Data Report NBP1309
NOAA

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Introduction

The NBP data acquisition systems continuously log data from the instruments used during 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.

The data is distributed on a DVD-R written in written in UDF format. It is readable by most modern computer platforms.

All the data has been compressed using Unix “gzip,” identified by the “.tz” extension. It has been copied to the distribution media in the Unix tar archive format, “.tar” extension. Tools are available on all platforms for uncompressing and de-archiving these formats: On Macintosh, one can use Stuffit Expander with DropStuff. On Windows operating systems, one can use WinZip.

MultiBeam and raw ADCP data are distributed separately.

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

Distribution Contents at a Glance

Volume 1 of 1: NBP1309

File	Description
/	Root level directory
NBP1309.trk	Text file of cruise track (lat,lon)
NBP1309.mgd	Full Cruise MGD77 data file
NBP1309.gmt	GMT binary file of MGD77 data
INSTCOEF.TXT	Instrument Coefficient File
1309DATA.doc	Data Report NBP1309 (MS Word)
1309DATA.pdf	Data Report NBP1309 (PDF format)
/cal-sheets	Cruise track plots
NBP1309-Sensors.doc	Sensor Calibration Sheet Reference
NBP1309-CalSheets.zip	Sensor Calibration Sheet files
/plots	Cruise track plots
NBP1309-track.jpg	Cruise track plot (JPEG format)
NBP1309-track.png	Cruise track plot (PNG format)
/process	Processed data
1309JGOF.tz	JGOFS format data files
1309QC.tz	Daily RVDAS QC postcript plots
1309PCO2.tz	Merged pCO2 data files
1309MGD.tz	MGD Data
1309PROC.tz	Other processed data
/rvdas/nav	Navigation data
1309adcp.tz	ADCP Data Sets
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1309eng1.tz	Engineering data
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1309hdas.tz	HydroDAS raw data
1309knud.tz	Knudsen raw data
1309mbdp.tz	Multibeam depth data
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1309oxyg.tz	Oxygen sensor
1309pco2.tz	pCO2 raw data
1309pguv.tz	GUV raw data
1309rtmp.tz	Remote temperature data
1309svp1.tz	Sound velocity probe (in ADCP well)
1309tsg1.tz	Micro TSG data
1309tsg2.tz	2nd Micro TSG data
1309twnc.tz	Winch data
/Imagery	Satellite Imagery
1309Imagery.tz	Collection of Imagery Files
/ocean	Ocean data

1309xbt.tz	XBT Data
1309ctd.tz	CTD Data

Extracting Data

The Unix tar command has many options. It is often useful to know exactly how an archive was produced when expanding its contents. All archives are gzipped tar files and were created using the command,

```
tar -czvf archive_filename files_to_archive
```

To create a list of the files in the archive, use the Unix command,

```
tar -tvf  archive_filename  > contents.list
```

where `contents.list` is the name of the file to create

To extract the files from the archive:

```
tar -xvf  archive_filename file(s)_to_extract
```

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

```
gunzip filename.tz
```

Distribution Contents

Cruise Information

NBP1309 departed

Data logging was started at -52° 47.2 -67° 57.5 on 11 August 2013 03:08 UTC

Crossed out of the EEZ at -57° 45.0 -61° 37.5 on 12 August 2013 19:00 UTC

Crossed in to the EEZ at -57° 48.2 -61° 36.9 on 07 September 2013 02:42 UTC

Data logging was stopped at -52° 43.8 -68° 03.0 on 08 September 2013 21:15 UTC

Cruise Track

The distribution DVD includes a GMT cruise track file (NBP1309.trk). It contains the longitude and latitude of the ship's position at one-minute intervals extracted from the NBP1309.gmt file.

PNG and PDF cruise track files have been produced and placed in the /plots directory.

Satellite Images

Satellite Images received for this cruise can be found in the file called /Imagery/1309Imagery.tar. Each type of image is contained in a .tz file within that file.

NBP Data Products

The IT staff on the NBP creates two processed data products for every cruise: JGOFS and MGD77.

The data processing scripts used to produce JGOFS and MGD77 data sets create a lot of intermediate files. These files are included on the data distribution media in a file called /process/1309proc.tar. These files are not intended to be end-products. They are included to make re-processing easier in the event of an error, but no extensive detail of the formats is included in this document. If you have any questions, please contact itvessel@usap.gov.

JGOFS

The JGOFS data set can be found on the distribution media in the file /process/1309jgof.tar. The archive contains one file produced for each day named jgDDD.dat.tz, where DDD is the year-day the data was acquired. The ".tz" extension indicates that the individual files are compressed before archiving. Each daily file consists of 22 columnar fields in text format as described in the table below. The JGOFS data set is created from calibrated data decimated at one-minute intervals. Several fields are derived measurements from more than a single raw input. For example, Course Made Good (CMG) and Speed Over Ground (SOG) are calculated from gyro and GPS inputs. Daily plots during the cruise are produced from the JGOFS data set. Note: Null, unused, or unknown fields are indicated as "NAN" 9999 in the JGOFS data.

Field	Data	Units
01	UTC date	dd/mm/yy
02	UTC 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	μEinsteins/meter^2 sec
10	Sea surface temperature (remote)	°C
11	Sea surface conductivity (TSG1)	siemens/meter
12	Sea surface salinity (TSG1)	PSU
13	Sea depth (uncorrected, calc. sw sound 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 (mg/m^3)
20	Transmissometer	%
21	PSP	W/m^2
22	PIR	W/m^2

MGD77

The MGD77 data set is contained in a single file for the entire cruise. It can be found in the top level of the distribution data structure as NBP1309.mgd. The file NBP1309.gmt is created from the MGD77 dataset using the "mgd77togmt" utility. NBP1309.gmt can be used with the GMT plotting package.

The data used to produce the NBP1309.mgd file can be found on the distribution media in the file /process/1309proc.tar. The data files in the archive contain a day's data and follow the naming convention Dddd.fnl.tz, where ddd is the year-day. These files follow a space-delimited columnar format that may be more accessible for some purposes. They contain data at one-second intervals rather than one minute and are individually "gzipped" to save space. Below is a detailed description of the MGD77 data set format. The other files in the archive contain interim processing files and are included to simplify possible reprocessing of the data using the RVDAS NBP processing scripts.

All decimal points are implied. Leading zeros and blanks are equivalent. Unknown or unused fields are filled with 9's. All "corrections", such as time zone, diurnal magnetics, and EOTVOS, are understood to be added.

Col	Len	Type	Contents	Description, Possible Values, Notes
1	1	Int	Data record type	Set to "5" for data record
2-9	8	Char	Survey identifier	
10-12	3	int	Time zone correction	Corrects time (in characters 13-27) to UTC when added; 0 = UTC
13-16	4	int	Year	4 digit year
17-18	2	int	Month	2 digit month
19-20	2	int	Day	2 digit day
21-22	2	int	Hour	2 digit hour
23-27	5	real	Minutes x 1000	
28-35	8	real	Latitude x 100000	+ = North - = South. (–9000000 to 9000000)
36-44	9	real	Longitude x 100000	+ = East - = West. (–18000000 to 18000000)
45	1	int	Position type code	1=Observed fix 3=Interpolated 9=Unspecified
46-51	6	real	Bathymetry, 2- way travel time	In 10,000th of seconds. Corrected for transducer depth and other such corrections
52-57	6	real	Bathymetry, corrected depth	In tenths of meters.
58-59	2	int	Bathymetric correction code	This code details the procedure used for determining the sound velocity correction to depth
60	1	int	Bathymetric type code	1 = Observed 3 = Interpolated (Header Seq. 12) 9 = Unspecified
61-66	6	real	Magnetics total field, 1^{ST} sensor	In tenths of nanoteslas (gammas)
67-72	6	real	Magnetics total field, 2^{ND} sensor	In tenths of nanoteslas (gammas), for trailing sensor
73-78	6	real	Magnetics residual field	In tenths of nanoteslas (gammas). The reference field used is in Header Seq. 13
79	1	int	Sensor for residual field	1 = 1^{st} or leading sensor 2 = 2^{nd} or trailing sensor 9 = Unspecified
80-84	5	real	Magnetics diurnal correction	In tenths of nanoteslas (gammas). (In nanoteslas) if 9-filled (i.e., set to "+9999"), total and residual fields are assumed to

Col	Len	Type	Contents	Description, Possible Values, Notes
				be uncorrected; if used, total and residuals are assumed to have been already corrected.
85-90	6	F6.0	Depth or altitude of magnetics sensor	(In meters) + = Below sea level 3 = Above sea level
91-97	7	real	Observed gravity	In 10^{th} of mgals. Corrected for Eotvos, drift, tares
98-103	6	real	EOTVOS correction	In 10^{th} of mgals. E = 7.5 V cos phi sin alpha + 0.0042 V*V
104-108	5	real	Free-air anomaly	In 10^{th} of mgals G = observed G = theoretical
109-113	5	char	Seismic line number	Cross-reference for seismic data
114-119	6	char	Seismic shot-point number	
120	1	int	Quality code for navigation	5=Suspected, by the originating institution 6=Suspected, by the data center 9=No identifiable problem found

Science of Opportunity

ADCP

The shipboard ADCP system measures currents in a depth range from about 30 to 300 m -- in good weather. In bad weather or in ice, the range is reduced, and sometimes no valid measurements are made. ADCP data collection is the OPP-funded project of Eric Firing (University of Hawaii) and Teri Chereskin (Scripps Institution of Oceanography). Data is collected on both the LMG and the NBP for the benefit of scientists on individual cruises, and for the long-term goal of building a profile of current structure in the Southern Ocean.

A data feed is sent from the ADCP system to RVDAS whenever a reference layer is acquired. This feed contains east and north vectors for ship's speed, relative to the reference layer, and ship's heading. Collected files (one per day) are archived in 1309adcp.tar in the directory /rvdas/nav.

Note: **ADCP data collection was halted mid-cruise to perform a software configuration change. As such, this cruise's ADCP data is split into two data sets.**

pCO_2

The NBP carries a pCO2 measurement system from Lamont-Doherty Earth Observatory (LDEO). pCO2 data is recorded by RVDAS and transmitted to LDEO at the end of each cruise. You will find pCO2 data in a file named 1309pco2.tar in the /process directory, which contains the pCO2 instrument's data merged with GPS, meteorological and other oceanographic measurements. For more information contact Colm Sweeney (csweeney@ldeo.columbia.edu).

Cruise Science

XBT

During the cruise, eXpendable BathyThermographs were used to obtain water column temperature profiles, providing corrections to the sound velocity profile for the multibeam system. The data files from these launches are included as 1309xbt.tar in the /ocean directory.

RVDAS

The Research Vessel Data Acquisition System (RVDAS) was developed at Lamont-Doherty Earth Observatory of Columbia University and has been in use on its research ship for many years. It has been extensively adapted for use on the USAP research vessels.

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

NBP[CruiseID][ChannelID].dDDD

Example: `NBP1309mwx1.d025`

- The CruiseID is the numeric name of the cruise, in this case, NBP1309.
- 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

Meteorology and Radiometry

Measurement	Channel ID	Collect. Status	Rate	Instrument
Air Temperature	mwx1	continuous	1 sec	R.M. Young 41372LC
Relative Humidity	mwx1	continuous	1 sec	R.M. Young 41372LC
Wind Speed/Direction	mwx1	continuous	1 sec	Gill 1390-PK-062/R
Barometer	mwx1	continuous	1 sec	R.M. Young 61201
PIR (LW radiation)	mwx1	continuous	1 sec	Eppley PIR
PSP (SW radiation)	mwx1	continuous	1 sec	Eppley PSP
PAR	mwx1	continuous	1 sec	BSI QSR-240
GUV	pguv	continuous	2 sec	BSI PUV-2511
PUV	pguv	not collected		BSI PUG-2500

Geophysics

Measurement	Channel ID	Collect. Status	Rate	Instrument
Gravimeter	grv1	continuous	10 sec*	LaCoste & Romberg
Magnetometer	mag1	not collected	15 sec	EG&G G-866
Bathymetry	knud	continuous	Varies	Knudsen 320B/R

*Data is output every second but it only changes every 10 seconds.

Oceanography

Measurement	Channel ID	Collect. Status	Rate	Instrument
Conductivity	mtsg	Continuous	6 sec	SeaBird SBE-45
Salinity	mtsg	Continuous	6 sec	Calc. from pri. temp
Sea Surface Temp	mtsg	Continuous	6 sec	SeaBird SBE 38
Fluorometry	hdas	Continuous	2 sec	WET Lab AFL
Transmissometry	hdas	Continuous	2 sec	WET Lab C-Star
pCO_2	pco2	Continuous	70 sec	(LDEO)
ADCP	adcp	Continuous	varies	RD Instruments
Oxygen	oxyg	Continuous	10 sec	Oxygen Optode 3835

Navigational Instruments

Measurement	Channel ID	Collect. Status	Rate	Instrument
Trimble GPS	PCOD	Continuous	1 sec	Trimble 20636-00SM
Gyro	gyr1	Continuous	0.2 sec	Yokogawa Gyro
SeaPath	seap	Continuous	1 sec	SeaPath 200

Data

Data is received from the RVDAS system via RS-232 serial connections. A time tag is added at the beginning of each line of data in the form,

```
yy+dd:hh:mm:ss.sss [data stream from instrument]
```

where

yy = two-digit year
ddd = day of year
hh = 2 digit hour of the day
mm = 2 digit minute
ss.sss = seconds

All times are reported in UTC.

