LMG2001

Cruise Data Report

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Andrew F. Nunn

W. Kevin Pedigo

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Introduction

The LMG data acquisition systems continuously log data from a suite of instrumentation throughout the cruise. This document describes:

- The structure and organization of the data on the distribution media
- The format and contents of the data strings
- Formulas for calculating values
- Information about the specific instruments in use during the cruise
- A log of acquisition problems and events during the cruise that may affect the data
- Scanned calibration sheets for the instruments in use during the cruise.

All the data has been archived using 'tar' and compressed using 'gzip', identified by the '.gz' extension. Tools are available on all platforms for uncompressing and de-archiving these formats: On Macintosh use the built-in Archive Utility, or tar in the terminal. On Windows operating systems use WinZip or 7Zip.

IMPORTANT: Read the last section, "Acquisition Problems and Events," for important information that may affect the processing of this data.

Archive Data Extraction

It is often useful to know exactly how an archive was produced when expanding its contents. Tar files were created using the following commands:

```
tar cvf archive-file files-to-be-archived
```

To create a list of the files in the archive:

```
tar tvf  archive-file  > contents.list
```

To extract the files from the archive:

```
tar xvf  archive-file file(s)-to-extract
```

G-zipped files will have a ".gz" extension on the filename. These files can be decompressed after de-archiving, using:

```
gunzip filename.gz
```

Distribution Contents

ADCP data (/ADCP)

This directory contains a tar file of the ADCP system's "proc" directory, which is generated by the well-known ADCP system UHDAS, and contains averaged ping data, files used in processing the data, and daily graphs of the currents. For more information contact Teri Chereskin at tchereskin@ucsd.edu .

Data collection parameters (/CAL)

Refer to the InstCoef.txt file along with the specific instrument calibration sheets in this report for information on how the RVDAS data was collected and processed.

Imagery (/Imagery)

This directory contains things such as ice imagery, isobar charts, sat imagery, wave and wind images, and weather reports.

Automatically processed data (/process)

Contains automatically processed datasets and QC graphs produced by the RVDAS system

QC Plots (/process/QC.tar)

Postscript files of data stored each day on RVDAS for quality control analysis during the cruise. There are 3 types of files, named metXXX.ps, navXXX.ps, and oceanXXX.ps, where XXX is represents the Julian day. Met files are a summary of the data from the meteorological instruments, Nav files are a summary of navigational data, and Ocean files are a summary of the underway seawater and bathymetry data. Some files may have a PNG (Portable Network Graphics) format copy generated.

Reports (/Report)

Copies of this report in MS Word and pdf formats, and scanned copies of logsheets provided by various science groups.

Additional Data (/Science)

Instrument data (/rvdas)

Contains data collected by the suite of standard instruments on the LMG. This data is detailed later in the report

Utility programs (/Utility)

Contains utility programs to access the data on the distribution.

JGOFS Data Set

/Process/JGOF/

The JGOFS data set consists of a single file produced each day named jg<julian_day>.dat.gz where <julian_day> is the day the data was acquired. The ".gz" extension indicates that the individual files are compressed before archiving. The daily file consists of 22 separate columnar fields in text format, which are described below. The JGOFS data set is obtained primarily by applying calibrations to raw data and decimating to whole minute intervals. However, several fields are derived measurements from more than a single raw input. *Note: Null, unused, or unknown fields are filled with 9's in the JGOFS data.*

Additionally, 3 separate QC plots are generated daily by the ET using the JGOFS data set. These plots include TSG and Bathymetry data, meteorological data, and navigation data. The files are called ocean<julian_day>.ps, met<julian_day>.ps, and nav<julian_day>.ps respectively.

Field	Data	Units
01	GMT Date	dd/mm/yy
02	GMT Time	hh:mm:ss
03	Seapath Latitude (negative is South)	tt.tttt
04	Seapath Longitude (negative is West)	ggg.gggg
05	Speed Over Ground	knots
06	GPS HDOP	-
07	Gyro Heading	Degrees (azimuth)
08	Course Made Good	Degrees (azimuth)
09	Mast PAR	µEinstein's/meter^2
10	Sea Surface Temperature	°C
11	Sea Surface Conductivity	siemens/meter
12	Sea Surface Salinity	PSU
13	Sea Depth (uncorrected, 1500 m/s)	meters
14	True Wind Speed (max speed windbird)	meters/sec
15	True Wind Direction (max speed windbird)	degrees (azimuth)
16	Ambient Air Temperature	°C
17	Relative Humidity	%
18	Barometric Pressure	mBars
19	Sea Surface Fluorometry	µg/l
20	Transmissometer Voltage[1]	V
21	PSP	W/m2
22	PIR	W/m2

[1] Calibration factors to calculate % transmission can be found in the calibration sheet section and in instrument.coeff

pCO2-merged Data Set

/Process/PCO2/

```
23:59:00 00+346:23:58:20.672 2000346.9991 2398.4 1008.4 0.01 45.4 350.3 342.6 15.77 Equil -43.6826
173.1997 15.51 33.90 0.33 5.28 9.05 1007.57 40.0 14.87 182.44 -1

00:02:00 19+013:00:02:29.361 2019013.00358 2753.08 38.49 981.73 52.50 408.58 393.25 1.28 1.23 6.00
CB08811 -66.4966 -69.8680 0.97 33.87 0.94 6.36 48.43 983.08 35.07 2.21 8.86 296.40 1.65 33.86 2.06
```

Field	Data	Format	Unit
1	Elapsed time	hh:mm:ss	min
1	RVDAS time tag	yy+ddd:hh:mm:ss.sss	UTC
2	pCO_2 time tag*	yyyyddd.ttt	UTC
3	Raw Voltage (IR)	xxxx.xx	mV
4	Cell Temperature	xx.xx	°C
5	pCO_2 system internal Barometer	xxx.xx	mBar
6	Flowrate	xxx.xx	cm^3/min
7	VCO_2 Concentration	xxx.xx	µAtm
8	pCO_2 Pressure	xx.xx	ppm
9	Equilibrator Temperature, RTD	xx.xx	°C
10	Equilibrator Temperature, SBE38	xx.xx	°C
11	Valve Position	xx	numeric
12	Gas Flow Source (Equil = pCO_2 measurement)		text
13	Latitude	xx.x	degrees
14	Longitude	xxx.xxxxx	degrees
15	Sea Water Intake Temperature	xx.xxx	°C
16	Sea Surface Salinity	xx.xxx	PSU
17	Sea Surface Fluorometry	x.xxx	mg/m^3
18	True Wind Speed	x.xx	m/s
19	True Wind Direction	x.xx	degrees
20	Barometric Pressure	xxx.xx	mBar
21	Hydro-Lab H_2O Flow Rate	xxx.x	Raw counts
22	Speed over Ground	x.xx	knots
23	Course Made Good	xx.xx	degrees
24	Oxygen	xxx.xx	µm/kg
25	TSG2 Internal Temperature	x.xx	°C
26	TSG2 Salinity	xx.xx	PSU
27	TSG1 Internal Temperature	x.xx	°C

*decimal is fractional time of day

RVDAS

/RVDAS/

RVDAS (Research Vessel Data Acquisition System) was originally developed at Lamont-Doherty Earth Observatory of Columbia University and was used on the R/V Maurice Ewing for many years. It was modified extensively for use on the Nathaniel B. Palmer and her sister ship, the R/V Laurence M. Gould.

Daily data processing of the RVDAS data is performed to calibrate and convert values into useable units and as a quality control on operation of the DAS. Raw and processed data sets from RVDAS are included in the data distribution. The tables below provide detailed information on the sensors and data. Be sure to read the "Significant Acquisition Events" section for important information about data acquisition during this cruise.

Sensors and Instruments

We divide RVDAS data into two general categories, *underway and navigation*. The raw data can be found on the distribution media as subdirectories under the top-level rvdas directory: /rvdas/uw, and /rvdas/nav. Processed data is in the top level directory, /process. Each instrument or sensor produces a data file named with its channel ID. Each data file is g-zipped to save space on the distribution media. Not all data types are collected every day or on every cruise.

The naming convention for data files produced by the sensors and instruments is

```
LMG[CruiseID][ChannelID].dDDD
```

Example: `LMG1804lmwx.d112`

The CruiseID is the numeric name of the cruise, in this case.

The ChannelID is a 4-character code representing the system being logged. An example is "mwx1," the designation for meteorology.

DDD is the day of year the data was collected

Underway Sensors

Meteorological Data

Measurement	String ID	Collection Status	Rate	Instrument
Air Temperature	lmwx (met)	Continuous	1/sec	Rotronic HC2-S3
Relative Humidity	lmwx (met)	Continuous	1/sec	Rotronic HC2-S3
Wind Speed / Direction	lmwx (pus,sus)	Continuous	1/sec	Gill Instruments 1390-PK-062
Barometer	lmwx (met)	Continuous	1/sec	Vaisala PTB210B
PAR	lmwx (met)	Continuous	1/sec	Biospherical Instruments QSR-240
PIR	lmwx (met)	Continuous	1/sec	Eppley PIR
PSP	lmwx (met)	Continuous	1/sec	Eppley PSP
GUV	lguv	Continuous	2/sec	Biospherical Instruments GUV-2511

Navigational Data

Measurement	String ID	Collection Status	Rate	Instrument
Gyroscope	lgyr	Continuous	5/sec	Meridian Bridgemate Gyro
Seapath GPS	lsep	Continuous	1/sec	Seapath 330
Garmin GPS	lgar	Continuous	1/sec	Garmin 19
AIS	lais	Continuous	var	Standard Horizon GX2150

Geophysical Data

Measurement	String ID	Collection Status	Rate	Instrument
Bathymetry	lknu	Variable	Varies	Knudsen Chirp 3260
Dush-11 Winch	lwn1	Variable	20/sec	Markey DUSH-11
Dush-5 Winch	lwn1	Variable	20/sec	Markey DUSH-5
Dush-4 Winch	lwn1	Variable	20/sec	Markey DUSH-4

Oceanographic Data

Measurement	String ID	Collection Status	Rate	Instrument
Salinity	utsg	Continuous	3 sec	Seabird-45
Salinity (secondary)	tsg2	Continuous	3 sec	Seabird-45
Sea Surface Temperature	lrtm	Continuous	1 sec	Seabird-38
Fluorometry	ldfl	Continuous	1 sec	WetLabs ECO
ADCP, Speed Log	ladc	Continuous	1 sec	RD Instruments Workhorse 150
Dissolved Oxygen	loxy	Continuous	1 sec	Anderaa Optode
pCO_2	lpco2	Continuous	2.5 min	PCO2 System

Data File Names and Structures

RVDAS data is divided into two broad categories, ***Underway*** and ***Navigation***. The groups are abbreviated "uw" and "nav". Thus, these two tar files, lmguw.tar and lmgnav.tar exist under the top-level rvdas directory. The instruments are broken down as shown. Each data file is g-zipped to save space on the distribution. Not all data types are collected every day or on every cruise.

RVDAS data files are named following the convention: LMG[FileID].dDDD.

- The FileID is a 4-character code representing the system being logged, for example: lmet (for meteorology)
- DDD is the Julian day of the data collection

Underway Data	File ID	Navigation Data	File ID
Meteorological	lmwx	Gyro Compass	lgyr
Knudsen	lknu	Garmin GPS	lgar
microTSG	utsg	Seapath GPS	lsep
Sea Surface Temperature	lrtm	AIS	lais
Fluorometer	ldfl		
ADCP	ldfl		
Sound Velocity Probe	lsvp		
GUV & PUV	lguv		
PCO2 system	lpco		
Dissolved Oxygen	loxy		
Sea Water Wall	lsea		
Winches	lwn1		

Data is received by the RVDAS system via RS-232 serial connections. The data files that comprise the rvdas data set are described below. A time tag is added to each line of data received and the data is written to disk.

```
YY+DDD:HH:MM:SS.SSS [data stream from instrument]
```

Where, YY: two-digit year, DDD: Julian Day, HH: 2 digit hours, MM: 2 digit minutes SS.SSS: seconds. All times are UTC.

The delimiters used to separate fields in the raw data files are usually spaces and commas, but other delimiters are used (::, =, @) and occasionally there is no delimiter. Care should be taken when reprocessing the data that the field separations are clearly understood. Example data strings of the loggers follow.

lknu – Knudsen Chirp 3260 Sonar

```
14+002:19:07:04.648 3.5kHz,4000.92,1,12.0kHz,4001.12,1,1500,-57.343073,-63.750720
```

Field	Data	Format	Unit
1	RVDAS time tag	yy+ddd:hh:mm:ss.sss	UTC
2	3.5kHz = Low frequency in use	text	3.5kHz
3	Low Frequency Depth	xxxx.xx	m
4	Valid Flag	x	0 or 1
5	12.0kHz = High frequency in use	text	12.0kHz
6	High Frequency Depth	xxxx.xx	m
7	Valid Flag	x	0 or 1
8	Empty Field	0.00	NA
9	Latitude	xx.xxxxxx	degrees
10	Longitude	xx.xxxxxx	degrees

lwn1 - Winches

```
16+093:16:55:49.561 -01RD,2016-04-02T12:38:50.854,DUSH11,-0000233,00000000,000000.0,3275
```

Field	Data	Format	Unit
1	RVDAS time tag	yy+ddd:hh:mm:ss.sss	UTC
2	Record Identifier, RD=Remote Data		alphanumeric
3	LCI-90i Date and Time	yyyy-mm-ddThh:mm:ss	
4	Winch Identifier		text
5	Winch Name		alphabetical
6	Tension	xxxxxxxx	lbs
7	Speed	xxxxx.x	m/min
8	Payout	xxxxx.x	m
9	Checksum	x.xxxx	numeric

lmwx – Campbell Meteorological DAS

```
17+050:00:00:00.258 MET,12.5,58,-0.25,90.6,14.16584,0.0273877,-0.02605171,272.1153, 272.0825,993.81
```

Field	Data	Format	Unit
1	RVDAS time tag	yy+ddd:hh:mm:ss.sss	UTC
2	MET Flag		
3	Power Supply Voltage	vv.v	V
4	Enclosure Relative Humidity (not implemented)	xx	%
5	Air Temperature, Celsius	xx.xx	°C
6	Air Relative Humidity	xx.x	%
7	PAR (Photosynthetically Available Radiation)	xxx.xxxxx	mV
8	PSP (Shortwave Radiation)	x.xxxxxxxx	mV
9	PIR Thermopile (Longwave Radiation)	x.xxxxxxxx	mV
10	PIR Case Temperature	xxx.xxxx	°K
11	PIR Dome Temperature	xxx.xxxx	°K
12	Barometer	xxx.xxxx	mBar

```
08+034:13:52:14.216 PUS,A,356,002.15,M,+332.28,+000.97,60,08
08+034:13:52:14.216 SUS,A,356,002.15,M,+332.28,+000.97,60,08
```

Field	Data	Format	Unit
1	RVDAS time tag	yy+ddd:hh:mm:ss.sss	UTC
2	Identifier (PUS = port, SUS = stbd)	xxx	Text
3	A	x	A
4	Port Wind Relative Direction	xxx	degrees
5	Port Wind Relative Speed	xxx.xx	m/s
6	M = Meters (for previous)	x	M
7	Sound Speed	xxx.xx	m/s
8	Sonic Temperature	xxx.xx	ºC
9	Unit Status	xx	numeric
10	Checksum	xx	alphanumeric

lguv – Biospherical GUV

```
08+037:14:17:59.211 020608 141758 -.000099 1.307E0 7.24E0 1.316E1 2.609E1 3.285E1 3.505E1 8.075E-2
38.993 17.985
```

