STRATUS 16 Data Report

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Contents

1 Introduction

This document details the preprocessing, quality control, and merging steps for the deep temperature and salinity (T/S) data from stratus 16. This report is supplemented by the Python code used in the analysis.

1.1 Deployment Summary

- **Deployment Period:** From 2017/05/06 19:00 to 2018/04/12 14:50
- **Instruments Used:** SBE37 10600 and SBE37 10601
- **Merged Data:** SBE37 10600 was selected for the merged dataset
- **Overlap with Previous Deployment (stratus 15):** no

2 Pre-Processing

Detailed steps described during the pre-processing of stratus 16 data include:

2.1 Data Loading and Initial Processing

- Read .mat files containing SBE37 data using custom functions.
- Convert MATLAB data to xarray datasets for use in Python.
- Process and update metadata.

2.2 Time Correction

- Adjust time data to account for MATLAB's year zero issue.
- Convert time units to 'days since 0001-01-01'.
- Subtract 365 days from converted times to correct for MATLAB's leap year assumption.
- Time base Interpolation (if necessary): Data are interpolated from the initial timing mark to the final timing mark, so this needs to be done before truncation.

Potential timing errors are addressed by referring to the "recover.xls" spreadsheet on buoy5, under the "subsurface" tab, to compare spike start and end times with the apparent time in the instrument data. If the offset is greater than one sample interval (+/- 5 min for Stratus deployments), it indicates misalignment in time, and the data is linearly interpolated to a new time base to synchronize instruments.

In reviewing the temperature data against recorded spike times for stratus 16, it is observed that the differences are consistently within 5 minutes. Specifically, for the deployment phase, the significant temperature drop commences at 2017/05/06 19:00, closely aligning with the recorded spike time of 2017/05/06 19:05:00. Similarly, during the recovery phase, a notable temperature drop starts at 2018/04/12 14:50, which slightly follows the recorded spike time of 2018/04/12 14:45:00.

Time Correction Decision: Based on these findings, interpolation was not performed for stratus 16 as the temperature data aligns well with the recorded times, suggesting minimal time offset. See Figs.1 and 2 for details.

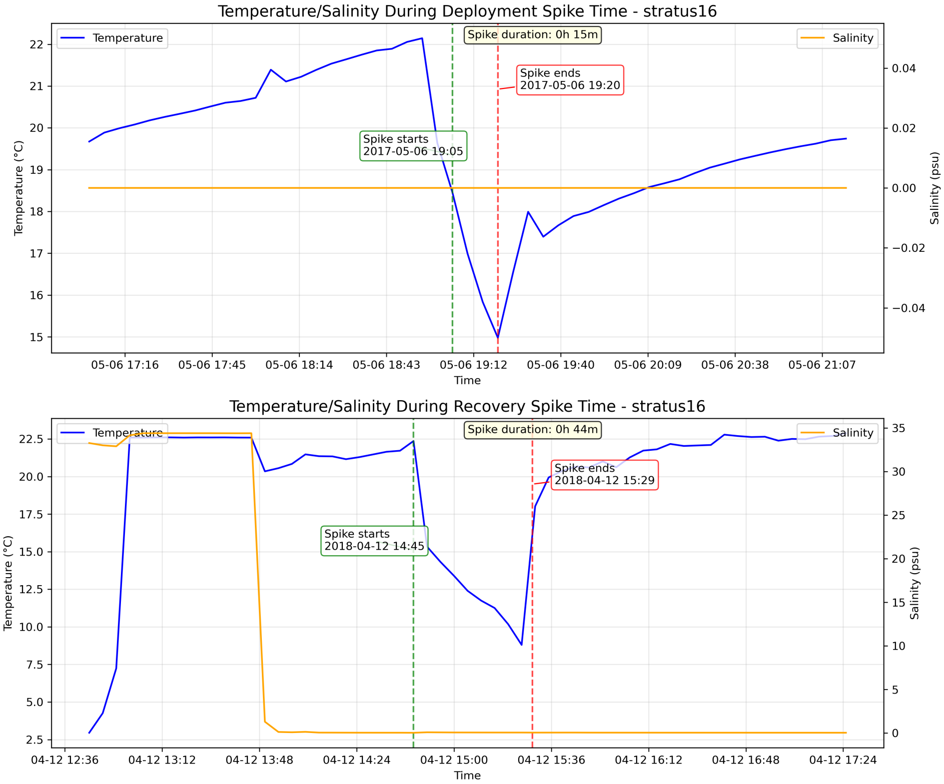

Figure 1: Deployment and recovery spike times for instrument SBE37 10600 of stratus 16 showing temperature changes during deployment and recovery operations. The vertical dashed lines indicate the recorded spike times (2017/05/06 19:05:00 for deployment and 2018/04/12 14:45:00 for recovery).

