General processing report of continuous thermosalinograph oceanography

from RV POLARSTERN cruises: PS110, PS111, PS113, PS112

(20.12.2017 - 10.06.2018)

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1 Introduction

This report describes the processing of raw data acquired by the thermosalinographs on board RV Polarstern during the expeditions PS110, PS111, PS113, PS112 to receive cleaned up and corrected salinity data.

2 Workflow

The different steps of processing are visualized in Figure 1. Two thermosalinographs (SBE21, Sea-Bird GmbH) are installed in the same tank in the keel of RV Polarstern for simultaneous measurements of temperature and conductivity. Both sensors are equipped with an internal and an external temperature sensor (SBE38, Sea-Bird GmbH). The external temperature sensors are installed close to the sea water inlet. After the cruise, the measured conductivity and temperature data of both sensors are extracted in hexadecimal form as 1 sec values from the DAVIS SHIP database (https://dship.awi.de). Data of every cruise are processed separately. First, the hexadecimal sentences are converted to raw data according to the instruction given by the manufacturer and time shifts between the sensors of max. 1sec are aligned. Afterwards the raw data are converted to temperature and conductivity values using the calibration coefficients from the calibration before deployment. However, data can only be finally processed after replacement and renewed calibration because correction values for the sensor drift can only be obtained by the post cruise calibration. The sensor drift is treated as a linear function during deployment and correction factors are calculated and applied for every day of deployment. See chapter 5 for further details on conductivity slope and temperature offset corrections. From the obtained internal temperature and conductivity data the salinity can be calculated according to the instructions from the Practical Salinity Scale PSS-78. Afterwards 10-min-means are calculated with outliers outside a 2-times standard deviation range being removed from the calculations of the 10-min-means. Statistics about the differences between both sensors are calculated and referred to in this report. The 10-min-means are visually inspected and - if necessary - manually despiked. Finally, the positions from the corrected mastertracks are assigned as spot-positions for the corresponding times. A speed filter of 0.5 knots minimum speed is applied to avoid redundant data.

Measurements of salinity with an OPTIMARE Precision Salinomter conducted during the cruises are represented for comparison in the Appendix of this report. Drift corrections using bottle samples were not attempted.

Both sensors are processed together and treated as equal. If there are no further objections, data from the sensor with the slope correction closer to 1.0 are prepared for the upload in PANGAEA. Also see the single detailled processing reports for each cruise.