Field	Data	Units
1	RVDAS time tag	yy+ddd:hh:mm:ss.sss
2	GUV Computer date	mmddyy
3	GUV Computer Time	hhmmss
4	Ed0Gnd	Volts
5	Ed0305	$\mu W/cm^2nm$
6	Ed0313	$\mu W/cm^2nm$
7	Ed0320	$\mu W/cm^2nm$
8	Ed0340	$\mu W/cm^2nm$
9	Ed0380	$\mu W/cm^2nm$
10	Ed0395	$\mu W/cm^2nm$
11	Ed0PAR	$\mu E/cm^2sec$
12	Ed0Temp	°C
13	Ed0Vin	Volts

lsea – seawater DAS

Seawater wall flows, sensor data, ad hoc instrumentation and display

```
12+004:12:01:04.438 WetLab_1,14.1,XMISS,3.098,V,0.000,0.000,0.000,-928.535,-
220.566,0.000,0.000,T,NAN,NAN,NAN,NAN,P,0,0,F,47.91811,0,6.815308,0,0,0,0,0,I,1,1,1,1
```

Field	Data	Unit
1	RVDAS time tag	UTC
2	WetLab_1	Text
3	Internal Temperature	ºC
4	XMISS	Text
5	Transmissometer Reading	volts
6	V	Text
7	High precision voltage #1 (not used)	mV
8	High precision voltage #2 (not used)	mV
9	High precision voltage #3 (not used)	mV
10	Standard precision voltage #1 (not used)	mV
11	Standard precision voltage #2 (not used)	mV
12	Standard precision voltage #3 (not used)	mV
13	Standard precision voltage #4 (not used)	mV
14	T	Text
15	Temperature Probe 1 (not used)	°C
16	Temperature Probe 2 (not used)	°C
17	Temperature Probe 3 (not used)	°C
18	Temperature Probe 4 (not used)	°C
19	P	Text
20	Pulse Counter 1 (not used)	counts
21	Pulse Counter 2 (not used)	counts
22	F	Text
23	Flow Counter #1	counts
24	Flow Counter #2 (not used)	counts
25	Flow Counter #3	counts
26	Flow Counter #4 (not used)	counts
27	Flow Counter #5 (not used)	counts
28	Flow Counter #6 (not used)	counts
29	Flow Counter #7 (not used)	counts
30	Flow Counter #8 (not used)	counts
31	I	Text
32	Digital Input #1 (not used)	1 or 0
33	Digital Input #2 (not used)	1 or 0
34	Digital Input #3 (not used)	1 or 0
35	Digital Input #4 (not used)	1 or 0

utsg & tsg2 – Thermosalinograph

For further information on this data, check www.seabird.com for SBE 45 MicroTSG Thermosalinograph

```
08+037:13:45:57.596   2.6470,  3.03853,  33.8129, 1475.332
```

Field	Data	Format	Unit
1	RVDAS time tag	yy+ddd:hh:mm:ss.sss	UTC
2	Internal water temperature	xx.xxxx	C
3	Conductivity	xx.xxxx	s/m
4	Salinity	xx.xxxx	PSU
5	Sound Velocity[1]	xxxx.xxx	m/sec

[1]This field usually not logged. Detailed for reference only.

lrtm – Digital Remote Temperature

For further information on this data, check on www.seabird.com on SBE38 Digital Thermometer

```
08+037:13:47:17.841   2.2527
```

Field	Data	Format	Unit
1	RVDAS time tag	yy+ddd:hh:mm:ss.sss	UTC
2	Temperature, Seawater Intake	xx.xxxx	C

ldfl – Fluorometer

```
08+037:13:55:08.434 99/99/99    99:99:99        0.00    2585    73      543
```

Field	Data	Format	Unit
1	RVDAS time tag	yy+ddd:hh:mm:ss.sss	UTC
2	Fluorometer Date	mm/dd/yy	text
3	Fluorometer Time	hh:mm:ss	text
4	Chlorophyl Signal	x.xx	µg/l
5	Reference	xxxx	λq
6	Counts – Chlorophyll Signal	xx	counts
7	Thermistor Counts	xxxx	counts

loxy – Oxygen (Part of PCO2 system)

For further information on this data, contact Tim Newberger at ***tim.newberger@noaa.gov***

```
04+117:23:57:23.504 MEASUREMENT         3830     380  Oxygen:           309.95      Saturation:         83.48
       Temperature:       -1.35      DPhase:             33.41      BPhase:             32.22      RPhase:
0.00    BAmp:      262.09      BPot:      163.00      RAmp:        0.00      RawTem.:           694.92
```

Field	Data	Unit
1	RVDAS time tag	UTC
2 - 4	Measurement ID, Model Number, Serial Number	text
5	Oxygen (literal text heading)	text
6	Oxygen reading	Numeric (raw)
7	Saturation (literal text heading)	text
8	Saturation reading	Numeric (raw)
9	Temperature (literal text heading)	text
10	Water Temperature	ºC
11	Dphase (literal text heading)	text
12	D-phase	Numeric (raw)
13	BPhase (literal text heading)	text
14	B-phase	Numeric (raw)
15	RPhase (literal text heading)	V
16	R-phase	Numeric (raw)
17	Bamp (literal textheading)	text
18	B-amplitude	Numeric (raw)
19	Bpot (literal text heading)	text
20	Bpot	Numeric (raw)
21	Ramp (literal text heading)	text
22	R-amplitude	Numeric (raw)
23	RawTem (literal text heading)	Text
24	Raw Temperature	Numeric (raw)

lpco – PCO2 system

For further information on this data, contact Tim Newberger at ***tim.newberger@noaa.gov***

```
02+319:23:59:13.748 2002319.99851    7154.27     26.49    1033.6     325.79      6.74     329.3   53.76    0
Equil
```

Field	Data	Unit
1	RVDAS time tag	UTC
2	Julian date file string	Julian date
3	IR voltage reading	mV
4	Cell temperature	°C
5	Barometer	millibar
6	Gas flow	ml/min
7	VCO2 dry value	PPM
8	PCO2 wet/Delta value	PPM
9	Equilibrator temperature from RTD	°C
10	Equilibrator temperature from SBE-38	°C
11	Solenoid position ID	number
12	Measured gas	text

lsvp - Sound Velocity Probe in ADCP Transducer Well

NOTE: This value does not represent or reflect the sound speed in the ocean, and is for internal use by the ADCP.

```
00+348:01:59:52.128  1536.45
```

Field	Data	Format	Unit
1	RVDAS time tag	yy+ddd:hh:mm:ss.sss	UTC
2	Sound Speed	xxxx.xx	m/s

ladc – ADCP Speed Log

```
00+019:23:59:59.099 $PUHAW,UVH,-1.48,-0.51,250.6
19+017:00:00:05.734 $VDVBW,6.39,-2.82,A,11.56,0.35,A*4D
```

Field	Data	Unit
1	RVDAS time tag	UTC
2	$PUHAW (used when speedlog derived from the NB150)	text
3	UVH (E-W, N-S, Heading)	text
4	Ship speed over water relative to reference[1] layer velocity[2], East vector	knots
5	Ship speed over water relative to reference[1] layer velocity[2], North vector	knots
6	Ship heading	Degrees (true)

Field	Data	Unit
1	RVDAS time tag	UTC
2	$VDVBW (used when speedlog derived from the OS38)	text
3	Longitudinal water speed (negative means astern)	knots
4	Transverse water speed (negative means to port)	knots
5	Status	A = Data Valid
6	Longitudinal ground speed[3]	knots
7	Transverse ground speed[3]	knots
8	Status[3]	A = Data Valid
9	Checksum	ASCII Hex

[1]The reference layer is an average velocity measured in a number of depth "bins". On the LMG, the bins are typically eight meters deep and bins 3-10 define the reference layer. Hence, the reference layer is the water column from 16-80 meters beneath the ship.

[2]The speed ouput is water velocity relative to the ship's hull and is therefore opposite of the actual movement of the ship. For example, if the ship's heading is due north, the North/South reference layer velocity is likely to be negative (southerly).

[3] The ADCP system only supplies speed over water. These fields are experimental calculations

lgyr - Gyrocompass

```
02+315:23:59:58.616 $HEHDT,287.7,T*25
```

Field	Data	Format	Unit
1	RVDAS time tag	yy+ddd:hh:mm:ss.sss	UTC
2	$HEHDT		
3	Heading	x.xx	degrees
4	T = True (for previous)	x	T
5	Checksum	xx	alphanumeric

lsep – Seapath 330 GPS

INZDA: Time and Date Data

```
10+351:23:59:58.142 $INZDA,235958.08,17,12,2010,,*78
```

Field	Data	Format	Unit
1	RVDAS time tag	yy+ddd:hh:mm:ss.sss	UTC
2	$INZDA		
3	Time	hhmmss.ss	UTC
4	Day	dd	UTC
5	Month	mm	UTC
6	Year	yyyy	UTC
7	(empty field)	x	Blank or 0
8	Checksum	xx	alphanumeric

INGGA: Global Positioning Fix Data

```
10+351:23:59:58.142 $INGGA,235958.07,6118.168460,S,06008.089527,W,1,12,0.7,22.57,M,17.79,M,,*46
```

Field	Data	Format	Unit
1	RVDAS time tag	yy+ddd:hh:mm:ss.sss	UTC
2	$INGGA		
3	Time	hhmmss.ss	UTC
4	Latitude in degrees with decimal minutes	ddmm.mmmmmm	degrees
5	North or South (for previous)	x	N or S
6	Longitude in degrees with decimal minutes	ddmm.mmmmmm	ddmm.mmmmmm
7	East or West (for previous)	x	E or W
8	GPS quality indicator	x	0 – 6
9	Number of satellites in use (00-99)	xx	00-99
10	Horizontal dilution of precision (HDOP)	x.x	
11	Antenna height	x.xx	meters
12	M = meters (for previous)	X	M
13	Geoidal separation	x.xx	meters
14	M = meters (for previous)	X	M
15	Age of DGPS corrections (null with no DGPS)	x.x	seconds
16	If used, ID of DGPS reference station	Xxxx	0000 – 1023
17	Checksum	xx	alphanumeric

INRMC: Recommended Minimum Specific GNSS Data

10+351:23:59:58.200 $INRMC,235958.07,A,6118.168460,S,06008.089527,W,12.8,331.22,171210,11.3,E,A*1C

Field	Data	Format	Unit
1	RVDAS time tag	yy+ddd:hh:mm:ss.sss	UTC
2	$INRMC		
3	Time	hhmmss.sss	UTC
4	Status A=valid data, N=receiver warning	x	A or N
5	Latitude	ddmm.mmmmmm	degrees
6	North or South (for previous)	x	N or S
7	Longitude	ddmm.mmmmmm	degrees
8	East or West (for previous)	x	E or W
9	Speed over Ground, True	x.x	knots
10	Course over Ground True	x.xx	degrees
11	Date	ddmmyy	UTC
12	Magnetic Variation	x.x	degrees
13	East or West (for previous)	x	E or W
14	Mode	x	alphanumeric
15	Checksum	xx	alphanumeric

INVTG: Speed Over Ground, Course Over Ground

14+025:23:59:59.100 $INVTG,32.69,T,,M,10.6,N,19.6,K,A*1A

Field	Data	Format	Unit
1	RVDAS time tag	yy+ddd:hh:mm:ss.sss	UTC
2	$GPVTG		
3	Heading	x.xx	degrees
4	T = True (for previous)	x	T
5	Heading	x.xx	degrees
6	M = Magnetic (for previous)	x	M
7	Speed over Ground (knots)	x.x	knots
8	N = knots (for previous)	x	N
9	Speed over Ground (kilometers per hour)	x.x	km/h
10	K = km per hour (for previous)	x	K
11	Mode*	X	A,D,E, or N
12	Checksum	xx	alphanumeric

* Mode Indicator: One character indicator per constellation tracked. First character for GPS, second (optional) for GLONASS

A = Autonomous, N = No fix, D = Differential, P = Precise

PSXN,20: Data Quality

10+351:23:59:58.200 $PSXN,20,1,2,0,0*38

Field	Data	Format	Unit
1	RVDAS time tag	yy+ddd:hh:mm:ss.sss	UTC
2	$PSXN		
3	20		
4	Horizontal position and velocity quality	x	0,1,2
5	Height and vertical velocity quality	x	0,1,2
6	Heading quality	x	0,1,2
7	Roll and pitch quality	x	0,1,2
8	Checksum	xx	alphanumeric

Quality flags: 0 = normal, 1 = reduced performance, 2 = invalid data

PSXN,23: Roll, Pitch, Heading and Heave

10+351:23:59:58.213 $PSXN,23,0.02,-0.76,330.56,*0B

Field	Data	Format	Unit
1	RVDAS time tag	yy+ddd:hh:mm:ss.sss	UTC
2	$PSXN		
3	23		
4	Roll, port side up is positive	x.xx	degrees
5	Pitch, bow up is positive	x.xx	degrees
6	Heading, True	x.xx	degrees
7	Heave, positive is down	x.xx	m
8	Checksum	xx	alphanumeric

lgar - Garmin GPS

RMC: Recommended Minimum for Navigation

15+051:21:02:04.741 $GPRMC,210204.38,A,7712.979182,S,16741.063669,W,9.4,270.82,200215,105.6,E,A*06

Field	Data	Format	Unit
1	RVDAS time tag	yy+ddd:hh:mm:ss.sss	UTC
2	$GPRMC		
3	Time	hhmmss.sss	UTC
4	Status*	x	A or N
5	Latitude	ddmm.mmmmmm	degrees
6	North or South (for previous)	x	N or S
7	Longitude	ddmm.mmmmmm	degrees
8	East or West (for previous)	x	E or W
9	Speed over Ground, True	x.x	knots
10	Course over Ground True	x.xx	degrees
11	Date	ddmmyy	UTC
12	Magnetic Variation	x.x	degrees
13	East or West (for previous)	x	E or W
14	Checksum	xx	alphanumeric

GGA: Global Positioning Fix Data

08+034:12:26:06.131 $GPGGA,122607,6446.4733,S,06403.4455,W,1,11,0.9,-193.4,M,9.7,M,,*5A

Field	Data	Format	Unit
1	RVDAS time tag	yy+ddd:hh:mm:ss.sss	UTC
2	$GPGGA		
3	Time	hhmmss.ss	UTC
4	Latitude in degrees with decimal minutes	ddmm.mmmmmm	degrees
5	North or South (for previous)	x	N or S
6	Longitude in degrees with decimal minutes	ddmm.mmmmmm	ddmm.mmmmmm
7	East or West (for previous)	x	E or W
8	GPS quality indicator	x	0 – 6
9	Number of satellites in use (00-99)	xx	00-99
10	Horizontal dilution of precision (HDOP)	x.x	
11	Antenna height	x.xx	meters
12	M = meters (for previous)	X	M
13	Geoidal separation	x.xx	meters
14	M = meters (for previous)	X	M
15	Age of DGPS corrections (null with no DGPS)	x.x	seconds
16	If used, ID of DGPS reference station	Xxxx	0000 - 1023

