CTD Calibration Report
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Cruise summary

Ship: RV *ARMSTRONG*
Project Name: OSNAP
Dates: August 27th – October 3rd, 2018
Ports: Reykjavik, Iceland - Reykjavik, Iceland

Data files included as part of this distribution

AR30-06_CTD_Calibration_Report.pdf
This document in pdf format

*AR30-06_****.dcc*
One 2 dB pressure-averaged file per station following WOCE format specifications for CTD data. Final .dco 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.

*AR30-06_****.cbot_s*
One file per station following the WOCE format specifications for cruise bottle data. The final .cbot_s 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 temperature (°C)
Sal(1)	Calibrated salinity (psu)
OxCur	Oxygen Current (V)
OXYG	Dissolved Oxygen (ml/l)
wocecode	WOCE quality word for each variable

Final .cnut_qc variable definitions

CTD Bottle Number	CTD rosette trigger position (Niskin number)
CTD Pres	CTD pressure (dB)
CTD T1	Calibrated temperature (°C)
CTD TH1	Calculated potential temperature (°C)
CTD Sal1	Calibrated 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
296 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 12 discrete intervals and analyzed for salinity. A rosette frame holding 12 5 L Niskin bottles was used for collecting water samples.

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 can be found in Appendix A.

CTD sensor calibration dates

Sensor Type	Sensor Number	Manufacturer	Calibration Dates	Stations Used
Pressure	0383	Sea-Bird	15-May-15	1-296
Temperature 1	4360	Sea-Bird	21-Oct-17	1-296
Temperature 2	4230	Sea-Bird	19-Oct-17	1-296
Conductivity 1	2707	Sea-Bird	20-Oct-17	1-296
Conductivity 2	3089	Sea-Bird	25-Oct-17	1-296
Oxygen 1	0930	Sea-Bird	17-Jan-18	1-296
Fluorometer	0149	WET Labs	28-Nov-16	1-296
Turbidity	FLNTURTD-149	WET Labs	28-Nov-16	1-296
Transmissometer	CST-116DR	WET Labs	7-Sept-11	1-296

Outline of important events and problems

Aug 29 2018 18:08 UTC: unphysical secondary temperature sensor
Secondary temperature sensor recorded unphysical data for stations 1-3. As such, secondary salinity was also bad. The problem was determined to be a loose connection on the CTD and was fixed for the remainder of the cruise. Secondary temperature and salinity were replaced with primary sensor values for stations 1-3.

Sep 17 2018 22:06 UTC: unphysical secondary salinity on upcast
Secondary conductivity and salinity were unphysical for the entire upcast of station 151. The problem was determined to be sea slime in the conductivity cell. Flushing the CTD resolved the issue. The secondary conductivity and salinity upcast data were replaced with the primary upcast data.

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 oxygen by 3.5 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
DERIVE oxy	Compute oxygen from oxygen current (filtered), temperature, and pressure
BINAVG	Average data into the 2 dbar pressure bins
SPLIT	Split .cnv file into upcast and downcast files

Post-processing conductivity calibrations

Basic fitting procedure

CTD salinity data were then 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 was 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:

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

BC - *bottle conductivity [mS/cm]*
CC - *pre-cruise calibrated CTD conductivity [mS/cm]*
CP - *CTD pressure [dbar]*
m - *conductivity slope*
b - *conductivity bias [mS/cm]*

β - *linear pressure term [mS/cm/dbar]*

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. Both primary and secondary sensors experienced a slow drift during the cruise. In order to characterize this, all stations were grouped together for the conductivity calibration. Once calibrated, the overall standard deviation of the primary CTD conductivity measurements (s/n 2707) and water sample differences is **0.0025 psu**. The overall standard deviation of the secondary CTD conductivity measurements (s/n 3089) and water sample differences is **0.0025 psu**. Figures that summarize conductivity calibrations are included in Appendix B.

Sensor	**Stations**	**Bias**	**Slope (min/max)**	**Beta**	**Final standard**
Primary					**0.0025 psu**
2707	0 – 296	-0.01256038	1.00041257/1.00056778	-2.30321589e-08	
Secondary					**0.0025 psu**
3089	0 – 296	-0.00831345	1.00035018/1.00049408	-2.59353139e-07	

Salinity water sample measurements

Summary

842 salinity water samples were collected from most stations occupied during the AR30-06 cruise. Samples were analyzed for concentrations 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 22˚C, they were analyzed for salinity using a Guildline Salinometer model 8400 B. The salinometer's bath temperature was set to 24˚C and was standardized before and after each run using IAPSO Standard Seawater (batch 171). Accuracies of salinity measurements were ±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.

