General processing report of continuous thermosalinograph oceanography

from RV POLARSTERN cruises: PS121, PS122_1, PS122_2, PS122_3, PS122_4, PS122_5

(10.08.2019 - 12.10.2020)

Contents

Contact:
Gerd Rohardt
Alfred-Wegener-Institute
Am Handelshafen 12, D-27570 Bremerhaven, GERMANY
Mail: info@awi.de

Processing Agency:
FIELAX
Gesellschaft für wissenschaftliche Datenverarbeitung mbH
Schleusenstr. 14, D-27568 Bremerhaven, GERMANY
Tel: +49 (0) 471 30015 0
Fax: +49 (0) 471 30015 22
Mail: info@fielax.de

Ref.: TSG_Data_PS121, PS122_1, PS122_2, PS122_3, PS122_4, PS122_5 .pdf	Vers.: 1	Date: 2021/05/06	Status: final

1 Introduction

This report describes the processing of raw data acquired by the thermosalinographs on board RV Polarstern during the expeditions PS121, PS122_1, PS122_2, PS122_3, PS122_4, PS122_5 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. A pressure of 11dbar representing the 11m water depth of the water inlet of the TSG system on R.V. Polarstern is applied for the salinity calculations.
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 the data of PS121 in order to avoid redundant data. The speed filter was NOT applied to the different legs of PS122 because of the slow drifting speeds during these expeditions which would have resulted in almost complete deletion of the data by the speed filter.
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.

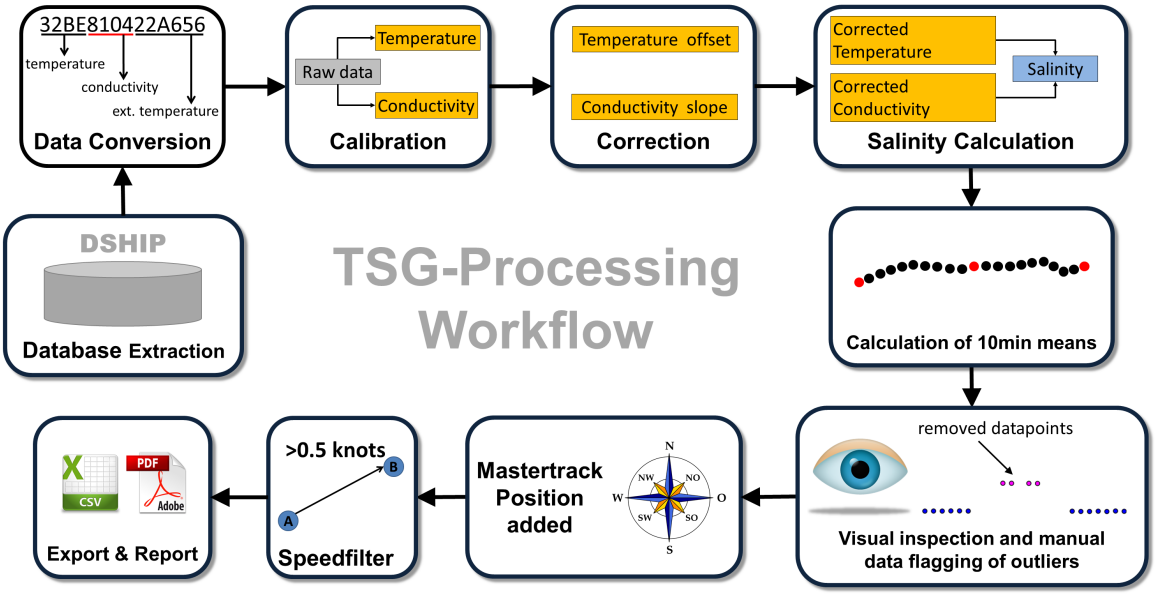

Figure 1: Workflow of Salinity data processing

3 Sensor Details

	TSG1	TSG2
Serial number	SBE21-3189	SBE21-3354
Installation	2019-06-28	2019-06-28
Deinstallation	2020-10-30	2020-10-30
Days installed	490	490
External temperature sensor	SBE38-0136	SBE38-0154
Calibration before installation	2018-10-31	2018-07-12
Calibration after installation	2021-02-09	2021-02-09
Temperature offset	-0.0010	0.000800
Conductivity slope	0.9997775	0.9996833