The delimiters that separate fields in the raw data files are often spaces and commas but can be other characters such as : = @. Occasionally no delimiter is present. Care should be taken when reprocessing the data that the field's separations are clearly understood.

In the sections below a sample data string is shown, followed by a table that lists the data contained in the string.

Underway Data /rvdas/uw

Each section below describes a type of data file (file name extension in parentheses) followed by a typical line of data in the file. In the table(s) for each section is a description of the fields within each line of data. Note: most data files listed below will be included with each cruise's data distribution; however some types of files may be omitted if the instrument was not operating during the cruise. The available data files can be found in the /rvdas/uw directory on the distribution disc.

Sound Velocity Probe (svp1)

```
08+330:00:00:49.011  1519.35
```

Field	Data	Units
1	RVDAS Time tag	
2	Sound velocity in ADCP sonar well	m/s

Meteorology (mwx1)

```
There are 3 different data strings in the mwx1 data file:

MET

08+330:23:59:57.725 MET,12.1,-54,6.64,88.7,111.3374,0.02414567,-
0.4827508,282.9581,281.8823,1005.119

PUS

08+330:23:59:58.546 PUS,A,020,008.53,M,+337.12,+009.00,00,0F

SUS

08+330:23:59:58.779 SUS,A,017,008.76,M,+335.53,+006.35,00,02
```

MET string

Field	Data	Units
1	RVDAS time tag	
2	MET (string flag)	
3	Power Supply Voltage	V
4	Enclosure Relative Humidity (not currently implemented)	%
5	Air temperature	°C
6	Air Relative Humidity	%
7	PAR (photosynthetically available radiation)*	mV
8	PSP (short wave radiation)*	mV
9	PIR Thermopile (long wave radiation)*	mV
10	PIR Case Temperature	°Kelvin
11	PIR Dome Temperature	°Kelvin
12	Barometer	mBar

*See page 21 for calculations.

PUS string

Field	Data	Units
1	RVDAS time tag	
2	PUS (string flag)	
3	A (unit identification)	
4	Port Wind direction relative	deg
5	Port Wind speed relative	m/s
6	Units	
7	Sound Speed	m/s
8	Sonic Temperature	°C
9	Unit Status (00 or 60 are good, any other value indicates fault)	
10	Check Sum	

SUS string

Field	Data	Units
1	RVDAS time tag	
2	SUS (string flag)	
3	A (unit identification)	
4	Starboard Wind direction relative	deg
5	Starboard Wind speed relative	m/s
6	Units	
7	Sound Speed	m/s
8	Sonic Temperature	°C
9	Unit Status (00 or 60 are good, any other value indicates fault)	
10	Check Sum	

Knudsen (knud)

```
99+099:00:18:19.775 HF,305.2,LF,304.3
```

Field	Data	Units
1	RVDAS time tag	
2	HF = High frequency flag (12 kHz)	
3	High frequency depth	meters
4	LF = Low frequency flag (3.5 kHz)	
5	Low frequency depth	meters

Fluorometer (flr1)

This Fluorometer is not in use. The current Fluorometer goes to the hdas string.

```
00+019:23:59:58.061 0  0818 ::  1/19/00 17:23:17 = 0.983  (RAW)   1.2 (C)
```

Field	Data	Units
1	RVDAS time tag	
2	Marker 0 to 8	
3	4-digit index	
4	Date	mm/dd/yy
5	Time	hh:mm:ss
6	Signal	
7	Signal units of measurement	
8	Cell temperature (if temperature compensation package is installed)	
9	Temperature units (if temperature compensation package is installed)	

pCO_2 (pco2)

```
00+021:23:59:43.190 2000021.99920 2382.4 984.2 30.73 50.8 345.9 334.1 -1.70   -
68.046 -144.446 Equil
```

Field	Data	Units
1	RVDAS time tag	
2	pCO_2 time tag (decimal is fractional time of day)	yyyyddd.ttt
3	Raw voltage (IR)	mV
4	Cell temperature	°C
5	Barometer	MBar
6	Concentration	ppm
7	Equilibrated temperature	°C
8	pCO_2 pressure	microAtm
9	Flow rate	ml / min
10	Source ID #	1 or 2 digits
11	Valve position	1 or 2 digits
12	Flow source (Equil = pCO_2 measurement)	text

Micro-TSG (tsg1)

```
08+330:23:59:40.894   5.9322,  3.34685,  34.0550, 1473.281
```

Field	Data	Units
1	RVDAS time tag	
2	Internal Temperature	°C
3	Conductivity	s/m
4	Salinity	PSU
5	Sound velocity	m/s

Micro-TSG #2 (tsg2)

```
08+330:23:59:40.894   5.9322,  3.34685,  34.0550, 1473.281
```

Field	Data	Units
1	RVDAS time tag	
2	Internal Temperature	°C
3	Conductivity	s/m
4	Salinity	PSU
5	Sound velocity	m/s

Gravimeter (grv1)

There are now two sets of fields output by the gravity meter. The data record is output once per second, and identified by “$DAT” in the id field. A summary of sensor environmental data is output every ten seconds, identified by “%ENV” in the id field.

Data record ($DAT):

05+194:00:00:27.995 $DAT,2005/ 7/13, 0: 7: 7.36,194, 9050.37, 9050.06, 5410.86, -0.00, -0.01, -0.02, 0.00, 0.00, 0.70, 0.19, -0.12, -0.25, 0.00, -69.45711315, -54.32181487, 0.000, 285.200,

Field	Data	Conversion	Units
1	RVDAS time tag		
2	Text string (id field)	$DAT for data record	
3	Date	YYYY/MM/DD	
4	Time	HH:MM:SS.SS	
5	Day of Year	DDD	
6	Gravity count	mgal = count x 1.0046 + offset	count
7	Spring Tension		CU
8	Beam Position	Volts x 750,000	
9	VCC		
10	AL		
11	AX		
12	VE		
13	AX2		
14	XACC2		
15	LACC2		
16	CROSS ACCEL		GAL
17	LONG ACCEL		GAL
18	EOTVOS CORR		MGAL
19	LONGITUDE		Degrees
20	LATITUDE		Degrees
21	HEADING		Degrees
22	VELOCITY		Knots

Environmental record ($ENV)

```
05+183:19:13:10.945 %ENV,2005/ 7/ 2,19:19:52.16,183,S-036/V1.5,    3.34,   47.19,
20.34,1.111840E-1,-0.57700,-0.10591, 0.40180, 2.55260, 0.43000,   1, 300
```

Field	Data	Conversion	Units
1	RVDAS time tag		
2	Text string (id field)	$ENV for environmental record	
3	Date	YYYY/MM/DD	
4	Time	HH:MM:SS.SS	
5	Day of Year	DDD	
6	Meter ID		
7	Meter Pressure		inch-Hg
8	Meter temp		°C
9	Ambient temp		°C
10	K-Factor		
11	VCC Coeff		
12	AL Coeff		
13	AX Coeff		
14	VE Coeff		
15	AX2 Coeff		
16	Serial Filter Length		Seconds
17	QC Filter Length		Seconds

Engineering (eng1)

```
13+079:10:22:16.035 12.26 19.68 507.4  0.3 173.3 -751.9 0 0 NAN NAN 43.2 85.7
```

Field	Data	Units
1	RVDAS time tag	
2	Power Supply Voltage	V
3	Internal Case Temperature	°C
4	Pump #1 flow rate (aquarium room)	L/min
5	Pump #2 flow rate (helo deck)	L/min
6	Pump #3 flow rate (hydro-lab)	L/min
7	Seismic air pressure	Lbs/sq-in
8	PIR case resistance (not currently hooked up, data is irrelevant)	Kohm
9	PIR case ratiometric output (not currently hooked up, data is irrelevant)	mV
10	Freezer #1 temperature	°C
11	Freezer #2 temperature	°C
12	Altimeter, OIS benthic (yoyo) camera; distance from the seafloor	m
13	Transmissometer, OIS benthic (yoyo) camera	%

*See page 24 for PIR calculations.

Hydro-DAS (hdas)

```
08+330:23:59:41.877 12.15836 14.22853 368.9655 4060.69 -1 65.5 65.5 80 57
```

Field	Data	Units
1	RVDAS time tag	
2	Supply voltage	V
3	Panel temperature	°C
4	Fluorometer	mV
5	Transmissometer	mV
6	Sea Water Valve (-1 = stern thruster valve, 0 = moon pool valve)	
7	Flow meter 1 frequency	Hz
8	Flow meter 2 frequency	Hz
9	Flow meter 3 frequency	Hz
10	Flow meter 4 frequency	Hz

GUV Data (pguv)

```
08+330:23:59:40.328 112508 235940 .000197 1.856E-1 1.116E0 4.987E-2 -1.959E-4
1.637E0 4.153E-3 1.76E0 42.296 17.844
```

Field	Data	Units
1	RVDAS time tag	
2	Date	mmddyy
3	Time (UTC)	hhmmss
4	Ed0Gnd	V
5	Ed0320	uW (cm^2 nm)
6	Ed0340	uW (cm^2 nm)
7	Ed0313	uW (cm^2 nm)
8	Ed0305	uW (cm^2 nm)
9	Ed0380	uW (cm^2 nm)
10	Ed0PAR	uE (cm^2 nm)
11	Ed0395	uW (cm^2 nm)
12	Ed0Temp	°C
13	Ed0Vin	V

Remote Temperature (rtmp)

```
07+272:00:00:15.960 -1.7870
```

Field	Data	Units
1	RVDAS time tag	
2	Temperature at seawater intake	°C

Oxygen Data (oxyg)

Internal reference salinity is set to 34 ppt. For further information on this data, contact Sharon Stammerjohn, sstammer@ucsc.edu.

11+011:00:21:48.109 MEASUREMENT 3835 1424 Oxygen: 334.01 Saturation: 90.71 Temperature: -0.78 DPhase: 37.65 BPhase: 35.95
RPhase: 0.00 BAmp: 212.13 BPot: 30.00 RAmp: 0.00
RawTem.: 788.05

Field	Data	Units
1	RVDAS time tag	
2-4	Measurement ID, Model Number, Serial Number	alphanumeric
5	Oxygen heading	text
6	Oxygen Reading	µM
7	Saturation heading	text
8	Saturation Reading	%
9	Temperature heading	text
10	Water Temperature	°C
11	Dphase heading	text
12	Dphase	Raw numeric
13	Rphase heading	Text
14	Rphase	Raw numeric
15	Bamp heading	Text
16	Bamp	Raw numeric
17	Bpot heading	Text
18	Bpot	Raw numeric
19	Ramp heading	Text
20	Ramp	Raw numeric
21	RawTem heading	Text
22	RawTemp	V

Winch Data (bwnc, twnc, cwnc)

```
13+157:04:20:20.976 ^^^A03RD,2013-06-06T04:20:29.352,BALTIC,00000236,-
00000.0,-00009.3,3306
```

Field	Data	Units
1	RVDAS time tag	alphanumeric
2	LAN ID	alphanumeric
3	LCI-90i Date and Time	alphanumeric
4	Winch Name	alphanumeric
5	Tension	lbs
6	Speed	m/min
7	Pay-out	m
8	Checksum	numeric

Navigational Data /rvdas/nav

Seapath GPS (seap)

The Seapath GPS outputs the following data strings, four in NMEA format and two in proprietary PSXN format:

- GPZDA
- GPGGA
- GPVTG
- GPHDT
- PSXN, 20
- PSXN, 22
- PSXN, 23

GPZDA

```
02+253:00:00:00.772 $GPZDA,235947.70,09,09,2002,,*7F
```

Field	Data	Units
1	RVDAS time tag	
2	$GPZDA	
3	time	hhmmss.ss
4	Day	dd
5	Month	mm
6	Year	yyyy
7	(empty field)	
8	Checksum	

GPGGA

```
02+253:00:00:00.938
GPGGA,235947.70,6629.239059,S,06827.668899,W,1,07,1.0,11.81,M,,M,,*6F
```

Field	Data	Units
1	RVDAS time tag	
2	$GPGGA	
3	time	hhmmss.ss
4	Latitude	ddmm.mmmmmm
5	N or S for north or south latitude	
6	Longitude	ddmm.mmmmmm
7	E or W for east or west longitude	
8	GPS quality indicator, 0=invalid, 1=GPS SPS, 2=DGPS, 3=PPS, 4=RTK, 5=float RTK, 6=dead reckoning	
9	number of satellites in use (00-99)	
10	HDOP	x.x
9	height above ellipsoid in meters	m.mm
11	M	
12	(empty field)	
13	M	
14	age of DGPS corrections in seconds	s.s
15	DGPS reference station ID (0000-1023)	
16	Checksum	

