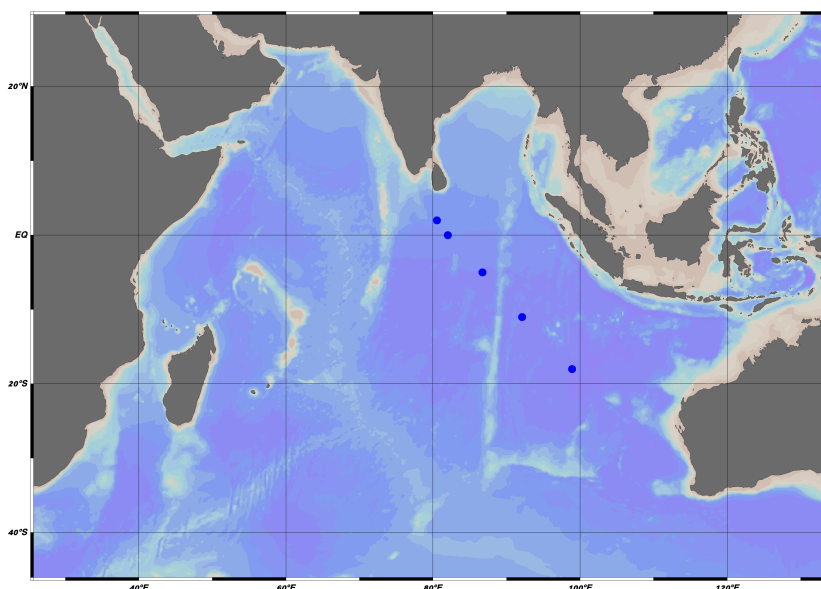


CRUISE REPORT: RR2307

Downloaded: March 2024 Created: April 2024



Highlights

Cruise Summary Information

Section Designation	GOA Transit		
Expedition Designation (ExpoCode)	33RR20230629		
Chief Scientist	Todd Martz / UCSD / SIO		
Dates	29 June – 14 July 2023		
Ship	<i>R/V Roger Revelle</i>		
Ports of Call	N/A		
Geographic Boundaries	80° 5"E	2° "N	98° 9"E
		18° "S	
Stations	5		
Floats and Drifters Deployed	5		
Moorings Deployed and Recovered	0		

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Report assembled by Savannah Lewis

RR2307 GOA Transit

Release Working Draft

Todd Martz

Apr 22, 2024

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CTDO AND HYDROGRAPHIC ANALYSIS

Technicians

- Todd Martz (SIO)
- Ben Freiberger (SIO)
- Kieran Claassen (SJSU)

Post-Cruise Data Analysts

- Allen Smith (SIO)
- Aaron Mau (SIO)

1.1 CTDO and Bottle Data Acquisition

A total of 5 stations (1 - 5) were occupied on RR2307.

The CTD data acquisition system consisted of an SBE-11+ (V1) deck unit and a networked generic PC workstation running Windows 10. SBE SeaSave7 v.7.26.7.121 software was used for data acquisition and to close bottles on the rosette.

Equipment	Model	S/N	Cal Date	Stations	Group
CTD	SBE9+	0569		1-5	STS/ODF
Pressure Sensor	Digiquartz		07-Dec-2021	1-5	STS/ODF
Primary Temperature	SBE3+	4907	14-Mar-2023	1-5	STS/ODF
Primary Conductivity	SBE4C	4651	20-Jan-2023	1-5	STS/ODF
Secondary Temperature	SBE3+	4588	25-Oct-2022	1-5	STS/ODF
Secondary Conductivity	SBE4C	4650	13-Dec-2022	1-5	STS/ODF
Transmissometer	Cstar	0479DR	02-Aug-2023	1-5	STS/ODF
Fluorometer Chlorophyll	WetLabs ECO-FL-RTD	4334	07-Jan-2022	1-5	ODF
Dissolved Oxygen	SBE43	1508	07-Oct-2022	1-5	STS/ODF
Altimeter	Valeport VA500	53821	28-Jan-2016	1-5	STS/ODF
PAR	QCP2300	70444	06-Feb-2019	1-5	STS/ODF

The transmissometer used on the CTD was tested with a light-dark test to acquire coefficients prior to the first station.

Transmissometer	M	B
1814DR	21.1461	-1.2265

1.2 CTDO Data Processing

Shipboard CTD data processing was performed after deployment using SIO/ODF CTD processing software “ctdcal” v. 0.1.4b. CTD acquisition data were copied onto a OS X system, and then processed. CTD data at bottle trips were extracted, and a 2-decibar downcast pressure series created. The pressure series data set was submitted for CTD data distribution after corrections outlined in the following sections were applied.

CTDO/Bottle data were processed following the cruise by ODF, including discrete salinity, oxygen, and nutrient analyses. Discrete salinity and oxygen data were used for fitting of CTD conductivity and oxygen sensors.

1.3 Pressure Analysis

The lab calibration coefficients provided on the calibration report were used to convert frequencies to pressure. Initial SIO pressure lab calibration slope and offsets coefficients were applied to cast data. A shipboard calibration offset was applied to the converted pressures during each cast. These offsets were determined by the pre and post-cast on-deck pressure offsets.

ODF CTD #0569:

	Start P (dbar)	End P (dbar)
Min	0.36	0.06
Max	0.65	0.27
Average	0.51	0.19

On-deck pressure reading varied from 0.36 to 0.65 dbar before the casts, and 0.06 to 0.27 dbar after the casts. The pressure offset varied from -0.45 to -0.12, with a mean value of -0.33 dbar.

1.4 Temperature Analysis

Laboratory calibrations of temperature sensors were performed prior to the cruise at the SIO Calibration Facility. Dates of laboratory calibration are recorded on the underway sampling package table and calibration documents are provided in the appendices.

The pre-cruise laboratory calibration coefficients were used to convert SBE3plus frequencies to ITS-90 temperature. Additional shipboard calibrations were performed to correct systematic sensor bias. At each bottle closure, the primary and secondary temperature were compared with each other.

The 95% confidence limits for the mean low-gradient (values $-0.002\text{ °C} \leq T1-T2 \leq 0.002\text{ °C}$) differences are $\pm 0.00143\text{ °C}$ for T1-T2. The 95% confidence limits for the deep temperature residuals (where pressure ≥ 2000 dbar) are $\pm 0.00083\text{ °C}$ for T1-T2.

Sensor quality was consistent across the casts and no sensor substitutions were required.

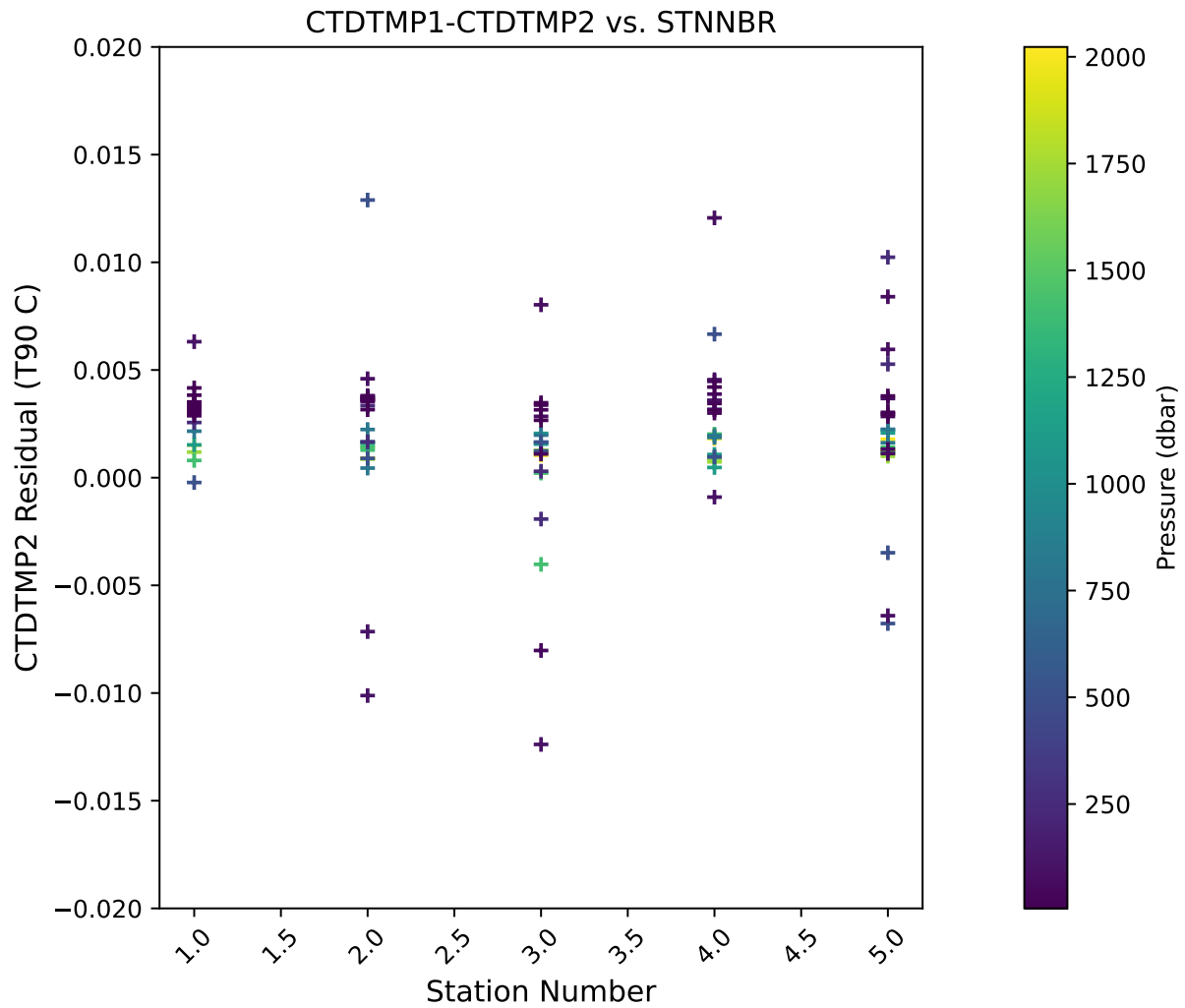


Fig. 1: T1-T2 versus station.

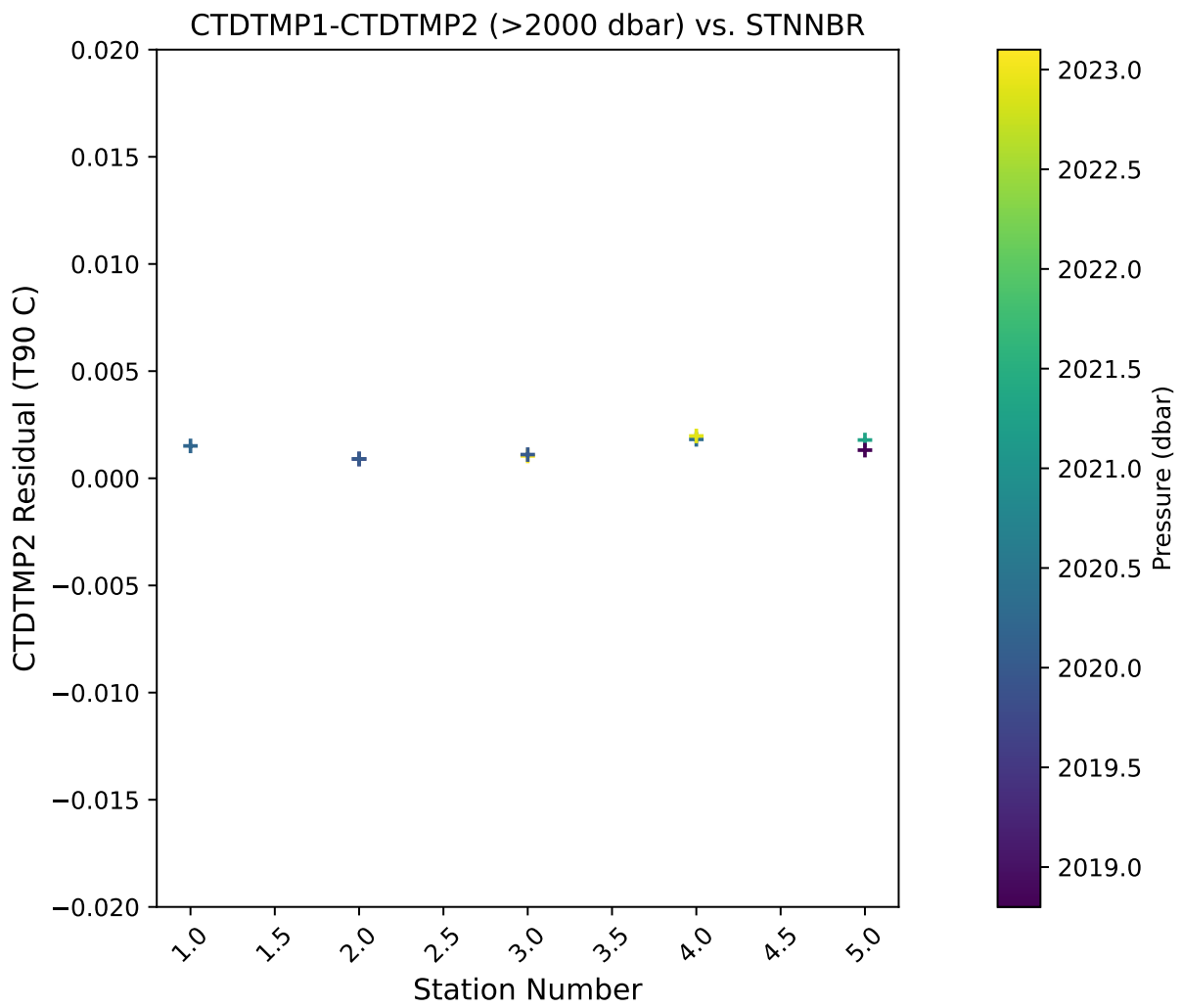


Fig. 2: Deep T1-T2 versus station (Pressure \geq 2000dbar).

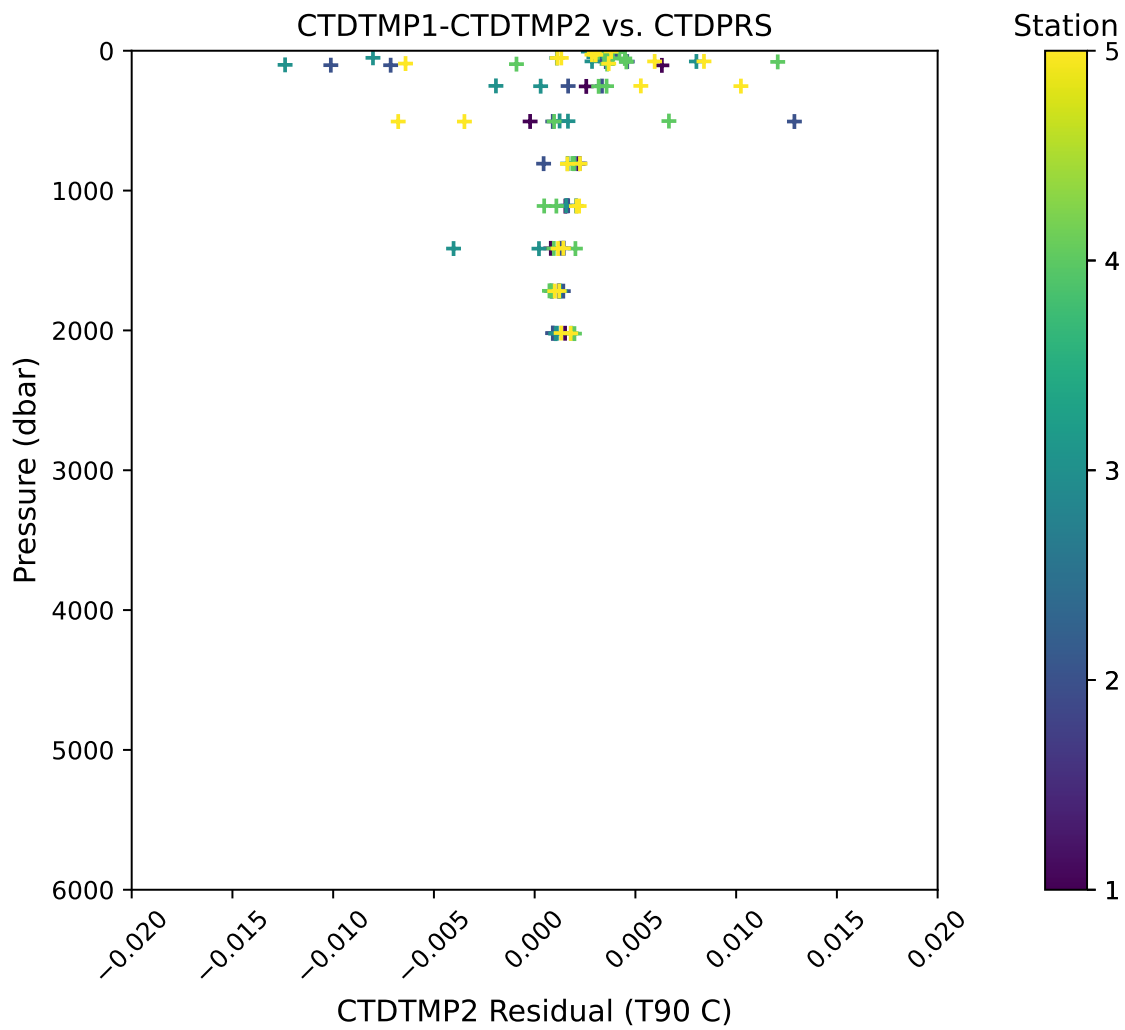


Fig. 3: T1-T2 versus pressure.

