	0	0	0	0	0
064_01	0	0	0	0	0	0	0	0	0	0
065_01	0	0	0	0	0	0	0	0	0	0
066_01	0	0	0	0	11	0	0	0	0	0
067_01	0	0	0	0	0	0	0	0	0	0
077_01	0	0	0	0	0	0	0	0	0	0
078_01	0	0	0	0	0	0	0	0	0	0
079_01	0	0	0	0	0	0	0	0	0	0
080_01	0	0	0	0	0	0	0	0	0	0
082_01	0	0	0	0	0	0	0	0	0	0
086_01	0	0	0	0	0	0	0	0	0	0
089_01	0	0	0	0	0	0	0	0	0	0
090_01	0	0	0	0	0	0	0	0	0	0
091_01	0	0	0	0	0	0	0	0	0	0
092_01	0	0	0	0	0	0	0	0	0	0
093_01	0	0	0	0	0	0	0	0	0	0
094_01	0	0	0	0	0	0	0	0	0	0
100_01	0	0	0	0	0	0	0	0	0	0
101_01	0	0	0	0	0	0	0	0	0	0
102_01	0	0	0	0	0	0	0	0	0	0
103_01	0	0	0	0	0	0	0	0	0	0

Station_Cast	Temperature		Salinity		Oxygen		Transmissometer		Fluorometer	
	NaN	INT	NaN	INT	NaN	INT	NaN	INT	NaN	INT
104_01	0	0	0	0	0	0	0	0	0	0
114_02	0	0	0	0	0	0	0	0	0	0
115_02	0	0	0	0	0	0	0	0	0	0
116_01	0	0	0	0	0	0	0	0	0	0
120_01	0	0	0	0	0	0	0	0	0	0
123_01	0	0	0	0	0	0	0	0	0	0
124_01	0	0	0	0	0	0	0	0	0	0
125_04	0	0	0	0	0	0	0	0	0	0
126_01	0	0	0	0	0	0	0	0	0	0
128_01	0	0	0	0	0	0	0	0	0	0
130_01	0	0	0	0	0	0	0	0	0	0
131_01	0	0	0	0	0	0	0	0	0	0
132_01	0	0	0	0	0	0	0	0	0	0
133_02	0	0	0	0	0	0	0	0	0	0
134_01	0	0	0	0	0	0	0	0	0	0
135_01	0	0	0	0	0	0	1	0	0	0
136_01	0	0	0	0	0	0	0	0	0	0
137_01	0	0	0	0	0	0	0	0	0	0
138_01	0	0	0	0	0	0	0	0	0	0
140_01	0	0	0	0	0	0	0	0	0	0
141_01	0	0	0	0	0	0	0	0	0	0
142_02	0	0	0	0	0	0	1166	0	0	0
143_01	0	0	0	0	0	0	639	0	0	0
144_01	1	0	1	0	1	0	1	0	1	0
149_01	0	0	0	0	0	0	362	0	0	0
151_01	0	0	0	0	0	0	318	0	0	0
152_01	0	0	0	0	0	0	327	0	0	0
153_01	0	0	0	0	0	0	532	0	0	0
156_01	0	0	0	0	0	1894	3385	0	0	191
157_01	0	0	0	0	0	1993	3626	0	3626	0

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

A difference between the primary and secondary temperature sensor was observed during the data acquisition in the order of less than -0.001 °C (T0-T1). The post-calibration from October 27th 2017 (see appendix) indicated for both temperature sensors an offset which confirms the observed difference T0-T1, see Table 5.

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

Temperature Sensor	Serial Number	Offset
Primary (T0)	5101	0.00034 °C
Secondary (T1)	5112	0.00063 °C

The secondary sensor pair was removed because the salinity correction increase stronger than the one from the primary sensor pair. For all profiles the primary temperature was corrected with a constant offset of +0.00034/2 °C.

$$T0_{corr} = T0 + 0.00017$$

Salinity was corrected based on the in-situ calibration; see Chapter 5, Figure 2.

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

$$\text{with } ds = -0.0275 + 1.0435e-04 \times \text{day}^*$$

*:= Date/time given as the decimal day of the year.