VTG: Track Made Good and Speed over Ground

15+051:16:47:06.625 $GPVTG,357.84,T,251.99,M,9.5,N,17.7,K,A*15

Field	Data	Format	Unit
1	RVDAS time tag	yy+ddd:hh:mm:ss.sss	UTC
2	$GPVTG		
3	Heading	x.xx	degrees
4	T = True (for previous)	x	T
5	Heading	x.xx	degrees
6	M = Magnetic (for previous)	x	M
7	Speed over Ground (knots)	x.x	knots
8	N = knots (for previous)	x	N
9	Speed over Ground (kilometers per hour)	x.x	km/h
10	K = km per hour (for previous)	x	K
11	Mode*	X	A,D,E, or N
12	Checksum	xx	alphanumeric

Modes

A = GPS used, D = DGPS used, E = Dead reckoning used, N = Invalid position / velocity

GNS: Global Positioning Fix Data

16+148:00:00:01.835 $GPGNS,000001,6451.3766,S,06352.1432,W,AA,21,0.5,33.0,M,12.7,M,,*50

Field	Data	Format	Unit
1	RVDAS time tag	yy+ddd:hh:mm:ss.sss	UTC
2	$GPGNS		
3	Time	hhmmss.ss	UTC
4	Latitude in degrees with decimal minutes	ddmm.mmmmmm	degrees
5	North or South (for previous)	x	N or S
6	Longitude in degrees with decimal minutes	ddmm.mmmmmm	ddmm.mmmmmm
7	East or West (for previous)	x	E or W
8	Mode indicator*	x[x]	N, A, D, P
9	Number of satellites in use (00-99)	xx	00-99
10	Horizontal dilution of precision (HDOP)	x.x	
11	Antenna height	x.xx	meters
12	M = meters (for previous)	X	M
13	Geoidal separation	x.xx	meters
14	M = meters (for previous)	X	M
15	Age of DGPS corrections (null with no DGPS)	x.x	seconds
16	If used, ID of DGPS reference station	xxxx	0000 - 1023
17	Checksum	xx	alphanumeric

*** Mode Indicator:** One character indicator per constellation tracked. First character for GPS, second (optional) for GLONASS

A = Autonomous, N = No fix, D = Differential, P = Precise

lais – AIS receiver

AIVDM: AIS Data

14+070:00:02:38.575 !AIVDM,1,1,,B,15O5G4000oKPfggK2F2RQj7>0@FU,0*04

Field	Data	Format
1	RVDAS time tag	yy+ddd:hh:mm:ss.sss
2	!AIVDM	text
3	Total number of sentences needed to transfer message	(1-9)
4	Message sentence number	(1-9)
5	Sequential identifier to link multiple messages	(0-9 or null)
6	AIS channel	A or B
7	Encapsulated Binary Coded Data[1]	ASCII text
8	Number of fill bits	(0-5)
9	*Checksum	hexadecimal

[1]Data is encoded as described in ITU-R M.1371

LMG Sensors

Shipboard Sensors (Science Mast & Underway System)

Sensor	Description	Serial #	Cal. Date	Status
Port Anemometer	Gill Ultrasonic Wind Observer II	1246001-WC45	N/A	Collected
Starboard Anemometer	Gill Ultrasonic Wind Observer II	1246002-WC45	N/A	Collected
Barometer	Vaisala PTB210B	M2940058	22-Jul-2016	Collected
Humidity/Wet Temp	Rotronic HygroClip HC2A-S3	20285976	13-Jun-2018	Collected
PAR for Mast	Biosph. Inst. QSR-240P	6394	05-Jun-2017	Collected
PIR	Eppley PIR	28903F3	05-Feb-2019	Collected
PSP	Eppley PSP	28933F3	30-Oct-2018	Collected
GUV (Mast)	Biosph. GUV-2511	25110805127	28-Nov-2018	Collected
Transmissometer	WET Labs C-Star 25 cm deep	CST-406DR	12-Mar-2019	Collected
MicroTSG (Primary)	Sea-Bird 45	200	04-Mar-2018	Collected
MicroTSG (Secondary)	Sea-Bird 45	390	1-Mar-2018	Collected
Digital Remote Temp	Sea-Bird 38	262	25-May-2017	Collected
Fluorometer	WET Labs ECO-FL	FLRTD-380	21-June-2018	Collected

CTD Sensors

Sensor	Model	Serial #	Cal. Date
CTD Fish	Seabird SBE-9plus	0328	21-Apr-2019
Temperature	Seabird SBE-3	2444	18-Jun-2019
Temperature	Seabird SBE-3	2470	09-Nov-2018
Conductivity	Seabird SBE-4	2047	09-Nov-2018
Conductivity	Seabird SBE-4	2065	03-Apr-2019
Conductivity	Seabird SBE-4	2247	09-Nov-2018
Conductivity	Seabird SBE-4	2293	02-Apr-2019
Fluorometer	WETLabs FLRTD	398	19-Jul-2019
Fluorometer	WETLabs FLRTD	399	25-Nov-2018
Fluorometer	WETLabs FLRTD	1735	19-Jul-2019
Transmissometer	WETLabs C-Star	830-DR	26-Jun-2018
PAR	Biospherical QSP-200L4S	4403	14-May-2018
Altimeter	Valeport VA500	54772	12-Jul-2016

MOCNESS Sensors

Sensor	Description	Serial #	Cal. Date
Pressure Sensor	SBE-9plus	232	25-Apr-2019
Temperature	SBE-3	5034	21-Mar-2019
Conductivity	SBE-4	2048	29-Mar-2019
Oxygen	SBE-43	0181	16-Mar-2019
Fluorometer	FLTRD	867	23-Apr-2019
Transmissometer	C-Star	248-DR	18-Apr-2019

Underway Calibration Sheets

Anemometer- Port

WindObserver II™
Product Test Report

Product Tested: WindObserver II
Part Number: 1390-70-B-322
Serial Number: 1246001 - WC45
Test Data: 15/11/2012
Location: Gill Instruments Ltd

GILL ensures that quality is inherent in all aspects of the activities and ensures that compliance with BS EN ISO9001: 2008 is maintained.

This report certifies that the above instrument has been tested in accordance with Gill internal procedures

Results

Test	Limits	Passed
Still Air Test (Zero Wind Speed)	< 0.02m/s	Pass
Wind Tunnel Test (12 m/s nominal)	Pass/Fail	Pass

Generic calibration is traceable to the University of Southampton wind tunnel and instrumentation is maintained in accordance with UKAS.

All tests have been successfully completed

On behalf of Gill Instruments Ltd

Tony Raine
Quality Control

2002-0395 Issue 1

Gill Instruments Ltd
Solent Park
67 Gosport Street
Lymington
Hampshire
SO41 9ZG, UK

T: +44 (0) 1590 613 500
F: +44 (0) 1590 613 501
E: sales@gill.co.uk

www.gill.co.uk

ISO 9001 Registered

WindObserver II™

Product Test Report

Product Tested: WindObserver II
Part Number: 1390-70-B-322
Serial Number: 1246002 - WC45
Test Date: 15/11/2012
Location: Gill Instruments Ltd

GILL ensures that quality is inherent in all aspects of the activities and ensures that compliance with BS EN ISO9001: 2008 is maintained.

This report certifies that the above instrument has been tested in accordance with Gill internal procedures

Results

Test	Limits	Passed
Still Air Test (Zero Wind Speed)	< 0.02m/s	Pass
Wind Tunnel Test (12 m/s nominal)	Pass/Fail	Pass

Generic calibration is traceable to the University of Southampton wind tunnel and instrumentation is maintained in accordance with UKAS.

All tests have been successfully completed

On behalf of Gill Instruments Ltd

Tony Raine
Quality Control

2002-0395 Issue 1

www.gill.co.uk

VAISALA

Certificate report no. H12-16290011

CALIBRATION CERTIFICATE

Instrument	PTB210B Digital Barometer
Serial number	M2940058
Manufacturer	Vaisala Oyj, Finland
Calibration date	22nd July 2016

The above instrument was calibrated by comparing the readings of the instrument to the factory working standard of Vaisala.

The pressure readings of the factory working standard have been calibrated at an ISO/IEC 17025 accredited calibration laboratory (FINAS), Vaisala Measurement Standards Laboratory (MSL), by using MSL working standards traceable to NIST.

Calibration results

Reference hPa	Observed hPa	Correction* hPa	Acceptance limit hPa
510.0	510.0	0.0	± 0.2
610.0	610.0	0.0	± 0.2
700.0	700.0	0.0	± 0.2
810.0	810.0	0.0	± 0.2
910.0	910.0	0.0	± 0.2
950.0	950.0	0.0	± 0.2
1000.0	1000.0	0.0	± 0.2
1098.0	1098.0	0.0	± 0.2

*To obtain the true pressure, add the correction to the barometer reading.
Interpolated corrections may be used at intermediate readings of the scale of the barometer.

Equipment used in calibration

Type	Serial number	Calibration date	Certificate number
PPC3	909	2016-07-14	K008-Z02226

Uncertainty (95 % confidence level, k=2)
Pressure ± 0.15 hPa

Ambient Conditions

Humidity	40 %RH ± 5 %RH
Temperature	21 °C ± 1 °C
Pressure	1013 hPa ± 1 hPa

Technician

doc223087-B

Vaisala Oyj | P.O.Box 26, FI-00421 Helsinki, Finland

CERTIFICATE

rotronic
LEADING IN HUMIDITY MEASUREMENT

Device type	**HC2A-S3**
Serialnumber	**0020285976**
RPC-number	**19-0356621018**

ROTRONIC AG certifies that this instrument meets the published specifications. It has been calibrated using standards and instruments as stated below and corresponds to the process requirements of ISO 9001-2008. The references are traceable to national standards. The calibrated values are only valid at the time of measurement and are referenced to the indicated references and working standards.

FACTORY CALIBRATION

Adjustment

Temperature	23.56°C
Humidity 1	11.61%rH (@23.58°C)
Humidity 2	34.73%rH (@23.61°C)
Humidity 3	79.01%rH (@23.71°C)

Calibration

	Device	Reference
Temperature	23.59°C	23.62°C
Humidity	50.11%rH	50.03%rH

Date of calibration: 13.07.2018

Reference System

HC2-S (SCS certified)

FUNCTION TEST

Firmware	V1.2
Analog Output	Out1: Humi 0..100%rH (0..1V) Set: 40.00%rH, measured 39.98%rH (0.400V) Out2: Temp -40..60°C (0..1V) Set: 20.00°C, measured 20.02°C (0.600V)
Printnumber	66.1085.0301

Final test passed – 16.08.2018 – quality engineer: V. Doan
Control number: 304

ROTRONIC AG, Grindelstrasse 6, CH - 8303 Bassersdorf
www.rotronic.com

Biospherical Instruments Inc.

CALIBRATION CERTIFICATE

Calibration Date	7/16/2018
Model Number	QSR240
Serial Number	6394
Operator	TPC
Standard Lamp	V-042(7/21/16)
Probe Excitation Voltage Range:	6 to 18 VDC(+)
Output Polarity:	POSITIVE

Probe Conditions at Calibration(in air):

Calibration Voltage:	6	VDC(+)
Probe Current:	4.0	mA

Probe Output Voltage:

Probe Illuminated	103.7	mV
Probe Dark	0.3	mV
Probe Net Response	103.4	mV
RG780	0.3	mV

Corrected Lamp Output:

Output In Air (same condition as calibration):

9.430E+15	quanta/cm²sec
0.015659	uE/cm^{2}sec

Calibration Scale Factor:
(To calculate irradiance, divide the net voltage reading in Volts by this value.)

Dry:	1.0965E-17	V/(quanta/cm²sec)
	6.6032E+00	V/(uE/cm^{2}sec)

Notes:
1. Annual calibration is recommended.
2. Calibration is performed using a Standard of Spectral Irradiance traceable to the National Institute of Standards and Technology (NIST).
3. The collector should be cleaned frequently with alcohol.
4. Calibration was performed with customer cable, when available.

EPLAB

THE EPPLEY LABORATORY, INC.

12 Sheffield Avenue, PO Box 419, Newport, Rhode Island USA 02840
Phone: 401.847.1020 Fax: 401.847.1031 Email: info@eppleylab.com

Calibration Certificate

Instrument:	Precision Infrared Radiometer, Model PIR, Serial Number 28903F3
Procedure:	This pyrgeometer was compared against Eppley's Blackbody Calibration System under radiation intensities of approximately 350 Wm^{-2} with an average ambient temperature of 24°C according to procedures described in Technical Procedure, TP05 of The Eppley Laboratory, Inc.'s Quality Assurance Manual on Calibrations.
Transfer Standard:	Eppley Precision Infrared Radiometer, Model PIR, Serial Number 32227F3
Results:	**Sensitivity: S = 3.56 µV / Wm^{-2}** Uncertainty: U_{95} = ±1.7% (95% confidence level, k=2) Resistance: 674 Ω at 23°C
	Date of Test: February 5, 2019
Traceability:	This calibration is traceable to the International Practical Temperature Scale (IPTS). Additionally, transfer standard PIR #32227F3 provides traceability to the World Infrared Standand Group (WISG) of pyrgeometers housed at the Infrared Radiometry Section of the World Radiation Centre (WRC-IRS). Unless otherwise stated in the remarks section below or on the Sales Order, the results of this calibration are "AS FOUND / AS LEFT".
Due Date:	Eppley recommends a minimum calibration cycle of five (5) years but encourages annual calibrations for highest measurement accuracy.
Customer:	NSF / LEIDOS Port Hueneme, CA
Signatures:	Debra L. Hanty, In Charge of Test; Thomas J. Kubo, Reviewed by:
Eppley SO:	65371
Date of Certificate	February 6, 2019
Remarks:	

End of Report

EPLAB

THE EPPLEY LABORATORY, INC.

12 Sheffield Avenue, PO Box 419, Newport, Rhode Island USA 02840
Phone: 401.847.1020 Fax: 401.847.1031 Email: info@eppleylab.com

Calibration Certificate

Instrument:	Precision Spectral Pyranometer, Model PSP, Serial Number 28933F3
Procedure:	This pyranometer was compared in Eppley's Integrating Hemisphere according to procedures described in ***ISO 9847 Section 5.3.1*** and Technical Procedure, TP01 of The Eppley Laboratory, Inc.'s Quality Assurance Manual on Calibrations.
Transfer Standard:	Eppley Standard Precision Pyranometer, Model SPP, Serial Number 37501F3
Results:	**Sensitivity:** **S = 7.41 µV / Wm^{-2}** Uncertainty: U_{95} = ±0.91% (95% confidence level, k=2) Resistance: 686 Ω at 23°C
	Date of Test: October 30, 2018
Traceability:	This calibration is traceable to the World Radiation Reference (WRR) through comparisons with Eppley's AHF standard self-calibrating cavity pyrheliometers which participated in the Twelfth International Pyrheliometric Comparisons (IPC XII) at Davos, Switzerland in September-October 2015. Unless otherwise stated in the remarks section below or on the Sales Order, the results of this calibration are "AS FOUND / AS LEFT".
Due Date:	Eppley recommends a minimum calibration cycle of five (5) years but encourages annual calibrations for highest measurement accuracy.
Customer:	NSF/Leidos Port Hueneme, CA
Signatures:	Debra L. Hunty In Charge of Test: Reviewed by:
Eppley SO:	65314
Date of Certificate	November 1, 2018
Remarks:	

Biospherical Instruments Inc.

