LMG 1610

Cruise Data Report

Jake Bolewski

Austin McHugh

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Photo by Captain Zsolt Esztergomi

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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All the data has been archived using 'tar' and compressed using 'gzip', identified by the '.gz' extension.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 contains a database of the averaged ping data, Matlab m-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.

Maps (/Maps)

This directory maps and mapping data generated by the ship's MCIS and automated scripts, plus any maps provided for this purpose by the on-board science party.

Ocean data (/ocean)

XBT Data (/Ocean/XBT)

Contains two zip archives of XBT data generated for the Drake Transect by NOAA standard "AMVERSEAS" software.

XCTD Data (/Ocean/XCTD)

Expendable Conductivity, Temperature, and Depth (XCTD) digital probes were used to obtain water column temperature and Salinity profiles. The two files were created for each drop .RDF files contain the raw data, and the .EDF contain the exported ascii data.

CTD Data (/Ocean/CTD)

This directory contains the directory structure copied over from the CTD computer, and includes subdirectories for graphs, software configuration files, processing scripts, calibration files, raw data, and processed data.

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.

Reports (/Report)

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

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/meter2
10	Sea Surface Temperature	°C
11	Sea Surface Conductivity	siemens/meter
12	Sea Surface Salinity	PSU
13	Sea Depth (uncorrected, calc. sw soud vel. 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	Transmissometry	%
21	PSP	W/m2
22	PIR	W/m2

pCO2-merged Data Set

/Process/PCO2/

```
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
```

Field	Data	Format	Unit
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

RVDAS

/RVDAS/

RVDAS (Research Vessel Data Acquisition System) was 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

RVDAS data is divided into two general categories, *underway and navigation*. They can be found on the distribution media as subdirectories under the top level rvdas directory: /rvdas/uw, and /rvdas/nav. Processed oceanographic 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: `LMG1603lmwx.d025`

- 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	RM Young 41372LC
Relative Humidity	lmwx (met)	Continuous	1/sec	RM Young 41372LC
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
Oxygen	lgo2	Continuous	1/min	UCAR Oxygen system

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		
Net Depth Sensor	lnds		

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	Latitude	xx.xxxxxx	degrees
9	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 Indentifier		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

```
08+034:13:52:14.454 MET,12.22322,44.25706,-75,-25,-363.6365,2.332982,-0.08215196,278.6845,
279.2192,854.6198,854.6184
```

Note that secondary barometer was removed from logging 19-Jul-16

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.x	%
5	Air Temperature, Celsius	xx.x	°C
6	Air Relative Humidity	xx.x	%
7	PAR (Photosynthetically Available Radiation)	xxx.xxxx	mV
8	PSP (Shortwave Radiation)	x.xxxxxx	mV
9	PIR Thermopile (Longwave Radiation)	x.xxxxxx	mV
10	PIR Case Temperature	xxx.xxxx	°K
11	PIR Dome Temperature	xxx.xxxx	°K
12	Barometer	xxx.xxxx	mBar
13	Secondary 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 – wet wall flows, transmissometer

```
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	V
8	High precision voltage #2	V
9	High precision voltage #3	V
10	Standard precision voltage #1 (historically used for YoYo Cam xmiss)	V
11	Standard precision voltage #2 (historically used for YoYo Cam altimeter)	V
12	Standard precision voltage #3	V
13	Standard precision voltage #4	V
14	T	Text
15	Temperature Probe 1	°C
16	Temperature Probe 2	°C
17	Temperature Probe 3	°C
18	Temperature Probe 4	°C
19	P	Text
20	Pulse Counter 1	counts
21	Pulse Counter 2	counts
22	F	Text
23	Flow Counter #1	counts
24	Flow Counter #2	counts
25	Flow Counter #3	counts
26	Flow Counter #4	counts
27	Flow Counter #5	counts
28	Flow Counter #6	counts
29	Flow Counter #7	counts
30	Flow Counter #8	counts
31	I	Text
32	Digital Input #1	1 or 0
33	Digital Input #2	1 or 0
34	Digital Input #3	1 or 0
35	Digital Input #4	1 or 0

utsg – microTSG, 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, 1459.351
```

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	xxxx.xxx	m/s

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, Wetlab ECO

```
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

lgo2 – Oxygen System

For further information on this data, please contact Britt Stephens at stephens@ucar.edu

