

AR84-02 CTD Calibration Report  
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**Cruise summary**

Ship: RV *ARMSTRONG*  
Project Name: Cape Farewell OSNAP  
Dates: July 9, 2024 – August 14, 2024  
Ports: Reykjavik Iceland

**Data files included as part of this distribution**

*AR84-02\_CTD\_Calibration\_Report.pdf*  
This document in pdf format

*AR84-02\_\*\*\*\*.dcc*

One 2 db pressure-averaged file per station following WOCE format specifications for CTD data. Final .dcc files contain CTD sensor pressure, temperature, salinity, oxygen, and altimeter data. CTD temperatures, pressures, and conductivities have been scaled with pre-cruise calibrations from the sensor manufacturer. All CTD salinity data have been post-calibrated using bottle salinity measurements.

*AR84-02\_\*\*\*\*.cbot\_so*

One file per station following the WOCE format specifications for cruise bottle data. The final .cbot\_so files contain fully calibrated pressure, temperature, salinity, and oxygen data at the location of each bottle sample.

*Variable definitions*

*Final .dcc variable definitions*

Pres	Binned pressure (db)
T90(1)	Calibrated primary temperature (°C)
T90(2)	Calibrated secondary temperature (°C)
Sal(1)	Calibrated primary salinity (psu)
Sal(2)	Calibrated secondary salinity (psu)
OxCur	Oxygen Current (V)
OXYG (ml/l)	Dissolved Oxygen (ml/l)
uOXY (um/kg)	Dissolved Oxygen (umol/kg)
Trans	Beam transmission (%)
Flur	Fluorescence (mg/m <sup>3</sup> )
wocecode	WOCE quality word for each variable

*Final .cbot\_s variable definitions*

CTD Bottle Number	CTD rosette trigger position (Niskin number)
CTD Pres	CTD pressure (db)
CTD T1	Calibrated primary temperature (°C)
CTD T2	Calibrated secondary temperature (°C)
CTD TH1	Calculated primary potential temperature (°C)
CTD TH2	Calculated secondary potential temperature (°C)
CTD Sal1	Calibrated primary salinity (psu)
CTD Sal2	Calibrated secondary salinity (psu)
CTD OXY	CTD Dissolved Oxygen (ml/l)
Meas SAL	Bottle salinity (psu)
QUAL	WOCE quality word for each variable

*WOCE quality word definitions:*

- 1 = Not calibrated with water samples
- 2 = Acceptable measurement
- 3 = Questionable measurement
- 4 = Bad measurement
- 9 = not sampled

## CTD configuration

### *General*

268 casts were performed using a SeaBird 911plus CTD and deck unit configured to measure pressure, temperature, conductivity, and oxygen current. Data from the CTD were acquired at 24 Hz. The CTD data were acquired by an SBE Model 11 plus V2 CTD Deck Unit providing demodulated data to a personal computer running SEASAVE (SeaBird). Bottom approach was controlled by real time altimeter data and ship provided ocean depth information. For each cast, water samples were collected at up to 24 discrete intervals and analyzed for salinity. A rosette frame holding 24 10-L Niskin bottles was used for collecting water samples.

The CTD rosette included an integrated SBE43 oxygen sensor, which is commonly used for collection of CTD dissolved oxygen profiles. While the SBE43 records dissolved oxygen profile data at 24 Hz (the same frequency as CTD temperature and conductivity), it is prone to calibration drifts. In an effort to better understand dissolved oxygen sensor drift and to provide insight on the performance of newly deployed sensors in the OSNAP mooring array, two additional oxygen sensors were added to the CTD rosette:

1. An JFE Advantech Co. RINKO III analog dissolved oxygen sensor was integrated into the CTD instrument package (sensor provided by SCRIPPS ODF; integration cable provided by SSSG Croy Carlin). Cables and pin-out connection information were shared by ODF with SSSG for setup. Sensor output was connected to the SBE9 analog voltage 'V6' for recording.



Figure 1: Mount location of the Rinko optode sensor

### CTD calibrations

Calibrations for CTD sensors were performed by the manufacture before the cruise. A listing of sensors and calibration dates are presented in the following table. Configuration report files for the SBE 911plus containing sensor calibration coefficients and channels can be found in Appendix A.