System Calibration Certificate

THE INSTRUMENTS REFERENCED BELOW WERE FACTORY TESTED AND CALIBRATED BY

BIOSPHERICAL INSTRUMENTS INC.
5340 Riley Street
San Diego, California 92110 USA

Instruments: GUV-2511 No 25110805127

Optical Calibrations:

NIST Traceability. For wavelengths longer than 313 nm, the specific instruments cited here were calibrated using a 1000W FEL **#V-040 (7/20/16)** following procedures and standards traceable to NIST Standard of Spectral Irradiance **F616**. Traceability paths and all procedures for all calibrated lamps and associated apparatus (shunts, power supplies, DMMs, etc) are maintained following calibration methodologies per National Bureau of Standards (US) (NBS) Special Publication 250-20 Spectral Irradiance Calibrations (1987) and NBS Publication 594–13 Optical Radiation Measurements: The 1973 Scale of Spectral Irradiance (1977).

Solar Calibrations. Lamp calibrations are problematic for solar UV measurements (wavelengths below 320 nm) because the solar spectrum is radically different from the lamp spectrum and changes greatly as a function of wavelength. Solar calibrations are achieved through direct comparison with measurements of a high resolution scanning spectroradiometer in San Diego (SUV-100), which is part of the National Science Foundation's UV Monitoring Network. The SUV-100 instrument has a bandwidth of 1 nm. Calibrated filter radiometer data therefore report spectral irradiance at the channel's nominal wavelengths with a bandwidth of 1 nm. Solar calibrations are typically accurate to within ±10% for solar zenith angles smaller than 75°. At larger solar zenith angles, UV channels have a greater uncertainty due to the rapid change of the solar UV spectrum.

Note that this certificate contains a subset of the information delivered in the calibration database **25110805127v9.mdb**. This database is required for operation of this system using Biospherical Instruments Inc.'s Logger® software.

PO Box 518
620 Applegate St.
Philomath, OR 97370

(541) 929-5650
Fax (541) 929-5277
www.wetlabs.com

WET Labs

C-Star Calibration

Date 3.12.19 S/N# CST-406DR Pathlength 25 cm

	Analog output	
V_d	0.058 V	
V_{air}	4.772 V	
V_{ref}	4.674 V	
Temperature of calibration water		20.3 ℃
Ambient temperature during calibration		21.9 ℃

Relationship of transmittance (Tr) to beam attenuation coefficient (c), and pathlength (x, in meters): $Tr = e^{-cx}$

To determine beam transmittance: $Tr = (V_{sig} - V_{dark}) / (V_{ref} - V_{dark})$

To determine beam attenuation coefficient: $c = -1/x * \ln(Tr)$

V_d Meter output with the beam blocked. This is the offset.
V_{air} Meter output in air with a clear beam path.
V_{ref} Meter output with clean water in the path.
Temperature of calibration water: temperature of clean water used to obtain V_{ref}.
Ambient temperature: meter temperature in air during the calibration.
V_{sig} Measured signal output of meter.

Revision M 7/26/11

Thermosalinograph (Temperature) – Primary (utsg file)

Sea-Bird Scientific
13431 NE 20th Street
Bellevue, WA 98005
USA

+1 425-643-9866
seabird@seabird.com
www.seabird.com

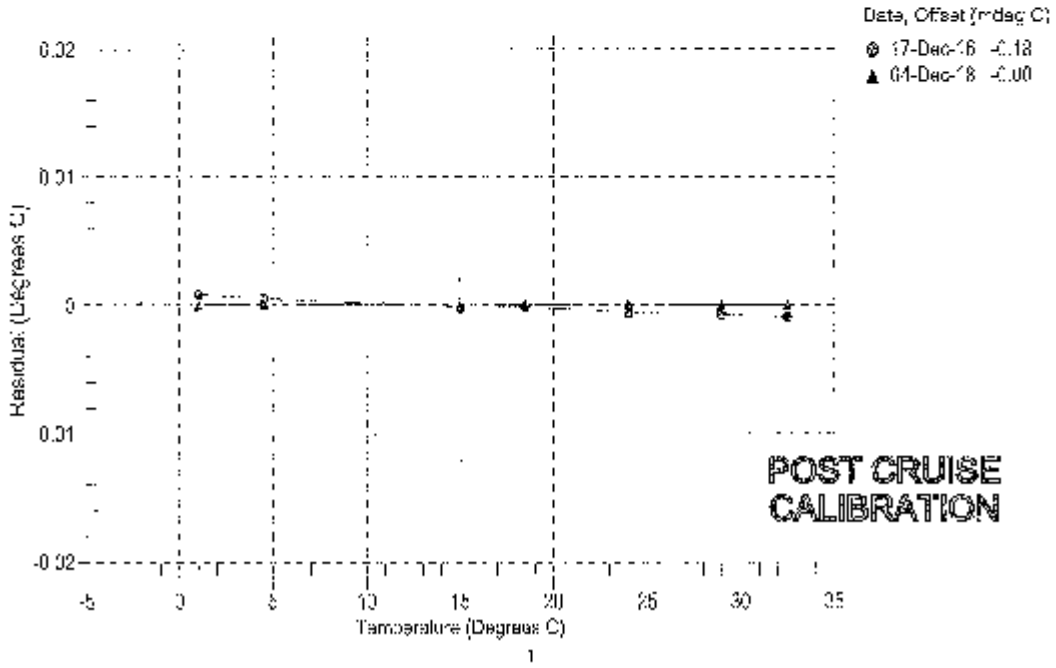
SENSOR SERIAL NUMBER: 0200
CALIBRATION DATE: 04-Dec-18

SBE 45 TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

COEFFICIENTS:
a0 = [illegible]
a1 = 2.723640e-004
a2 = -2.[illegible]e-006
a3 = 1.[illegible]e-007

BATH TEMP (°C)	INSTRUMENT OUTPUT (counts)	INST TEMP (°C)	RESIDUAL (°C)
1.0000	694988.2	1.0000	-0.0000
4.5000	555087.3	4.5000	0.0000
14.0000	383818.1	14.0000	-0.0000
18.5000	332167.8	18.5000	-0.0000
24.0000	285376.2	24.0001	0.0001
28.0000	218870.1	28.0000	0.0000
32.5000	191885.2	32.5001	-0.0000

n = Instrument Output (counts)
Temperature ITS-90 (°C) = 1/{a0 + a1[ln(n)] + a2[ln²(n)] + a3[ln³(n)]} - 273.15
Residual (°C) = instrument temperature - bath temperature



Thermosalinograph (Conductivity) – Primary (utsg file)

SEA-BIRD

Sea-Bird Scientific
13431 NE 20th Street
Bellevue, WA 98005
USA

+1 425-643-9866
seabird@seabird.com
www.seabird.com

SENSOR SERIAL NUMBER: 0200
CALIBRATION DATE: 04-Dec-18

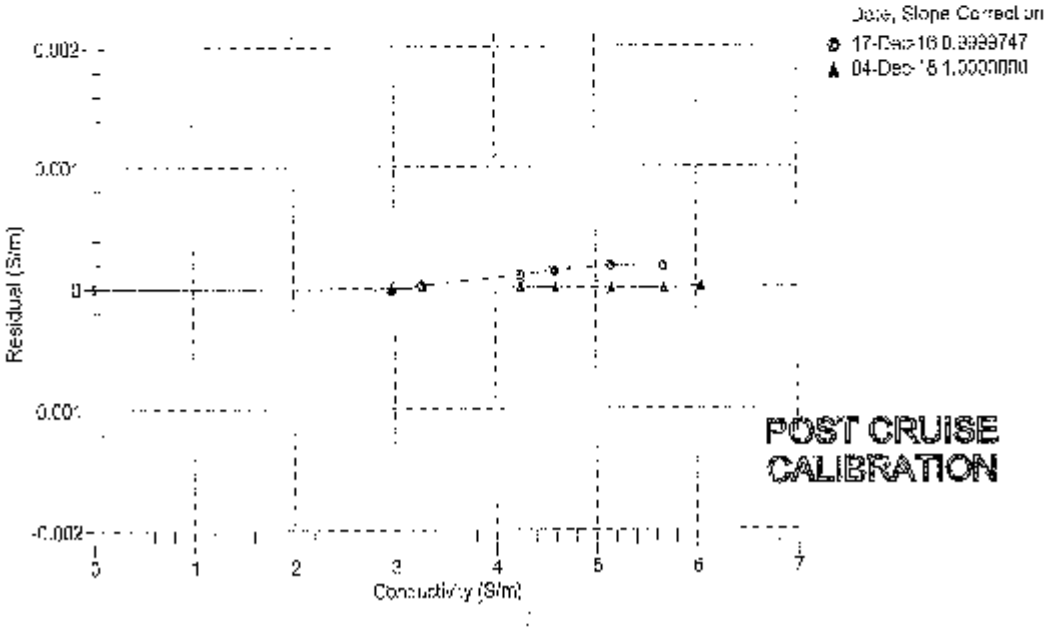
SBE 45 CONDUCTIVITY CALIBRATION DATA
PSS 1978: C(35,15,0) = 4.2914 Siemens/meter

COEFFICIENTS:

g =	-1.02622e+00	CPcor =	9.57000e-08
h =	1.38118e-01	CTcor =	3.25000e-06
i =	-8.10653e-04	WBOTC =	1.08778e-05
j =	2.43291e-05		

BATH TEMP (°C)	BATH SAL (PSU)	BATH COND (S/m)	INSTRUMENT OUTPUT (Hz)	INSTRUMENT COND (S/m)	RESIDUAL (S/m)
22.0300	0.0000	0.00000	2765.75	0.00000	0.00000
1.0000	34.2468	2.97857	5490.83	2.97856	-0.00001
2.5000	34.2572	3.27716	5673.39	3.27716	0.00001
12.0000	34.6935	4.35726	6283.71	4.35727	0.00001
18.5000	34.8288	4.60196	6484.72	4.60193	-0.00003
21.0000	34.8671	5.15896	6796.63	5.15897	0.00001
29.0000	34.8610	5.67974	7075.94	5.67974	-0.00000
30.5700	34.8501	6.05721	7266.38	6.05731	0.00001

Frequency = Instrument Output (Hz) * sqrt(1.0 + WBOTC * t) / 1000.0
t = temperature (°C); p = pressure (decibars); δ = CTcor; ε = CPcor;
Conductivity (S/m) = (g + h * f^2 + i * f^3 + j * f^4) / (1 + δ * t + ε * p)
Residual (Siemens/meter) = instrument conductivity - bath conductivity



Thermosalinograph (Temperature) – Secondary (tsg2 file)

Sea-Bird Scientific
13431 NE 20th Street
Bellevue, WA 98005
USA

+1 425-643-9866
seabird@seabird.com
www.seabird.com

SENSOR SERIAL NUMBER: 0390
CALIBRATION DATE: 01-Mar-19

SBE 45 TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

COEFFICIENTS:

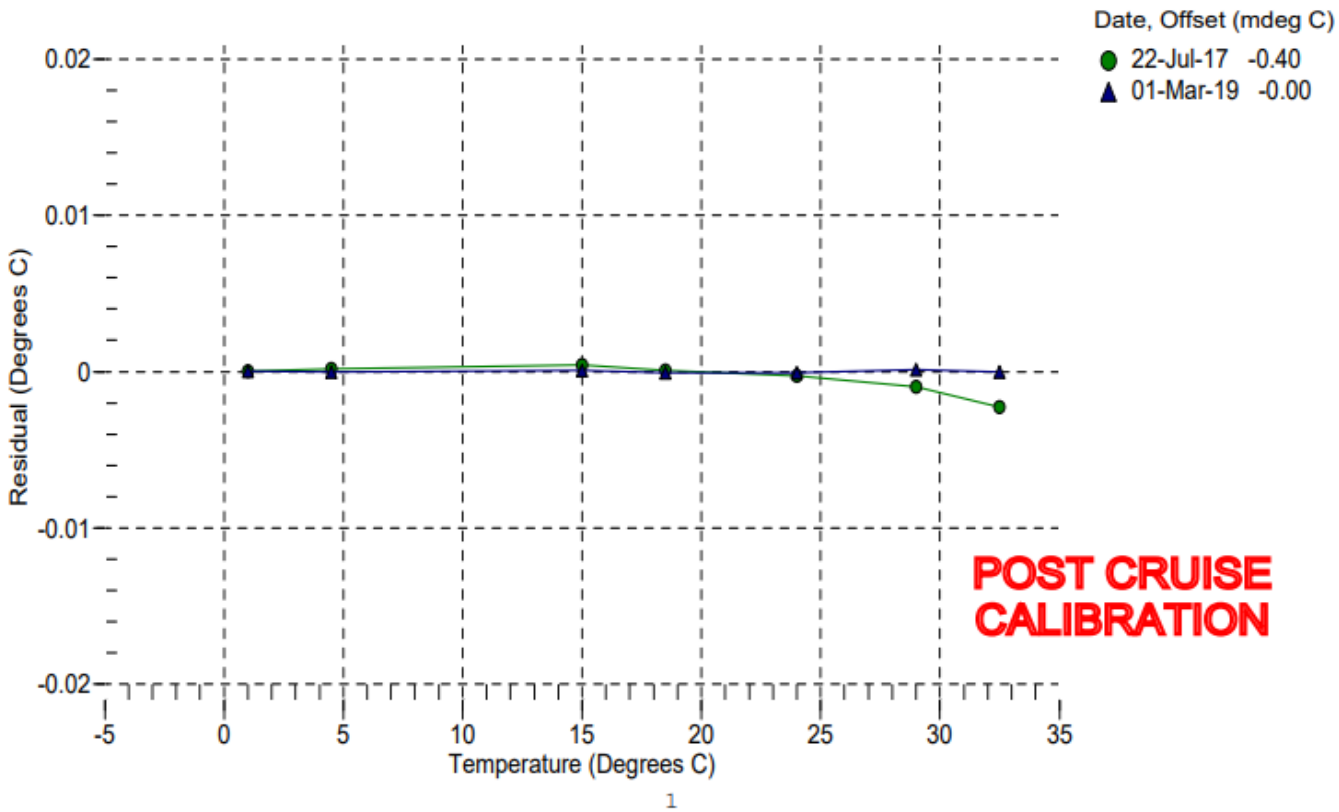
a0 = 9.800567e-005
a1 = 2.617307e-004
a2 = -1.473112e-006
a3 = 1.271496e-007

BATH TEMP (° C)	INSTRUMENT OUTPUT (counts)	INST TEMP (° C)	RESIDUAL (° C)
0.9999	662320.0	0.9999	0.0000
4.5000	565266.5	4.5000	-0.0000
15.0000	358390.9	15.0001	0.0001
18.5000	309817.9	18.4999	-0.0001
24.0000	247915.1	23.9999	-0.0001
29.0001	203676.9	29.0002	0.0001
32.5000	178090.4	32.5000	-0.0000

n = Instrument Output (counts)

