General processing report of continuous thermosalinograph oceanography

from RV POLARSTERN cruises: PS123, PS124, PS125

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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 PS123, PS124, PS125 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 the data in order 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.

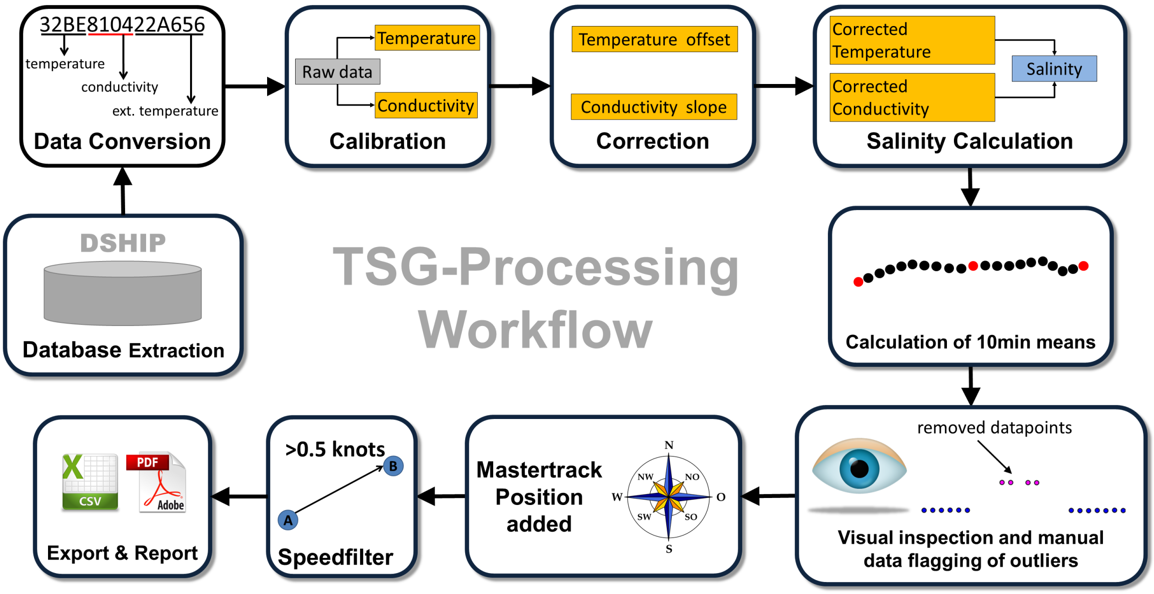

Figure 1: Workflow of Salinity data processing

3 Sensor Details

	TSG1	TSG2
SBE21 Serial number	SBE21-3191	SBE21-3271
Installation	2020-12-20	2020-12-20
Deinstallation	2021-04-29	2021-04-29
Days installed	130	130
SBE21 Calibration before installation	2018-10-31	2019-07-09
SBE21 Calibration after installation	2021-08-12	2021-08-12
SBE21 Temperature offset °C	-0.00135	0.00211
SBE21 Conductivity slope	1.0001850	1.0001773
SBE38 Serial number	SBE38-0118	SBE38-0137
SBE38 Calibration before installation	2018-11-29	2018-10-31
SBE38 Calibration after installation	2021-08-31	2021-08-31
SBE38 Temperature offset °C	0.00058	0.00044

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
PS123	2020-12-20	2021-02-01	Bremerhaven	Port Stanley	43
PS124	2021-02-04	2021-03-31	Port Stanley	Port Stanley	55
PS125	2021-04-02	2021-04-29	Port Stanley	Bremerhaven	27

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
PS123	2020-12-22T08:31:02	2021-01-31T21:19:44	875159	875159	5327
PS124	2021-02-04T16:00:03	2021-03-29T16:55:03	1143404	1141472	5241
PS125	2021-04-03T14:17:30	2021-04-28T18:04:50	543411	543412	3622

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 SBE21 sensors using following equations. The temperature offsets recorded for the external temperature sensors SBE38 by the post cruise calibration were not applied since the offsets are negligibly small.