Table 1: CTD sensor calibration dates

Sensor Name	Serial Num	Cal Date
Temperature	4406	03-Oct-23
Conductivity	2304	27-Oct-23
Pressure, Digiquartz with TC	1478	13-Sept-21
Temperature, 2	4481	14-Oct-23
Conductivity, 2	2670	18-Oct-23
Altimeter	VA500-46506	2018
Oxygen, SBE 43	0072	03-Oct-23
Fluorometer, WET Labs ECO-AFL/FL	FLNTURT-969	2019-05-09
Turbidity Meter, WET Labs, ECO-NTU	FLTURT-969	2019-May-19
Transmissometer, WET Labs C-Star	CST-2034	2021-Aug-20
Oxygen, SBE 43, 2	0449	06-Mar-24
Rinko III DO	0483	09-27-2023
Rinko III Temp	0483	9-27-2023
SPAR, Biospherical/Licor		

### Summary of CTD events and problems

Stations 1 – 168:

Salinity samples collected on stations [4 5 7 11 12 14 16 17 18 22 62 64 66 68 80 82 84 86 89 101 109 112 115 117 118 119 125 131 135 138 140 142 145 148 168], were recorded using an incorrect suppression on the autosal. I was able to recover most of these values with a small loss in accuracy. Instructions via correspondence with a chemist from OSIL:

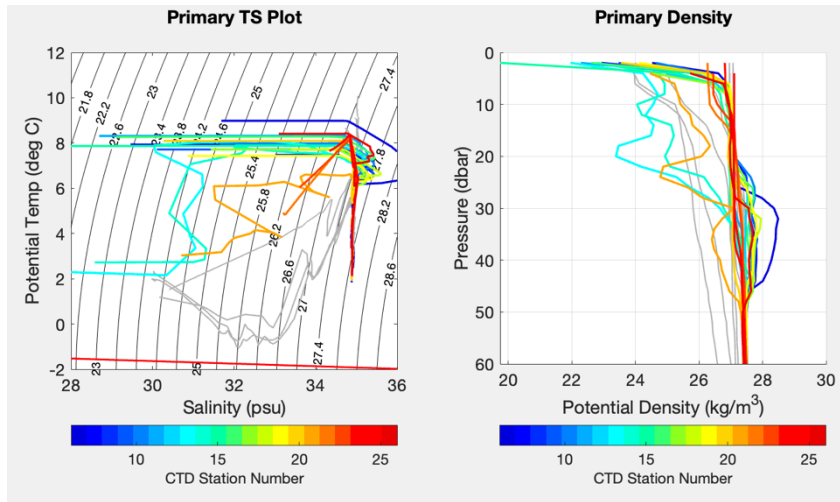
*If we were to try to and back process the data, we would need to know what values were recorded and if the display was flashing with a '+' or a '-', i.e. the suppression step needed to be increased or decreased. I have just run a simple test with as random sample, see results below:*

Supp	+ / -	Value		
2.0	-	0	Flashing	Supp 3 high
1.9	-	4056	Flashing	Supp 2 high
1.8	-	4056		Supp 1 high
1.7	+	5944		Correct
1.6	+	5944	Flashing	Supp 1 low
1.5	+	0	Flashing	Supp 2 low

*If the display reads a '-' number, but not flashing, for example as above 1.8-4056, this can be corrected to the lower suppression value as the equivalent '+' value is 1.7+5944. There is 10000 between the two values. Therefore, if the reading was take as 1 step higher, deduct that value from 10000 to correct, in this instance, we would get 10000 - 4056 = 5944. It also appears that if the suppression was one step low, the last 4 digits of the ratio value will be correct, you will simply need to add 1 to the suppression, in this instance, 1.6+5944 will become 1.7+5944.*

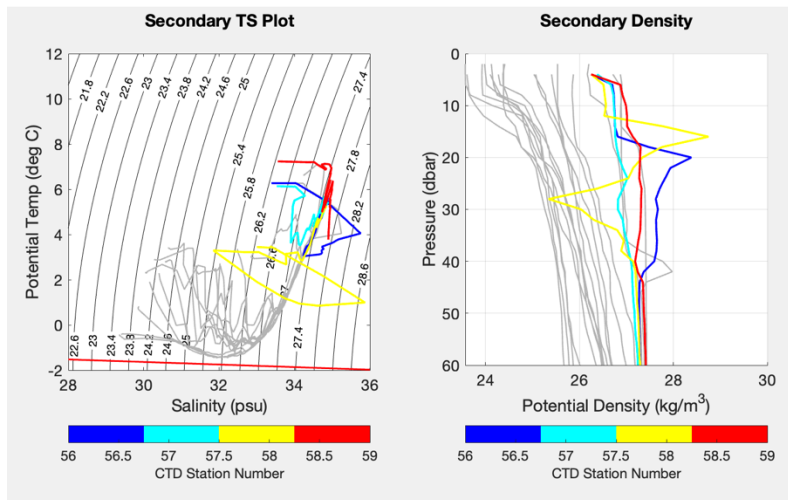
Stations 6 – 26:

Unphysical density in primary sensors during the beginning of the downcast. Primary t and s data overwritten by secondary.