GPVTG

```
02+253:00:00:00.940 $INVTG,19.96,T,,M,4.9,N,,K,A*39
```

Field	Data	Units
1	RVDAS time tag	
2	$GPVTG	
3	course over ground, degrees true	d.dd
4	T	
5	,	
6	M	
7	speed over ground in knots	k.k
8	N	
9	,	
10	K	
11	Mode	
12	Checksum	

GPHDT

```
02+253:00:00:00.941 $GPHDT,20.62,T*23
```

Field	Data	Units
1	RVDAS time tag	
2	$GPHDT	
3	Heading, degrees true	d.dd
4	T	
5	Checksum	

PSXN,20

```
02+253:00:00:00.942 $PSXN,20,0.43,0.43*39
```

Field	Data	Units
1	RVDAS time tag	
2	$PSXN	
3	20	
4	Horizontal position & velocity quality: 0=normal, 1=reduced performance, 2=invalid data	
5	Height & vertical velocity quality: 0=normal, 1=reduced performance, 2=invalid data	
6	Heading quality: 0=normal, 1=reduced performance, 2=invalid data	
7	Roll & pitch quality: 0=normal, 1=reduced performance, 2=invalid data	
8	Checksum	

PSXN,22

```
02+253:00:00:00.942 $PSXN,22,0.43,0.43*39
```

Field	Data	Units
1	RVDAS time tag	
2	$PSXN	
3	22	
4	gyro calibration value since system start-up in degrees	d.dd
5	short term gyro offset in degrees	d.dd
6	Checksum	

PSXN,23

```
02+253:00:00:02.933 $PSXN,23,0.47,0.57,20.62,0.03*0C
```

Field	Data	Units
1	RVDAS time tag	
2	$PSXN	
3	23	
4	roll in degrees, positive with port side up	d.dd
5	pitch in degrees, positive with bow up	d.dd
6	Heading, degrees true	d.dd
7	heave in meters, positive down	m.mm
8	Checksum	

Trimble (P-Code) GPS (PCOD)

The Trimble GPS, which formerly output Precise Position (*P-Code*) strings, but now only outputs Standard Position (*Civilian*) strings, outputs three NMEA standard data strings:

- Position fix (GGA)
- Latitude / longitude (GLL),
- Track and ground speed (VTG)

GGA: GPS Position Fix – Geoid/Ellipsoid

```
01+319:00:04:11.193 $GPGGA,000410.312,6227.8068,S,06043.6738,W,1,06,1.0,
031.9,M,-017.4,M,,*49
```

Field	Data	Units
1	RVDAS Time tag	
2	$GPGGA	
3	UTC time at position	hhmmss.sss
4	Latitude	ddmm.mmm
5	North (N) or South (S)	
6	Longitude	ddmm.mmm
7	East (E) or West (W)	
8	GPS quality: 0 = Fix not available or invalid 1 = GPS, SPS mode, fix valid 2 = DGPS (differential GPS), SPS mode, fix valid 3 = P-CODE PPS mode, fix valid	
9	Number of GPS satellites used	
10	HDOP (horizontal dilution of precision)	
11	Antenna height	meters
12	M for meters	
13	Geoidal height	meters
14	M for meters	
15	Age of differential GPS data (no data in the sample string)	
16	Differential reference station ID (no data in the sample string)	
17	Checksum (no delimiter before this field)	

GLL: GPS Latitude/Longitude

```
01+319:00:04:11.272 $GPGLL,6227.8068,S,06043.6738,W,000410.312,A*32
```

Field	Data	Units
1	RVDAS Time tag	
2	$GPGLL	
3	Latitude	degrees
4	North or South	
5	Longitude	degrees
6	East or West	
7	UTC of position	hhmmss.sss
8	Status of data (A = valid)	
9	Checksum	

VTG: GPS Track and Ground Speed

```
01+319:00:04:11.273 $GPVTG,138.8,T,126.0,M,000.0,N,000.0,K*49
```

Field	Data	Units
1	RVDAS time tag	
2	$GPVTG	
3	Heading	degrees
4	Degrees true (T)	
5	Heading	degrees
6	Degrees magnetic (M)	
7	Ship speed	knots
8	N = knots	
9	Speed	km/hr
10	K = km per hour	
11	Checksum	

Gyro Compass (gyr1)

```
00+019:23:59:59.952 $HEHDT 25034,-020*73
```

Field	Data	Units
1	RVDAS time tag	
2	$HEHDT	
3	Heading, Degrees True	degrees
5	Checksum	

ADCP Course (adcp)

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

Field	Data	Units
1	RVDAS time tag	
2	$PUHAW	
3	UVH (E-W, N-S, Heading)	
4	Ship Speed relative to reference layer, east vector	knots
5	Ship Speed relative to reference layer, north vector	knots
6	Ship heading	degrees

Processed Data /process/

pCO2-merged

```
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	Units
1	RVDAS time tag	
2	pCO_2 time tag (decimal is fractional time of day)	yyyyddd.ttt
3	Raw voltage (IR)	mV
4	Cell temperature	°C
5	Barometer	MBar
6	Flow rate	ml / min
7	Concentration	ppm
8	pCO_2 pressure	microAtm
9	Equilibrated temperature	°C
10	Sea Water Temp	1 or 2 digits
11	Valve position	°C
12	Flow source (Equil = pCO_2 measurement)	text
13	RVDAS latitude	degrees
14	RVDAS longitude	degrees
15	TSG external temperature	°C
16	TSG 1 salinity	PSU
17	Fluorometer	V
18	RVDAS true wind speed	m/s
19	RVDAS true wind direction	degrees
20	Barometric Pressure	mBars
21	Uncontaminated seawater pump flow rate	l/min
22	Speed over ground	knots
23	Course made good	degrees
24	Oxygen	µM
25	TSG 2 internal temperature	°C
26	TSG 2 salinity	PSU
27	TSG 1 internal temperature	°C
28	H2O Input Source	-1 stern thrustor 0 moonpool

Calculations

The file `instrument.coeff` located in the `/` directory contains the calibration factors for shipboard instruments. This was the file used by the RVDAS processing software.

PAR

Coefficients parc1 and parcv for this cruise can be found in the `instrument.coeff` file as the variable labeled PAR, respectively. Variable par is the raw data in mV, as described in the "mwx1" file description. The calibration scale and probe offset dark are values taken from the PAR Cal Sheet.

```
par = raw data mV
calibration scale = 5.8644 V/(μEinstiens/cm2sec)
parc1 = 1 / scale = .17
probe offset dark = -.1 mV
parcv = dark x 1000 mV/V = -0.0001 V
((par / 1000 mV/V) – parcv) x parc1 x 10000 cm2/m2 = μEinstiens/m2sec

Calculations (extracted from the C code):
/* Convert from mV to V */
par /= 1000;
/* (par V - vdark V) / Calibration Scale Factor V/uE/cm2sec */
parCalc = (par - parcv) * parc1 * 10000;
```

PSP

Coefficient pspCoeff for this cruise can be found in the `instrument.coeff` file as the variable labeled PSP1. Variable psp is the raw data in mV, as described in the "mwx1" file description.

```
psp = raw data mV
calibration scale =  pspCoeff x 10^-6  V/(W/m2)
psp / (scale x 1000 mV/V) = W/m2

Calculations (extracted from the C code):
     /* Convert from mV to W/m^2  */
     pspCalc = (psp * 1000 / pspCoeff);
```

PIR

Coefficient pirCoeff for this cruise can be found in the `instrument.coeff` file as the variable labeled PIR1. Variable pir_thermo is the raw data in mV, pir_case is the PIR case temperature in Kelvins and pir_dome is the PIR dome temperature in Kelvins, as described in the “mwx1” file description. Hard-coded “C” coefficients are shown below:

```
Dome constant = 3.5
Sigma = 5.6704e-8

pir_thermo = raw data mV
calibration scale = pirCoeff x 10^-6  V/(W/m2)
pir_thermo / (scale x 1000 mV/V) = W/m2

