



Data Synopsis for HLY0806



September 05 – October 01, 2008
Barrow to Barrow

Chief Scientist- Jonathan Childs
Healy Captain- Captain Frederick Sommer



Version of 2008-10-01



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Project Summary

This cruise was a two-ship program with the Canadian Coast Guard icebreaker Louis S. St-Laurent (LSSL) and the US Coast Guard Healy. The Healy sailed from Barrow, AK and the LSSL sailed from Tuktoyuktuk, CA. The ship's met on **_month-day-year at xxxx latitude, yyyy longitude** and worked in close proximity until they separated on September 27, 2008 in the vicinity of **xxx latitude, yyy longitude**. Two modes of operation were employed during this cruise. The primary mode was multichannel seismic survey. During this mode the Healy led, breaking a channel for the LSSL to follow while towing their seismic source and streamer. The secondary mode was focused on collecting multibeam bathymetry. During multibeam-mode, the LSSL lead, breaking a channel for the Healy to follow.

2008 USGS/NRCAN

Healy – Louis Joint Science Plan (prepared before the cruise)

The primary purpose of the two-ship experiment is to collect seismic and bathymetric data in support of delineating the extended continental shelf in the western Arctic Ocean for both Canada and the United States. The extended continental shelf is that region beyond 200 nautical miles where a nation can show it satisfies the conditions of Article 76 of the United Nations Convention on the Law of the Sea. The data most relevant to fulfilling the conditions of Article 76 are bathymetric and seismic reflection data. The logistical difficulties of collecting seismic data in ice-covered regions make it much more likely that the data will be collected successfully if two icebreakers participate, one in the lead to break a path for the second following with the towed seismic acquisition system. *USCGC Healy* is equipped to collect multibeam bathymetric, high-resolution subbottom, and gravity data during the expedition and the *CCGS Louis S. St. Laurent (Louis)* is equipped to collect multichannel seismic reflection and refraction data as well as gravity data. With two ships, the priority areas will be those locations where ice cover requires a two-ship operation.

Because acquiring seismic data is the reason for having a two-ship experiment, alterations to the original science plan during the experiment need to ensure successful acquisition of seismic data with coincident bathymetric data to foot of slope, and second on obtaining additional multibeam bathymetric data. If the ice is too thick for ship profiling along the seismic profile in the vicinity of the foot of the slope, the fall-back strategy is to take spot soundings using the helicopter and use those spot sounding to define foot of slope. Ice conditions and ship location with respect to the continental margin will determine when the helicopter soundings will be employed in this manner.

Along the Canadian continental margin north of Banks Island, where the planned ship tracks are parallel to the margin, a secondary priority is to collect bathymetric data to identify the foot of the slope between the seismic profiles. To fulfill this secondary objective, it may be optimal to have *Louis* as the lead vessel to break ice for *Healy*. If ice conditions are heavy, a decision at sea will need to be made to determine how much effort to expend obtaining bathymetry along the continental margin between seismic profiles. If this secondary operation delays the seismic survey significantly, it will be abandoned and a faster route taken to the start of the next seismic line. The foot of slope information between seismic profiles is useful but not essential.

A Summary of the Joint Operations on The Louis S. St-Laurent

By: Ruth Jackson (Canadian Geological Survey) and Deborah Hutchinson (US Geological Survey)

UNCLOS 2008 Arctic Ocean: Canada - U.S. Joint Expedition

The purpose of the *Louis S. St-Laurent* 2008 UNCLOS expedition is to collect data that will help define the limits of the extended continental shelf for both Canada and the United States in the Arctic Ocean. The Convention on the Law of the Sea (UNCLOS) allows every coastal state a continental shelf out to 200 nm. UNCLOS also allows coastal states, under certain circumstances, to exert sovereign rights over portions of the continental margin beyond 200 nm. The portion of the continental margin beyond 200 nm is called the extended continental shelf. Both Canada and the United States have a national interest in knowing (and declaring to others) the locations of the outer limits of their respective extended continental shelf.

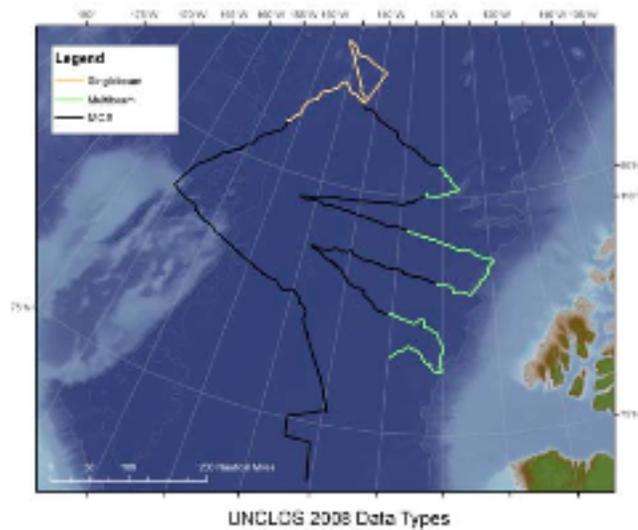


Photo: Kelly Hansen

Two kinds of data are necessary for defining the outer limits of the extended continental shelf: sediment thickness and morphology. Sediment thickness information is gathered using seismic reflection techniques that can image many kilometers beneath the sea floor. Morphology data are gathered using echo sounders which typically only image the surface of the sea floor. The collaboration between Canada and the United States grew from recognizing that Canada has developed a seismic reflection system for use in the Arctic Ocean (using *Louis S. St-Laurent*) whereas the United States operates a sophisticated multibeam echo sounder aboard its Arctic Research vessel, *Healy*.

Collaboration makes sense in the remote and harsh conditions of operating in the Arctic. Not only do the U.S. and Canada have a long history of cooperation, but the collaboration saves money for each country, provides a more complete dataset for UNCLOS purposes, and facilitates collecting these kinds of data in conditions of thick ice where it is impractical for one ship to operate.

HLY0806 Data Synopsis



During the 2008 cruise, approximately 2800 km of multichannel seismic data were collected. Of those, ~1500 km were with *Healy* breaking ice for *Louis*. An additional ~950 km of multibeam data were collected with *Louis* breaking ice for *Healy*. *Louis* reached 83°N, 146°W during profiling.

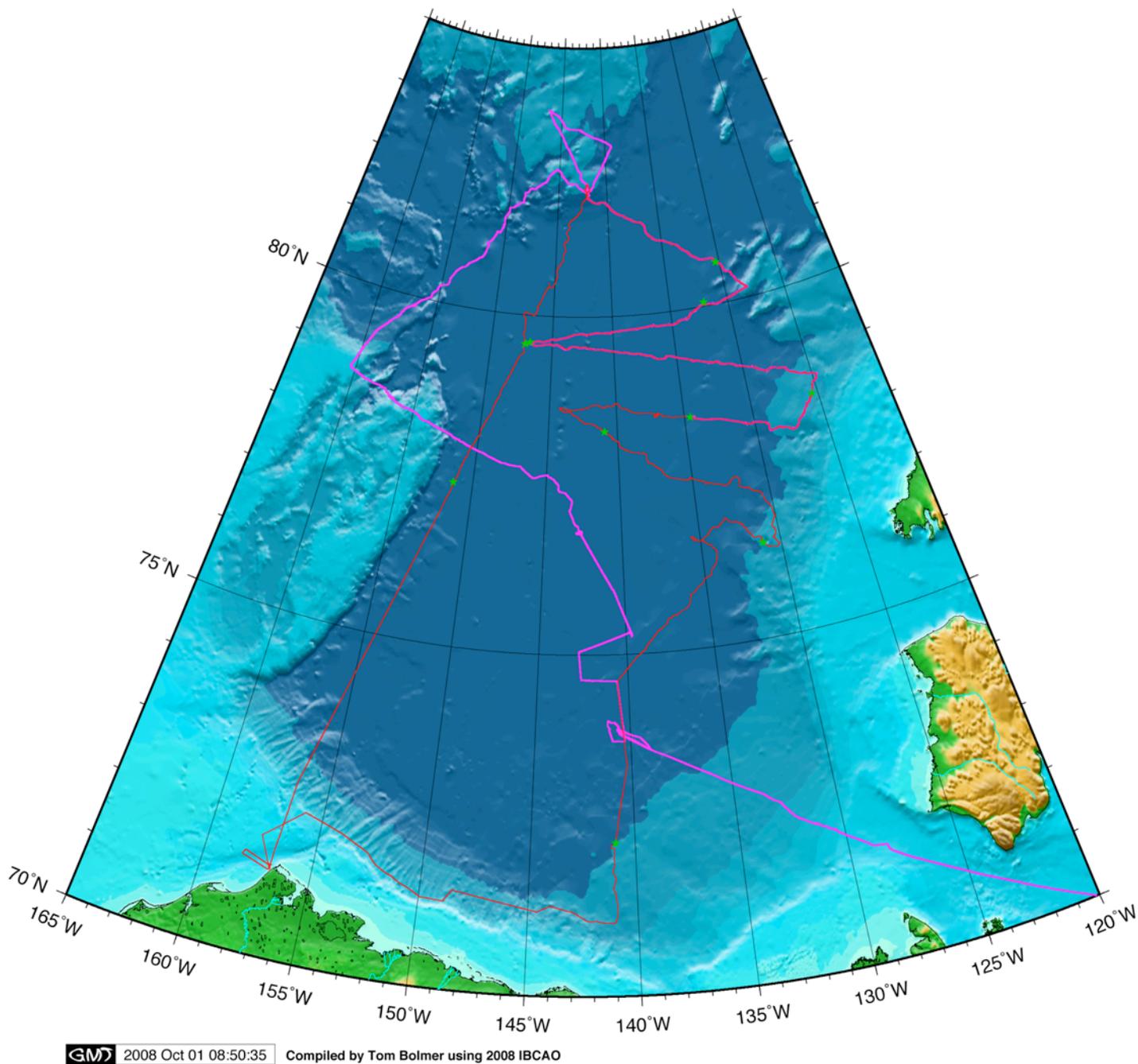
In addition, these data are in regions never before explored by surface ship. Not only are the results relevant to Law of the Sea, they are also scientifically exciting for revealing the geologic and tectonic history of the Canada Basin of the Arctic Ocean.

29 September, 2008,

Aboard *Louis S. St-Laurent*

Cruise Track

HLY0806 09/05/08 - 10/01/08



Personnel**HLY0806 Science Party Personnel**

| <i>Name</i> | <i>Institution</i> | <i>Position</i> | <i>Phone</i> | <i>Email</i> |
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Ship's Crew

| | | |
|------------------------|-----------------------------|---------------------------|
| Sommer, Frederick CAPT | Hurtado, Daniell EM1 | Rose, John CWO |
| Bateman, Dale CDR | Imgarten, Christopher DC1 | Roy, Evan BM3 |
| Stewart, Jeffrey CDR | Irwin, Paul EM2 | Rudibaugh, Kenneth MK1 |
| Petrusa, Douglas LCDR | Jacobs, Bryson ENS | Schendorf, Tara ENS |
| Angelo, James YNC | Jones, Greg MKCS | Shaffer, Hans EM1 |
| Appleberry, Jason LT | Kidd, Wayne BMC | Siciak, Anthony MK3 |
| Ayers, Silas LT | Kimmel, Brian BM3 | Smith, Corey MK3 |
| Bartlett, Charles MST1 | Kruger, Thomas MST3 | Smith, Josh LTJG |
| Baldwin, Robin FS3 | Ladd, Donald EM2 | Starling, Wendy MK2 |
| Beasley, Corey HSCS | Laisure, Jeremy SK2 | Swanson, Shawn ET1 |
| Bender, Zachary ENS | Lambert, Douglas MKC | Thomas, Tasha ENS |
| Berringer, Mike ETC | Layman, Rich MST1 | Thompson, Emily SN |
| Blas, Paul FN | Liebrecht, Brian ET1 | Tysin, Alley SNFS |
| Brogan, John MKC | Lyons, Sean R CWO3 | Von Kauffmann, Daniel IT1 |
| Brown, Betty MK3 | Manangan, Sorjen OSC | Wagner, Alexander FN |
| Buford, Aimee BM2 | Marsden, George DCC | Whiting, Allan, MK1 |
| Coombe, Jeffrey MK2 | McNally, Terence SK1 | Williams, Tony FSCS |
| Dabe, Jeffrey IT1 | McManus, Gene SN | Wilson, Thomas BMCM |
| Davis, Jonathon ET2 | Merten, James SN | Worrell, Kenneth EM1 |
| Dolton, Peter ENS | Miller, Valerie CWO2 | Yeckley, Andy BM3 |
| Dull, Steven FS2 | Murphy, Nicholas MK2 | Zitting, Arrene FS1 |
| Dunning, Lara BM3 | Murray, Justin SN | |
| Fernandez, Chelsey SN | Myatt, Lisa ENS | |
| Ford, Angela SN | Olson, James EM3 | |
| Galvez, Oscar R. LT | O'Sullivan, Brandon MK2 | |
| Glenzer, William BM1 | Passalacqua, Joseph ETCM | |
| Ghosn, Kathleen FN | Podhora, Curtis EMCM | |
| Gray, Deidre SN | Powell, Gregory ET3 | |
| Griffin, Bobby SK2 | Quichocho, Robert MK1 | |
| Hamilton, H. Mark FS3 | Redd, Davion DC2 | |
| Harbinsky, Mark ET2 | Rieg, Mark MSTC | |
| Harris, Daniel SK1 | Rivera-Maldonado, Abner SKC | |
| Huneycutt, Gaines BM2 | Rodermund, Michael, SA | |

Science Components and their major sampling activities

Auxiliary Science (Healy)

IABP - National Ice Center
Pablo Clemente-Colon (NIC/NOAA)

This effort represents continued participation of NIC personnel and the testing and deployment of International Arctic Buoy Program (IABP) buoys. Drifting buoys will be deployed in open water during the most western and southern tracks of the cruise. None of these deployments should require on ice operations. Although unlikely, depending on need, opportunity, and sea ice conditions encountered, one of the seasonal buoys may instead be deployed on multiyear sea ice (MYI). In this case, the deployment on MYI, if needed, would be scheduled to take advantage of other planned stops but in all cases will be conducted strictly as independent and separate field activities from other cruise plans. Typical deployments on MYI take 30-45 minutes of on-the-ice time. The seasonal buoys testing and deployment should be completed during HLY0805. A pre-cruise nowcast analysis of sea ice conditions in the Beaufort Sea and Canada Basin region will be provided by the NIC to the Chief Scientist. In addition to on board sea ice analysis and imagery cruise support, the NIC personnel will collect hourly observations of sea ice characteristic as the Healy navigates ice infected waters. Recorded observations will include estimates of ice thickness and snow depth during icebreaking operations in the ice pack. NIC personnel will also coordinate with the Louis St. Laurent the acquisition and analysis of satellite imagery from NIC and Canadian Ice Service sources under the North American Ice Service collaboration.