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
PS121	2019-08-10	2019-09-13	Bremerhaven	Tromsoe	34
PS122_1	2019-09-20	2019-12-13	Tromsoe	Arctic Ocean	84
PS122_2	2019-12-13	2020-02-24	Arctic Ocean	Arctic Ocean	73
PS122_3	2020-02-24	2020-06-04	Arctic Ocean	Longyearbyen	101
PS122_4	2020-06-04	2020-08-12	Longyearbyen	North Greenland Sea	69
PS122_5	2020-08-12	2020-10-12	North Greenland Sea	Bremerhaven	61

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
PS121	2019-08-11T07:31:31	2019-09-13T06:01:43	710531	710286	2992
PS122_1	2019-09-27T02:51:46	2019-12-13T09:09:58	1664702	1664698	11099
PS122_2	2019-12-13T09:04:02	2020-02-24T08:59:58	1576674	1576673	10511
PS122_3	2020-02-24T09:00:02	2020-06-03T13:58:15	2164132	2164131	14426
PS122_4	2020-06-08T20:32:31	2020-08-12T09:59:56	1394514	1394514	9296
PS122_5	2020-08-12T10:00:04	2020-10-11T06:10:25	1290043	1290045	8599

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 (490 days) and TSG2 (490 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
PS121	44	77	1.00001998	1.00003497	-0.00008980	-0.00015714
PS122_1	91	168	1.00004133	1.00007630	-0.00018571	-0.00034286
PS122_2	168	241	1.00007630	1.00010946	-0.00034286	-0.00049184
PS122_3	241	341	1.00010946	1.00015488	-0.00049184	-0.00069592
PS122_4	346	411	1.00015715	1.00018667	-0.00070612	-0.00083878
PS122_5	411	471	1.00018667	1.00021392	-0.00083878	-0.00096122

TSG2	deployed days		Conductivity slope		Temperature offset	
Cruise	first	last	start	stop	start	stop
PS121	44	77	1.00002845	1.00004978	0.00007184	0.00012571
PS122_1	91	168	1.00005883	1.00010862	0.00014857	0.00027429
PS122_2	168	241	1.00010862	1.00015581	0.00027429	0.00039347
PS122_3	241	341	1.00015581	1.00022047	0.00039347	0.00055673
PS122_4	346	411	1.00022370	1.00026572	0.00056490	0.00067102
PS122_5	411	471	1.00026572	1.00030452	0.00067102	0.00076898

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).

