General processing report of continuous thermosalinograph oceanography

from RV POLARSTERN cruises: PS114, PS115.1, PS115.2

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Contents

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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 PS114, PS115.1, PS115.2 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.

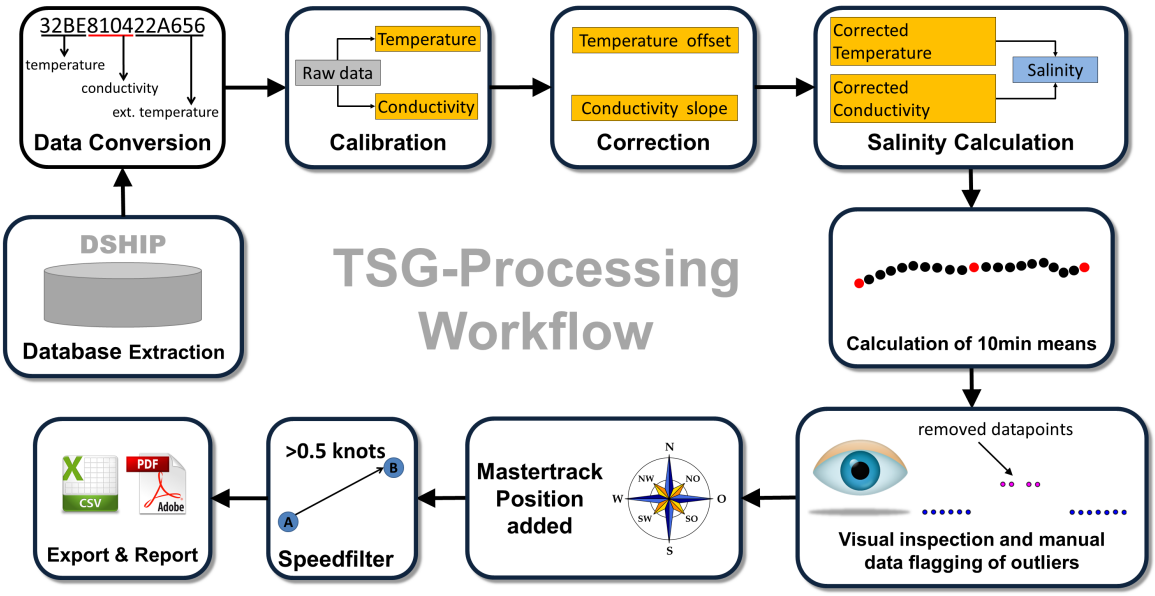


Figure 1: Workflow of Salinity data processing

3 Sensor Details

Under normal circumstances thermosalinographs are exchanged during maintenance at the shipyard between two cruises. However, TSG2 originally installed in June 2018 broke already during the first part of cruise PS114 and had to be exchanged along the way. Therefore two TSG2 sensors have to be considered. Data from cruise PS114 were separated first according to the date of the replacement of TSG2. After calibration of the two PS114 dataset data were combined again for final processing and visualization.

	TSG1	**TSG2-A**	**TSG2-B**
Serial number	SBE21-3189	SBE21-3190	SBE21-3191
Installation	15.06.2018	15.06.2018	2018-07-17
Deinstallation	16.10.2018	17.07.2018	2018-10-16
Days installed	123	32	91
External temperature sensor	SBE38-118	SBE38-137	SBE38-137
Calibration before installation	24.11.2016	24.11.2016	2017-11-15
Calibration after installation	31.10.2018	30.08.2018	2018-10-31
Temperature offset	0.00089	-0.00046	0.002
Conductivity slope	0.9999544	0.999992	1.0000027

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
PS114	2018-07-10	2018-08-03	Bremerhaven	Tromsoe	24
PS115.1	2018-08-05	2018-09-03	Tromsoe	Longyearbyen	29
PS115.2	2018-09-05	2018-10-16	Longyearbyen	Bremerhaven	41

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
PS114	2018-07-11T11:42:02	2018-08-02T13:15:42	466692	466203	2210
PS115.1	2018-08-06T06:52:02	2018-09-02T14:02:48	940703	940734	3447
PS115.2	2018-09-14T07:36:46	2018-10-15T12:46:23	596111	595989	3317

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 with valid TSG data points within the deployment interval of TSG1 (123 days), TSG2-A (32 days) and TSG2-B (91 days) . The start and stop values in the columns conductivity slope and temperature offset show the correction values for the first and last day with valid data points of each cruise.