Mixotrophy in Arctic Protists – Alternative Nutritional Strategies

Rebecca J. Gast (WHOI) and Robert Sanders (Temple University)

One-celled plankton traditionally have been divided into either phototrophic (algal, using light for metabolism) or heterotrophic (using complex organic compounds for metabolism). However, mixotrophic behavior, whereby organisms combine both modes of nutrition within a single cell, has been increasingly recognized and documented in recent decades. The potential nutritional benefits of being able to use chemosynthesis as well as particle ingestion gives greater survival potential to the phytoplankton, by enabling it to utilize potential diverse sources of energy, major nutrients, and micronutrients including vitamins and trace metals during long periods of polar darkness when chemosynthesis is not practical. This science experiment involves taking water samples in the Arctic to test for the presence of mixotrophic one-celled organisms. The participating scientists have conducted numerous studies of mixotrophy off Antarctica and are unaware of similar studies in the Arctic.

Water samples are to be collected via CTD equipped with the 24-place rosette with 12L Niskin bottles and silicone O-rings, Chelsea fluorometer, and PAR sensor. Optimally, water is to be collected about every other day (so about 12-13 casts total), at the near surface (5m) and the chlorophyll maximum (around 20-30m in the Antarctic). The samples are cultured, and examined microscopically for evidence of mixotrophy

Distribution Contents

Introduction to Data

The Healy 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 scaled, calibrated values from logged data.
- Information about the specific instruments in use during the cruise.
- A log of instrumentation issues, adjustments, acquisition problems, and events during the cruise that may affect the data.
- Calibration data for the instruments in use during the cruise.

The data is distributed on a small USB disk drive.

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

There are two logging systems on the Healy. The US Coast Guard Seattle Electronic Support Unit (ESU) runs the NOAA/SCS logging system and the LDEO support group runs the Lamont Data System (LDS) logging system. Although this provides some redundancy in logging, LDS is required to provide precision time-stamping, real-time reformatting, and logging of data that SCS was not designed to support including the sonar systems, web cameras, and gravity meters.

The NOAA-developed Scientific Computer System (SCS) (version 4.2) is a data acquisition, and display system designed for Oceanographic, Atmospheric, and Fisheries research applications and was originally intended to log data from supporting sensors (not the mapping sonar’s) on survey launches. It acquires sensor data from shipboard oceanographic, atmospheric, and fisheries sensors and provides this information to scientists in real time via text and graphic displays, while simultaneously logging the data to disk for later analysis. SCS also performs quality checks by monitoring I/O, providing delta/range checks and plotting data after acquisition.

The LDEO Data System (LDS) is derived the logging code originally developed on the R/V Conrad in 1986 and has evolved through use on the Conrad, Ewing, Nathaniel B. Plamer, R/V Gould, six SCICEX submarine cruises and a number of smaller, short field programs since 1987. LDS is the result of significant restructuring of the code base in 2004 and has been data acquisition system on the R/V Langseth since she went into service.

SCS Data Overview

SCS receives all of its data through asynchronous serial (RS-232) connections. In SCS a time tag is added at the beginning of each line of data in the form,

mm/dd/yyyy,hh:mm:ss.sss,[data stream from instrument] where:

| Format | Value used |
|--------|---------------------------|
| mm | 2 digit month of the year |
| dd | 2 digit ay of the year |
| yyyy | 4 digit year |
| hh | 2 digit hour of the day |
| mm | 2 digit minute |
| ss.sss | seconds |

An example string from the Seabeam Centerbeam file is:

04/13/2007,06:49:20.920,\$SBCTR,2007,4,13,06:49:09.437,57.158792,-165.664322 ,69.15,60*00

All times are reported in UTC. Each file type has it's own NEMA string name (\$SBCTR as an example).

The delimiters that separate fields in the raw data files are commas. Care should be taken when reprocessing the data that the field's separations are clearly understood.

By design, SCS separates different data records from a single serial data stream into different directories. For instance, a GPS receiver may transmit \$GPGGA, \$GPHDT, and \$GPGLL records. In the SCS data architecture, each of these messages will be logged in a different directory.

LDS Data Overview:

LDS receives most of its data through serial ports like SCS and like SCS, prepends a time stamp. Unlike SCS, LDS uses remote nodes to acquire and timestamp data and provide it to the central LDS logger. Data from the two ship's gyrocompasses is handled by a remote node installed on the bridge and data form the two gravity meters is handled by a node in IC/Gyro. Remote nodes are substantively different than terminal servers in that they timestamp the data locally which eliminates the network latency associated with acquiring data through a terminal server and then providing the timestamp later.

An example LDS data record is shown below. The first field is the instrument identifier, the second is a precioisn time stamp and the remainder is the raw data from the device, in this case, an LDEO iLab BGM-3 gravity meter interface:

| | | | |
|--------|------------------------|-----------|----|
| bgm222 | 2008:264:00:00:26.9340 | 04:025508 | 00 |
|--------|------------------------|-----------|----|

Directories:

- 1_Minute_Averaged_Data:** This directory contains one minute averages of many of the the under way data types.
- data:** This directory contains the data directories below.
- SCS_Data:** This directory contains serial data collected by the SCS version 4.2 data collection system in different directories. Directory names are labeled by the instrument name and string type of the data collected. A description of the data contained in this directory is below.
- LDS_Data:** This directory contains data collected by the Lamont LDS data collection system in different directories. Directory names are labeled by the name of the instrument. A description of the data contained in this directory is below.
- Raw:** This directory contains raw data as recorded by individual instruments and put into different directories. Directory names are labeled by the instrument name. A description of the data contained in this directory is below.
- Meta_data:** This directory contains documents useful in the post analysis of the data on this DVD media set. The data types are separated into different directories. A description of these directories is below.
- Plots:** This directory contain daily and hourly plots of underway data that were generated in LDS.

1_Minute_Averaged_Data:

- HLY0806_distance.csv.gz Distance along track from port.
- HLY0806_Averaged.csv.gz All the Under way data averaged for 1 minute.
- Shapefile All of the 1 minute under way data averaged at 1 minute spacing in shp, shx and dbf GIS files.

data

SCS_Data:

- /aft_a_frame Wire tension, wire out, and wire speed for the Aft A frame sheaves.
- /air_temp_f Temperature data from the RM Young wind sensor in Fahrenheit. Data is derived from data from files in the rmyoung_air directory
- /ashtech_attitude Attitude in NMEA format from the Ashtech ADU5 GPS receiver
- /ashtech_gga Position data in NMEA GGA format from the Ashtech ADU5 GPS receiver
- /ashtech_gll Position data in NMEA GLL format from the Ashtech ADU5 GPS receiver

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|-------------------|--|
| /ashtech_hdt | Heading data in NMEA HDT format from the Ashtech ADU5 GPS receiver |
| /dew_point_f | Dew point temperature derived from air temp |
| /flomet_a | Flow meter data just upstream of the A TSG and Fluorometer. |
| /fluro_a | Flurometer for the A TSG sensor. |
| /glonass_gga | Position data in NMEA GGA format from the GLONASS GPS receiver. |
| /glonass_gll | Position data in NMEA GLL format from the GLONASS GPS receiver. |
| /gyro_mk27 | Heading data in NMEA HDT format from the Sperry MK27gyro compass |
| /gyro_mk39 | Heading data in NMEA HDT format from the Sperry MK39 gyro compass |
| /ibs_waypoints | Waypoints from the Healy's Integrated Bridge System |
| /isus | ISUS Nitrate Sensor small file |
| /isus3v | ISUS Nitrate Sensor 3V full file |
| /knudsen | Depth data in the Knudsen PKEL format received from Knudsen 320 B/R serial output |
| /met3a_sen | Meteorology data from the top of the Jack Staff on the bow. |
| /oxygen_a | Dissolved oxygen values from A TSG. |
| /pcode_aft_gga | Position data in NMEA GGA format from the Trimble Centurion P-Code GPS receiver located in the Computer Lab |
| /pcode_aft_gll | Position data in NMEA GLL format from the Trimble Centurion P-Code GPS receiver located in the Computer Lab |
| /pcode_aft_vtg | Course made good and speed over ground in NMEA VTG format from the Trimble Centurion P-Code GPS receiver located in the Computer Lab |
| /pcode_aft_zda | Time and date data in the NMEA ZDA format from the Trimble Centurion P-Code GPS receiver located in the Computer lab |
| /pcode_bridge_gga | Position data in NMEA GGA format from the Trimble GPS receiver located on the bridge. |
| /pcode_bridge_gll | Position data in NMEA GLL format from the Trimble GPS receiver located on the bridge. |
| /pcode_bridge_vtg | Course and speed over ground data in NMEA VTG format from the Trimble GPS receiver located on the bridge. |
| /posmv_gga | Position data in NMEA GGA format from the POS/MV |
| /posmv_gst | Pseudorange error statistics in NMEA GST format from the POS/MV |
| /posmv_hdt | Heading data in NMEA HDT format from the POS/MV |
| /posmv_pashr | Roll, pitch and heave from POS MV inertial navigation system. |
| /posmv_vtg | Course and speed over ground in NMEA VTG format from the POS/MV |
| /posmv_zda | Time and date data in NMEA ZDA format from the POS/MV |
| /pressure_sen | Water pressure in the Uncontaminated Seawater System in the Bio Chem Lab in pounds per square inch. |

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| | |
|--------------------|--|
| /rmyoung_air | Temperature, relative humidity, and atmospheric pressure in NMEA format from the RM Young meteorological system on the bridge and flying bridge. |
| /rmyportwind | Wind speed and direction data in NMEA format from the RM Young weather vane on the port side of the Healy. |
| /rmystbdwind | Wind speed and direction data in NMEA WMV format from the RM Young weather vane on the starboard side of the Healy. |
| /samos_data | Derived (assembled) meteorology data reported automatically during the cruise for SAMOS. |
| /sbd_a_frame | Wire tension, wire out, and wire speed for the starboard A frame sheaves. |
| /seabeam_center | Center depth extracted in real-time from the SeaBeam 2112 |
| /solar_radiometers | Short wave and long wave solar Radiometer data from sensors on the top of HCO. |
| /sperry_speedlog | Ground/water speed data from the Sperry SRD-500 Speed Log. The speed log is retracted and not operated when the ship is operating in ice. |
| /surface_par | Photosynthetic Active Radiation volts and microeinstens/m ² from the surface PAR sensor on the top of HCO. |
| /sv2000 | Speed of sound in the water/propylene glycol solution as measured by the SV2000 acoustic velocimeter located in the ADCP BB150 sonar well |
| /true_wind_port | True wind speed calculated by SCS from gyro heading (source undefined) and the port-side RM Young windbird |
| /true_wind_stbd | True wind speed calculated by SCS from gyro heading and the starboard-side RM Young windbird. |
| /winch_data | Wire data (line out, tension and wire speed) from the Totco wire metering system. |
| /wind_sen_a | Wind data from the ultrasonic anemometer on the Jack Staff. |
| /wind_sen_b | Wind data from the the ultrasonic anemometer on the starboard yard arm (of the mast.) |

Extra files in the directory SCS_Data:

| | |
|-------------------------------|---|
| ACQLOG.LOG | Contains the data as to what occurred with SCS data. It shows when data collection was started and stopped. Includes startup and shutdown events. |
| Incidents_YYYYMMDD-TTTTTT.DTM | Contains any incident data, which were triggered in SCS. Refer to the SCS documentation for the definition of "incidents." |
| sensor_YYYYMMDD-TTTTTT.scf | Contains the configuration file for data collection as configured by SCS. |

LDS_Data:

| | |
|--------------|--|
| /AloftConCam | Contains photographs (images) in JPEG format from the digital camera mounted in Aloftcon and pointed forward. Picture files are grouped in |
|--------------|--|

HLY0806 Data Synopsis

subdirectories by folders by Day of Year (YYYYJJJ). The picture files are in 5 minute JPEG format.

| | |
|---------------|---|
| /FantailCam | Photographs from a digital camera mounted in AftCon and pointed at the fantail/stern A-frame. Same structure as the AloftCon photos but not at the same resolution. |
| /adu5 | Contains the data from the Thales (Ashtech) ADU5 GPS Receiver whose antenna array is mounted on the top of HCO.. |
| /aggps | Contains the data from the Trimble AG132 differential GPS Receiver. Antenna is on the top of HCO.. |
| /ais | Contains data from the Automatic Identification System (AIS) receiver mounted on the top of HCO. These are binary messages encapsulated in NMEA VDM sentences. |
| /bgm221 | Contains the data from the Bell BGM-3 Marine Gravity meter system serial number 221 installed in IC/Gyro. |
| /bgm222 | Contains the data from the Bell BGM-3 Marine Gravity meter system serial number 222 installed in IC/Gyro.. |
| /events | Contains the LDS event log for each logging process. Typically a record for each time that process was started plus any other messages. |
| /mk27 | Contains the data from the ship's Sperry MK27 Gyrocompass |
| /mk30 | Contains the data from the ship's Sperry MK30 Gyro. |
| /posatt | Contains the attitude data from the POSMV GPS aided inertial guidance, heading and attitude reference system. |
| /posnav | Contains the navigation data records in NMEA format from the POSMV GPS. |
| /posreform2sb | Contains the navigation data from the POSMV GPS reformatted in real-time for the SeaBeam 2112 multibeam sonar. |
| /sbctr | Contains the center beam data in NMEA format extracted from the SeaBeam 2112 data. |
| /sbsv | Contains the surface sound speed calculated in real-time from the TSG records and formatted for the SeaBeam. |
| /seabeam | Contains the raw SeaBeam 2112 multibeam data. These data are in MB-System Type 41 format which is the native format of the sonar. |
| /tsg_met | Contains the all data from the TSG and Met sensors installed and supported by the Ocean Data Facility (ODF) of the Scripps Institution of Oceanography (SIO). |
| /SwapPingHLY | Contains network performance statistics (from 'ping ')for the Healy/LSSL SWAP2 wireless network connection. |
| /SwapRoute | Contains routing table information for Healy/LSSL SWAP2 wireless network connection. |
| /SwapStatsHLY | Contains Healy wireless stats for Healy/Louis wireless network(swap) connection. |
| /SwapStatsLSL | Contains Louis wireless stats for Healy/Louis wireless network(swap) connection. |