1.5 Conductivity Analysis

Laboratory calibrations of conductivity sensors were performed prior to the cruise at the Sea-Bird Calibration Facility. Dates of laboratory calibration are recorded on the underway sampling package table and calibration documents are provided in the appendices.

The pre-cruise laboratory calibration coefficients were used to convert SBE4C frequencies to mS/cm conductivity values. Additional shipboard calibrations were performed to correct sensor bias. Corrections for both pressure and temperature sensors were finalized before analyzing conductivity differences. Two independent metrics of calibration accuracy were examined. At each bottle closure, the primary and secondary conductivity were compared with each other. Each sensor was also compared to conductivity calculated from check sample salinities (Autosalinometer samples) using CTD pressure and temperature.

The differences between primary and secondary temperature sensors were used as filtering criteria to reduce the contamination of conductivity comparisons by package wake. The coherence of this relationship is shown in the following figures.

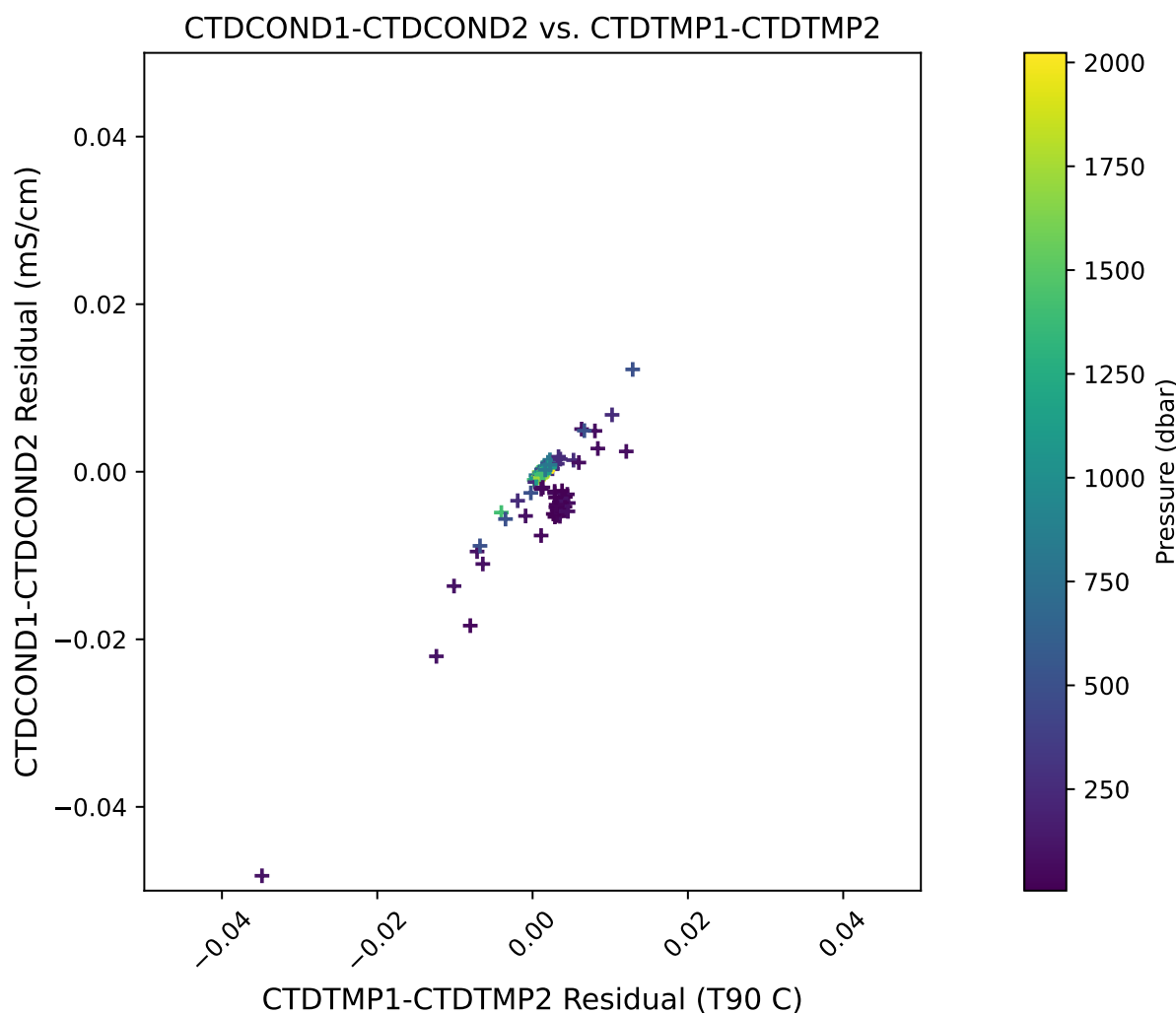
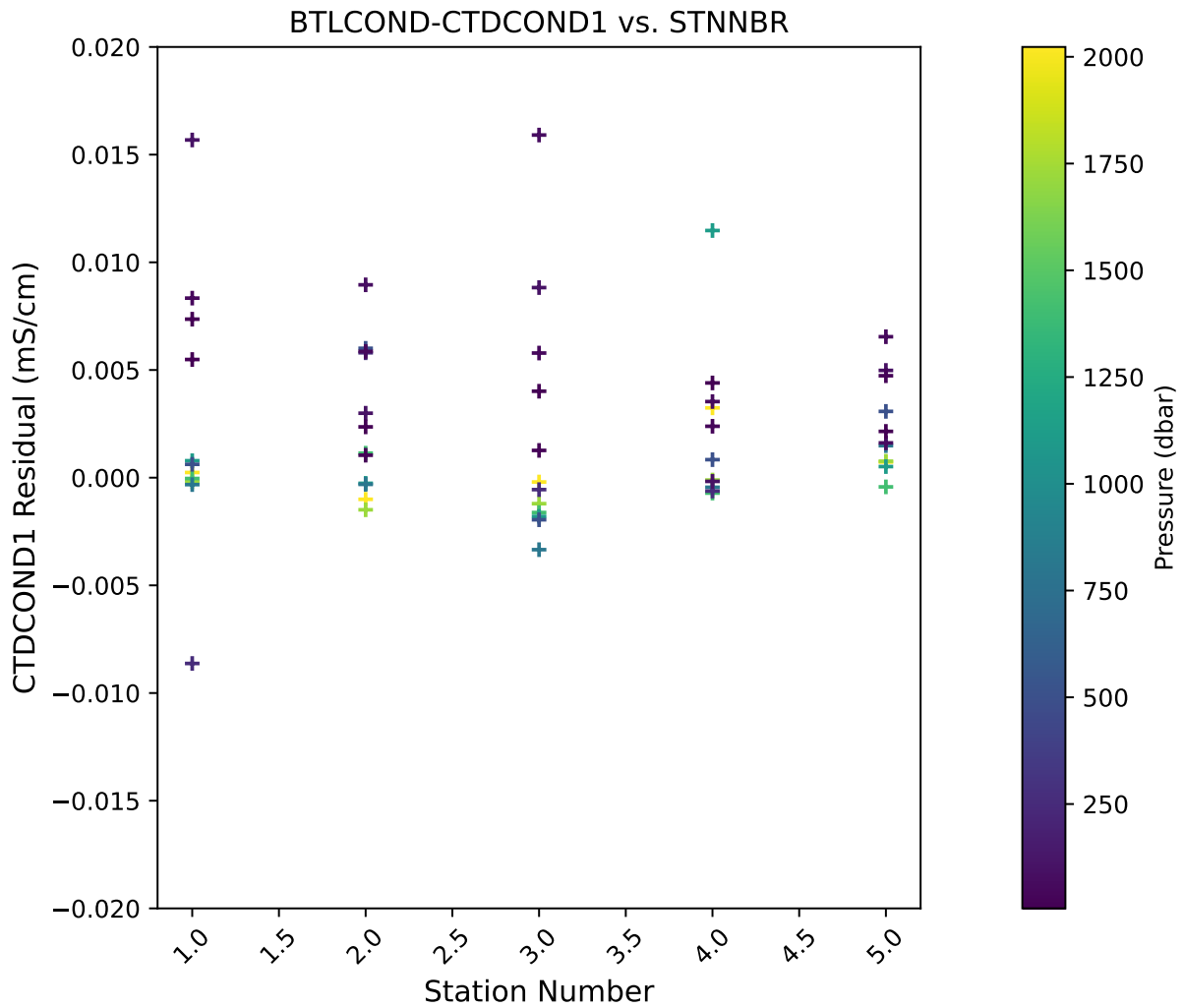


Fig. 4: Coherence of conductivity differences as a function of temperature differences.

A functioning SBE4C sensor typically exhibit a predictable modeled response. Offsets for each C sensor were deter-

Fig. 5: Corrected $C_{\text{Bottle}} - C_1$ versus station.

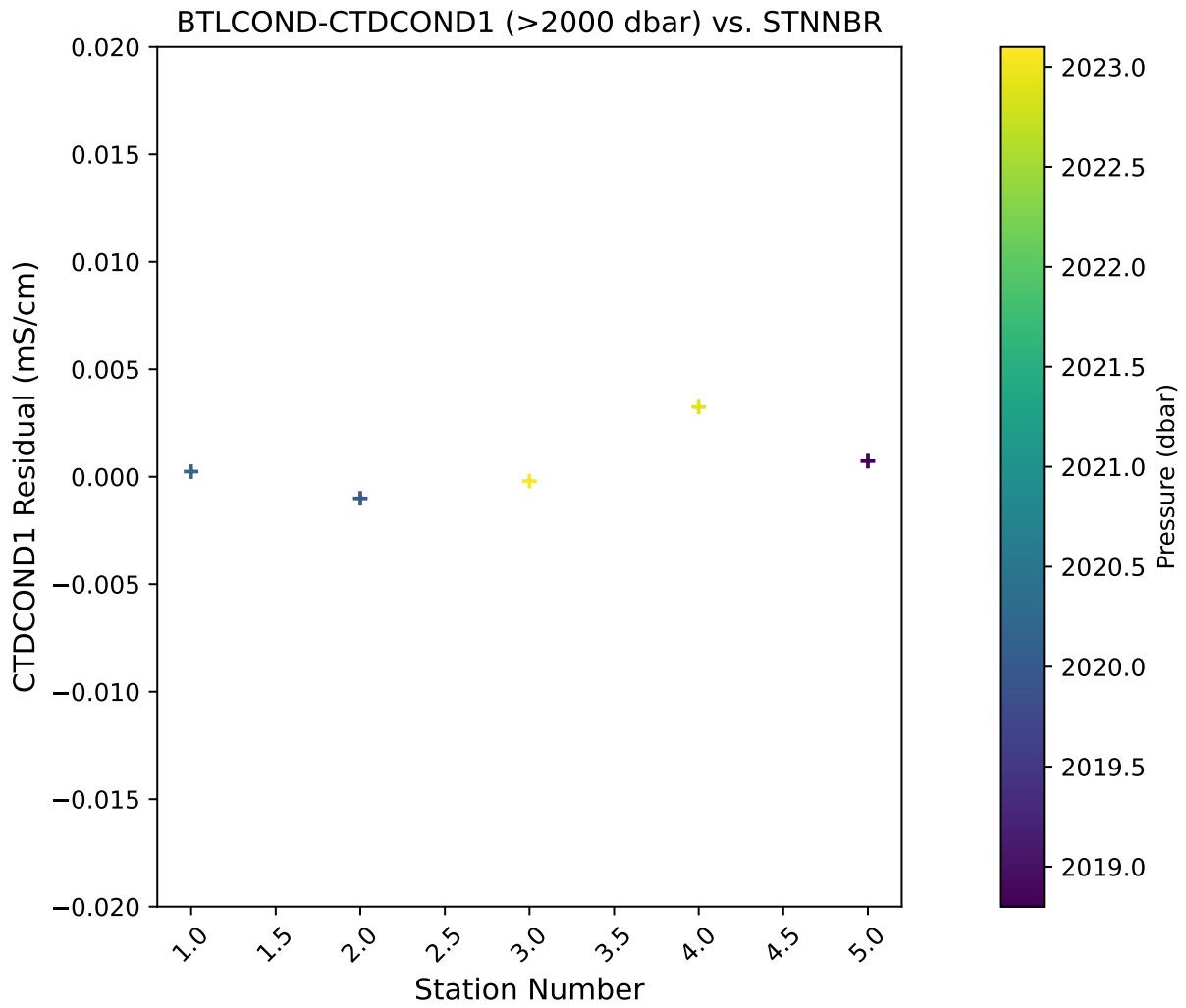


Fig. 6: Deep Corrected $C_{\text{Bottle}} - C_1$ versus station (Pressure ≥ 2000 dbar).

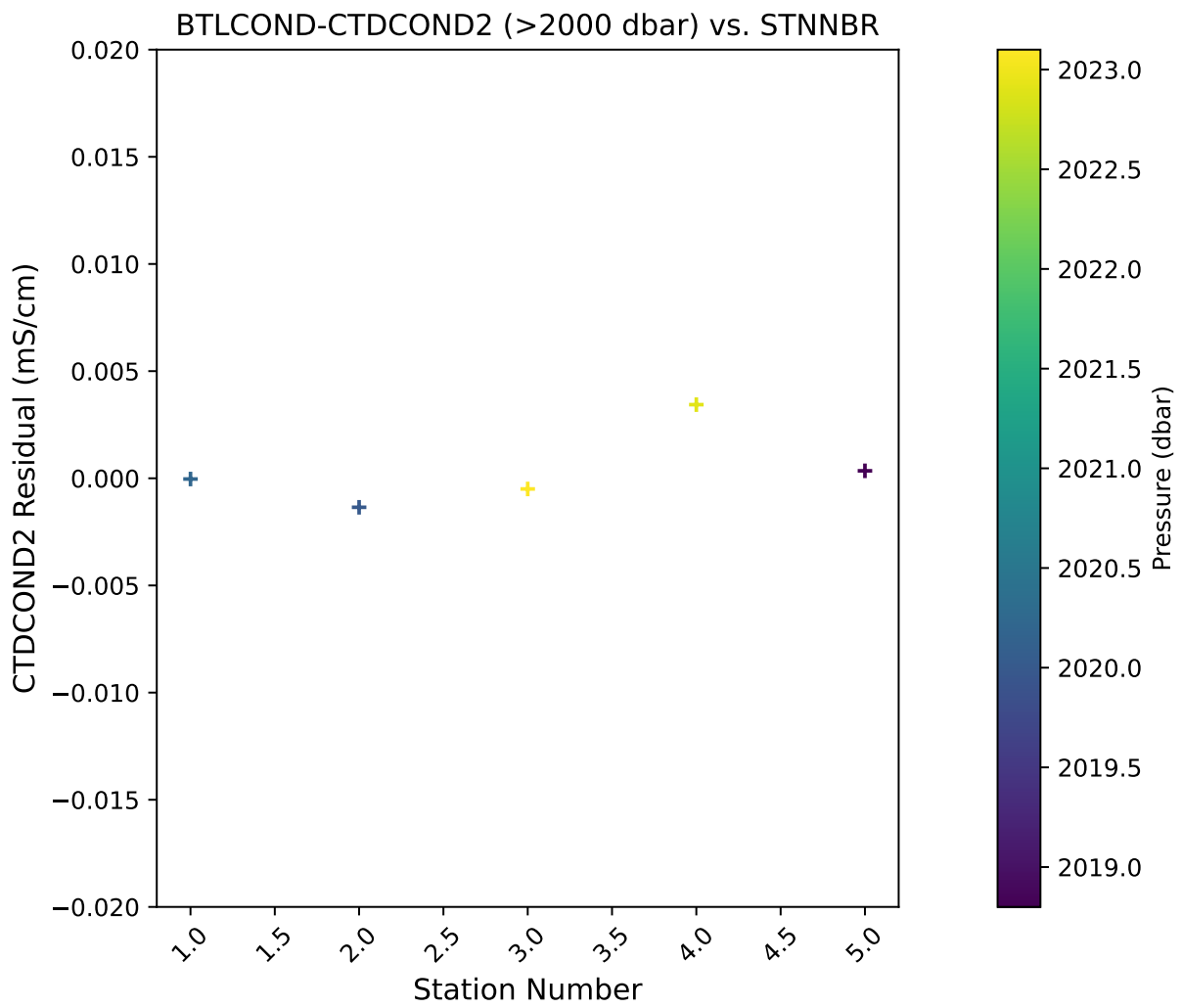


Fig. 8: Deep Corrected $C_{\text{Bottle}} - C_2$ versus station (Pressure ≥ 2000 dbar).