Calculations (extracted from the C code):
      /* convert mV to W/m^2 */
     pirCalc = (pir_thermo * 1000 / pirCoeff)
     /* correct for case temperature */
     pirCalc += sigma * pow(pir_case,4)
     /* correct for dome temperature */
     pirCalc -= 3.5 * sigma * (pow(pir_dome, 4) - pow(pir_case, 4))
```

Acquisition Problems and Events

This section lists problems with acquisition noted during this cruise including instrument failures, data acquisition system failures and any other factor affecting this data set. The format is ddd:hh:mm (ddd is year-day, hh is hour, and mm is minute). Times are reported in UTC.

Start	End	Description
223:03:08		Data collection started -52° 47.2 -67° 57.5
224:19:00		Crossed out of the EEZ/200 mile limit -57° 45.0 -61° 37.5
250:02:42		Crossed in to the EEZ/200 mile limit -57° 48.2 -61° 36.9
251:21:15		Data collection stopped -52° 43.8 -68° 03.0

Appendix: Sensors and Calibrations

Sensor	*Serial Number*	*Last Cal.*	*Comments*
Meteorology & Radiometers			
Stbd Anemometer (Gill US)	847014	9/29/2010	Installed 11/17/2010
Port Anemometer (Gill US)	924057	11/18/09	Installed 3/5/2010
Barometer	01706	2/12/2010	Installed 5/9/2013
Humidity/Wet Temp	06733	7/20/2011	Installed 5/9/2013
PIR	33023F3	7/20/2011	Installed 4/7/2013
PSP	33090F3	7/19/2011	Installed 4/7/2013
Mast PAR	6356	8/4/2011	Installed 7/30/2012
GUV (Mast)	25110203113	7/29/2011	Installed 7/31/2012
Underway			
Micro-TSG #1	4546167-0242	12/29/2012	Installled 5/9/2013
Micro-TSG #2	4566350-0389	10/20/2011	Installled 9/7/2012
Digital Remote Temp (Primary)	3846730-0178	9/21/2012	Installed 5/9/2013
Oxygen Optode	3835-1424	10/21/2010	Installed12/30/2010
Fluorometer	AFLD-009	9/12/2011	Installed 12/24/2012
Transmissometer	CST-1316DR	12/6/2012	Installed 5/13/2011
CTD			
CTD Fish	1130	12/11/2012	Installed 5/13/2013
CTD Fish Pressure	120089	12/11/2012	Installed 5/13/2013
CTD Deck Unit	11P19858-0490	N/A	Installed11/8/2007
Slip-Ring Assembly	1.406	N/A	Installed 3/27/04
Carousel Water Sampler	3214153-0140	N/A	Installed 5/13/2013
Pump (primary)	055643 3.0K	11/28/2010	Installed 5/13/2013
Pump (secondary)	055641 3.0K	11/28/2010	Installed 5/13/2013
Temperature (primary)	03P5730	11/13/2012	Installed 5/13/2013
Temperature (secondary)	03P2438	8/22/2012	Installed 5/13/2013
Conductivity (primary)	043503	6/17/2011	Installed 5/13/2013
Conductivity (secondary)	043505	6/17/2011	Installed 5/13/2013
Dissolved Oxygen (primary)	430082	8/21/2012	Installed 5/13/2013
Dissolved Oxygen (secondary)	430139	8/17/2012	Installed 5/13/2013
Fluorometer	FLRTD-397	11/15/2012	Installed 5/13/2013
Transmissometer	CST-892DR	12/5/2012	Installed 5/13/2013
PAR	4721	10/26/2012	Installed 5/13/2013
Altimeter	42434	N/A	Installed 5/13/2013
Bottom Contact Switch	#3	N/A	Installed 5/13/2013
Mocness			
Pressure Sensor	178	11/18/2010	Installed 5/15/2013
Temperature	031541	2/27/13	Installed 5/15/2013
Conductivity	041431	7/25/12	Installed 5/15/2013

Gravity Tie Spreadsheet

The fields outlined in BOLD MUST BE FILLED IN for this spreadsheet to operate properly.
The automatically calculated values show up in the shaded fields.

Date: **11/5/2013**
Location: **Punta Arenas, Chile**
Station: Harbour Admin. Bldg.
Latitude: 53 09 S
Longitude: 070 55 W
Elevation:
Gravity: 981320.82

Reference Code Numbers:
Station no. 9337-50
ISGN no. 51230N

	Value	Time (GMT)
Ship's meter before gravity tie (Gravity (cu))	8778.5	19:14
Ship's meter after gravity tie (Gravity (cu))	8778.6	20:42
Average	8778.6	
Ship Gravimeter's Calibration Constant	1.0046	
Corrected ship's meter (QC Grav (mgal))	8818.9	

	Value	Time (GMT)
Ship's meter before gravity tie (serial, RVDAS)	8777.5	19:15
Ship's meter after gravity tie (serial, RVDAS)	8777.9	20:42
Average (for comparison check only)	8777.7	

Portable Gravimeter Interval Factor: 1.01007 From Table 1 of Model G #807 Meter

Station	Value	Time (GMT)	Temp	Date	OBS mgal, averaged
Pier measurement 1	4918.35	19:26	54	November 5, 2013	
Pier measurement 2	4918.44	19:29	54	November 5, 2013	4967.93
Pier measurement 3	4918.41	19:32	54	November 5, 2013	
Average	4918.40				
Station measurement 1	4919.07	19:43	54	November 5, 2013	
Station measurement 2	4919.09	19:45	54	November 5, 2013	4968.64
Station measurement 3	4919.16	19:47	54	November 5, 2013	
Average	4919.11				
Pier measurement 4	4918.33	20:36	54	November 5, 2013	
Pier measurement 5	4918.54	20:38	54	November 5, 2013	4967.98
Pier measurement 6	4918.48	20:40	54	November 5, 2013	
Average	4918.45				

Gravity offset from last tie 972504.56
Drift since last tie -3.37

OBS Differences	
Station to Pier (1, 2, & 3 averaged)	-0.71
Station to Pier (4, 5, & 6 averaged)	-0.66
Averaged Differences	-0.69
Gravity at pier	981320.13
Elevation of pier above gravimeter, meters	0.0
Earth differential gravity, mgal/meter	0.3
Gravity at ship's gravimeter	981320.12
Gravity Offset (for RVDAS)	972501.19

Comments

Tie performed by George Aukon and Barry Bjork. Conditions average.

Note about Elevation of Pier: *If pier is below the ship's gravimeter, this value is negative. If above, positive.*

Bridge Anemometer

RM Young Anemometer Calibration, Model 05106

S/N: 45835 Date: 27-Sep-04 Cal'd By: W. Gallagher

Clockwise Cal Motor RPM	Calculated Windspeed m/s	Measured Windspeed m/s	Delta m/s	Knots
0	0.00	0.0	0.0	0.0
200	0.98	0.9	0.1	1.9
500	2.45	2.3	0.2	4.8
1000	4.90	4.8	0.1	9.5
1500	7.35	7.3	0.0	14.3
2000	9.80	9.7	0.1	19.0
3000	14.70	14.7	0.0	28.6
4000	19.60	19.7	-0.1	38.1
5000	24.50	24.6	-0.1	47.6
6000	29.40	29.7	-0.3	57.1
7000	34.30	34.7	-0.4	66.6
8000	39.20	39.7	-0.5	76.2
9000	44.10	44.7	-0.6	85.7
10000	49.00	49.6	-0.6	95.2
12000	58.80	59.6	-0.8	114.2

Direction	Measured Direction	Delta Direction
0	0	0
30	28	2
60	59	1
90	89	1
120	119	1
150	150	0
180	180	0
210	210	0
240	240	0
270	270	0
300	300	0
330	330	0
0	0	0

Note: Delta direction should not exceed + or - 3 degrees.

Counter Clockwise Cal Motor RPM	Calculated Windspeed m/s	Measured Windspeed m/s	Delta m/s
0	0.00	0.0	0.0
200	0.98	0.9	0.1
500	2.45	2.3	0.2
1000	4.90	4.9	0.0
1500	7.35	7.3	0.0
2000	9.80	9.8	0.0
3000	14.70	14.7	0.0
4000	19.60	19.8	-0.2
5000	24.50	24.7	-0.2
6000	29.40	29.8	-0.4
7000	34.30	34.7	-0.4
8000	39.20	39.7	-0.5
9000	44.10	44.7	-0.6
10000	49.00	49.7	-0.7
12000	58.80	59.6	-0.8

Caution: Do Not exceed 12000 rpm during Wind Speed test.

Wind Speed Threshold < 2.9 gm?	yes
Wind Direction Threshold < 30 gm?	yes

Additional Comments

Installed new housing assy.and wind direction coupling. Adjusted clearence on wind direction potentiometer thumbwheel.

Note: Delta Windspeed should not exceed + or - 0.3 m/s for 0 - 5000 rpm

Mast Barometer

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

YOUNG

CALIBRATION REPORT

Barometric Pressure

Customer: *Raytheon Technical Services Company LLC*

Test Number: 2126-01B
Test Date: 26 January 2012
Customer PO: RR84145-01
Sales Order: 2430

Test Sensor:
Model: 61201
Serial Number: *BP01706*
Description: Barometric Pressure Sensor

Report of calibration comparison of test barometric pressure sensor with National Institute of Standards and Technology traceable standard pressure calibrator at five pressures in the R.M. Young Company controlled pressure facility. Calibration accuracy ± 1.0 hPa.

Reference Pressure (hPa)	Voltage Output (millivolts)	Indicated (1) Pressure (hPa)
800.0	0	800.0
875.0	1251	875.0
950.0	2501	950.1
1025.0	3750	1025.0
1100.0	4998	1099.9

(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
Druck Pressure Controller Model DPI515	51500497	UKAS Lab 0221
Fluke Multimeter Model 8060A	4865407	234027

Tested By: E. Chenowith

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

Mast Humidity Sensor

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

YOUNG

CALIBRATION REPORT

Relative Humidity

Customer: *Raytheon Technical Services Company LLC*

Test Number: 1721-01R
Test Date: 21 July 2011

Customer PO: RR59934-01
Sales Order: 2040

Test Sensor:
Model: 41372LC
Description: Temperature/Relative Humidity Sensor
Serial Number: *TS66733*

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 (%)
10.1	5.9	11.7
30.1	8.8	30.1
50.0	12.2	51.0
70.1	15.3	70.5
90.0	18.1	87.9

(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	234027

Tested By: E Chenney

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

Mast Temperature Sensor

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

YOUNG

CALIBRATION REPORT

Temperature

Customer: *Raytheon Technical Services Company LLC*

Test Number: 1720-09T
Test Date: 20 July 2011
Customer PO: RR59934-01
Sales Order: 2040

Test Sensor:
Model: 41372LC