TSG1	**deployed days**		**Conductivity slope**		**Temperature offset**	
Cruise	first	last	start	stop	start	stop
PS114	26	48	1.00000964	1.00001780	0.00018813	0.00034732
PS115.1	52	79	1.00001928	1.00002929	0.00037626	0.00057163
PS115.2	91	122	1.00003374	1.00004523	0.00065846	0.00088276

TSG2-A	**deployed days**		**Conductivity slope**		**Temperature offset**	
Cruise	first	last	start	stop	start	stop
PS114	26	32	1.0000065	1.000008	-0.00037375	-0.00046

TSG2-B	**deployed days**		**Conductivity slope**		**Temperature offset**	
Cruise	first	last	start	stop	start	stop
PS114	0	16	1.0000065	1.000008	-0.00037375	-0.00046
PS115.1	20	47	0.99999941	0.99999861	0.00043956	0.00103297
PS115.2	59	90	0.99999825	0.99999733	0.0012967	0.00197802

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).

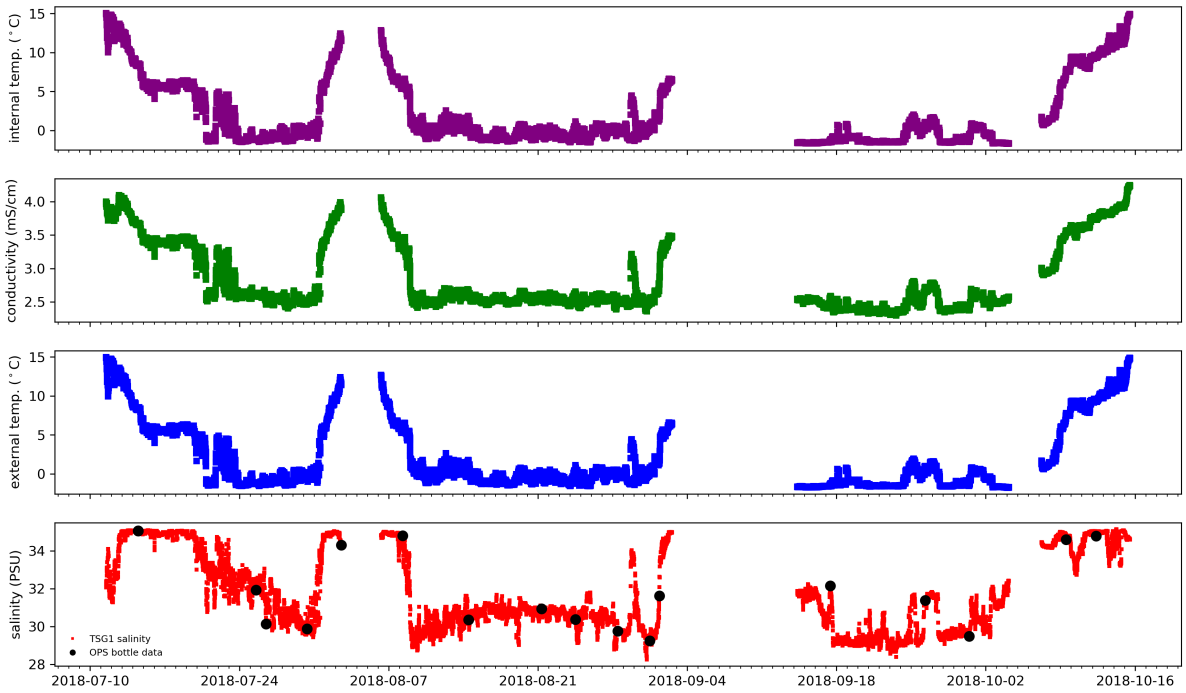


Figure 2: 10min means of data from TSG1

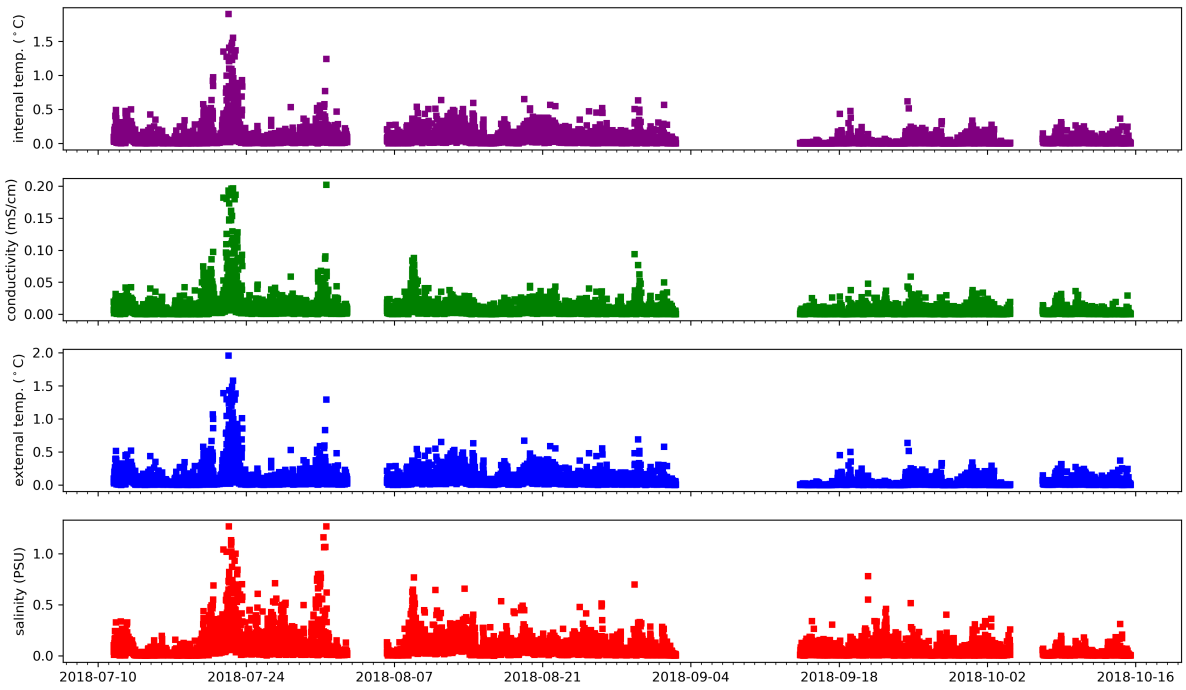


Figure 3: Standard deviations of 10min means of data from TSG1

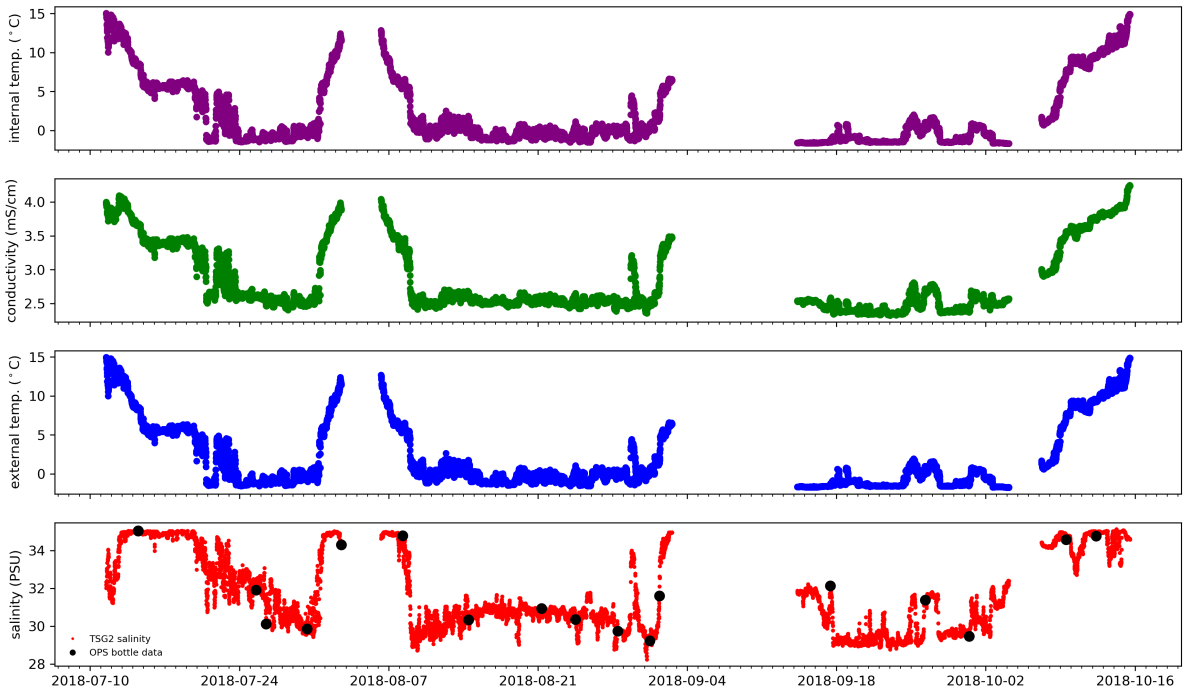