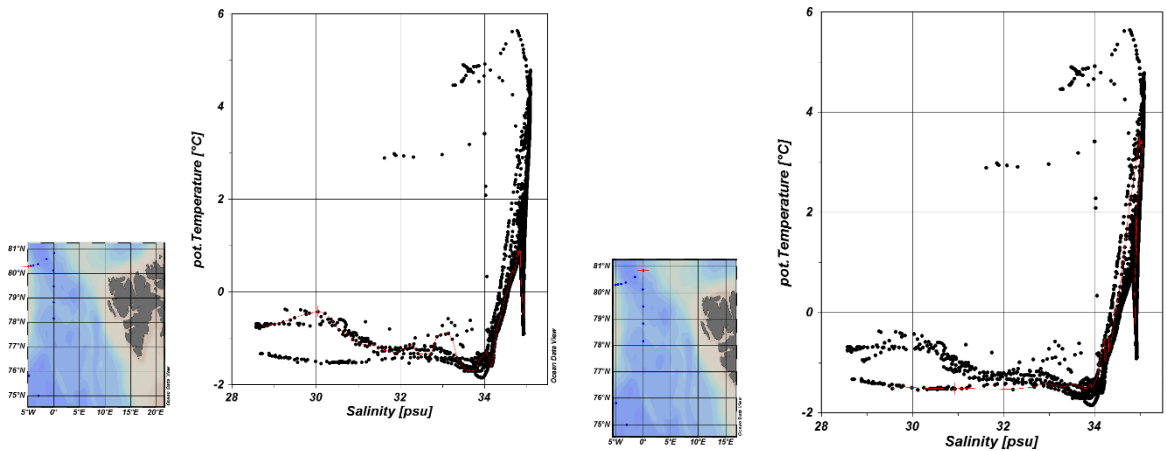


Fig. 4: T/S-Plot from the deep casts; left: uncorrected and right: corrected

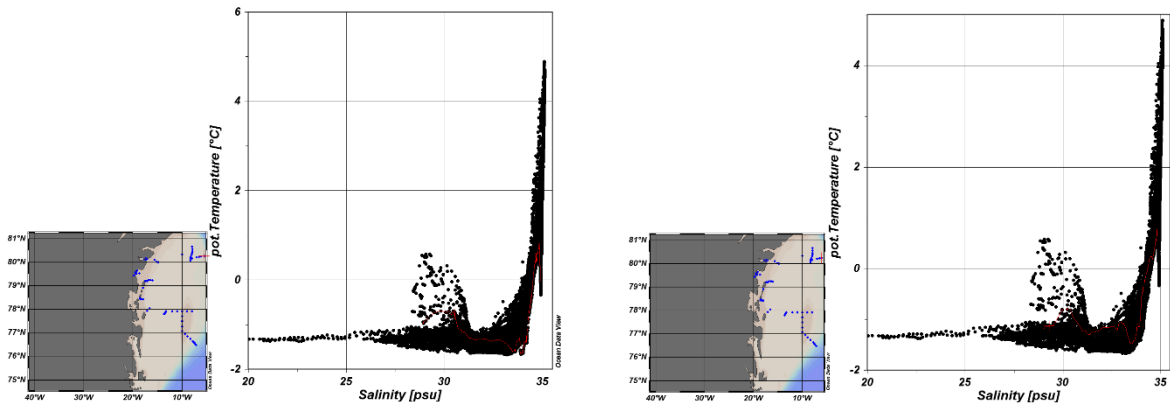


Fig. 5: T/S-Plot from the shallow casts; left: uncorrected and right: corrected

The comparison of the T/S-Plot with uncorrected and corrected casts was used to verify the salinity correction.

Oxygen, transmissometer and fluorometer

The oxygen measured with the CTD, sensor SBE43, was corrected based on Winkler titrations (see Chapter 6, Figure 4)

$$O2_{corr} = O2_{ctd} + dO$$

with $dO = -1.371e-08 * PRES^2 + 1.316e-04 * PRES + 0.5092$

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.

