

SKQ2020-14S CTD Calibration Report
Leah McRaven
Woods Hole Oceanographic Institution

Cruise summary

Ship: RV *SIKULIAQ*
Project Name: Arctic Observing Network
Dates: 15 October – 19 November, 2020
Ports: Seward, AK – Seward, AK

Data files included as part of this distribution

SKQ202014S_CTD_Calibration_Report.pdf
This document in pdf format

*SKQ202014S_****.dcc*

One 1 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.

*SKQ202014S_****.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, and salinity 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 primary current (V)
OXYG	Dissolved primary oxygen (ml/l)
uOXY	Dissolved primary oxygen (µm/kg)
OxCur2	Oxygen primary current (V)
OXYG2	Dissolved secondary oxygen (ml/l)
uOXY2	Dissolved secondary oxygen (µm/kg)
Trans	Transmissivity (%)
Flur	Fluorescence (mg/m ³)
wocecode	WOCE quality word for each variable

Final .cbot_so 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	Bottle-calibrated primary salinity (psu)
CTD Sal2	Bottle-calibrated secondary salinity (psu)

CTD OXY	CTD primary dissolved oxygen (ml/l)
CTD OXY2	CTD secondary dissolved oxygen (ml/l)
CTD OXYu	CTD primary dissolved oxygen ($\mu\text{m}/\text{kg}$)
CTD OXY2u	CTD secondary dissolved oxygen ($\mu\text{m}/\text{kg}$)
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

148 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 and additional parameters. A rosette frame holding 24 10-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 and channels can be found in Appendix A.

CTD sensor calibration dates

Sensor Type	Sensor Number	Manufacturer	Calibration Dates	Stations Used
Pressure	1365	Sea-Bird	08-Jun-18	0-148
Temperature 1	6177	Sea-Bird	30-Jan-20	0-148
Temperature 2	6310	Sea-Bird	30-Jan-20	0-148
Conductivity 1	4790	Sea-Bird	26-Feb-20	0-148
Conductivity 2	4791	Sea-Bird	13-Feb-20	0-148
Oxygen 1	2643	Sea-Bird	03-Mar-20	0-148
Oxygen 2	2945	Sea-Bird	29-Jan-20	0-148
Fluorometer	FLNTURTD-3090	WET Labs	13-Jan-18	0-148
Transmissometer	1681DR	WET Labs	08-Oct-19	0-148

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 8 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 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]
β	- linear pressure term [mS/cm/db]

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

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

Results

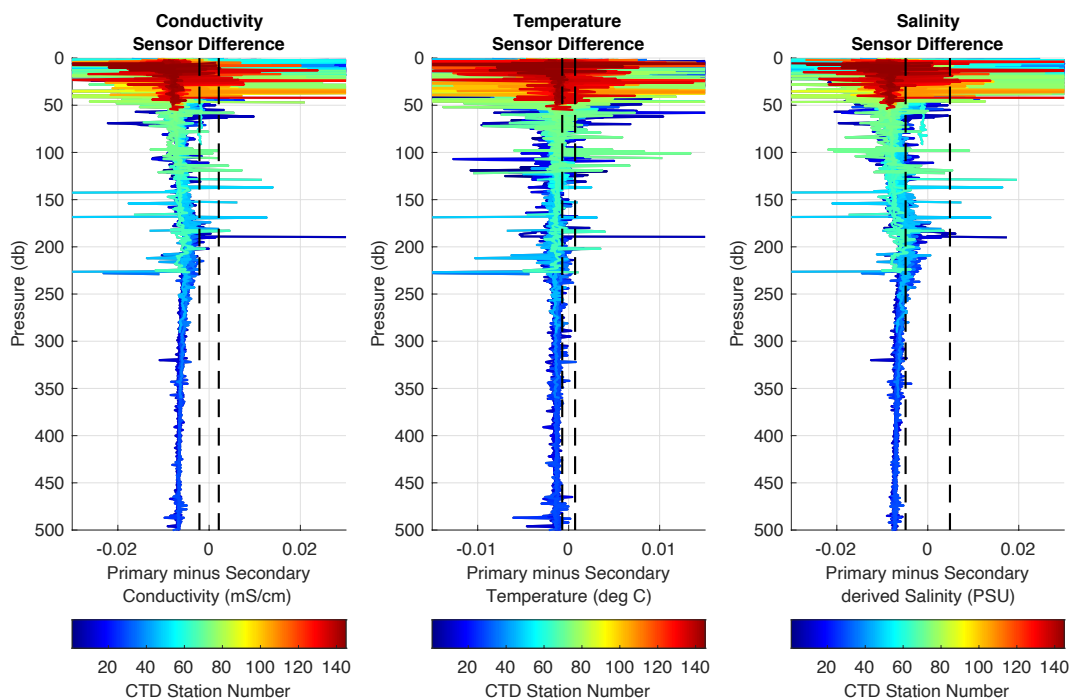
The polynomial functions determined for both primary and secondary sensor data are presented in the following table. Bottle salinity values from one deep cast early in the cruise were used for a calibration. Once bottle data were quality controlled and calibration applied to CTD data, the overall standard deviation of the primary CTD conductivity measurements (s/n 4790) and water sample differences is **0.0029 psu**. The overall standard deviation of the secondary CTD conductivity measurements (s/n 4791) and water sample differences is **0.0025 psu**. Figures that summarize conductivity calibrations are below and included in Appendix B.