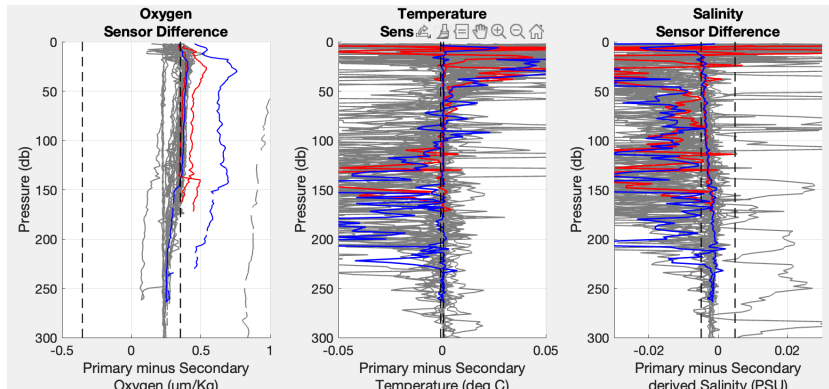
Stations 55 – 59:

Unphysical density in secondary sensors during the beginning of the downcast. Secondary t and s data overwritten by primary.



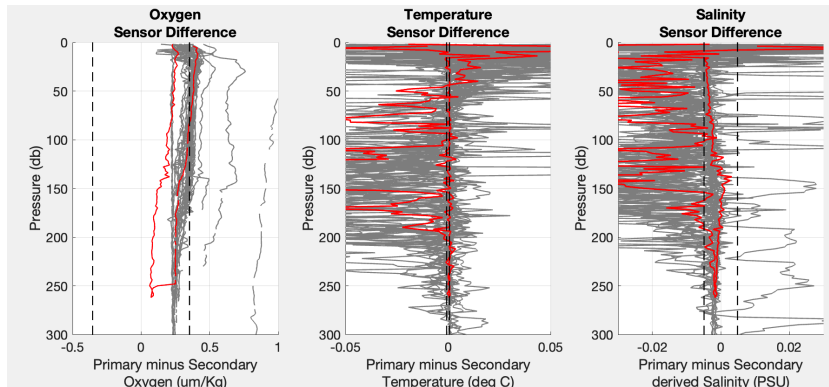
Stations 103 – 104:

Unphysical oxygen during downcast and upcast in both primary and secondary sensors. T and S looked OK.



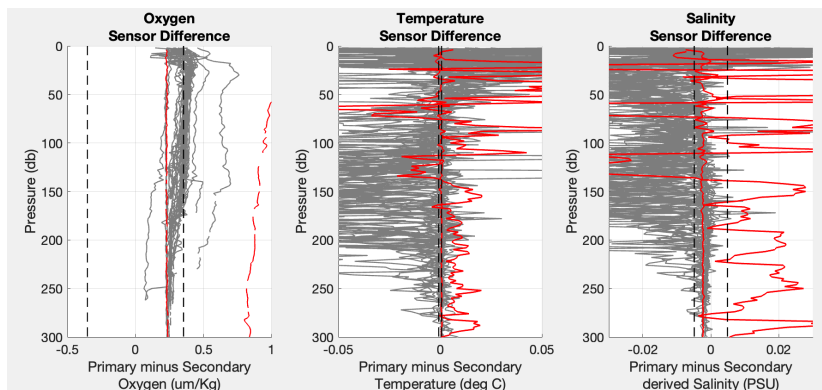
Station 114:

Unphysical oxygen during downcast and upcast in primary sensor. T and S looked OK.