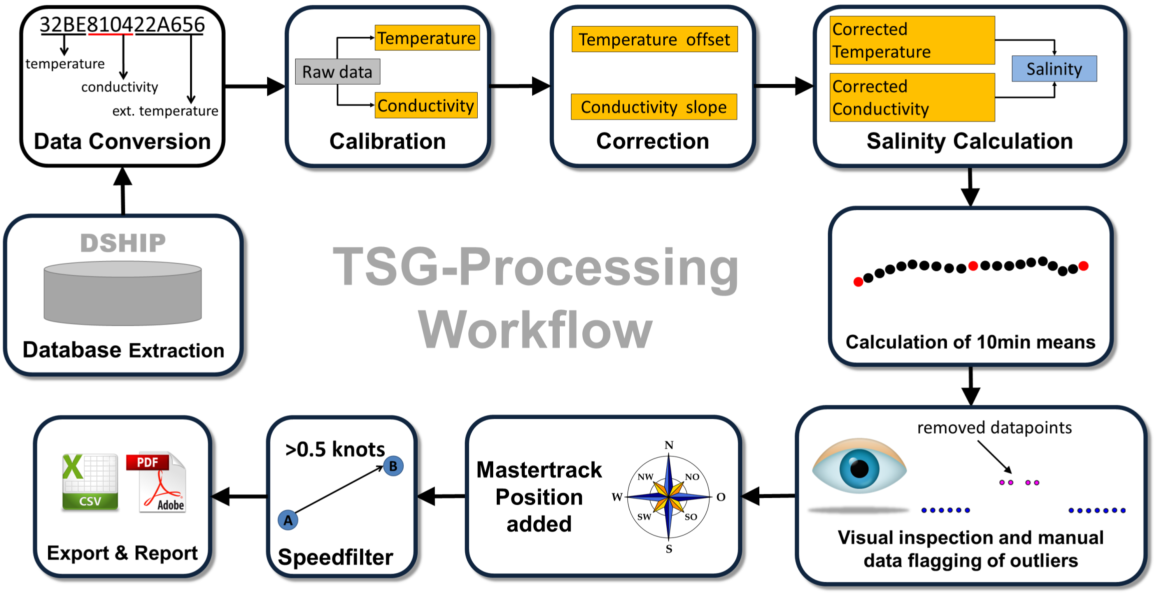


Figure 1: Workflow of Salinity data processing

3 Sensor Details

	TSG1	TSG2
Serial number	SBE21-3203	SBE21-3354
Installation	2017-12-20	2017-12-20
Deinstallation	2018-06-15	2018-06-15
Days installed	177	177
External temperature sensor	SBE38-136	SBE38-154
Calibration before installation	2016-05-31	2016-05-31
Calibration after installation	2018-07-12	2018-07-12
Temperature offset	0.001100	0.000400
Conductivity slope	0.9999727	0.9998394

4 Campaign Details

Data of following cruises were processed with the above mentioned sensors and calibration data. (Data extracted from **https://www.pangaea.de/expedition**)

Campaign	Start	Stop	From	To	Days
PS110	2017-12-20	2018-01-15	Bremerhaven	Cape Town	26
PS111	2018-01-19	2018-03-14	Cape Town	Punta Arenas	54
PS112	2018-03-17	2018-05-06	Punta Arenas	Punta Arenas	50
PS113	2018-05-08	2018-06-10	Punta Arenas	Bremerhaven	33

Following table shows the data details of the cruises considered in this report. The number of TSG1 and TSG2 messages is the number of data downloaded from DSHIP for the individual cruises. The number of result messages is the number of data remaining after calculation of 10min means, manual flagging and speed flagging.

Campaign	first message	last message	TSG1 messages	TSG2 messages	Result messages
PS110	2017-12-25T15:00:02	2018-01-09T15:08:14	314704	314628	2080
PS111	2018-01-19T13:08:46	2018-03-12T17:47:57	1121201	1121203	5752
PS112	2018-03-21T00:39:32	2018-05-03T02:47:40	927714	927713	4629
PS113	2018-05-10T17:17:04	2018-06-09T13:08:18	635222	635214	4107

5 Processing results

Correction for conductivity and temperature drift

Correction for conductivity and temperature drift of the sensors was accomplished following the instructions by SEA-BIRD Application Note 31 (Revision June 2016). Conductivity slope and temperature offset values were calculated for each day of deployment of the TSG1 and TSG2 sensors using following equations.

Correction of conductivity data: islope = 1.0 + (b / n) [(1 / postslope) - 1.0]
b = number of days between begin of deployment and day of measurement
n = number of days between deployment and deinstallation
postslope = slope from post-cruise calibration sheet
corrected conductivity = islope * computed conductivity

Correction of temperature data: offset = b * (residual / n)
b = number of days between begin of deployment and day of measurement
n = number of days between deployment and deinstallation
residual = residual from post-cruise calibration sheet
corrected temperature = offset + computed temperature

Data for the correction values are given in the following two table for TSG1 and TSG2 respectively. The deployed days columns indicate the number of the first and the last day of each cruise within the deployment interval of TSG1 (177 days) and TSG2 (177 days). The start and stop values in the columns conductivity slope and temperature offset show the correction values for the first and last day of the cruise.