Final CTD conductivity calibration parameters

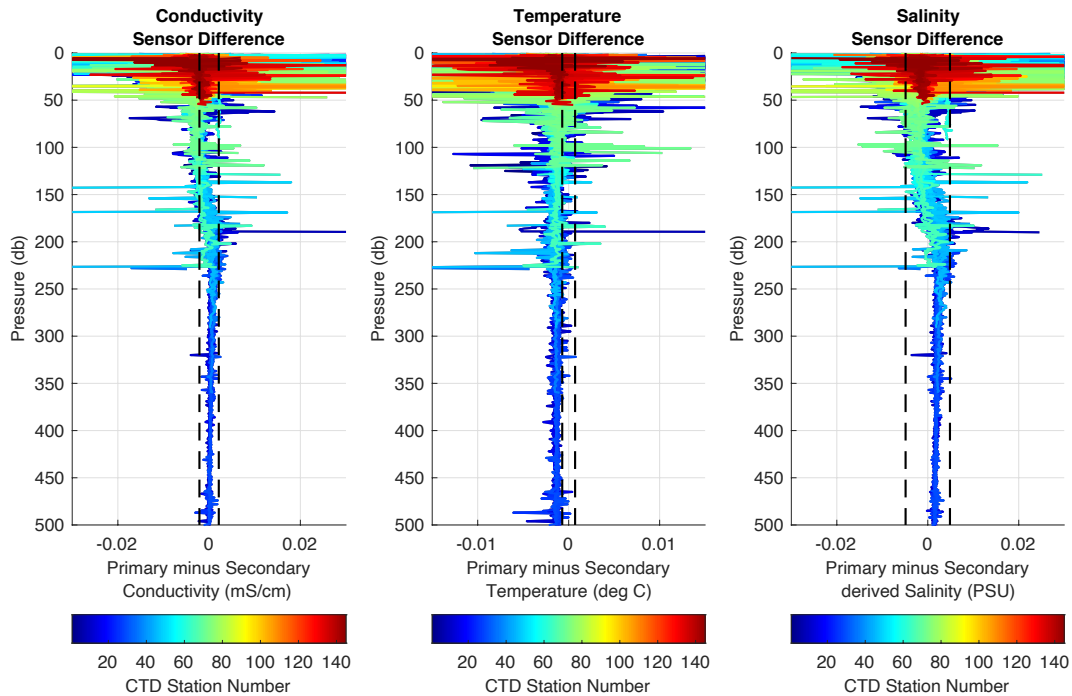
Sensor	Stations	Bias	Slope (min/max)	Beta	Final standard deviation
Primary					0.0029 psu
4790	0 – 148	0.33038966	0.98900301	-2.66901492e-06	
Secondary					0.0025 psu
4791	0 – 148	0.34835469	0.98815701	-1.60444630e-06	