```
12+301:22:35:30.558 81300.8 16.0 32.0 000.0 005.0 1.2589631 1.2379622 744.549 111.853 131.642
-2.089 -2.448 723.594 002.50 086.43 099.74 002.77 000.97 050.65 0.000 001.19 065.59 039.48
1966.097 01.345 37.0171 37.8433 000.0 000.0 20.66 20.41 -92.0 28.66 37.44 42.33 37.80 47.95
0.0 01.88 0.0001711 0.0001712 0.0000747 0.0000725 02.657 02.678 -1 0.0000895 -043.94
```

Field	Data
01	RVDAS Time Tag
02	jsecoday - Seconds since midnight
03	jselflag - 8 bit decimal value indicated selected gases
04	jprgflag - 8 bit decimal value indicated purged gases
05	jmfcflag - 8 bit decimal value indicated mass-flow controller states
06	jgenflag - 8 bit decimal value indicated other parameters
07	jfcv1 - voltage on Fuel Cell #1
08	jfcv2 - voltage on Fuel Cell #2
09	jpfcell - pressure in torr at fuel cells
10	jlico2a - CO2 in ppm in Li7000 Cell A
11	jlico2b - CO2 in ppm in Li7000 Cell B [CO2 MEASUREMENT]
12	jlih2oa - H2O in ppt in Li7000 Cell A
13	jlih2ob - H2O in ppt in Li7000 Cell B
14	jlipb - pressure in torr at Li7000 Cell B
15	flmfcset - mass-flow controller set voltage
16	jfll1 - flow in sccm on Inlet Line #1
17	jfll2 - flow in sccm on Inlet Line #2
18	jfllt - flow in sccm on Long-Term reference cylinder
19	jflcal - flow in sccm on selected Calibration cylinder
20	jflwta - flow in sccm on selected Working Tank Cylinder
21	jvsoset - purge line voltage-sensitive orifice set voltage
22	jflpurge - flow in sccm on purge line
23	jflwtb - flow in sccm on Working Tank line through sensors
24	jflsp - flow in sccm on Span line through sensors
25	jpfridge - pressure in torr inside fridge trap
26	jtfridge - temperature in C inside fridge trap
27	jtmpt - fuel-cell control temperature (thermistor) in C for MPT10000
28	jtfcell - fuel-cell thermistor temperature in C
29	jtach1 - rmp of fan inside Line #1 Inlet
30	jtach2 - rmp of fan inside Line #2 Inlet
31	jtcyl1 - temperature in C from cylinder box RTD #1
32	jtcyl2 - temperature in C from cylinder box RTD #2
33	jtchill - temperature in C from chiller RTD
34	jtamb - temperature in C RTD near Analyzer Box electronics
35	jtomega - Analyzer Box control temperature (RTD) for Omega CNi2332
36	jtu4ch - temperature in C inside USB4CH 24-bit A/D box
37	jtfcrtd - fuel-cell RTD temperature in C

38	jtirga - temperature in C inside Li7000
39	jliflags - Li7000 status flag
40	jlirhsrc - Li7000 source/detector relative humidity
41	jsdfcv1 - standard deviation of 1-Hz Fuel Cell #1 voltage
42	jsdfcv2 - standard deviation of 1-Hz Fuel Cell #2 voltage
43	jslfcv1 - slope of 1-Hz Fuel Cell #1 voltage
44	jslfcv2 - slope of 1-Hz Fuel Cell #2 voltage
45	jsdco2a - standard deviation of 1-Hz Li7000 Cell A CO2 in ppm
46	jsdco2b - standard deviation of 1-Hz Li7000 Cell B CO2 in ppm
47	posneg - flag indicating position of fuel-cell changeover valve
48	jogdeltadiff - amplitude of 3-jog O2 difference-signal [O2 MEASUREMENT]

loxy – Oxygen (Part of PCO2 system, separate from Oxygen 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  177204
```

Field	Data	Format	Unit
1	RVDAS time tag	yy+ddd:hh:mm:ss.sss	UTC
2	Raw data counts	xxxxxx	Integer

ladc – ADCP Speed Log

```
00+019:23:59:59.099 $PUHAW,UVH,-1.48,-0.51,250.6
```

Field	Data	Unit
1	RVDAS time tag	UTC
2	$PUHAW	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)

[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).

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

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	UTC

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

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	Mode*	x	alphanumeric
15	Checksum	xx	UTC

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

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 (primary)	Vaisala PTB210B	K284002	10-July-2014	Collected
Humidity/Wet Temp	RM Young 41372LC	6720	27-Sep-2017	Collected
PAR for Mast	Biosph. Inst. QSR-240P	6393	31-Mar-2015	Collected
PIR	Eppley PIR	32031F3	10-Mar-2016	Collected
PSP	Eppley PSP	31701F3	18-Mar-2016	Collected
GUV (Mast)	Biosph. Inst. GUV-2511	25110805126	26-Mar-2015	Collected
Transmissometer	WET Labs C-Star 25 cm deep	CST-407DR	21-Aug-2015	Collected
MicroTSG (Primary)	Sea-Bird 45	227	14-July-2016	Collected
MicroTSG (Secondary)	Sea-Bird 45	390	30-Oct-2014	Collected
Digital Remote Temp	Sea-Bird 38	351	28-Dec-2013	Collected
Fluorometer	WET Labs ECO-FL	FLRTD-1735	22-Jun-2015	Collected

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
47 Gosport Street
Lymington
Hampshire
SO41 9EG, UK

www.gill.co.uk

ISO 9001 Registered

Anemometer-Starboard

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

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2002-0395 Issue 1

Gill Instruments Ltd
Solent Way
Lymington
Hampshire
SO41 9ZG, UK

T: +44 (0) 1590 613 500
F: +44 (0) 1590 613 555
E: gill@gill.co.uk

www.gill.co.uk

ISO 9001 Registered

Barometer

VAISALA

1 (1)
Certificate report no. H44-14280026

CALIBRATION CERTIFICATE

Instrument	PTB210B Digital Barometer
Serial number	K2840001
Manufacturer	Vaisala Oyj, Finland
Calibration date	10th July 2014

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
PPC4	476	2014-05-27	K008-X01113

Uncertainty (95 % confidence level, k=2)