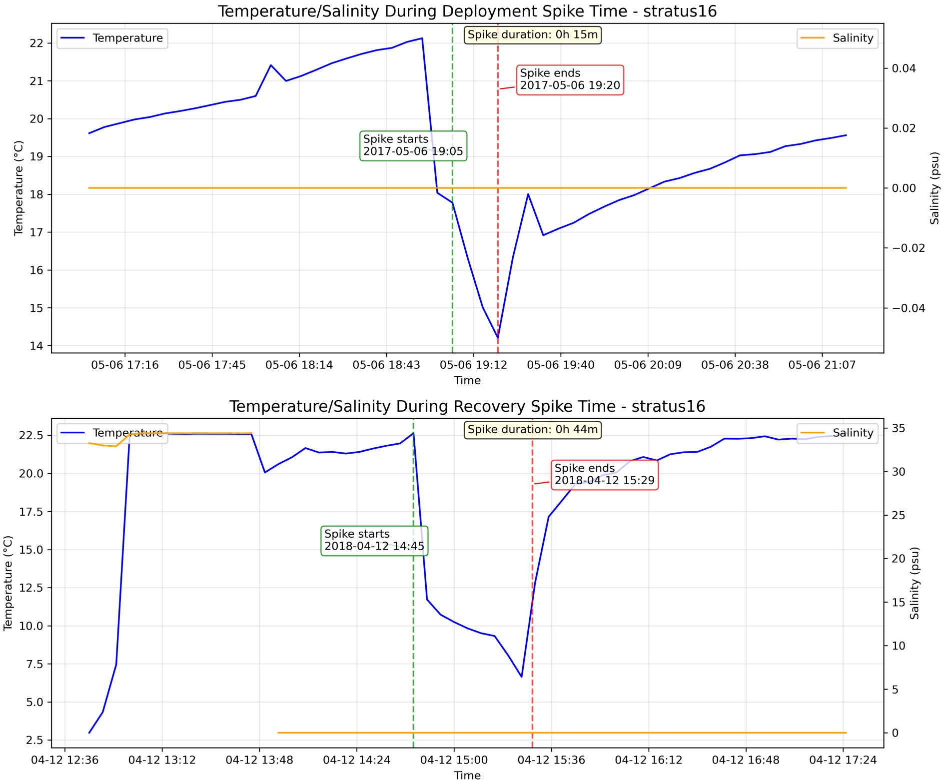

Figure 2: Deployment and recovery spike times for instrument SBE37 10601 of stratus 16 showing temperature changes during deployment and recovery operations. The vertical dashed lines indicate the recorded spike times (2017/05/06 19:05:00 for deployment and 2018/04/12 14:45:00 for recovery).

The deployment and recovery phases are visualized in Figs.3 and 4. The figures show the temperature changes during deployment and recovery operations for both instruments. The vertical dashed lines indicate the anchor over time (anchor dropped) and release fired times (moooring released), which are used to truncate the data.

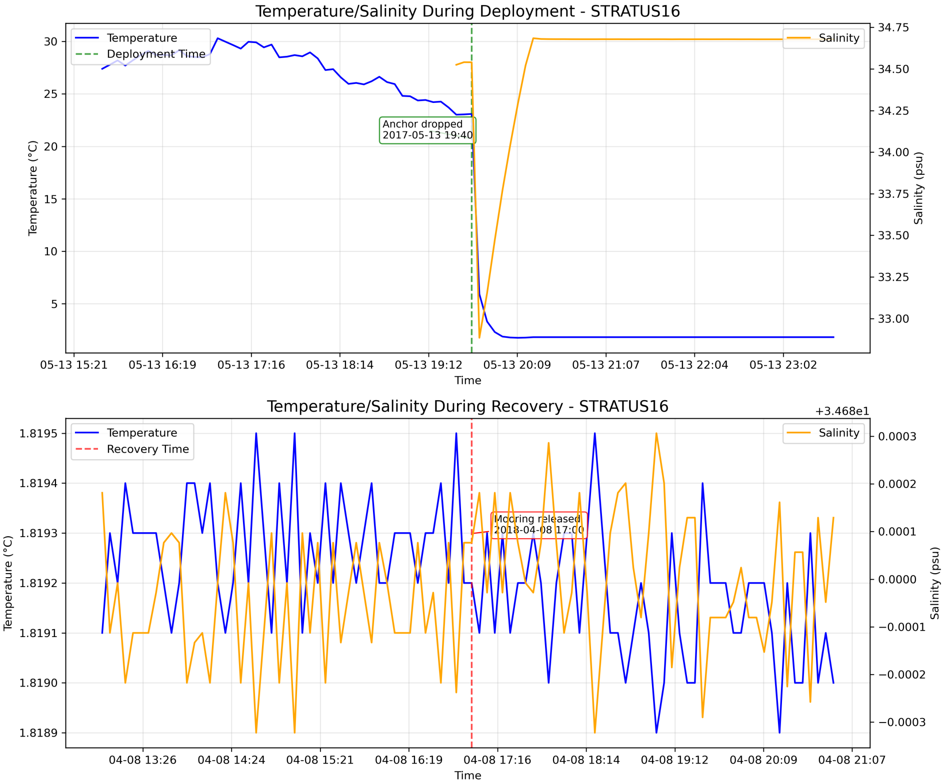

Figure 3: Detailed view of temperature changes during deployment and recovery phases for stratus 16, showing instrument SBE37 10600.