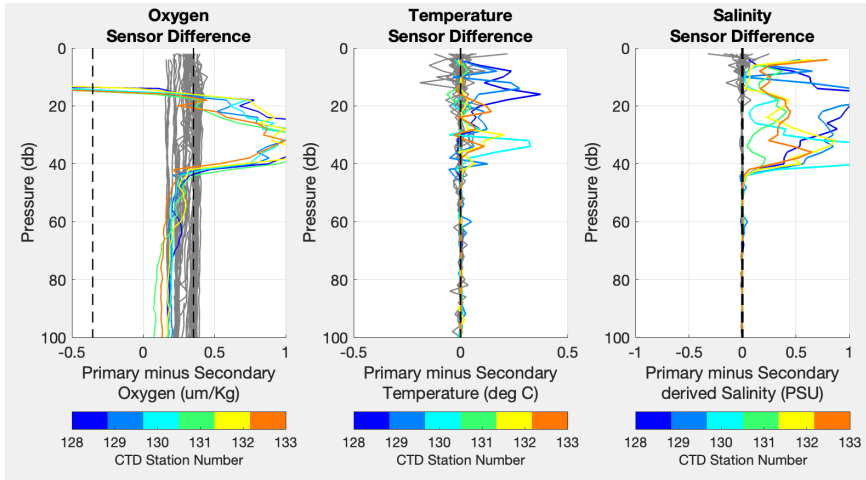
Station 120:

Unphysical secondary temperature, salinity and dissolved oxygen data on downcast and upcast. Secondary temperature and salinity overwritten by primary data.



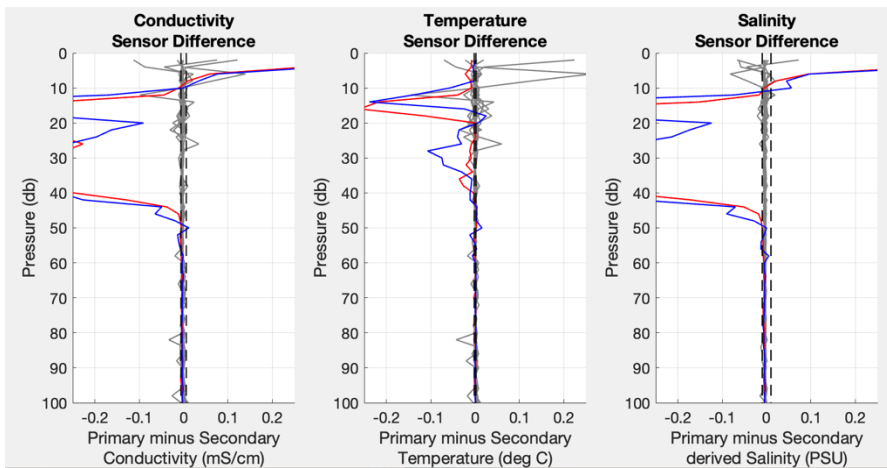
Stations 128 – 134:

Unphysical secondary temperature, salinity and dissolved oxygen data on downcast and upcast.  
Secondary temperature and salinity overwritten by primary data.



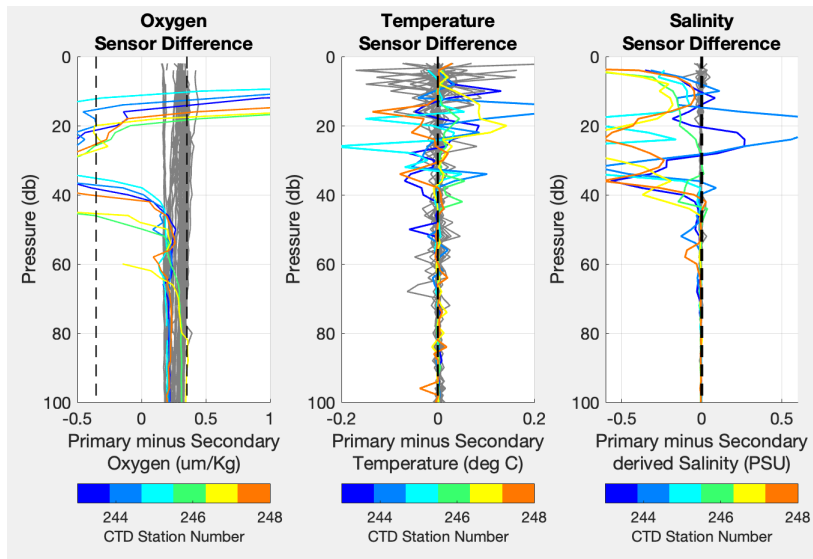
Stations 164 – 165:

Unphysical secondary temperature, salinity and dissolved oxygen data on downcast and upcast.  
Secondary temperature and salinity overwritten by primary data.