Raw:

| | |
|-------------|---|
| /adcp75 | The VMDAS native-format data for the RDI OS75 KHz ADCP data |
| /adcp150 | The VMDAS native format data for the RDI VM150 Acoustic Doppler Profiler (ADCP) 150 KHz |
| /ctd | CTD data in directories by Cast number. |
| /xbt | Expendable Bathythermograph data in raw (RDF) and export (EDF) formats. |
| /knudsenraw | Data from the Knudsen 320B/R chirp subbottom profiler. |

Satellite_Images:

| | |
|--------|--|
| | Contains satellite imagery in jpeg format |
| /dmosp | Data from the Defense Meteorology Satellite Program passes logged by the Healy's Terascan . Directories are identified by Year, Month, Day |
| /hrpt | Data from the NOAA weather satellite passes logged by the Healy's Terascan . Directories are identified by Year, Month, Day |

Meta_Data:

| | |
|------------------------|---|
| /elog | Contains the technical support staff narrative of important events, which occurred both to the network and to individual sensors. |
| /Bridge_Logs | |
| DDMMMYY.doc | The "smooth log" containing events recorded by the bridge watch. |
| DDMMMYYWX.xls | Weather log recorded by the watch. |
| DDMMMYYNAV.xls | Navigation logs recorded by the watch. |
| /Sensor_Formats | Contains html and PDF files documenting the formats of all the files collected under way during the cruise. |
| ./Systems_Calibrations | All of the calibrations sheets for the underway instruments are here. |
| ./WHOisWHO | The directory has information about contacts for the Science personnel on this cruise. |

SVP:

Sound speed profiles used for the Seabeam

Plots:

- ./knudsen_hourly_plots: Directories of the SIOSEIS plots of the Knudsen 3.5 kHz data are in directories named by year, month, and day. These images are in the png format. There are two plots for each window in time. One is a large sized plot and one is a smaller plot. The files start 10 minutes before the file name and 10 minutes after the hour the file is named for.
- ./surface_daily_plots Directories containing daily plots of under way data.

Contents by directory:

SCS Data:

aft_a_frame
 air_temp_f
 ashtech_attitude
 ashtech_gga
 ashtech_gll
 ashtech_hdt
 dew_point_f
 flomet_a
 fluro_a
 glonass_gga
 glonass_gll
 gyro_mk27
 gyro_mk39
 ibs_waypoints
 isus
 knudsen
 met3a_sen
 oxygen_a
 pcode_aft_gga
 pcode_aft_gll
 pcode_aft_vtg
 pcode_aft_zda
 pcode_bridge_gga
 pcode_bridge_gll
 pcode_bridge_vtg
 posmv_gga
 posmv_gst
 posmv_hdt
 posmv_pashr
 posmv_vtg
 posmv_zda
 rmyoung_air
 rmyportwind

rmystbdwind
 samos_data
 seabeam_center
 solar_radiometers
 sperry_speedlog
 stbd_a_frame
 surface_par
 surface_temp
 sv2000
 true_wind_port
 true_wind_stbd
 tsg_a
 wind_sen_a
 wind_sen_b

Raw:

adcp150
 adcp75
 ctd
 knudsenraw
 xbt

Satellite Images:

dmsp
 hrpt
LDS Data:
 AloftConnCam
 FantailCam
 SwapPingHLY
 SwapRoute
 SwapStatsHLY
 SwapStatsLSL

adu5
 aggps
 ais
 bgm221

bgm222
 events
 mk27
 mk30
 posatt
 posnav
 posreform2sb
 sbctr
 sbsv
 seabeam
 tsg_met

Meta Data:

Bridge_Logs
 Systems_Calibration_Data
 Elog
 WHOisWHO
 Sensor_Formats

Plots:

Knudsen_hourly_plots
 Surface_daily_plots

SVP:

1 Minute Averaged Data:

Merged Data

LDEO Averaged One Minute Data File

The data are summarized into an averaged one (1) minute data file by the LDEO technician. This file takes the average value centered around the minute, (30 seconds either side of the whole minute). The averages are calculated from the raw values as they are logged. There has been no quality control done on these files prior to the averaging. Those wishing more accurate and quality controlled values should process the data in the directories described below in the document.

HLY0806_track.csv

```
16945,2008/09/17 02:56,79.4979640,-140.5858535,108.9,3.4,115.4,3786.4,-1.313,-
0.801,21.6495,26.034,0.474,0.047,0.000,0.010,2.77,11.98,320.65,271.60,271.58,34.78,-
1.82,98.20,1019.26,5.01,143.96,4.36,267.71,5.94,129.06,4.07,258.55,5.46,7.350,-0.801,,,1,-20,8,0,1,-
20,8,0,11.91,263.1,8.72,1.37
16946,2008/09/17 02:57,79.4976388,-140.5811450,112.1,3.3,119.0,3785.6,-1.311,-
0.802,21.6451,26.029,0.482,0.048,0.000,0.010,2.77,11.98,320.57,271.60,271.58,34.78,-
1.82,98.20,1019.23,5.02,144.36,5.54,270.33,7.07,121.20,3.88,255.88,5.10,7.352,-0.802,,,1,-20,8,0,1,-
20,8,0,12.46,259.4,8.72,1.36
16947,2008/09/17 02:58,79.4972918,-140.5765272,112.7,3.3,119.3,3781.4,-1.310,-
0.803,21.6409,26.024,0.478,0.048,0.000,0.010,2.77,11.98,320.64,271.59,271.57,34.34,-
1.83,98.18,1019.20,5.02,148.16,5.97,272.92,7.51,132.40,4.11,264.42,5.51,7.352,-0.803,,,1,-20,8,0,1,-
20,8,0,13.82,265.1,8.72,1.36
```

| <i>Field</i> | <i>Data</i> | <i>Example</i> | <i>Units</i> |
|--------------|-------------|------------------|---|
| 01 | ID | 16945 | sample count |
| 02 | date | 2008/09/17 02:56 | date & time UTC (year/month/day hour:minute) |
| 03 | lat | 79.4979640 | \$INGGA, POSMV Latitude (decimal degrees) |
| 04 | lon | -140.5858535 | \$INGGA, POSMV Longitude (decimal degrees) |
| 05 | cog | 108.9 | \$INVTG, POSMV Course Over Ground (angular distance from 0 (North) clockwise through 360, 1 minute average) |
| 06 | sog | 3.4 | \$INVTG, POSMV Speed Over Ground (Knots, 1 minute average) |
| 07 | heading | 115.4 | \$PASHR, POSMV ship heading(angular distance from 0 (North) clockwise through 360, 1 minute average) |
| 08 | depth | 3786.4 | \$SBCTR, Seabeam centerbeam depth(meters, 1 minute average) |
| 09 | SST | -1.313 | \$PSSTA, SBE3s RemoteTemperature, Sea Chest intake (Celsius, 1 minute average) |
| 10 | TSG_InTemp | -0.801 | \$PSTSA, SBE45 internal temperature (Celsius, 1 minute average) |
| 11 | TSG_Cond | 21.6495 | \$PSTSA, SBE45 Water Conductivity (millisiemens/centimeter, 1 minute average) |
| 12 | TSG_Sal | 26.034 | \$PSTSA, SBE45 Water Salinity (PSU, 1 minute average) |
| 13 | SCF-FL | 0.474 | \$PSFLA, SCF Fluorometer (Ug/l, 1 minute average) |
| 14 | SCF-FL-V | 0.047 | \$PSFLA, SCF Fluorometer (Volts, 1 minute average) |
| 15 | SCF-Turb | 0.000 | \$PSFLA, SCF Turbidity (NTU, 1 minute average) |
| 16 | SCF-Turb-V | 0.010 | \$PSFLA, SCF Turbidity (Volts, 1 minute average) |

HLY0806 Data Synopsis

| Field | Data | Example | Units |
|--------------|--------------|----------------|--|
| 17 | tsg_flow_A | 2.77 | \$PSFMA, Flowmeter in-line with PSTSGA, PSOXA, PSFLA (LitersPerMinute, minimum value in 1 minute interval) |
| 18 | SWR | 11.98 | \$PSSRA, Short Wave Radiation (W/M ² , 1 minute average) |
| 19 | LWR | 320.65 | \$PSSRA, Long Wave Radiation (W/M ² , 1 minute average) |
| 20 | LWR_Dome_T | 271.60 | \$PSSRA, LWD Dome Temperature (Deg K, 1 minute average) |
| 21 | LWR_Body_T | 271.58 | \$PSSRA, LWD Body Temperature (Deg K, 1 minute average) |
| 22 | PAR | 34.78 | \$PSSPA, Surface PAR (uE/Sec/M ² , 1 minute average) |
| 23 | MET3A_Temp | -1.82 | \$PSMEA, MET3A Air Temperature (Deg C, 1 minute average) |
| 24 | MET3A_RH | 98.20 | \$PSMEA, MET3A Relative Humidity (% , 1 minute average) |
| 25 | MET3A_Baro | 1019.26 | \$PSMEA, MET3A Barometric Pressure (millibars, 1 minute average) |
| 26 | MET3A_Precip | 5.01 | \$PSMEA, MET3A Precipitation (mm, 1 minute average) |
| 27 | JS_WndDirR | 143.96 | \$PSWDA, Jackstaff Relative wind direction (deg, 1 minute average) |
| 28 | JS_WndSpdR | 4.36 | \$PSWDA, Jackstaff Relative wind speed (m/s, 1 minute average) |
| 29 | JS_WndDirT | 267.71 | \$PSWDA, Jackstaff True wind direction (deg, 1 minute average) |
| 30 | JS_WndSpdT | 5.94 | \$PSWDA, Jackstaff True wind speed (m/s, 1 minute average) |
| 31 | MM_WndDirR | 129.06 | \$PSWDB, Main Mast Relative wind direction (deg, 1 minute average) |
| 32 | MM_WndSpdR | 4.07 | \$PSWDB, Main Mast Relative wind speed (m/s, 1 minute average) |
| 33 | MM_WndDirT | 258.55 | \$PSWDB, Main Mast True wind direction (deg, 1 minute average) |
| 34 | MM_WndSpdT | 5.46 | \$PSWDB, Main Mast True wind speed (m/s, 1 minute average) |
| 35 | SBE_Oxy | 7.350 | \$PSOXA, SBE-43 Oxygen(ml/l, 1 minute average) |
| 36 | SBE_Oxy_T | -0.801 | \$PSOXA, SBE-43 Oxygen Temperature(Deg C, 1 minute average) |
| 37 | Isus_1 | | \$PSNTA, Isus Aux 1(Volts, 1 minute average) |
| 38 | Isus_2 | | \$PSNTA, Isus Aux 2(Volts, 1 minute average) |
| 39 | WinchAft | 1 | Aft A-Frame Winch number |
| 40 | TensionAft | -20 | Aft A-Frame Winch Wire tension(Pounds, 1 minute average) |
| 41 | WireOutAft | 8 | Aft A-Frame Winch Wire out (Meters, 1 minute average) |
| 42 | SpeedAft | 0 | Aft A-Frame Winch Wire speed (Meters/minute, 1 minute average) |
| 43 | WinchSbd | 1 | Starboard A-Frame Winch number |
| 44 | TensionSbd | -20 | Starboard A-Frame Winch Wire tension (Pounds, 1 minute average) |
| 45 | WireOutSbd | 8 | Starboard A-Frame Winch Wire out (Meters, 1 minute average) |
| 46 | SpeedSbd | 0 | Starboard A-Frame Winch Wire speed (Meters/minute, 1 |

| <i>Field</i> | <i>Data</i> | <i>Example</i> | <i>Units</i> |
|--------------|-------------|----------------|---|
| | | | minute average) |
| 47 | StbdWndSpdT | 11.91 | RM Young True Wind Speed, starboard (Knots, 1 minute average) |
| 48 | StbdWndDirT | 263.1 | RM Young True Wind Direction, starboard (angular distance from 0 (North) clockwise through 360, 1 minute average) |
| 49 | OxySat | 8.72 | Dissolved oxygen (DO) saturation as a function of T and S (Weiss)(ml/L, 1 minute average) |
| 50 | AOU | 1.37 | Apparent Oxygen Utilization (AOU)(ml/L, 1 minute average) |

File Formats of Data Collected Underway

The formats of the Under way data files that were collected on this cruise are in a separate document named HLY0806_Sensors. This is now a separate document due to its large size. The file HLY0806_Sensors.htm is found in the Meta_Data directory. A PDF version of this file should also be here. To use this html file you will need to have the directory HLY0806_Sensors_files in the same directory as the html file.

Also in the Meta_Data directory there may be some PDF files for data that was collected but not part of the normal science routine.

APPENDIX:

Acquisition Problems and Events

A electronic logbook (elog) is utilized on the ship for logging of science related problems and events as they happen. A dump of the logbook is done at the end of the cruise and saved in the Meta_Data directory under the “elog” subdirectory. Two logbooks are kept: one by the technical support personnel and one of entries by the science party watchstanders. Several dump formats are made available such as html, csv, xml and raw. These logs should be consulted to help identify instrument and system anomalies affecting data quality. Times are reported in GMT (UTC, Z).

Below here is a summary of technical logbook. For exact details you should check the files in elog. The science watchstanders log is not summarized here.