Temperature ITS-90 (°C) = $1/\{a0 + a1[ln(n)] + a2[ln^2(n)] + a3[ln^3(n)]\} - 273.15$

Residual (°C) = instrument temperature - bath temperature



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Thermosalinograph (Conductivity) – Secondary (tsg2 file)

Sea-Bird Scientific
13431 NE 20th Street
Bellevue, WA 98005
USA

+1 425-643-9866
seabird@seabird.com
www.seabird.com

SENSOR SERIAL NUMBER: 0390
CALIBRATION DATE: 01-Mar-19

SBE 45 CONDUCTIVITY CALIBRATION DATA
PSS 1978: C(35,15,0) = 4.2914 Siemens/meter

COEFFICIENTS:

```
g = -9.864960e-001          CPcor = -9.5700e-008
h =  1.451399e-001          CTcor =  3.2500e-006
i = -3.279979e-004          WBOTC =  2.8724e-007
j =  4.580433e-005
```

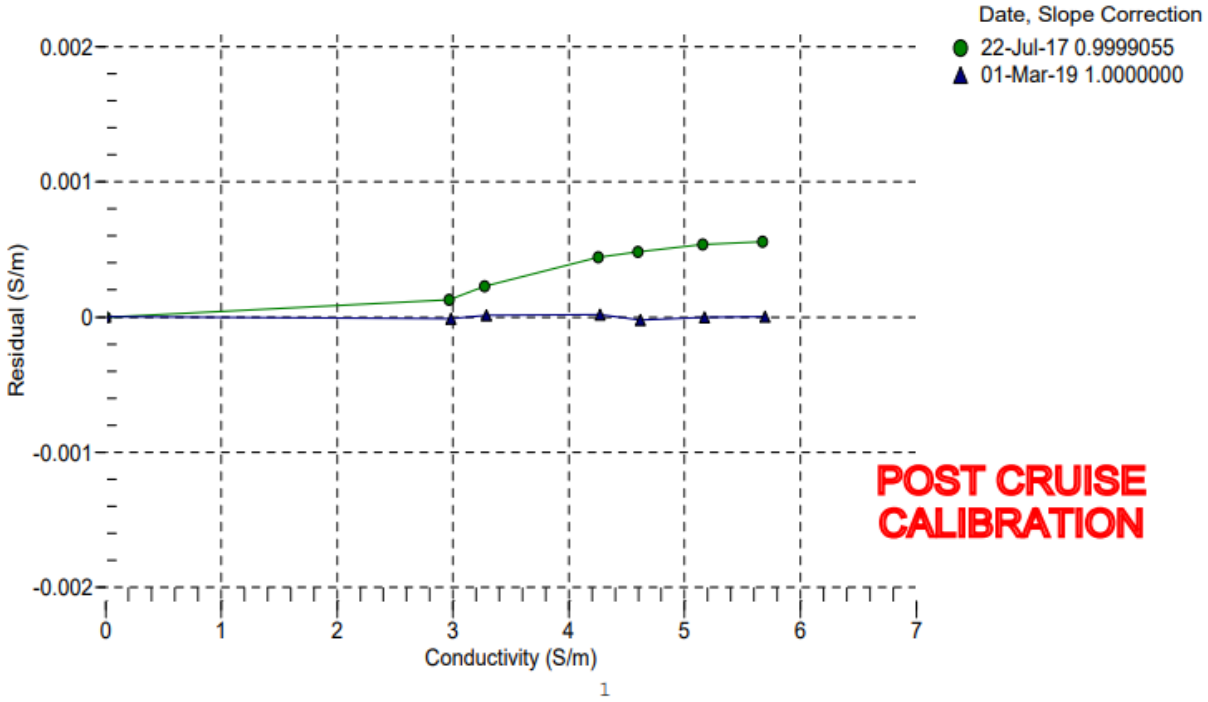
BATH TEMP (° C)	BATH SAL (PSU)	BATH COND (S/m)	INSTRUMENT OUTPUT (Hz)	INSTRUMENT COND (S/m)	RESIDUAL (S/m)
22.0000	0.0000	0.00000	2611.97	0.00000	0.00000
0.9999	34.8773	2.98067	5236.47	2.98066	-0.00001
4.5000	34.8548	3.28800	5434.95	3.28801	0.00001
15.0000	34.8116	4.27110	6025.29	4.27112	0.00002
18.5000	34.8009	4.61655	6219.12	4.61652	-0.00002
24.0000	34.7872	5.17478	6519.90	5.17477	-0.00000
29.0001	34.7750	5.69633	6788.53	5.69633	0.00000
32.5000	34.7594	6.06719	6973.07	6.06725	0.00006

f = Instrument Output(Hz) * sqrt(1.0 + WBOTC * t) / 1000.0

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

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

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



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Digital Remote Temperature (lrtm file)

Sea-Bird Scientific
13431 NE 20th Street
Bellevue, WA 98005
USA

+1 425-643-9866
seabird@seabird.com
www.seabird.com

SENSOR SERIAL NUMBER: 0324
CALIBRATION DATE: 23-Aug-18

SBE 38 TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

COEFFICIENTS:

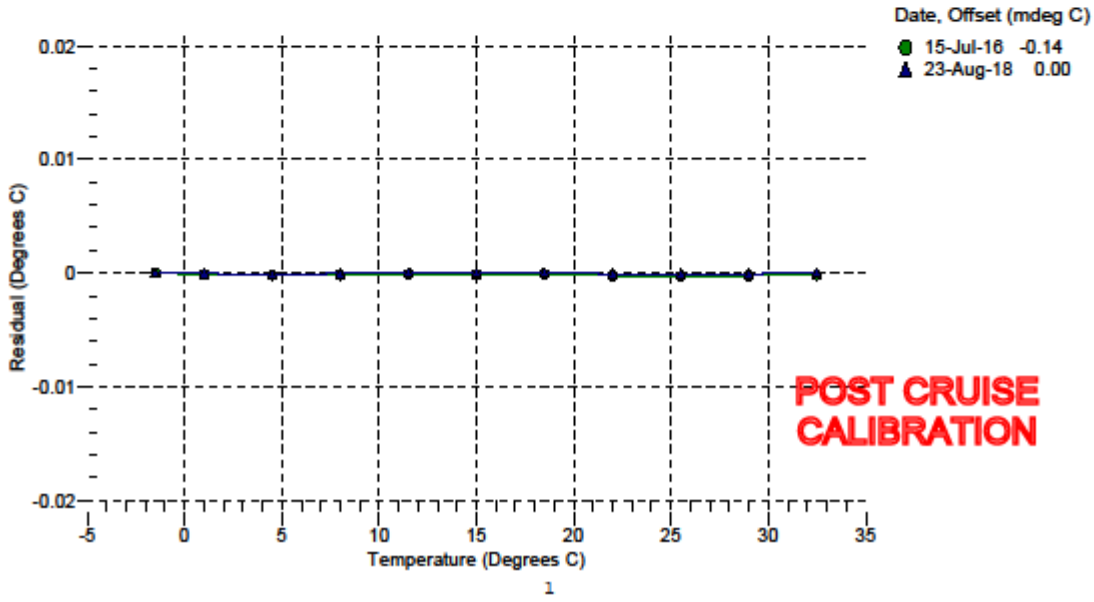
a0 = -2.961813e-005
a1 = 2.775606e-004
a2 = -2.635048e-006
a3 = 1.560819e-007

BATH TEMP (° C)	INSTRUMENT OUTPUT (counts)	INST TEMP (° C)	RESIDUAL (° C)
-1.5000	895405.3	-1.5000	0.0000
1.0000	798432.2	1.0000	-0.0000
4.5000	682045.7	4.4999	-0.0001
8.0000	584558.5	8.0000	-0.0000
11.5000	502622.8	11.5001	0.0001
15.0000	433529.3	15.0001	0.0001
18.5000	375074.5	18.5001	0.0001
22.0000	325463.5	21.9999	-0.0001
25.5000	283226.4	25.4999	-0.0001
29.0000	247160.1	28.9999	-0.0001
32.5000	216272.6	32.5001	0.0001

n = Instrument Output (counts)

Temperature ITS-90 (°C) = $1/\{a0 + a1[ln(n)] + a2[ln^2(n)] + a3[ln^3(n)]\} - 273.15$

Residual (°C) = instrument temperature - bath temperature



PO Box 518
620 Applegate St.
Philomath, OR 97370

WET Labs

(541) 929-5650
Fax (541) 929-5277
www.wetlabs.com

ECO Chlorophyll Fluorometer Characterization Sheet

Date: 6/21/2018 S/N: FLRTD-380

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

CHL (µg/l) = Scale Factor * (Output - Dark Counts)

	Analog Range 1	Analog Range 2	Analog Range 4 (default)		Digital	
Dark Counts	0.074	0.042	0.028	V	49	counts
Scale Factor (SF)	5	11	22	µg/l/V	0.0067	µg/l/count
Maximum Output	4.99	4.99	4.99	V	16380	counts
Resolution	1.2	1.2	1.2	mV	1.0	counts

Ambient temperature during characterization 22.0 °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 ÷ (output - 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.

FLRTD-380 Revision J 3/17/08

CTD Calibration Sheets

CTD Pressure Sensor

Sea-Bird Scientific
13431 NE 20th Street
Bellevue, WA 98005
USA

+1 425-643-9866
seabird@seabird.com
www.seabird.com

SENSOR SERIAL NUMBER: 0328
CALIBRATION DATE: 24-Apr-19

SBE 9plus PRESSURE CALIBRATION DATA
10000 psia S/N 59980

DIGIQUARTZ COEFFICIENTS:

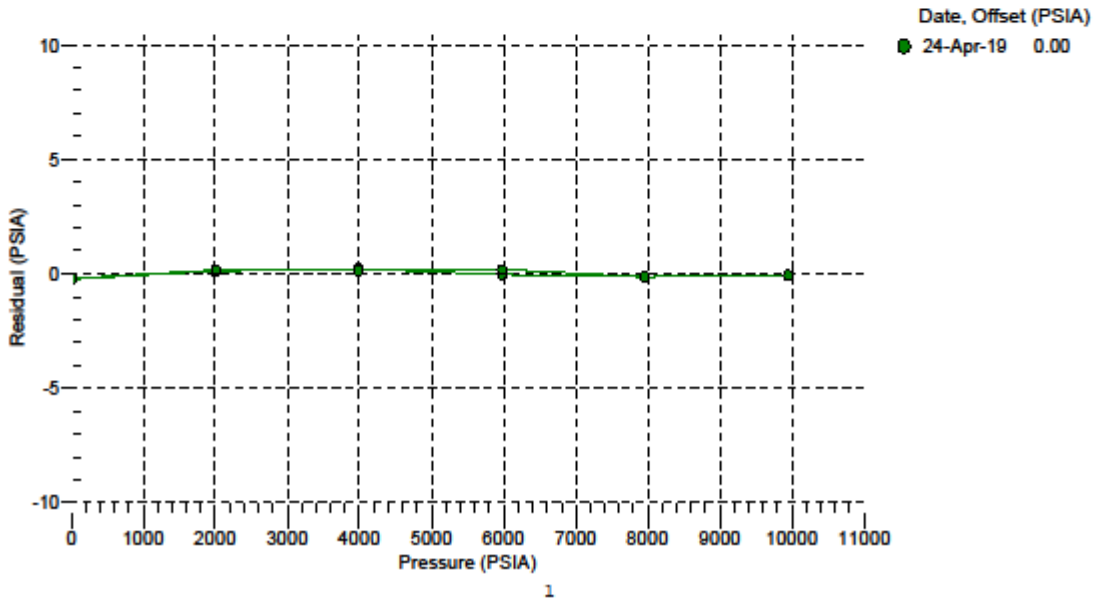
C1 =	-5.847002e+004
C2 =	6.910390e-001
C3 =	1.753360e-002
D1 =	4.241600e-002
D2 =	0.000000e+000
T1 =	3.026040e+001
T2 =	-1.938830e-004
T3 =	4.330190e-006
T4 =	2.020250e-009
T5 =	0.000000e+000

AD590M, AD590B, SLOPE AND OFFSET:

AD590M =	1.13300e-002
AD590B =	-8.47592e+000
Slope =	0.99999
Offset =	0.5662 (dbars)

PRESSURE (PSIA)	INSTRUMENT OUTPUT (Hz)	INSTRUMENT TEMPERATURE (°C)	INSTRUMENT PRESSURE (PSIA)	CORRECTED PRESSURE (PSIA)	RESIDUAL (PSIA)
14.760	33052.70	23.6	13.711	14.532	-0.228
2001.263	33608.90	23.7	2000.572	2001.367	0.104
3988.020	34154.50	23.8	3987.463	3988.231	0.211
5975.128	34690.00	23.8	5974.339	5975.080	-0.048
7962.144	35215.90	23.8	7961.301	7962.015	-0.129
9949.743	35732.80	23.9	9948.988	9949.675	-0.068
7962.148	35215.90	23.9	7961.296	7962.010	-0.138
5974.136	34689.80	23.9	5973.582	5974.323	0.187
3988.078	34154.50	23.9	3987.458	3988.226	0.148
2001.198	33608.90	24.0	2000.575	2001.369	0.171
14.762	33052.70	24.0	13.732	14.553	-0.209

Residual (PSIA) = corrected instrument pressure - reference pressure



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Sea-Bird Scientific
13431 NE 20th Street
Bellevue, WA 98005
USA

+1 425-643-9866
seabird@seabird.com
www.seabird.com

SENSOR SERIAL NUMBER: 2470
CALIBRATION DATE: 09-Nov-18

SBE 3 TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

COEFFICIENTS:

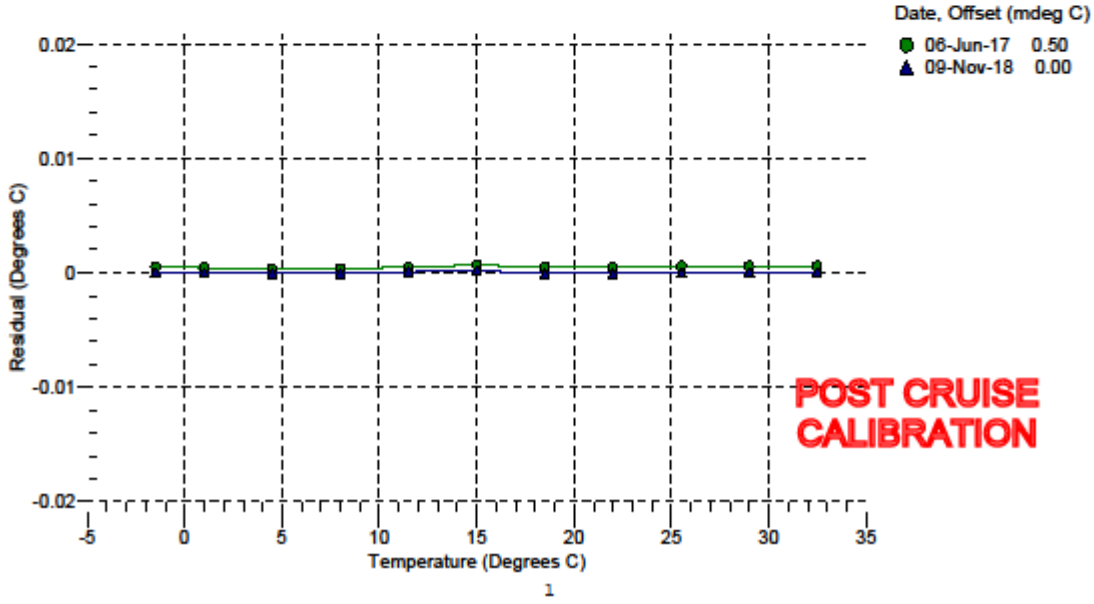
g = 4.31687947e-003
h = 6.54871450e-004
i = 2.44883243e-005
j = 2.32031357e-006
f0 = 1000.0