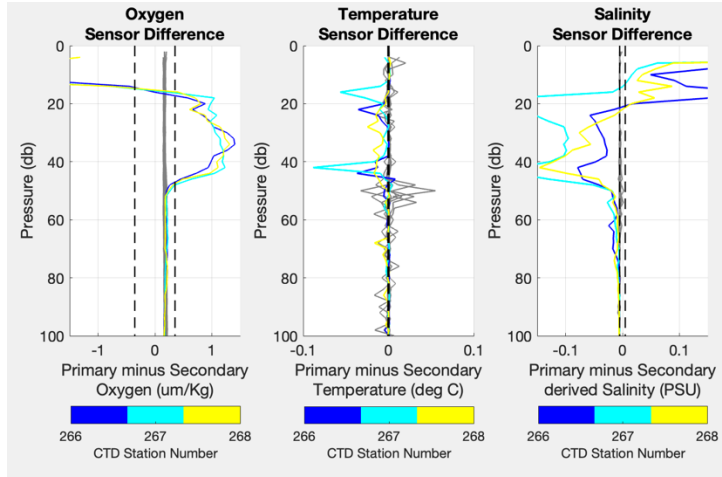
Stations 243 – 248:

Upper 40 meters during the downcast experienced unphysical primary t, s, and o data as shown in the density downcast and dissolved oxygen differences. Primary t and s replaced with secondary.



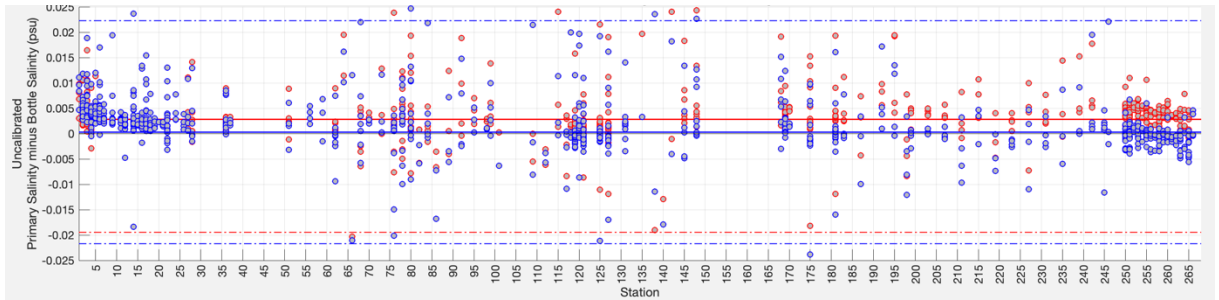
Stations 266 – 268:

Upper 40 meters during the downcast experienced unphysical secondary t, s, and o data as shown in the density downcast and dissolved oxygen differences. Secondary t and s replaced with primary.



### Stations 1:268:

The secondary conductivity sensor drifted towards a higher conductivity when compared to both the primary sensor and the bottle data. A station-dependent correction was used to address this at the calibration stage. Since the offset of the primary sensor remained more constant throughout the cruise, and because it was less impacted by the events summarized above, it is recommended that the primary sensor be used for science applications.



## SeaBird processing

As per manufacturer recommendations, CTD data were processed using SeaBird data processing software (ver. 7.22.0). The raw CTD data were converted from HEX to ASCII, lag corrected, edited for large spikes, smoothed according to sensor, and pressure averaged into 2 db bins for final data quality control and analysis. The following table summarizes the processing routines used together with SeaBird-recommended parameters for the sensor configuration used.

### SeaBird processing routines

SeaBird Module	Description (SeaBird, Version 7.22.0)
DATCNV	Convert the raw data to pressure, temperature, conductivity, and dissolved oxygen
BOTTLESUM	Writes out a summary of the bottle data to a file with a .btl extension
ALIGNCTD	Advance primary oxygen data by 5 seconds and secondary oxygen by 4 seconds relative to pressure
WILDEDIT	Checks for and marks 'wild' data points: first pass 2.0 standard deviations; second pass 20 standard deviations
CELLTM	Conductivity cell thermal mass correction $\alpha = 0.03$ and $1/\beta = 7.0$
FILTER	Low pass filter pressure and depth with a time constant of 0.15 seconds to increase pressure resolution for LOOPEDIT
LOOPEDIT	Mark scans where the CTD is moving less than the minimum velocity (0.25 m/s) or traveling backwards due to ship roll
DERIVE sal	Compute salinity
BINAVG	Average data into the 2 db pressure bins
SPLIT	Split .cnv file into upcast and downcast files