Serial Number: *TS06733*
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)
-49.91	4.009	-49.94
0.03	12.007	0.04
50.08	20.013	50.06

(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	6006-118	204365
Brooklyn Thermometer Model 22332-D5-FC	25071	249783
Brooklyn Thermometer Model 2X400-D7-FC	77532	228060
Keithley Multimeter Model 191	15232	234027

Tested By: E Chenowith

METEOROLOGICAL INSTRUMENTS
Tel: 231-946-3980 Fax: 231-946-4772 Email: metsales@yoususa.com Website: yoususa.com
ISO 9001:2008 CERTIFIED

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: 33023F3

Resistance: 739 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 25°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:

3.85×10^{-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: Raytheon Polar Services NSF
Port Hueneme, CA

S.O. Number: 63090
Date: July 28, 2011

Date of Test: July 20, 2011

In Charge of Test: Debra L. Hurley

Reviewed by: Thomas J. Kirk

Remarks:

Mast 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

STANDARDIZATION OF EPPLEY PRECISION SPECTRAL PYRANOMETER Model PSP

Serial Number: 33090F3

Resistance: 700 Ω at 23°C
Temperature Compensation Range: -20° to +40°C

This radiometer has been compared with Standard Precision Spectral Pyranometer, Serial Number 21231F3 in Eppley's Integrating Hemisphere under radiation intensities of approximately 700 watts meter^{-2} (roughly one half a solar constant).

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

8.03×10^{-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 1400 watts meter^{-2}. This radiometer is linear to within ± 0.5% up to this intensity.

The calibration of this instrument is traceable to standard self-calibrating cavity pyrheliometers in terms of the Systems Internationale des Unites (SI units), which participated in the Tenth International Pyrheliometric Comparisons (IPC X) at Davos, Switzerland in September-October 2005.

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".

Useful conversion facts: 1 cal cm^{-2} min^{-1} = 697.3 watts meter^{-2}
1 BTU/ft^2-hr^{-1} = 3.153 watts meter^{-2}

Shipped to: Raytheon Polar Services NSF
Port Hueneme, CA

S.O. Number: 63091
Date: July 28, 2011

Date of Test: July 19, 2011

In Charge of Test: Debra L. Beighley

Reviewed by: Thomas D. Kucik

Remarks:

Mast PAR

PAR for Mast

Biospherical Instruments Inc.

CALIBRATION CERTIFICATE

Calibration Date	8/4/2011
Model Number	QSR-240
Serial Number	6356
Operator	TPC
Standard Lamp	GS-1024(7/22/11)
Probe Excitation Voltage Range:	6 to 18 VDC(+)
Output Polarity:	Positive

Probe Conditions at Calibration(in air):

Calibration Voltage:	6 VDC(+)
Probe Current:	1.2 mA

Probe Output Voltage:

Probe Illuminated	97.2 mV
Probe Dark	0.1 mV
Probe Net Response	97.0 mV
RG780	0.3 mV

Corrected Lamp Output:

Output In Air (same condition as calibration):

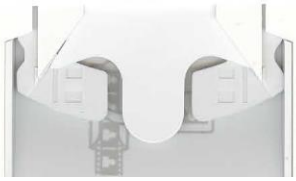
9.298E+15 quanta/cm²sec
0.01544 uE/cm²sec

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

Dry:	1.0436E-17 V/(quanta/cm²sec)
	6.2847E+00 V/(uE/cm²sec)

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



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 25110203113

Optical Calibrations:

NIST Traceability. For wavelengths longer than 313 nm, the specific instruments cited here were calibrated using a 1000W FEL **#GS-1024 (7/22/11)** following procedures and standards traceable to NIST Standard of Spectral Irradiance **F473**. 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 **25110203113v6.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	25110203113	Date of Calibration	7/29/2011
Calibration database	25110203113.mdb	Date of Certificate	8/1/2011
DASSN	0068	Standard of Spectral Irradiance	GS1024(7/22/11)
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
Ed0320	2	320	2.5711E-10	2.6225E-05	7.6619E-03	2.7126E+00	-5.8115E-06	-9.1758E-06	1.7218E-04	µW/(cm²nm)
Ed0340	6	340	2.0927E-10	2.1346E-05	6.2363E-03	2.1989E+00	3.0451E-04	3.0474E-04	1.1770E-03	µW/(cm²nm)
Ed0313	8	313	2.1800E-10	2.2286E-05	6.5111E-03	2.3245E+00	6.3074E-05	6.4994E-05	7.6713E-04	µW/(cm²nm)
Ed0305	10	305	1.6400E-11	1.6687E-06	4.8753E-04	1.5082E-01	3.4984E-04	3.3908E-04	-2.2555E-03	µW/(cm²nm)
Ed0380	12	380	6.6055E-11	6.7376E-06	1.9684E-03	6.5646E-01	1.0888E-03	1.0755E-03	-1.4791E-03	µW/(cm²nm)
Ed0PAR	13	0	1.8677E-05	1.9051E+00	5.5658E+02	1.9817E+05	8.5258E-04	8.4359E-04	-1.3226E-03	µE/(cm²sec)

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
Ed0395	18	400-700	3.3639E-10	3.4312E-05	1.0024E-02	3.2744E+00	6.7600E-05	6.2557E-05	2.1591E-04	µW/(cm²nm)

Auxiliary Channels	Address	Wavelength	Responsivity	ScaleS	ScaleM	ScaleL	OffsetS	OffsetM	OffsetL	Measurement Units
Ed0Gnd	0	0	1	1.00	1.00	1.00	0	0	0	V
Ed0Temp	22	0	1	0.01	0.01	0.01	0	0	0	C
Ed0Vin	27	0	1	-0.25000	-0.25000	-0.25000	0.0000	0.0000	0.0000	V

AANDERAA DATA INSTRUMENTS

CALIBRATION CERTIFICATE

Form No. 622, Dec 2005
Page 1 of 2

Sensing Foil Batch No: 5009
Certificate No:

Product: Oxygen Optode 3835
Serial No: 1424
Calibration Date: 21 October 2010

This is to certify that this product has been calibrated using the following instruments:

Calibration Bath model FNT	321-1-40
ASL Digital Thermometer model F250	Serial: 6792/06

Parameter: Internal Temperature:

Calibration points and readings:

Temperature (°C)	1.17	12.12	24.11	36.08
Reading (mV)	730.09	383.95	-11.29	-379.10

Giving these coefficients

Index	0	1	2	3
TempCoef	2.37613E01	-3.08128E-02	2.84735E-06	-4.15311E-09

Parameter: Oxygen:

	O2 Concentration	Air Saturation
Range:	0-500 µM [1)]	0 - 120%
Accuracy [1)]:	< ±8µM or ±5% (whichever is greater)	±5%
Resolution:	< 1 µM	< 0.4%
Settling Time (63%):	< 25 seconds	

Calibration points and readings [2)]:

	Air Saturated Water	Zero Solution (Na_2SO_3)
Phase reading (°)	3.27669E+01	6.65595E+01
Temperature reading (°C)	9.90918E+00	2.04774E+01
Air Pressure (hPa)	9.76884E+02	

Giving these coefficients

Index	0	1	2	3
PhaseCoef	-4.44928E00	1.17131E00	0.00000E00	0.00000E00

[1)] Valid for 0 to 2000m (6562ft) depth, saliniy 33 - 37ppt
[2)] The calibration is performed in fresh water and the saliniy setting is set to: 0

AANDERAA DATA INSTRUMENTS AS

5851 BERGEN, NORWAY Tel. +47 55 60 48 00 Fax. +47 55 60 48 01 E-mail: info@aadi.no Web: http://www.aadi.no

AANDERAA DATA INSTRUMENTS

CALIBRATION CERTIFICATE

Sensing Foil Batch No: 5009
Certificate No:

Product: Oxygen Optode 3835
Serial No: 1424
Calibration Date: 21 October 2010

SR10 Scaling Coefficients:

At the SR10 output the Oxygen Optode 3830 can give either absolute oxygen concentration in µM or air saturation in %. The setting of the internal property "Output" [3], controls the selection of the unit. The coefficients for converting SR10 raw data to engineering units are fixed.

Output = -1	Output = -2
A = 0	A = 0
B = 4.883E-01	B = 1.465E-01
C = 0	C = 0
D = 0	D = 0
Oxygen (µM) = A + BN + CN2 + DN3	Oxygen (%)= A + BN + CN2 + DN3

[3] The default output setting is set to -1

Date: 22 October 2010

Sign:

Tor Ove Kvalvaag, Calibration Engineer

AANDERAA DATA INSTRUMENTS AS

5851 BERGEN, NORWAY Tel. +47 55 60 48 00 Fax. +47 55 60 48 01 E-mail: info@aadi.no Web: http://www.aadi.no

Underway Micro-TSG number 1

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: 0242
CALIBRATION DATE: 29-Dec-12

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

COEFFICIENTS:

g = -9.992296e-001	CPcor = -9.5700e-008
h = 1.524743e-001	CTcor = 3.2500e-006
i = -4.722991e-004	WBOTC = -0.0000e+000
j = 6.065458e-005	

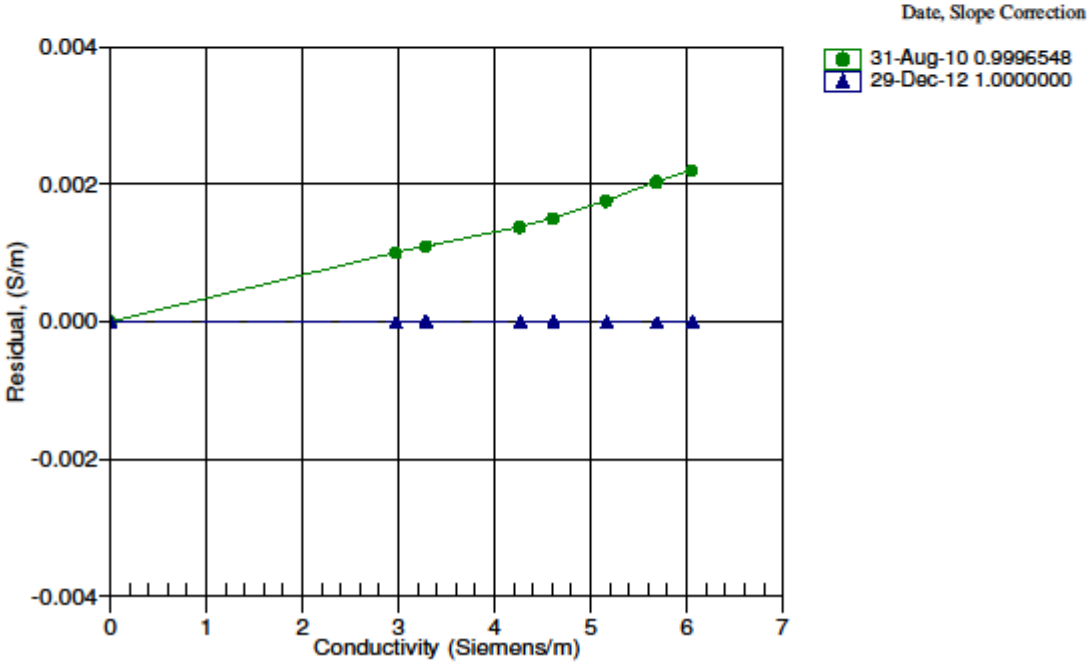
BATH TEMP (ITS-90)	BATH SAL (PSU)	BATH COND (Siemens/m)	INST FREQ (Hz)	INST COND (Siemens/m)	RESIDUAL (Siemens/m)
22.0000	0.0000	0.00000	2566.82	0.00000	0.00000
1.0000	34.8118	2.97562	5119.70	2.97561	-0.00001
4.5000	34.7917	3.28263	5313.24	3.28264	0.00001
15.0000	34.7487	4.26420	5888.60	4.26420	0.00000
18.5000	34.7394	4.60927	6077.64	4.60927	0.00001
24.0000	34.7293	5.16711	6371.04	5.16711	-0.00001
29.0000	34.7238	5.68887	6633.34	5.68886	-0.00001
32.5000	34.7207	6.06120	6814.13	6.06121	0.00001

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

Conductivity = $(g + hf^2 + if^3 + jf^4) / (1 + \delta t + \varepsilon p)$ Siemens/meter

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

Residual = instrument conductivity - bath conductivity



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: 0242
CALIBRATION DATE: 29-Dec-12

SBE 45 TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

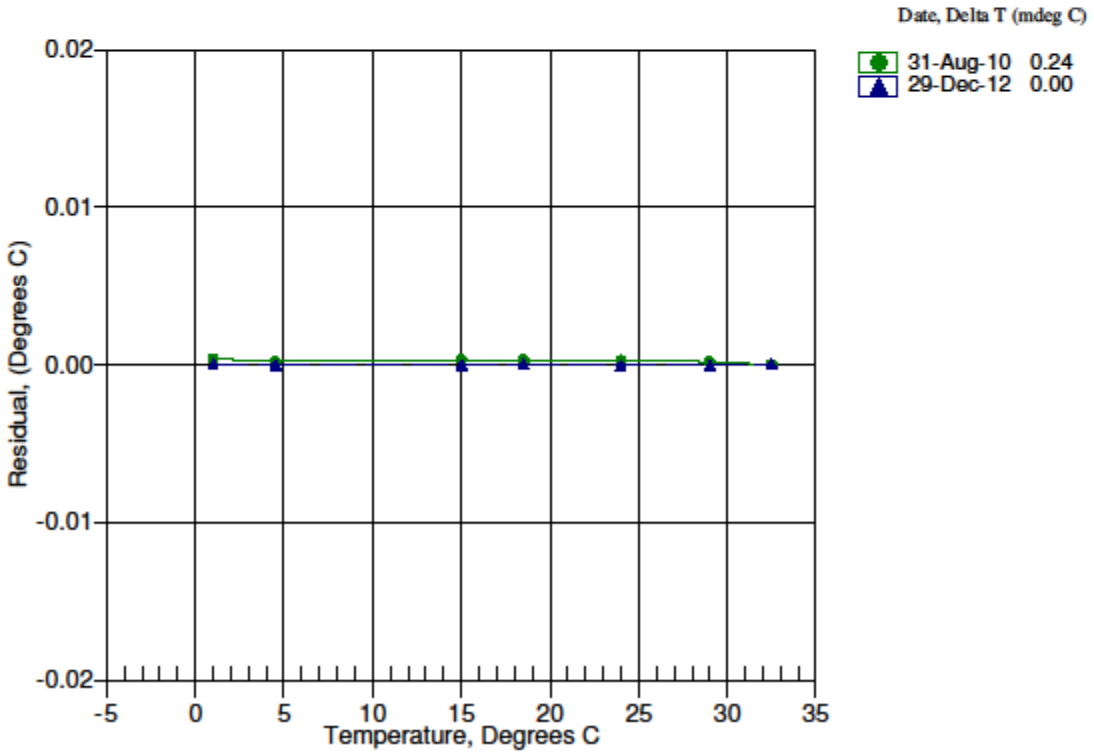
ITS-90 COEFFICIENTS

a0 = 4.555848e-005
a1 = 2.733778e-004
a2 = -2.324224e-006
a3 = 1.499077e-007