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 (130 days) and TSG2 (130 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
PS123	2	42	0.99999715	0.99994024	-0.00002077	-0.00043615
PS124	46	99	0.99993455	0.99985914	-0.00047769	-0.00102808
PS125	104	129	0.99985203	0.99981646	-0.00108000	-0.00133962

TSG2	**deployed days**		**Conductivity slope**		**Temperature offset**	
Cruise	first	last	start	stop	start	stop
PS123	2	42	0.99999727	0.99994273	0.00003246	0.00068169
PS124	46	99	0.99993727	0.99986500	0.00074662	0.00160685
PS125	104	129	0.99985819	0.99982410	0.00168800	0.00209377

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).

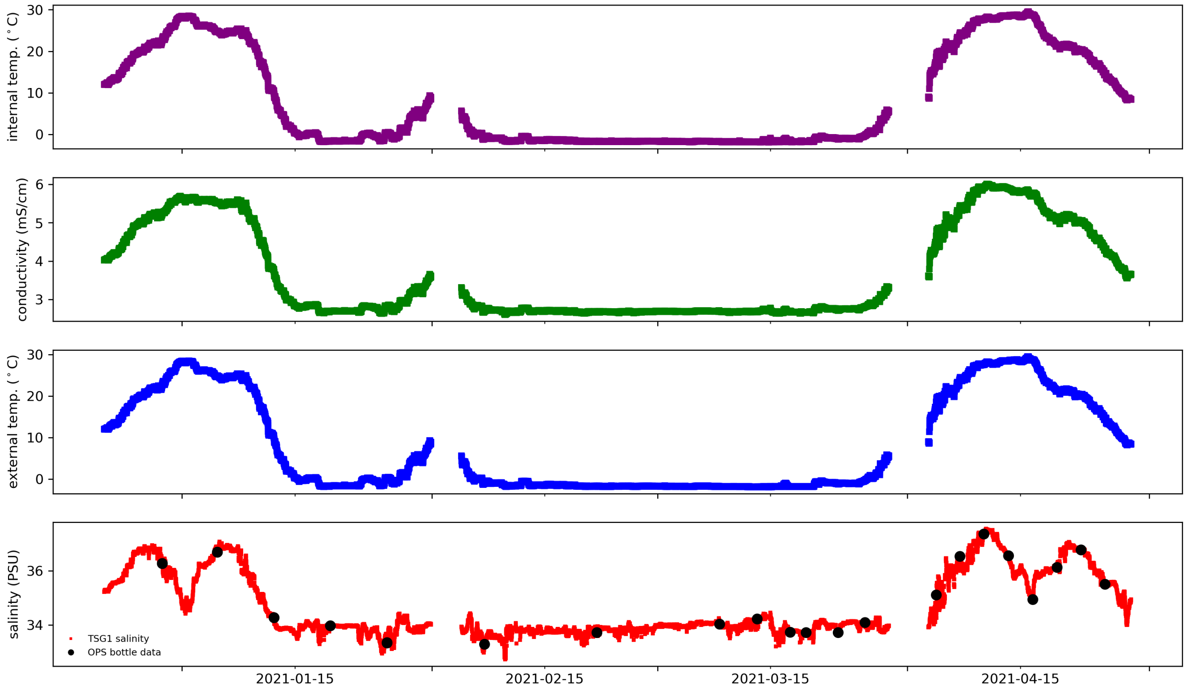

Figure 2: 10min means of data from TSG1

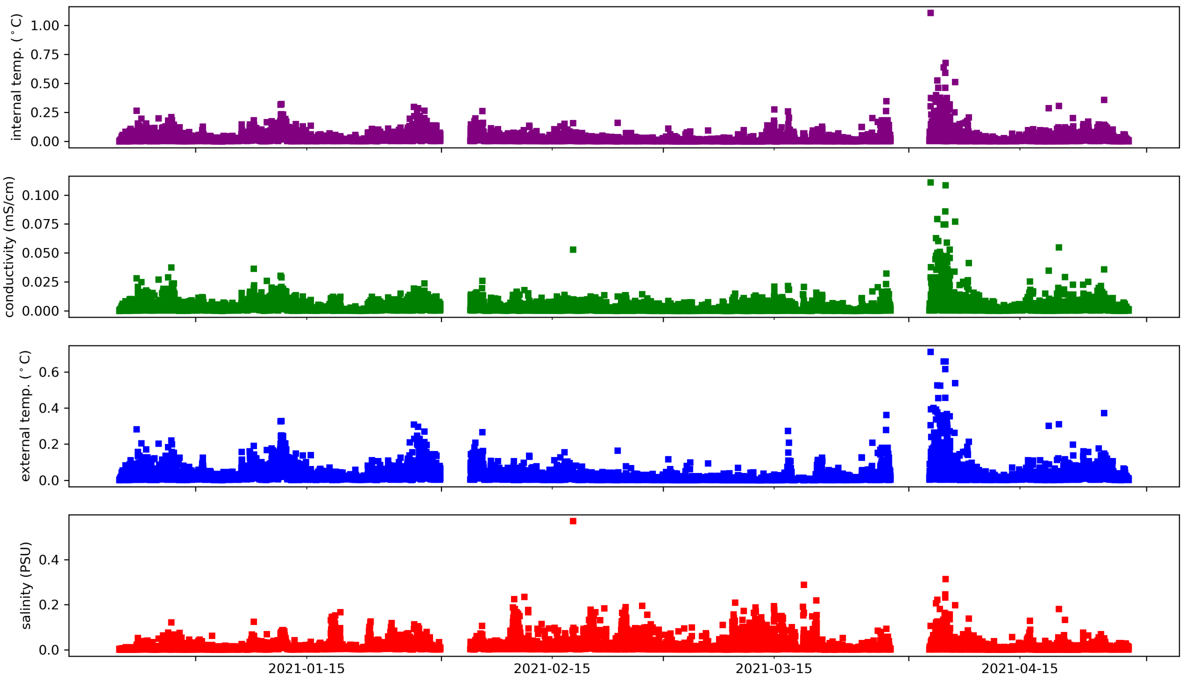

Figure 3: Standard deviations of 10min means of data from TSG1

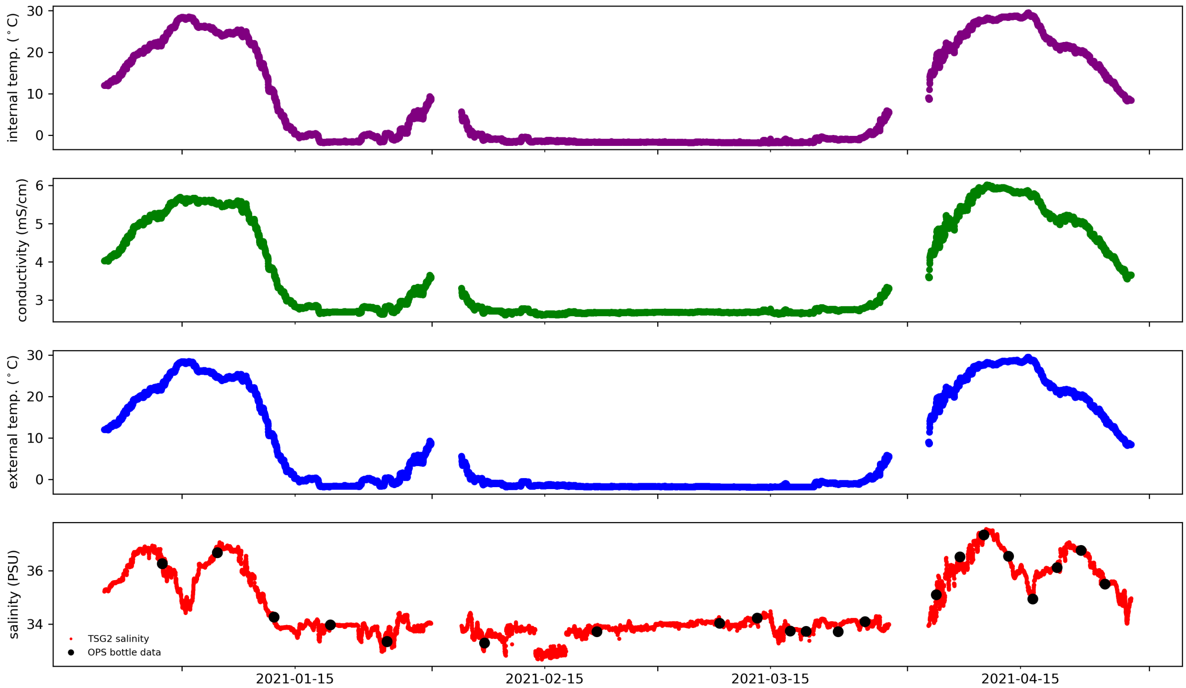

