

Continuous thermosalinograph oceanography along RV METEOR cruise track M203

Data Processing Report

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1 Introduction

This report describes the processing of raw data from the thermosalinograph (TSG) on board RV Meteor during expedition M203.

2 Sensor Details

Here the details of the used devices are listed. Currently three SBE38 (SNs: 0667, 0747, 0749) and five SBE21 are used (SNs: 3313, 3388, 3389, 3394, 3413) on RV Meteor. Unfortunately, the dates for calibration and installation are not available yet.

Table 1. Overview of used SBE21 and SBE38 with calibration and installation dates.

	TSG1	TSG2
Serial number SBE21	3388	3394

Calibration SBE21		
Installation SBE21		
Serial number SBE38	0667	0747
Calibration SBE 38		
Installation SBE 38		

3 Processing Report

Database extraction

Data were extracted from the DSHIP database at BSH (dship.bsh.de). The whole dataset was downloaded in one-second resolution and afterwards reduced to the period of actual observations. The RV Meteor has two independent TSGs, which worked independent from each other throughout the whole cruise. Within the TSGs conductivity and internal temperature are measured and salinity is estimated subsequently. Furthermore, two temperature measurements are conducted at two water inlets in ~5m depth. Those two devices (SBE38) also worked during the whole cruise. Data are logged every ten seconds for both TSGs. The following table gives information about the raw data as they were downloaded.

Table 2. Start time, end time, and number of lines of raw data file.

	Time/No. of raw data
Start of raw file	2024-08-10T08:00:00
End of raw file	2024-09-24T07:59:59
Raw data lines	3887956

Every single parameter is now checked for obvious dummy values (e.g. 0 or 9.999 or 99.999 etc). This is also done for position data. The following table shows the counts of dummy data, which were set to NaN afterwards.

Table 3. Number of discarded dummy values per quantity.

	No. of dummy values
Latitude	0
Longitude	0
TSG1 Conductivity	3110536
TSG1 Salinity	3110536
TSG1 Temperature	3110536
TSG2 Conductivity	3553611
TSG2 Salinity	3553612
TSG2 Temperature	3553612
SBE38_1	3110536

SBE38_2	3553612
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Only timestamps with reliable position data are used. For this, the dataset is compared to the 1-second mastertrack dataset of this cruise obtained from the PANGAEA database (<https://doi.pangaea.de/10.1594/PANGAEA.974753>). Timestamps of the cruise dataset, which are not part of the mastertrack dataset, were discarded. As a next step, data lines were discarded when one of the position data was NaN. Finally, all data lines were discarded when all physical data was NaN. The following table shows the number of discarded data lines due to the abovementioned reasons.

Table 4. Number of discarded data lines due to misalignment with the mastertrack, wrong position data or empty data lines.

	No. of discarded lines
Not part of mastertrack	499999
Either lat or lon is NaN	0
All physical values are NaN	2578100

As a last step the remaining raw data are checked for the position regarding Exclusive Economic Zones (EEZs). All data within an EEZ without a research permission were discarded. For this cruise only data from international waters are used. Additionally, a research permission was approved for the EEZs of Namibia and Angola. The following table shows the number of discarded data lines due travelled EEZs without research permission.

Table 5. Number of discarded data to EEZ s without a permission.

	No. of discarded lines
All values are NaN due to EEZs	0

The resulting dataset is used for further examination. The number of remaining valid one-second data is given in the following table.

Table 6. Number of data used for averaging. Shown are start time, end time, and number of lines. Number of data per TSG and per SBE38 are shown as well.

	Time/No. of valid data
Start of valid data	2024-08-16T02:53:21
End of valid data	2024-09-24T07:59:53
Valid data lines	809857
TSG1	677576
TSG2	334345

SBE38_1	677576
SBE38_2	334344

Calculation of 1-min means

The data were averaged into one-minute-means as long as at least half of the data per minute are available (i.e. 7 for TSG1 and 4 for TSG2). Values outside of a 2-time standard deviation were discarded. The numbers of outliers are given for both systems and all properties individually.