BATH TEMP (ITS-90)	INSTRUMENT OUTPUT	INST TEMP (ITS-90)	RESIDUAL (ITS-90)
1.0000	649816.0	1.0000	0.0000
4.5000	554883.5	4.5000	-0.0000
15.0000	352327.7	15.0000	-0.0000
18.5000	304717.7	18.5000	0.0000
24.0000	244011.0	24.0000	0.0000
29.0000	200602.2	29.0000	-0.0000
32.5000	175478.8	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



Underway Micro-TSG number 2

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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

Micro TSG

SENSOR SERIAL NUMBER: 0389
CALIBRATION DATE: 20-Oct-11

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

COEFFICIENTS:

g =	-9.860211e+00	CPcor =	-9.5700e-08
h =	1.453869e+00	CTcor =	3.2500e-06
i =	-6.022911e-04	WBOTC =	1.2700e-07
j =	5.189313e-05		

BATH TEMP (ITS-90)	BATH SAL (PSU)	BATH COND (Siemens/m)	INST FREQ (Hz)	INST COND (Siemens/m)	RESIDUAL (Siemens/m)
23.3000	0.0000	0.00003	2004.51	0.00030	0.00000
1.3000	34.9210	2.98400	5241.92	2.98436	0.00000
4.3000	34.9005	3.29188	5443.39	3.29188	-0.00000
14.3999	34.8864	4.27003	6056.44	4.27002	0.00001
18.4999	34.8867	4.62199	6279.28	4.62199	-0.00000
24.3000	34.8894	5.18115	6628.11	5.18115	-0.00000
29.3000	34.8877	5.70357	6951.07	5.70357	-0.00000
32.5000	34.8811	6.07673	7162.11	6.07673	0.00000

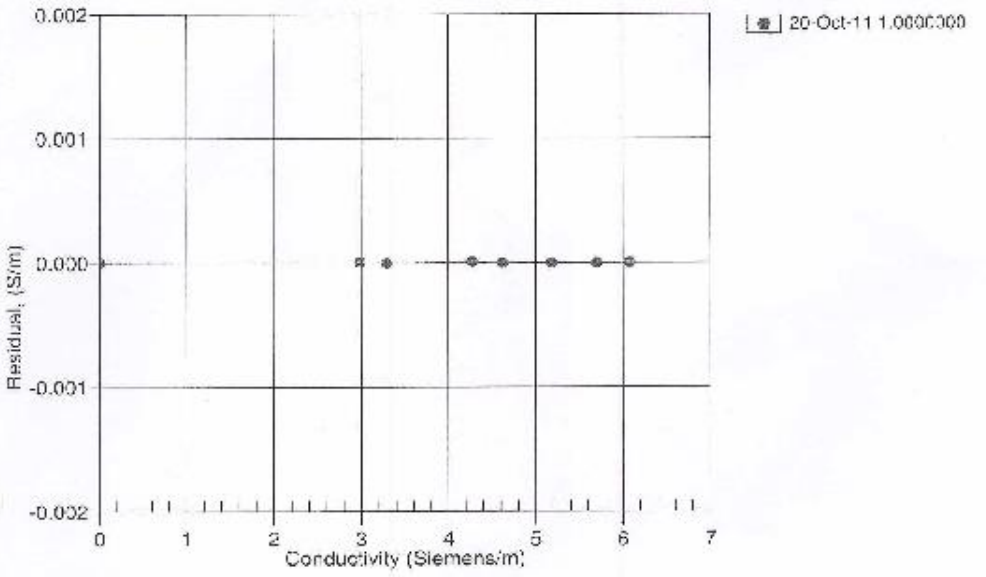
f = INST FREQ / sqrt(1.0 + WBOTC * t) / 1000.0

Conductivity = (g + hf^2 + if^3 + jf^4) / (1 + δ + εp) Siemens/meter

t = temperature[°C]; p = pressure[decibars]; δ = CTcor; ε = CPcor;

Residual = instrument conductivity - bath conductivity

Data: Slope Correction



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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

Micro TSG

SENSOR SERIAL NUMBER: 0589
CALIBRATION DATE: 20 Oct. 11

SBE 45 TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

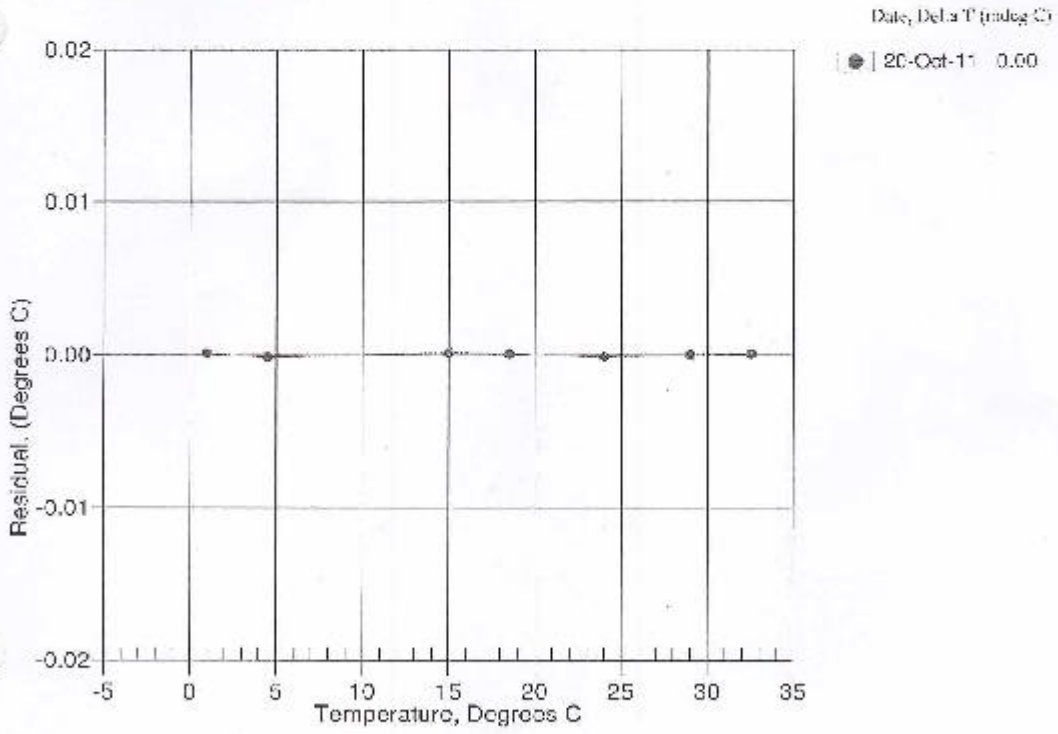
ITS-90 COEFFICIENTS

a0 = 3.1[illegible]e-003
a1 = 2.6561[illegible]e-004
a2 = -1.8286[illegible]e-006
a3 = 1.3971[illegible]e-007

BATH TEMP (ITS-90)	INSTRUMENT OUTPUT	INST TEMP (ITS-90)	RESIDUAL (ITS-90)
1.0000	826314.5	1.0021	0.0021
4.5000	706709.4	4.4998	-0.0002
14.8999	447335.5	14.9030	0.0031
18.4998	386307.8	18.5029	0.0031
24.0000	305348.6	23.9969	-0.0031
26.0000	283727.3	29.9970	-0.0030
32.5000	221749.5	32.5030	0.0030

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

Residual = instrument temperature - bath temperature



Underway 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: 0178
CALIBRATION DATE: 21-Sep-12

SBE 38 TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

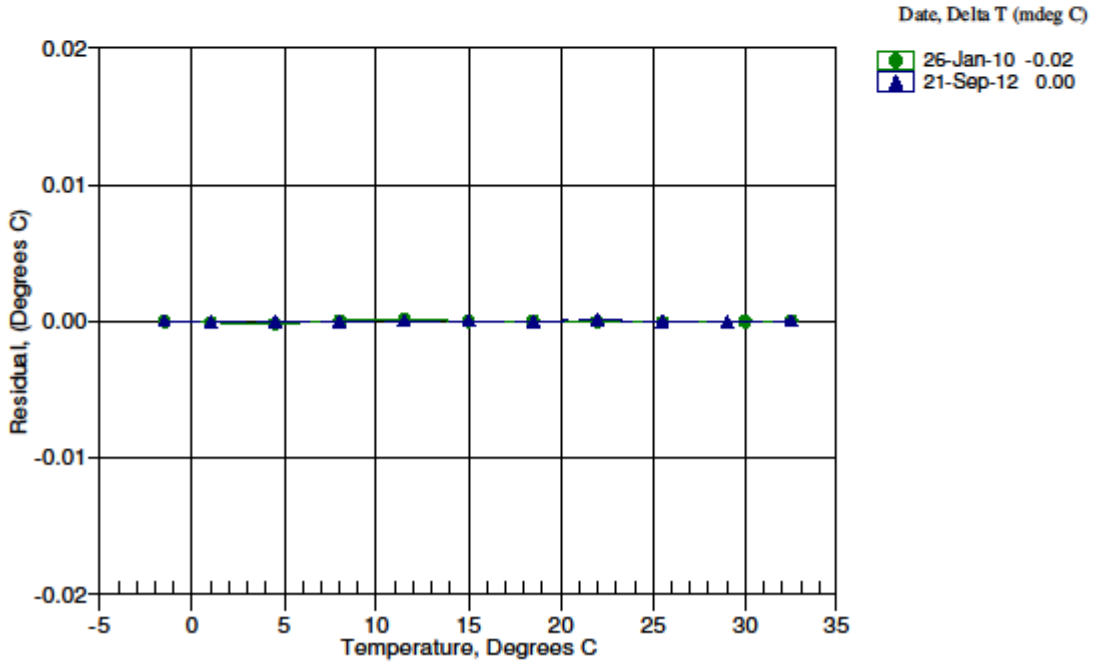
ITS-90 COEFFICIENTS

a0 = -4.740793e-005
a1 = 2.820902e-004
a2 = -2.754939e-006
a3 = 1.681819e-007

BATH TEMP (ITS-90)	INSTRUMENT OUTPUT	INST TEMP (ITS-90)	RESIDUAL (ITS-90)
-1.50000	750879.8	-1.49997	0.00003
1.00000	671250.6	0.99996	-0.00004
4.50000	575382.9	4.49998	-0.00002
8.00000	494802.5	7.99999	-0.00001
11.50000	426843.9	11.50002	0.00002
15.00000	369343.4	15.00002	0.00002
18.50000	320537.2	18.49998	-0.00002
21.99990	278981.8	21.99999	0.00009
25.50000	243494.9	25.49993	-0.00007
28.99990	213101.3	28.99982	-0.00008
32.49990	186993.9	32.49996	0.00006

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

Residual = instrument temperature - bath temperature



PO Box 518
620 Applegate St.
Philomath OR 97370

WET Labs

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

Chlorophyll Fluorometer Characterization, New Proxy .

Date:	**09/12/2011**
Serial #:	AFLT-009
Job#:	006066
Tech:	SML

Dark Counts	**0.193 volts**
CEV	**1.429 volts**
SF	**19.29**
FSV	**5.36 volts**
Linearity:	**0.999 R^2 (0–1.5 volts)**
	0.995 R^2 (0– 5.45 volts)

Notes:

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

CEV is the chlorophyll equivalent voltage. This value is the signal output of the fluorometer when using a fluorescent proxy that has been determined to be approximately equivalent to **24.63 µg/l** of a *Thalassiosira weissflogii* phytoplankton culture.

SF is the scale factor used to derive chlorophyll concentration from the signal voltage output of the fluorometer. The scale factor is determine by using the following equation: SF = (24.63) / (CEV – dark) e.g.(24.63 / (1.429 – 0.193) = 19.29)

FSV is the maximum signal voltage output that the fluorometer is capable of.

Chlorophyll concentration expressed in µg/l (mg/m^3) can be derived by using the following equation: (µg/l) = (Vmeasured -dark) * SF

The relationship between fluorescence and chlorophyll-*a* concentrations in-situ is high variable. The scale factor listed on this document was determined by 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 determination of chlorophyll concentration see [Standard Methods For The Examination Of Water And Wastewater] part 10200 H published jointly by: American Public Health Association, American Water Works Association and Water Environment Federation.

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Philomath OR 97370

WET Labs

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

Chlorophyll Fluorometer Pre-Characterization, Old Proxy .

Date:	**09/12/2011**
Serial #:	AFLT-009
Job#:	006066
Tech:	SML

Dark Counts	**0.193 volts**
CEV	**2.372 volts**
SF	**10.142**
FSV	**5.36 volts**
Linearity:	**0.999 R^2 (0–1.5 volts)**
	0.995 R^2 (0– 5.45 volts)

Notes:

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

CEV is the chlorophyll equivalent voltage. This value is the signal output of the fluorometer when using a fluorescent proxy that has been determined to be approximately equivalent to **22.1 µg/l** of a *Thalassiosira weissflogii* phytoplankton culture.

SF is the scale factor used to derive chlorophyll concentration from the signal voltage output of the fluorometer. The scale factor is determine by using the following equation: SF = (22.1) / (CEV – dark) e.g.(22.1 / (2.372 – 0.193) = 9.516)

FSV is the maximum signal voltage output that the fluorometer is capable of.

Chlorophyll concentration expressed in µg/l (mg/m^3) can be derived by using the following equation: (µg/l) = (Vmeasured -dark) * SF

The relationship between fluorescence and chlorophyll-*a* concentrations in-situ is high variable. The scale factor listed on this document was determined by 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 determination of chlorophyll concentration see [Standard Methods For The Examination Of Water And Wastewater] part 10200 H published jointly by: American Public Health Association, American Water Works Association and Water Environment Federation.

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Philomath, OR 97370

WET Labs

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

C-Star Calibration

Date December 6, 2012 S/N# CST-1316DR Pathlength 25 cm

	Analog output	Digital output
V_d	0.008 V	0 counts
V_{air}	4.804 V	15733 counts
V_{ref}	4.705 V	15405 counts

Temperature of calibration water	20.0 °C
Ambient temperature during calibration	20.8 °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

CTD Fish and Pressure Sensor

SEA-BIRD ELECTRONICS, INC.
13431 NE 20th St, Bellevue Washington 98005 USA
Phone: (425) 643-9866 Fax: (425) 643-9954 Email: seabird@seabird.com

Digiquartz Pressure Calibration dP/dT Corrected Coefficients
(Changed coefficients are posted in italics)

Pressure Transducer Serial Number: 120089
Original Calibration Date: 2011-01-28
Date of Correction: 2012-12-11
Installed in: SBE 9Plus S/N 1130

PRESSURE COEFFICIENTS

C1	*-42307.76*	*psia*
C2	*1.4900785e-01*	*psia/deg C*
C3	1.5073e-02	psia/deg C^2
D1	0.03413	
D2	0.0	
T1	*30.0225*	*psec*
T2	*-2.774198e-04*	*psec/deg C*
T3	4.796e-06	µsec/deg C^2
T4	1.75442e-09	µsec/deg C^3
T5	0e+00	

AD590M = 0.01281
AD590B = -8.819139
Slope = 1.0
Offset = 0.0

Corrected at Sea-Bird Electronics as per Paroscientific Calibration and Sea-Bird Electronics dP/dT tests. The original calibration from Paroscientific assumes an operating temperature range of 0 to 125 degrees C. dP/dT correction adjusts this operating range to a nominal range of 0 to 22 degrees C. This increases the accuracy of the transducer in this temperature range.

NOTE: Original coefficients from Paroscientific are attached to this form for informational purposes and should not be used.

CTD Conductivity (Primary)

SEA-BIRD ELECTRONICS, INC.
13431 NE 20th Street, Bellevue, Washington, 98005-2010 USA
Phone: (425) 643 - 9866 Fax (425) 643 - 9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 3503
CALIBRATION DATE: 17-Jun-11

SBE4 CONDUCTIVITY CALIBRATION DATA
PSS 1978: C(35,15,0) = 4.2914 Seimens/meter

GHIJ COEFFICIENTS