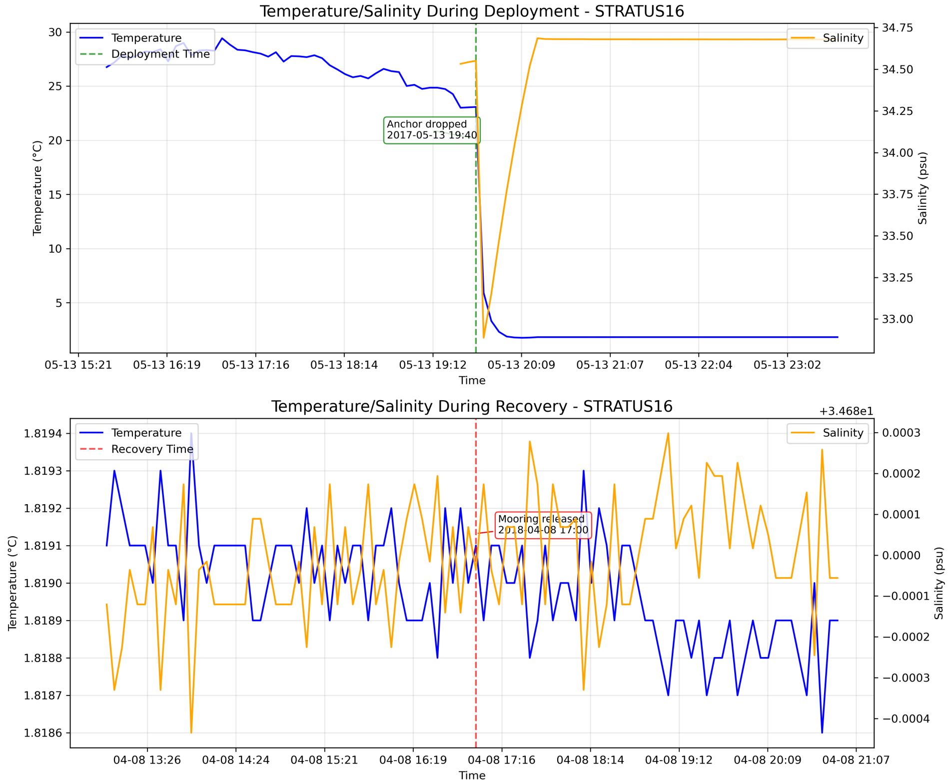

Figure 4: Detailed view of temperature changes during deployment and recovery phases for instrument SBE37 10601 of stratus 16.

3 Truncation and Visualization

3.1 Data Truncation

- Read anchor over time and release fired time from metadata.
- Truncated dataset starts 4 hours after anchor over time and ends at release fired time.
- Plot and inspect temperature time series for both SBE37 instruments.
- Ensure that truncation has successfully excluded data from before deployment and after recovery.
- The time-corrected (if needed) and truncated data files are saved after this stage of processing. These define the "baseline" files for each deployment, before quality control but after time correction and truncation.

The truncated data (Fig.5) shows the expected time window of good data after truncation, starting 4 hours after anchor deployment time and ending at the release fired time.