Table 7. Number of outliers discarded during averaging.

	TSG1/SBE38_1	TSG2/SBE38_2
Conductivity	12344	528
Internal temperature	11856	267
External temperature	17011	266
Salinity	13502	235

Afterwards any remaining data lines with only NaNs in it are discarded. The following table gives the number of discarded data lines.

Table 8. Number of discarded lines due to empty data.

	No. of discarded lines
All physical values are NaN	0

First and last averaged minute and number of data is given in the following table.

Table 9. Start time, end time, and number of one-minute-averaged data lines.

First 1-min dataset	2024-08-16T02:53:00
Last 1-min dataset	2024-09-24T07:59:00
No. of 1-min means	56467

Global range, spike, gradient, and flow speed tests

The timeseries obtained from averaging were checked and flagged after passing several QC tests. These tests follow the “SeaDataNet Data Quality Control Procedures” and are the global range test, spike test, gradient test, and a test of reliable flow speed. The flagging scheme is taken from SeaDataNet as well and consists of the flags:

Table 10. Flag keys of SeaDataNet flagging scheme.

Key	Term	Definiton
0	no QC	No QC has been applied/unknown
1	good	Good quality data value which has been verified
2	probably good	Good quality data value which has not been verified
3	probably bad	Data value which is obviously inconsistent to the phenomenon
4	bad	Obviously erroneous value
5	not used	
6	not used	
7	not used	
8	interpolated	Value derived by interpolation
9	missing	Value is missing

Initially all 1-min averaged data get the flag “0”.

After passing the global range test data values get the flag “1”. To the values, which didn’t pass this test, the flag “4” is assigned.

Global ranges are for temperature $-2.5^{\circ}\text{C} \leq T \leq 45^{\circ}\text{C}$, and for salinity $0 \leq S \leq 60$.

Values, which didn’t pass the spike or the gradient test, get the flag “3”.

For values, which do not have adjacent values within a minute, the flag “2” is assigned.

During these tests, all values are compared with their adjacent ones. A test value is defined, which must not exceed 6°C for temperature and 0.9 for salinity for the spike test. For the gradient test the test value must not exceed 9°C for temperature and 1.5 for salinity.

Spike test: Test value = $|V2 - (V3 + V1) / 2| - |(V3 - V1) / 2|$

Gradient test: Test value = $|V2 - (V3 + V1) / 2|$

V2...value tested as a spike

V1, V3...previous and next value

The flow speed through the system is an indicator for a reliable measurement. If flow speed is too low, the wrong water might have been measured. Timeseries of flow speed for both TSGs is shown in the following:

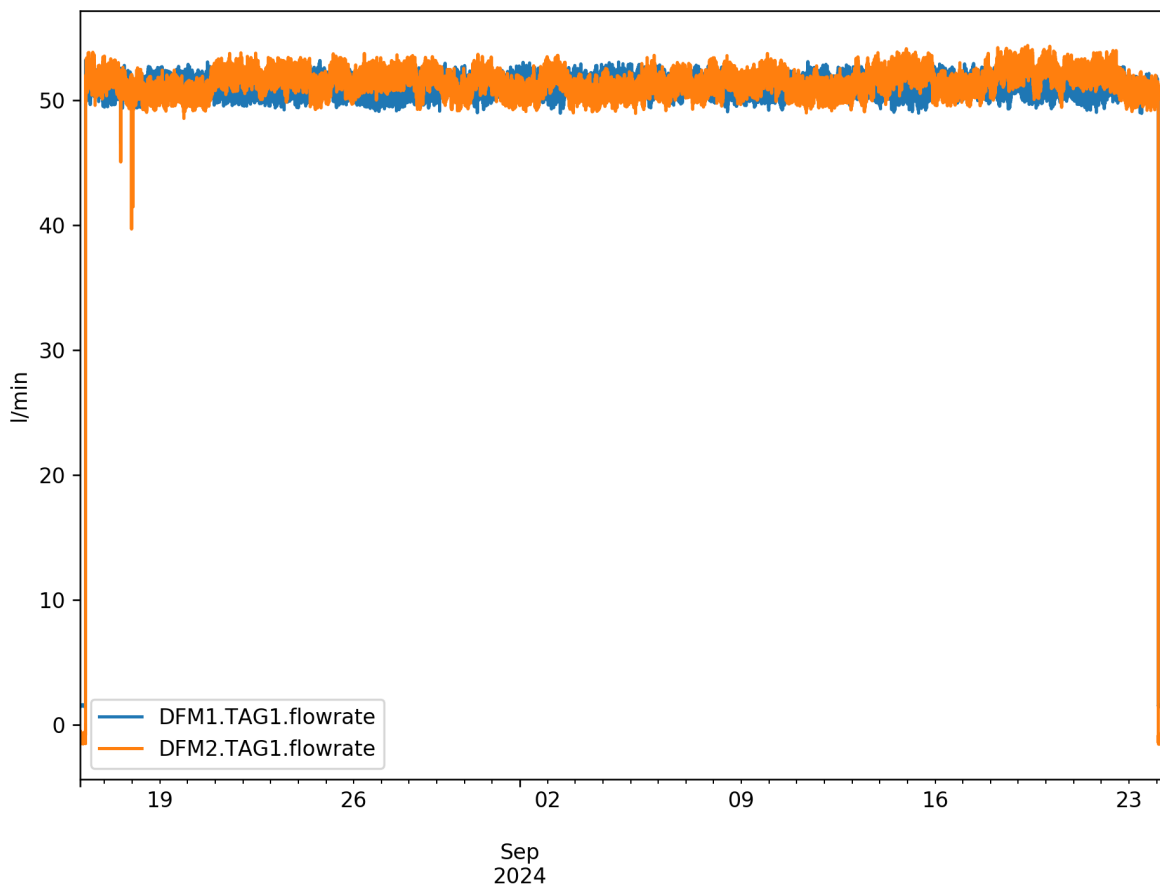


Figure 1. Time series of flow speed (in l/min) through the seawater system.

The plot reveals a couple of regimes with each a relatively steady flow speed between 48.5-56 l/min for both TSGs. The boundaries were taken as accepted flow speeds for this cruise.

Table 11. Range of flow speed assigned with flag 1.

	Range of flow speed (l/min)
TSG1	48.5-56
TSG2	48.5-56

All data values for which the flow speed is lower(higher) than the lower(upper) threshold, the flag “3” is assigned. Due to the fact, that flow distortion effects last for a while, the data in the two following minutes get the flag “3” as well.

Temperature calibration

CTD temperatures from 5m depth were compared with the TSG 1-min means for both SBEs. Here, the difference of the two means of the particular data is taken, while only data within one standard deviation were used. Finally, temperature offsets were estimated for both SBEs.