## Post-processing conductivity calibrations

### *Basic fitting procedure*

CTD salinity data were further calibrated by utilizing water sample salinity measurements. WHOI post-processing fitting procedures are modeled after methods used in Millard and Yang, 1993. CTD conductivity and water sample salinity differences were characterized as a function of pressure and time. One fit was created by grouping together data from all CTD stations occupied. The group was fit for a slope and bias adjustment using only water sample data that were within a defined physical range of CTD values. The slope term is a polynomial function of the station number based upon chronological station collection order. A linear pressure term (modified beta) was applied to conductivity slopes using a least-squares minimization of CTD and bottle conductivity differences.

The function minimized was:

$$BC - m * CC - b - \beta * CP$$

<i>BC</i>	- bottle conductivity [mS/cm]
<i>CC</i>	- pre-cruise calibrated CTD conductivity [mS/cm]
<i>CP</i>	- CTD pressure [db]
<i>m</i>	- conductivity slope
<i>b</i>	- conductivity bias [mS/cm]
$\beta$	- linear pressure term [mS/cm/db]

The final conductivity, FC [mS/cm] is:

$$FC = m * CC + b + \beta * CP$$

## Results

The polynomial functions determined for both primary and secondary sensor data are presented in the following table. Stations were grouped together by unique sensor configuration for determining post-calibration values. Once calibrated, the overall standard deviation of the primary CTD conductivity measurements (s/n 2304) and water sample differences is **0.0012 psu**. The overall standard deviation of the secondary CTD conductivity measurements (s/n 2670) and water sample differences is **0.0013 psu**. Figures that summarize conductivity calibrations are included in Appendix B.

Final CTD conductivity calibration parameters

Sensor	Stations	Bias	Slope (stations 1-268)	Beta	Final standard deviation
<b>Primary</b>					<b>0.0012 psu</b>
2304	1 – 268	0.01438093	0.99971252-0.99970632	-7.57221612e-07	
<b>Secondary</b>					<b>0.0013 psu</b>
2670	1 – 268	0.00010173	1.00013408-0.99999403	0	

## Salinity water sample measurements

### Summary

1020 salinity salinity samples were collected during the AR84-02 cruise. Samples were analyzed at sea and used to post-calibrate the CTD sensors.

### Methods

Water was collected in 200 ml glass bottles. The bottles were rinsed three times, and then filled to the neck. After the samples reached the lab temperature of approximately 20 °C, they were analyzed for salinity using a Guildline Salinometer model 8400 B. The salinometer's bath temperature was set to 21 °C and was standardized before and after each run using IAPSO Standard Seawater (batch 171). Accuracies of salinity measurements were  $\pm 0.002$  psu when a good standardization was achieved (see above notes from Outline of important events and problems). Bottle salinities were assigned a quality control flag based upon the difference between CTD salinity (calibrated) at the same pressure and/or at the same potential temperature.

## Oxygen water sample measurements

Dissolved oxygen samples were analyzed during the cruise with an SIO/ODF-designed automated oxygen titrator. A total of 589 oxygen samples were collected (including duplicates). Flasks were rinsed 3 times with minimal agitation using a silicone draw tube, then filled and allowed to overflow, ensuring no bubbles remained. Pickling reagents MnCl<sub>2</sub> and NaI/NaOH (1 mL of each) were added via bottle-top dispensers to fix samples before stoppering. Flasks were shaken to assure thorough dispersion of the precipitate - once immediately after drawing and then again after 20-60 minutes. Sample draw temperatures were used to calculate  $\mu\text{mol/kg}$  concentrations. Niskin samples were analyzed within 2-24 hours of collection. Sample values have been merged with AR84-02\_\*\*\*\*.cbot\_so files and additional sensor corrections will be applied by Kristen Fogaren of Boston College.

## DIC/TA water sample measurements

57 DIC/TA samples were drawn, poisoned with Mercuric Chloride, and stored for onshore analysis. DIC/TA samples were taken at all oxygen sample sites. DIC/TA supplies were provided by H. Palevsky, who is responsible for analyzing the samples (Boston College; palevsky@bc.edu; GOHSNAP co-PI).