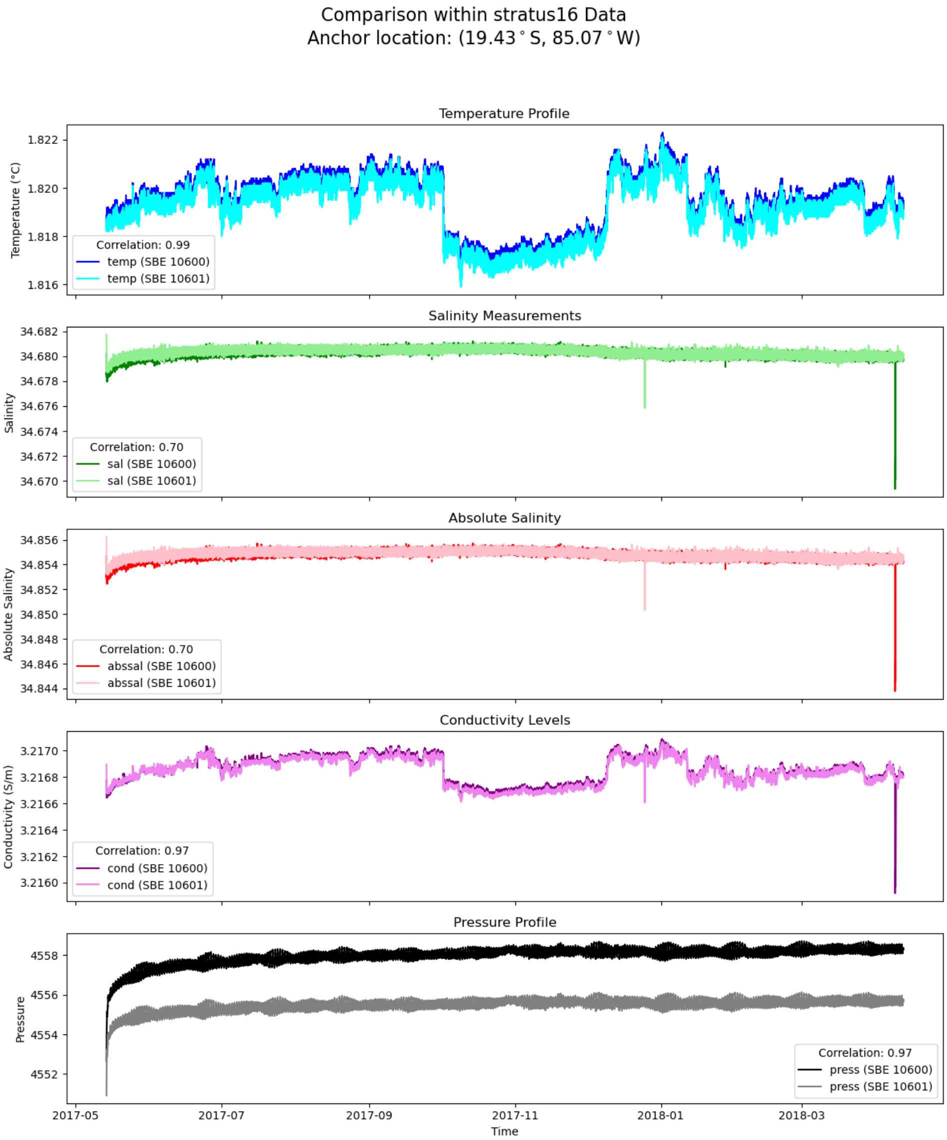

Figure 5: Deployment and recovery timing analysis for stratus 16, comparing instruments SBE37 10600 and SBE37 10601. This figure shows the expected time window of good data after truncation. Truncated dataset starts 4 hours after anchor over time and ends at release fired time.

3.2 Re-calculate Salinity

Pressure data is available for this deployment but may have drifted significantly in the SBE37 instruments, which can lead to inaccurate salinity calculations. Therefore, we recalculate salinity using a fixed pressure value based on the instrument depth. For stratus 16, salinity was recalculated using the following procedure:

1. **Pressure Calculation:** Instead of using the potentially drifting pressure sensor data, we calculate a fixed pressure value based on instrument depth:
   - Calculate pressure using the GSW function `p_from_z`, which converts geometric height to pressure

- Use the formula $z = -1 \times$ instrument_depth (negative because depth is positive downward)
- Use latitude from the anchor survey for the calculation

2. **Practical Salinity Calculation:**
   - Convert conductivity from S/m to mS/cm by multiplying with a factor of 10
   - Apply the TEOS-10 (Thermodynamic Equation Of Seawater - 2010) algorithm via `gsw.SP_from_C`
   - Use measured temperature and the calculated fixed pressure (rather than varying measured pressure)
   - Store the computed values as `sea_water_practical_salinity` with units 'psu'

3. **Absolute Salinity Calculation:**
   - Use the TEOS-10 algorithm `gsw.SA_from_SP` to convert practical salinity to absolute salinity
   - Incorporate geographical dependencies using latitude and longitude from the anchor survey
   - Store the computed values as `sea_water_absolute_salinity` with units 'g/kg'

4. **Post-Processing:**
   - The original salinity variables (`sal` and `abssal`) are removed from the output datasets

This method ensures consistent salinity calculations and eliminates potential errors from pressure sensor drift, which can be substantial at deep ocean deployments. Using a fixed pressure calculated from the known instrument depth produces more reliable salinity values.

3.3 Data Export

- Ensure all required variables (sea_water_temperature, sea_water_electrical_conductivity, sea_water_practical_salinity, sea_water_absolute_salinity, sea_water_pressure) exist in the dataset.

- Fill missing data or create non-existent variables with -99999 values and encode them as missing values.

- Carry forward time series for all five variables even if not present, by setting missing values to -99999.

- Save the time-corrected, truncated datasets as NetCDF files for further processing.

- Files are saved in the directory `/data/truncated/stratus16` as `stratus16_10600_truncated.nc` and `stratus16_10601_truncated.nc`.

4 Quality Control and Deployment Catalog

The following quality control measures are implemented:

4.1 Spike Removal

Spike detection and removal are set up in function `src/qc_function.py`. The spike removal function identifies and removes spikes from time series data using a rolling mean and standard deviation. It calculates these statistics within a specified window size around each data point. Points that deviate from the rolling mean by more than 3 times the standard deviation are considered spikes and replaced with missing values (-99999). For stratus 16 processing, the window size was 12 points and the threshold was 3 times the standard deviation.

See Figs.6 and 7 for examples of the original and cleaned plots for temperature, salinity, absolute salinity, conductivity, and pressure for both instruments. These serve as a basis for collaborative review and further data correction.

The spikes removed from the datasets are shown in the table below.

Table 1: Spike removal statistics for stratus 16

Variable	SN 10600 (%)	SN 10601 (%)
sea_water_absolute_salinity	0.3412	0.3117
sea_water_electrical_conductivity	0.7993	0.7256
sea_water_practical_salinity	0.3138	0.2801
sea_water_pressure	0.0000	0.0032
sea_water_temperature	0.0042	0.0021

4.2 Difference Statistics

When both instruments are available and functional, the mean and standard deviation of the difference between sensors and of individual sensors are computed. These statistics provide benchmarks for accuracy and precision, and are critical for quality control decisions. The difference statistics are computed after spike removal to avoid contamination by known bad points.

The difference statistics are shown in tables below.