Figure 4: 10min means of data from TSG2

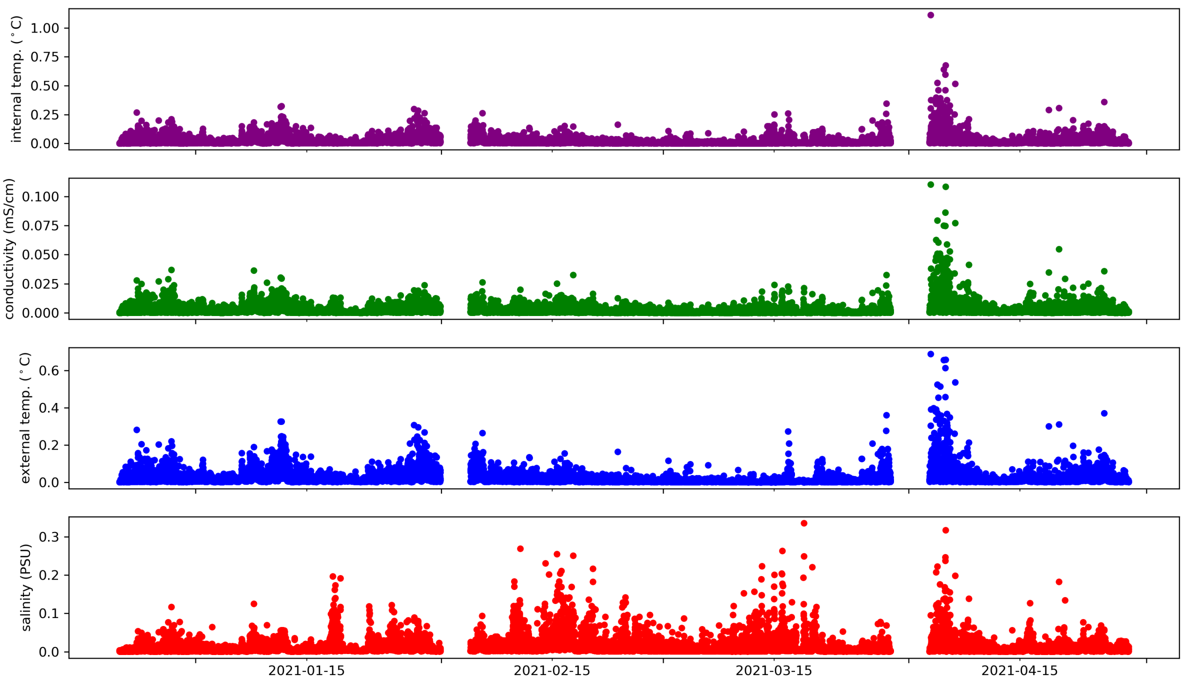

Figure 5: Standard deviations of 10min means of data from TSG2

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]	0.00204 ± 0.00447	0.00217 ± 0.00210
Conductivity [mS/cm]	0.00947 ± 0.12722	0.00681 ± 0.11873
External temperature [°C]	-0.00050 ± 0.00162	-0.00048 ± 0.00058
Salinity [PSU]	0.01514 ± 0.17400	0.01122 ± 0.16251