```
g = -1.03262410e+001
h =  1.56275016e+000
i = -3.00997664e-003
j =  3.20040950e-004
CPcor = -9.5700e-008 (nominal)
CTcor =  3.2500e-006 (nominal)
```

ABCDM COEFFICIENTS

```
a =  1.71106814e-007
b =  1.55458632e+000
c = -1.03093231e+001
d = -8.08777604e-005
m =  6.9
CPcor = -9.5700e-008 (nominal)
```

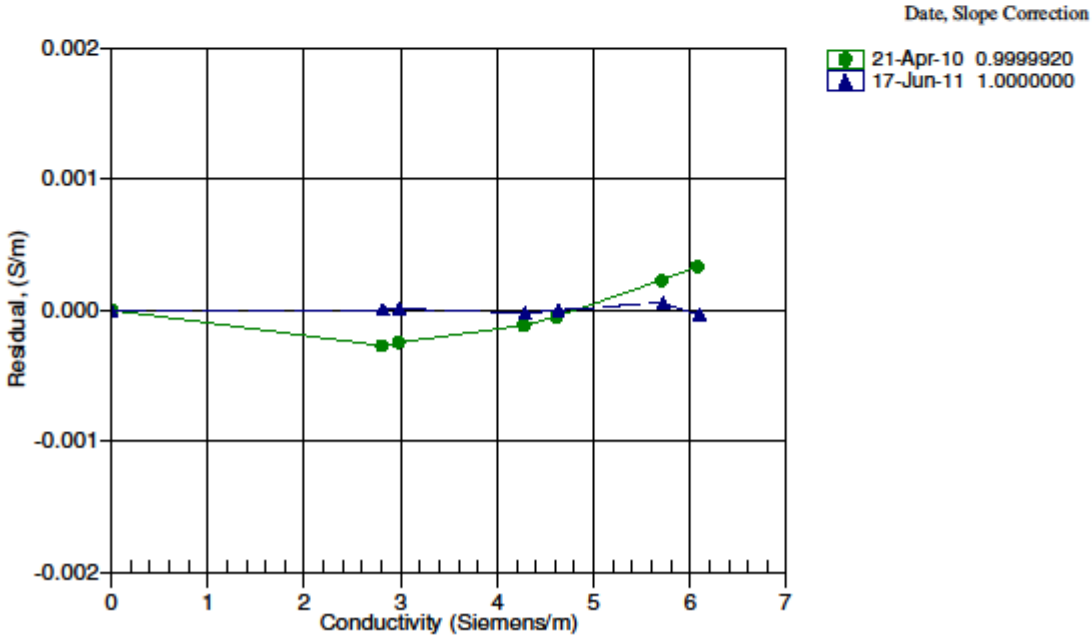
BATH TEMP (ITS-90)	BATH SAL (PSU)	BATH COND (Siemens/m)	INST FREQ (kHz)	INST COND (Siemens/m)	RESIDUAL (Siemens/m)
0.0000	0.0000	0.00000	2.57519	0.00000	0.00000
-1.0000	34.9369	2.81338	4.97213	2.81338	0.00000
1.0000	34.9374	2.98533	5.08204	2.98534	0.00001
15.0000	34.9374	4.28489	5.84581	4.28487	-0.00002
18.5000	34.9364	4.63258	6.03365	4.63257	-0.00000
29.0000	34.9333	5.71932	6.58591	5.71937	0.00006
32.5001	34.9258	6.09293	6.76517	6.09289	-0.00004

Conductivity = $(g + hf^2 + if^3 + jf^4)/10(1 + \delta t + \varepsilon p)$ Siemens/meter

Conductivity = $(af^m + bf^2 + c + dt)/[10(1 + \varepsilon p)$ Siemens/meter

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

Residual = (instrument conductivity - bath conductivity) using g, h, i, j coefficients



SEA-BIRD ELECTRONICS, INC.
13431 NE 20th Street, Bellevue, Washington, 98005-2010 USA
Phone: (425) 643 - 9866 Fax (425) 643 - 9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 3505
CALIBRATION DATE: 17-Jun-11

SBE4 CONDUCTIVITY CALIBRATION DATA
PSS 1978: C(35,15,0) = 4.2914 Seimens/meter

GHIJ COEFFICIENTS