Pressure	± 0.15 hPa

Ambient Conditions

Humidity	34 %RH ± 5 %RH
Temperature	23 °C ± 1 °C
Pressure	1019 hPa ± 1 hPa

Technician

doc223087-B

Air Temperature / Relative Humidity

R.M. Young Company
2801 Aero Park Drive
Traverse City, Michigan 49686 USA

YOUNG

CALIBRATION REPORT
Temperature

Customer: *Lockheed Martin Corp*

Test Number: 6310-01T
Test Date: 1 April 2016
Customer PO: 4102366553
Sales Order: 5361

Test Sensor:
Model: 41372LC
Serial Number: *TS06720*
Description: Temperature/Relative Humidity Sensor

Report of calibration comparison of test temperature sensor with National Institute of Standards and Technology traceable standard thermometers at three temperatures in the R.M. Young Company controlled temperature calibration bath facilities. Calibration accuracy ± 0.1° Celsius.

Bath Temperature (degrees C)	Current Output (milliamps)	Indicated (1) Temperature (degrees C)
-49.90	4.017	-49.89
-0.01	11.997	-0.02
50.09	20.014	50.09

(1) Calculated from current output

All reference equipment used in this calibration procedure have been tested by comparison to traceable standards certified by the National Institute of Standards and Technology.

Reference Instrument	Serial #	NIST Test Reference
Brooklyn Thermometer Model 43-FC	3006-118	W204690
Brooklyn Thermometer Model 22332-D5-FC	25071	W204691
Brooklyn Thermometer Model 2X400-D7-FC	77532	W204692
Keithley Multimeter Model 191	15232	8604897

Tested By: _____

METEOROLOGICAL INSTRUMENTS
Tel: 231-946-3980 Fax: 231-946-4772 Email: met.sales@youngusa.com Website: youngusa.com
ISO 9001:2008 CERTIFIED

R.M. Young Company
2801 Aero Park Drive
Traverse City, Michigan 49686 USA

CALIBRATION REPORT
Relative Humidity

Customer: *Lockheed Martin*

Test Number: 6310-01R
Test Date: 1 April 2016
Customer PO: 4102366553
Sales Order: 5361

Test Sensor:
Model: 41372LC
Serial Number: *TS06720*
Description: Temperature/Relative Humidity Sensor

Report of calibration comparison of test relative humidity sensor with National Institute of Standards and Technology traceable standard relative humidity sensor at five humidity levels in the R.M. Young Company controlled humidity chamber facility. Calibration accuracy ± 2.0 %.

Reference Humidity (%)	Current Output (milliamps)	Indicated (1) Humidity (%)
10.0	6.1	12.8
30.1	9.1	31.9
50.1	12.5	53.2
70.0	15.6	72.3
90.0	18.3	89.7

(1) Calculated from voltage output

All reference equipment used in this calibration procedure have been tested by comparison to traceable standards certified by the National Institute of Standards and Technology.

Reference Instrument	Serial #	NIST Test Reference
Vaisala Humidity Sensor Model 35AC	N475040	TN 266152
Fluke Multimeter Model 8060A	4865407	8604897

Tested By: _____

METEOROLOGICAL INSTRUMENTS
Tel: 231-946-3980 Fax: 231-946-4772 Email: met.sales@youngusa.com Website: youngusa.com
ISO 9001:2008 CERTIFIED

PAR for mast

Biospherical Instruments Inc.

CALIBRATION CERTIFICATE

Calibration Date	3/31/2015			
Model Number	QSR240			
Serial Number	6393			
Operator	TPC			
Standard Lamp	V-033(3/3/15)			
Probe Excitation Voltage Range:	6	to	18	VDC(+)
Output Polarity:	Positive			

Probe Conditions at Calibration (in air):

Calibration Voltage:	6	VDC(−)
Probe Current:	1.3	mA

Probe Output Voltage:

Probe Illuminated	97.9	mV
Probe Dark	0.4	mV
Probe Net Response	97.5	mV
RG780	0.4	mV

Corrected Lamp Output:

Output In Air (same condition as calibration):

9.391E+15	quanta/cm²sec
155.94603	uE/m²sec

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

Dry:	1.0379E-17	V/(quanta/cm²sec)
	6.2504E-04	V/(uE/m²sec)

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.

QSR240R 05/24/95

PIR

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

STANDARDIZATION OF EPPLEY PRECISION INFRARED RADIOMETER Model PIR

Serial Number: 32031F3

Resistance: 709 Ω at 23°C
Temperature Compensation Range: -20° to +40°C

This pyrgeometer has been compared against Eppley's Blackbody Calibration System under radiation intensities of approximately 200 watts meter^{-2} and an average ambient temperature of 23°C as measured by Standard Omega Temperature Probe, RTD#1.

As a result of a series of comparisons, it has been found to have a sensitivity of:

3.87×10^{-6} volts/watts meter^{-2}

The calculation of this constant is based on the fact that the relationship between radiation intensity and emf is rectilinear to intensities of 700 watts meter^{-2}. This radiometer is linear to within ±1.0% up to this intensity.

The calibration of this instrument is traceable to the International Practical Temperature Scale (IPTS) through a precision low-temperature blackbody.

Eppley recommends a minimum calibration cycle of five (5) years but encourages annual calibrations for highest measurement accuracy. Unless otherwise stated in the remarks section below or on the Sales Order, the results are "AS FOUND / AS LEFT".