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
```

CTD Data Processing Report



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

CTD Data Processing Report



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: 5101
 CALIBRATION DATE: 27-Oct-17

SBE 3 TEMPERATURE CALIBRATION DATA
 ITS-90 TEMPERATURE SCALE

COEFFICIENTS:

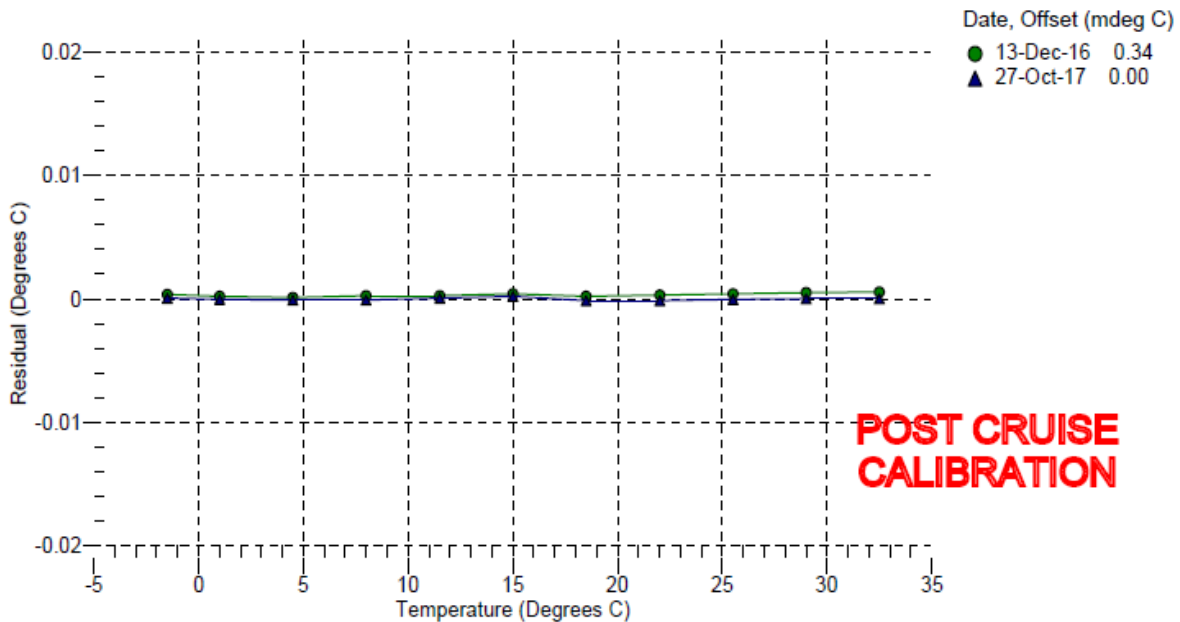
g = 4.35082709e-003
 h = 6.37412260e-004
 i = 2.10027602e-005
 j = 1.82003828e-006
 f0 = 1000.0

BATH TEMP (° C)	INSTRUMENT OUTPUT (Hz)	INST TEMP (° C)	RESIDUAL (° C)
-1.5000	2961.560	-1.4999	0.00006
1.0000	3132.734	1.0000	-0.00004
4.5000	3384.236	4.4999	-0.00008
8.0000	3649.927	7.9999	-0.00007
11.5000	3930.201	11.5001	0.00009
15.0000	4225.422	15.0002	0.00024
18.5000	4535.910	18.4999	-0.00012
22.0000	4862.096	21.9999	-0.00011
25.5000	5204.300	25.5000	-0.00000
29.0000	5562.833	29.0000	0.00001
32.5000	5938.023	32.5000	0.00003

f = Instrument Output (Hz)

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

Residual (°C) = instrument temperature - bath temperature





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SENSOR SERIAL NUMBER: 5112
 CALIBRATION DATE: 27-Oct-17

SBE 3 TEMPERATURE CALIBRATION DATA
 ITS-90 TEMPERATURE SCALE