BATH TEMP (° C)	INSTRUMENT OUTPUT (Hz)	INST TEMP (° C)	RESIDUAL (° C)
-1.5000	2731.485	-1.5000	0.00004
1.0000	2885.563	1.0000	-0.00001
4.5000	3111.667	4.4999	-0.00008
8.0000	3350.203	7.9999	-0.00006
11.5000	3601.495	11.5001	0.00007
15.0000	3865.846	15.0002	0.00016
18.5000	4143.535	18.4999	-0.00005
22.0000	4434.893	21.9999	-0.00008
25.5000	4740.193	25.5000	-0.00002
29.0000	5059.695	29.0000	0.00000
32.5000	5393.659	32.5000	0.00003

f = Instrument Output (Hz)

Temperature ITS-90 (°C) = $1/\{g + h[ln(f0 / f)] + i[ln^2(f0 / f)] + j[ln^3(f0 / f)]\} - 273.15$

Residual (°C) = instrument temperature - bath temperature



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13431 NE 20th Street
Bellevue, WA 98005
USA

+1 425-643-9866
seabird@seabird.com
www.seabird.com

SENSOR SERIAL NUMBER: 2444
CALIBRATION DATE: 18-Jun-19

SBE 3 TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

COEFFICIENTS:

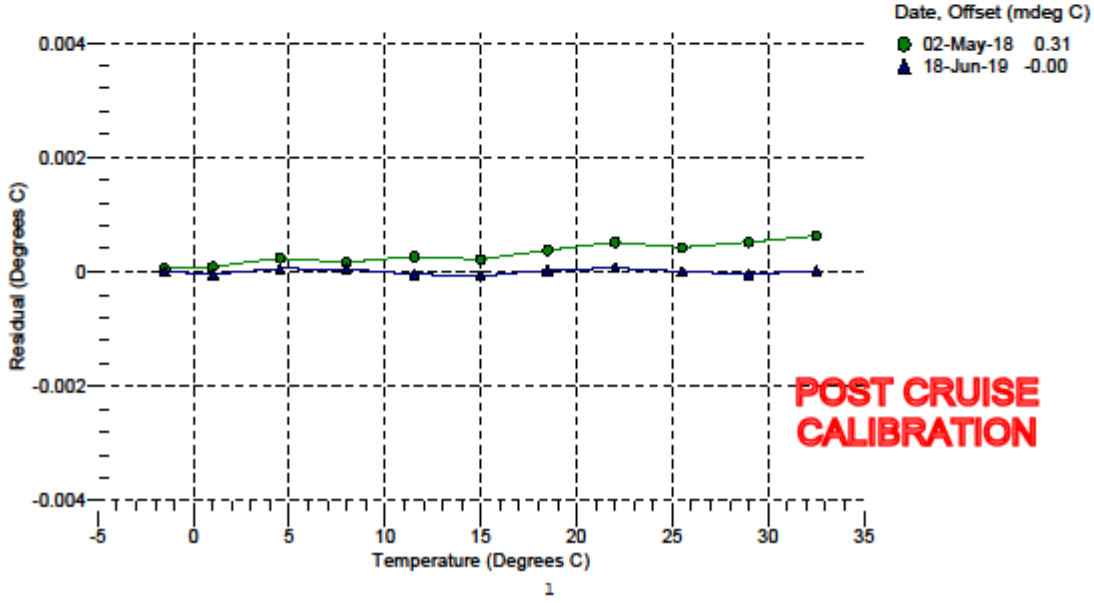
g = 4.38203014e-003
h = 6.50377577e-004
i = 2.46509318e-005
j = 2.38509474e-006
f0 = 1000.0

BATH TEMP (° C)	INSTRUMENT OUTPUT (Hz)	INST TEMP (° C)	RESIDUAL (° C)
-1.5000	3064.708	-1.5000	0.00001
1.0000	3240.091	1.0000	-0.00004
4.5000	3497.686	4.5001	0.00005
8.0000	3769.683	8.0000	0.00004
11.5000	4056.466	11.5000	-0.00005
15.0000	4358.418	14.9999	-0.00007
18.5000	4675.905	18.5000	0.00003
22.0000	5009.258	22.0001	0.00006
25.5000	5358.807	25.5000	0.00000
29.0000	5724.883	29.0000	-0.00004
32.5000	6107.801	32.5000	0.00001

f = Instrument Output (Hz)

Temperature ITS-90 (°C) = $1/\{g + h[ln(f0 / f)] + i[ln^2(f0 / f)] + j[ln^3(f0 / f)]\} - 273.15$

Residual (°C) = instrument temperature - bath temperature



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13431 NE 20th Street
Bellevue, WA 98005
USA

+1 425-643-9866
seabird@seabird.com
www.seabird.com

SENSOR SERIAL NUMBER: 2047
CALIBRATION DATE: 09-Nov-18

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

COEFFICIENTS:

g = -1.06198193e+001
h = 1.45440195e+000
i = -5.44595459e-003
j = 6.04694029e-004

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

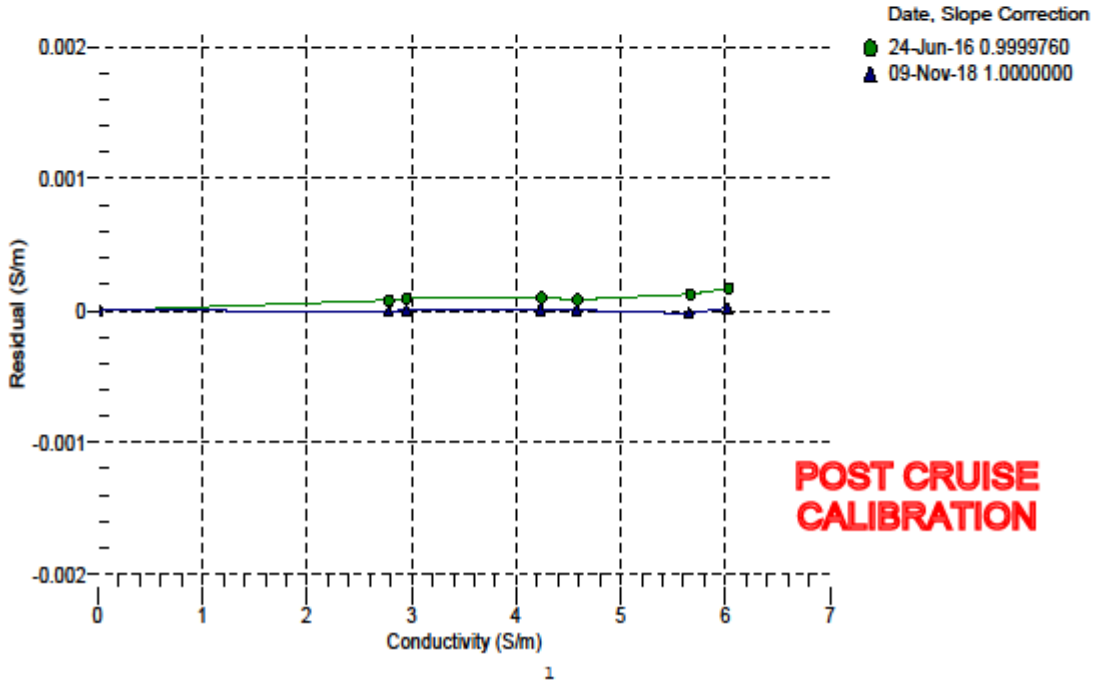
BATH TEMP (° C)	BATH SAL (PSU)	BATH COND (S/m)	INSTRUMENT OUTPUT (kHz)	INSTRUMENT COND (S/m)	RESIDUAL (S/m)
0.0000	0.0000	0.00000	2.71183	0.00000	0.00000
-1.0000	34.4685	2.77916	5.16043	2.77915	-0.00001
1.0000	34.4683	2.94904	5.27315	2.94904	0.00000
15.0000	34.4656	4.23312	6.05651	4.23313	0.00001
18.5000	34.4629	4.57652	6.24901	4.57652	0.00000
29.0001	34.4511	5.64920	6.81438	5.64918	-0.00002
32.5000	34.4339	6.01680	6.99729	6.01682	0.00002

f = Instrument Output (kHz)

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

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

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



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13431 NE 20th Street
Bellevue, WA 98005
USA

+1 425-643-9866
seabird@seabird.com
www.seabird.com

SENSOR SERIAL NUMBER: 2065
CALIBRATION DATE: 02-Apr-19

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

COEFFICIENTS:

g = -9.82355885e+000
h = 1.36114943e+000
i = -3.64222373e-003
j = 3.37069565e-004

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

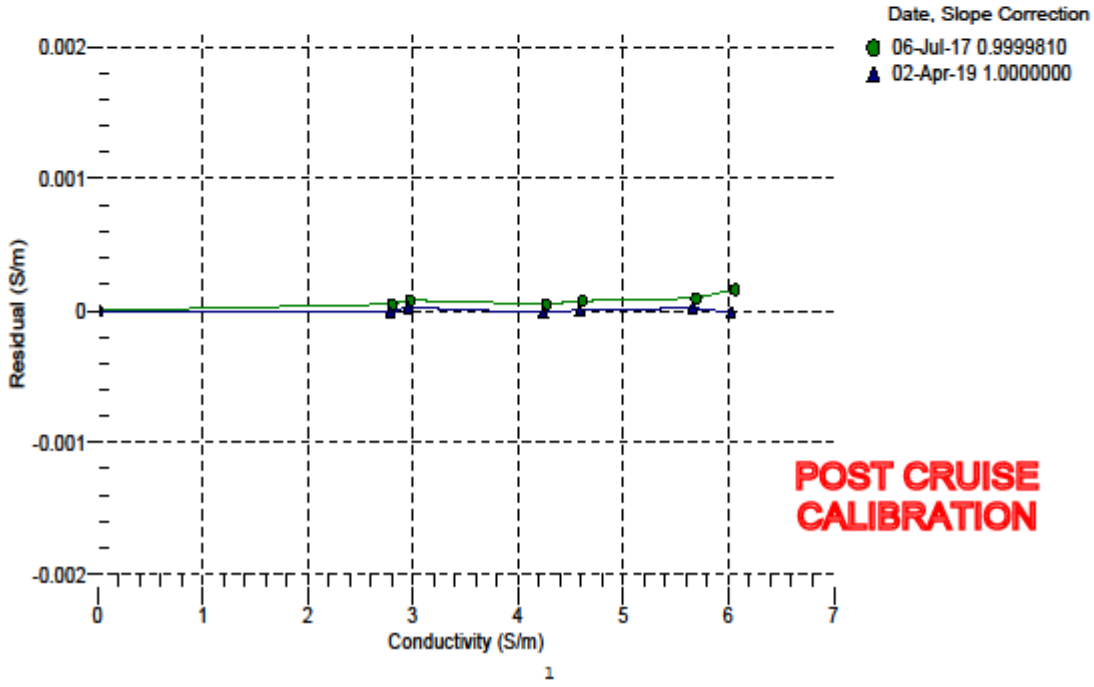
BATH TEMP (° C)	BATH SAL (PSU)	BATH COND (S/m)	INSTRUMENT OUTPUT (kHz)	INSTRUMENT COND (S/m)	RESIDUAL (S/m)
0.0000	0.0000	0.00000	2.69377	0.00000	0.00000
-1.0000	34.5225	2.78310	5.27873	2.78309	-0.00001
0.9999	34.5224	2.95322	5.39670	2.95324	0.00002
15.0000	34.5202	4.23911	6.21571	4.23910	-0.00002
18.5000	34.5179	4.58303	6.41690	4.58304	0.00000
29.0000	34.5096	5.65771	7.00789	5.65773	0.00002
32.5000	34.4962	6.02645	7.19928	6.02644	-0.00001

f = Instrument Output (kHz)

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

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

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



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13431 NE 20th Street
Bellevue, WA 98005
USA

+1 425-643-9866
seabird@seabird.com
www.seabird.com

SENSOR SERIAL NUMBER: 2247
CALIBRATION DATE: 08-Nov-18

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

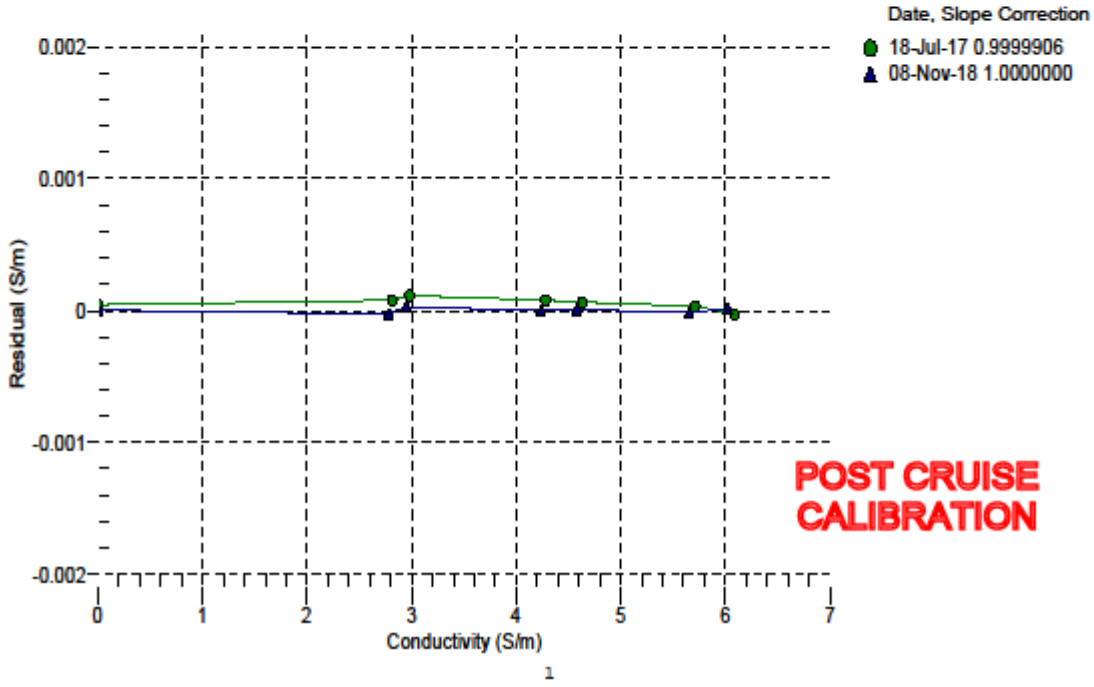
COEFFICIENTS:

g = -1.03580909e+001
h = 1.37390056e+000
i = -2.14819791e-003
j = 2.19952679e-004