Shipped to: NSF/Lockheed Martin
Port Hueneme, CA

S.O. Number: 64668
Date: March 10, 2016

Remarks:

Date of Test: March 10, 2016

In Charge of Test: Debra L. Hourty

Reviewed by:

End of Report

PSP

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 31701F3

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 = 7.58 µV / Wm^{-2}**
Uncertainty: U_{95} = ±0.91% (95% confidence level, k=2)
Resistance: 674 Ω at 23°C

Date of Test: March 18, 2016

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 Eleventh International Pyrheliometric Comparisons (IPC XI) at Davos, Switzerland in September-October 2010. 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/Lockheed Martin
Port Hueneme, CA

Signatures: In Charge of Test: Reviewed by:

Eppley SO: 64669

Date of Certificate: March 18, 2016

Remarks: Sensitivity before Repainting Element = 8.11 µV / Wm^{-2}

End of Report

GUV

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 25110805126

Optical Calibrations:

NIST Traceability. For wavelengths longer than 313 nm, the specific instruments cited here were calibrated using a 1000W FEL #V-**033 (3/3/15)** 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 **25110805126v7.mdb**. This database is required for operation of this system using Biospherical Instruments Inc.'s Logger® software.

Biospherical Instruments Inc.

GUV-2511 Calibration Certificate

System Serial Number	25110805126	Date of Calibration	3/26/2015
Calibration database	25110805126v7.mdb	Date of Certificate	3/26/2015
DASSN	0109	Standard of Spectral Irradiance	V-033(3/3/15)
Microprocessor Tag Number	2	Operator	TC

Monochromatic Channels	Address	Wavelength [nm]	Responsivity [Amps per µW/(cm²·nm)]	ScaleSmall [Volts per µW/(cm²·nm)]	ScaleMedium [Volts per µW/(cm²·nm)]	ScaleLarge [Volts per µW/(cm²·nm)]	OffsetSmall [volts]	OffsetMedium [volts]	OffsetLarge [volts]	Measurement Units
Ed0305	2	305	4.5490E-11	4.6797E-06	1.3675E-03	4.1636E-01	-1.5873E-05	-1.7560E-05	1.1270E-03	µW/(cm²nm)
Ed0313	6	313	2.4245E-10	2.4723E-05	7.2276E-03	2.5437E+00	-6.2071E-05	-6.1061E-05	1.0222E-03	µW/(cm²nm)
Ed0320	8	320	2.6374E-10	2.6841E-05	7.8887E-03	2.7307E+00	-2.2212E-04	-2.2188E-04	4.7992E-04	µW/(cm²nm)
Ed0340	10	340	1.9986E-10	2.0351E-05	5.9658E-03	2.1085E+00	-6.2615E-05	-6.1632E-05	1.1020E-03	µW/(cm²nm)
Ed0380	12	380	7.2720E-11	7.4101E-06	2.1623E-03	7.5907E-01	-3.4233E-04	-3.4152E-04	3.2530E-04	µW/(cm²nm)
Ed0395	13	395	2.9103E-10	2.9760E-05	8.7388E-03	3.0398E+00	1.0107E-04	1.0516E-04	1.4394E-03	µW/(cm²nm)

Broadband Channels	Address	Wavelength [nm]	Responsivity [Amps per µE/(cm²·s)]	ScaleSmall [Volts per µE/(cm²·s)]	ScaleMedium [Volts per µE/(cm²·s)]	ScaleLarge [Volts per µE/(cm²·s)]	OffsetSmall [volts]	OffsetMedium [volts]	OffsetLarge [volts]	Measurement Units
Ed0PAR	18	400-700	1.7133E-05	1.7452E+00	5.1139E+02	1.7900E+05	1.8944E-05	2.3095E-05	1.3509E-03	µE/(cm²sec)

Auxilliary Channels	Address	Wavelength	Responsivity	ScaleS	ScaleM	ScaleL	OffsetS	OffsetM	OffsetL	Measurement Units
Ed0Temp	22	0	1	0.01	0.01	0.01	0	0	0	°C
Ed0VIn	27	0	1	-0.25	-0.25	-0.25	0	0	0	V

Transmissometer

PO Box 518
620 Applegate St.
Philomath, OR 97370

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

C-Star Calibration

Date 8.21.15 S/N# CST-407DR Pathlength 25cm

	Analog output	Digital output
V_d	0.004 V	0 counts
V_{air}	4.821 V	15832 counts
V_{ref}	4.699 V	15433 counts

Temperature of calibration water	24.3 °C
Ambient temperature during calibration	22.8 °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

Thermosalinograph (Temperature) – Primary

Sea-Bird Electronics, Inc.
13431 NE 20th Street, Bellevue, WA 98005-2010 USA
Phone: (+1) 425-643-9866 Fax (+1) 425-643-9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 0227
CALIBRATION DATE: 14-Jul-16

SBE 45 TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

COEFFICIENTS:

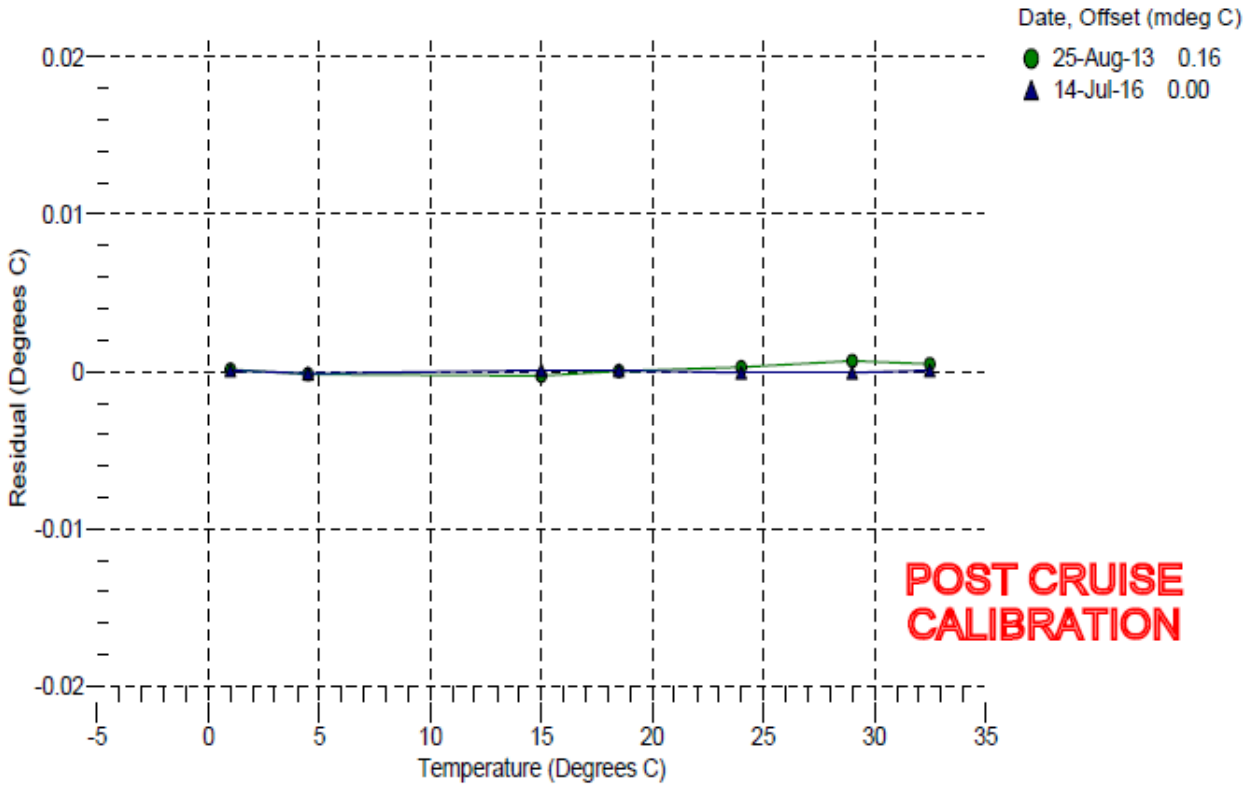
a0 = 9.075552e-006
a1 = 2.775935e-004
a2 = -2.569659e-006
a3 = 1.571654e-007

BATH TEMP (° C)	INSTRUMENT OUTPUT (counts)	INST TEMP (° C)	RESIDUAL (° C)
1.0000	664655.5	1.0001	0.0001
4.5000	568082.5	4.4999	-0.0001
15.0000	361660.6	15.0001	0.0001
18.5000	313053.4	18.5001	0.0001
24.0000	251010.6	23.9999	-0.0001
29.0000	206591.2	28.9999	-0.0001
32.5000	180857.5	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



Thermosalinograph (Conductivity) – Primary

Sea-Bird Electronics, Inc.
13431 NE 20th Street, Bellevue, WA 98005-2010 USA
Phone: (+1) 425-643-9866 Fax (+1) 425-643-9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 0227
CALIBRATION DATE: 14-Jul-16

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

COEFFICIENTS:

g = -1.019501e+000	CPcor = -9.5700e-008
h = 1.579848e-001	CTcor = 3.2500e-006
i = -4.519137e-004	WBOTC = 1.0472e-006
j = 6.150548e-005	