TSG1	**deployed days**		**Conductivity slope**		**Temperature offset**	
Cruise	first	last	start	stop	start	stop
PS110	5	20	1.00000077	1.00000308	0.00003107	0.00012429
PS111	30	82	1.00000463	1.00001265	0.00018644	0.00050960
PS112	91	134	1.00001404	1.00002067	0.00056554	0.00083277
PS113	141	171	1.00002175	1.00002638	0.00087627	0.00106271

TSG2	**deployed days**		**Conductivity slope**		**Temperature offset**	
Cruise	first	last	start	stop	start	stop
PS110	5	20	1.00000454	1.00001815	0.00001130	0.00004520
PS111	30	82	1.00002722	1.00007441	0.00006780	0.00018531
PS112	91	134	1.00008258	1.00012160	0.00020565	0.00030282
PS113	141	171	1.00012796	1.00015518	0.00031864	0.00038644

Measured data

Data from the time range considered are show in Figures 2 and 4. Salinometer measurements of bottle samples are depicted in the plots of the salinity of TSG1 and TSG2 (also see Appendix: Measurements of salinity with the OPTIMARE salinometer). Also given are plots of the standard deviations of the 10min means for every parameter (Figures 3 and 5).

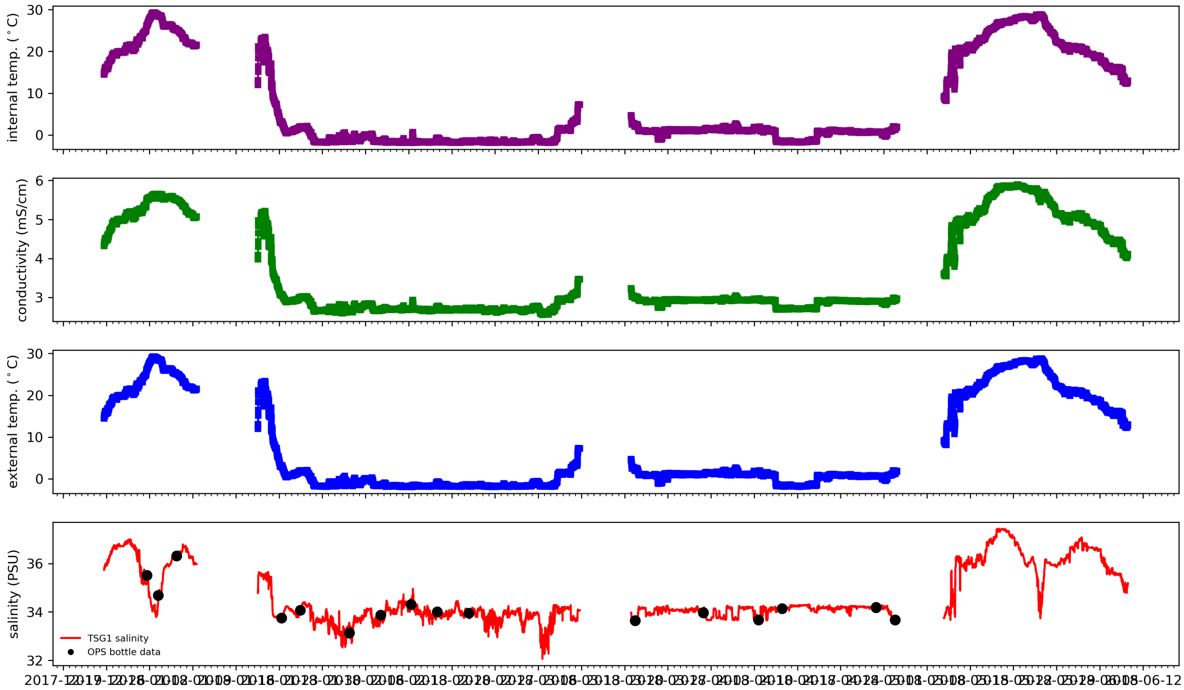


Figure 2: 10min means of data from TSG1