Appendix A

From instrument configuration file: C:\data\ctd\IGP0118\raw\AR30-06_000.XMLCON

```
Instrument configuration file: C:\Documents and
Settings\chris\Desktop\AR30-06_001.XMLCON

Configuration report for SBE 911plus/917plus CTD
------------------------------------------------

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               : No
NMEA device connected to      : PC
Surface PAR voltage added     : Yes
Scan time added               : Yes

1) Frequency 0, Temperature

   Serial number : 4360
   Calibrated on : 21-Oct-17
   G             : 4.36258532e-003
   H             : 6.49689897e-004
   I             : 2.29935721e-005
   J             : 1.83426760e-006
   F0            : 1000.000
   Slope         : 1.00000000
   Offset        : 0.0000

2) Frequency 1, Conductivity

   Serial number : 2707
   Calibrated on : 20-Oct-17
   G             : -1.07309518e+001
   H             : 1.56086062e+000
   I             : -1.68173679e-003
   J             : 2.14726944e-004
   CTcor         : 3.2500e-006
   CPcor         : -9.57000000e-008
   Slope         : 1.00000000
   Offset        : 0.00000

3) Frequency 2, Pressure, Digiquartz with TC

   Serial number : 0383
   Calibrated on : 15-May-15
   C1            : -4.928049e+004
   C2            : -5.591409e-001
   C3            : 1.510530e-002
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```
   D1             : 3.944700e-002
   D2             : 0.000000e+000
   T1             : 3.017493e+001
   T2             : -4.671701e-004
   T3             : 3.967900e-006
   T4             : 3.098920e-009
   T5             : 0.000000e+000
   Slope          : 1.00004608
   Offset         : 1.67673
   AD590M         : 1.135000e-002
   AD590B         : -8.132450e+000

4) Frequency 3, Temperature, 2

   Serial number : 4230
   Calibrated on : 19-Oct-17
   G             : 4.37243607e-003
   H             : 6.48288745e-004
   I             : 2.27023046e-005
   J             : 1.80599980e-006
   F0            : 1000.000
   Slope         : 1.00000000
   Offset        : 0.0000