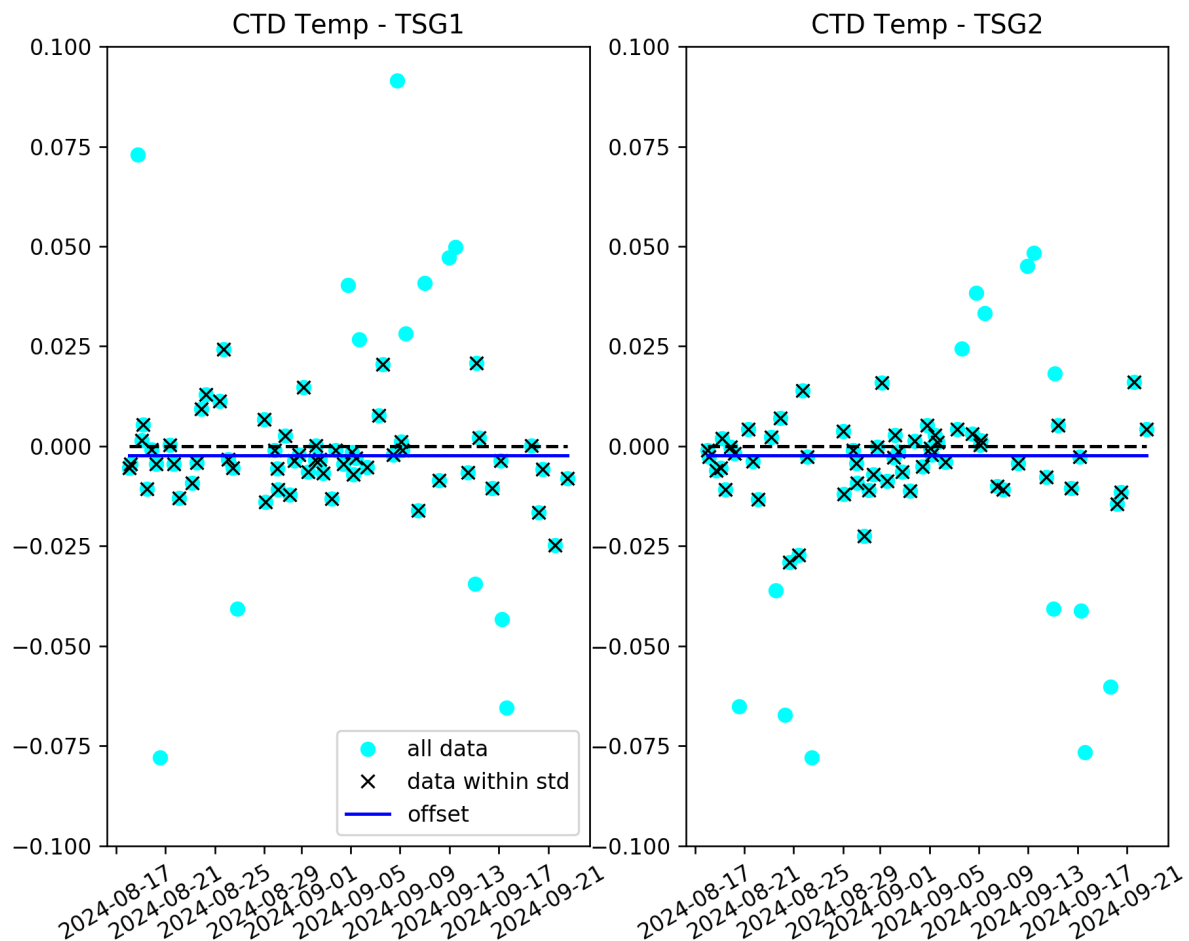


Figure 2. Differences (in °C) of CTD (from 5m depth) and TSG temperatures for TSG1 (left) and TSG2 (right). The cyan dots show all available data after a cutoff of 0.1, while the black crosses show only data, which are within one standard deviation. The blue line shows the offset, which is eventually applied to the TSG temperature data.

Salinity calibration

CTD salinities from 5m depth were compared with the TSG 1-min means for both TSGs. Here, the difference of the particular data is taken at the CTD time spots, while only data within one standard deviation were used. Finally, temperature offsets were estimated for both TSGs.