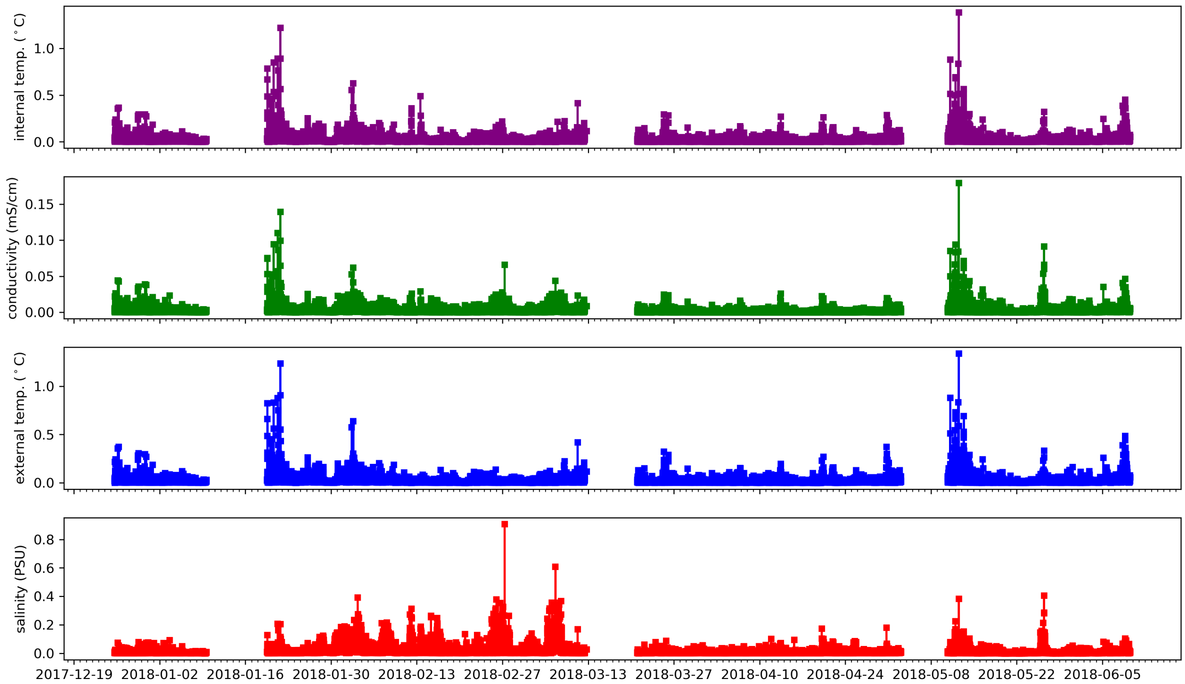


Figure 3: Standard deviations of 10min means of data from TSG1

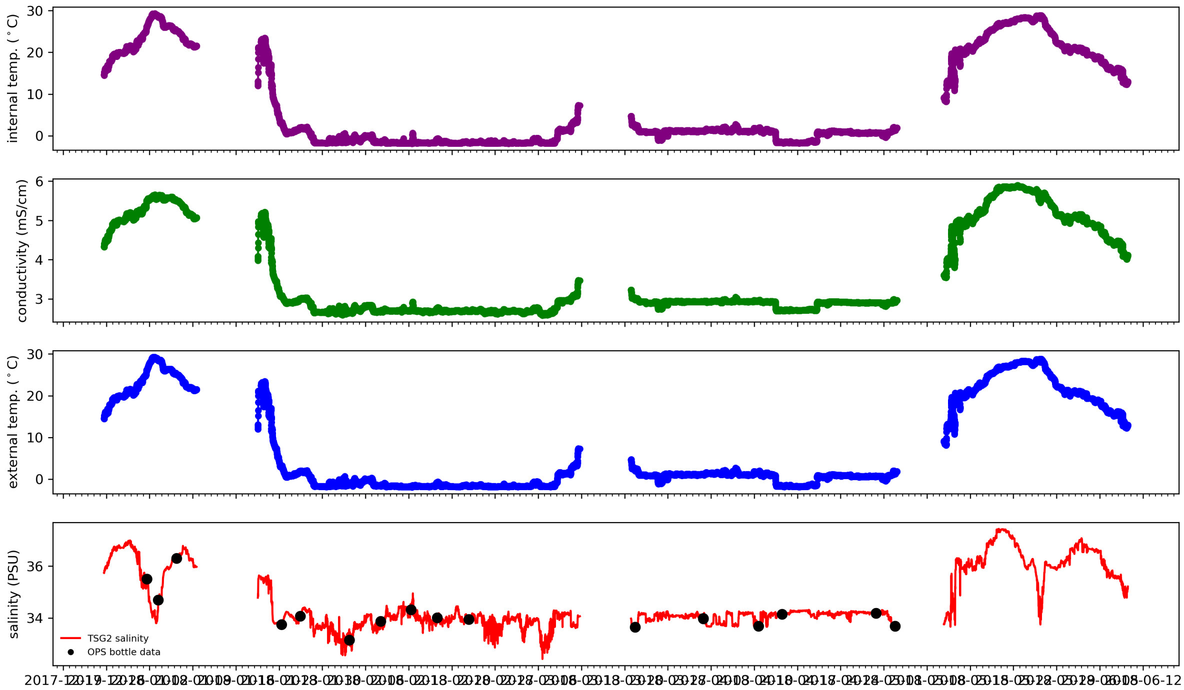


Figure 4: 10min means of data from TSG2

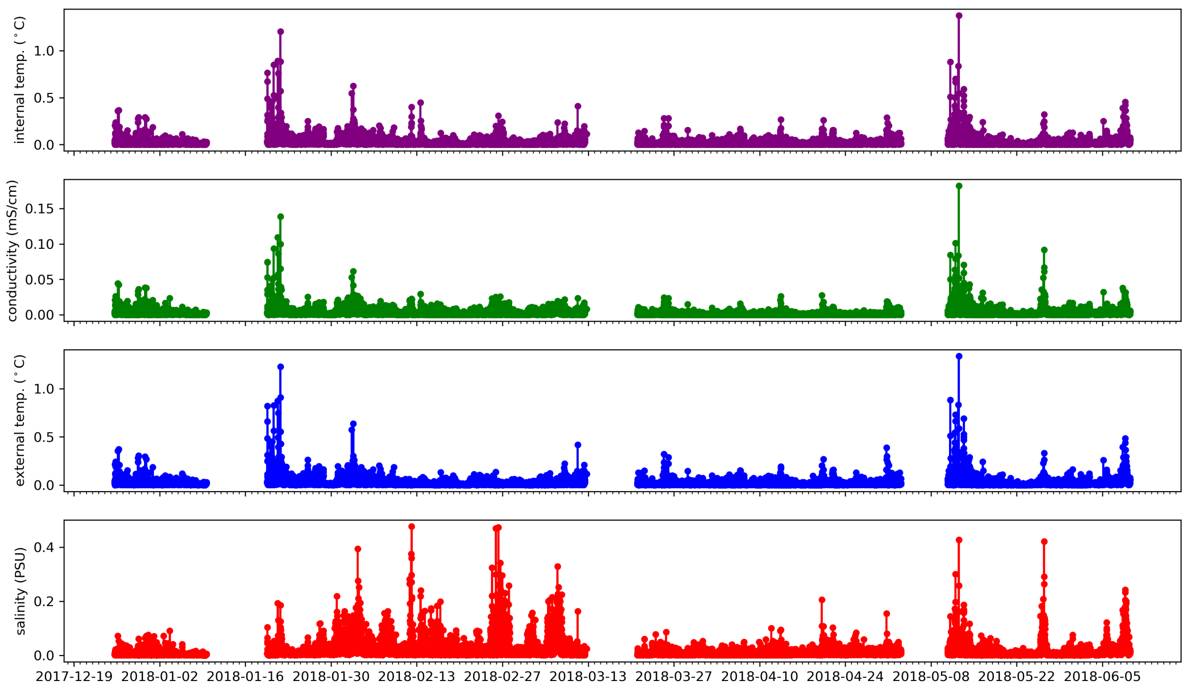


Figure 5: Standard deviations of 10min means of data from TSG2

Differences between TSG1 and TSG2

Differences between the two thermosalinographs are show in Figure 6. Only data within 2-times standard deviation are depicted. For the comparison of the spot values only data with a maximum time difference of 1sec between TSG1 und TSG2 are considered.