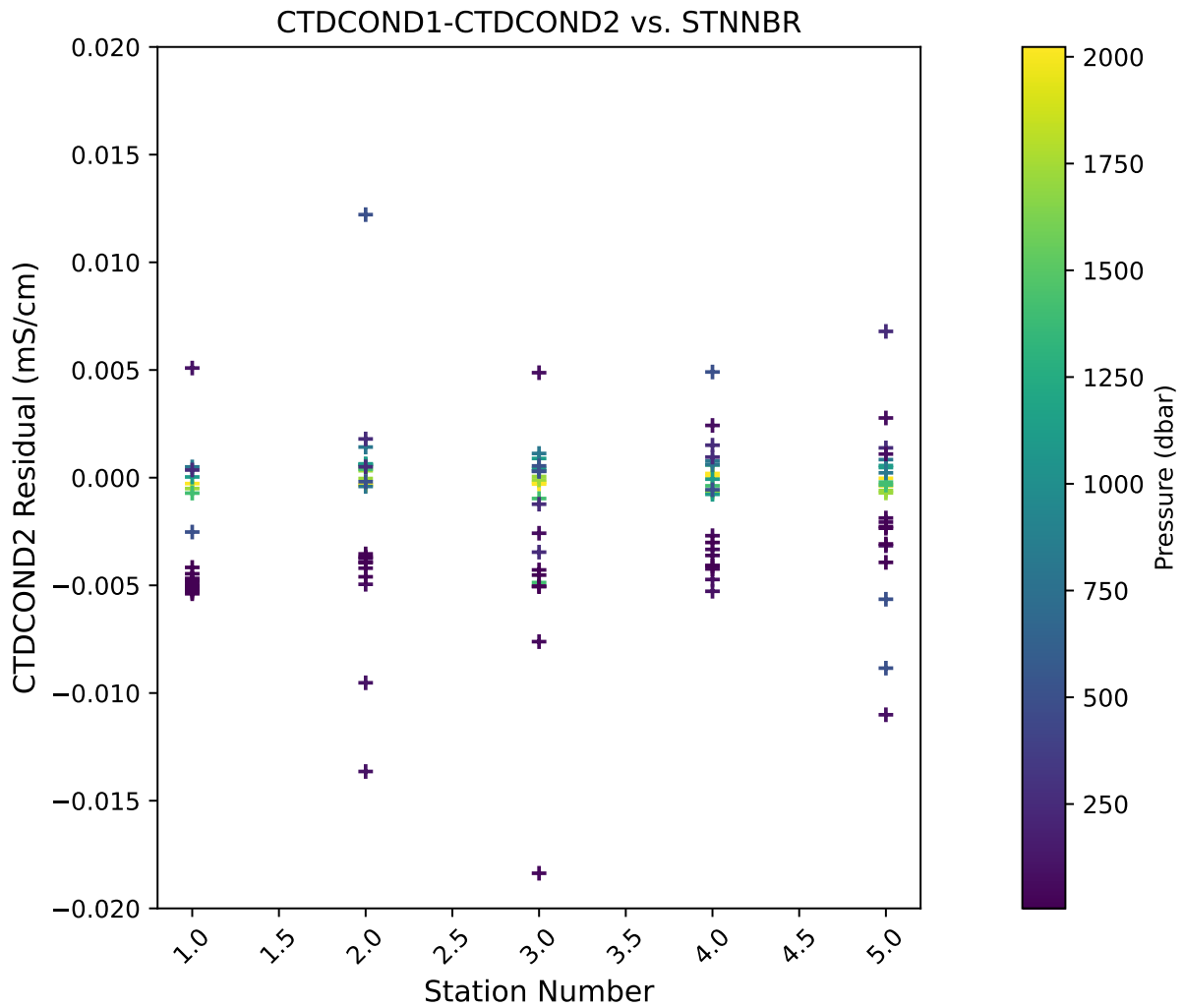


Fig. 9: Corrected C1-C2 versus station.

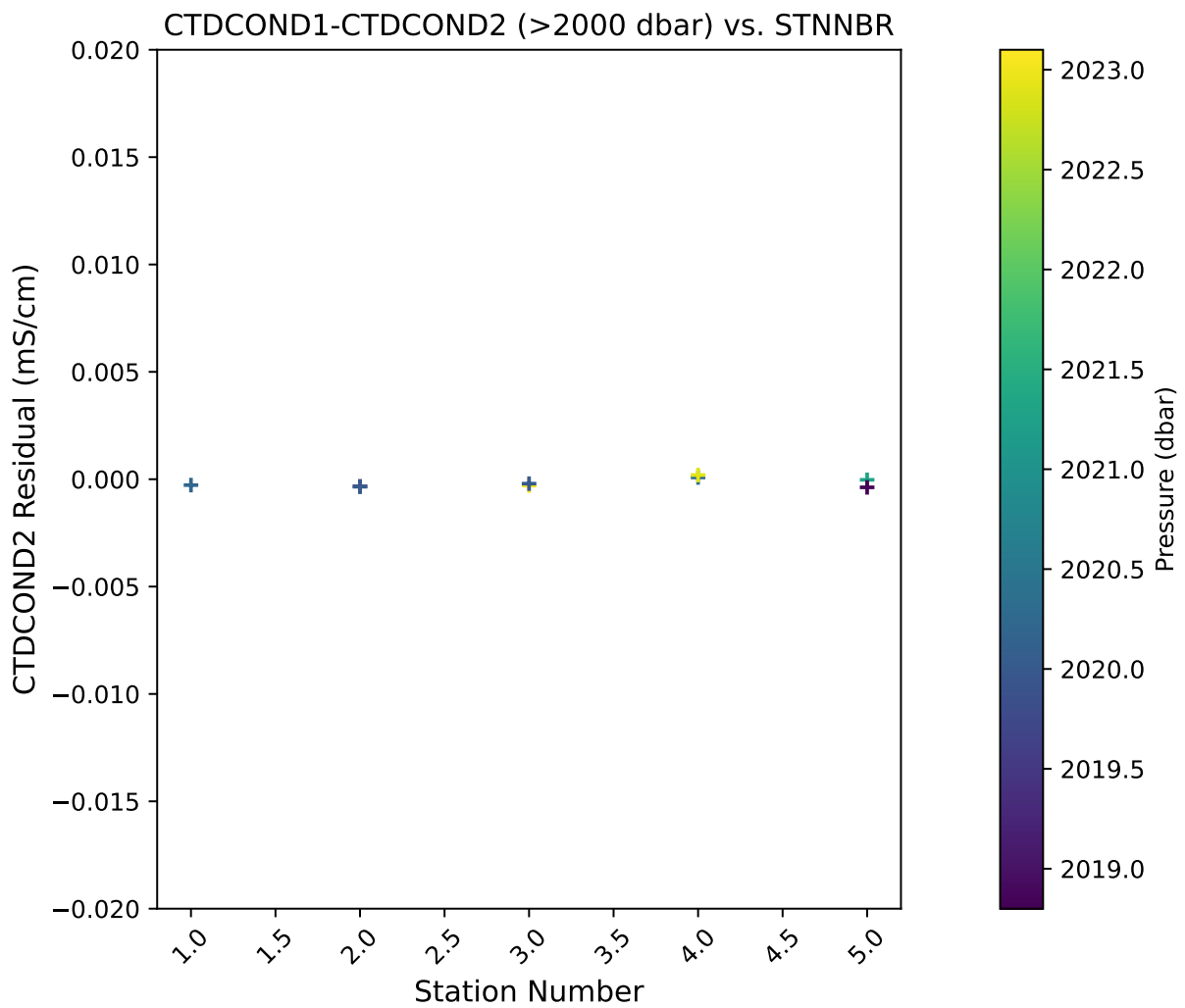
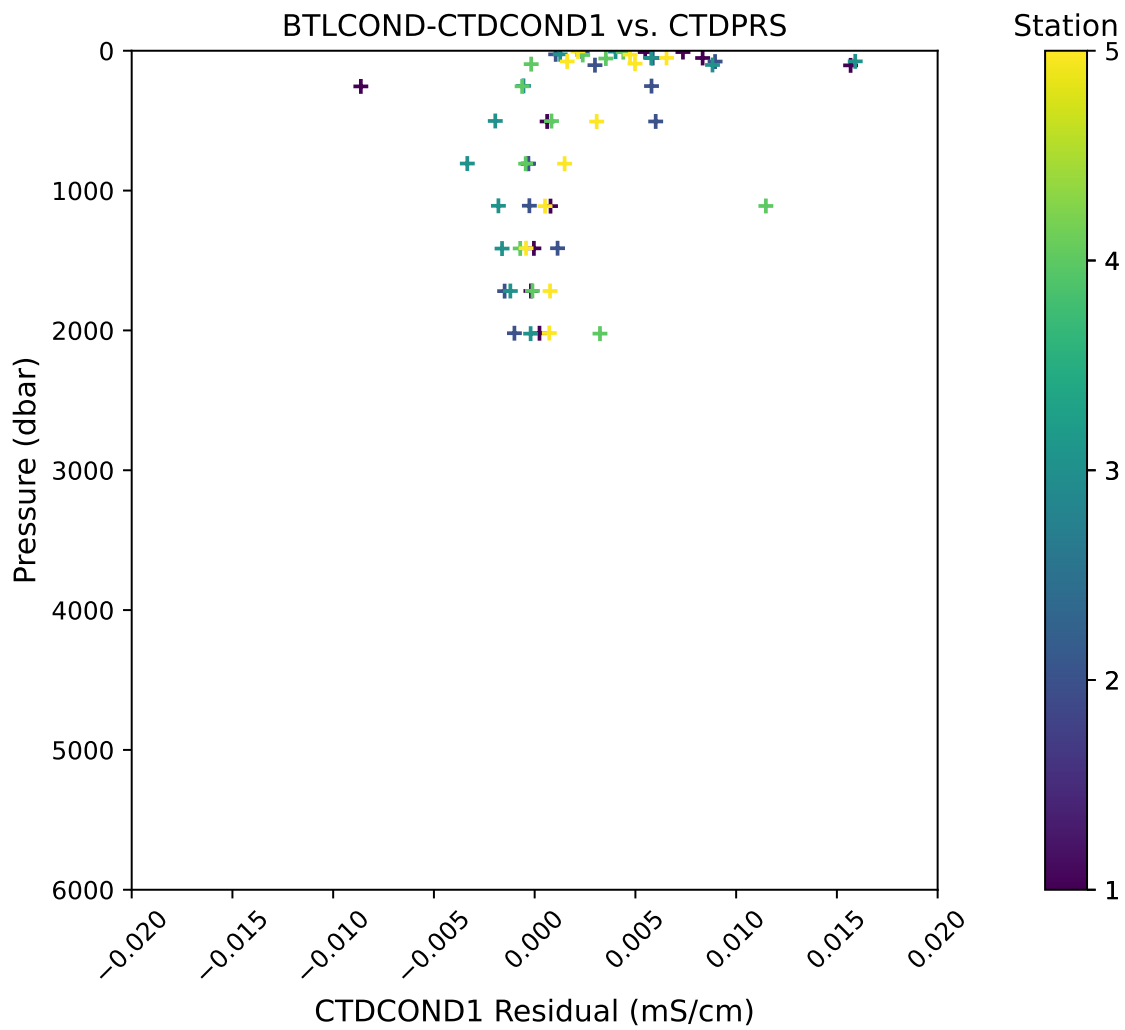


Fig. 10: Deep Corrected C1-C2 versus station (Pressure \geq 2000dbar).

Fig. 11: Corrected $C_{\text{Bottle}} - C_1$ versus pressure.

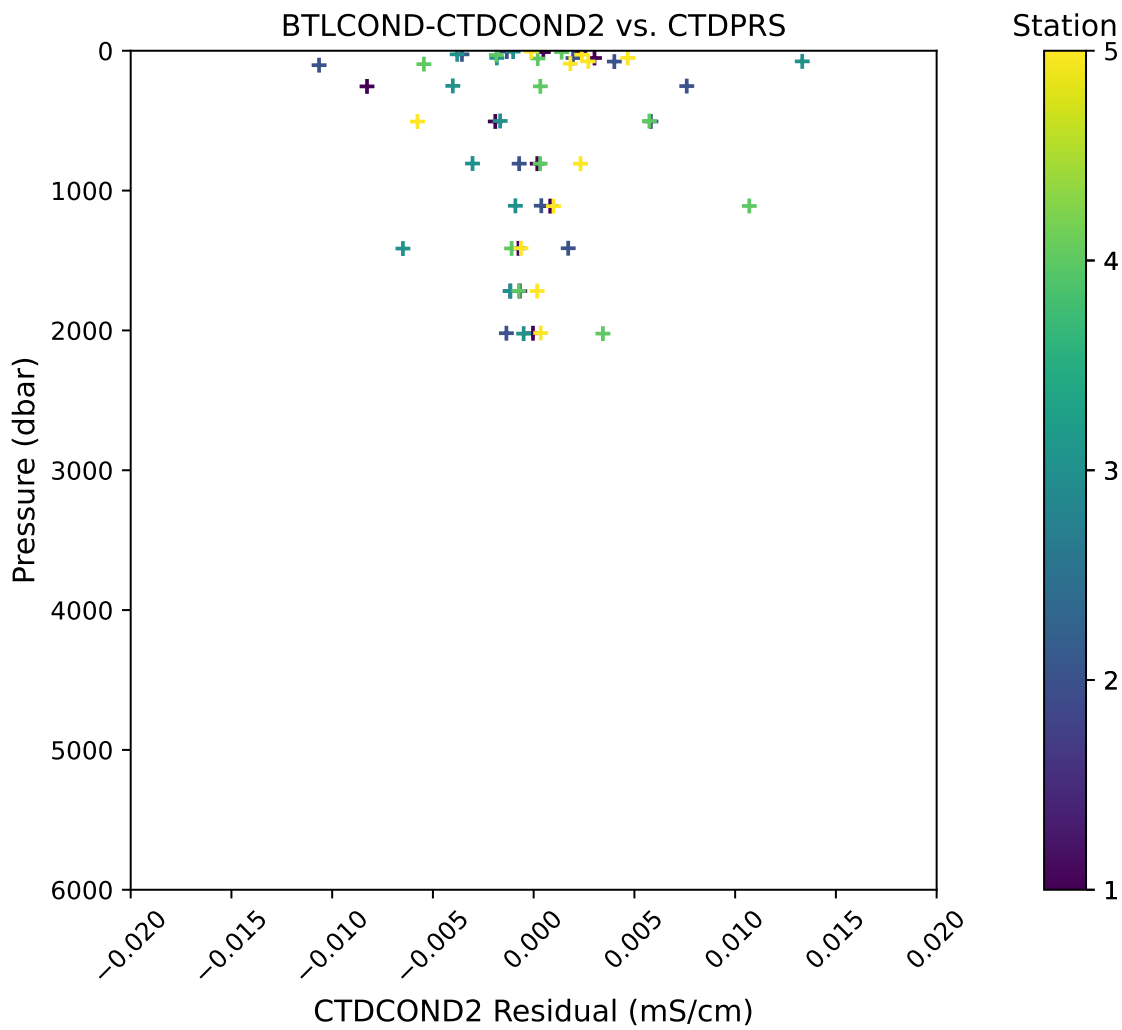


Fig. 12: Corrected $C_{\text{Bottle}} - C_2$ versus pressure.