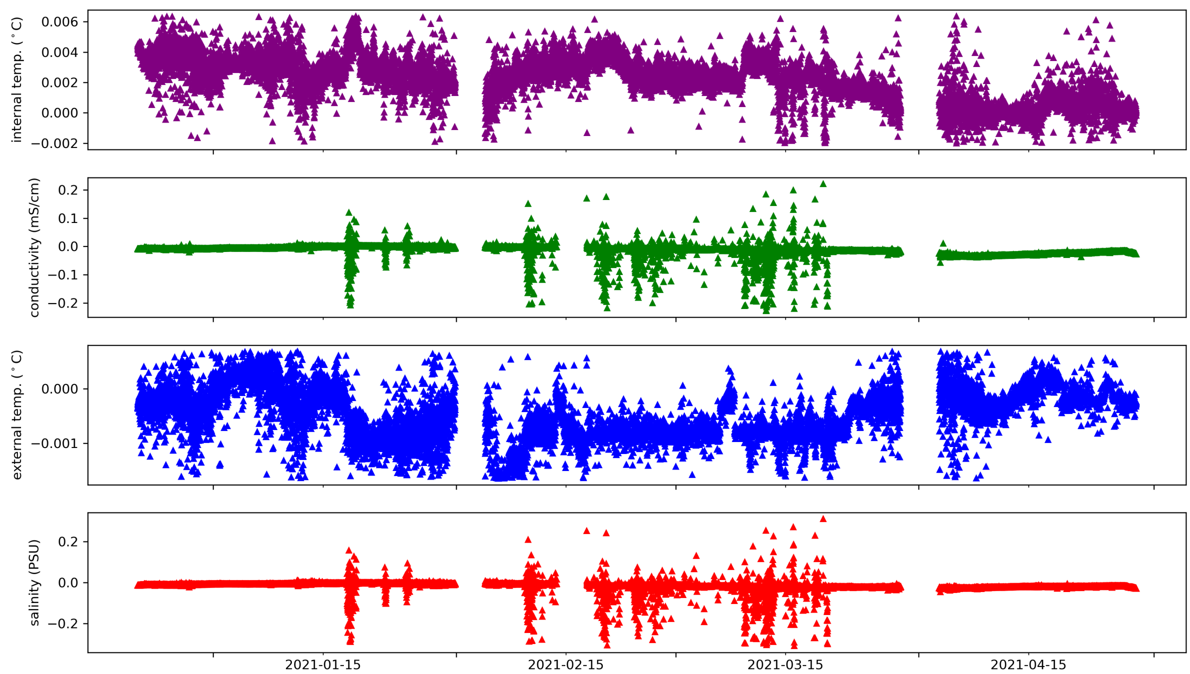

Figure 6: Differences between 10min means TSG1 - TSG2

Post calibration values show a smaller temperature offset (-0.00135) for TSG1 compared to TSG2 (0.00211) while slope correction values do not differ much (1.0001850 and 1.0001773). Without further quality criteria the decision was to upload the TSG1 (SBE21-3191) 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. The broad peak around 0.003°C originates from cruises PS123 an PS124 while the difference between internal temperatures of TSG1 and TSG2 approaches 0.0°C during PS125. Differences between external temperature sensors are slightly greater in the cold waters of the Weddell Sea during the end of PS123 and most of PS124 with TSG2 always showing

higher external temperatures than TSG1.