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	2.75001	0.00000	0.00000
-1.0000	34.4777	2.77983	5.27994	2.77980	-0.00002
1.0000	34.4775	2.94975	5.39623	2.94978	0.00003
15.0000	34.4757	4.23423	6.20451	4.23422	-0.00000
18.5000	34.4728	4.57769	6.40325	4.57770	0.00001
29.0000	34.4624	5.65084	6.98746	5.65082	-0.00002
32.5001	34.4465	6.01876	7.17670	6.01878	0.00001

f = Instrument Output (kHz)
t = temperature (°C); p = pressure (decibars); δ = CTcor; ε = CPcor;
Conductivity (S/m) = $(g + h * f^2 + i * f^3 + j * f^4) / 10 (1 + \delta * t + \varepsilon * p)$
Residual (Siemens/meter) = instrument conductivity - bath conductivity



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13431 NE 20th Street
Bellevue, WA 98005
USA

+1 425-643-9866
seabird@seabird.com
www.seabird.com

SENSOR SERIAL NUMBER: 2293
CALIBRATION DATE: 02-Apr-19

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

COEFFICIENTS:

g = -1.07155632e+001
h = 1.48164179e+000
i = -2.65227515e-003
j = 2.69624621e-004

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

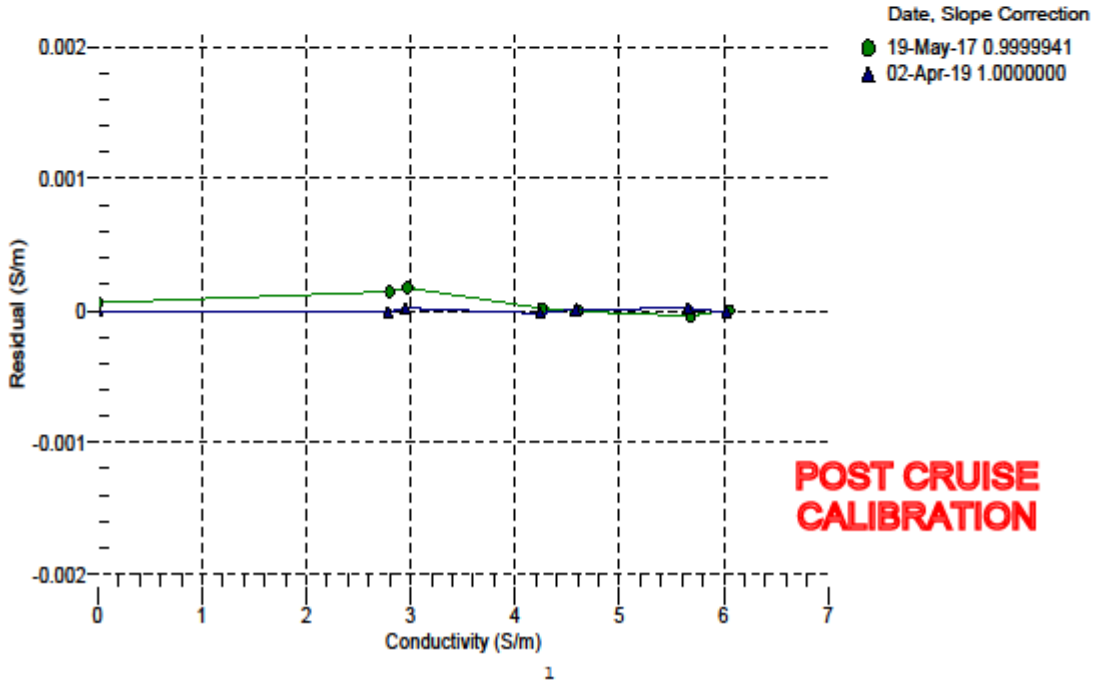
BATH TEMP (° C)	BATH SAL (PSU)	BATH COND (S/m)	INSTRUMENT OUTPUT (kHz)	INSTRUMENT COND (S/m)	RESIDUAL (S/m)
0.0000	0.0000	0.00000	2.69400	0.00000	0.00000
-1.0000	34.5225	2.78310	5.11184	2.78309	-0.00001
0.9999	34.5224	2.95322	5.22342	2.95324	0.00002
15.0000	34.5202	4.23911	5.99960	4.23909	-0.00002
18.5000	34.5179	4.58303	6.19061	4.58304	0.00001
29.0000	34.5096	5.65771	6.75235	5.65773	0.00002
32.5000	34.4962	6.02645	6.93446	6.02644	-0.00001

f = Instrument Output (kHz)

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

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

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



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PO Box 518
620 Applegate St.
Philomath, OR 97370

(541) 929-5650
Fax (541) 929-5277
www.wetlabs.com

ECO Chlorophyll Fluorometer Characterization Sheet

Date: 7/19/2019 S/N: FLRTD-398

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

CHL (µg/l) = Scale Factor * (Output - Dark Counts)

	Analog Range 1	Analog Range 2	Analog Range 4 (default)		Digital
Dark Counts	0.090	0.050	0.027	V	68 counts
Scale Factor (SF)	6	12	24	µg/l/V	0.0072 µg/l/count
Maximum Output	5.00	5.00	5.00	V	16328 counts
Resolution	0.4	0.4	0.4	mV	1.0 counts

Ambient temperature during characterization 22.0 °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 ÷ (output - 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.

FLRTD-398.xls Revision J 3/17/08

PO Box 518
620 Applegate St.
Philomath, OR 97370

WET Labs

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ECO Chlorophyll Fluorometer Characterization Sheet

Date: 11/26/2018 S/N: FLRTD-399

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

CHL (µg/l) = Scale Factor * (Output - Dark Counts)

	Analog Range 1	Analog Range 2	Analog Range 4 (default)		Digital
Dark Counts	0.083	0.058	0.045	V	42 counts
Scale Factor (SF)	6	13	26	µg/l/V	0.0077 µg/l/count
Maximum Output	4.99	4.99	4.99	V	16380 counts
Resolution	1.1	1.1	1.1	mV	1.0 counts

Ambient temperature during characterization 22.0 °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 ÷ (output - 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.

FLRTD-399 Revision J 3/17/08

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ECO Chlorophyll Fluorometer Characterization Sheet

Date: 7/19/2019 S/N: FLRTD-1735

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

CHL (µg/l) = Scale Factor * (Output - Dark Counts)

	Analog Range 1	Analog Range 2	Analog Range 4 (default)		Digital
Dark Counts	0.056	0.024	0.008	V	50 counts
Scale Factor (SF)	6	11	23	µg/l/V	0.0070 µg/l/count
Maximum Output	5.00	5.00	5.00	V	16380 counts
Resolution	0.4	0.4	0.4	mV	1.0 counts

Ambient temperature during characterization 0.0 °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 ÷ (output - 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.

FLRTD-1735.xls Revision J 3/17/08

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Philomath, OR 97370

SEA-BIRD SCIENTIFIC

(541) 929-5650
Fax (541) 929-5277
www.sea-birdscientific.com

C-Star Calibration

Date 6.26.18 S/N# CST-830DR Pathlength 25 cm

	Analog output	Digital output
V_d	0.007 V	0 counts
V_{air}	4.966 V	16272 counts
V_{ref}	4.701 V	15405 counts

Temperature of calibration water	23.5 °C
Ambient temperature during calibration	23.2 °C

Relationship of transmittance (Tr) to beam attenuation coefficient (c), and pathlength (x, in meters): $Tr = e^{-cx}$

To determine beam transmittance: $Tr = (V_{sig} - V_{dark}) / (V_{ref} - V_{dark})$

To determine beam attenuation coefficient: $c = -1/x * \ln (Tr)$

V_d Meter output with the beam blocked. This is the offset.
V_{air} Meter output in air with a clear beam path.
V_{ref} Meter output with clean water in the path.
Temperature of calibration water: temperature of clean water used to obtain V_{ref}.
Ambient temperature: meter temperature in air during the calibration.
V_{sig} Measured signal output of meter.

Revision L 6/9/09

Biospherical Instruments Inc

CALIBRATION CERTIFICATE

UNDERWATER PAR SENSOR WITH LOG AMPLIFIER

Calibration Date: 05/14/18 **Job No.:** R13258
Model Number: QSP200L
Serial Number: 4403
Operator: TPC
Standard Lamp: V-042(7/21/16)
Operating Voltage Range: 6 to 15 VDC (+)

Note. The QSP200L uses a log amplifier to measure the detector signal current with V = log I (Amps) / IRef
To calculate irradiance, use this formula:

Irradiance = Calibration factor * (10^Light Signal Voltage - 10^Dark Voltage)

With the appropriate (solar corrected) Irradiance Calibration Factor:

Dry Calibration Factor:	**2.19E+13**	**quanta/cm²·sec per volt**	**3.64E-05**	**µEinsteins/cm²·sec per volt**
Wet Calibration Factor:	**3.87E+13**	**quanta/cm²·sec per volt**	**6.43E-05**	**µEinsteins/cm²·sec per volt**

Sensor Test Data and Results[4]

Sensor Supply Current (Dark):	65.9	mA			
Supply Voltage:	8	Volts			
Lamp Integrated PAR Irradiance:	9.43E+15	quanta/cm²·sec	0.01566	µEinsteins/cm²sec	
SC3 Immersion Coefficient:	0.5864	Scalar Correction:	1	PAR Solar Correction:	1.0000

Nominal Filter OD	Calibrated Trans.		Measured Trans.		Measured Signal (Amps)	Estimated Signal (Amps)	Calc. Output (Volts)	Error (Volts)	Error (%)	Test Irrad. (quanta/cm²·sec)
No Filter	100.00%	2.635	100.00%		4.32E-08	4.32E-08	2.636	0.001	0.0	9.43E+15
0.3	36.10%	2.202	36.67%		1.58E-08	1.56E-08	2.196	-0.005	-1.5	3.46E+15
0.5	27.60%	2.093	28.46%		1.23E-08	1.19E-08	2.081	-0.012	-3.0	2.68E+15
1	9.27%	1.681	10.08%		4.35E-09	4.00E-09	1.617	-0.034	-8.1	9.51E+14
2	1.11%	0.847	1.31%		5.65E-10	4.79E-10	0.791	-0.056	-15.3	1.24E+14
3	0.05%	0.258	0.10%		4.18E-11	2.30E-11	0.211	-0.047	-44.9	9.14E+12

Dark Before: 0.144 Volts
Light - No Filter Hldr.: 2.635 Volts
Dark After - NFH: 0.145 Volts
Average Dark 0.144 Volts

I_{Ref} = 1.00E-10 Amps
I_{Dark} = 1.39E-10 Amps
10^{VDark} = 1.394441

RG780 0.206

Notes:
1. Annual calibration is recommended.
2. The collector should be cleaned frequently with a cotton
4) This section is for internal use and for more advanced analysis.

QSP200L-QSP2300 (4-2013-).xls

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:	45683
Instrument Type:	Altimeter
Instrument Serial Number:	54772
Calibrated By:	L.Bicknell
Date:	12/07/2016
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.

Valeport Ltd | St Peter's Quay | Totnes | Devon | TQ9 5EW | UK
T: +44 (0) 1803 869292 | F: +44 (0) 1803 869293
E: sales@valeport.co.uk | www.valeport.co.uk

MOCNESS Calibration Sheets

MOCNESS pressure sensor

Sea-Bird Scientific
13431 NE 20th Street
Bellevue, WA 98005
USA

+1 425-643-9866
seabird@seabird.com
www.seabird.com

SENSOR SERIAL NUMBER: 0232
CALIBRATION DATE: 22-Apr-19

SBE 9plus PRESSURE CALIBRATION DATA
10000 psia S/N 43528

DIGIQUARTZ COEFFICIENTS:

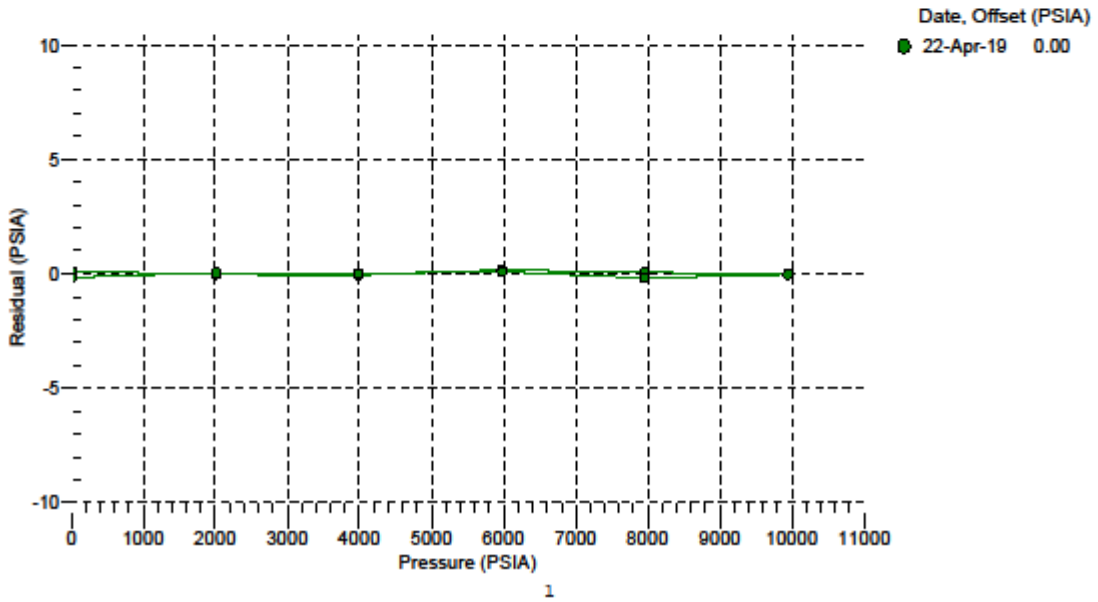
C1 = -5.103000e+004
C2 = 8.606365e-002
C3 = 1.481220e-002
D1 = 3.642300e-002
D2 = 0.000000e+000
T1 = 3.004925e+001
T2 = -3.406308e-004
T3 = 4.125600e-006
T4 = 1.811600e-009
T5 = 0.000000e+000

AD590M, AD590B, SLOPE AND OFFSET:

AD590M = 1.13600e-002
AD590B = -8.42350e+000
Slope = 0.99979
Offset = 3.5192 (dbars)

PRESSURE (PSIA)	INSTRUMENT OUTPUT (Hz)	INSTRUMENT TEMPERATURE (°C)	INSTRUMENT PRESSURE (PSIA)	CORRECTED PRESSURE (PSIA)	RESIDUAL (PSIA)
14.727	33288.40	24.9	9.726	14.831	0.104
2000.759	33929.20	24.9	1996.055	2000.733	-0.026
3987.784	34556.70	24.9	3983.461	3987.713	-0.071
5974.881	35171.40	24.9	5971.217	5975.042	0.161
7962.065	35773.80	24.9	7958.739	7962.138	0.073
9949.629	36364.70	24.9	9946.621	9949.593	-0.036
7962.018	35773.70	24.8	7958.428	7961.827	-0.191
5974.655	35171.30	24.8	5970.924	5974.749	0.094
3987.740	34556.70	24.8	3983.511	3987.763	0.023
2000.755	33929.20	24.8	1996.112	2000.790	0.035
14.731	33288.30	24.8	9.470	14.576	-0.155