Variable	SN 10600		SN 10601	
	Mean	Std Dev	Mean	Std Dev
sea_water_temperature	1.81939	0.00116	1.81915	0.00116
sea_water_practical_salinity	34.68066	0.00908	34.68073	0.00904
sea_water_absolute_salinity	34.85521	0.02975	34.85527	0.02982
sea_water_electrical_conductivity	3.21686	0.00010	3.21684	0.00010
sea_water_pressure	4557.95974	0.42124	4555.45939	0.30482

Table 2: Statistics for individual sensors on stratus 16

Variable	Mean Diff	Std Diff	QC Threshold
sea_water_temperature	0.00023	0.00164	0.00492
sea_water_practical_salinity	-0.00007	0.01281	0.03844
sea_water_absolute_salinity	-0.00006	0.04213	0.12638
sea_water_electrical_conductivity	0.00001	0.00014	0.00042
sea_water_pressure	2.50035	0.51996	1.55988

Table 3: Statistics for difference between sensors on stratus 16

Note: These statistics are also stored as metadata in the NetCDF files with the following attributes:

- `std_single_sensor`: Standard deviation of the time series from a single sensor
- `std_sensor_diff`: Standard deviation of the difference between two co-located sensors
- `mean_sensor_diff`: Mean of the difference between two co-located sensors

Note: NaN values that exist in the difference statistics are because the data were not available for that time period.

4.3 Human in the Loop (HITL) Quality Control

A catalog of results for each deployment was created, featuring original and QC plots for all measured variables.

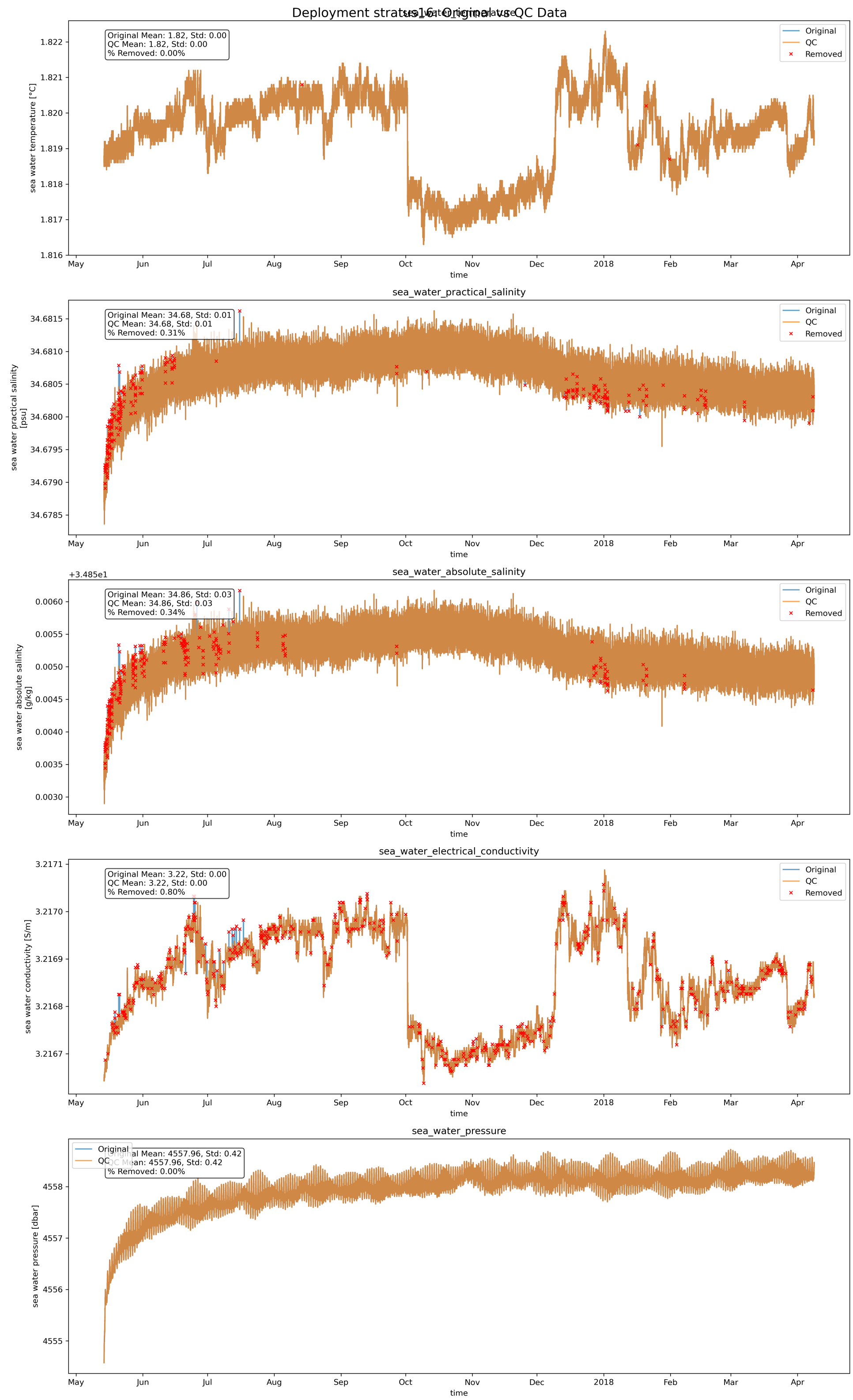

Figure 6: Original and clean plots of temperature, salinity, absolute salinity, conductivity, and pressure for instrument SBE37 10600 of stratus 16.