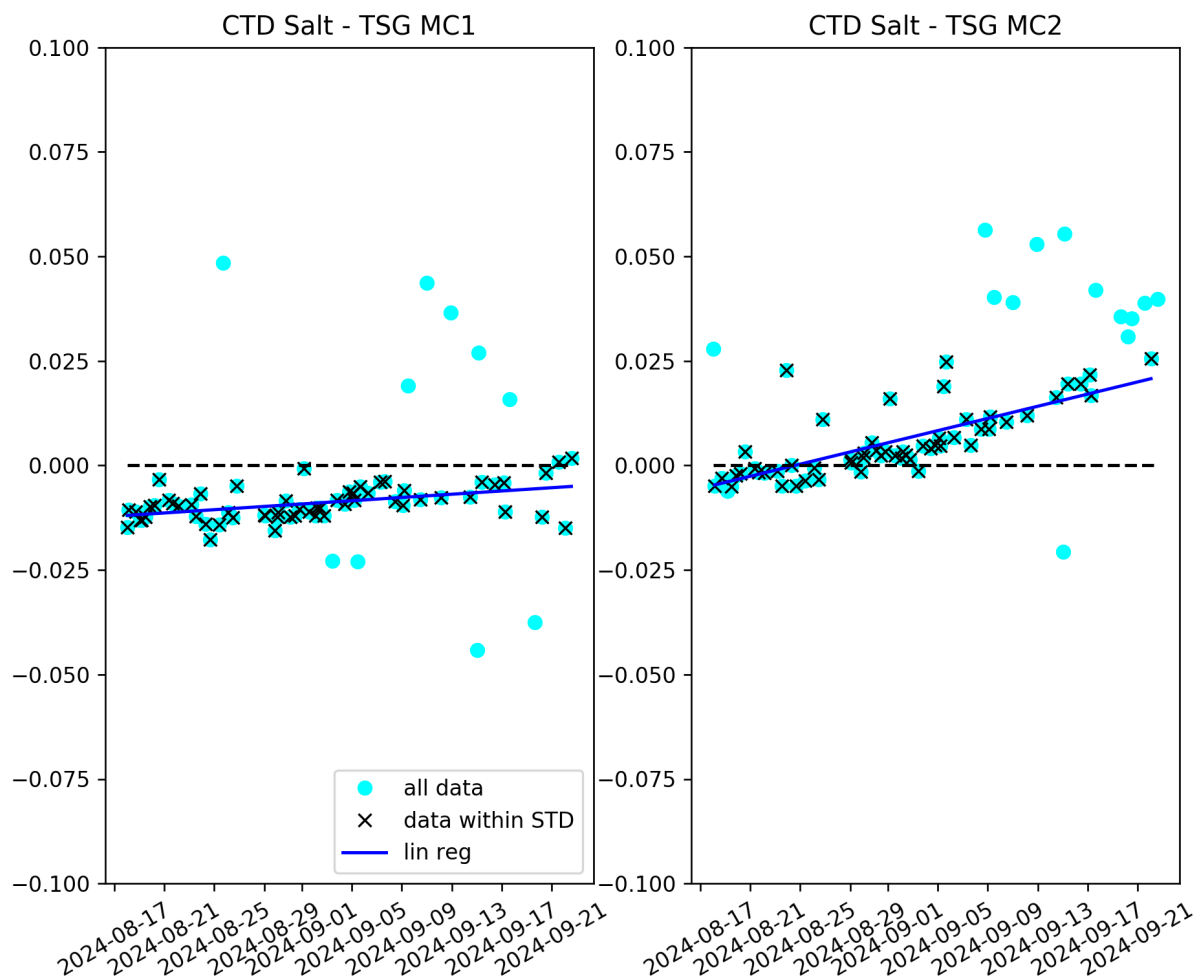


Figure 3. Differences of CTD (from 5m depth) and TSG salinities for TSG1 (left) and TSG2 (right). The cyan dots show all available data after a cutoff of 0.1, while the black crosses show only data, which are within one standard deviation. The blue line shows the linear fit, which is eventually applied to the TSG salinity data.

It turned out, that the salinity differences for both TSGs show a positive trend with time, therefore a time-dependent fitting scheme was used. Eventually, linear salinity fits were estimated and applied for both TSGs (tim is the time in days since Expocode of this cruise (06M320240810), i.e. since 2024-08-10T00:00:00).