Residual (PSIA) = corrected instrument pressure - reference pressure



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Sea-Bird Scientific
13431 NE 20th Street
Bellevue, WA 98005
USA

+1 425-643-9866
seabird@seabird.com
www.seabird.com

SENSOR SERIAL NUMBER: 5034
CALIBRATION DATE: 21-Mar-19

SBE 3 TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

COEFFICIENTS:

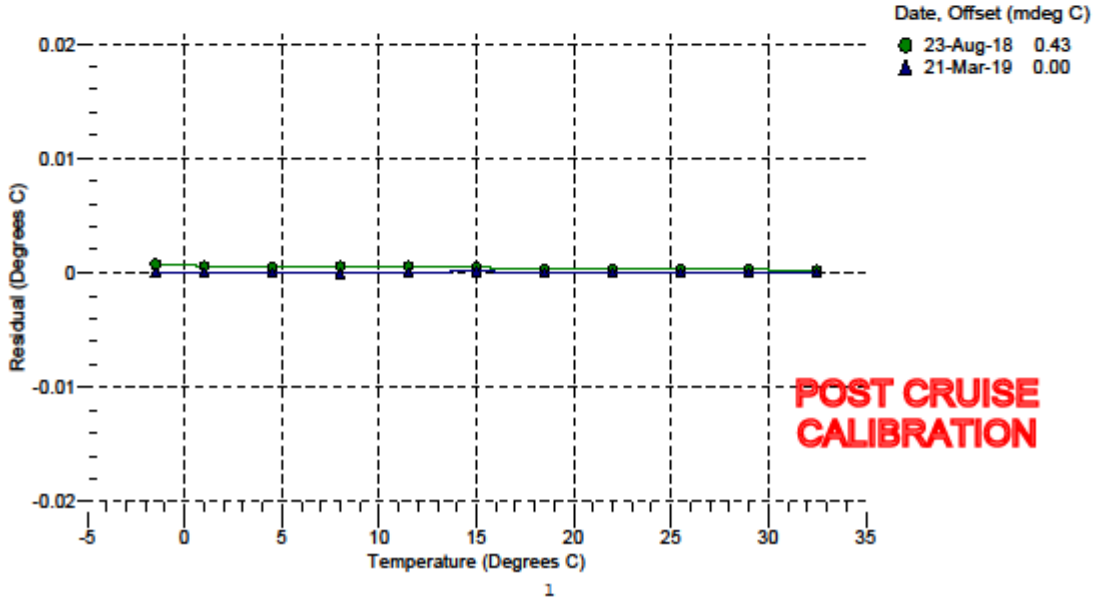
g = 4.33932102e-003
h = 6.35631440e-004
i = 2.10496597e-005
j = 1.86996017e-006
f0 = 1000.0

BATH TEMP (° C)	INSTRUMENT OUTPUT (Hz)	INST TEMP (° C)	RESIDUAL (° C)
-1.5000	2914.388	-1.5000	0.00000
1.0000	3083.200	1.0000	0.00003
4.5000	3331.255	4.5000	-0.00002
8.0000	3593.340	7.9999	-0.00009
11.5000	3869.857	11.5000	0.00004
15.0000	4161.159	15.0001	0.00012
18.5000	4467.593	18.5000	-0.00004
22.0000	4789.543	22.0000	-0.00005
25.5000	5127.341	25.5000	-0.00000
29.0000	5481.305	29.0000	-0.00001
32.5000	5851.759	32.5000	0.00002

f = Instrument Output (Hz)

Temperature ITS-90 (°C) = $1/\{g + h[ln(f0 / f)] + i[ln^2(f0 / f)] + j[ln^3(f0 / f)]\} - 273.15$

Residual (°C) = instrument temperature - bath temperature



Sea-Bird Scientific
13431 NE 20th Street
Bellevue, WA 98005
USA

+1 425-643-9866
seabird@seabird.com
www.seabird.com

SENSOR SERIAL NUMBER: 2048
CALIBRATION DATE: 29-Mar-19

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

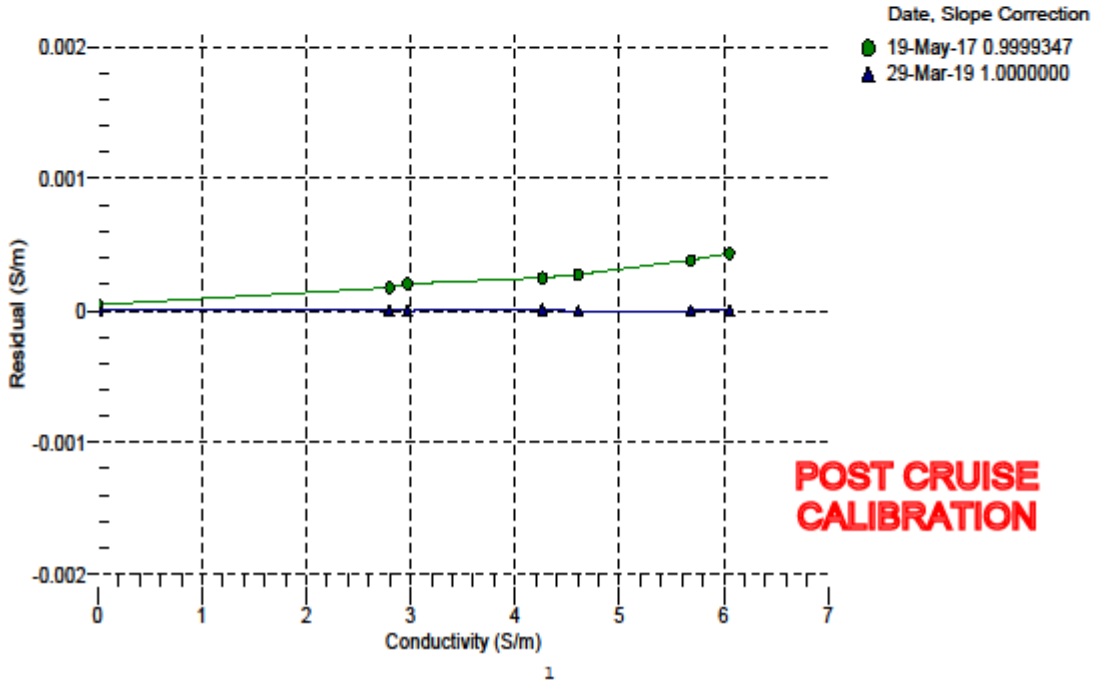
COEFFICIENTS:

g = -1.03087606e+001
h = 1.43342094e+000
i = -5.43911243e-003
j = 6.00495499e-004

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	2.69142	0.00000	0.00000
-1.0001	34.6930	2.79556	5.18852	2.79556	0.00000
0.9999	34.6935	2.96646	5.30295	2.96645	-0.00000
15.0000	34.6927	4.25805	6.09753	4.25806	0.00001
18.5000	34.6922	4.60368	6.29277	4.60367	-0.00001
29.0000	34.6849	5.68321	6.86590	5.68321	-0.00000
32.5002	34.6708	6.05350	7.05139	6.05351	0.00000

f = Instrument Output (kHz)
t = temperature (°C); p = pressure (decibars); δ = CTcor; ε = CPcor;
Conductivity (S/m) = $(g + h * f^2 + i * f^3 + j * f^4) / 10 (1 + \delta * t + \varepsilon * p)$
Residual (Siemens/meter) = instrument conductivity - bath conductivity



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USA

+1 425-643-9866
seabird@seabird.com
www.seabird.com

SENSOR SERIAL NUMBER: 0181
CALIBRATION DATE: 16-Mar-19

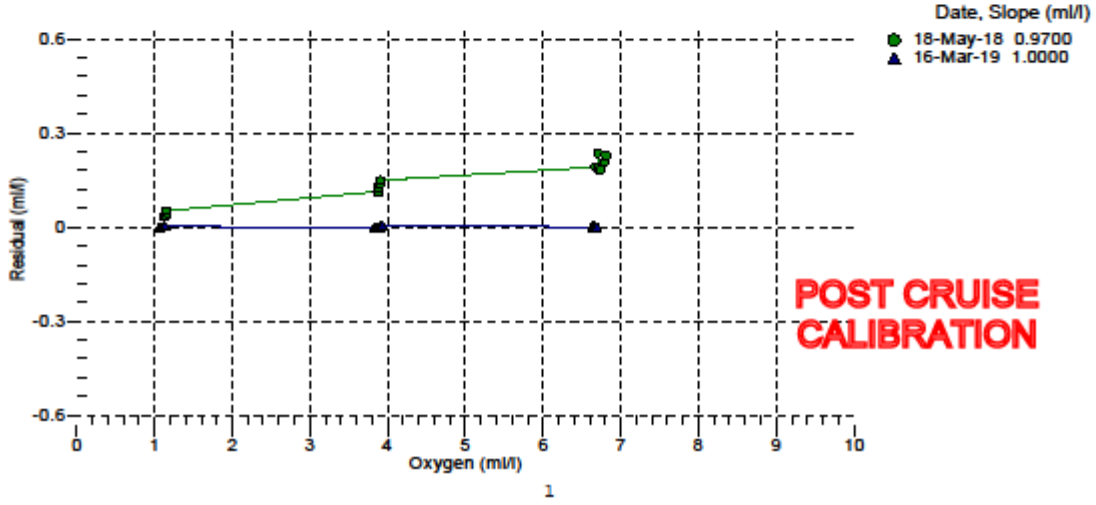
SBE 43 OXYGEN CALIBRATION DATA

COEFFICIENTS:
Soc = 0.5421
Voffset = -0.5046
Tau20 = 1.14
A = -4.7267e-003
B = 1.8910e-004
C = -2.8666e-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)
1.07	2.00	0.00	0.710	1.07	-0.00
1.07	6.00	0.00	0.736	1.07	-0.00
1.08	12.00	0.00	0.779	1.08	0.00
1.11	20.00	0.00	0.841	1.11	0.00
1.12	26.00	0.00	0.888	1.13	0.00
1.13	30.00	0.00	0.921	1.14	0.00
3.84	2.00	0.00	1.242	3.84	-0.00
3.86	6.00	0.00	1.341	3.86	-0.00
3.87	12.00	0.00	1.485	3.87	-0.00
3.89	20.00	0.00	1.681	3.89	-0.00
3.92	26.00	0.00	1.840	3.92	0.00
3.93	30.00	0.00	1.948	3.94	0.00
6.63	2.00	0.00	1.780	6.63	0.00
6.65	6.00	0.00	1.944	6.65	0.00
6.65	29.95	0.00	2.941	6.65	-0.00
6.66	12.00	0.00	2.193	6.66	-0.00
6.69	20.00	0.00	2.531	6.70	0.00
6.69	26.00	0.00	2.783	6.69	-0.00

V = instrument output (volts); T = temperature (°C); S = salinity (PSU); K = temperature (°K)
Oxsol(T,S) = oxygen saturation (ml/l); P = pressure (dbar)
$Oxygen\ (ml/l) = Soc * (V + Voffset) * (1.0 + A * T + B * T^2 + C * T^3) * Oxsol(T,S) * \exp(E * P / K)$
Residual (ml/l) = instrument oxygen - bath oxygen



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PO Box 518
620 Applegate St.
Philomath, OR 97370

WET Labs

(541) 929-5650
Fax (541) 929-5277
www.wetlabs.com

ECO Chlorophyll Fluorometer Characterization Sheet

Date: 4/23/2019 S/N: FLRTD-867

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

CHL (µg/l) = Scale Factor * (Output - Dark Counts)

	Analog Range 1	Analog Range 2	Analog Range 4 (default)	Digital
Dark Counts	0.092	0.057	0.040 V	57 counts
Scale Factor (SF)	6	12	24 µg/l/V	0.0074 µg//count
Maximum Output	4.96	4.96	4.96 V	16326 counts
Resolution	0.6	0.6	0.6 mV	1.0 counts

Ambient temperature during characterization 22.0 °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 ÷ (output - 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.

FLRTD-867 Revision J 3/17/08

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C-Star Calibration

Date 4.18.19 S/N# CST-248DR Pathlength 25 cm

	Analog output	
V_d	0.058 V	
V_{air}	4.739 V	
V_{ref}	4.625 V	
Temperature of calibration water		21.6 ℃
Ambient temperature during calibration		24.2 ℃

Relationship of transmittance (Tr) to beam attenuation coefficient (c), and pathlength (x, in meters): $Tr = e^{-cx}$

To determine beam transmittance: $Tr = (V_{sig} - V_{dark}) / (V_{ref} - V_{dark})$

To determine beam attenuation coefficient: $c = -1/x * \ln (Tr)$

V_d Meter output with the beam blocked. This is the offset.
V_{air} Meter output in air with a clear beam path.
V_{ref} Meter output with clean water in the path.
Temperature of calibration water: temperature of clean water used to obtain V_{ref}.
Ambient temperature: meter temperature in air during the calibration.
V_{sig} Measured signal output of meter.

Revision M 7/26/11

Acquisition and Processing Information

Errors and Events

Day Of Year	Time (GMT)	Event	Location
365	0338	Started Data Acquisition	68W
001	~0100	ADCP bottom tracking off	Leaving Continental Shelf SB
001	0316	ADCP Turned off BB mode	
002	1546	ADCP bottom tracking on	Arriving at Antarctic Shelf SB
003	1145	Water wall off, sonars off	Arrive Palmer Station
004	2231	Water wall on, sonars on	Depart Palmer Station
007	1121	Seawater flow off to fix leak	
007	1159	Seawater flow back on.	
007	1955	ADCP and Sonar off for EK-80 tow	
008	1033	ADCP and Sonar reactivated	
009	1000	ADCP stopped for NB150 calibration update	
009	1003	ADCP started	
009	1636	ADCP and Sonar off for EK-80 tow	
009	2215	ADCP and Sonar back on	
010	2200	Changed primary conductivity sensor on CTD from s/n 2047 to s/n 2065	After CTD Cast #7
011	2135	Changed secondary conductivity sensor on CTD from s/n 2247 to s/n 2293	After CTD Cast #8
011	2241	ADCP bottom tracking off	
015	1535	ADCP and sonars off for mooring operations	
015	2108	ADCP and sonars on	
015	2315	Changed CTD Fluorometer from s/n 399 to s/n 398	After Deep Cast CTD
016	2045	Changed CTD Fluorometer from s/n 398 to s/n 1735	After CTD Cast #20
020	1000	PCO2 system inadvertently shut off	
020	1120	PCO2 system restarted	
021	2305	Changed secondary conductivity sensor on CTD from s/n 2293 to s/n 2247 (previously used on secondary)	After CTD Cast #28
022	2049	Changed secondary conductivity sensor on CTD from s/n 2247 to s/n 2047 (previously used on primary)	After CTD Cast #30
025	1400	Heavy ice clogging lab pump intakes. Seawater sampling unreliable.	
025	1710	Moved out of ice, seawater system back on running normally	
036	0900	ADCP off for EK-80 survey	
036	1222	ADCP on	
036	1753	ADCO off for EK-80 survey	
037	0959	ADCP on	
037	1100	Sonars and water off	Palmer Station
039	1210	Sonars and water sampling on	Depart Palmer Station
041	2226	ADCP Bottom Tracking On	Patagonian shelf
042	1605	Data acquisition stopped	@68W