HLY0806 Data Synopsis

| <i>Date</i> | <i>Time (UTC)</i> | <i>Comment</i> |
|-------------|-----------------------|---|
| 09/05/08 | 09:17 | Start Knudsen for HLY0806 |
| 09/06/08 | 04:00 | Start SeaBeam for HLY0806 |
| 09/06/08 | 16:21 | Start ADCP 150 for HLY0806 |
| 09/07/08 | 00:30 | Start ADCP 75 for HLY0806 |
| 09/07/08 | 21:09 | Adjust flow rate for Science Seawater |
| 09/08/08 | 20:17 | Load codes into P-Code GPS |
| 09/09/08 | 06:20 | Note at about 10Z 9/8/8 the Jack Staff and Yard Arm Ultrasonics rime iced |
| 09/09/08 | 17:21 | WDS system configured to encrypted mode |
| 09/13/08 | 02:38 | Port side Ship's wind bird frozen for the last few days |
| 09/13/08 | 02:45 | Ship to ship SWAP came up today |
| 09/13/08 | 05:22 | SeaBeam stopped ½ hour ago, investigating |
| 09/13/08 | 05:55 | SeaBeam running again with new MO disk |
| 09/18/08 | 03:27 | Gravimeter 221 failed around 00:00 UTC |
| 09/18/08 | 11:03 | Around 01:30Z the winds sensors look like they are mostly working again |
| 09/18/08 | 23:05 | Attempt Gravimeter 221 restart 15 minutes ago |
| 09/19/08 | 21:38 | ice in Biochem sink, TSG flow clogged. MST water flow tests |
| 09/19/08 | 23:58 | TSG flow rate at about 2.5 l/m |
| 09/20/08 | 03:29 | TSG was getting various tests with water flowing on the bow (see notes) |
| 09/22/08 | 07:07 | on 9/21 at 21:04Z ADCP 75 was secured to get cleaner 150 data. |
| 09/22/08 | 07:14 | ADCP 150 gyro input locked |
| 09/22/08 | 07:40 | ADCP 150 gyro reset |
| 09/22/08 | 12:45 | SCS display adjusted. SCS restarted?? |
| 09/22/08 | 15:10 | ADU5 Attitude stopped at about 18Z on 9/19 |
| 09/22/08 | 16:35 | ADU5 Attitude reset |
| 09/23/08 | 07:04 | ADCP 150 gyro input locked |
| 09/23/08 | 07:16 | ADCP 150 reset |
| 09/25/08 | 03:33 | Gravimeter roll gyro replaced and restarted |
| 09/25/08 | 16:47 | Saltwater flow adjusted |
| 09/25/08 | 16:57 | Earlier Gyro MK27 failed. Reset and up again |
| 09/25/08 | 19:35 | Various TSG tests conducted over the day |
| 09/28/08 | 00:16 | Maybe a restart of some SeaBeam serial console windows? |
| 09/28/08 | 09:02 | AU5 heading stopped at 21:00Z the previous day, contact ECC |
| 09/28/08 | 09:11 | AU5 reset heading working again |
| 09/29/08 | 07:52 | SeaVenture crashed. Links to other computers re-established |
| 09/29/08 | 21:20 | VMS was taken down without notice. SeaBeam time thrown off. |
| 10/01/08 | 05:46 | ADCP 150 stopped. End of HLY0806 data. |
| 10/01/08 | 05:47 | ADCP 75 stopped. End of HLY0806 data. |
| 10/01/08 | 05:51 | Knudsen stopped. End of HLY0806 data. |
| 10/01/08 | 06:02 | SCS recording stopped. End of HLY0806 data. |
| 10/01/08 | 06:07 | LDS recording stopped. End of HLY0806 data. |

Comments that might help when using the data

The SCS system has to be stopped when fixing some kinds of issues. If this is the case, you should consult the elog entries for possible explanations and look for the corresponding data in the LDS_Data directories. The data may have been recorded there.

The Knudsen data written into SCS_Data/Knudsen has an inconsistent time in the data. The time that the SCS writes to the start of the KEA file should be used. The Knudsen internal clock adds about 22.8 seconds to the internal clock each day near 00:00. But this is reset when the recording program is started up and when watchstanders manually synchronize the time. Use only the SCS time stamp for time in this data and it should be fine. The accuracy of the time in the SEG-Y files and KEB files should be inspected and compared to the time-stamped KEA records.

The SeaBeam data is raw and unedited. This data may need significant editing and care depending on the intended use. The SeaBeam 2112 has significant issues with the near-nadir beams: the bathymetry tends to be less repeatable in the near-nadir region compared to the middle of the swath. The outer beams are noisier in the icebreaker 2112 installations than those installed on non-icebreakers.. The acoustic noise plus bubble-sweep down and masking by ice under the hull all contribute to degrading the data quality while operating in ice.

The Knudsen subbottom data is not an accurate source of water depth for a number of reasons, including the fact that it is always recorded using a sound speed of 1500 meters/second., because the beam pattern is large (3- to 60 degrees), because of its bottom detection algorithm and because it penetrates the seafloor.

Both the mechanical windbirds and the ultrasonic anemometers spent much of the trip iced up. Care should be taken when using the data from the wind sensors. Although the ultrasonic anemometers are heated, it seems like there amount of heat was not up to the task.

Part way into the cruise the Gravimeter #221 failed. This was fixed and the meter was restarted. There is a difference in offset of the raw counts compared to the #222 Gravimeter after the restart. Care should be taken when using this data until calibrations have been completed.

During the cruise at various times the MSTs were changing the water flow in the Science Sea Water system to test the system's response to various flow rates in the ice. This changes the amount of water going through the TSG and has discernable impact on the dissolved oxygen measurement among other things. You should closely follow the elog entries for the TSG to see when water flow rates were adjusted. These events were not always accurately entered into elog.

In the SVP directory are the sound speed profiles used for the SeaBeam. These are constructed from various sources including XBTs, historical data (the Levitus climatology), CTDs and from the XCTDs deployed from LSSL. These files were created from the full XCTD data, which is proprietary. The Sound Speed Profiles used are entered into the SeaBeam. When the MO crashes, the SVP's used are not preserved and need to be transferred to the new MO disk. The SVP directory has many of the SVPs used but not all of them.

HLY0806 Data Synopsis

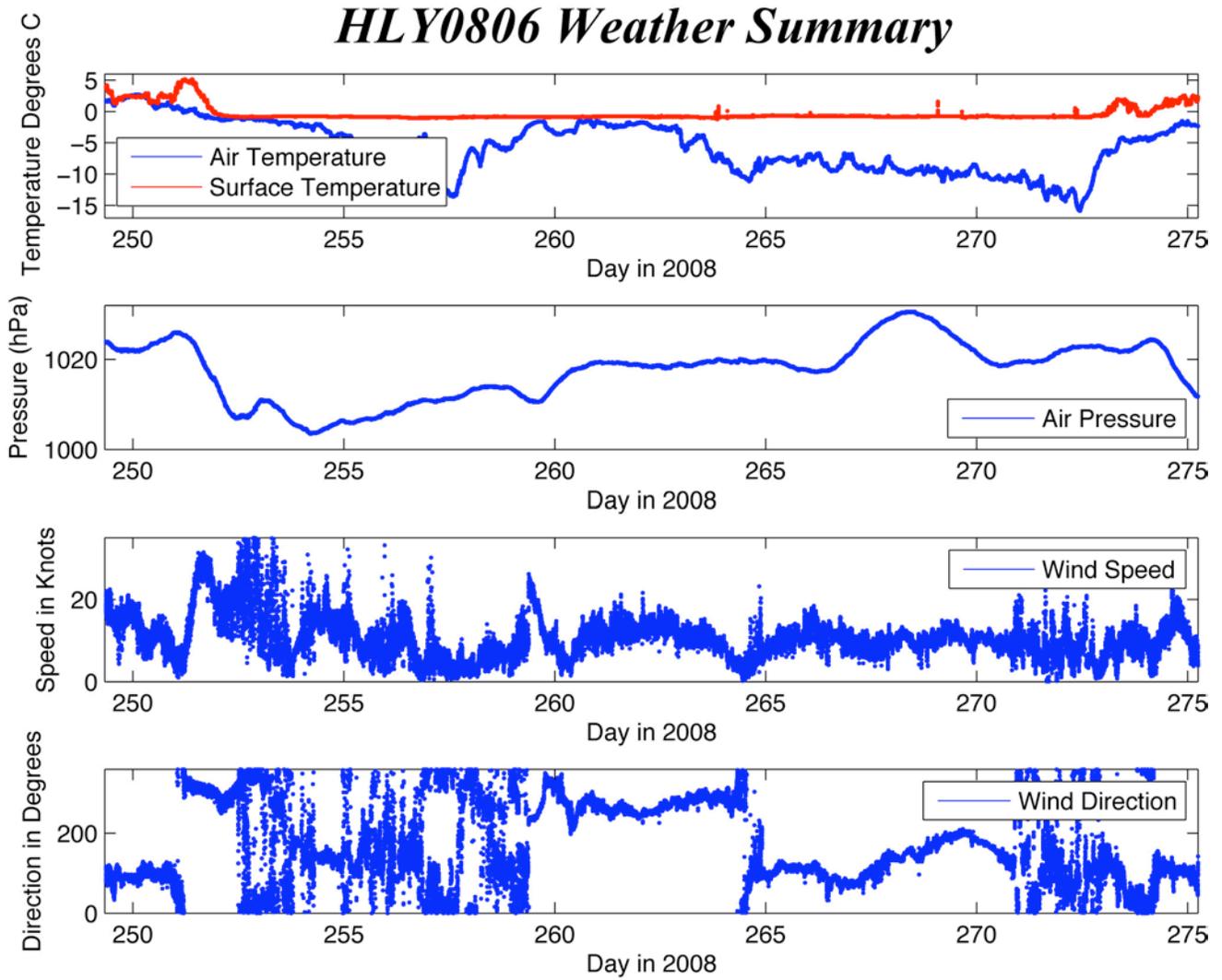
The ADCP file naming uses a series number after a base name. Below is a summary of the dates and the series numbers used for this cruise for each ADCP. Details of events that affect the ADCP data recording were logged in both the Technicians' and the Watch Standers' electronic logs for **HLY0806**.

ADCP Operational summary:

| <i>150Khz Broadband</i> | | <i>75KHz Narrowband</i> | |
|---|---------------|---|---------------|
| HLY0806001* | 09/06 - 09/16 | HLY0806001* | 09/06 - 09/21 |
| tests | | | |
| HLY0806002-4* | 09/16 | | |
| | | turned off to check interference on 150 | 09/21 |
| New configuration w/ low exclusion thresholds | | | |
| HLY0806005* | 09/16 - 09/24 | | |
| System hung, had to restart | | | |
| HLY0806006* | 09/24 - 09/28 | | |
| | | turned back on | |
| | | HLY0806002* | 09/26 - |
| Trouble restarting, several tries to start | | | |
| HLY0806007-11* | 09/28 - | | |

The POSMV navigation system reports it's location as the master reference point and not at the antenna locations above the Helicopter Control Shack (HCO). The Location of the Master Reference Point (MRP) can be seen in the diagram at the end of this document showing instrument locations on the ship.

Cruise Weather Summary



Underway Sensors and Calibrations

Sensors and Calibrations

HLY0806 Shipboard Sensors

| Sensor | Description | Serial # | Last Calibration Date | Status |
|--|----------------------|-------------|-----------------------|-----------|
| Meteorology & Radiometers | | | | |
| Port Anemometer | RM Young 09101 | L001 | 02/06/07 | Collected |
| Stbd Anemometer | RM Young 09101 | L003 | 03/07/07 | Collected |
| Barometer | RM Young 612011 | BP01643 | 02/22/08 | Collected |
| Air Temp/Rel. Hum. | RM Young 41382V | 13352 | 02/22/08 | Collected |
| Helo shack PAR | BSI QSR-2200 | 20270 | 01/09/07 | Collected |
| Shortwave Radiation | Eppley labs - PSP | 35032F3 | 08/01/07 | Collected |
| Longwave Radiation | Eppley labs - PIR | 34955F3 | 08/17/07 | Collected |
| Barometer | Paroscientific MET3A | 101757 | 06/27/07 | Collected |
| Bow Temperature | Paroscientific MET3A | 101757 | 06/27/07 | Collected |
| Precipitation | Paroscientific MET3A | 101757 | 06/27/07 | Collected |
| Relative Humidity | Paroscientific MET3A | 101757 | 06/27/07 | Collected |
| Jack Staff Ultrasonic Anemometer | RM Young 85004 | 00703 | 09/20/07 | Collected |
| Yard Arm Stb Ultrasonic Anemometer | RM Young 85004 | 00704 | 09/20/07 | Collected |
| Underway Ocean | | | | |
| TSG A | SeaBird SBE45 | 0215 | 08/01/07 | Collected |
| Remote Sea Temp | SeaBird SBE3S | 4063 | 12/13/07 | Collected |
| Fluorometer A | Seapoint SCF | SCF2957 | 12/15/07 | Collected |
| Oxygen Sensor A | SeaBird SBE-43 | 1307 | 09/28/07 | Collected |
| Flowmeter A | Flocat C-ES45-B003 | 09061005 | 01/07/08 | Collected |
| AC-S Spectral Attenuation and Absorption Meter | Wetlabs | 053 | 010/10/8 | Collected |
| Sonars | | | | |
| Knudsen- subbottom | 320 B/R | K2K-00-0013 | N/A | Collected |
| ADCP 150 kHz | Broad Band (BB150) | 80 | N/A | Collected |

HLY0806 Data Synopsis

| Sensor | Description | Serial # | Last Calibration Date | Status |
|-------------------|--|-----------------|-----------------------|-----------|
| ADCP 75 kHz | Ocean Surveyor | 172 | N/A | Collected |
| Multibeam | Seabeam 2112 | ? | N/A | Collected |
| Speed log | Sperry | ? | N/A | Collected |
| Navigation | | | | |
| P-Code GPS (aft) | Trimble Centurion | 0220035469 | N/A | Collected |
| Attitude GPS | Ashtech ADU5 | AD52003351 3 | N/A | Collected |
| DGPS | Trimble AGGPS- AG132 | 0224016199 | N/A | Collected |
| POSMV | Model- MV V4 | 2306 | N/A | Collected |
| P-Code GPS (fwd) | Rockwell | ? | N/A | Collected |
| Glonass GPS | ? | ? | N/A | Collected |
| GYRO 1 | Sperry MK39 Mod 3A PN 03956-1982416-2 | 340 | ? | Collected |
| GYRO 2 | Sperry MK27A 4800880-1 | 025 | N/A | Collected |

HLY0806- CTD Sensors

| Sensor | Comments | Serial # | Last service/ Calibration Date | Status |
|--------------------|----------------------|-----------------|---|---------------|
| CTD sensor | SBE 911plus | 639 | 01/18/08 | |
| Pressure Sensor #1 | Digiquartz with TC | 83012 | 01/18/08 | Collected |
| Temperature #1 | SBE3- Primary | 2855 | 01/21/08 | Collected |
| Temperature #2 | SBE3- Secondary | 2796 | 01/27/08 | Collected |
| Temperature #3 | SBE 35 | 0011 | 03/08 | Collected |
| Conductivity #1 | SBE4- Primary | 2568 | 01/18/08 | Collected |
| Conductivity #2 | SBE4- Secondary | 2561 | 01/18/08 | Collected |
| Pump | SBE5 Primary | 3115 | 01/08 | NA |
| Pump | SBE5 Secondary | 3112 | 01/08 | NA |
| Deck Unit | SBE 11-Plus V2 | 0417 | 12/07 | NA |
| Altimeter | PSA916 | 843 | 01/08 | Collected |
| Oxygen | SBE43 | 458 | 12/12/07 | Collected |
| Fluorometer | Chelsea-Aquatrack3 | 088234 | 03/07 | Collected |
| Transmisometer | Wetlabs | CST-390DR | 01/08 | Collected |
| PAR | Biospherical QSP2300 | 70115 | 01/07 | Collected |
| Carousel | SBE32- 12 place | 347 | 01/08 | NA |

HLY0806 Sensor Calculations

The coefficients for temperature, conductivity, fluorometer and turbidity sensors can be found in the calibrations sheets below in the Appendix.