5) Frequency 4, Conductivity, 2

   Serial number : 3089
   Calibrated on : 25-Oct-17
   G             : -1.03675452e+001
   H             : 1.39508560e+000
   I             : -2.08055693e-004
   J             : 7.78467513e-005
   CTcor         : 3.2500e-006
   CPcor         : -9.57000000e-008
   Slope         : 1.00000000
   Offset        : 0.00000

6) A/D voltage 0, Fluorometer, WET Labs ECO-AFL/FL

   Serial number : 0149
   Calibrated on : 2016-11-28
   Dark output   : 0.0820
   Scale factor  : 1.60000000e+001

7) A/D voltage 1, Turbidity Meter, WET Labs, ECO-NTU

   Serial number : FLNTURTD-149-TU
   Calibrated on : 20161128
   ScaleFactor   : 4.000000
   Dark output   : 0.079000

8) A/D voltage 2, Oxygen, SBE 43

   Serial number : 0930
   Calibrated on : 17-Jan-18
```

```
   Equation      : Sea-Bird
   Soc           : 5.40740e-001
   Offset        : -4.97300e-001
   A             : -4.83140e-003
   B             : 2.48290e-004
   C             : -3.73310e-006
   E             : 3.60000e-002
   Tau20         : 1.37000e+000
   D1            : 1.92634e-004
   D2            : -4.64803e-002
   H1            : -3.30000e-002
   H2            : 5.00000e+003
   H3            : 1.45000e+003

9) A/D voltage 3, Free

10) A/D voltage 4, Free

11) A/D voltage 5, Free

12) A/D voltage 6, Altimeter

    Serial number : Valeport 46506
    Calibrated on :
    Scale factor  : 15.000
    Offset        : 0.000

13) A/D voltage 7, Transmissometer, WET Labs C-Star

    Serial number : CST-116DR
    Calibrated on : 07 Sept 2011
    M             : 22.1860
    B             : -1.2700
    Path length   : 0.250

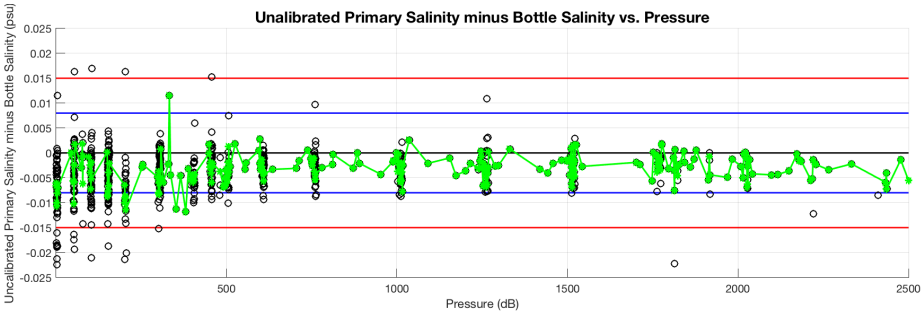
14) SPAR voltage, Unavailable

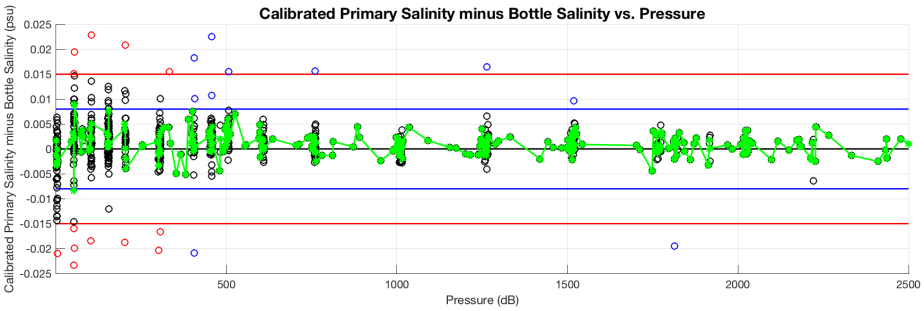
15) SPAR voltage, SPAR/Surface Irradiance

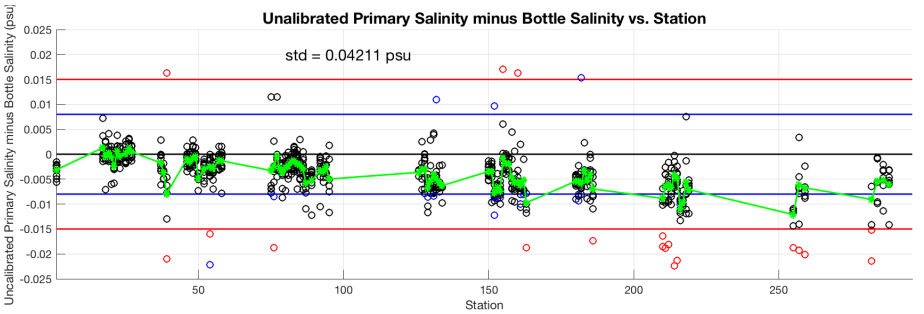
    Serial number     : QSR240 s/n 6294
    Calibrated on     : 8/2/2017
    Conversion factor : 1840.47619048
    Ratio multiplier  : 1.00000000

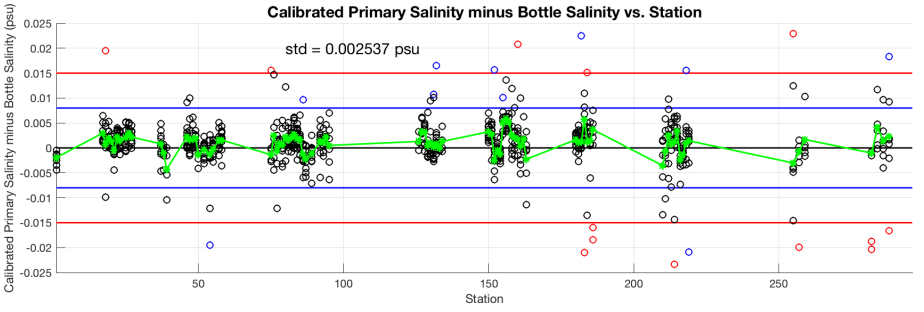
Scan length                  : 44
```