Primary and secondary sensor differences before and after bottle calibration applied:

Pre-calibration:



Post-calibration:



Salinity water sample measurements

Summary

A small subset of salinity water samples were collected from one deep station and from occasional stations to watch for drift throughout the SKQ2020-14S 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 ± 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

Date: 03/23/2021

Instrument configuration file: C:\data\ctd\SKQ202014S\raw\SKQ202014S_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 : No
Scan time added : No

1) Frequency 0, Temperature

Serial number : 6177
Calibrated on : 30-Jan-20
G : 4.35450935e-003
H : 6.38033080e-004
I : 2.26612163e-005
J : 2.16361245e-006
F0 : 1000.000
Slope : 1.00000000
Offset : 0.0000

2) Frequency 1, Conductivity

Serial number : 4790
Calibrated on : 26-Feb-20
G : -9.77021762e+000
H : 1.31431815e+000
I : 6.59471886e-004
J : 1.46277579e-005
CTcor : 3.2500e-006
CPcor : -9.57000000e-008
Slope : 1.00000000
Offset : 0.00000

3) Frequency 2, Pressure, Digiquartz with TC

Serial number : 1365
Calibrated on : 08-Jun-18
C1 : -4.670000e+004
C2 : 6.623170e-001
C3 : 1.237300e-002
D1 : 3.900500e-002

D2 : 0.000000e+000
T1 : 3.010334e+001
T2 : -1.135030e-004
T3 : 3.648920e-006
T4 : 3.282390e-009
T5 : 0.000000e+000
Slope : 1.00000000
Offset : 0.00000
AD590M : 1.278450e-002
AD590B : -9.515090e+000

4) Frequency 3, Temperature, 2

Serial number : 6310
Calibrated on : 30-Jan-20
G : 4.41070105e-003
H : 6.43810296e-004
I : 2.33985542e-005
J : 2.20148540e-006
F0 : 1000.000
Slope : 1.00000000
Offset : 0.0000

5) Frequency 4, Conductivity, 2

Serial number : 4791
Calibrated on : 13-Feb-20
G : -9.73597772e+000
H : 1.25429933e+000
I : -1.87704397e-005
J : 5.84225489e-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 : FLRTD-3090
Calibrated on : 13-Jan-18
Dark output : 0.0098
Scale factor : 2.40000000e+001

7) A/D voltage 1, Free

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

Serial number : 2643
Calibrated on : 03-Mar-20
Equation : Sea-Bird
Soc : 6.02190e-001
Offset : -5.17700e-001
A : -4.25690e-003
B : 1.41300e-004
C : -2.33560e-006
E : 3.60000e-002

Tau20 : 1.16000e+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, Oxygen, SBE 43, 2

Serial number : 2945
Calibrated on : 29-Jan-20
Equation : Sea-Bird
Soc : 4.50810e-001
Offset : -4.89200e-001
A : -4.35000e-003
B : 2.14670e-004
C : -2.88310e-006
E : 3.60000e-002
Tau20 : 1.01000e+000
D1 : 1.92634e-004
D2 : -4.64803e-002
H1 : -3.30000e-002
H2 : 5.00000e+003
H3 : 1.45000e+003

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

Serial number : 1681DR
Calibrated on : 08-Oct-19
M : 21.3390
B : -0.0213
Path length : 0.250

11) A/D voltage 5, PAR/Irradiance, Biospherical/Licor

Serial number : 70777
Calibrated on : 06/24/20
M : 1.00000000
B : 0.00000000
Calibration constant : 8403361344.53800010
Multiplier : 1.00000000
Offset : -0.12272893