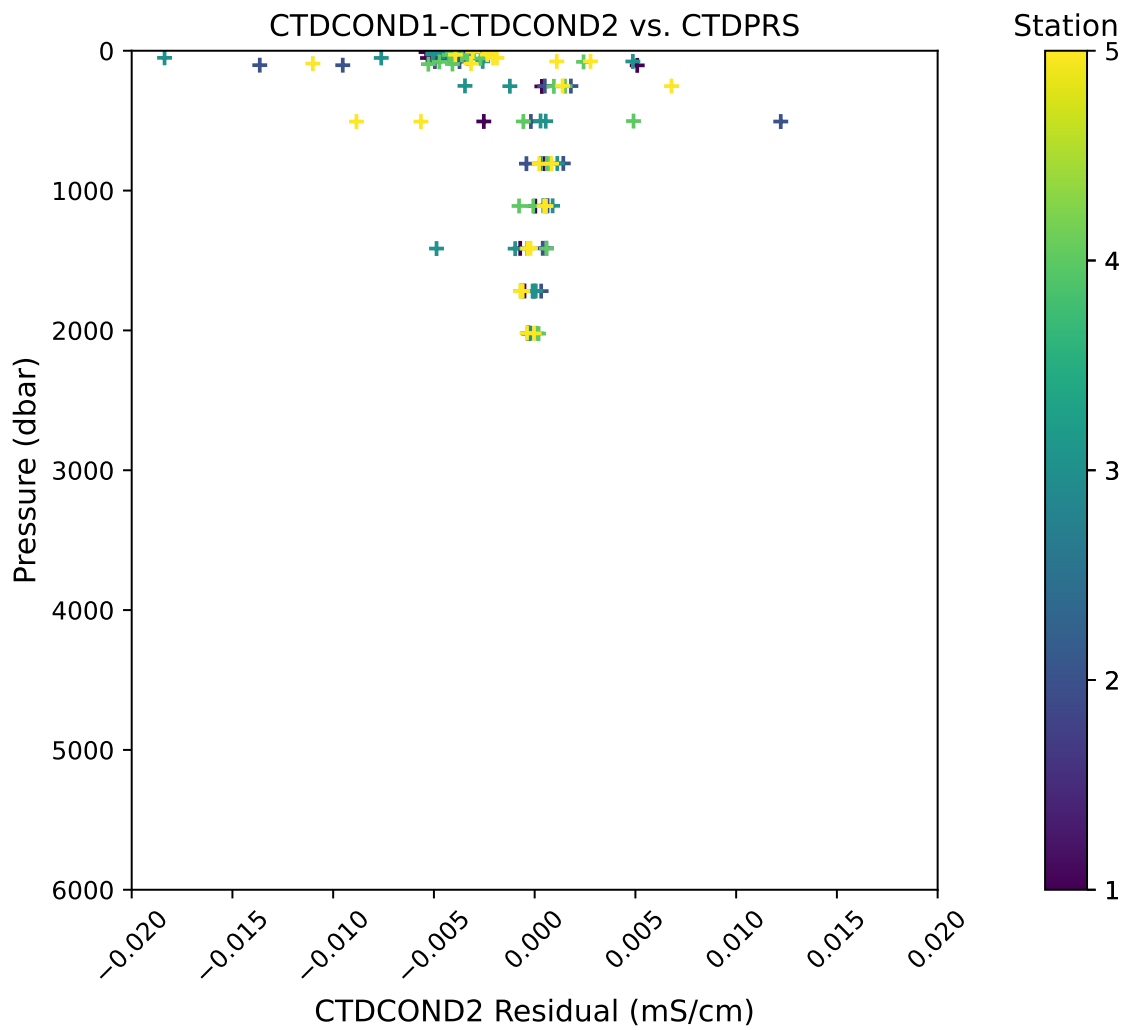


Fig. 13: Corrected C1-C2 versus pressure.

mined using $C_{\text{Bottle}} - C_{\text{CTD}}$ differences in a deeper pressure range (500 or more dbars). After conductivity offsets were applied to all casts, response to pressure, temperature and conductivity were examined for each conductivity sensor. The response model is second-order with respect to pressure, second-order with respect to temperature, and second-order with respect to conductivity:

$$C_{\text{cor}} = C + cp_2P^2 + cp_1P + ct_2T^2 + ct_1T + cc_2C^2 + cc_1C + \text{Offset}$$

Fit coefficients for the ODF rosette are shown in the following tables.

Table 1: ODF Primary conductivity (C1) coefficients.

Station	cp_2	cp_1	ct_2	ct_1	cc_2	cc_1	c_0
1-5	0.e+0	-5.9137e-7	0.e+0	0.e+0	0.e+0	0.e+0	4.626e-3

Table 2: ODF Secondary conductivity (C2) coefficients.

Station	cp_2	cp_1	ct_2	ct_1	cc_2	cc_1	c_0
1-5	0.e+0	7.2722e-7	0.e+0	0.e+0	0.e+0	0.e+0	1.2113e-3

Salinity residuals after applying shipboard P/T/C corrections are summarized in the figures of this section. Only CTD and bottle salinity data with “acceptable” quality codes are included in the differences.

The 95% confidence limits for the mean low-gradient (values $-0.002 \text{ }^\circ\text{C} \leq T_1 - T_2 \leq 0.002 \text{ }^\circ\text{C}$) differences are ± 0.00471 mPSU for salinity-C1SAL, ± 0.00459 mPSU for salinity-C2SAL and ± 0.00308 mPSU for C1SAL-C2SAL. The 95% confidence limits for the deep salinity residuals (where pressure ≥ 2000 dbar) are ± 0.00147 mPSU for salinity-C1SAL, ± 0.00147 mPSU for salinity-C2SAL and ± 0.00033 mPSU for C1SAL-C2SAL.

No issues affected conductivity and calculated CTD salinities during this cruise.

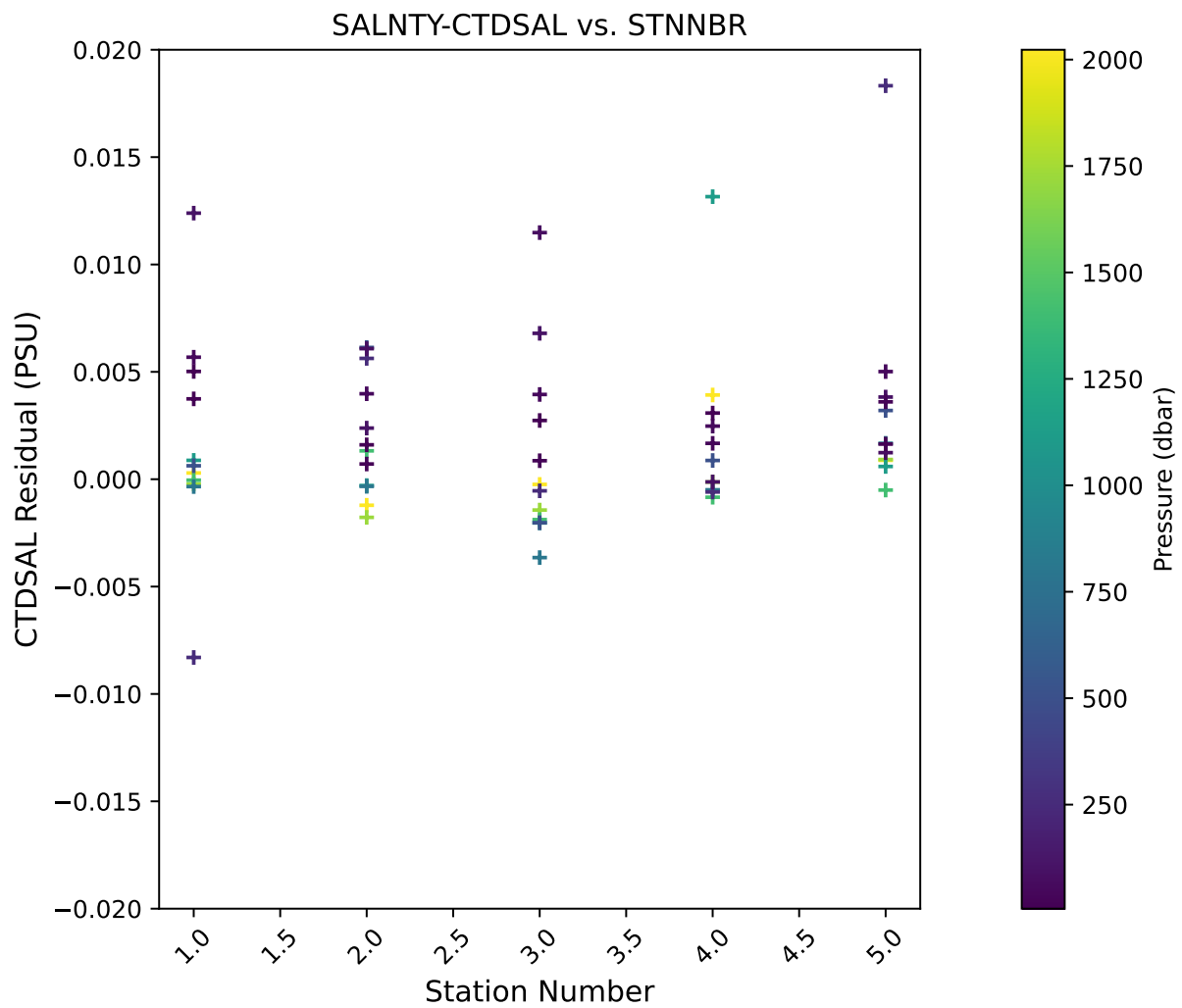


Fig. 14: Salinity residuals versus station.

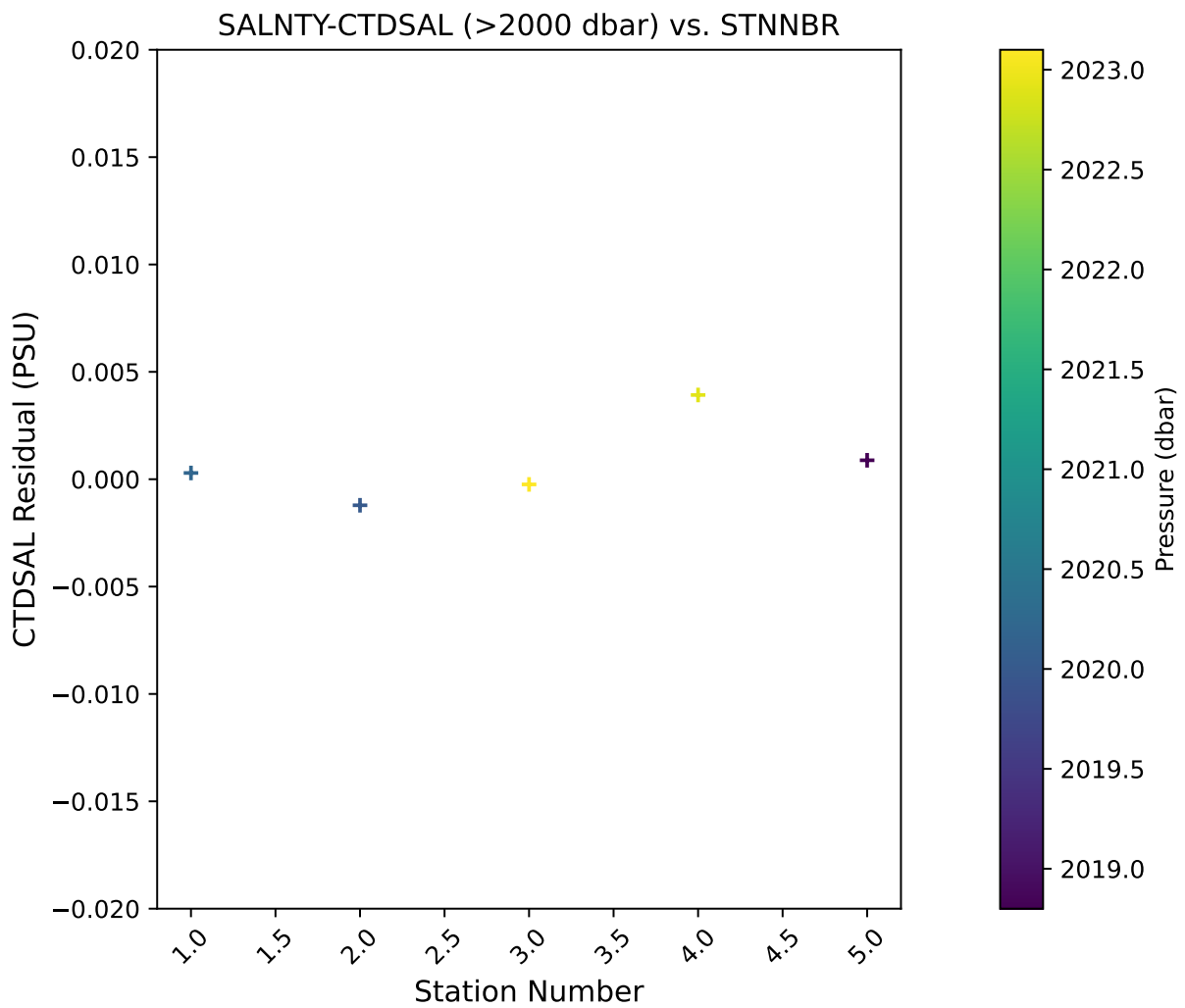


Fig. 15: Deep Salinity residuals versus station (Pressure \geq 2000dbar).

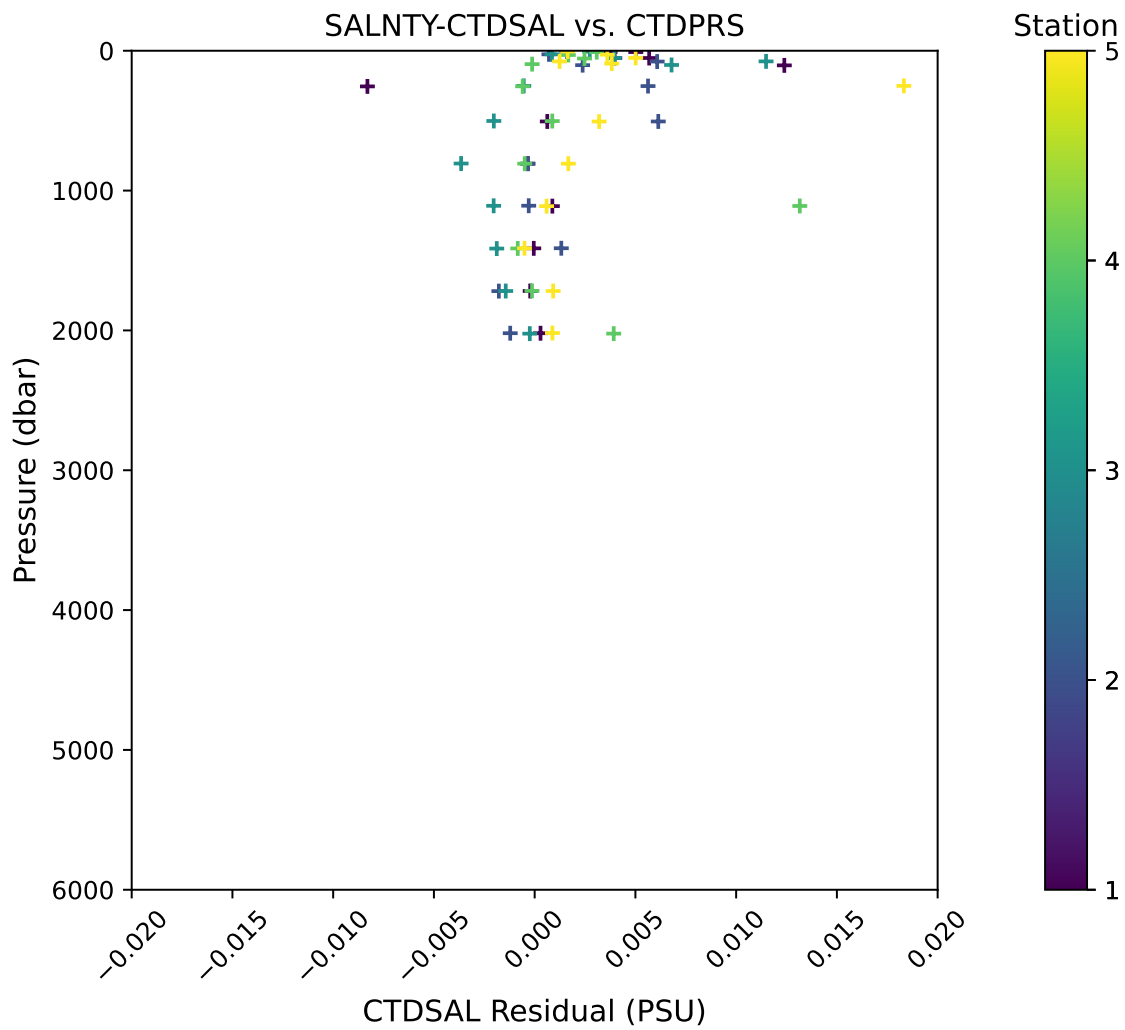


Fig. 16: Salinity residuals versus pressure.