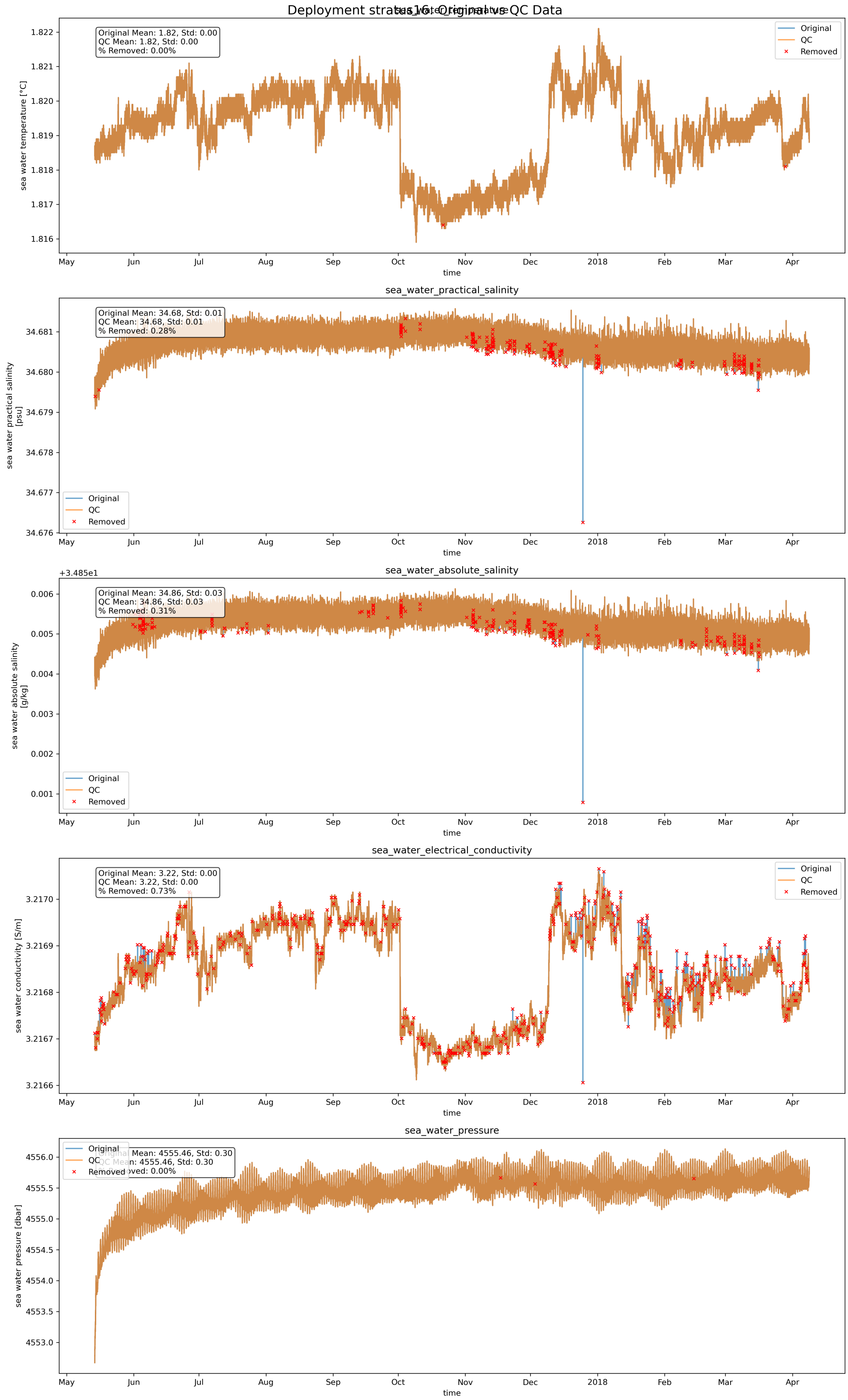

Figure 7: Original and clean plots of temperature, salinity, absolute salinity, conductivity, and pressure for instrument SBE37 10601 of stratus 16.

4.4 Data Export

- Export the cleaned datasets as NetCDF files for further processing.

- Files are saved in the directory `/data/cleaned/stratus16` as `stratus16_10600_cleaned.nc` and `stratus16_10601_cleaned.nc`
- Each file contains the following variables:
  - sea_water_temperature (°C)
  - sea_water_electrical_conductivity (S/m)
  - sea_water_practical_salinity (PSU)
  - sea_water_absolute_salinity (g/kg)
  - sea_water_pressure (dbar)

5 Merged Data Set

5.1 Metadata and Selection Strategy

- All necessary metadata are incorporated from individual deployments and retained in the merged file.
- Selection strategy for merging:
  - If both sensors for a deployment have full records and are of good quality, a Human-In-The-Loop (HITL) evaluation is done for the transitions at the start and end of the deployment, and data records with the least discrepancy between deployments are chosen to be merged.
  - If one sensor is obviously bad or does not have a complete record, the other sensor is used.
  - For stratus 16, SBE37 10600 was selected for the merged dataset.
  - If the sampling rate of the two time series is different, the time series with the higher sampling rate is resampled to match the lower sampling rate.