COEFFICIENTS:

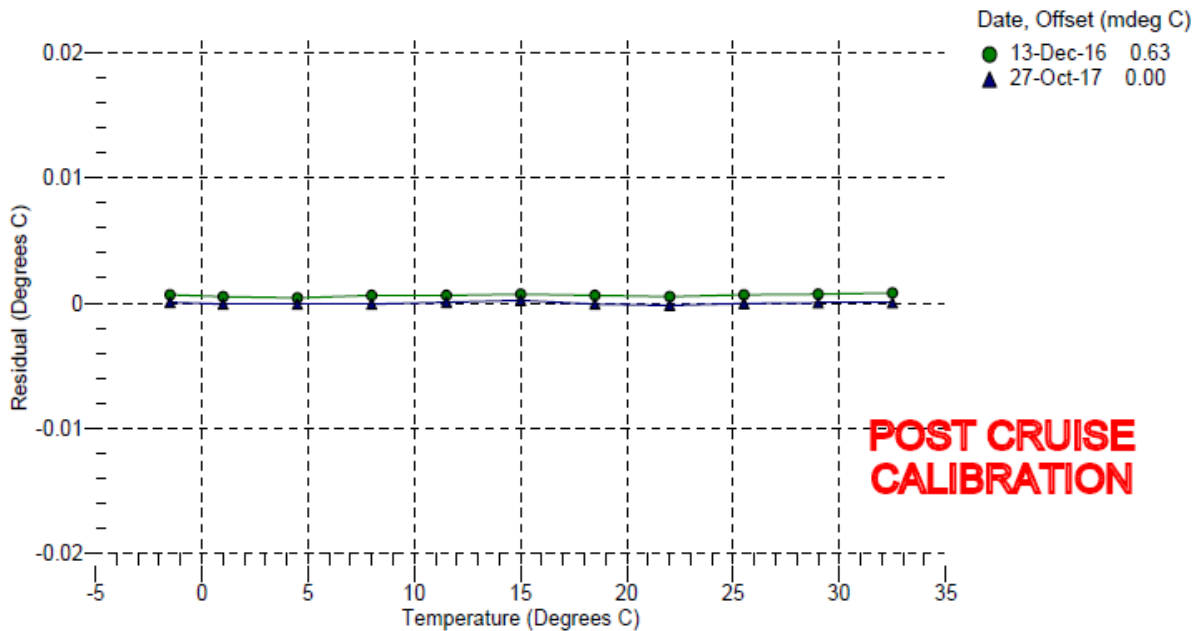
g = 4.37919132e-003
 h = 6.41749014e-004
 i = 2.19514488e-005
 j = 1.97760735e-006
 f0 = 1000.0

BATH TEMP (° C)	INSTRUMENT OUTPUT (Hz)	INST TEMP (° C)	RESIDUAL (° C)
-1.5000	3085.273	-1.4999	0.00008
1.0000	3263.115	0.9999	-0.00006
4.5000	3524.379	4.4999	-0.00009
8.0000	3800.332	7.9999	-0.00007
11.5000	4091.376	11.5001	0.00010
15.0000	4397.883	15.0002	0.00024
18.5000	4720.181	18.4999	-0.00008
22.0000	5058.695	21.9998	-0.00016
25.5000	5413.775	25.5000	-0.00000
29.0000	5785.719	29.0000	0.00003
32.5000	6174.854	32.5000	0.00002

f = Instrument Output (Hz)

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

Residual (°C) = instrument temperature - bath temperature





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SENSOR SERIAL NUMBER: 3290
CALIBRATION DATE: 08-Nov-17

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

COEFFICIENTS:

g = -9.84050613e+000
h = 1.51479602e+000
i = 6.33008739e-004
j = 6.07978828e-005

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

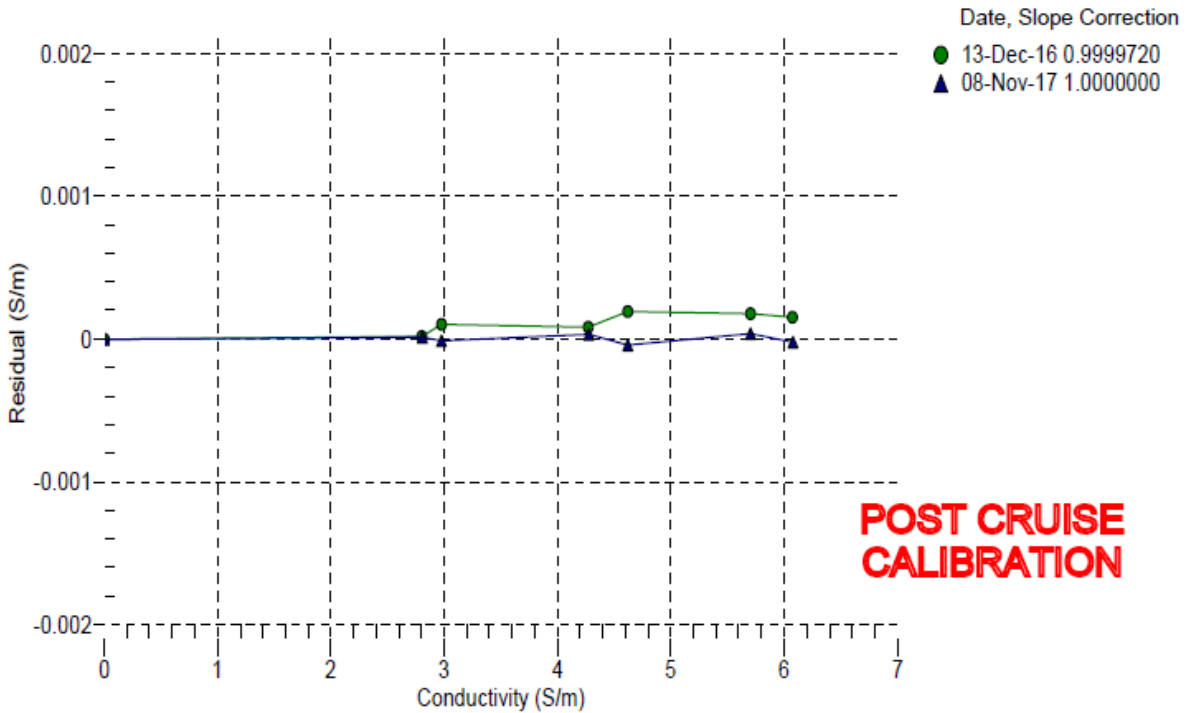
BATH TEMP (° C)	BATH SAL (PSU)	BATH COND (S/m)	INSTRUMENT OUTPUT (kHz)	INSTRUMENT COND (S/m)	RESIDUAL (S/m)
0.0000	0.0000	0.00000	2.54709	0.00000	0.00000