1.6 CTD Dissolved Oxygen

Laboratory calibrations of the dissolved oxygen sensors were performed prior to the cruise at the SBE calibration facility. Dates of laboratory calibration are recorded on the underway sampling package table and calibration documents are provided in the appendices.

The pre-cruise laboratory calibration coefficients were used to convert SBE43 frequencies to $\mu\text{mol/kg}$ oxygen values for acquisition only. Additional shipboard fitting were performed to correct for the sensors non-linear response. Corrections for pressure, temperature, and conductivity sensors were finalized before analyzing dissolved oxygen data. Corrections for hysteresis are applied following Sea-Bird Application Note 64-3. The SBE43 sensor data were compared to dissolved O_2 check samples taken at bottle stops by matching the downcast CTD data to the upcast trip locations along isopycnal surfaces. CTD dissolved O_2 was then calculated using Clark Cell MPOD O_2 sensor response model for Beckman/SensorMedics and SBE43 dissolved O_2 sensors. The residual differences of bottle check value versus CTD dissolved O_2 values are minimized by optimizing the NOAA-PMEL DO sensor response model coefficients using the BFGS non-linear least-squares fitting procedure.

The general form of the PMEL DO sensor response model equation for Clark cells follows Brown and Morrison [Mill82] and Owens [Owen85]. Dissolved O_2 concentration is then calculated:

$$O_2 = S_{oc} \cdot (V + V_{off} + \tau_{20} \cdot e^{(D_1 \cdot p + D_2 \cdot (T-20))}) \cdot dV/dt \cdot O_{sat} \cdot e^{T_{cor} \cdot T} \cdot e^{[(E \cdot p)/(273.15+T)]}$$

Where:

- V is oxygen voltage (V)
- D_1 and D_2 are (fixed) SBE calibration coefficients
- T is corrected CTD temperature ($^{\circ}\text{C}$)
- p is corrected CTD pressure (dbar)
- dV/dt is the time-derivative of voltage (V/s)
- O_{sat} is oxygen saturation
- S_{oc} , V_{off} , τ_{20} , T_{cor} , and E are fit coefficients

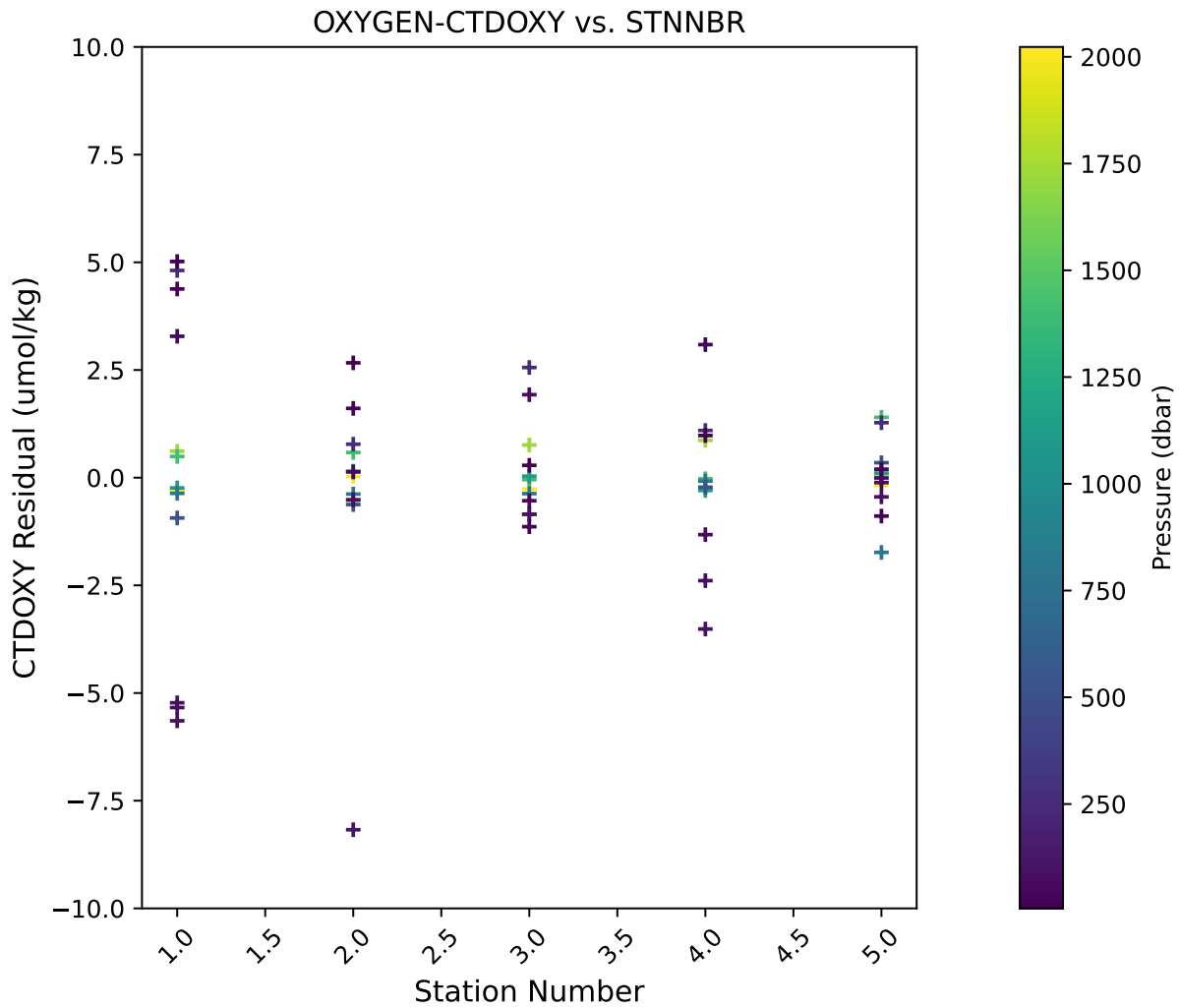
All stations were fit against post-cruise Winkler titrations together to get an initial coefficient estimate. Stations were then fit individually to refine the coefficients as the membrane does not deform the same way with each cast. If the fit of the individual cast had worse residuals than the group, they were reverted to the original group fit coefficients.

Table 3: ODF SBE43 group fit coefficients. Coefficients were further refined station-by-station.

Station	S_{oc}	V_{off}	τ_{20}	T_{cor}	E
1-5 group	5.8609e-1	-5.2011e-1	9.4008e-1	-3.6850e-4	4.0942e-2
00101	5.2154e-1	-4.9243e-1	9.4088e-1	2.339e-3	4.9013e-2
00202	6.1597e-1	-5.2899e-1	9.4079e-1	-1.8902e-3	3.4814e-2
00301	5.1095e-1	-4.9235e-1	9.4013e-1	3.5923e-3	4.9584e-2
00401	5.0694e-1	-4.8706e-1	9.4045e-1	3.9501e-3	5.0410e-2
00501	5.4219e-1	-4.8161e-1	9.4009e-1	2.8786e-3	4.4413e-2

CTD dissolved O_2 residuals are shown in the following figures *O2 residuals versus station* through *Deep O2 residuals versus station (Pressure >= 2000dbar)*.

The 95% confidence limits of 1.218 ($\mu\text{mol/kg}$) for all acceptable (flag 2) dissolved oxygen bottle data values and 0.2529 ($\mu\text{mol/kg}$) for deep dissolved oxygen values are only presented as general indicators of the goodness of fit. CLIVAR GO-SHIP standards for CTD dissolved oxygen data are < 1% accuracy against on board Winkler titrated dissolved O_2 lab measurements.

Fig. 17: O₂ residuals versus station

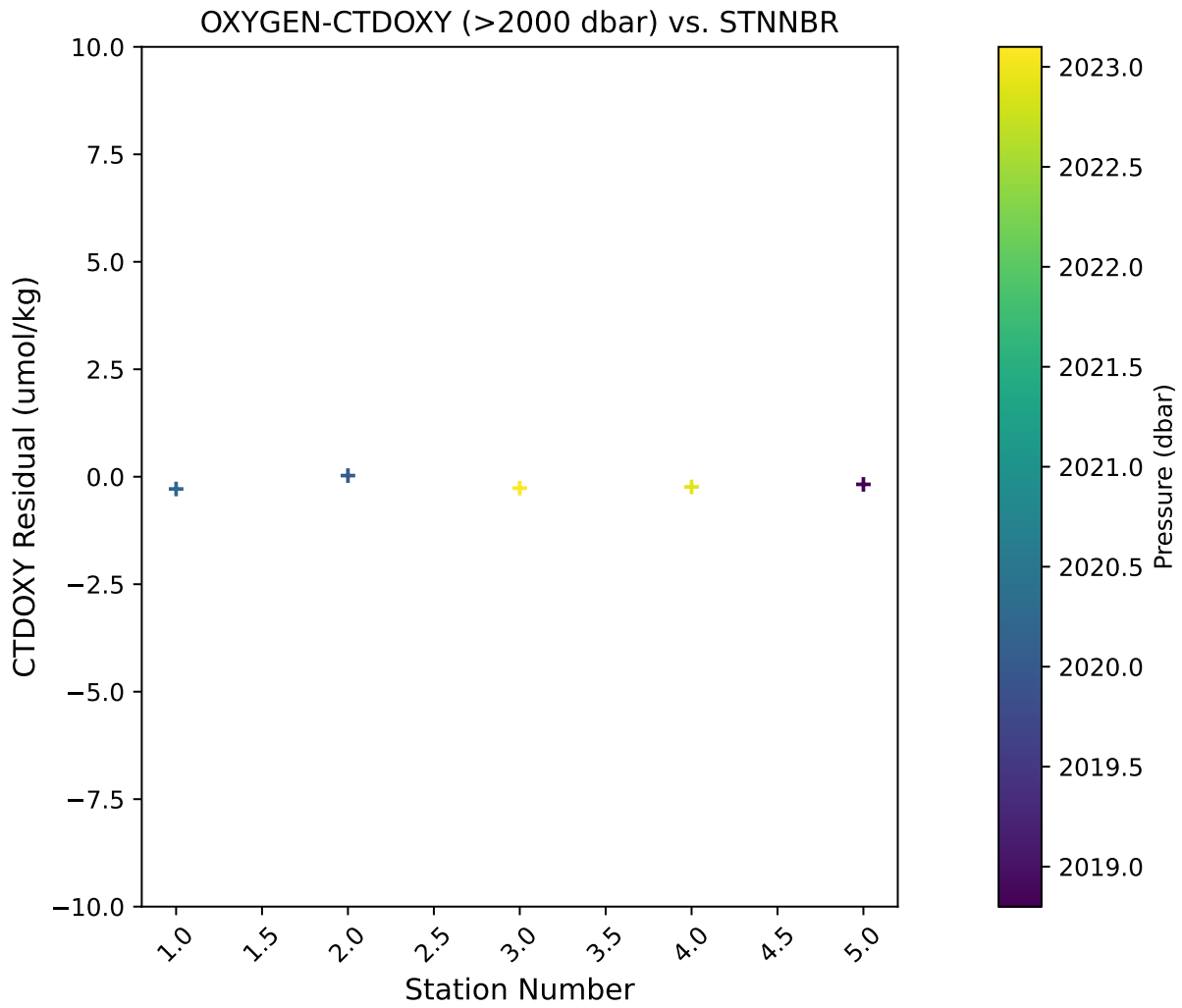
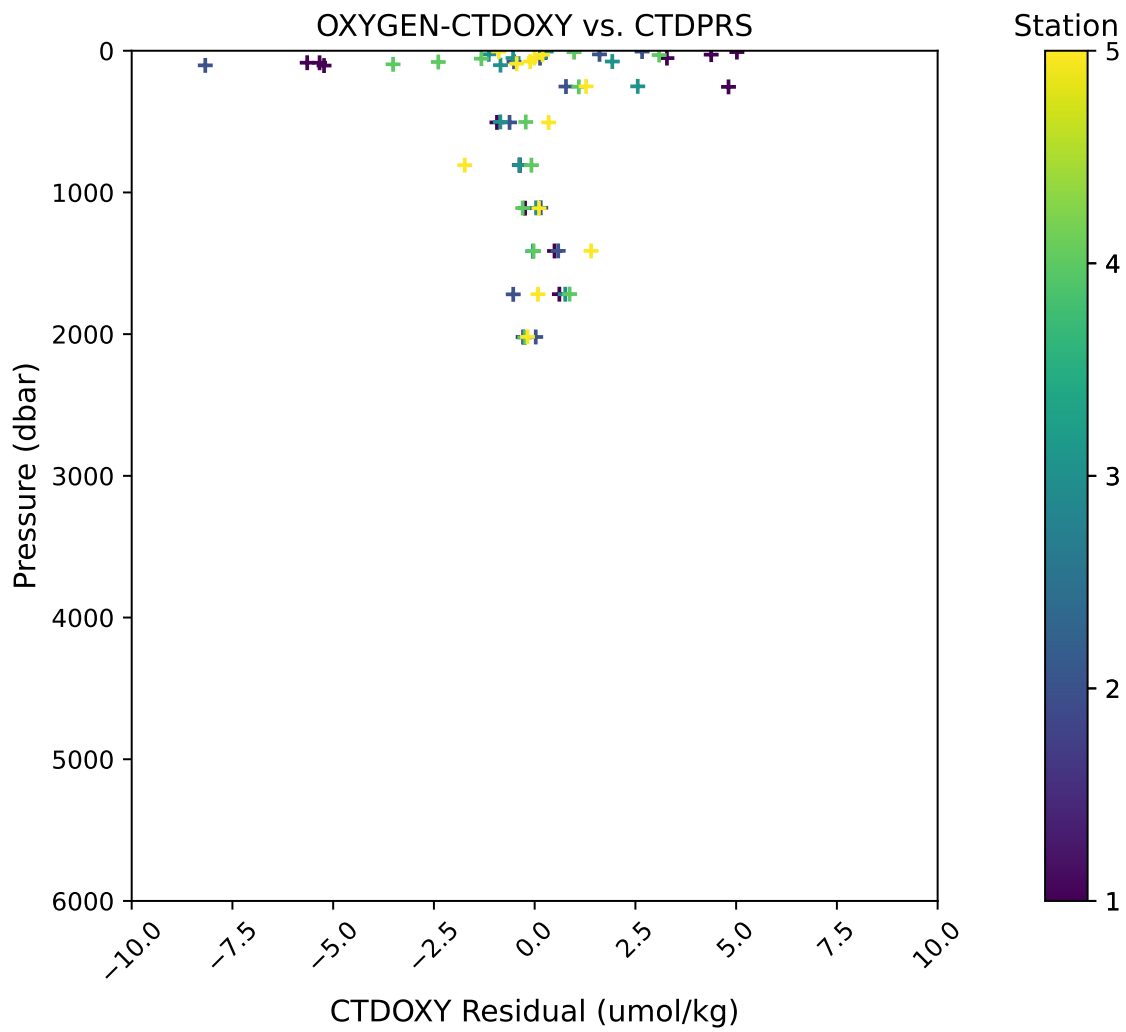


Fig. 18: Deep O₂ residuals versus station (Pressure >= 2000dbar).