## Appendix A

Date: 11/08/2024

Instrument configuration file: C:\ctd\AR84-02\raw\AR84-02\_001.XMLCON

Configuration report for SBE 911plus/917plus CTD

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Frequency channels suppressed : 0  
Voltage words suppressed : 0  
Computer interface : RS-232C  
Deck unit : SBE11plus Firmware Version >= 5.0  
Scans to average : 1  
NMEA position data added : Yes  
NMEA depth data added : No  
NMEA time added : Yes  
NMEA device connected to : PC  
Surface PAR voltage added : Yes  
Scan time added : No

### 1) Frequency 0, Temperature

Serial number : 4406  
Calibrated on : 03-Oct-23  
G : 4.33642307e-003  
H : 6.36720651e-004  
I : 2.08192034e-005  
J : 1.76403241e-006  
F0 : 1000.000  
Slope : 1.00000000  
Offset : 0.0000

### 2) Frequency 1, Conductivity

Serial number : 2304  
Calibrated on : 27-Oct-23  
G : -1.00502377e+001  
H : 1.51189473e+000  
I : 4.25832251e-004  
J : 7.17494918e-005  
CTcor : 3.2500e-006  
CPcor : -9.57000000e-008  
Slope : 1.00000000  
Offset : 0.00000

### 3) Frequency 2, Pressure, Digiquartz with TC

Serial number : 1478  
Calibrated on : 13-Sept-21  
C1 : -4.178653e+004  
C2 : 6.327420e-002  
C3 : 1.445100e-002

D1 : 3.433200e-002  
D2 : 0.000000e+000  
T1 : 3.015270e+001  
T2 : -2.695360e-004  
T3 : 4.669030e-006  
T4 : 2.411500e-009  
T5 : 0.000000e+000  
Slope : 1.00001150  
Offset : 1.80000  
AD590M : 1.279495e-002  
AD590B : -9.556051e+000

#### 4) Frequency 3, Temperature, 2

Serial number : 4481  
Calibrated on : 14-Oct-23  
G : 4.33633901e-003  
H : 6.38110320e-004  
I : 2.19101911e-005  
J : 2.03407172e-006  
F0 : 1000.000  
Slope : 1.00000000  
Offset : 0.0000

#### 5) Frequency 4, Conductivity, 2

Serial number : 2670  
Calibrated on : 18-Oct-23  
G : -1.03878838e+001  
H : 1.50194648e+000  
I : -7.87972807e-004  
J : 1.50474203e-004  
CTcor : 3.2500e-006  
CPcor : -9.57000000e-008  
Slope : 1.00000000  
Offset : 0.00000

#### 6) A/D voltage 0, Altimeter

Serial number : VA500-46506  
Calibrated on : 2018  
Scale factor : 15.000  
Offset : 0.000

#### 7) A/D voltage 1, Oxygen, SBE 43

Serial number : 0072  
Calibrated on : 03-Oct-23  
Equation : Sea-Bird  
Soc : 4.63190e-001  
Offset : -4.88200e-001  
A : -5.35510e-003  
B : 2.42950e-004  
C : -3.49330e-006  
E : 3.60000e-002  
Tau20 : 1.19000e+000

D1 : 1.92634e-004  
D2 : -4.64803e-002  
H1 : -3.30000e-002  
H2 : 5.00000e+003  
H3 : 1.45000e+003

8) A/D voltage 2, Fluorometer, WET Labs ECO-AFL/FL

Serial number : FLNTURT-969  
Calibrated on : 2019-05-09  
Dark output : 0.0790  
Scale factor : 1.10000000e+001

9) A/D voltage 3, Turbidity Meter, WET Labs, ECO-NTU

Serial number : FLTURT-969  
Calibrated on : 2019-May-19  
ScaleFactor : 5.000000  
Dark output : 0.050000

10) A/D voltage 4, Transmissometer, WET Labs C-Star

Serial number : CST-2034  
Calibrated on : 2021-Aug-20  
M : 21.0838  
B : -0.1054  
Path length : 0.250

11) A/D voltage 5, Oxygen, SBE 43, 2

Serial number : 0449  
Calibrated on : 06-Mar-24  
Equation : Sea-Bird  
Soc : 3.81570e-001  
Offset : -7.17000e-001  
A : -3.49850e-003  
B : 1.49470e-004  
C : -2.69920e-006  
E : 3.60000e-002  
Tau20 : 1.12000e+000  
D1 : 1.92634e-004  
D2 : -4.64803e-002  
H1 : -3.30000e-002  
H2 : 5.00000e+003  
H3 : 1.45000e+003