12) A/D voltage 6, Altimeter

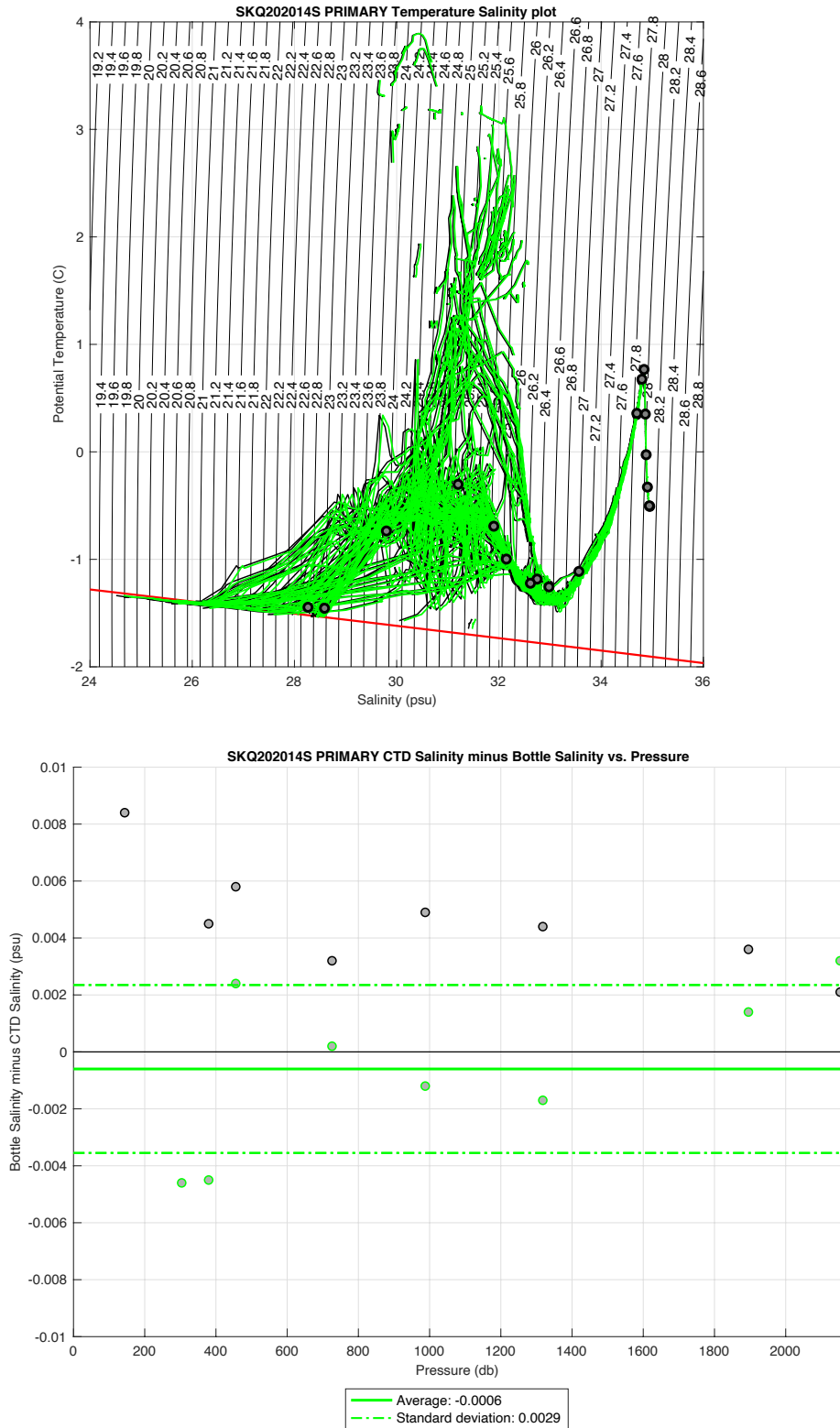
Serial number : 7232.302492
Calibrated on : 19-Sept-2013
Scale factor : 15.000
Offset : 0.000

13) A/D voltage 7, Free

Scan length : 37

Appendix B

Primary conductivity post-calibration summary. Black indicates CTD data before bottle calibration, green 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.