Fig. 19: O₂ residuals versus pressure

No issues arose with the acquisition and processing of CTD dissolved oxygen data.

1.7 Post-Cruise Processing

All casts from the ODF rosette were inspected and manually flagged using ctdcal. Bottle data were flagged as questionable (WOCE flag 3) in accordance with limits as a function of depth, as well as data which indicated a mistrip or otherwise were not believed to be accurate. Data were then reprocessed with updated flags to assess any changes to fitting residuals.

Table 4: Residual flagging limits.

Residual tolerance	Depth (m)
0.020	0-500
0.010	500-1000
0.005	1000-2000
0.002	2000-6000

Other discrete data, such as nutrients, were merged into the dataset for submission to the CCHDO.

OXYGEN ANALYSIS

62 samples from 5 CTD/float stations were collected, fixed, and run during set up for the GO-SHIP I05/RR2308 expedition. Once the samples were fixed they were kept in the dark with a small amount of liquid in the neck of the flasks until analysis was performed.

Methods used on I05 are described here.

2.1 Equipment and Techniques

Dissolved oxygen analyses were performed with an SIO/ODF-designed automated oxygen titrator using photometric end-point detection based on the absorption of 365nm wavelength ultra-violet light.

The titration of the samples and the data logging were controlled by PC LabView software. Thiosulfate was dispensed by a Dosimat 665 buret driver fitted with a 1.0 ml burette.

ODF used a whole-bottle modified-Winkler titration following the technique of Carpenter [Carpenter1965] with modifications by [Culberson1991] but with higher concentrations of potassium iodate standard (~0.012 N), and thiosulfate solution (~55 g/L).

Pre-made liquid potassium iodate standards and reagent/distilled water blanks were run every day (approximately every 3-4 stations), with samples analysed within 24 hours of the last standard.

2.2 Sampling and Data Processing

Niskin samples were collected soon after the rosette was secured on deck.

Nominal 125 mL volume-calibrated biological oxygen demand (BOD) flasks were rinsed 3 times with minimal agitation using a silicone draw tube, then filled and allowed to overflow for at least 3 flask volumes, ensuring no bubbles remained. Pickling reagents MnCl₂ and NaI/NaOH (1 mL of each) were added via bottle-top dispensers to fix samples before stoppering. Flasks were shaken twice (10-12 inversions) to assure thorough dispersion of the precipitate - once immediately after drawing and then again after 30-60 minutes.

Sample draw temperatures, measured with an electronic resistance temperature detector (RTD) embedded in the draw tube, were used to calculate umol/kg concentrations, and as a diagnostic check of bottle integrity.

Thiosulfate normalities were calculated for each standardization and corrected to 20°C. The 20°C thiosulfate normalities and blanks were plotted versus time and were reviewed for possible problems and were subsequently determined to be stable enough that no smoothing was required.

2.3 Volumetric Calibration

Oxygen flask volumes were determined gravimetrically with degassed deionised water to determine flask volumes at ODF's chemistry laboratory. This is done once before using flasks for the first time and periodically thereafter when a suspect volume is detected. The 10 mL Dosimat buret used to dispense standard iodate solution was calibrated using the same method.

2.4 Standards

Liquid potassium iodate standards were prepared in 6 L batches and bottled in sterile glass bottles at ODF's chemistry laboratory prior to the expedition. The normality of the liquid standard was determined by calculation from weight. The standard was supplied by Alfa Aesar and has a reported purity of 99.4-100.4%. All other reagents were "reagent grade" and were tested for levels of oxidising and reducing impurities prior to use.

2.5 Narrative

The oxygen analytical rig was setup in the main lab of the Revelle. Batches of reagents were prepared as needed during the cruise.

No major analytical issues were encountered. A few high end points occurred and were corrected for. Only one sample was lost due to a LabView error. The Dosimat base used to deliver liquid potassium iodate standard malfunctioned after station 11 and was replaced with a spare unit. The analytical computer would freeze occasionally, but never while doing analysis.

The thiosulfate stability was considered in 6 batches and showed remarkable stability throughout the entire cruise. No trends were observed or corrected for.

No data updates are expected.

DISCRETE SALINITY SAMPLING

Samples from 5 CTD/float stations were collected and sorted for analysis prior to the GO-SHIP I05/RR2308 expedition. Methods used on I05 are described here.

3.1 Equipment & Techniques

Two Guildline Autosals were on board and operational, SIO-owned 8400A S/N 57-526 and 8400A S/N 55-654. S/N 57-526 was used for all salinity measurements during this cruise. The salinity analysis was run in the ship's Climate Controlled Chamber, a refrigerator, port and amidships between the Computer Lab and Bioanalytical Lab. The chamber temperature varied between about 21 and 24 degrees Celsius around 3 times each hour, with an average (based on measuring temperatures of items in the chamber) of about 22.5°C. IAPSO Standard Seawater Batch P166 was used for all calibrations: K15 = 0.99987, Practical salinity = 34.995, expiration 2025-04-06. A LabView program developed by Carl Mattson was used for monitoring temperatures, logging data, and prompting the operator. Salinity analyses were performed after samples had equilibrated to a laboratory temperature of 23°C, 8 hours or more after collection. Samples were placed under fans to speed their acclimatization to the set room temperature. The salinometer was standardized for each group of samples analyzed (up to 3 casts, or up to 108 samples) using two bottles of standard seawater: one at the beginning and one at the end of each set of measurements. For each calibration standard and sample reading, the salinometer cell was initially flushed at least 2 times before a set of conductivity ratio readings was recorded. Standardization conductivity offsets did not exceed 0.00005 mS/cm for all casts. Between runs, the water from the last standard was left in the cell.

3.2 Sampling & Data Processing

The salinity samples were collected in 200 ml Kimax high-alumina borosilicate bottles that had been rinsed at least three times with sample water prior to filling. The bottles were sealed with plastic insert thimbles and Nalgene screw caps. This assembly provides very low container dissolution and sample evaporation. Prior to sample collection, inserts were inspected for proper fit, and loose inserts were replaced to ensure an airtight seal. Laboratory temperature was also monitored electronically throughout the cruise. PSS-78 salinity [UNESCO1981] was calculated for each sample from the measured conductivity ratios. The offset between the initial standard seawater value and its reference value was applied to each sample. Then the difference (if any) between the initial and final vials of standard seawater was applied to each sample as a function of elapsed run time. The corrected salinity data was then incorporated into the cruise database. 6340 salinity samples were collected and run during I05, using approximately 194 bottles of standard seawater. There were 2 crates (62 total samples) of samples run at the beginning of the cruise that had been collected from CTD casts done during the transit from Goa, India to Fremantle, Australia. These were used for training salinity analysts but are not included in the data for RR2308.

3.3 Problems

10 sample bottles were broken or chipped during this cruise, and all were replaced during sampling. During various points of the cruise, it was noted that some sample bottles had red algae growing in them. To clean the bottles, they were rinsed with acid (10% HCl) and then rinsed with fresh water prior to being added back into the crates for sampling. To help with cell filling, capillary tubes were carefully cleaned with MilliQ, followed by air, once during the cruise, to help with cell filling.

Within the first 24 stations, the climate-controlled chamber lost temperature control 3 times due to a bad valve in the condenser line. Engineers from the ship's crew worked to fix this issue and the room maintained its after their work.

Towards the last 3 weeks of the cruise, the air temperature probe connected to LabView began to show some extremely unrealistic values (air temperatures between 500-1200 degrees Celsius). The air temperature probe that is used is old and both the connection prongs and the contacts in the electronics are oxidized. To combat unrealistic readings the prongs were cleaned which worked temporarily but continuous upkeep was unrealistic because of the placement. In tandem with the external temperature probes throughout the chamber, the temperature range between 21 and 24 degrees Celsius was maintained.

NUTRIENTS

- 62 samples from 5 CTD/float stations were frozen and run during GO-SHIP I05/RR2308.

Nutrient samples were drawn into 30 ml polypropylene screw-capped centrifuge tubes. The tubes and caps were rinsed 2-3 times with sample before filling. Samples were frozen in the scientific freezer.

Prior to analysis, the samples were thawed in a warm water bath set to 50C for 30 minutes. Once completely thawed samples were shaken to ensure homogeneity and then allowed to come back to room temperature before being analyzed.

Methods used on I05 are described here.

4.1 Equipment and Techniques

Nutrient analyses (phosphate, silicate, nitrate+nitrite, and nitrite) were performed on a Seal Analytical continuous-flow AutoAnalyzer 3 (AA3). The methods used are described by Gordon et al [Gordon1992] Hager et al. [Hager1972], and Atlas et al. [Atlas1971]. Details of modification of analytical methods used in this cruise are also compatible with the methods described in the nutrient section of the updated GO-SHIP repeat hydrography manual (Becker et al., 2019, [Becker2019]).

4.2 Nitrate/Nitrite Analysis

A modification of the Armstrong et al. (1967) [Armstrong1967] procedure was used for the analysis of nitrate and nitrite. For nitrate analysis, a seawater sample was passed through a cadmium column where the nitrate was reduced to nitrite. This nitrite was then diazotized with sulfanilamide and coupled with N-(1-naphthyl)-ethylenediamine to form a red dye. The sample was then passed through a 10mm flowcell and absorbance measured at 520nm. The procedure was the same for the nitrite analysis but without the cadmium column.

REAGENTS

Sulfanilamide

Dissolve 10g sulfanilamide in 1.2N HCl and bring to 1 liter volume. Add 2 drops of 30% Brij-35 surfactant. Store at room temperature in a dark poly bottle.

Note: 30% Brij-35 is 30% Brij-35 dissolved in 100 mL DIW.

N-(1-Naphthyl)-ethylenediamine dihydrochloride (N-1-N)

Dissolve 1g N-1-N in DIW, bring to 1 liter volume. Add 2 drops 30% Brij-35 surfactant. Store at room temperature in a dark poly bottle. Discard if the solution turns dark reddish brown.

Imidazole Buffer

Dissolve 13.6g imidazole in ~3.8 liters DIW. Stir for at least 30 minutes to completely dissolve. Add 60 ml of CuSO₄ + NH₄Cl mix (see below). Add 4 30% Brij-35 surfactant. Let sit overnight before proceeding. Using a

calibrated pH meter, adjust to pH of 7.83-7.85 with 10% (1.2N) HCl (about 10 ml of acid, depending on exact strength). Bring final solution to 4L with DIW. Store at room temperature.

NH₄Cl + CuSO₄ mix

Dissolve 2g cupric sulfate in DIW, bring to 100 ml volume (2%). Dissolve 250g ammonium chloride in DIW, bring to 1 liter volume. Add 5ml of 2% CuSO₄ solution to this NH₄Cl stock. This should last many months.

4.3 Phosphate Analysis

Ortho-Phosphate was analyzed using a modification of the Bernhardt and Wilhelms (1967) [Bernhardt1967] method. Acidified ammonium molybdate was added to a seawater sample to produce phosphomolybdic acid, which was then reduced to phosphomolybdous acid (a blue compound) following the addition of dihydrazine sulfate. The sample was passed through a 10mm flowcell and absorbance measured at 820nm.

REAGENTS

Ammonium Molybdate H₂SO₄ sol'n

Pour 420 ml of DIW into a 2 liter Erlenmeyer flask or beaker, place this flask or beaker into an ice bath. SLOWLY add 330 ml of conc H₂SO₄. This solution gets VERY HOT!! Cool in the ice bath. Make up as much as necessary in the above proportions.

Dissolve 27g ammonium molybdate in 250ml of DIW. Bring to 1 liter volume with the cooled sulfuric acid sol'n. Add 3 drops of 15% DDS surfactant. Store in a dark poly bottle.

Dihydrazine Sulfate

Dissolve 6.4g dihydrazine sulfate in DIW, bring to 1 liter volume and refrigerate.

4.4 Silicate Analysis

Silicate was analyzed using the basic method of Armstrong et al. (1967). Acidified ammonium molybdate was added to a seawater sample to produce silicomolybdic acid which was then reduced to silicomolybdous acid (a blue compound) following the addition of stannous chloride. The sample was passed through a 10mm flowcell and measured at 660nm.

REAGENTS

Tartaric Acid

Dissolve 200g tartaric acid in DW and bring to 1 liter volume. Store at room temperature in a poly bottle.

Ammonium Molybdate

Dissolve 10.8g Ammonium Molybdate Tetrahydrate in 1000ml dilute H₂SO₄. (Dilute H₂SO₄ = 2.8ml conc H₂SO₄ or 6.4ml of H₂SO₄ diluted for PO₄ moly per liter DW) (dissolve powder, then add H₂SO₄) Add 3-5 drops 15% SDS surfactant per liter of solution.

Stannous Chloride

stock: (as needed)

Dissolve 40g of stannous chloride in 100 ml 5N HCl. Refrigerate in a poly bottle.

NOTE: Minimize oxygen introduction by swirling rather than shaking the solution. Discard if a white solution (oxychloride) forms.

working: (every 24 hours) Bring 5 ml of stannous chloride stock to 200 ml final volume with 1.2N HCl. Make up daily - refrigerate when not in use in a dark poly bottle.

4.5 Data Collection and Processing

Data collection and processing was done with the software provided with the instrument from Seal Analytical (AACE). After each run, the charts were reviewed for any problems during the run, any blank was subtracted, and final concentrations (micro moles/liter) were calculated, based on a linear curve fit. Once the run was reviewed and concentrations calculated a text file was created. That text file was reviewed for possible problems and then converted to another text file with only sample identifiers and nutrient concentrations that was merged with other bottle data.

4.6 Standards and Glassware Calibration

Primary standards for silicate (Na_2SiF_6), nitrate (KNO_3), nitrite (NaNO_2), and phosphate (KH_2PO_4) were obtained from Johnson Matthey Chemical Co. and/or Fisher Scientific. The supplier reports purities of >98%, 99.999%, 97%, and 99.999 respectively.

All glass volumetric flasks and pipettes were gravimetrically calibrated prior to the cruise. The primary standards were dried and weighed out to 0.1mg prior to the cruise. The exact weight was noted for future reference. When primary standards were made, the flask volume at 20C, the weight of the powder, and the temperature of the solution were used to buoyancy-correct the weight, calculate the exact concentration of the solution, and determine how much of the primary was needed for the desired concentrations of secondary standard. The new standards were compared to the old before use.

All the reagent solutions, primary and secondary standards were made with fresh distilled deionized water (DIW).

Standardizations were performed at the beginning of each group of analyses with working standards prepared every 12-16 hours from a secondary. Working standards were made up in low nutrient seawater (LNSW). Multiple batches of LNSW were used on the cruise. The first batch of LNSW was treated in the lab. The water was re-circulated for ~8 hours through a 0.2 micron filter, passed a UV lamp and through a second 0.2 micron filter. The actual concentration of nutrients in this water was empirically determined during the standardization calculations.

The concentrations in micro-moles per liter of the working standards used were:

-	N+N (uM)	PO ₄ (uM)	SIL (uM)	NO ₂ (uM)
0	0.0	0.0	0.0	0.0
3	15.50	1.2	60	0.50
5	31.00	2.4	120	1.00
7	46.50	3.6	180	1.50

4.7 Quality Control

All final data was reported in micro-moles/kg. NO₃, PO₄, and NO₂ were reported to two decimals places and SIL to one. Accuracy is based on the quality of the standards the levels are:

NO ₃	0.05 uM (micro moles/Liter)
PO ₄	0.004 uM
SIL	2-4 uM
NO ₂	0.05 uM

Reference materials for nutrients in seawater (RMNS) were used as a check sample run with every station. The RMNS preparation, verification, and suggested protocol for use of the material are described by Aoyama [Aoyama2006] [Aoyama2007] [Aoyama2008], Sato [Sato2010], and Becker et al. [Becker2019]. RMNS batch CM was used on

this cruise, with each bottle being used for all runs in one day before being discarded and a new one opened. Data are tabulated below.