Calculating Temperature – ITS-90

- T = decimal equivalent of bytes 1-4
- Temperature Frequency: $f = T/19 + 2100$
- Temperature = $1/\{g + h[\ln(f_0/f)] + i[\ln^2(f_0/f)] + j[\ln^3(f_0/f)]\} - 273.15$ (°C)

Calculating Conductivity – ITS-90

- C = decimal equivalent of bytes 5-8
- Conductivity Frequency $f = \sqrt{C*2100+6250000}$
- Conductivity = $(g + hf^2 + if^3 + jf^4)/[10(1 + \delta t + \epsilon p)]$ (siemens/meter)
- t = temperature (°C); p = pressure (decibars); $\delta = Ct_{cor}$; $\epsilon = CP_{cor}$

Calculating Fluorometry Voltage

- f = decimal equivalent of bytes 15-17
- Fluorometry Voltage = $f/819$

Calculating Transmittance

- $V_{dark} = 0.058$ V
- $V_{ref} = 4.765$ V
- t = decimal equivalent of bytes 18 - 20
- Transmittometer Voltage (V_{signal}) = $t/819$
- % Transmittance = $(V_{signal} - V_{dark}) / (V_{ref} - V_{dark})$

Calculating PAR for surface PAR

- raw data = mV
- calibration scale = 6.08 V/(μ Einstiens/cm²sec)
- offset (V_{dark}) = 0.3 mV
- $(raw\ mV - V_{dark})/scale \times 10^4\ cm^2/m^2 \times 10^{-3}\ V/mV = \mu$ Einstiens/m²sec
- or
- $(data\ mV - 0.3\ mV) \times 1.65\ (\mu$ Einstiens/m²sec)/mV = μ Einstiens/m²sec

Calculating Pyrgometer Values

V = Eppley PIR Thermopile voltage

S = Sensitivity (Calibration factor from Eppley Cal sheet)

S = 3.32

J = Stefan-Boltzmann Constant

J = 5.6697e-8

B = [absorption constant (for Eppley Black paint formula) 0.985 / dome glass IR transmission 0.5]

B= 3.5 for Stock Eppley PIR

Tb = Eppley Body Temperature in degrees Kelvin

Td = Eppley Dome Temperature in degrees Kelvin

Tb and Td calculated as follows:

$$T = 1 / (a + \ln(Vo/Irt) * (b + c * (\ln(Vo/Irt) ** 2)));$$

$$Irt = (Vref-Vin)/R1$$

On Healy R1 = 82500

Vref = 5.0

a= 0.0010295

b= 0.0002391

c = 1.568e-7

$$W/M2 = V/S + (J * Tb^4) + (B*J*(Tb^4 - Td^4))$$

Calibrations

The following pages are replicas of current calibration sheets for the sensors used during this cruise.

Meteorology & Radiometers

R.M. Young Wind Bird, Starboard

Serial # L001

R. M. Young Wind bird Calibration Results
Model # 09101, S/N L003 (Starboard Windbird)
 As per Young Meteorological Instruments
 Wind System Calibration Manual

Date: 07 Mar 07 Technician: ET1 Berringer / ETC Rodda

Wind speed torque: Passed

Maximum torque = 2.4 gm/cm

Test results:

CW 0.7
 CCW 0.7

Wind direction torque: Passed

Maximum torque = 30 gm/cm

Test results:

CW 20 gm/cm
 CCW 22 gm/cm

Wind speed signal:

Maximum % error = 1%

Test results: **Passed**

| Actual RPM | Actual Wind Speed | Measured | % Error |
|------------|-------------------|----------|---------|
| 200 | 1.90 | 1.9 | 0.21 |
| 500 | 4.76 | 4.8 | 0.84 |
| 1200 | 11.42 | 11.4 | 0.21 |
| 3600 | 34.27 | 34.3 | 0.08 |
| 5000 | 47.60 | 47.6 | 0.00 |

Note: Wind speed in knots = 0.00952 * shaft RPM

Wind direction signal:

Maximum error = +/- 2 degrees

Test results: **Failed – off by 1 degree**

| Actual | Measured | Error |
|--------|----------|-------|
| 0 | 358 | -2 |
| 30 | 27 | 3 |
| 60 | 58 | 2 |
| 90 | 88 | 2 |
| 120 | 118 | 2 |
| 150 | 149 | 1 |
| 180 | 178 | 2 |
| 210 | 207 | 3 |
| 240 | 238 | 2 |
| 270 | 268 | 2 |
| 300 | 297 | 3 |
| 330 | 327 | 3 |

R.M. Young Wind Bird Port

Serial # L001

R. M. Young Wind bird Calibration Results
Model # 09101, S/N L001 (Port Windbird)

As per Young Meteorological Instruments
 Wind System Calibration Manual

Date: 06 Feb 07

Technician: ET3 Daem / ET2 Davis

Wind speed torque: Passed

Maximum torque = 2.40 gm/cm

Test results:

CW .2 gm/cm
 CCW .2 gm/cm

Wind direction torque: Passed

Maximum torque = 30 gm/cm

Test results:

CW 10gm/cm
 CCW 10gm/cm

Wind speed signal: Passed

Maximum % error = 1%

Test results:

| Actual RPM | Actual Wind Speed | Measured | % Error |
|------------|-------------------|----------|---------|
| 200 | 1.90 | 1.9 | 0.21 |
| 500 | 4.76 | 4.8 | 0.84 |
| 1200 | 11.42 | 11.4 | 0.21 |
| 3600 | 34.27 | 34.3 | 0.08 |
| 5000 | 47.60 | 47.6 | 0.00 |

Note; Wind speed in knots = 0.00952 * shaft RPM

Wind direction signal: Passed

Maximum error = +/- 2 degrees

Test results:

| Actual | Measured | Error |
|--------|----------|-------|
| 0 | 359 | -1 |
| 30 | 29 | 1 |
| 60 | 59 | 1 |
| 90 | 90 | 0 |
| 120 | 120 | 0 |
| 150 | 150 | 0 |
| 180 | 180 | 0 |
| 210 | 210 | 0 |
| 240 | 240 | 0 |
| 270 | 269 | 1 |
| 300 | 298 | 2 |
| 330 | 330 | 0 |
| | | |
| | | |

Barometer

Serial # BP01643

**Baro Pres Calibration Report
STS/ODF Calibration Facility**

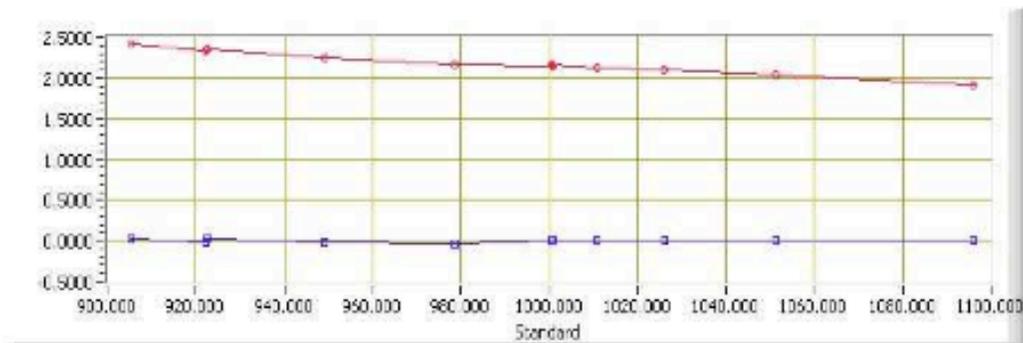
SENSOR SERIAL NUMBER: BP01643
 CALIBRATION DATE: 22-Feb-08
 SENSOR ID: BPR80
 Mfg: RM Young Model: 612011
 Previous Cal Date: 01-Jan-00
 Calibration Tech: CM
 CALIBRATION AT 25.0 DegC

A= 5.98528E+1
 B= 8.02635E+2

Calibration Standard: Mfg: Paroscientific Model: 765-16B s/n: 101778
 Polynomial Order = 1
 Xcalc = A*X+B

| SENSOR VOLTS | STANDARD DATA | SENSOR New_Coefs | SPRT-INST Prev_Coefs | SPRT-INST New_Coefs |
|--------------|---------------|------------------|----------------------|---------------------|
| 4.901 | 1095.960 | 1095.953 | 1.920 | 0.007 |
| 4.151 | 1051.090 | 1051.086 | 2.028 | 0.004 |
| 3.731 | 1025.970 | 1025.963 | 2.092 | 0.007 |
| 3.475 | 1010.640 | 1010.645 | 2.118 | -0.005 |
| 3.306 | 1000.490 | 1000.479 | 2.159 | 0.011 |
| 3.314 | 1000.990 | 1000.986 | 2.151 | 0.004 |
| 2.939 | 978.480 | 978.517 | 2.165 | -0.037 |
| 2.445 | 948.980 | 949.001 | 2.254 | -0.021 |
| 2.004 | 922.570 | 922.555 | 2.355 | 0.015 |
| 1.998 | 922.190 | 922.205 | 2.326 | -0.015 |
| 1.713 | 905.210 | 905.180 | 2.413 | 0.030 |

Previous_Coefs 
 New_Coefs 



Air Temperture / Relative Humidity

Serial # 13352

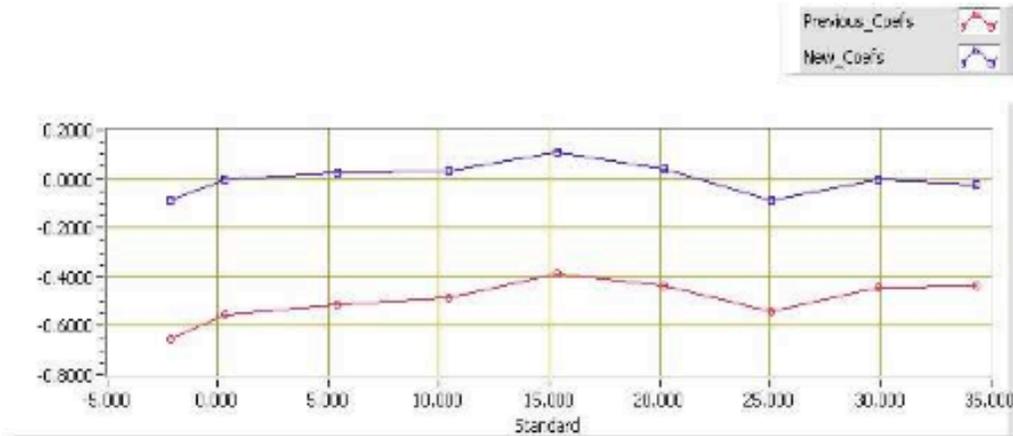
**Air Temperature Calibration Report
STS/ODF Calibration Facility**

SENSOR SERIAL NUMBER: 13352
 CALIBRATION DATE: 22-Feb-08
 SENSOR ID: HRH17
 Mfg: RM Young Model: 41382V
 Previous Cal Date: 01-Jan-2000
 Calibration Tech: CM

A= 1.01413E+2
 B= -5.07642E+1

Calibration Standard: Mfg: Seabird Model: SBE35 s/n: 0006
 Polynomial Order = 1
 Xcalc = A*X+B

| SENSOR | STANDARD DATA | SENSOR New_Coefs | SPRT-INST Prev_Coefs | SPRT-INST New_Coefs |
|--------|---------------|------------------|----------------------|---------------------|
| 0.480 | -2.122 | -2.035 | -0.652 | -0.087 |
| 0.504 | 0.337 | 0.338 | -0.557 | -0.001 |
| 0.554 | 5.421 | 5.398 | -0.513 | 0.023 |
| 0.603 | 10.448 | 10.418 | -0.485 | 0.030 |
| 0.651 | 15.345 | 15.235 | -0.386 | 0.110 |
| 0.699 | 20.190 | 20.154 | -0.439 | 0.036 |
| 0.748 | 25.029 | 25.113 | -0.539 | -0.084 |
| 0.796 | 29.914 | 29.920 | -0.442 | -0.006 |
| 0.840 | 34.361 | 34.382 | -0.439 | -0.021 |