```
g = -1.00495277e+001
h =  1.48833566e+000
i = -1.51676049e-003
j =  2.01820274e-004
CPcor = -9.5700e-008 (nominal)
CTcor =  3.2500e-006 (nominal)
```

ABCDM COEFFICIENTS

```
a =  3.64626762e-006
b =  1.48467285e+000
c = -1.00428577e+001
d = -8.59276632e-005
m =  5.4
CPcor = -9.5700e-008 (nominal)
```

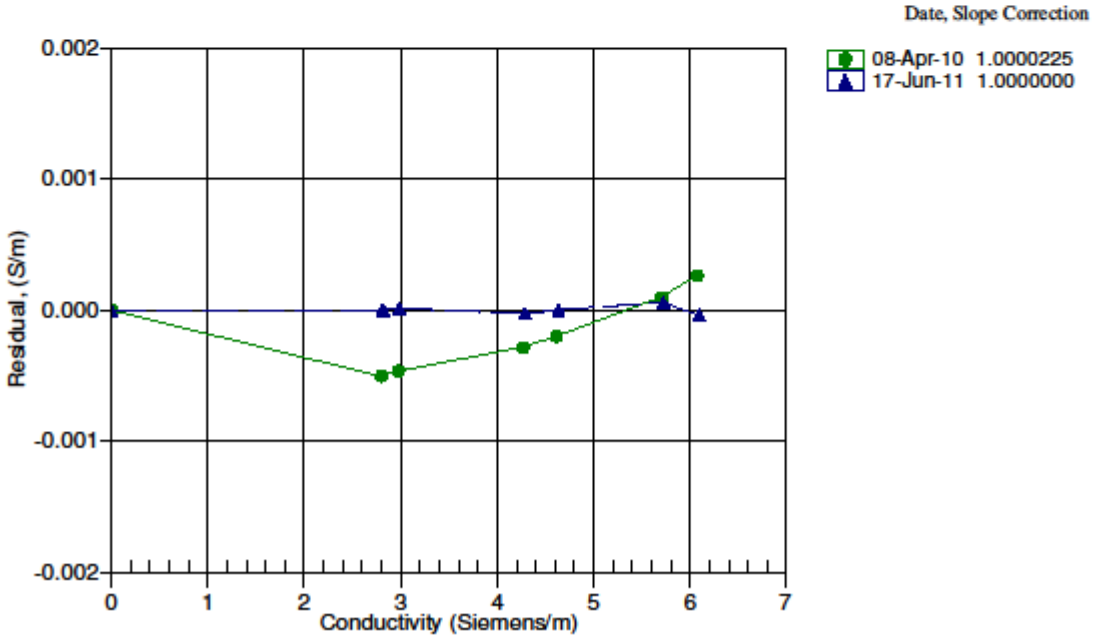
BATH TEMP (ITS-90)	BATH SAL (PSU)	BATH COND (Siemens/m)	INST FREQ (kHz)	INST COND (Siemens/m)	RESIDUAL (Siemens/m)
0.0000	0.0000	0.00000	2.60075	0.00000	0.00000
-1.0000	34.9369	2.81338	5.06934	2.81338	-0.00000
1.0000	34.9374	2.98533	5.18214	2.98534	0.00001
15.0000	34.9374	4.28489	5.96556	4.28486	-0.00003
18.5000	34.9364	4.63258	6.15816	4.63258	-0.00000
29.0000	34.9333	5.71932	6.72432	5.71938	0.00006
32.5001	34.9258	6.09293	6.90806	6.09289	-0.00004

$$\text{Conductivity} = (g + hf^2 + if^3 + jf^4)/10(1 + \delta t + \varepsilon p) \text{ Siemens/meter}$$

$$\text{Conductivity} = (af^m + bf^2 + c + dt)/[10(1 + \varepsilon p) \text{ Siemens/meter}$$

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

Residual = (instrument conductivity - bath conductivity) using g, h, i, j coefficients



CTD Temperature (Primary)

11

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: 5730
CALIBRATION DATE: 13 Nov 12

SBE3 TEMPERATURE CALIBRATION DATA
ITS 90 TEMPERATURE SCALE

ITS-90 COEFFICIENTS

g = 4.35188740e-003
h = 6.29746782e-004
i = 1.97095106e-005
j = 1.49614024e-006
f0 = 1000.0

IPTS-68 COEFFICIENTS

a = 3.68121342e-003
b = 5.91711217e-004
c = 1.90304619e-005
d = 1.42741670e-006
f0 = 3003.672

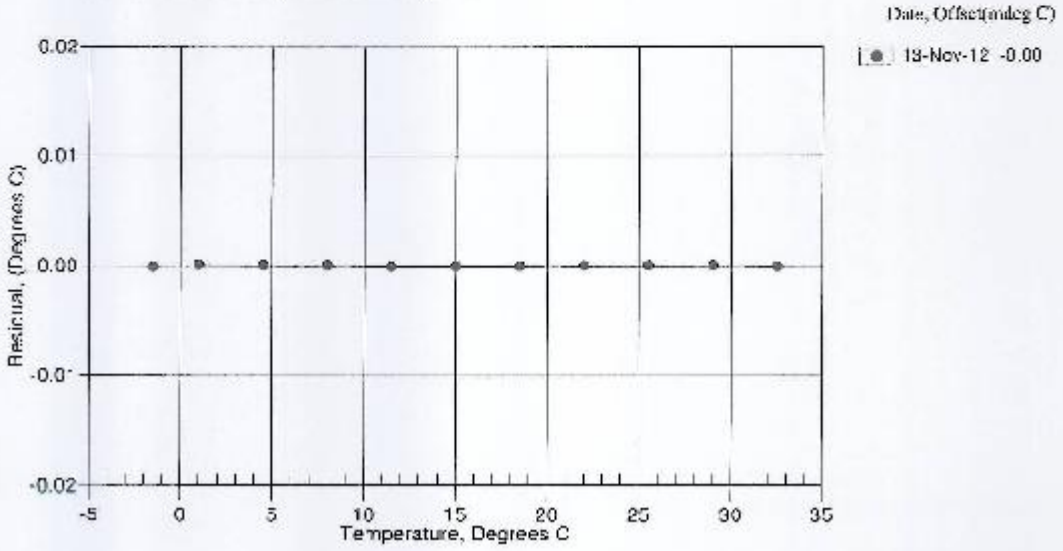
BATH TEMP (ITS 90)	INSTRUMENT FREQ (Hz)	INST TEMP (ITS-90)	RESIDUAL (ITS-90)
1.5000	3003.672	-1.5001	0.00008
1.0000	3179.320	1.0001	0.00010
6.5000	3437.383	6.5000	0.00005
7.9999	3710.673	7.9998	0.00002
11.5000	3999.035	11.4998	-0.00008
15.0000	4305.081	15.0005	-0.00005
18.5000	4623.218	18.5002	0.00004
22.0000	4959.855	22.0000	0.00004
25.5000	5313.373	25.5001	0.00007
29.0000	5684.149	29.0003	0.00003
32.5000	6072.544	32.4999	-0.00006

Temperature ITS-90 = $1/\{g + h[\ln(f_0/f)] + i[\ln^2(f_0/f)] + j[\ln^3(f_0/f)]\} - 273.15$ (°C)

Temperature IPTS-68 = $1/\{a + b[\ln(f_0/f)] + c[\ln^2(f_0/f)] + d[\ln^3(f_0/f)]\} - 273.15$ (°C)

Following the recommendation of JPOTS: T_{68} is assumed to be $1.00024 * T_{90}$ (2 to 35 °C)

Residual = instrument temperature - bath temperature



CTD 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: 2438
CALIBRATION DATE: 22-Aug-12

SBE3 TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

ITS-90 COEFFICIENTS

g = 4.31134824e-003
h = 6.41973049e-004
i = 2.30562159e-005
j = 2.19522017e-006
f0 = 1000.0

IPTS-68 COEFFICIENTS

a = 3.68121208e-003
b = 6.02099910e-004
c = 1.63994358e-005
d = 2.19678773e-006
f0 = 2759.345

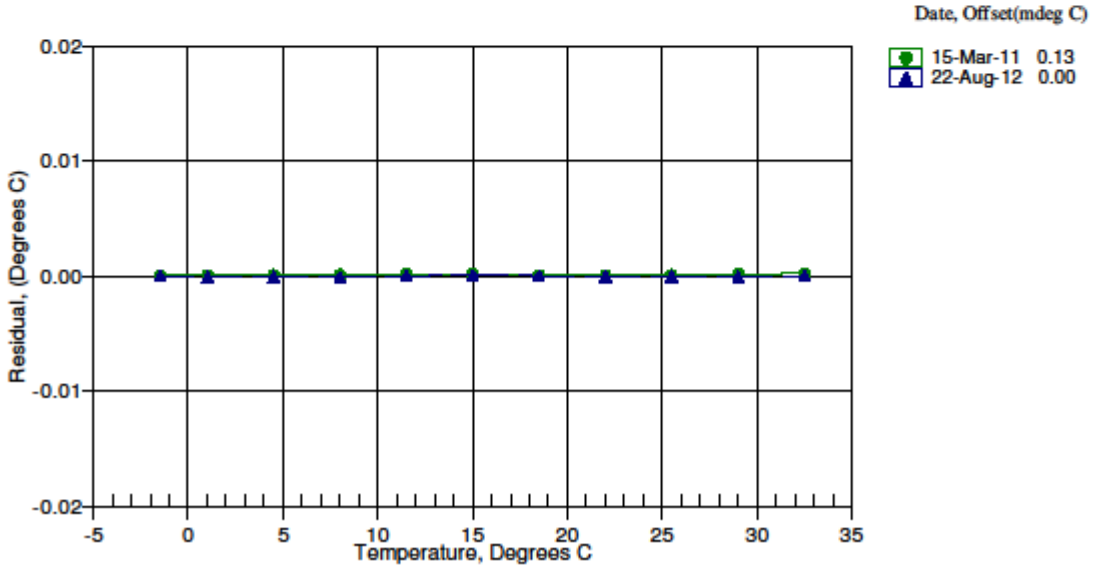
BATH TEMP (ITS-90)	INSTRUMENT FREQ (Hz)	INST TEMP (ITS-90)	RESIDUAL (ITS-90)
-1.5000	2759.345	-1.5000	0.00002
1.0000	2917.842	1.0000	-0.00000
4.5000	3150.675	4.5000	-0.00001
8.0000	3396.590	7.9999	-0.00007
11.5000	3655.956	11.5000	0.00001
14.9999	3929.098	15.0000	0.00010
18.4999	4216.353	18.4999	0.00003
22.0000	4518.054	21.9999	-0.00005
25.5000	4834.507	25.5000	-0.00003
29.0000	5166.008	29.0000	-0.00004
32.5000	5512.855	32.5000	0.00004

Temperature ITS-90 = $1/\{g + h[ln(f_0/f)] + i[ln^2(f_0/f)] + j[ln^3(f_0/f)]\} - 273.15$ (°C)

Temperature IPTS-68 = $1/\{a + b[ln(f_0/f)] + c[ln^2(f_0/f)] + d[ln^3(f_0/f)]\} - 273.15$ (°C)

Following the recommendation of JPOTS: T_{68} is assumed to be 1.00024 * T_{90} (-2 to 35 °C)

Residual = instrument temperature - bath temperature



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: 11/15/2012 S/N: FLRTD-397

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	0.106	0.064	0.043 V	68 counts
Scale Factor (SF)	6	13	25 µg/l/V	0.0077 µg/l/count
Maximum Output	4.96	4.96	4.96 V	16330 counts
Resolution	0.6	0.6	0.6 mV	1.0 counts
Ambient temperature during characterization				22.3 °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-397.xls Revision J 3/17/08

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Philomath, OR 97370

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

C-Star Calibration

Date December 5, 2012 S/N# CST-892DR Pathlength 25

	Analog output
V_d	0.060 V
V_{air}	4.802 V
V_{ref}	4.703 V

Temperature of calibration water	19.9 °C
Ambient temperature during calibration	21.8 °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

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: 0082
CALIBRATION DATE: 21-Aug-12

SBE 43 OXYGEN CALIBRATION DATA

COEFFICIENTS

Soc = 0.4221
Voffset = -0.6822
Tau20 = 1.57
A = -2.9945e-003
B = 6.5601e-005
C = -1.4073e-006
E nominal = 0.036

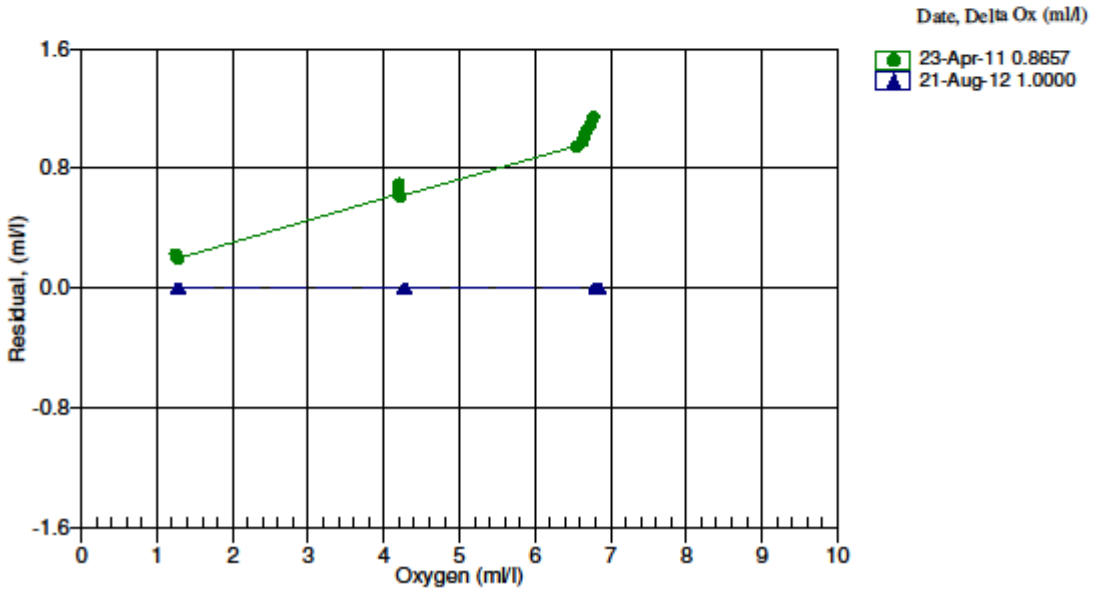
NOMINAL DYNAMIC COEFFICIENTS

D1 = 1.92634e-4 H1 = -3.30000e-2
D2 = -4.64803e-2 H2 = 5.00000e+3
H3 = 1.45000e+3

BATH OX (ml/l)	BATH TEMP ITS-90	BATH SAL PSU	INSTRUMENT OUTPUT(VOLTS)	INSTRUMENT OXYGEN(ml/l)	RESIDUAL (ml/l)
1.26	2.00	0.04	0.993	1.26	-0.00
1.27	6.00	0.04	1.034	1.27	-0.00
1.28	12.00	0.04	1.096	1.28	-0.00
1.30	20.00	0.04	1.187	1.29	-0.00
1.30	26.00	0.04	1.259	1.30	0.00
1.31	30.00	0.04	1.311	1.31	0.00
4.26	2.00	0.04	1.732	4.26	0.00
4.27	6.00	0.04	1.864	4.27	0.00
4.29	12.00	0.04	2.071	4.29	0.00
4.29	30.00	0.04	2.745	4.29	-0.00
4.29	26.00	0.04	2.586	4.29	0.00
4.29	20.00	0.04	2.356	4.29	-0.00
6.78	2.00	0.04	2.352	6.78	-0.00
6.79	12.00	0.04	2.879	6.79	0.00
6.81	6.00	0.04	2.564	6.81	-0.00
6.84	20.00	0.04	3.349	6.84	-0.00
6.85	26.00	0.04	3.719	6.85	0.00
6.86	30.00	0.04	3.985	6.86	0.00

$$\text{Oxygen (ml/l)} = Soc * (V + Voffset) * (1.0 + A * T + B * T^2 + C * T^3) * OxSol(T,S) * \exp(E * P / K)$$

V = voltage output from SBE43, T = temperature [deg C], S = salinity [PSU], K = temperature [Kelvin]
OxSol(T,S) = oxygen saturation [ml/l], P = pressure [dbar], Residual = instrument oxygen - bath oxygen



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: 0139
CALIBRATION DATE: 17-Aug-12

SBE 43 OXYGEN CALIBRATION DATA

COEFFICIENTS
Soc = 0.3794
Voffset = -0.5881
Tau20 = 1.31

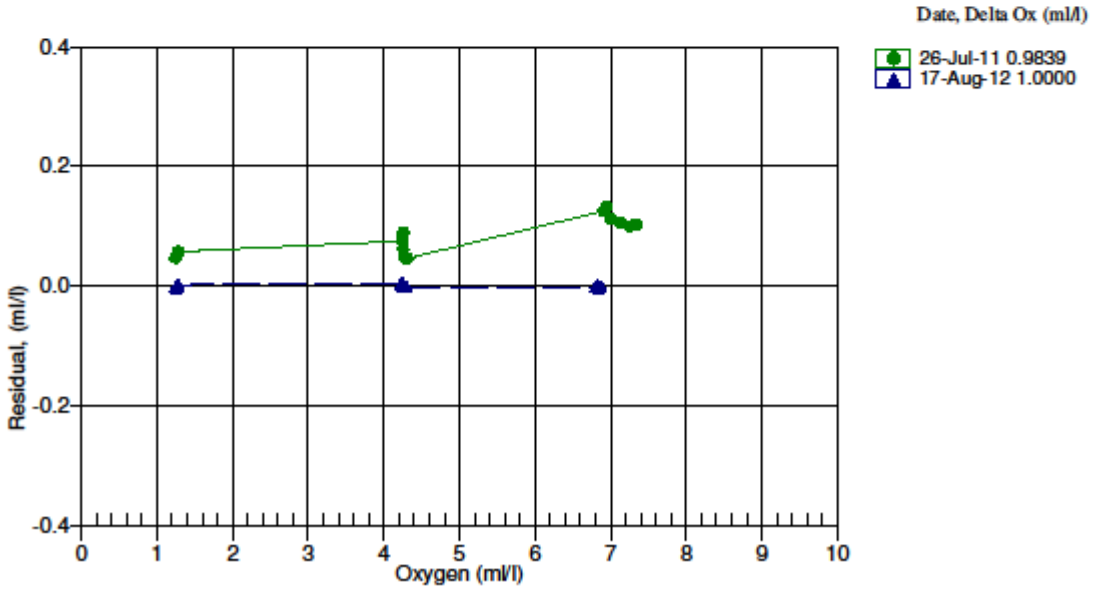
A = -2.6177e-003
B = 1.1822e-004
C = -1.9061e-006
E nominal = 0.036

NOMINAL DYNAMIC COEFFICIENTS
D1 = 1.92634e-4 H1 = -3.30000e-2
D2 = -4.64803e-2 H2 = 5.00000e+3
H3 = 1.45000e+3

BATH OX (ml/l)	BATH TEMP ITS-90	BATH SAL PSU	INSTRUMENT OUTPUT(VOLTS)	INSTRUMENT OXYGEN(ml/l)	RESIDUAL (ml/l)
1.24	2.00	0.04	0.928	1.24	-0.00
1.25	6.00	0.04	0.971	1.25	-0.00
1.26	12.00	0.04	1.037	1.26	-0.00
1.27	20.00	0.04	1.127	1.27	-0.00
1.28	26.00	0.04	1.195	1.28	0.00
1.28	30.00	0.04	1.244	1.28	0.00
4.23	2.00	0.04	1.748	4.24	0.00
4.25	6.00	0.04	1.890	4.25	0.00
4.25	12.00	0.04	2.103	4.26	0.00
4.26	20.00	0.04	2.389	4.26	-0.00
4.26	26.00	0.04	2.612	4.26	0.00
4.29	30.01	0.04	2.779	4.29	-0.00
6.81	20.00	0.04	3.466	6.80	-0.00
6.81	12.00	0.04	3.010	6.81	-0.00
6.83	26.00	0.04	3.831	6.83	0.00
6.84	2.00	0.04	2.459	6.83	-0.00
6.86	6.00	0.04	2.689	6.86	-0.00
6.87	30.04	0.04	4.096	6.87	-0.00

$$\text{Oxygen (ml/l)} = Soc * (V + Voffset) * (1.0 + A * T + B * T^2 + C * T^3) * OxSol(T,S) * \exp(E * P / K)$$

V = voltage output from SBE43, T = temperature [deg C], S = salinity [PSU], K = temperature [Kelvin]
OxSol(T,S) = oxygen saturation [ml/l], P = pressure [dbar], Residual = instrument oxygen - bath oxygen



CTD Underwater PAR

Biospherical Instruments Inc

CALIBRATION CERTIFICATE

UNDERWATER PAR SENSOR WITH LOG AMPLIFIER

Calibration Date: 10/26/12 **Job No.:** R11458
Model Number: QSP2300
Serial Number: 4721
Operator: TPC
Standard Lamp: V-030(3/7/12)
Operating Voltage Range: 0 to 15 VDC (+)

Note: The QSP-200 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:	**3.00E+13**	**quanta/cm²-sec/"amps"**	**4.99E-05**	**µEinsteins/cm²-sec/"amps"**
Wet Calibration Factor:	**5.30E+13**	**quanta/cm²-sec/"amps"**	**3.81E-05**	**µEinsteins/cm²-sec/"amps"**

Sensor Test Data and Results[1]

Sensor Supply Current (Dark):	84.7	mA	current dithers		
Supply Voltage:	6	Volts			
Lamp Integrated PAR Irradiance:	9.53E+15	quanta/cm²-sec	0.01632	µEinsteins/cm²sec	
SQ3 Immersion Coefficient:	0.5684	Scalar Correction:	1	PAR Solar Correction:	1.0000

Nominal Filter OD	Calibrated Trans.	Sensor Voltage	Measured Trans.	Measured Signal (Amps)	Estimated Signal (Amps)	Calc. Output (Volts)	Error (Volts)	Error (%)	Test Irrad. (quanta/ cm²-sec)
No Filter	100.00%	2.517	100.00%	3.29E-08	3.29E-08	2.519	0.002	0.0	9.83E+15
0.3	36.10%	2.080	36.26%	1.19E-08	1.19E-08	2.080	0.000	-0.4	3.56E+15
0.5	27.60%	1.967	27.86%	9.16E-09	9.07E-09	1.965	-0.002	-0.9	2.74E+15
1	9.27%	1.511	9.44%	3.10E-09	3.05E-09	1.506	-0.006	-1.8	9.28E+14
2	1.11%	0.720	1.14%	3.74E-10	3.65E-10	0.714	-0.006	-2.3	1.12E+14
3	0.05%	0.249	0.06%	2.52E-11	1.76E-11	0.230	-0.019	-30.4	7.54E+12

Dark Before: 0.183 Volts
Light - No Filter Hldr.: 2.517 Volts
Dark After - NFH: 0.183 Volts
Average Dark 0.183 Volts

I_{sig} = 3.29E-10 Amps
I_{dark} = 1.52E-10 Amps
10^{Vdark} = 1.52731E-10 Amps

RG780 0.2

Notes:
1. Annual calibration is recommended.
2. There is increasing error associated with readings below zero.
3. The collector should be cleaned frequently with alcohol.
4) This section is for internal use and for more advanced analysis.

QSP-200L,QSP2300(2008-)