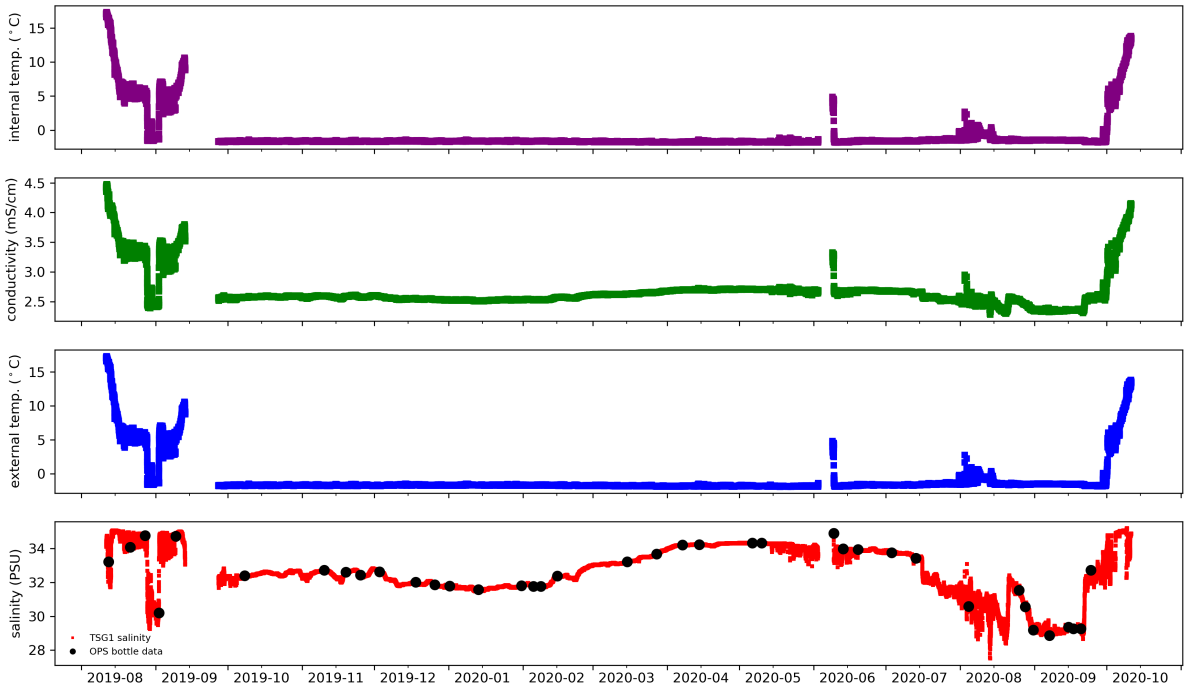

Figure 2: 10min means of data from TSG1

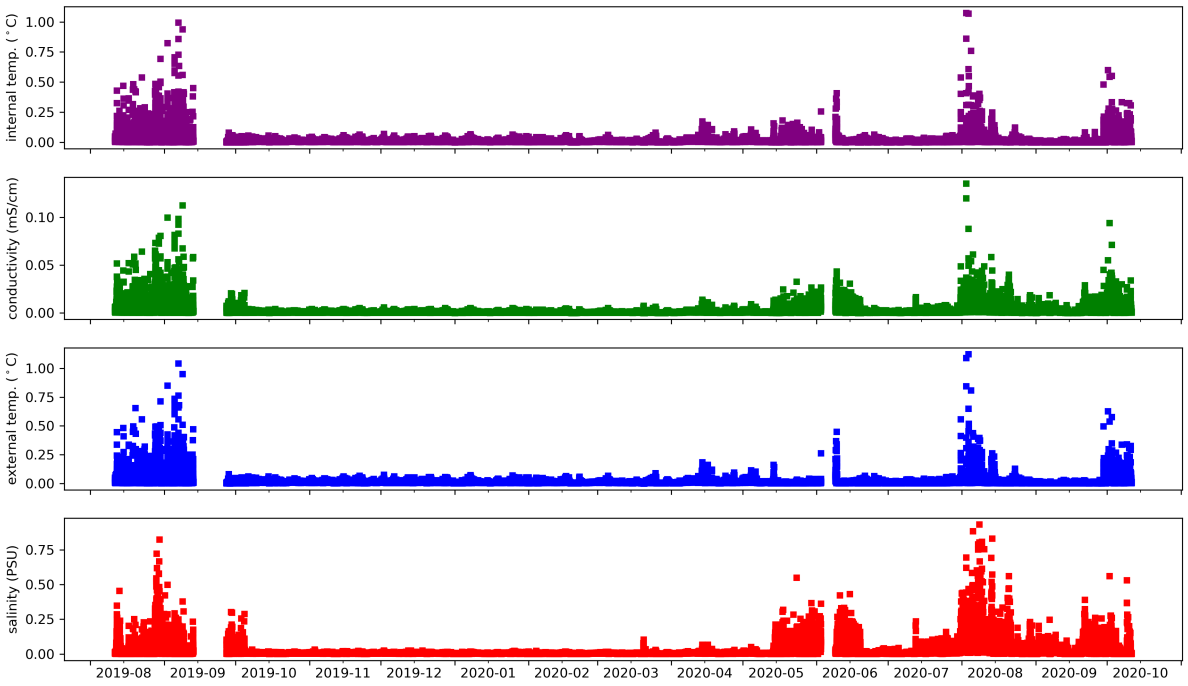

Figure 3: Standard deviations of 10min means of data from TSG1

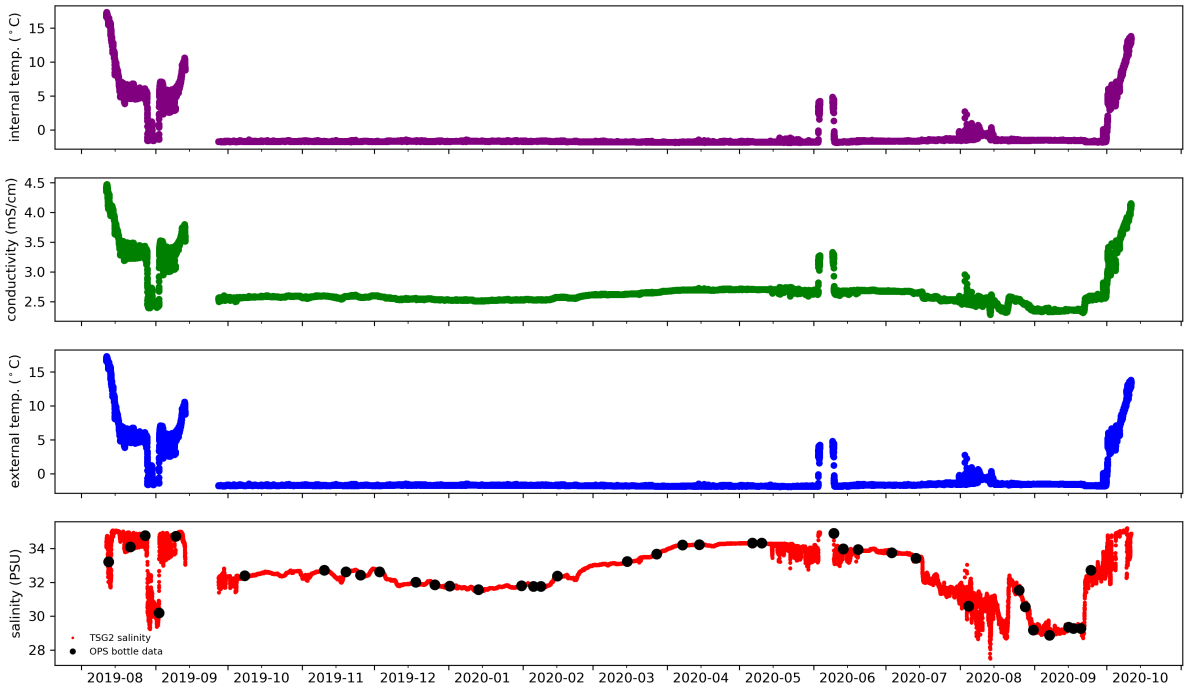

Figure 4: 10min means of data from TSG2

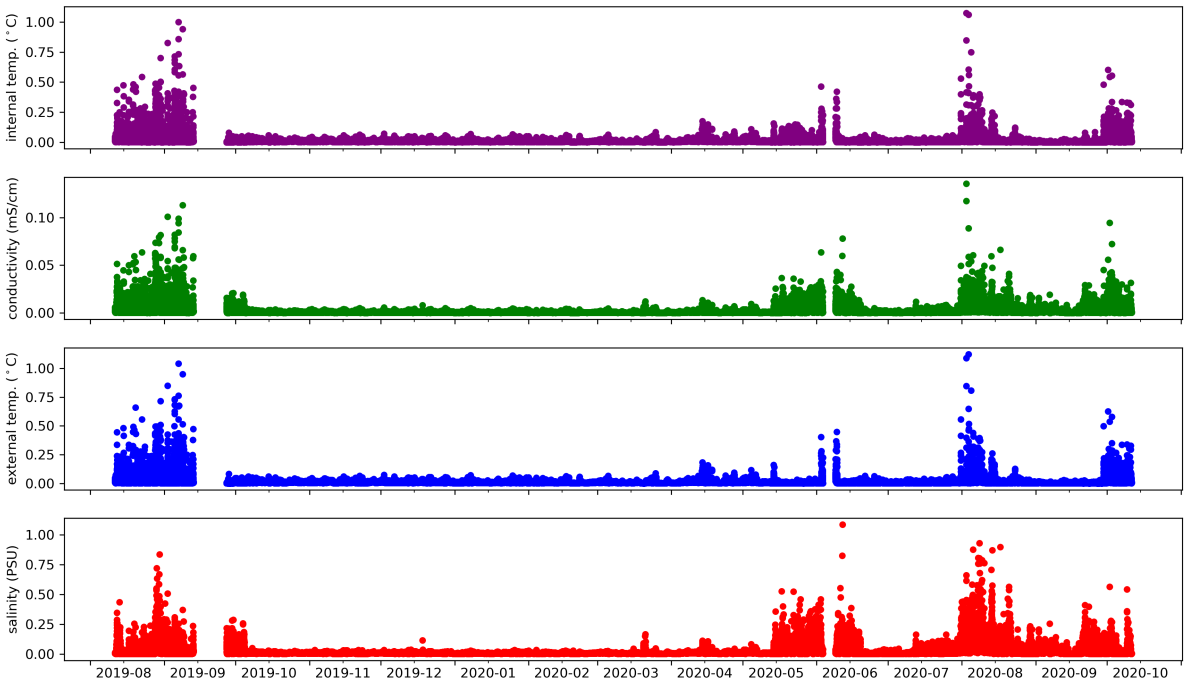

Figure 5: Standard deviations of 10min means of data from TSG2

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. During the slow drift of PS122_1, PS122_2 and PS122_3 the differences of the internal temperatures between TSG1 and TSG2 shows less deviation but higher values compared to the conditions during PS122_4 and PS122_5 with less ice coverage, faster drifts and cruise segments with normal cruise speeds.

Parameter	Spot measurements	10min means
Internal temperature [°C]	0.00424 ± 0.00494	0.00438 ± 0.00278
Conductivity [mS/cm]	0.00736 ± 0.05482	0.00770 ± 0.04109
External temperature [°C]	0.00086 ± 0.00183	0.00083 ± 0.00128
Salinity [PSU]	0.00550 ± 0.07600	0.00577 ± 0.05700