Figure 4: 10min means of data from TSG2

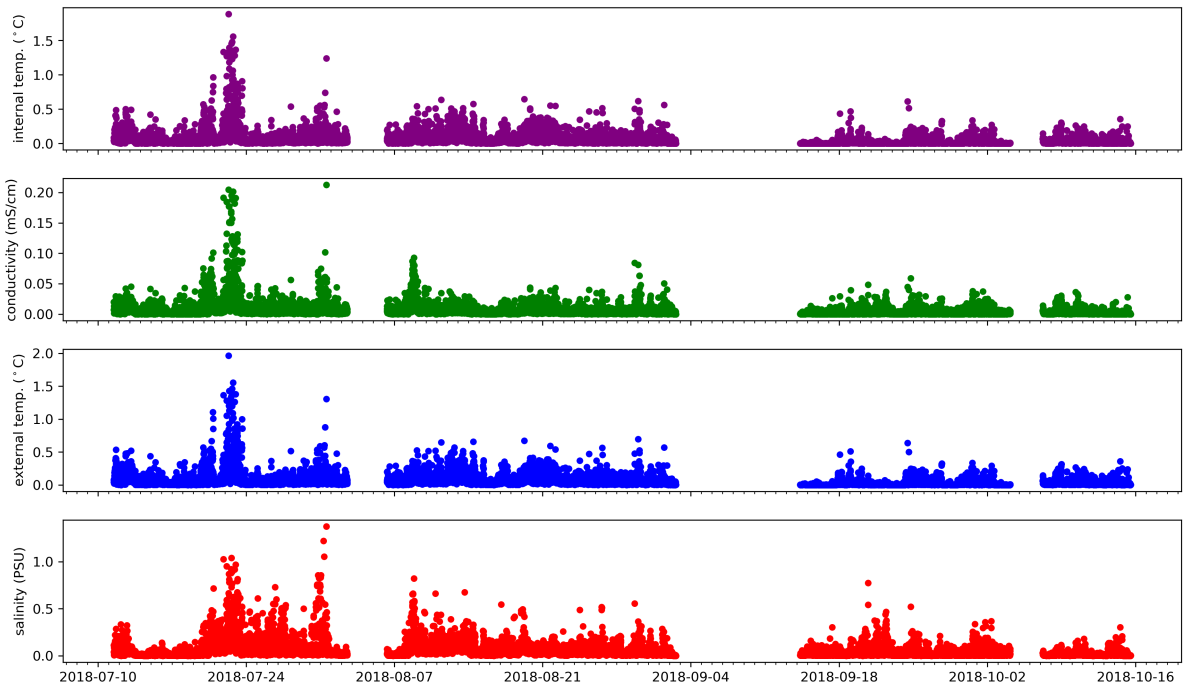


Figure 5: Standard deviations of 10min means of data from TSG2

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]	-0.00245 ± 0.01305	-0.00250 ± 0.00435
Conductivity [mS/cm]	-0.00228 ± 0.05176	-0.00187 ± 0.03657
External temperature [°C]	-0.00015 ± 0.03850	-0.00016 ± 0.00707
Salinity [PSU]	-0.00116 ± 0.06986	-0.00071 ± 0.04860

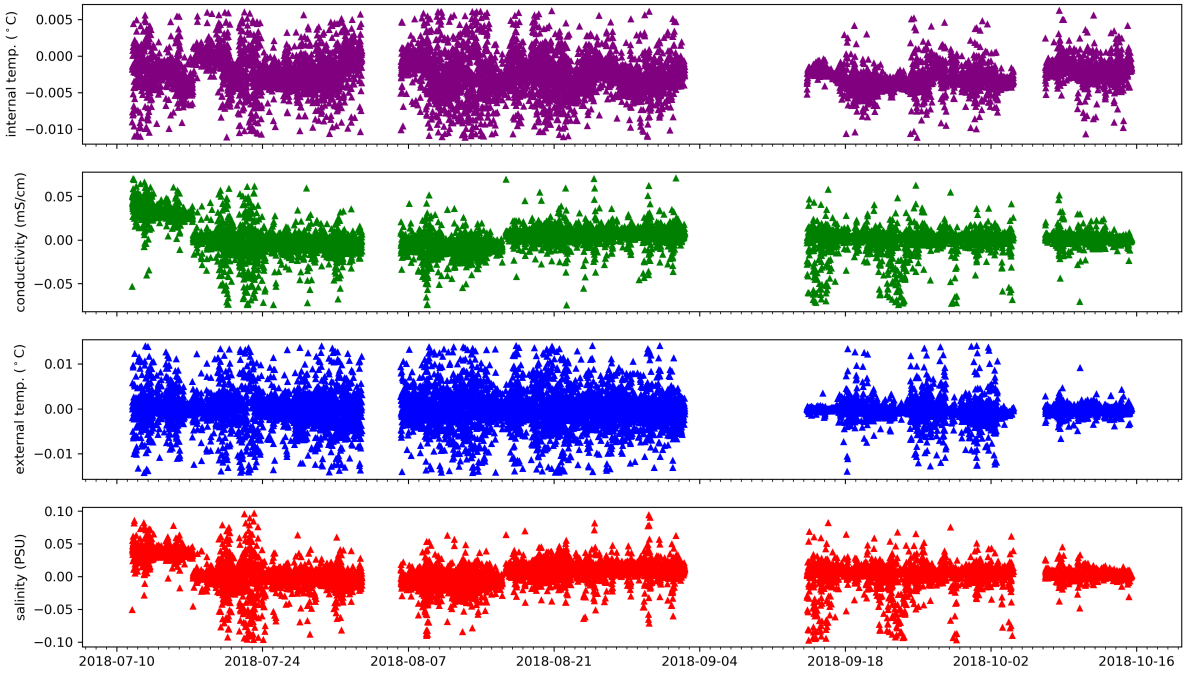


Figure 6: Differences between 10min means TSG1 - TSG2

The TSG2 sensor (SBE21-3190) had to be exchanged on July 17th 2018. The bimodal behaviour of the conductivity and salinity to be seen in Figure 7 is a result of this replacement. Besides the replacement of TSG2 the post-calibration the newly installed TSG2 sensor (SBE21-3191) showed a higher temperature offset (0.002) than the TSG1 sensor (SBE21-3189: 0.00089). This leads to the conclusion that TSG1 (SBE21-3189) data of the cruises dealed with in this report are uploaded to PANGAEA.