-1.0000	34.8391	2.80624	4.99447	2.80625	0.00001
1.0000	34.8395	2.97776	5.10599	2.97775	-0.00001
15.0000	34.8385	4.27405	5.88049	4.27408	0.00003
18.5000	34.8381	4.62095	6.07085	4.62091	-0.00004
29.0000	34.8317	5.70456	6.63020	5.70459	0.00004
32.5000	34.8204	6.07662	6.81154	6.07660	-0.00002

f = Instrument Output (kHz)

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

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

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





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SENSOR SERIAL NUMBER: 3570
 CALIBRATION DATE: 03-Nov-17

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

COEFFICIENTS:

g = -9.80575078e+000 CPcor = -9.5700e-008 (nominal)
 h = 1.21383100e+000 CTcor = 3.2500e-006 (nominal)
 i = -1.33960638e-003
 j = 1.52693919e-004

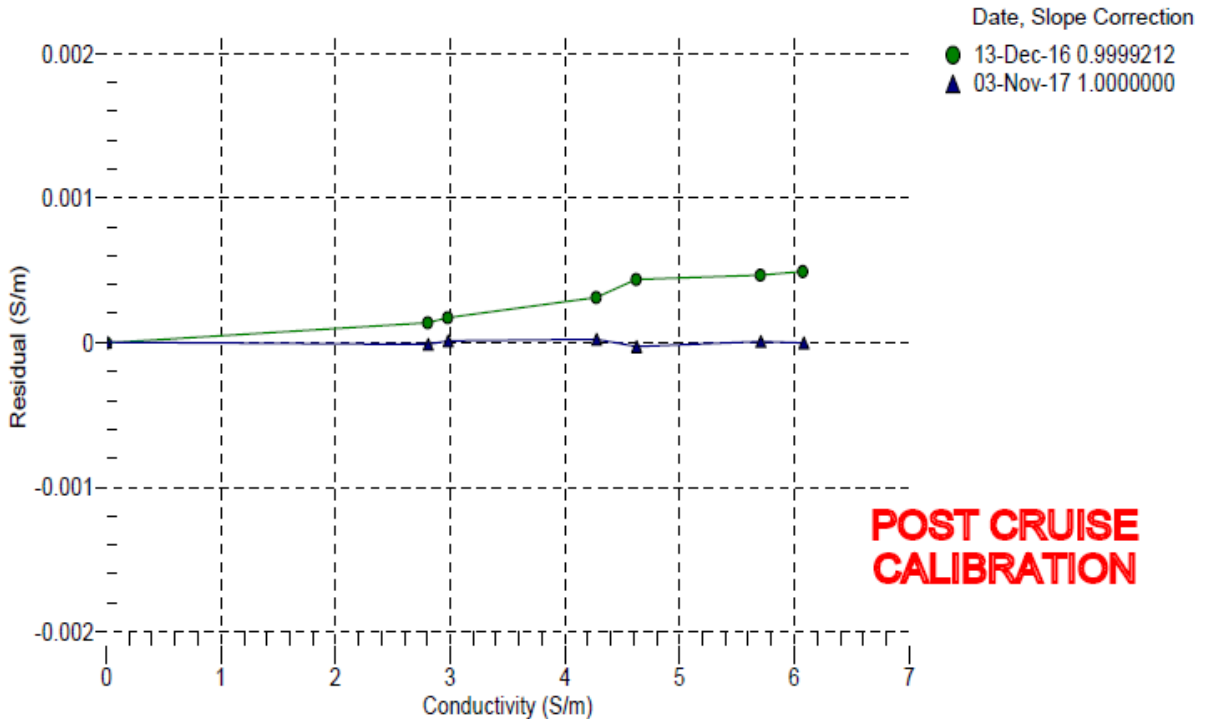
BATH TEMP (°C)	BATH SAL (PSU)	BATH COND (S/m)	INSTRUMENT OUTPUT (kHz)	INSTRUMENT COND (S/m)	RESIDUAL (S/m)
0.0000	0.0000	0.00000	2.84526	0.00000	0.00000
-1.0000	34.8720	2.80864	5.59346	2.80863	-0.00001
1.0000	34.8719	2.98026	5.71865	2.98028	0.00001
15.0000	34.8717	4.27769	6.58787	4.27771	0.00002
18.5000	34.8715	4.62490	6.80148	4.62487	-0.00003