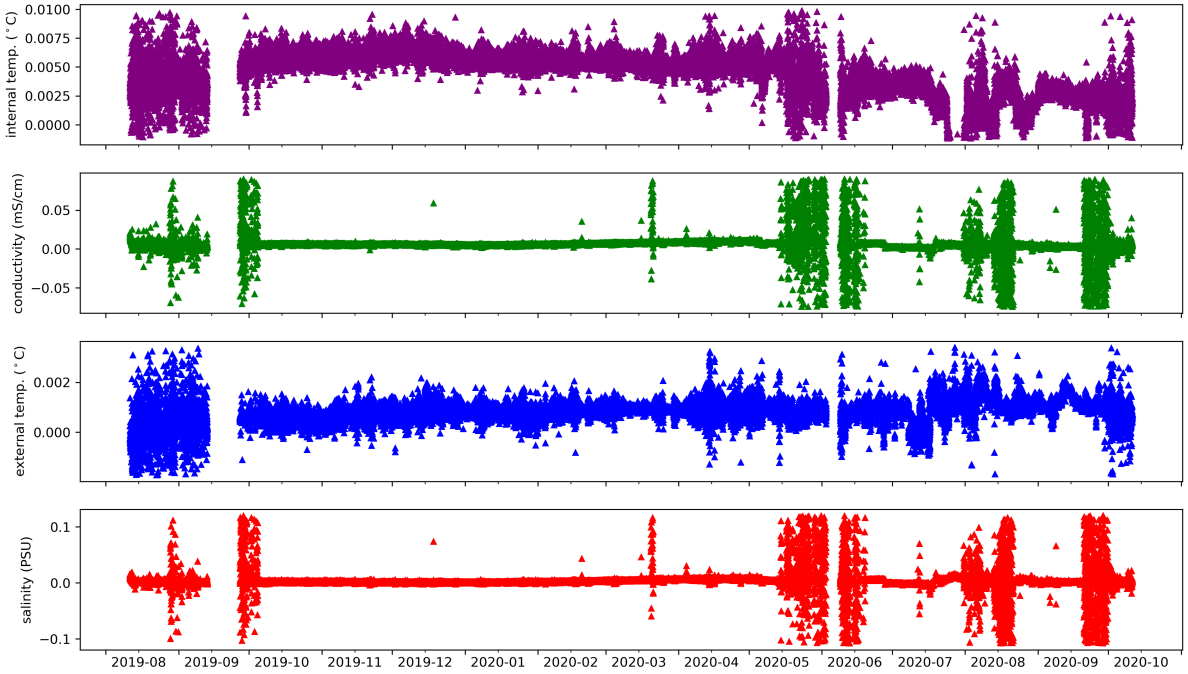

Figure 6: Differences between 10min means TSG1 - TSG2

Post calibration values show a slightly greater temperature offset (-0.0010) but a slope correction value closer to 1 (0.9997775) for TSG1 compared to TSG2 (0.000800 and 0.9996833). Without further quality criteria the decision was to upload the TSG1 (SBE21-3189) data to PANGAEA.
The histograms for the differences between TSG1 and TSG2 shown in Figure 7 show a bimodal behaviour for the comparison of the internal temperatures of TSG1 and TSG2. Two major groups can be distinguished in the histogram. Cruises PS122_1, PS122_2 and PS122_3 took place in

very cold regions with water temperatures around -1.7°C with complete ice coverage and very slow drift. During these cruises the differences between TSG1 and TSG2 internal temperatures range around 0.006°C causing one of the maxima in the histogram. The second maxima around 0.004°C correlates with the cruises PS121, PS122_4 and PS122_5 with higher water temperatures and normal cruise speed during PS121 and the transitions between the PS122 legs as well as higher drift speeds during PS122_4 and PS122_5. Please consider, that some of this behaviour may be explained by calibration data of the TSG which are calibrated only in the temperature range between +1 and +32°C. Although measurement range is given with -5 till +35°C the cold water cruises approximate the lower limit of the measurement range where small deviations from the ideal behaviour seem likely. Additionally, the accuracy of the sensor is given with 0.01°C and even the higher differences are well within the accuracy range.