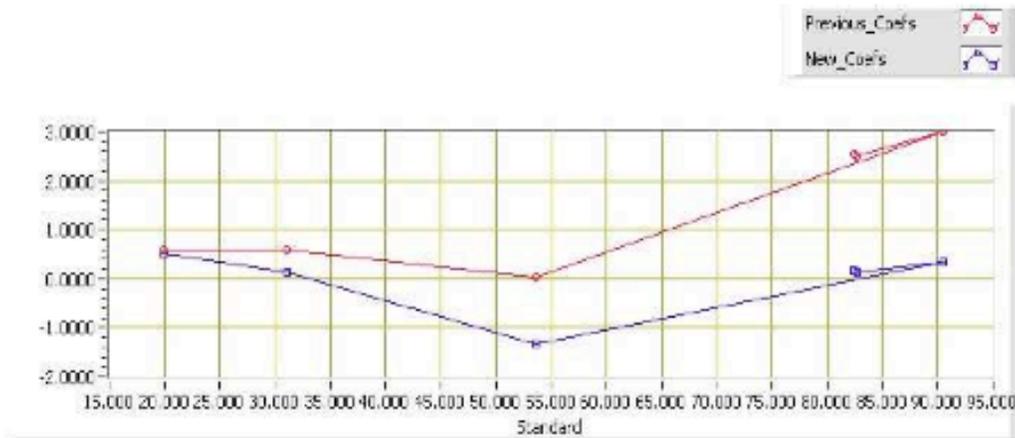
HUMIDITY Calibration Report STS/ODF Calibration Facility

SENSOR SERIAL NUMBER: 13352
CALIBRATION DATE: 24-Feb-08
SENSOR ID: HRH17
Mfg: RM Young Model: 41382V
Previous Cal Date: 01-Jan-2000
Calibration Tech: CM

A= 1.04836E+2
B= -6.79727E-1

Calibration Standard: Mfg: GE Sensing Model: Humilab s/n: 0240507
Polynomial Order = 1
Xcalc = A*X+B

| SENSOR | STANDARD DATA | SENSOR New_Coefs | SPRT-INST Prev_Coefs | SPRT-INST New_Coefs |
|--------|---------------|------------------|----------------------|---------------------|
| 0.791 | 82.450 | 82.266 | 2.539 | 0.184 |
| 0.794 | 82.710 | 82.560 | 2.516 | 0.150 |
| 0.866 | 90.460 | 90.108 | 2.994 | 0.352 |
| 0.530 | 53.570 | 54.904 | 0.020 | -1.334 |
| 0.301 | 31.000 | 30.876 | 0.599 | 0.124 |
| 0.192 | 19.920 | 19.396 | 0.579 | 0.524 |



PAR

Serial # 20270

Biospherical Instruments Inc.

CALIBRATION CERTIFICATE

Calibration Date 1/9/2007
 Model Number QSR-2200
 Serial Number 20270
 Operator TPC
 Standard Lamp F-863
 Probe Excitation Voltage Range: 6 to 18 VDC(+)
 Output Polarity: Positive

Probe Conditions at Calibration(in air):

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

Probe Output Voltage:

Probe Illuminated 95.87 mV
 Probe Dark 1.32 mV
 Probe Net Response 94.55 mV

Corrected Lamp Output:

Output In Air (same condition as calibration):

9.43E+15 quanta/cm²sec
0.01566 uE/cm²sec

Calibration Factor:

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

Dry: 1.00E-17 V/(quanta/cm²sec)
6.04E+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.

Shortwave Radiation Pyranometer

Serial # 35032F3

THE EPPLEY LABORATORY, INC.
 12 Sheffield Ave., P.O. Box 419, Newport, RI 02840 USA
 Telephone: 401-847-1020 Fax: 401-847-1031
 Email: info@eppleylab.com Internet: www.eppleylab.com

EPLAB
 Scientific Instruments
 for Precision Measurements
 Since 1917

**STANDARDIZATION OF
 EPPLEY PRECISION SPECTRAL PYRANOMETER
 Model PSP**

Serial Number: 35032F3

Resistance: 724 Ω at 23 $^{\circ}\text{C}$
 Temperature Compensation Range: -20 to 40 $^{\circ}\text{C}$

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:

8.35×10^{-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 $\pm 0.5\%$ 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/ft²-hr⁻¹ = 3.153 watts meter⁻²

Shipped to: UCSD/SIO
 La Jolla, CA

S.O. Number: 61245
 Date: August 1, 2007

Date of Test: July 5, 2007
 In Charge of Test: *R.T. Egan*
 Reviewed by: *Thomas D. Kuhl*

Remarks:

Longwave Radiation Pyrgeometer

Serial # 34955F3

THE EPPLEY LABORATORY, INC.

12 Sheffield Ave., P.O. Box 419, Newport, RI 02840 USA

Telephone: 401-847-1020

Fax: 401-847-1031

Email: info@eppleylab.com

Internet: www.eppleylab.com



Scientific Instruments
for Precision Measurements
Since 1917

**STANDARDIZATION OF
EPPLEY PRECISION INFRARED RADIOMETER
Model PIR**

Serial Number: 34955F3

Resistance: 708 Ω at 23 $^{\circ}\text{C}$
Temperature Compensation Range: -20 to 40 $^{\circ}\text{C}$

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 $^{\circ}\text{C}$ 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:

$$3.32 \times 10^6 \text{ volts/watts meter}^{-2}$$

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 $\pm 1.0\%$ 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:
UCSD/SIO
La Jolla, CA

S.O. Number: 61272
Date: August 17, 2007

Date of Test: May 31, 2007

In Charge of Test: *R.T. Gjeran*
Reviewed by: *Thomas Kub*

Remarks:

Jack Staff MET Station

Serial # 101757

Paroscientific, Inc.
Pressure Instrument Configuration

SN: 101757 Part Number: 1539-004 Model: MET3A Port:
 Calibration Date: 27-Jun-07 Report No: 7238 Technician: WMR
 Pressure Range: 500 to 1100 hPa Temperature Range: -50 to -60

Customer: Scripps Inst. of Oceanography Report Date: 27-Jun-07
 Address : 8825 Biological Grade Sales Order: 24387
 La Jolla, CA 92037 USA S/R Number :

| Configuration | | Calibration Coefficients | |
|---------------|--------------|--|--|
| BL: 0 | PT: N | U0: 5.766908 μ sec | |
| BR: 9600 | QD: - | Y1: -4015.973 deg C / μ sec | |
| DD: - | QO: - | Y2: -17065.37 deg C / μ sec ² | |
| DL: - | SL: - | Y3: -140256.4 deg C / μ sec ³ | |
| DM: - | SN: 101757 | C1: 94.87589 psi | |
| DO: - | ST: - | C2: 3.545282 psi / μ sec | |
| DP: - | SU: - | C3: -114.9551 psi / μ sec ² | |
| ID: 01 | TI: - | D1: 0.0345157 | |
| IM: - | TR: 00952 | D2: 0.0000000 | |
| LL: - | TU: - | T1: 28.00064 μ sec | |
| LH: - | UF: 1.000000 | T2: 0.837535 μ sec / μ sec | |
| MC: Y | UL: - | T3: 16.78157 μ sec / μ sec ² | |
| MD: 0 | UM: - | T4: -150.7085 μ sec / μ sec ³ | |
| MN: - | UN: 3 | T5: -129.729 μ sec / μ sec ³ | |
| OP: - | US: - | TC: 0.6782145 | |
| PP: - | VR: M1.02 | PA: 0.0000000 | |
| PI: - | ZI: - | PM: 1.0000000 | |
| PL: - | ZS: - | | |
| PO: - | ZL: - | | |
| PR: 00238 | ZV: - | | |
| PS: - | | | |

Met3/3A Coefficients

| | |
|---------------|-------------|
| E1: -0.551136 | E2: 0.84 |
| F1: -264.3591 | F2: 3.152 |
| G1: 12.56743 | G2: 0.00216 |
| H1: RHT894 | H2: 0.0036 |
| K1: 01842 | K2: 0.00511 |
| M1: 1 | M2: 1 |
| Z1: 0 | Z2: 0 |

Paroscientific, Inc.
 4500 148th Ave. N.E. Redmond, WA 98052
 Phone: (425)883-8700 Fax: (425)857-5497
 Web: <http://www.paroscientific.com>
 Email: support@paroscientific.com

Prepared by



CERTIFICATE OF CALIBRATION

TRANSDUCER MODEL: MET3A

SERIAL NUMBER: 101757

The Paroscientific transducer(s) identified above has been calibrated and tested with one or more of the following primary pressure and temperature standards. All have traceability to the National Institute of Standards and Technology.

Bell and Howell Primary Pressure Standard

Pneumatic Absolute or Gauge Dead Weight Tester Part Number: 6-201-0001, S/N 4034 and S/N 1014

— Piston/Cylinder: 6-001-0002, P2-919/C2-1523,
 Weight Set 1: 6-002-0002
 Range: 1.5 to 50 psi [10 to 345 kPa]
 Accuracy: 0.010 percent of reading

✓ Piston/Cylinder: 6-001-0002, P2-652/C2-1378,
 Weight Set 2: 6-002-0002
 Range: 1.5 to 50 psi [10 to 345 kPa]
 Accuracy: 0.010 percent of reading

— Piston/Cylinder: 6-001-0001, P1-949/C1-922,
 Weight Set 2: 6-002-0002
 Range: 0.3 to 5 psi [2 to 34 kPa]
 Accuracy: 0.015 percent of reading

DH Primary Pressure Standard

Pneumatic Absolute or Gauge Dead Weight Tester Part Number: PG7601 S/N 161

— Piston/Cylinder: S/N 305, Mass Set: S/N 2052
 Range: 0.7 to 50 psi [5 to 345 kPa] absolute mode, 0.29 to 50 psi [2 to 345 kPa] gauge mode
 Accuracy: 0.002 percent of reading

DH Primary Pressure Standard

Pneumatic Gauge Dead Weight Tester, Model 5203, S/N 5557

— Piston/Cylinder: S/N 4845, Mass Sets: S/N 2032, S/N 3293
 Range: 20 to 1,600 psi [0.14 to 11 MPa]
 Accuracy: 0.005 percent of reading

DH Primary Pressure Standard

Oil Operated Gauge Dead Weight Tester, Model 5306, S/N 3505

— Piston/Cylinder: S/N 3375, Mass Set: S/N 2032
 Range: 40 to 20,000 psi [0.3 to 138 MPa]
 Accuracy: 0.01 percent of reading above 200 psi [1.4 MPa]
 or 0.02 psi [0.14 kPa] at lower pressure

— Piston/Cylinder: S/N 3511, Mass Set: S/N 2032
 Range: 145 to 72,500 psi [1 to 500 MPa]
 Accuracy: 0.02 percent of reading above 725 psi [5 MPa]
 or 0.145 psi [1 kPa] at lower pressure

Hart Scientific Precision Thermometer (MET3A only)

✓ Black Stack model 1560 S/N 97568, PRT Scanner model 2562 S/N A34523, Temperature Probe Model A1959:
 S/Ns 4424A-02, 4424A-04, 4424A-05, 4424A-06 and 5177C-02.
 Range: -50° to 60° C.
 Accuracy: .015°C.

Tested By:  DATE 6-27-07



Underway Ocean Flow through Sensors

Seabird ThermoSalinograph

Serial # 0215

Temperature

SEA-BIRD ELECTRONICS, INC.

1808 136th Place N.E., Bellevue, Washington, 98005 USA

Phone: (425) 643 - 9866 Fax (425) 643 - 9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 0215
CALIBRATION DATE: 01-Aug-07

SBE 45 TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

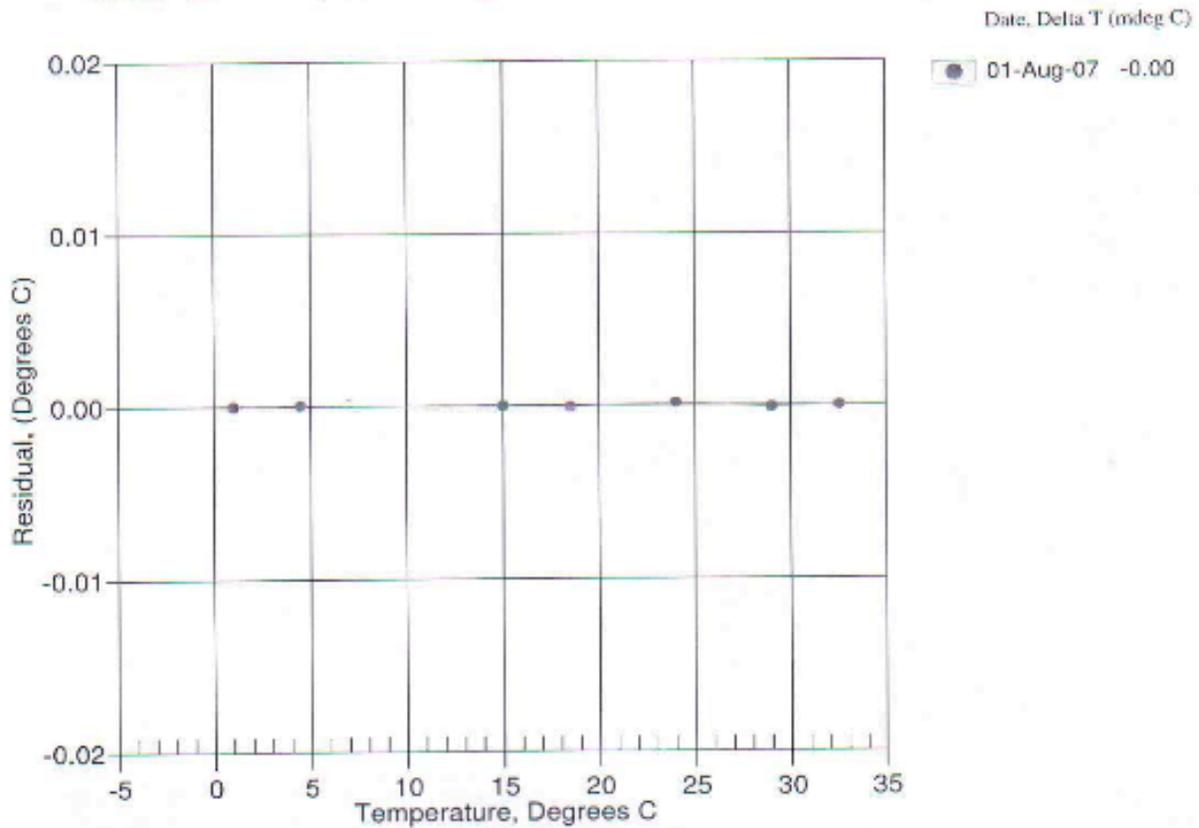
ITS-90 COEFFICIENTS

a0 = -1.277283e-006
a1 = 2.800988e-004
a2 = -2.767325e-006
a3 = 1.635307e-007

| BATH TEMP (ITS-90) | INSTRUMENT OUTPUT | INST TEMP (ITS-90) | RESIDUAL (ITS-90) |
|-----------------------|----------------------|-----------------------|----------------------|
| 1.0000 | 557610.8 | 0.9999 | -0.0001 |
| 4.5000 | 562392.5 | 4.5000 | 0.0000 |
| 15.0000 | 358334.1 | 14.9999 | -0.0000 |
| 18.5001 | 310251.4 | 18.5000 | -0.0001 |
| 24.0000 | 248855.2 | 24.0001 | 0.0002 |
| 29.0001 | 204884.7 | 29.0000 | -0.0001 |
| 32.4999 | 179404.2 | 32.5000 | 0.0000 |

Temperature ITS-90 = $1/[a_0 + a_1[n(n)] + a_2[n^2(n)] + a_3[n^3(n)]] - 273.15$ (°C)

Residual = instrument temperature - bath temperature



Conductivity

SEA-BIRD ELECTRONICS, INC.