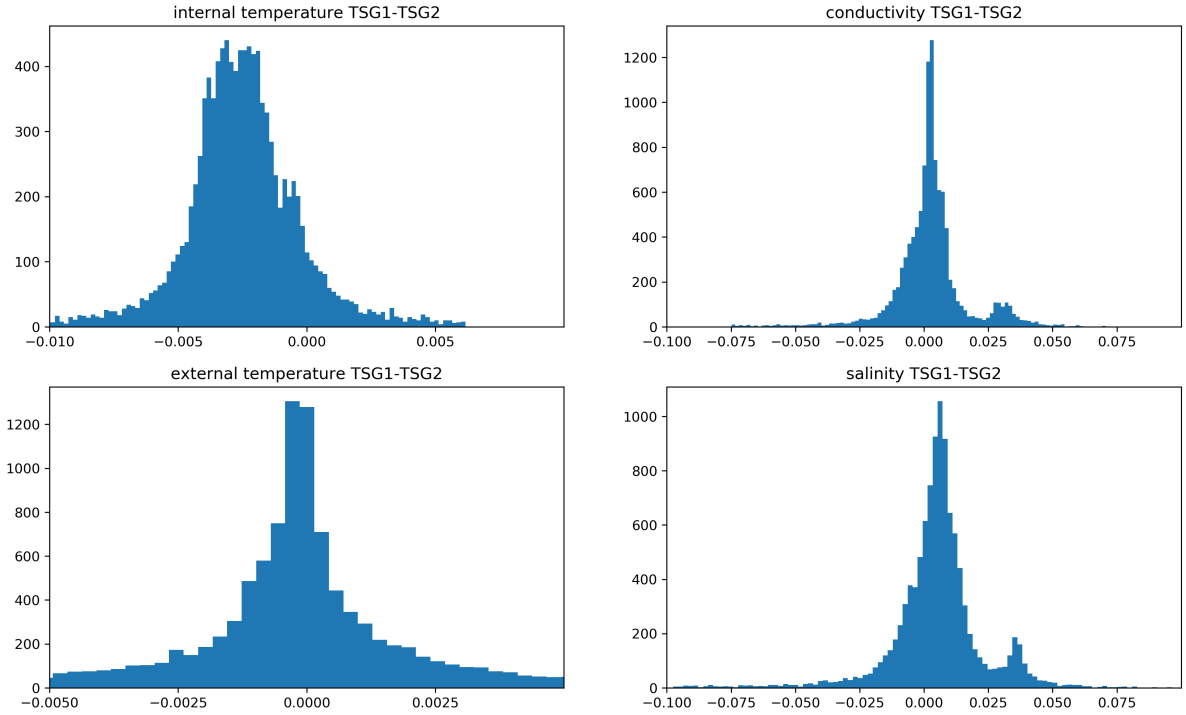
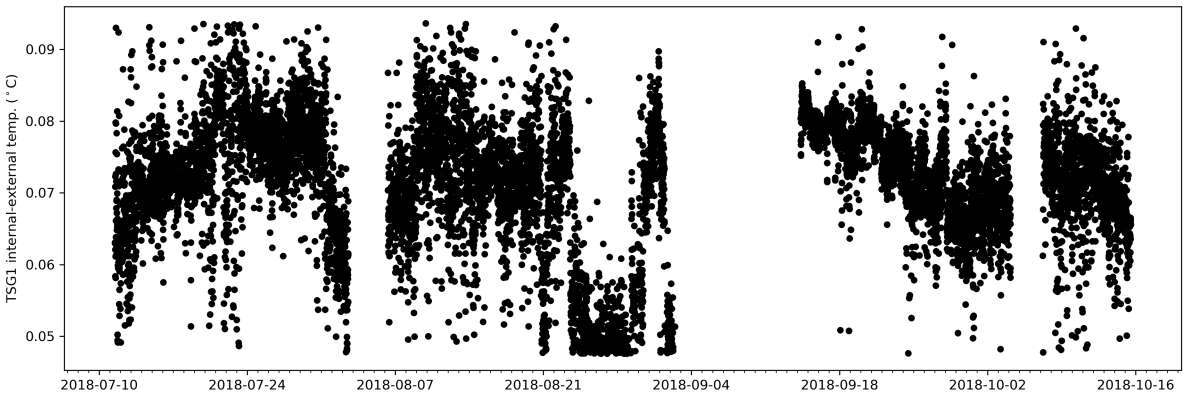