12) A/D voltage 6, User Polynomial

Serial number : 0483  
Calibrated on : 09-27-2023  
Sensor name : Rinko III DO  
A0 : 0.00000000  
A1 : 0.00000000  
A2 : 0.00000000  
A3 : 0.00000000

13) A/D voltage 7, User Polynomial, 2

Serial number : 0483  
Calibrated on : 9-27-2023  
Sensor name : Rinko III Temp  
A0 : 0.00000000  
A1 : 0.00000000  
A2 : 0.00000000  
A3 : 0.00000000

14) SPAR voltage, Unavailable

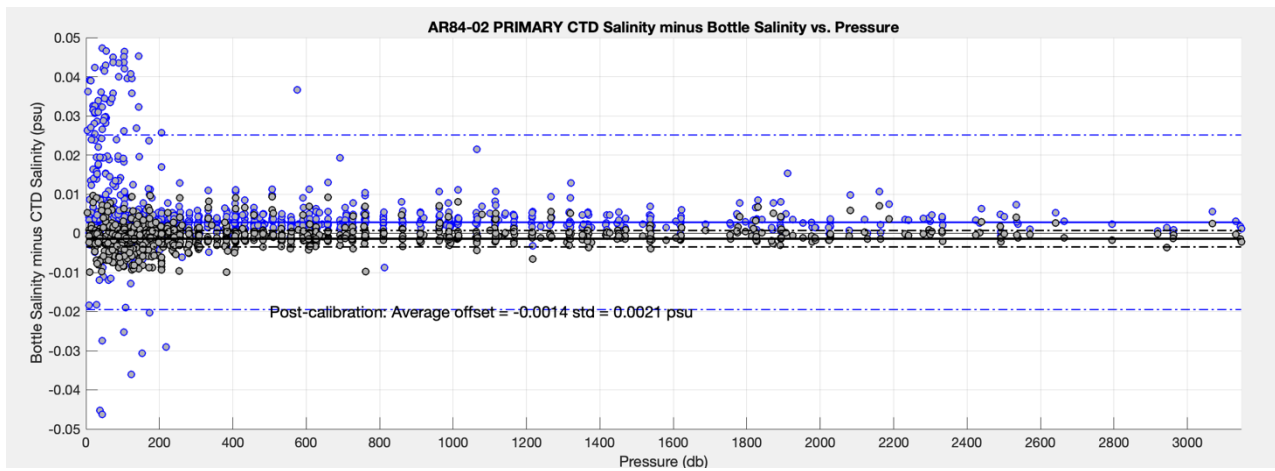
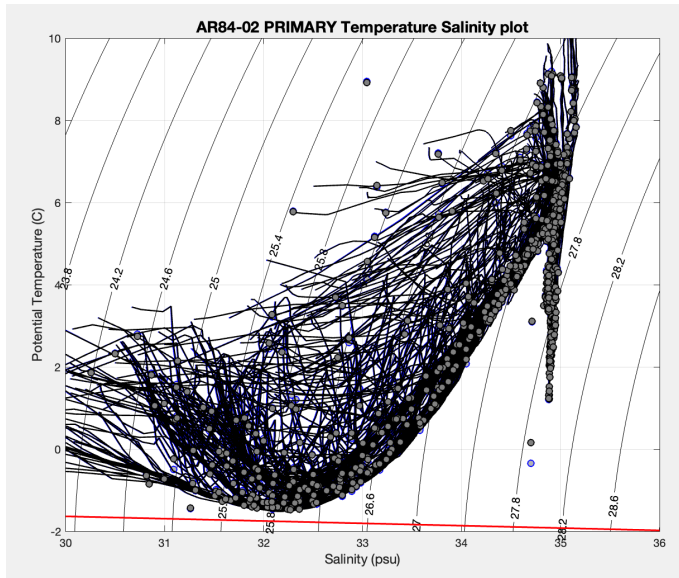
15) SPAR voltage, SPAR, Biospherical/Licor

Serial number :  
Calibrated on :  
Conversion units :  $\mu\text{mol photons/m}^2/\text{sec}$   
Conversion factor : 1.00000000  
Ratio multiplier : 0.00000000

Scan length : 44

## Appendix B

Primary conductivity post-calibration summary. Blue indicates CTD data before bottle calibration, black indicates CTD values after CTD calibration.



Secondary conductivity post-calibration summary. Red indicates CTD data before bottle calibration, black indicates CTD values after CTD calibration.