1808 136th Place N.E., Bellevue, Washington, 98005 USA

Phone: (425) 643 - 9866 Fax (425) 643 - 9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 0215
CALIBRATION DATE: 01-Aug-07

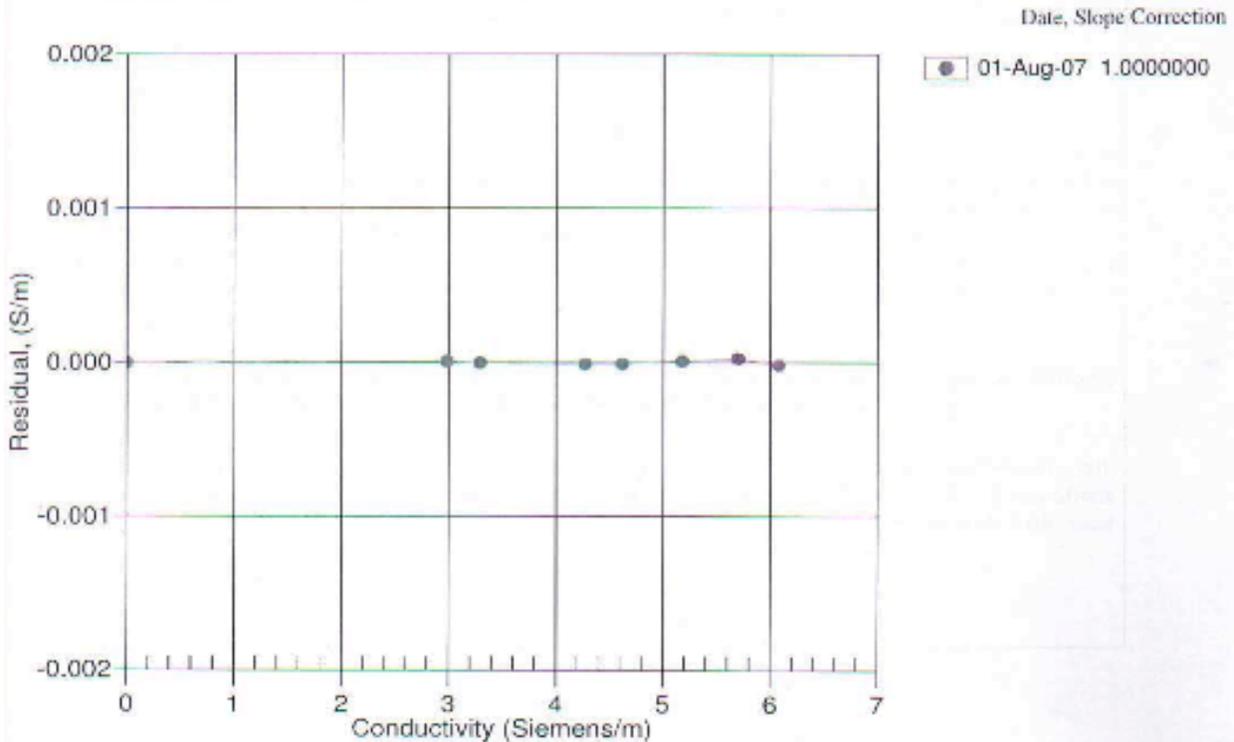
SBE 45 CONDUCTIVITY CALIBRATION DATA
PSS 1978: C(35,15,0) = 4.2914 Siemens/meter

COEFFICIENTS:

| | |
|--------------------|----------------------|
| g = -9.817728e-001 | CPcor = -9.5700e-008 |
| h = 1.408378e-001 | CTcor = 3.2500e-006 |
| i = -1.671624e-004 | WBOTC = 2.4202e-005 |
| j = 3.431539e-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 | 2641.45 | 0.00000 | 0.00000 |
| 1.0000 | 34.8934 | 2.93132 | 5303.53 | 2.98193 | 0.00001 |
| 4.5000 | 34.8731 | 3.28955 | 5504.48 | 3.28955 | -0.00000 |
| 15.0000 | 34.8297 | 4.27308 | 6101.73 | 4.27307 | -0.00001 |
| 18.5001 | 34.8207 | 4.61890 | 6297.94 | 4.61889 | -0.00001 |
| 24.0000 | 34.8111 | 5.17793 | 6602.44 | 5.17794 | 0.00001 |
| 29.0001 | 34.8062 | 5.70086 | 6874.67 | 5.70088 | 0.00002 |
| 32.4999 | 34.8046 | 6.07417 | 7062.34 | 6.07415 | -0.00002 |

f = INST FREQ * sqrt(1.0 + WBOTC * t) / 1000.0
 Conductivity = (g + hf² + if³ + jf⁴) / (1 + δt + εp) Siemens/meter
 t = temperature[°C]; p = pressure[decibars]; δ = CTcor; ε = CPcor;
 Residual = instrument conductivity - bath conductivity



Remote Sea Temperature (Sea Chest)

Serial # 4063

SEA-BIRD ELECTRONICS, INC.

1808 136th Place N.E., Bellevue, Washington, 98005 USA

Phone: (425) 643 - 9866 Fax (425) 643 - 9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 4063
CALIBRATION DATE: 13-Dec-07

SBE3 TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

ITS-90 COEFFICIENTS

g = 4.29921671e-003
h = 6.36406488e-004
i = 2.06912541e-005
j = 1.52019386e-006
f0 = 1000.0

IPTS-68 COEFFICIENTS

a = 3.68121265e-003
b = 5.99688417e-004
c = 1.61521904e-005
d = 1.52164480e-006
f0 = 2721.791

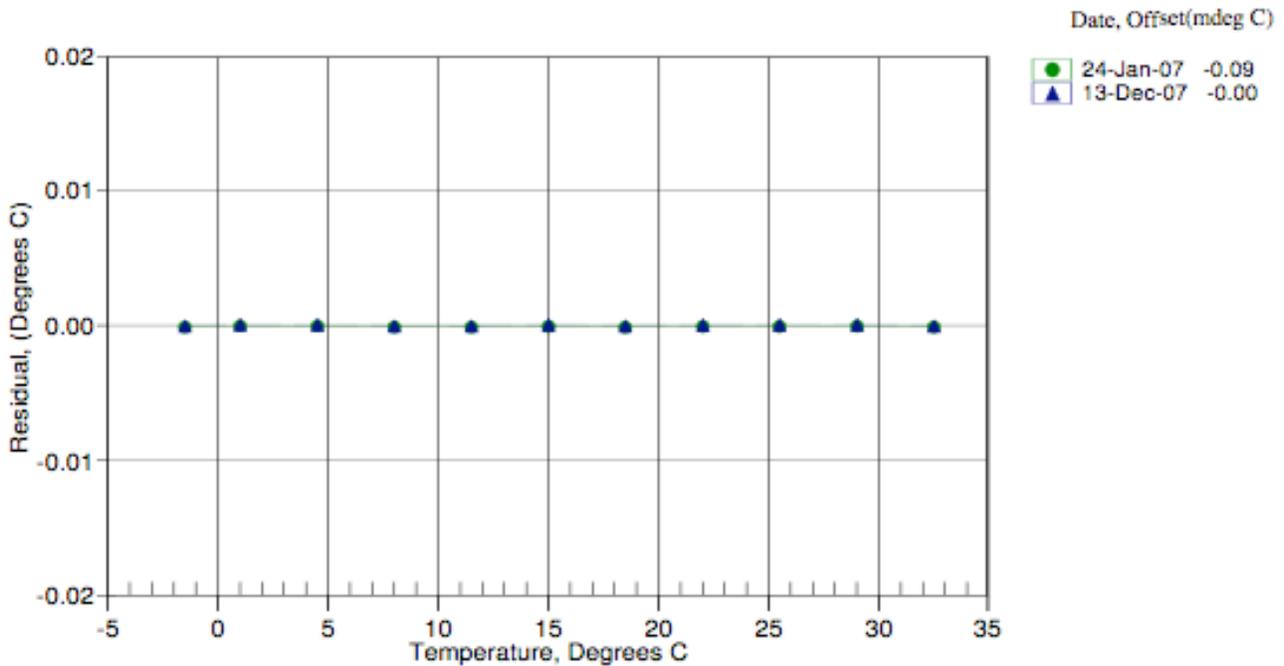
| BATH TEMP (ITS-90) | INSTRUMENT FREQ (Hz) | INST TEMP (ITS-90) | RESIDUAL (ITS-90) |
|-----------------------|-------------------------|-----------------------|----------------------|
| -1.5000 | 2721.791 | -1.5000 | -0.00002 |
| 1.0000 | 2878.781 | 1.0000 | 0.00003 |
| 4.5000 | 3109.455 | 4.5000 | 0.00002 |
| 8.0000 | 3353.176 | 8.0000 | -0.00001 |
| 11.5000 | 3610.316 | 11.5000 | -0.00001 |
| 15.0000 | 3881.236 | 15.0000 | 0.00002 |
| 18.5000 | 4166.278 | 18.5000 | -0.00004 |
| 22.0000 | 4465.803 | 22.0000 | 0.00000 |
| 25.5000 | 4780.134 | 25.5000 | 0.00003 |
| 29.0000 | 5109.596 | 29.0000 | 0.00002 |
| 32.5000 | 5454.501 | 32.5000 | -0.00002 |

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



Oxygen Sensor A

Serial # 1307

SEA-BIRD ELECTRONICS, INC.

1808 136th Place N.E., Bellevue, Washington, 98005 USA

Phone: (425) 643 - 9866 Fax (425) 643 - 9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 1307
CALIBRATION DATE: 28-Sep-07p

SBE 43 OXYGEN CALIBRATION DATA

COEFFICIENTS

Soc = 0.3834

TCor = 0.0025

Boc = 0.0000

PCor = 1.350e-04

Voffset = -0.4781

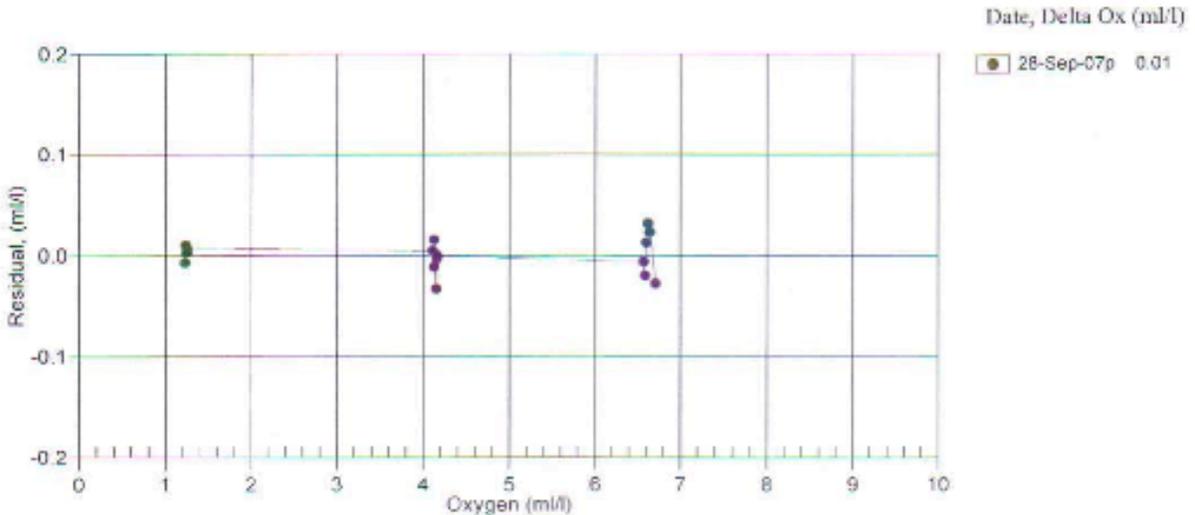
| BATH OX (ml/l) | BATH TEMP ITS-90 | BATH SAL PSU | INSTRUMENT OUTPUT(VOLTS) | INSTRUMENT OXYGEN(ml/l) | RESIDUAL (ml/l) |
|----------------|------------------|--------------|--------------------------|-------------------------|-----------------|
| 1.22 | 2.00 | 0.00 | 0.805 | 1.22 | -0.01 |
| 1.24 | 12.00 | 0.01 | 0.898 | 1.25 | 0.01 |
| 1.24 | 20.00 | 0.01 | 0.966 | 1.25 | 0.01 |
| 1.24 | 26.00 | 0.01 | 1.016 | 1.25 | 0.00 |
| 1.25 | 6.00 | 0.00 | 0.848 | 1.25 | 0.00 |
| 1.25 | 30.00 | 0.01 | 1.057 | 1.26 | 0.01 |
| 4.11 | 20.00 | 0.01 | 2.086 | 4.11 | 0.00 |
| 4.13 | 26.00 | 0.01 | 2.254 | 4.11 | -0.01 |
| 4.13 | 12.00 | 0.01 | 1.870 | 4.14 | 0.02 |
| 4.15 | 2.00 | 0.00 | 1.583 | 4.11 | -0.03 |
| 4.15 | 30.00 | 0.01 | 2.382 | 4.15 | -0.00 |
| 4.15 | 6.00 | 0.00 | 1.705 | 4.15 | -0.00 |
| 6.57 | 30.00 | 0.01 | 3.491 | 6.57 | -0.01 |
| 6.58 | 26.00 | 0.01 | 3.311 | 6.56 | -0.02 |
| 6.60 | 20.00 | 0.01 | 3.061 | 6.61 | 0.01 |
| 6.62 | 12.00 | 0.01 | 2.712 | 6.65 | 0.03 |
| 6.64 | 6.00 | 0.00 | 2.447 | 6.67 | 0.02 |
| 6.71 | 2.00 | 0.00 | 2.273 | 6.68 | -0.03 |

$$\text{oxygen (ml/l)} = (\text{Soc} * (\text{V} + \text{Voffset})) * \exp(\text{TCor} * \text{T}) * \text{Oxsat}(\text{T}, \text{S}) * \exp(\text{PCor} * \text{P})$$