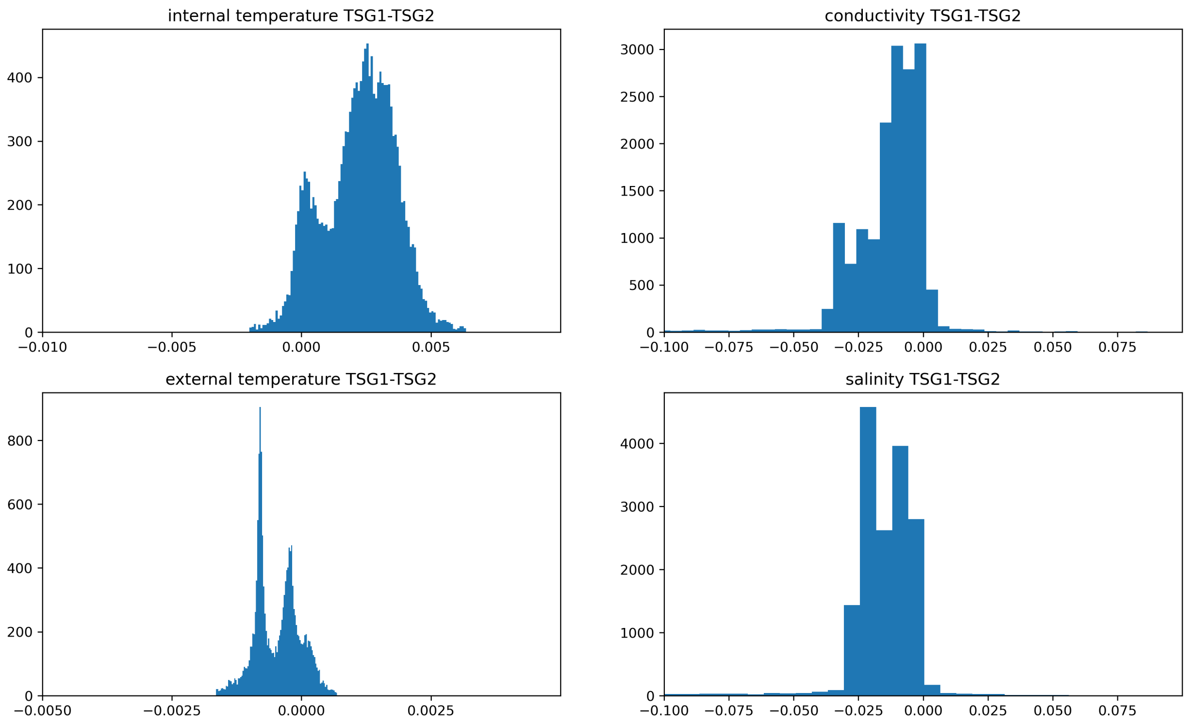

Figure 7: Histogramm of differences TSG1 - TSG2

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. High scatter around the middle of March most likely was attributed to contamination of the TSG system that required cleaning of the system on March 19th, 2021.

	TSG1 (mean ± std. dev.)	**TSG2** (mean ± std. dev.)
Spot values	0.04788 ± 0.04741°C	0.04478 ± 0.04131°C
10-min means	0.04725 ± 0.03438°C	0.04460 ± 0.03457°C