Figure 7: Histogramm of differences TSG1 - TSG2

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	0.06949 ± 0.02219°C	0.07187 ± 0.05134°C
10-min means	0.07067 ± 0.01155°C	0.07301 ± 0.01774°C



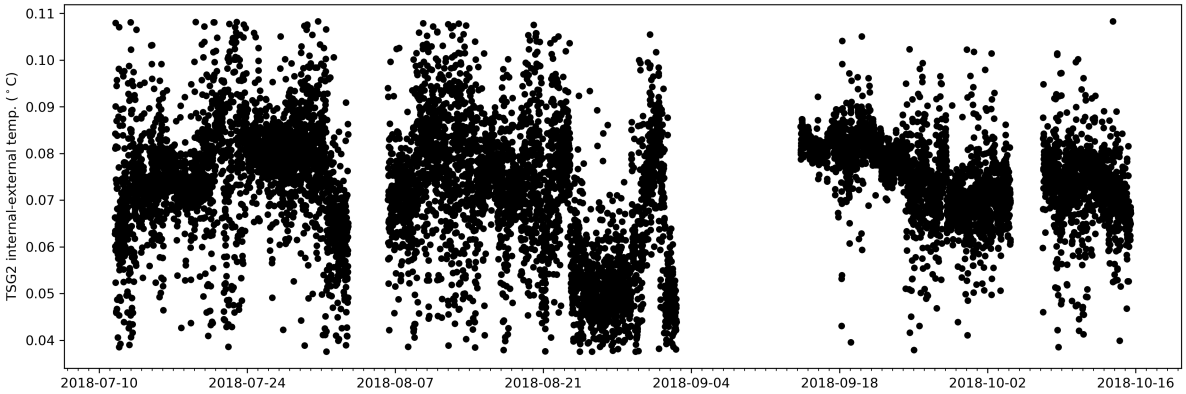


Figure 8: Temperature differences between internal and external temperature sensors of 10min means

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: PS114_TSG_nav.pdf, PS115.1_nav.pdf, PS115.2_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]
2018-07-14T11:39:00	35.0468
2018-07-14T11:45:00	35.0457
2018-07-14T11:50:30	35.0454
2018-07-25T13:02:00	31.9265
2018-07-26T12:16:00	30.1300
2018-07-30T08:28:00	29.8659
2018-08-02T13:13:00	34.3071
2018-08-08T07:29:00	34.7988
2018-08-14T11:29:00	30.3497
2018-08-21T07:47:30	30.9392
2018-08-24T12:02:00	30.3645
2018-08-28T11:53:30	29.7475
2018-08-31T11:33:00	29.2338
2018-09-01T09:04:30	31.6123
2018-09-17T10:01:00	32.1417
2018-09-26T07:32:00	31.3869
2018-09-30T10:22:30	29.4840
2018-10-09T12:47:30	34.5886
2018-10-12T08:30:00	34.7780