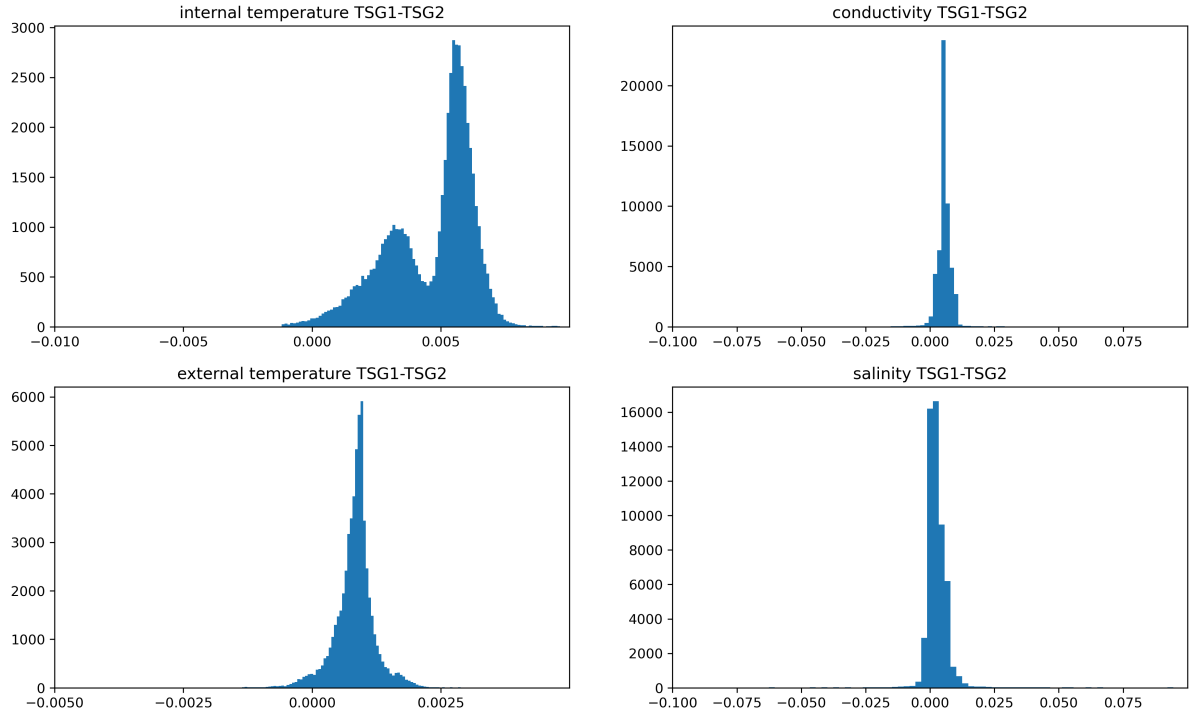

Figure 7: Histogramm of differences TSG1 - TSG2

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. Higher scatter obvious in Figure 8 is connected to higher cruise speeds during PS121 as well as on the transits between the PS122 legs PS122_3, PS122_4 and PS122_5.

	TSG1 (mean $\pm$ std. dev.)	**TSG2** (mean $\pm$ std. dev.)
Spot values	0.04493 $\pm$ 0.03555°C	0.04144 $\pm$ 0.03578°C
10-min means	0.04507 $\pm$ 0.03293°C	0.04152 $\pm$ 0.03352°C