Table 12. Offsets added (if applicable) to salinity and temperature data (°C).

	TSG1	TSG2
Offset added to salinity data	$0.0002320 \cdot \text{tim}$ -0.01142	$0.0001373 \cdot \text{tim}$ +0.17573
Offset added to temp data	-0.012624	-0.007968

Resulting timeseries

At a last step, final timeseries were produced by picking the salinity and the temperature observations of one of the TSGs and SBEs accordingly. For this cruise TSG1 was chosen, even though the performance of both TSGs was nearly identical.

One final time all data lines are discarded, where no temperature and salinity data are available. The number of discarded lines is shown in the following table.

Table 13. Number of discarded data lines after all processing steps.

	No. of discarded lines
Temperature and salinity values are NaN	0

The final dataset covers the following range:

Table 14. Start time, end time, and number of lines of final dataset.

First 1-min dataset	2024-08-16T02:53:00
Last 1-min dataset	2024-09-24T07:59:00
No. of 1-min means	56467

Timeseries of external temperature and salinities are shown in the following. First, the timeseries from both TSGs:

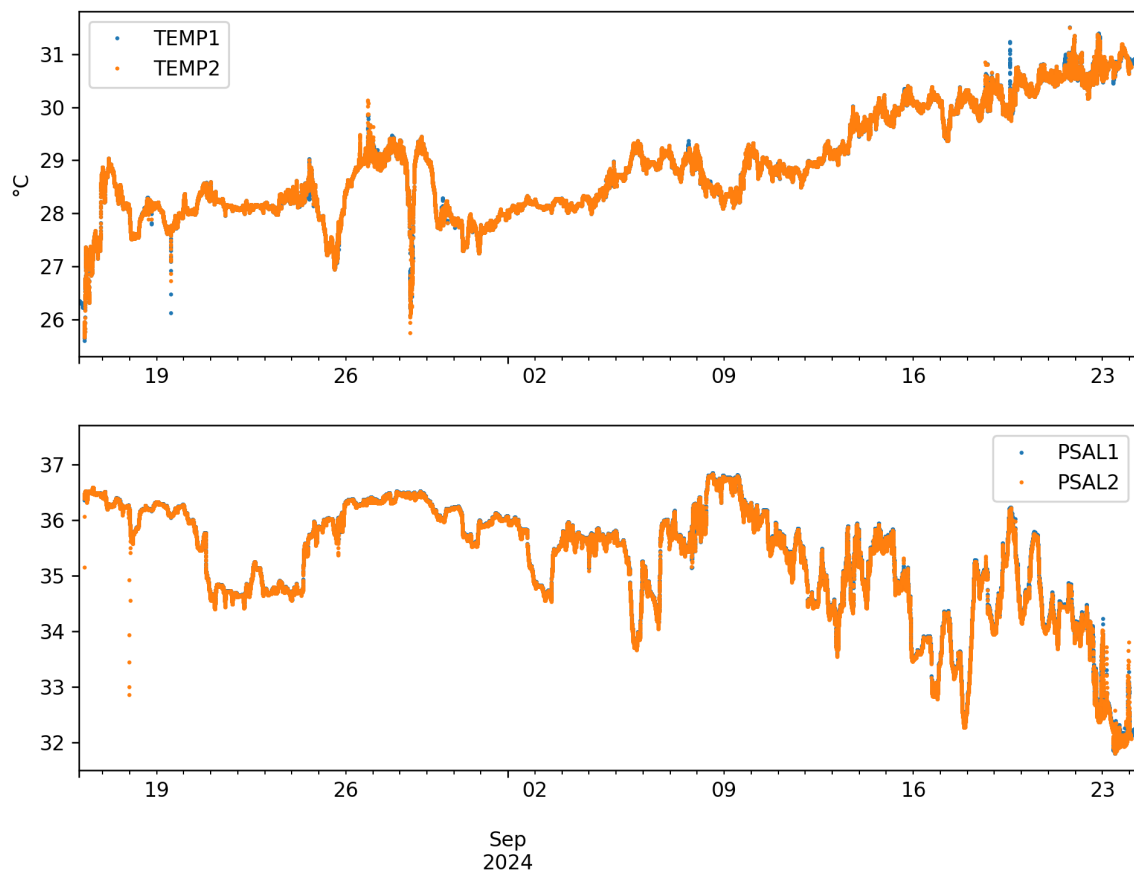


Figure 4. Time series of temperature (top; in °C) and salinity (bottom). Shown are the data from TSG1 (blue) and the data from TSG2 (orange).

Afterwards are shown the timeseries, which were eventually chosen for publication:

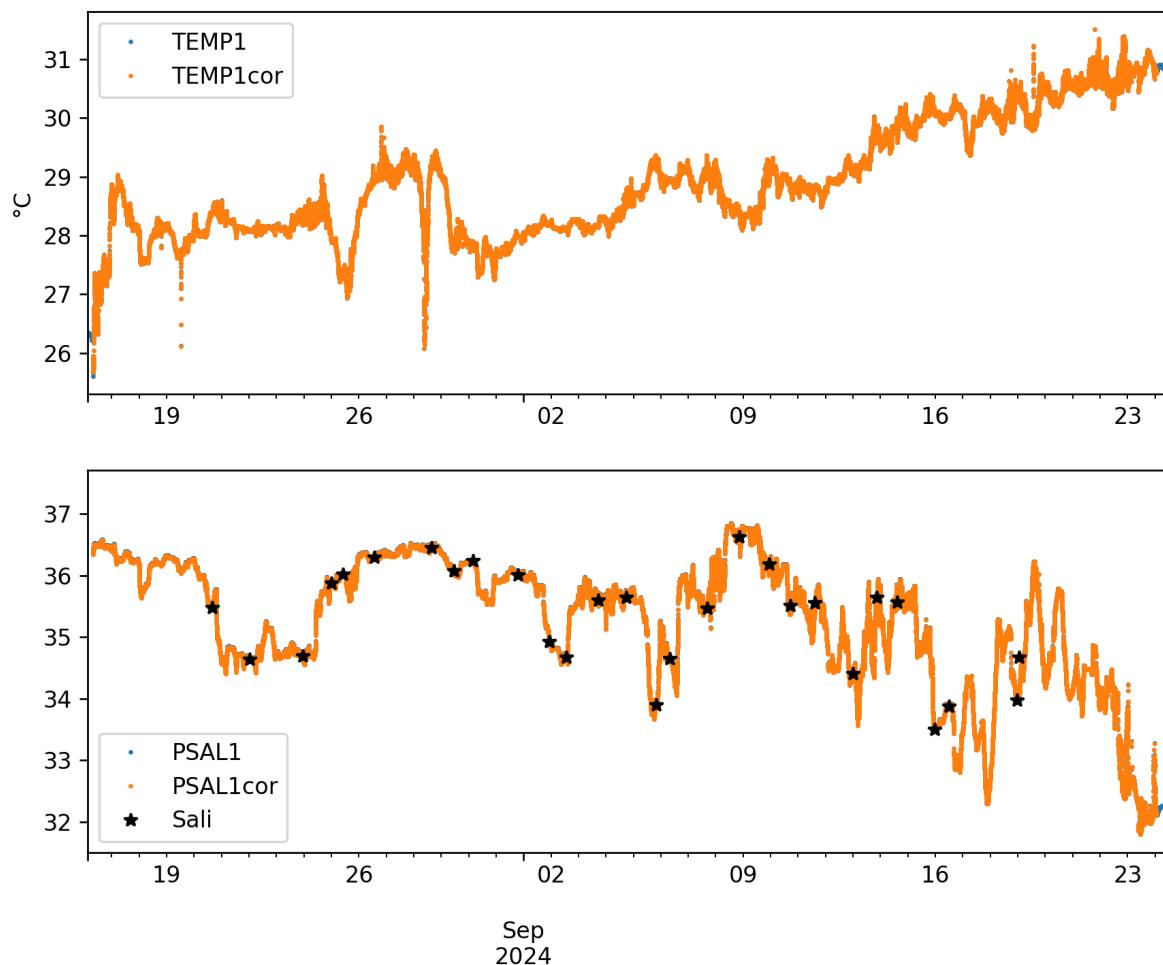


Figure 5. Time series of temperature (top; in °C) and salinity (bottom). Shown are all data (blue), data with a final flag 1 (orange), and the salinometer estimates (black dots)

Resulting file

A tab-delimited data file, named **M203_surf_oce.tab**, is the resulting file, which is published on PANGAEA.

Columns in the file are the time, position (latitude and longitude), depth of water inlet, external temperature, external temperature flag, conductivity, internal temperature, salinity, salinity flag, salinity sample data (obtained with a salinometer), and the picked TSG (TSG1 or TSG2).

Comments

No speed flagging was done. Values when the speed is small or close to zero (e.g. vessel on station) are kept.

All salinities are practical salinities following PPS-78 and hence shown dimensionless.

4 Appendix

Attached are the discrete salinity samples taken along the cruise track and measured on the cruise with an Guildline Autosol Salinometer. Due to the availability of CTD data (generally more data for comparison), those data are not used for calibration.

Date/Time	Latitude	Longitude	Sal
2024-08-20T15:36:00		8.6428560	-26.7952850 35.4721
2024-08-22T00:25:00		6.0549230	-25.9413570 34.6354
2024-08-23T23:07:00		5.6590520	-24.7666820 34.6942