Parameter	Concentration	stddev	assigned conc
-	(umol/kg)	-	(umol/kg)
NO ₃	33.12	0.17	33.2
PO ₄	2.40	0.02	2.38
Sil	100.	0.49	100.5
NO ₂	0.020	0.005	0.02

4.8 Analytical Problems

There were issues with columns losing efficiency quickly at the start of the cruise. These issues were resolved by cleaning, treating and repacking new columns.

There were no other analytical errors.

GO-BGC FLOAT DEPLOYMENTS

PIs

- Kenneth Johnson (MBARI)
- Lynne Talley (UCSD/SIO)
- Susan Wijffels (WHOI)
- Curtis Deutsch (Princeton)
- Steven Riser (UW)
- Jorge Sarmiento (Princeton)

Shipboard personnel

- Todd Martz (SIO)
- Ben Freiburger (SIO)
- Kieran Claassen (SJSU)

5 biogeochemical (BGC) Argo floats were deployed on RR2307 as part of the Global Ocean Biogeochemistry (GO-BGC) program (<https://go-bgc.org>). GO-BGC floats carry the standard (core) Argo sensor suite of pressure, temperature, and salinity, as well as O₂, NO₃, pH, fluorescence, and backscattering. The GO-BGC floats drift at 1,000 m depth and profile to between the surface and approximately 2,000 m every 10 days.

The BGC data will be processed at the Monterey Bay Aquarium Research Institute following their deployments. These data will then be combined with the core Argo processed at the University of Washington and the Woods Hole Oceanographic Institution and will be available in near real-time to the public.

At float deployment stations, CTD bottle data were taken to validate the float calibrations. These data are:

- Conductivity, temperature, and depth
- NO₃
- pH
- High-Performance Liquid Chromatography - HPLC
- Particulate organic carbon - POC
- O₂

Table 1: Float deployments.

Deployment	WMO	Float ID	Lat	Lon	Date and Time (UTC)	CTD Station
1	2903464	1472	01° 59.975N	080° 30.015E	2023/07/02 16:17	001
2	2903466	1501	00° 00.207S	081° 59.645E	2023/07/03 13:00	002
3	2903465	1473	05° 00.014S	086° 41.966E	2023/07/05 03:23	003
4	2903467	1502	10° 59.958S	092° 05.946E	2023/07/07 06:40	004
5	2903468	1503	17° 59.968S	098° 53.912E	2023/07/09 16:11	005

CALIBRATION DOCUMENTS

Temperature Calibration Report

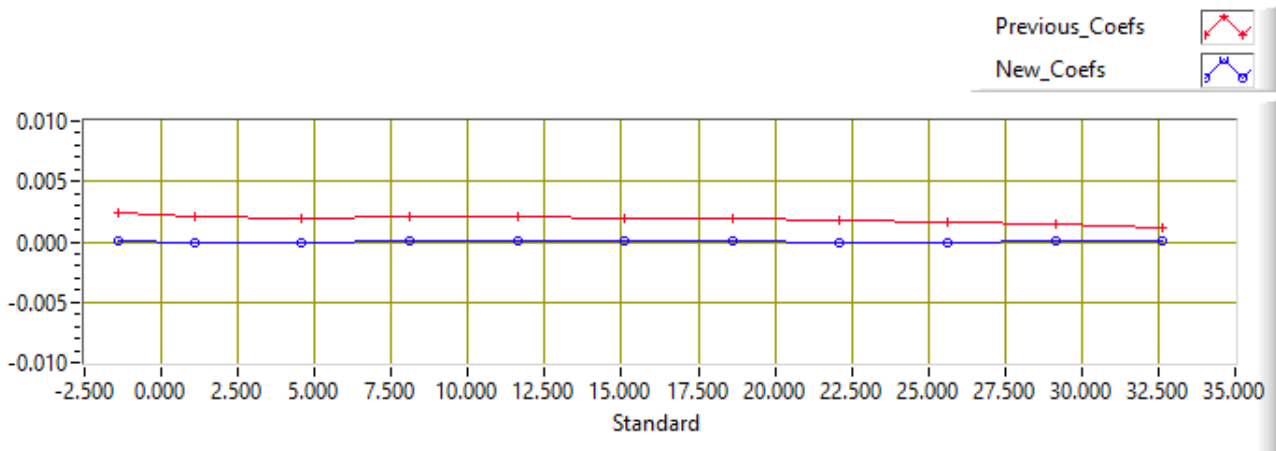
STS Calibration Facility

SENSOR SERIAL NUMBER: 4588
CALIBRATION DATE: 25-Oct-2022
Mfg: SEABIRD Model: 03
Previous cal: 17-Mar-22
Calibration Tech: AJM

ITS-90_COEFFICIENTS	IPTS-68_COEFFICIENTS ITS-T90	
g = 4.35572628E-3	a = 4.35592400E-3	
h = 6.38624856E-4	b = 6.38834399E-4	
i = 2.13547865E-5	c = 2.13865524E-5	
j = 1.86164699E-6	d = 1.86307120E-6	
f0 = 1000.0	Slope = 1.0	Offset = 0.0

Calibration Standard: Mfg: Isotech Model: MicroK100 s/n: 291088-2
Temperature ITS-90 = 1/[g+h[ln(f0/f)]+i[ln2(f0/f)]+j[ln3(f0/f)]] - 273.15 (°C)
Temperature IPTS-68 = 1/{a+b[ln(f0/f)]+c[ln2(f0/f)]+d[ln3(f0/f)]] - 273.15 (°C)
T68 = 1.00024 * T90 (-2 to -35 Deg C)

SBE3 Freq	SPRT ITS-T90	SBE3 ITS-T90	SPRT-SBE3 OLD Coefs	SPRT-SBE3 NEW Coefs
2985.8111	-1.4306	-1.4307	0.00245	0.00011
3158.5513	1.0741	1.0743	0.00207	-0.00013
3412.3253	4.5806	4.5807	0.00198	-0.00009
3680.5454	8.0887	8.0886	0.00208	0.00008
3963.6652	11.5986	11.5985	0.00204	0.00008
4261.1457	15.0997	15.0996	0.00194	0.00001
4575.1015	18.6123	18.6123	0.00192	0.00003
4904.6723	22.1220	22.1221	0.00171	-0.00010
5250.6178	25.6337	25.6337	0.00167	-0.00000
5612.7902	29.1421	29.1421	0.00148	0.00002
5992.2150	32.6542	32.6542	0.00114	0.00001



Temperature Calibration Report

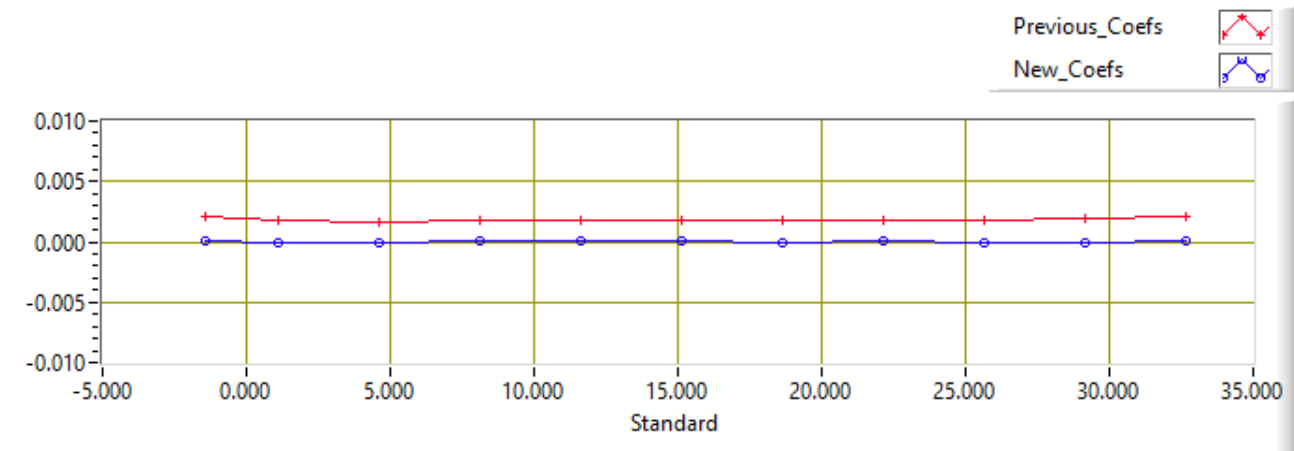
STS Calibration Facility

SENSOR SERIAL NUMBER: 4907
CALIBRATION DATE: 14-Mar-2023
Mfg: SEABIRD **Model:** 03
Previous cal: 20-Sep-22
Calibration Tech: AJM

ITS-90_COEFFICIENTS	IPTS-68_COEFFICIENTS ITS-T90	
g = 4.37064294E-3	a = 4.37084565E-3	
h = 6.30044752E-4	b = 6.30252852E-4	
i = 2.01947730E-5	c = 2.02257123E-5	
j = 1.55488611E-6	d = 1.55622822E-6	
f0 = 1000.0	Slope = 1.0	Offset = 0.0

Calibration Standard: Mfg: Isotech Model: MicroK100 s/n: 291088-2
Temperature ITS-90 = $1/[g+h[\ln(f_0/f)]+i[\ln^2(f_0/f)]+j[\ln^3(f_0/f)]] - 273.15$ (°C)
Temperature IPTS-68 = $1/[a+b[\ln(f_0/f)]+c[\ln^2(f_0/f)]+d[\ln^3(f_0/f)]] - 273.15$ (°C)
T68 = 1.00024 * T90 (-2 to -35 Deg C)

SBE3 Freq	SPRT ITS-T90	SBE3 ITS-T90	SPRT-SBE3 OLD Coefs	SPRT-SBE3 NEW Coefs
3106.1270	-1.4286	-1.4288	0.00208	0.00011
3288.3980	1.0756	1.0757	0.00174	-0.00012
3556.5123	4.5823	4.5824	0.00167	-0.00008
3840.1779	8.0902	8.0902	0.00171	0.00001
4139.9325	11.6001	11.6000	0.00175	0.00007
4455.3013	15.1016	15.1016	0.00175	0.00005
4788.4461	18.6140	18.6140	0.00175	0.00000
5138.5839	22.1241	22.1241	0.00185	0.00003
5506.6026	25.6364	25.6365	0.00183	-0.00007
5892.2716	29.1453	29.1454	0.00194	-0.00006
6296.6475	32.6571	32.6570	0.00216	0.00006





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SENSOR SERIAL NUMBER: 4650
 CALIBRATION DATE: 13-Dec-22

SBE 4 CONDUCTIVITY CALIBRATION DATA
 PSS 1978: C(35,15,0) = 4.2914 Siemens/meter

COEFFICIENTS:

g = -1.01379684e+001
 h = 1.34686637e+000
 i = -6.91604213e-005
 j = 6.87979907e-005

CPcor = -9.5700e-008 (nominal)
 CTcor = 3.2500e-006 (nominal)

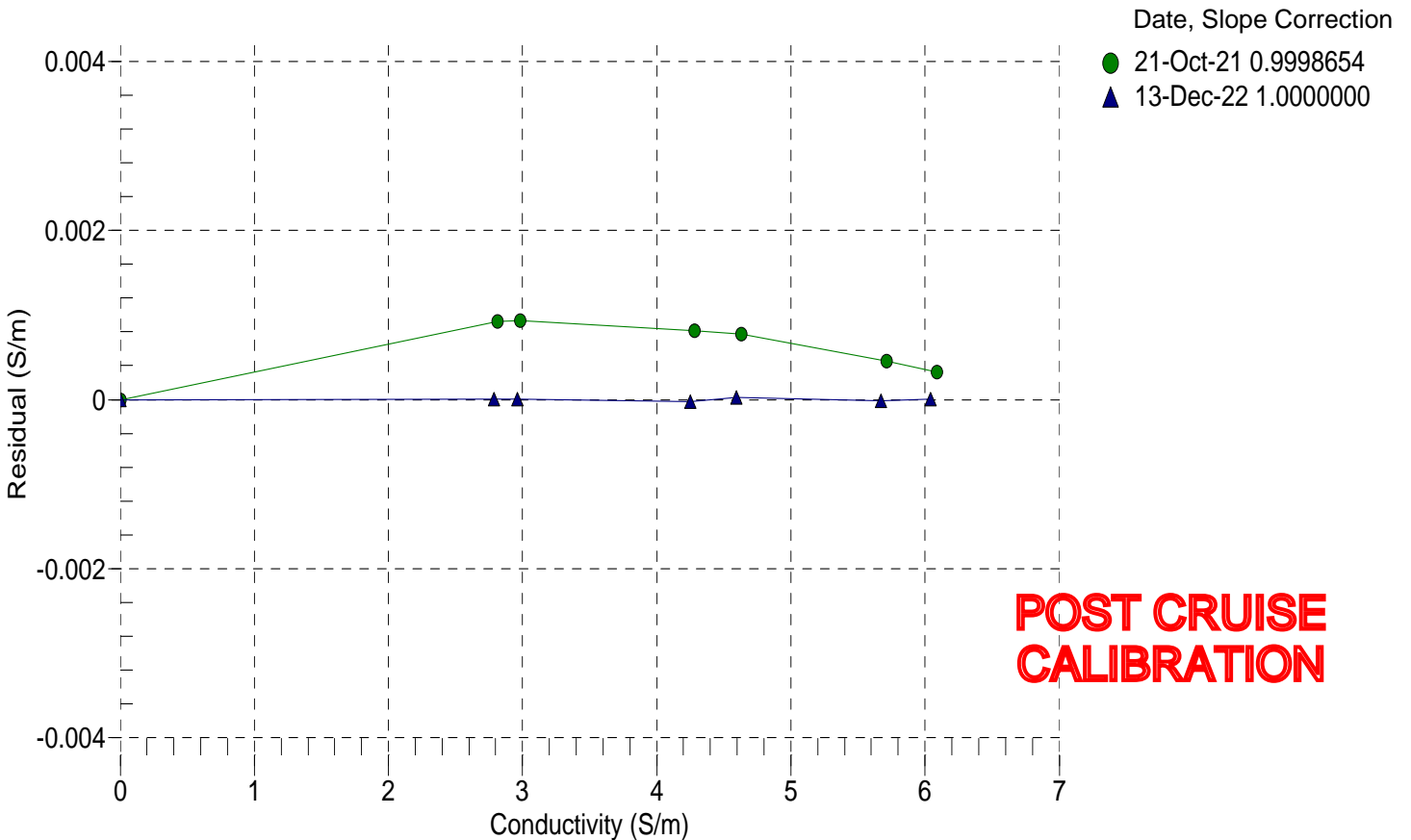
BATH TEMP (° C)	BATH SAL (PSU)	BATH COND (S/m)	INSTRUMENT OUTPUT (kHz)	INSTRUMENT COND (S/m)	RESIDUAL (S/m)
0.0000	0.0000	0.00000	2.74322	0.00000	0.00000
-1.0000	34.6046	2.78911	5.31058	2.78911	0.00000
1.0000	34.6046	2.95959	5.42816	2.95959	0.00000
15.0000	34.6034	4.24825	6.24540	4.24823	-0.00002
18.4999	34.6013	4.59291	6.44636	4.59293	0.00003
28.9999	34.5945	5.67005	7.03717	5.67004	-0.00001
32.4998	34.5787	6.03920	7.22847	6.03921	0.00001

f = Instrument Output (kHz)

t = temperature (°C); p = pressure (decibars); δ = CTcor; ϵ = CPcor;

Conductivity (S/m) = $(g + h * f^2 + i * f^3 + j * f^4) / 10 (1 + \delta * t + \epsilon * p)$

Residual (Siemens/meter) = instrument conductivity - bath conductivity





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SENSOR SERIAL NUMBER: 4651
 CALIBRATION DATE: 20-Jan-23

SBE 4 CONDUCTIVITY CALIBRATION DATA
 PSS 1978: C(35,15,0) = 4.2914 Siemens/meter

COEFFICIENTS:

g = -1.01436909e+001
 h = 1.37958024e+000
 i = -1.99313797e-005
 j = 6.35228858e-005

CPcor = -9.5700e-008 (nominal)
 CTcor = 3.2500e-006 (nominal)