Parameter	Spot measurements	10min means
Internal temperature [°C]	0.00008 ± 0.01068	0.00013 ± 0.00468
Conductivity [mS/cm]	-0.00403 ± 0.04352	-0.00377 ± 0.02536
External temperature [°C]	0.00080 ± 0.00278	0.00079 ± 0.00076
Salinity [PSU]	-0.00478 ± 0.05374	-0.00426 ± 0.03523

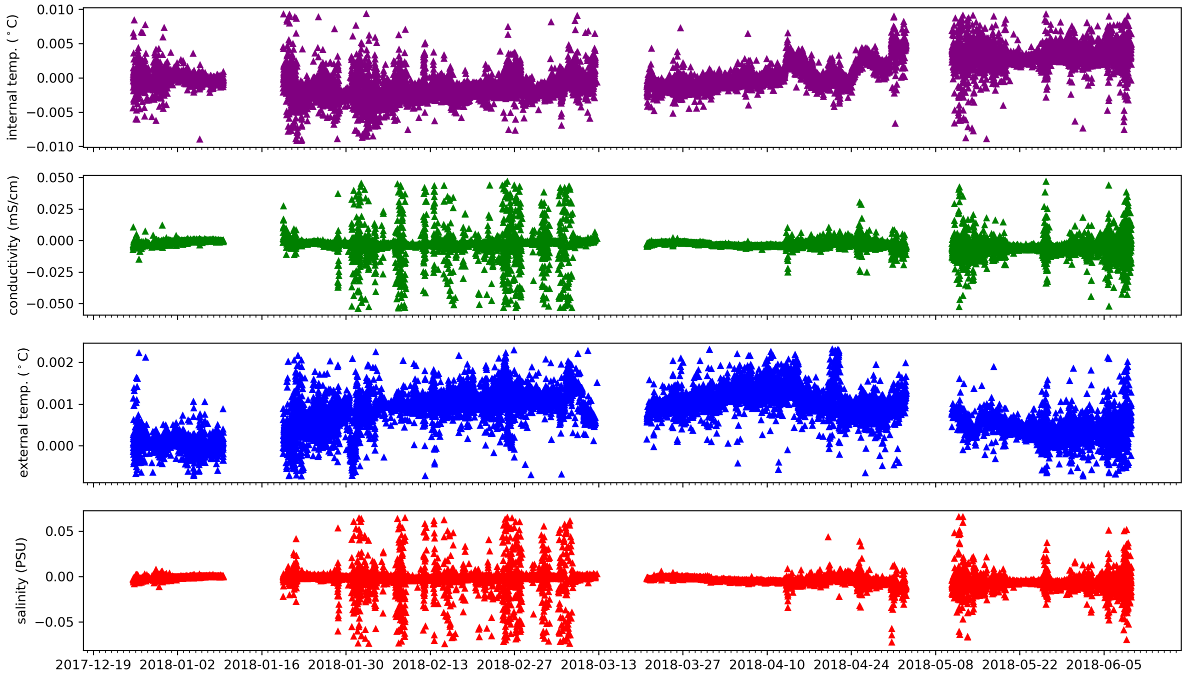


Figure 6: Differences between 10min means TSG1 - TSG2

Post calibration values show a higher temperature offset (0.001100) but less slope correction (0.9999727) for TSG1 compared to TSG2 (0.000400 and 0.9998394). Post calibration values therefore give no clear indication for a more consistent behaviour of TSG1 or TSG2. The histogramm (Figure 7) for the comparison of TSG1 and TSG2 internal temperatures indicate bimodal behaviour and there is a trend to be seen in the variation of the internal temperatures in Figure 6 from negative (TSG1 < TSG2) to positive (TSG1 > TSG2) differences. This change in behaviour may also explain the higher temperature offset for TSG1 given by the post calibration. Therefore the TSG2 (SBE21-3354) data of the cruises dealed with in this report are uploaded to PANGAEA.