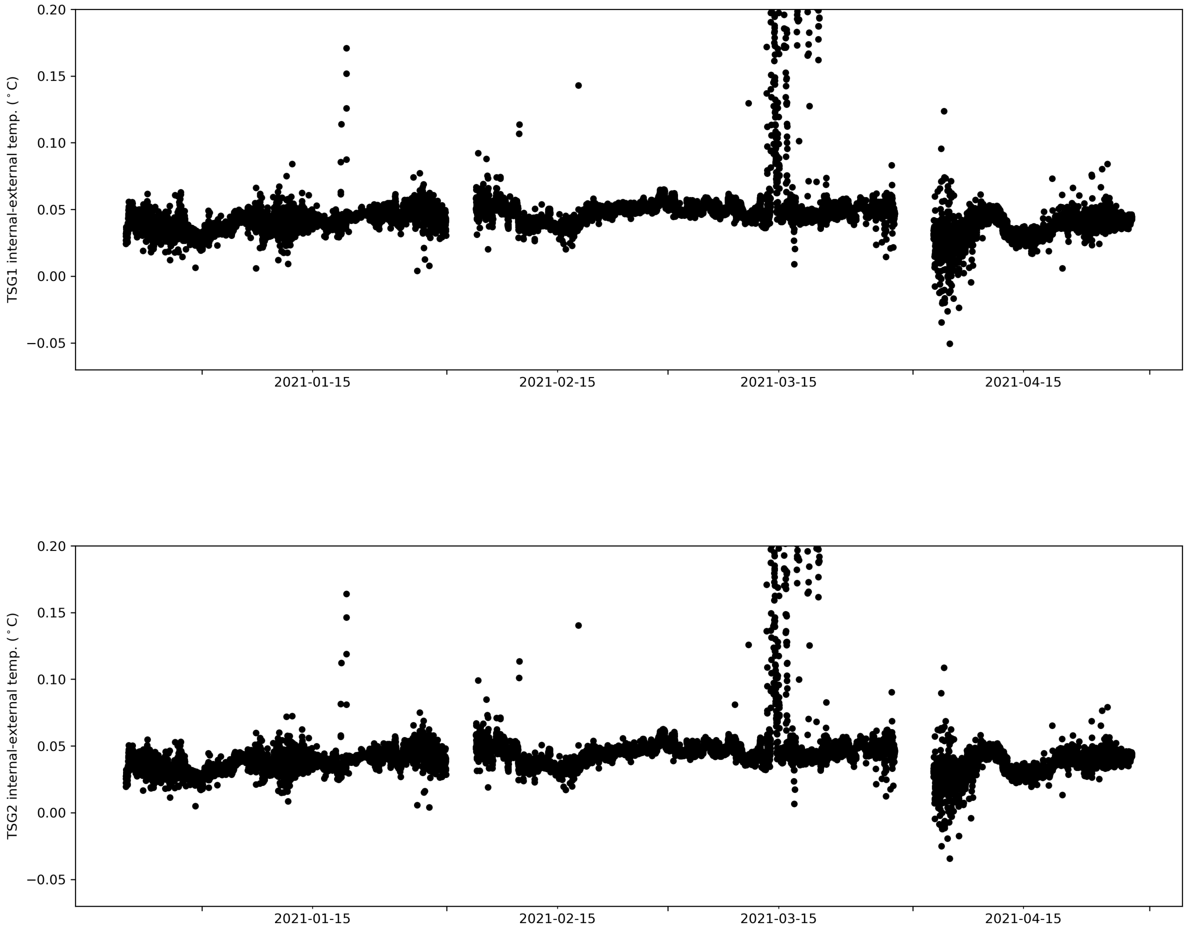

Figure 8: Temperature differences between internal and external temperature sensors of 10min means

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]
2020-12-29T13:15:00	36.2737
2020-12-29T13:15:30	36.2734
2021-01-05T09:15:00	36.6896
2021-01-05T09:15:30	36.6880
2021-01-12T09:45:00	34.2692
2021-01-12T09:45:30	34.2682
2021-01-19T09:45:30	33.9708
2021-01-26T09:45:00	33.3364
2021-01-26T09:45:30	33.3555
2021-02-07T12:37:00	33.2945
2021-02-21T10:56:00	33.7229
2021-03-08T16:17:00	34.0361
2021-03-13T08:39:00	34.2222
2021-03-17T10:42:00	33.7365
2021-03-19T09:49:00	33.7241
2021-03-23T09:53:00	33.7232
2021-03-26T17:11:00	34.0960
2021-04-04T13:31:00	35.1052
2021-04-07T11:40:00	36.5306
2021-04-10T11:45:00	37.3563
2021-04-13T12:20:00	36.5518
2021-04-16T13:10:00	34.9422
2021-04-19T13:15:00	36.1261
2021-04-22T12:20:00	36.7667
2021-04-25T12:15:00	35.5059