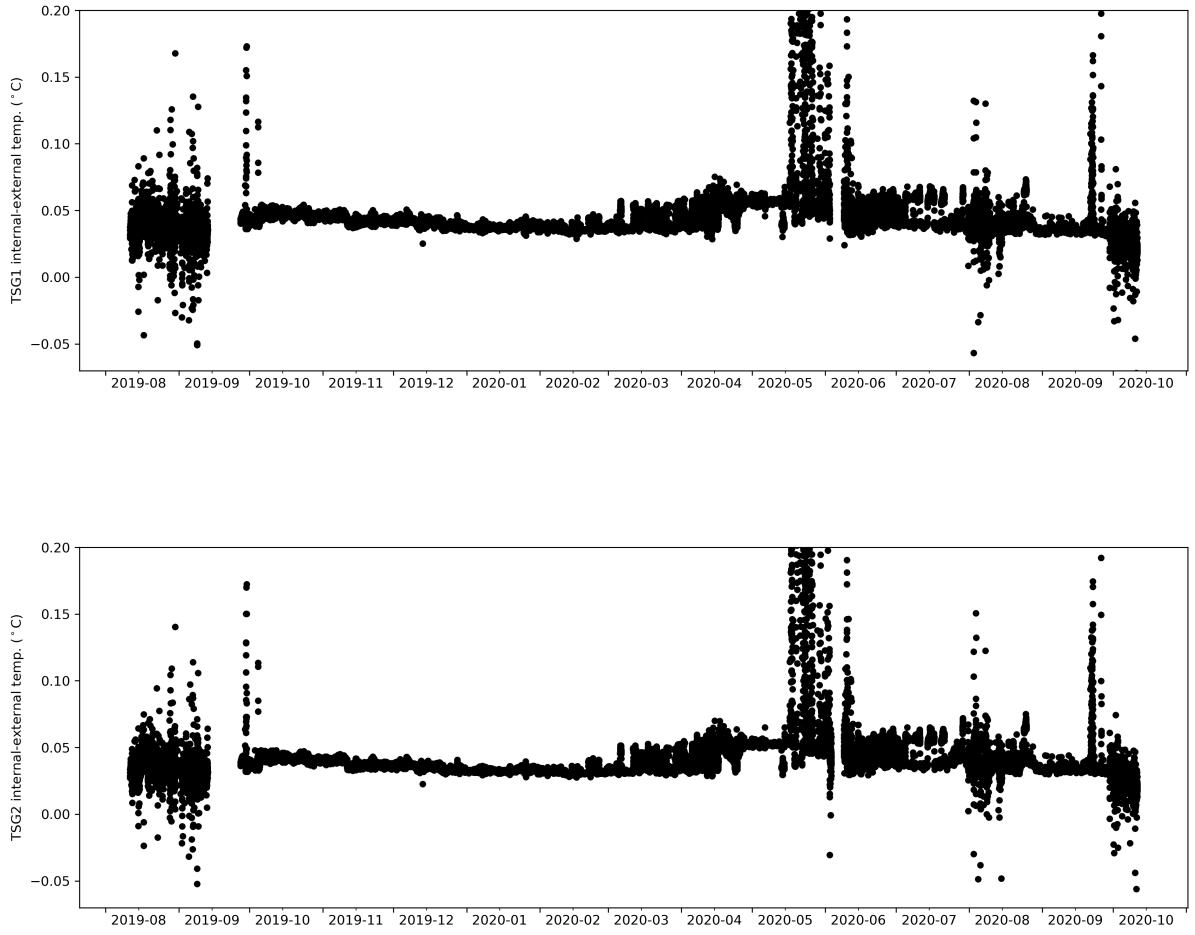

Figure 8: Temperature differences between internal and external temperature sensors of 10min means

Result files

Result files are provided for each cruise. These files are plain text (tab-delimited values) file named *Cruise*_surf_oce.tab with one data row in 10-min interval. Salinity values are calculated from the 10min means of conductivity and internal temperature data using a pressure of 11 dbar for the calculations. The pressure refers to the 11m water depth of the water inlet of the TSG system on R.V. Polarstern. Water temperature taken from the TSG external temperature sensor is given for reference.

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 Temperature, unit degree celsius
Column 5	TSG Internal Temperature, unit degree celsius
Column 6	Conductivity, unit mS/cm
Column 7	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]
2019-08-12T08:01:00	33.2231
2019-08-21T07:48:00	34.0872
2019-08-27T12:07:00	34.7738
2019-09-02T07:32:00	30.1975
2019-09-09T07:24:00	34.7210
2019-10-08T00:45:00	32.3910
2019-11-10T02:36:00	32.7210
2019-11-19T02:57:00	32.6168
2019-11-25T04:46:00	32.4351
2019-12-03T05:15:00	32.6228
2019-12-18T07:26:00	32.0093
2019-12-26T06:06:00	31.8594
2020-01-01T08:23:00	31.7793
2020-01-13T07:45:00	31.5695
2020-01-31T06:52:30	31.8020
2020-02-05T06:45:00	31.7627
2020-02-08T07:04:00	31.7682
2020-02-15T06:25:00	32.3798
2020-03-15T07:11:00	33.2289
2020-03-27T12:31:00	33.6759

Time of sampling	OPS Salinity [PSU]
2020-04-07T07:02:00	34.2154
2020-04-14T07:18:00	34.2370
2020-05-06T09:21:00	34.3343
2020-05-10T07:01:00	34.3245
2020-06-09T07:36:00	34.9036
2020-06-09T07:40:00	34.9023
2020-06-13T06:35:00	33.9842
2020-06-13T06:39:00	33.9847
2020-06-19T12:23:00	33.9485
2020-07-03T12:19:00	33.7532
2020-07-13T12:13:00	33.4299
2020-08-04T11:13:00	30.5880
2020-08-25T12:11:00	31.5326
2020-08-28T03:31:00	30.5638
2020-08-31T09:16:00	29.1812
2020-09-07T04:30:00	28.8674
2020-09-15T04:06:00	29.3593
2020-09-17T03:53:00	29.2727
2020-09-20T05:53:00	29.2697
2020-09-24T09:51:00	32.7207