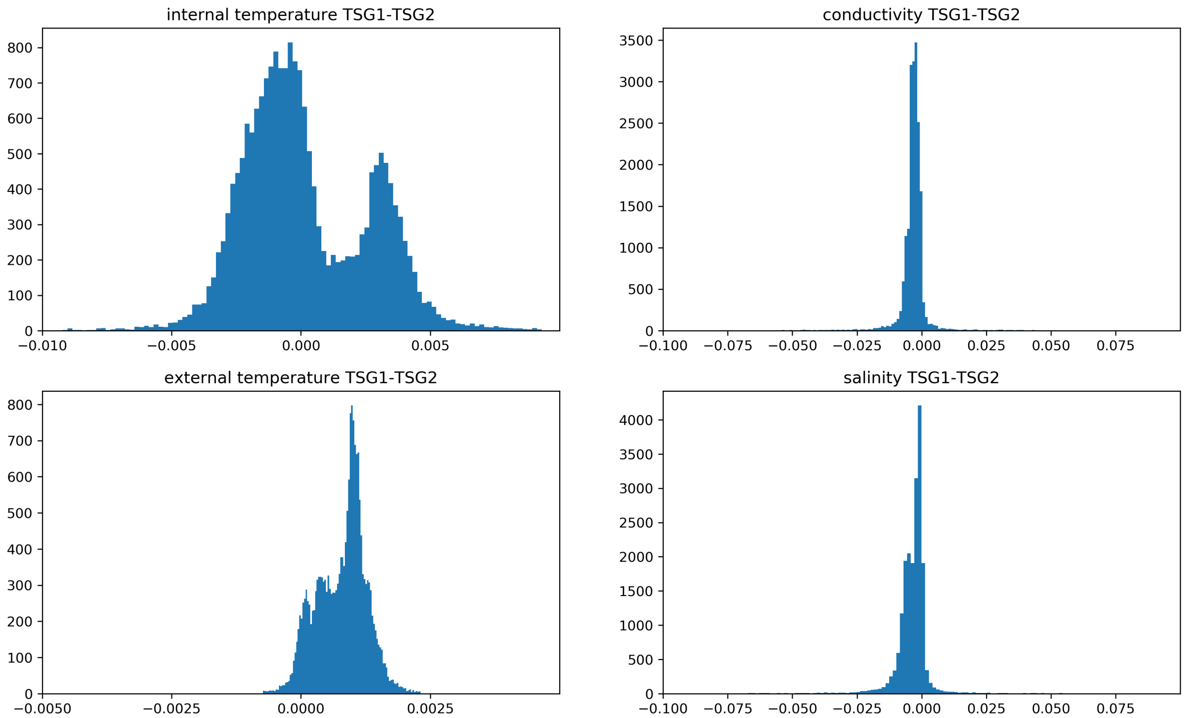
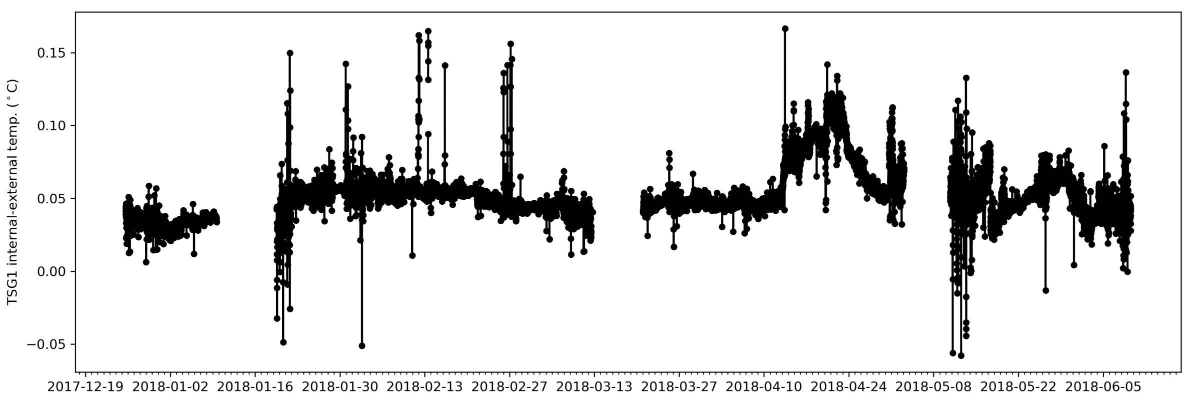


Figure 7: Histogramm of differences TSG1 - TSG2

Differences between internal and external temperature of TSG1 and TSG2 sensors

Temperature differences between the internal and the external temperature sensors have to be small under normal circulation conditions. Means and standard deviations for the temperature differences are given in the following table and are shown in Figure 8.