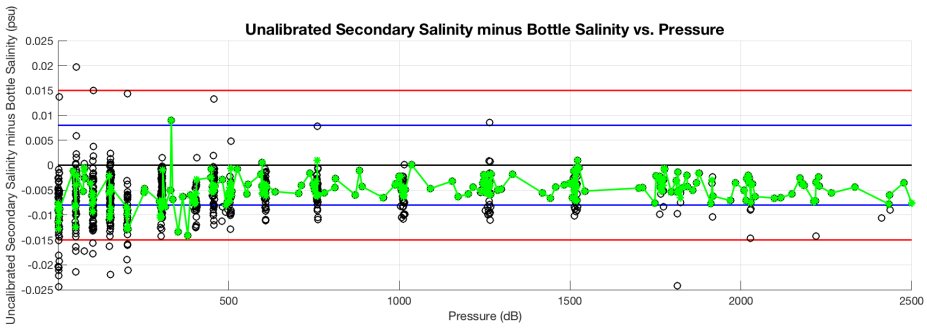
Appendix B

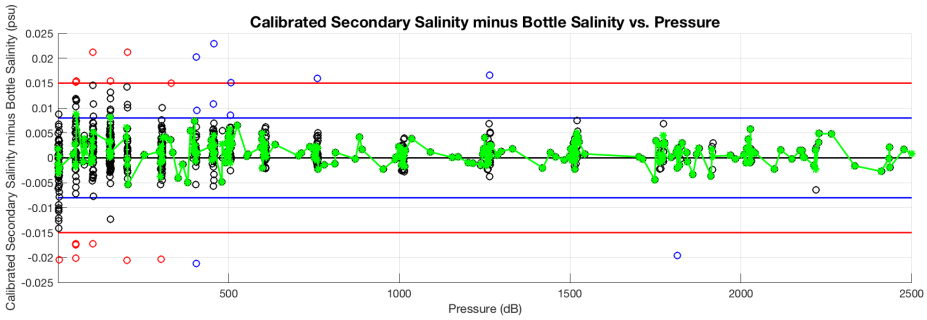

Unalibrated Primary Salinity minus Bottle Salinity vs. Pressure
Uncalibrated Primary Salinity minus Bottle Salinity (psu)
Pressure (dB)

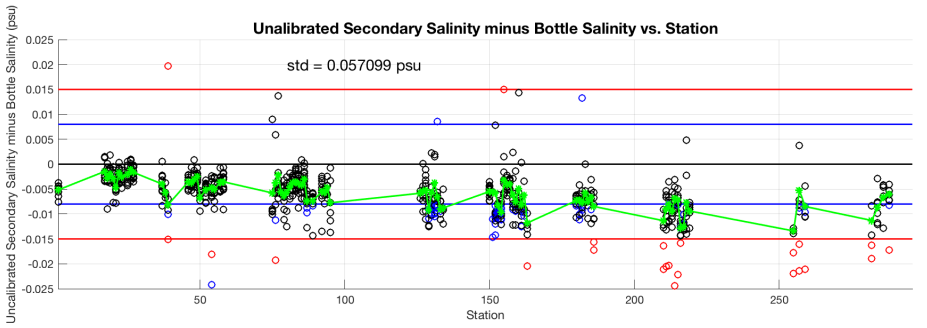

Calibrated Primary Salinity minus Bottle Salinity vs. Pressure
Calibrated Primary Salinity minus Bottle Salinity (psu)
Pressure (dB)

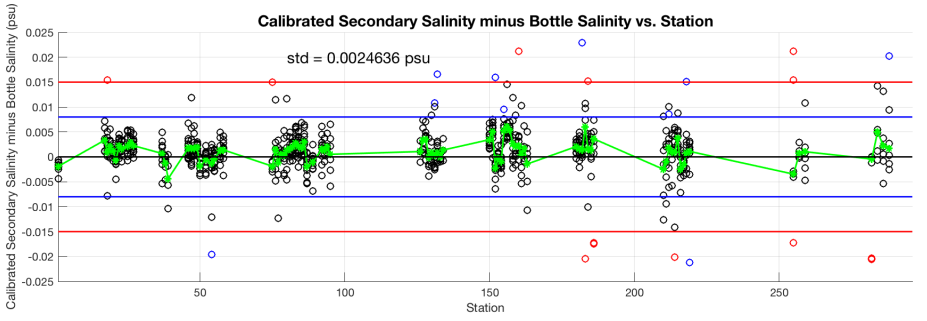

Unalibrated Primary Salinity minus Bottle Salinity vs. Station
std = 0.04211 psu
Uncalibrated Primary Salinity minus Bottle Salinity (psu)
Station


Calibrated Primary Salinity minus Bottle Salinity vs. Station
std = 0.002537 psu
Calibrated Primary Salinity minus Bottle Salinity (psu)
Station


Unalibrated Secondary Salinity minus Bottle Salinity vs. Pressure
Uncalibrated Secondary Salinity minus Bottle Salinity (psu)
Pressure (dB)


Calibrated Secondary Salinity minus Bottle Salinity vs. Pressure
Calibrated Secondary Salinity minus Bottle Salinity (psu)
Pressure (dB)


Unalibrated Secondary Salinity minus Bottle Salinity vs. Station
std = 0.057099 psu
Uncalibrated Secondary Salinity minus Bottle Salinity (psu)
Station


Calibrated Secondary Salinity minus Bottle Salinity vs. Station
std = 0.0024636 psu
Calibrated Secondary Salinity minus Bottle Salinity (psu)
Station