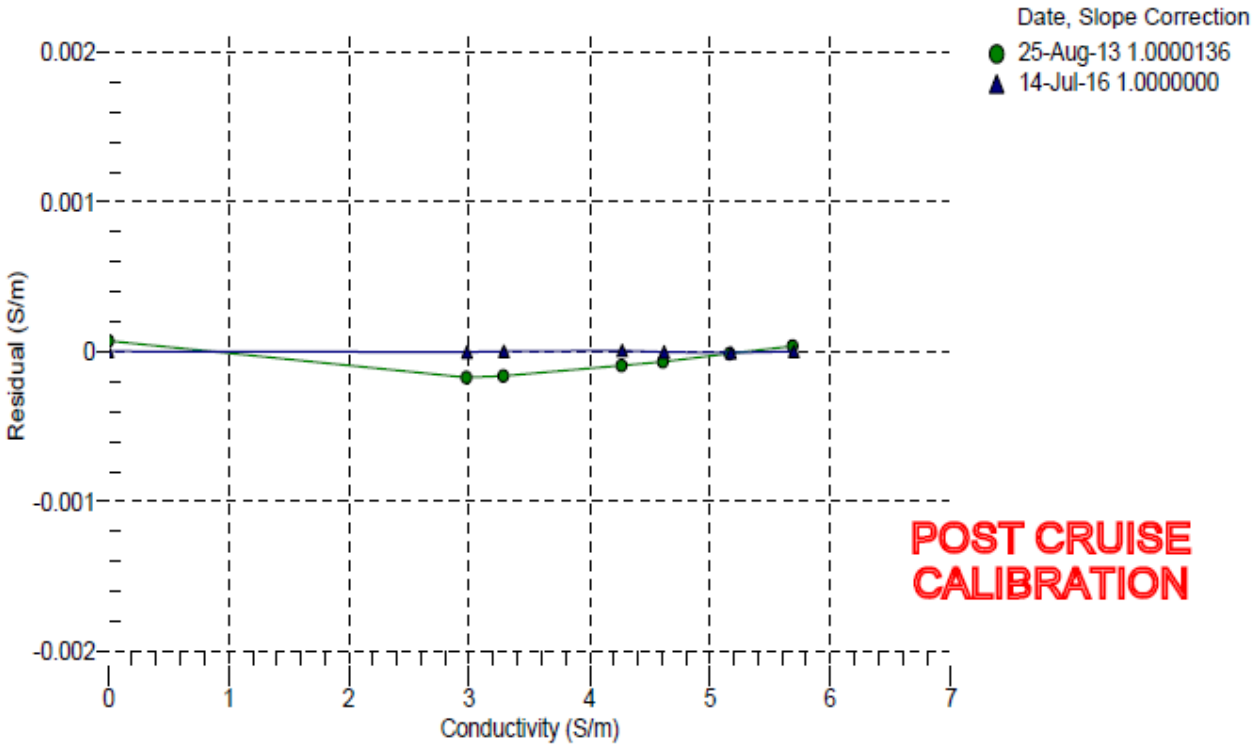
BATH TEMP (° C)	BATH SAL (PSU)	BATH COND (S/m)	INSTRUMENT OUTPUT (Hz)	INSTRUMENT COND (S/m)	RESIDUAL (S/m)
22.0000	0.0000	0.00000	2546.34	0.00000	0.00000
1.0000	34.8845	2.98124	5043.68	2.98124	-0.00000
4.5000	34.8634	3.28873	5233.36	3.28873	0.00000
15.0000	34.8195	4.27196	5797.58	4.27197	0.00001
18.5000	34.8096	4.61758	5982.97	4.61757	-0.00000
24.0000	34.7993	5.17638	6270.81	5.17637	-0.00001
29.0000	34.7942	5.69911	6528.23	5.69911	0.00000
32.5000	34.7920	6.07223	6705.75	6.07231	0.00008

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

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

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

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



Thermosalinograph (Temperature) – Secondary

Sea-Bird Electronics, Inc.
13431 NE 20th Street, Bellevue, WA 98005-2010 USA
Phone: (+1) 425-643-9866 Fax (+1) 425-643-9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 0390
CALIBRATION DATE: 30-Oct-14

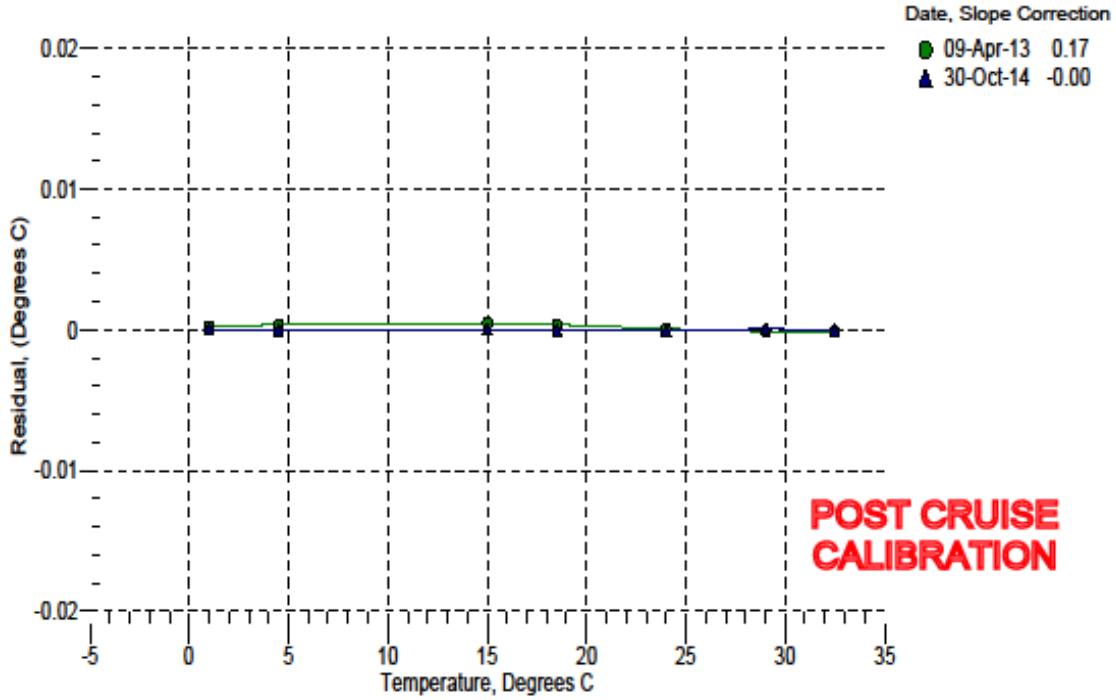
SBE 45 TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