5.2 Overlap Analysis

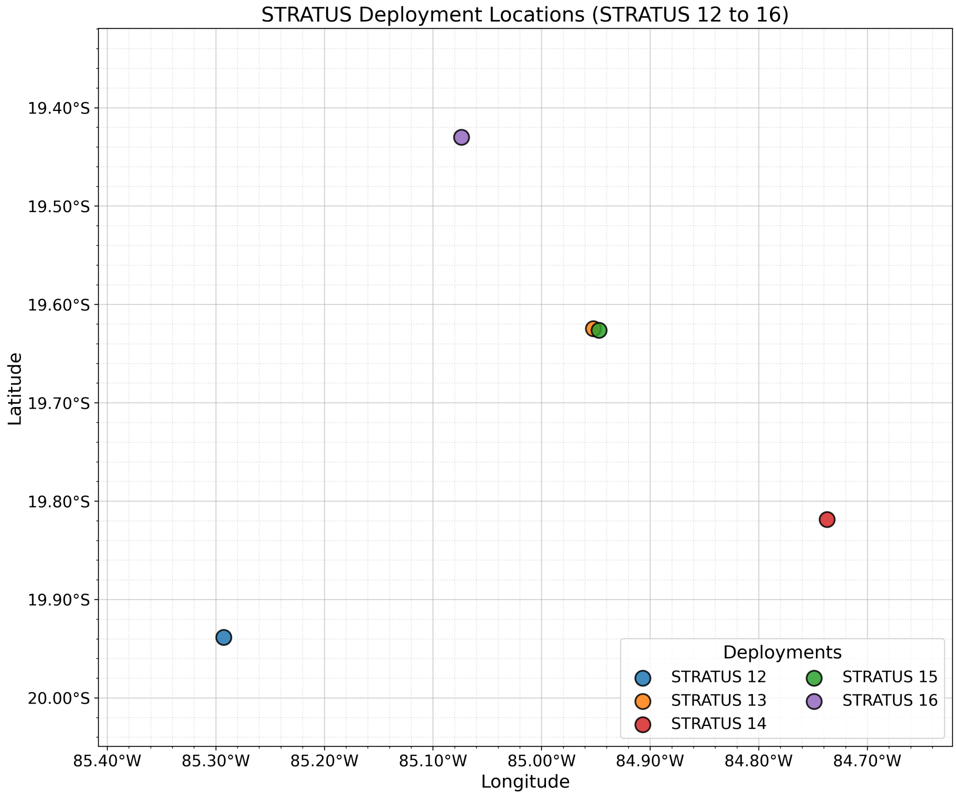

Figure 8: Deployment locations for Stratus moorings from Stratus 15 to Stratus 16. The map shows the anchor positions determined during deployment surveys.

The distance between STRATUS 15 and STRATUS 16 deployments is 25.53 kilometers (13.79 nautical miles).

Table 4: Deployment coordinates

Deployment	**Latitude**	**Longitude**
STRATUS 15	19.6262°S	84.9470°W
STRATUS 16	19.4302°S	85.0738°W

Figure 8 shows the positions of the Stratus 15 and 16 moorings, separated by approximately the distance mentioned above.

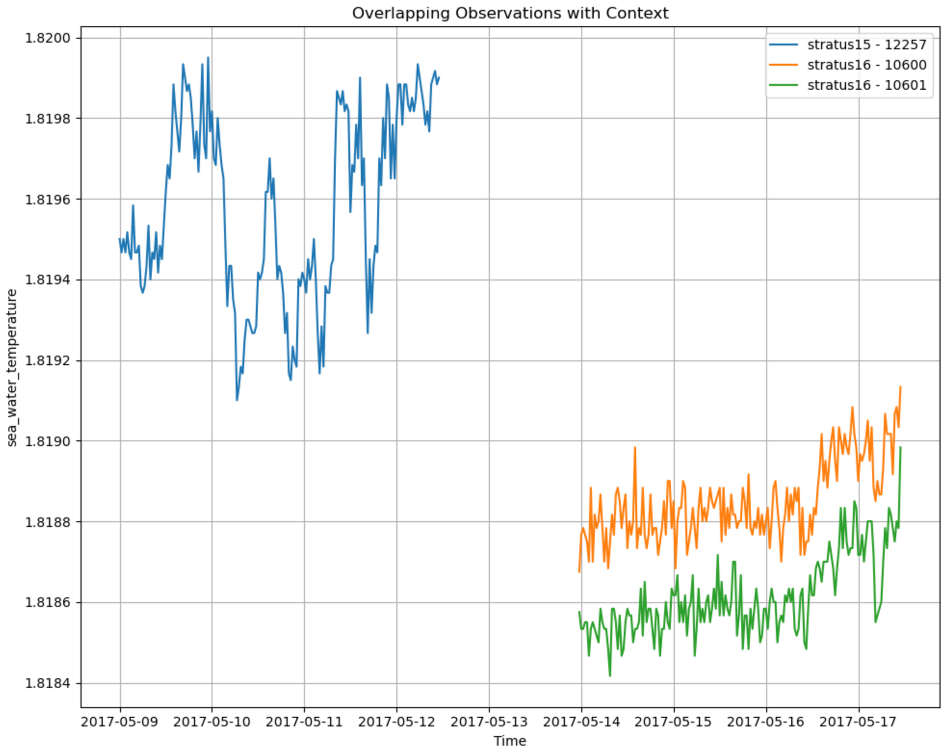

Figure 9: Visualization of overlapping observations between stratus 15 and stratus 16. The vertical dashed lines indicate: start of new deployment, optimal merge point, and end of previous deployment.