29.0000	34.8690	5.70998	7.42921	5.70999	0.00001
32.5000	34.8651	6.08354	7.63321	6.08353	-0.00000

f = Instrument Output (kHz)

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

Conductivity (S/m) = (g + h * f² + i * f³ + j * f⁴) / 10 (1 + δ * t + ε * p)

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





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SENSOR SERIAL NUMBER: 2292
 CALIBRATION DATE: 14-Nov-17

SBE 43 OXYGEN CALIBRATION DATA

COEFFICIENTS:
 Soc = 0.5204
 Voffset = -0.4973
 Tau20 = 1.27

A = -4.3708e-003
 B = 2.1717e-004
 C = -3.2443e-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)
1.15	12.00	0.00	0.798	1.15	-0.00
1.15	6.00	0.00	0.756	1.15	-0.00
1.16	20.00	0.00	0.856	1.16	-0.00
1.16	2.00	0.00	0.729	1.16	-0.00
1.17	26.00	0.00	0.902	1.17	0.00
1.17	30.00	0.00	0.933	1.17	0.00
3.91	2.00	0.00	1.281	3.92	0.00
3.91	6.00	0.00	1.378	3.92	0.00
3.92	12.00	0.00	1.524	3.92	0.00
3.93	20.00	0.00	1.716	3.93	0.00
3.95	26.00	0.00	1.865	3.94	-0.00
3.97	30.00	0.00	1.975	3.97	0.00
6.74	2.00	0.00	1.845	6.74	-0.00
6.75	6.00	0.00	2.016	6.75	-0.00
6.79	12.00	0.00	2.276	6.79	-0.00
6.82	20.00	0.00	2.612	6.82	-0.00
6.85	26.00	0.00	2.873	6.85	0.00
6.90	30.00	0.00	3.063	6.90	-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