COEFFICIENTS:

a0 = 8.496577e-006
a1 = 2.825921e-004
a2 = -3.093430e-006
a3 = 1.690910e-007

BATH TEMP (ITS-90)	INSTRUMENT OUTPUT	INST TEMP (ITS-90)	RESIDUAL (ITS-90)
1.0000	662306.1	1.0000	0.0000
4.5000	565262.5	4.5000	-0.0000
15.0000	358389.6	15.0000	0.0000
18.5000	309815.7	18.5000	-0.0000
24.0000	247915.6	23.9999	-0.0001
29.0000	203683.3	29.0001	0.0001
32.5000	178100.4	32.5000	-0.0000

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



Thermosalinograph (Conductivity) – Secondary

Sea-Bird Electronics, Inc.
13431 NE 20th Street, Bellevue, WA 98005-2010 USA
Phone: (+1) 425-643-9866 Fax (+1) 425-643-9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 0390
CALIBRATION DATE: 30-Oct-14

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

COEFFICIENTS:

g = -9.863328e-001
h = 1.453844e-001
i = -4.104173e-004
j = 5.237151e-005

CPcor = -9.5700e-008
CTcor = 3.2500e-006
WBOTC = 2.8724e-007

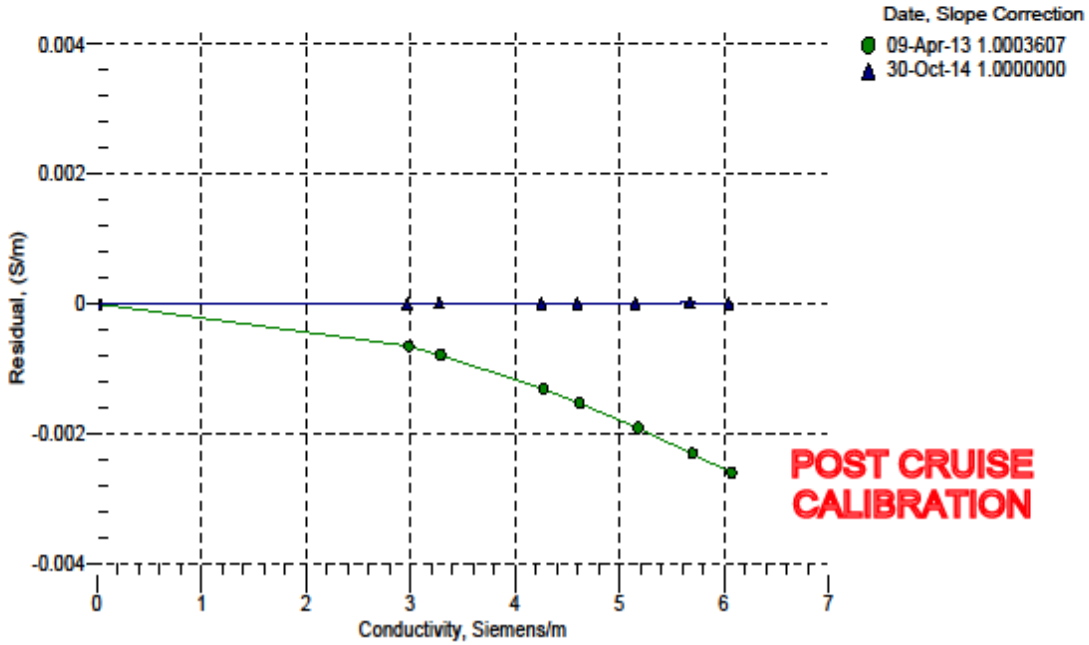
BATH TEMP (ITS-90)	BATH SAL (PSU)	BATH COND (Siemens/m)	INST FREQ (Hz)	INST COND (Siemens/m)	RESIDUAL (Siemens/m)
22.0000	0.0000	0.00000	2611.09	0.00000	0.00000
1.0000	34.6932	2.96644	5227.11	2.96644	-0.00000
4.5000	34.6730	3.27253	5425.21	3.27254	0.00001
15.0000	34.6287	4.25103	6014.01	4.25103	-0.00000
18.5000	34.6182	4.59492	6207.39	4.59491	-0.00000
24.0000	34.6058	5.15076	6507.48	5.15076	-0.00000
29.0000	34.5974	5.67049	6775.69	5.67050	0.00001
32.5000	34.5926	6.04138	6960.54	6.04137	-0.00001

f = INST FREQ * sqrt(1.0 + WBOTC * t) / 1000.0

Conductiv ity = $(g + h * f^2 + i * f^3 + j * f^4) / (1 + \delta * t + \varepsilon * p)$ Siemens / meter

t = temperatur e[°C)]; p = pressure[decibars]; δ = CTcor; ε = CPcor;

Residual = instrument conductivity - bath conductivity



Digital Remote Temperature

Sea-Bird Electronics, Inc.
13431 NE 20th Street, Bellevue, WA 98005-2010 USA
Phone: (+1) 425-643-9866 Fax (+1) 425-643-9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 0351
CALIBRATION DATE: 28-Dec-13