Figure 9 shows there is no overlap between stratus 15 and stratus 16. As a result, we chose the two time series with minimal differences to merge, and there is a gap in the continuous data record.

The merged dataset is visualized in Fig.10.

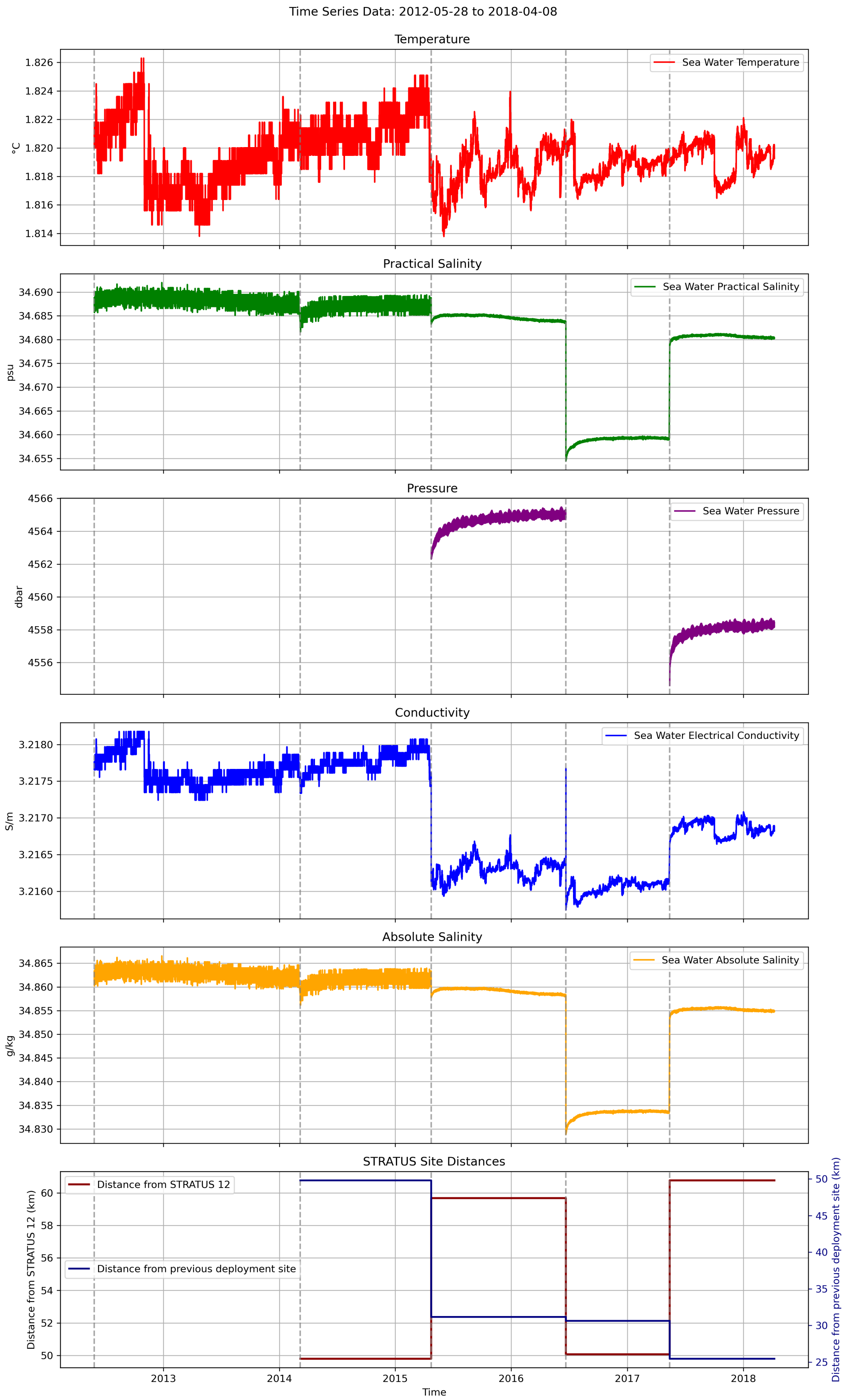

Figure 10: Merged dataset of stratus 12 to stratus 16 showing the transition at the merge point. This dataset combines data from the selected instrument (SBE37 12257) from stratus 15 and SBE37 10600 from stratus 16. This dataset incorporates all previous merges in the time series.

6 Documentation and Archiving

Finalized data sets are documented extensively and prepared for inclusion on the project website. The metadata is updated to be compliant with the NetCDF Climate and Forecast (CF) conventions, and OceanSITES data manual.

7 Conclusion

This report documents the preprocessing, quality control, and analysis steps for the deep temperature and salinity data from stratus 16. The data has been processed through several stages:

- Time correction and data truncation to isolate the deployment period
- Quality control including spike removal and difference statistics
- Recalculation of salinity using the TEOS-10 algorithm at the instrument depth with observed temperature and conductivity
- Merging with adjacent deployment data

The resulting cleaned and merged dataset provides a valuable record of deep ocean temperature and salinity at the stratus site, contributing to long-term climate monitoring efforts.