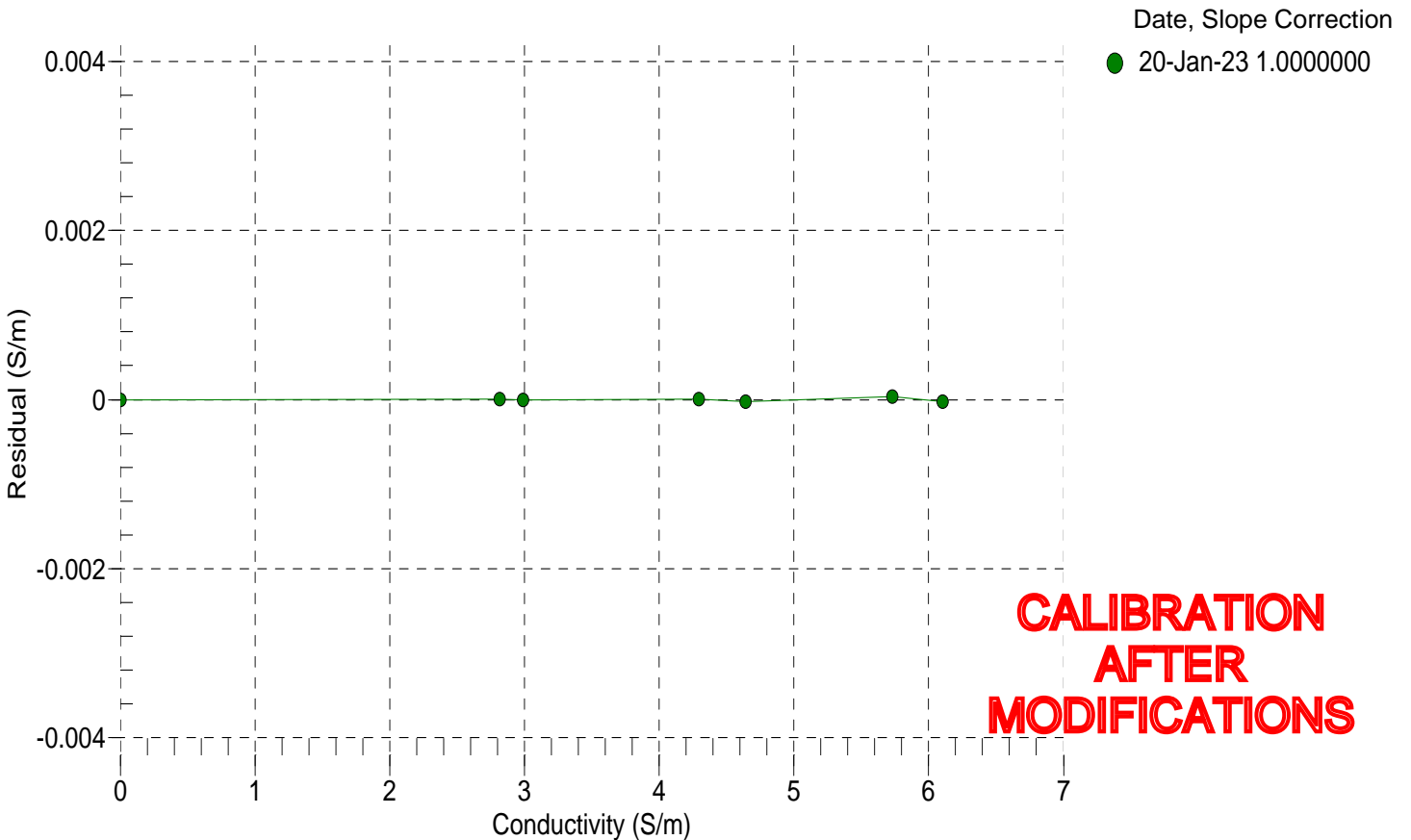
BATH TEMP (° C)	BATH SAL (PSU)	BATH COND (S/m)	INSTRUMENT OUTPUT (kHz)	INSTRUMENT COND (S/m)	RESIDUAL (S/m)
0.0000	0.0000	0.00000	2.71119	0.00000	0.00000
-1.0000	35.0061	2.81843	5.26774	2.81844	0.00001
1.0000	35.0064	2.99066	5.38464	2.99065	-0.00000
14.9999	35.0054	4.29234	6.19703	4.29234	0.00001
18.5000	35.0048	4.64067	6.39684	4.64064	-0.00003
29.0000	34.9983	5.72876	6.98410	5.72880	0.00004
32.4999	34.9843	6.10195	7.17433	6.10192	-0.00002

f = Instrument Output (kHz)

t = temperature (°C); p = pressure (decibars); δ = CTcor; ϵ = CPcor;

Conductivity (S/m) = $(g + h * f^2 + i * f^3 + j * f^4) / 10 (1 + \delta * t + \epsilon * p)$

Residual (Siemens/meter) = instrument conductivity - bath conductivity





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SENSOR SERIAL NUMBER: 1508
 CALIBRATION DATE: 07-Oct-22

SBE 43 OXYGEN CALIBRATION DATA

COEFFICIENTS:
 Soc = 0.5639
 Voffset = -0.4943
 Tau20 = 0.94

A = -4.1583e-003
 B = 1.7078e-004
 C = -2.5988e-006
 E nominal = 0.036

NOMINAL DYNAMIC COEFFICIENTS
 D1 = 1.92634e-4
 D2 = -4.64803e-2
 H1 = -3.300000e-2
 H2 = 5.00000e+3
 H3 = 1.45000e+3

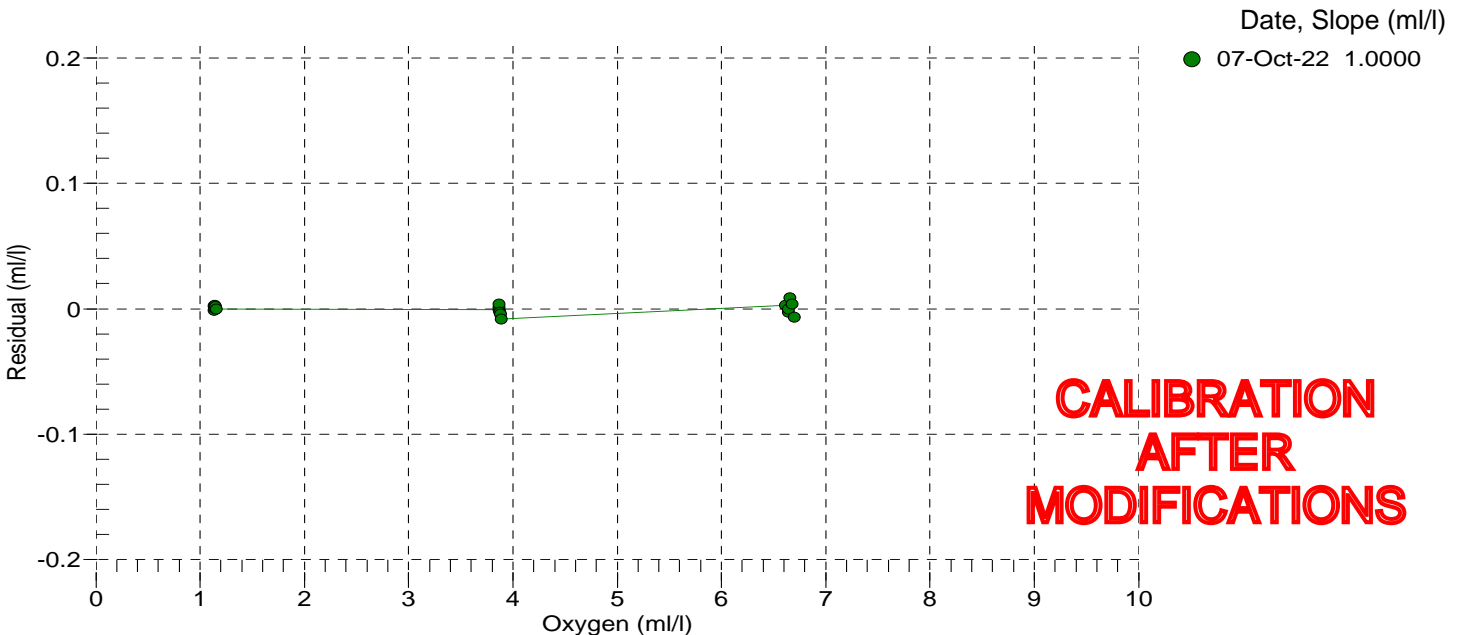
BATH OXYGEN (ml/l)	BATH TEMPERATURE (° C)	BATH SALINITY (PSU)	INSTRUMENT OUTPUT (volts)	INSTRUMENT OXYGEN (ml/l)	RESIDUAL (ml/l)
1.13	6.00	0.00	0.729	1.13	-0.00
1.13	12.00	0.00	0.770	1.14	0.00
1.14	2.00	0.00	0.705	1.14	0.00
1.14	20.00	0.00	0.825	1.14	0.00
1.15	26.00	0.00	0.867	1.15	0.00
1.15	30.00	0.00	0.897	1.15	-0.00
3.86	2.00	0.00	1.208	3.86	-0.00
3.87	12.00	0.00	1.432	3.87	0.00
3.87	20.00	0.00	1.613	3.87	0.00
3.87	6.00	0.00	1.297	3.87	-0.00
3.88	26.00	0.00	1.753	3.87	-0.00
3.88	30.00	0.00	1.850	3.88	-0.01
6.62	2.00	0.00	1.716	6.62	0.00
6.64	6.00	0.00	1.873	6.64	-0.00
6.64	12.00	0.00	2.105	6.64	-0.00
6.65	30.00	0.00	2.824	6.66	0.01
6.68	20.00	0.00	2.425	6.68	0.00
6.70	26.00	0.00	2.668	6.69	-0.01

V = instrument output (volts); T = temperature (°C); S = salinity (PSU); K = temperature (°K)

Oxsol(T,S) = oxygen saturation (ml/l); P = pressure (dbar)

Oxygen (ml/l) = Soc * (V + Voffset) * (1.0 + A * T + B * T² + C * T³) * Oxsol(T,S) * exp(E * P / K)

Residual (ml/l) = instrument oxygen - bath oxygen





ECO Chlorophyll Fluorometer Characterization Sheet

Date: 1/7/2022

S/N: FLRTD-4334

Chlorophyll concentration expressed in µg/l can be derived using the equation:

$$\text{CHL } (\mu\text{g/l}) = \text{Scale Factor} * (\text{Output} - \text{Dark Counts})$$

	Analog Range 1	Analog Range 2	Analog Range 4 (default)	Digital
Dark Counts	0.060	0.031	0.017 V	45 counts
Scale Factor (SF)	7	13	26 µg/l/V	0.0079 µg/l/count
Maximum Output	4.97	4.97	4.97 V	16380 counts
Resolution	0.9	0.9	0.9 mV	1.0 counts

Ambient temperature during characterization 21.0 °C

Analog Range: 1 (most sensitive, 0–4,000 counts), 2 (midrange, 0–8,000 counts), 4 (entire range, 0–16,000 counts).

Dark Counts: Signal output of the meter in clean water with black tape over detector.

SF: Determined using the following equation: $SF = x \div (\text{output} - \text{dark counts})$, where x is the concentration of the solution used during instrument characterization. SF is used to derive instrument output concentration from the raw signal output of the fluorometer.

Maximum Output: Maximum signal output the fluorometer is capable of.

Resolution: Standard deviation of 1 minute of collected data.

The relationship between fluorescence and chlorophyll-a concentrations *in-situ* is highly variable. The scale factor listed on this document was determined using a mono-culture of phytoplankton (*Thalassiosira weissflogii*). The population was assumed to be reasonably healthy and the concentration was determined by using the absorption method. To accurately determine chlorophyll concentration using a fluorometer, you must perform secondary measurements on the populations of interest. This is typically done using extraction-based measurement techniques on discrete samples. For additional information on determining chlorophyll concentration see "Standard Methods for the Examination of Water and Wastewater" part 10200 H, published jointly by the American Public Health Association, American Water Works Association, and the Water Environment Federation.

Calibration Date: 02/06/19
Model Number: QCP2300-HP
Serial Number: 70444
Operator: TPC
Standard Lamp: V-042(1/3/2019)

Job No.: R-13489

Operating Voltage Range: 6 to 15 VDC (+)

Note: The QCP2300-HP output is a voltage that is proportional to the log of the incident irradiance.
 To calculate irradiance, use this formula:

$$\text{Irradiance} = \text{Calibration factor} * (10^{\text{Light Signal Voltage}} - 10^{\text{Dark Voltage}})$$

Dry Calibration Factor: 2.89E+12 quanta/cm²-sec per volt 4.79E-06 μEinsteins/cm²-sec per volt
 Wet Calibration Factor: 3.10E+12 quanta/cm²-sec per volt 5.15E-06 μEinsteins/cm²-sec per volt

Sensor Test Data and Results²⁾

Sensor Supply Current (Dark): 3.4 mA
 Supply Voltage: 6 Volts
 Lamp Integrated PAR Irradiance: 9.40E+15 quanta/cm²-sec 0.01561 μEinsteins/cm²sec
 Immersion Coefficient: 0.931

Nominal Filter OD	Expected Transmission	Calibrated Trans.	Sensor Voltage	Expected Voltage	Voltage % Error	Measured Trans.	Transmission Error (%)	Test Irrad. (quanta/cm ² -sec)
No Filter	100%	100.00%	3.513	3.513	0%	100.00%	0.0	9.40E+15
0.3	50%	36.10%	3.077	3.071	0%	36.62%	-1.4	3.44E+15
0.5	32%	27.60%	2.963	2.954	0%	28.16%	-2.0	2.65E+15
1	10%	9.27%	2.503	2.480	1%	9.74%	-4.8	9.16E+14
2	1%	1.11%	1.610	1.558	3%	1.22%	-9.0	1.15E+14
3	0.10%	0.05%	0.484	0.241	50%	0.06%	-14.2	5.91E+12
RG780	0.00%	0.00%	0.056	0.009	84%	0.00%	-100.0	3.97E+11

Dark Before: 0.009 Volts
 Light - No Filter Hldr.: 3.513 Volts
 Dark After - NFH: 0.009 Volts
 Average Dark: 0.0092 Volts

Notes:

1. Annual calibration is recommended.
- 2) This section is for internal use and for more advanced analysis.

VALEPORT

This document certifies that the instrument detailed below has been calibrated according to Valeport Limited's Standard Procedures, using equipment with calibrations traceable to UKAS or National Standards.

Calibration Certificate Number: 43900

Instrument Type: Altimeter

Instrument Serial Number: 53821

Calibrated By: J.Harper

Date: 28/01/2016

Signed:



Full details of the results from the calibration procedure applied to each fitted sensor are available, on request, via email. This summary certificate should be kept with the instrument.



Instrument Serial Number	53821
Sensor Type	500kHz Neptune
Altimeter Range (m)	100m
Certificate Number	43900

Stage 1

Test the assembled altimeter in a body of water to ensure a signal is received at the minimum range. Taking direct readings from the unit immerse the head till it is roughly 0.1m from the bottom, readings should come through - if not then the signal is being saturated and there is a problem

To inhibit spurious readings set using: #226;40

	Pass/Fail
Bench Test Min Range <0.1m	Pass

Stage 2

Using a mini SVS or similar, measure the average sound velocity for the water in the tow tank and input the value in the cell below.

Enter the SOS	1481.712
---------------	----------

Input SOS value to the altimeter using: #830;1481.7120

Stage 3

Fit the altimeter into the calibration fixture and lower the assembly into the tank till it is about 0.5m down facing the far end of the tow tank and clamp in place. Using the distance markers on the wall align the front edge of the trolley with the datum line to set the front of the altimeter at stated distance from the wall.

To determine the Range Offset		
Distance m	Measured Range m	Measured Offset m
1	1.018	-0.018

Stage 4: Enter the Offset Correction

#828;-0.0180

Stage 5 - Range Check after Offset Correction

Distance m	Measured Range m	Measured Offset m	Pass/Fail
1	0.998	0.002	Pass
5	5.003	-0.003	Pass

Stage 6: Reset the SOS

#830;1500

Stage 7: Reset maximum range to 105m

#823;105 (500kHz units)

Stage 8: Reset spurious range

#226;0

Calibrated by:	J. Harper	Date:	28/01/2016
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