	TSG1 (mean ± std. dev.)	**TSG2** (mean ± std. dev.)
Spot values	0.05373 ± 0.06230°C	0.05411 ± 0.06527°C
10-min means	0.05450 ± 0.05645°C	0.05516 ± 0.05683°C



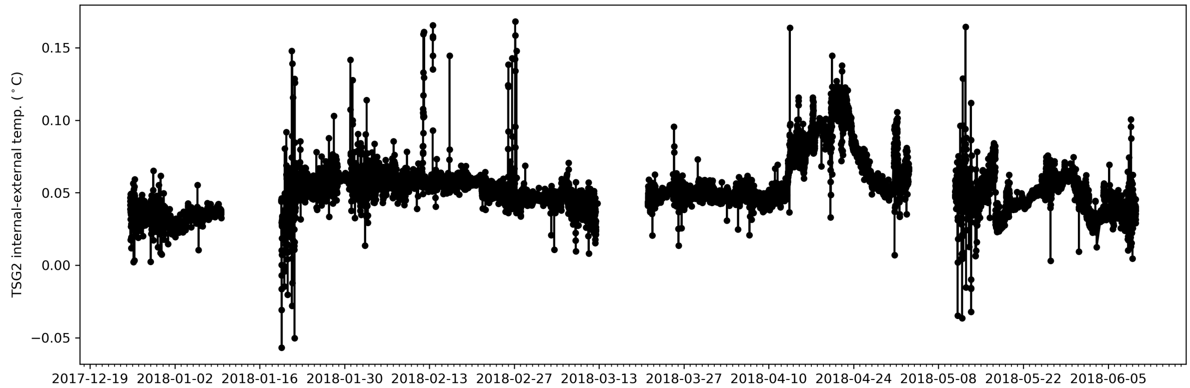


Figure 8: Temperature differences between internal and external temperature sensors of 10min means

Result file

Result files are given for each cruise individually. The result file is a plain text (tab-delimited values) file named *Cruise*_surf_oce.tab with one data row in 10-min interval. The water depth in the result file is the depth of the water inlet for the thermosalinographs. Further information about processing of the data of each cruise can be obtained from following cruise reports: PS110_TSG_nav.pdf, PS111_TSG_nav.pdf, PS112_TSG_nav.pdf, PS113_TSG_nav.pdf .

Column separator	Tabulator "\t"
Column 1	Date and time expressed according to ISO 8601
Column 2	Latitude in decimal format, unit degree
Column 3	Longitude in decimal format, unit degree
Column 4	Water depth, unit metre
Column 5	Temperature, unit degree Celsius
Column 6	Salinity PSU

6 Appendix

Measurements of salinity with the OPTIMARE salinometer

Bottle samples of sea water were continously taken during the cruises. Those samples were measured with the Optimare Salinometer onboard after temperature equalization. The bottle data are given here for reference. Drift correction using the bottle data was not applied.

Time of sampling	OPS Salinity [PSU]
2018-01-01T13:06:30	35.5116
2018-01-03T09:51:00	34.6891
2018-01-06T08:41:00	36.3112
2018-01-23T09:31:00	33.7469
2018-01-26T09:43:30	34.0743
2018-02-03T08:58:00	33.1417
2018-02-08T11:06:30	33.8683
2018-02-13T08:48:00	34.3158
2018-02-17T14:57:00	34.0061
2018-02-22T17:28:00	33.9500
2018-03-21T17:03:30	33.6429
2018-03-21T17:05:00	33.6402
2018-04-01T17:03:00	33.9695
2018-04-01T17:04:00	33.9820
2018-04-10T16:54:30	33.6761
2018-04-14T12:08:00	34.1410
2018-04-29T17:51:30	34.1830
2018-04-29T17:53:00	34.1873
2018-05-02T19:30:30	33.6772
2018-05-02T19:31:30	33.6763