2024-08-25T00:02:00		8.7259590	-24.3632350 35.8759
2024-08-25T10:04:00		9.7603310	-24.2272890 36.0212
2024-08-26T13:35:00		12.2214840	-23.8728700 36.2950
2024-08-28T15:25:00		14.2659580	-23.4030230 36.4433
2024-08-29T11:11:00		11.6539420	-22.6417470 36.0750
2024-08-30T03:58:00		11.5059100	-23.5840010 36.2408
2024-08-31T19:15:00		8.5055010	-23.8682500 36.0077
2024-09-01T22:40:00		8.4160110	-27.0398800 34.9273
2024-09-02T13:10:00		8.4409610	-28.4670440 34.6724
2024-09-03T17:31:00		8.4964160	-30.9133640 35.5939
2024-09-04T17:56:00		8.2637600	-34.2351230 35.6415
2024-09-05T20:11:00		8.0000190	-36.4799450 33.8957
2024-09-06T08:05:00		7.9400020	-38.0010790 34.6472
2024-09-07T16:33:00		10.9540790	-37.7994680 35.4694
2024-09-08T20:20:00		14.8474400	-37.7490360 36.6210
2024-09-09T22:53:00		12.1708690	-37.1335150 36.1836
2024-09-10T17:27:00		9.7966260	-36.4727440 35.5094
2024-09-11T14:48:00		8.2511650	-36.5889340 35.5536
2024-09-12T23:50:00		8.3321920	-39.6070170 34.4109
2024-09-13T20:45:00		8.9916230	-42.5159710 35.6370
2024-09-14T14:46:00		9.4795430	-44.6768720 35.5595
2024-09-15T23:13:00		8.7431570	-47.4414510 33.5005
2024-09-16T12:03:00		7.4853170	-47.6646750 33.8773
2024-09-18T23:28:00		10.1622660	-48.0113430 33.9753
2024-09-19T00:54:00		10.2346010	-48.2498960 34.6719