SBE 38 TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

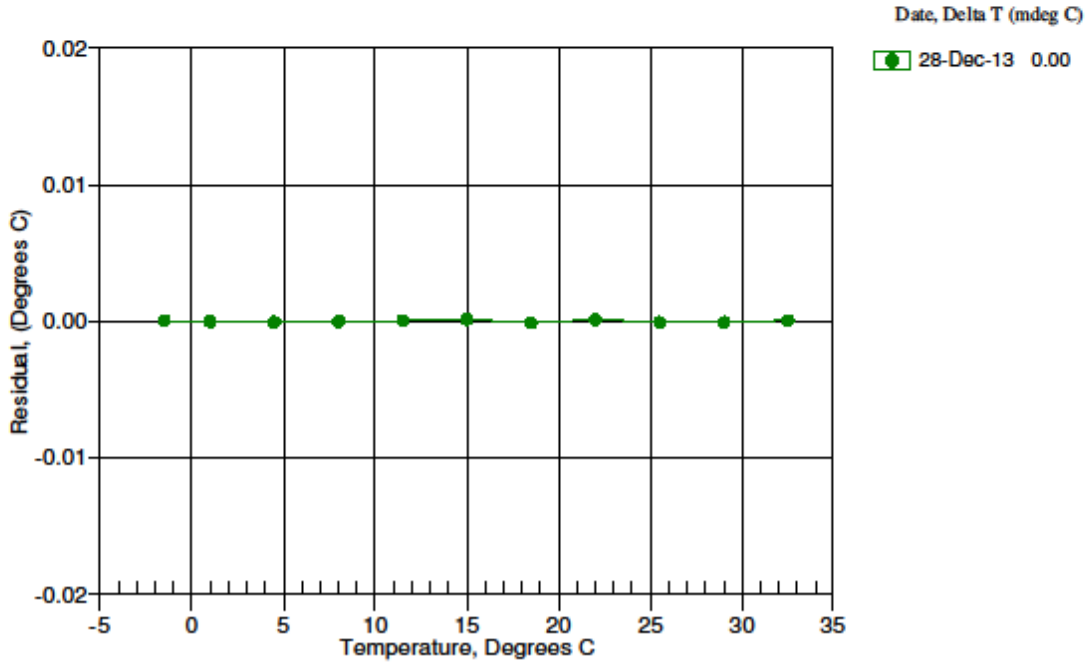
ITS-90 COEFFICIENTS

a0 = 6.847307e-005
a1 = 2.737587e-004
a2 = -2.376425e-006
a3 = 1.515438e-007

BATH TEMP (ITS-90)	INSTRUMENT OUTPUT	INST TEMP (ITS-90)	RESIDUAL (ITS-90)
-1.50000	674751.5	-1.49996	0.00004
1.00000	601342.4	0.99997	-0.00003
4.50020	513289.0	4.50015	-0.00005
8.00000	439602.0	7.99997	-0.00003
11.50000	377712.0	11.50004	0.00004
14.99990	325560.5	15.00003	0.00013
18.50020	281469.0	18.50008	-0.00012
22.00000	244073.8	22.00011	0.00011
25.50000	212261.3	25.49992	-0.00008
29.00010	185112.4	29.00003	-0.00007
32.50010	161877.4	32.50017	0.00007

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

Residual = instrument temperature - bath temperature



Fluorometer

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: 6/22/2015 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	0.054	0.025	0.010 V	48 counts
Scale Factor (SF)	6	13	25 µg/l/V	0.0076 µg/l/count
Maximum Output	4.99	4.99	4.99 V	16380 counts
Resolution	0.8	0.8	0.8 mV	1.0 counts
Ambient temperature during characterization				21.0 °C

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

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

SF: Determined using the following equation: SF = x ÷ (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

Acquisition and Processing Information

Errors and Events

Day Of Year	Time (GMT)	Event	Location
295	17:50	AT/RH sensor cleaned	PUQ
296	12:36	Departed PUQ. Turned ON O2, Knudsen	Departing PUQ
296	16:50	Partial O2 system maintenance	
297	01:15	DAS to Underway mode	68W
297	19:13	ADCP Bottom Tracking OFF	
297	22:17	Restart Knudsen PC for PC Updates	
299	14:32	ADCP Bottom Tracking ON	
300	12:09-12:37	Waterwall flow off/on to uTSGs for cleaning	
301	19:20-19:25	PCO2 off/on to swap in new bottle. Old bottle to 200psi	
302	11:47	Noticed no ADCP on DAS display. Reset ADCP to fix.	
302	17:20	Noticed no ADCP on DAS display. Reset ADCP to fix	
302	18:33	Exited PCO2	Approaching PAL
302	20:23	Turned off ADCP / Knudsen / PC02 / DAS	PAL
302	21:04	Turned O2 system off	Reboot to fix software bug
302	22:00	Turned O2 system on	
304	20:18	O2 system reboot	Fixed wind data bug
306	13:53	ADCP on ADCP / Knudsen / PCO2 / DAS	PAL
306	14:07	DAS set to underway mode	Leaving PAL
306	20:07	ADCP reboot	
306	23:16	ADCP reboot	
307	08:58	ADCP Bottom Tracking Off	
309	05:30	ADCP BI ON	
309	11:46	GUV restarted	Error in data stream
309	22:03	PCO2 off	68W data limit
309	22:38	DAS / ADCP / O2 off	68W data limit