V = voltage output from SBE43, T = temperature [deg C], S = salinity [PSU]

Oxsat(T,S) = oxygen saturation [ml/l], P = pressure [dbar]

Residual = instrument oxygen - bath oxygen



CTD Sensors

Pressure Sensor

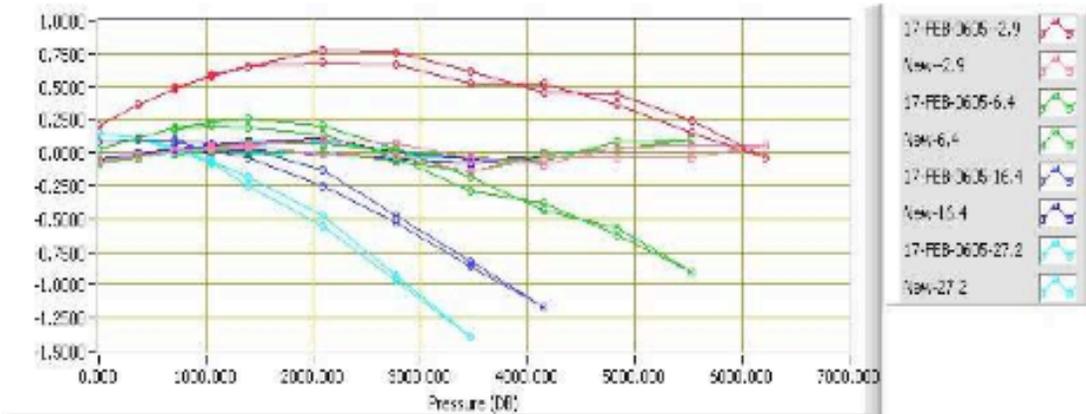
Serial # 83012

**Pressure Calibration Report
STS/ODF Calibration Facility**

SENSOR SERIAL NUMBER: 639
 CALIBRATION DATE: 18-JAN-2008
 Mfg: Seabird Model: SBE9P CTD Prs s/n: 83012

C1= -3.841449E+4
 C2= 4.630485E-1
 C3= 1.014581E-2
 D1= 3.051116E-2
 D2= 0.000000E+0
 T1= 3.019016E+1
 T2= -1.746821E-4
 T3= 4.517296E-6
 T4= -9.087207E-9
 T5= 0.000000E+0
 AD590M= 1.27551E-2
 AD590B= -9.09133E+0
 Slope = 1.0
 Offset = 0.0

Calibration Standard: Mfg: Ruska Model: 2400 s/n: 34336
 $t0 = t1 + t2 * td + t3 * td * td + t4 * td * td * td$
 $w = 1 - t0 * t0 * t0$
 $Pressure = (0.6894759 * ((c1 + c2 * td + c3 * td * td) * w * (1 - (d1 + d2 * td) * w) - 14.7)$



Temperature #1

Serial # 2855

**Temperature Calibration Report
STS/ODF Calibration Facility**

SENSOR SERIAL NUMBER: 2855
 CALIBRATION DATE: 21-JAN-2008
 Mfg: Seabird Model: SBE3Plus
 Previous Cal Date: 24-Jan-07
 Calibration Tech: CM

g= 4.35951439E-3
 h= 6.45648951E-4
 i= 2.38075037E-5
 j= 2.35385504E-6
 f0 = 1000.0
 Slope = 1.0
 Offset = 0.0

Calibration Standard: Mfg: ASL Model: F18 s/n: 245-5149
 Temperature ITS-90 = $1/(g+h[\ln(f0/f)]+i[\ln2(f0/f)]+j[\ln3(f0/f)]) - 273.15$ (°C)

| SBE3 Freq | SPRT | SBE3 New_Coefs | SPRT-SBE3 Prev_Coefs | SPRT-SBE3 New_Coefs |
|--------------|---------|-------------------|-------------------------|------------------------|
| 5479.6760 | 28.1875 | 28.1875 | 0.00140 | 0.00002 |
| 5798.0010 | 31.2142 | 31.2142 | 0.00189 | -0.00002 |
| 5174.8630 | 25.1737 | 25.1737 | 0.00101 | 0.00002 |
| 4839.0220 | 21.7073 | 21.7073 | 0.00066 | -0.00000 |
| 4563.9390 | 18.7410 | 18.7410 | 0.00045 | -0.00003 |
| 4313.5900 | 15.9306 | 15.9306 | 0.00036 | -0.00000 |
| 4062.6960 | 12.9964 | 12.9964 | 0.00029 | 0.00002 |
| 3819.2680 | 10.0242 | 10.0242 | 0.00019 | -0.00001 |
| 3580.6660 | 6.9771 | 6.9771 | 0.00011 | -0.00001 |
| 3359.2520 | 4.0167 | 4.0167 | 0.00007 | 0.00004 |
| 3216.0510 | 2.0264 | 2.0264 | -0.00010 | -0.00004 |
| 3143.3570 | 0.9916 | 0.9916 | -0.00010 | 0.00002 |
| 3042.0950 | -0.4792 | -0.4792 | -0.00018 | 0.00003 |
| 3003.6410 | -1.0471 | -1.0471 | -0.00029 | -0.00003 |
| 2934.0140 | -2.0888 | -2.0888 | -0.00036 | -0.00001 |

Temperature #2

Serial # 2796

**Temperature Calibration Report
STS/ODF Calibration Facility**

SENSOR SERIAL NUMBER: 2796
 CALIBRATION DATE: 21-JAN-2008
 Mfg: Seabird Model: SBE3Plus
 Previous Cal Date: 27-Jan-07
 Calibration Tech: CM

g= 4.30545772E-3
 h= 6.41541965E-4
 i= 2.26535491E-5
 j= 2.15838215E-6
 f0 = 1000.0
 Slope = 1.0
 Offset = 0.0

Calibration Standard: Mfg: ASL Model: F18 s/n: 245-5149
 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)

| SBE3 Freq | SPRT | SBE3 New_Coefs | SPRT-SBE3 Prev_Coefs | SPRT-SBE3 New_Coefs |
|--------------|---------|-------------------|-------------------------|------------------------|
| 5034.9080 | 28.1869 | 28.1869 | 0.00129 | -0.00001 |
| 5327.3120 | 31.2134 | 31.2134 | 0.00145 | 0.00001 |
| 4754.9570 | 25.1736 | 25.1736 | 0.00117 | -0.00003 |
| 4446.4900 | 21.7075 | 21.7075 | 0.00113 | 0.00003 |
| 4193.8400 | 18.7414 | 18.7414 | 0.00105 | 0.00000 |
| 3963.9100 | 15.9311 | 15.9311 | 0.00097 | -0.00004 |
| 3733.4680 | 12.9969 | 12.9969 | 0.00098 | 0.00001 |
| 3509.8970 | 10.0249 | 10.0248 | 0.00098 | 0.00005 |
| 3290.7460 | 6.9777 | 6.9777 | 0.00087 | -0.00002 |
| 3087.3980 | 4.0175 | 4.0175 | 0.00082 | -0.00001 |
| 2955.8690 | 2.0273 | 2.0273 | 0.00077 | -0.00001 |
| 2889.1220 | 0.9928 | 0.9928 | 0.00074 | -0.00001 |
| 2796.0920 | -0.4783 | -0.4783 | 0.00068 | -0.00002 |
| 2760.7580 | -1.0463 | -1.0463 | 0.00070 | 0.00001 |
| 2696.7970 | -2.0881 | -2.0881 | 0.00067 | 0.00003 |

Temperature #3

Serial # 0011

SBE35 V 2.0a SERIAL NO. 0011 25 Jun 2008

number of measurement cycles to average = 8

number of data points stored in memory = 0

bottle confirm interface = SBE 911plus

SBE35 V 2.0a SERIAL NO. 0011

29-mar-08

A0 = 5.030840630e-03

A1 = -1.387153030e-03

A2 = 2.040326840e-04

A3 = -1.129031550e-05

A4 = 2.392311380e-07

SLOPE = 1.000000

OFFSET = 0.000000

Conductivity #1

Serial # 2568

SEA-BIRD ELECTRONICS, INC.

1808 136th Place N.E., Bellevue, Washington, 98005 USA

Phone: (425) 643-9866 Fax (425) 643-9854 Email seabird@seabird.com

SENSOR SERIAL NUMBER: 2568
CALIBRATION DATE: 18-Jan-08

SBE4 CONDUCTIVITY CALIBRATION DATA
PSS 1978: C(35,15.0) = 4.2914 Siemens/meter

QUADRATIC COEFFICIENTS

g = -1.02670721e-001
h = -1.459463032e-007
i = -3.16405740e-004
j = -6.15237692e-007
CTemp = -0.5700e-008 (mohm/s)
CTPcor = -3.2500e-008 (mohm/s)

ABCDM COEFFICIENTS

a = -1.84930472e-004
b = -1.48492007e-007
c = -1.03867251e-001
d = -8.28372679e-007
m = 3.5
CTemp = -0.5700e-008 (mohm/s)

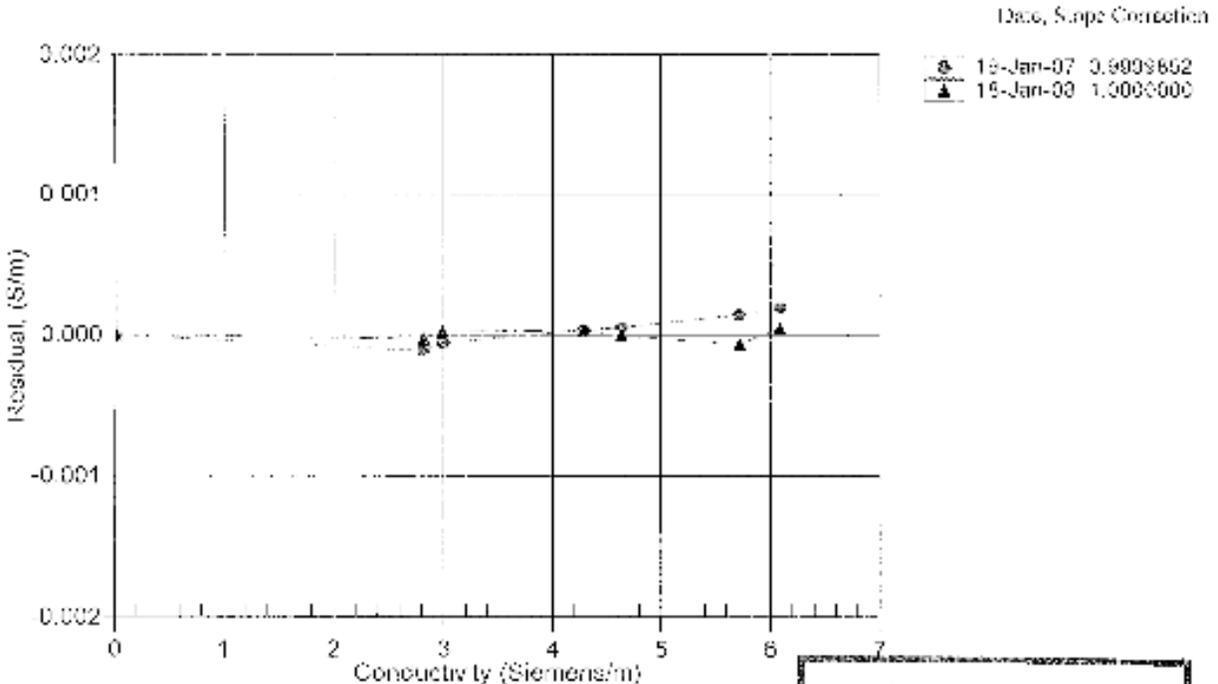
| BATH TEMP (ITS-90) | BATH SAL (PSU) | BATH COND (Siemens/m) | INST FR20 (Mho) | INST COND (Siemens/m) | RESIDUAL (Siemens/m) |
|--------------------|----------------|-----------------------|-----------------|-----------------------|----------------------|
| 0.0000 | 0.0000 | 0.00000 | 2.64769 | 0.00000 | 0.00000 |
| -1.0000 | 24.9207 | 2.91310 | 3.08747 | 2.91310 | -0.00000 |
| 1.0000 | 24.9240 | 2.98500 | 3.10062 | 2.98500 | 0.00000 |
| 15.0000 | 34.9362 | 4.28484 | 4.87907 | 4.28458 | 0.00000 |
| 18.0000 | 34.9300 | 4.67070 | 5.17084 | 4.68077 | -0.00000 |
| 20.0000 | 34.9290 | 5.71871 | 5.72469 | 5.71867 | -0.00000 |
| 30.0000 | 34.9198 | 6.09199 | 6.09777 | 6.09204 | 0.00000 |

Conductivity = (g + hf² + if³ + jf⁴) / (1 - Sp - qp) Siemens/meter

Conductivity = (af^m + bf³ + c + d) / (1 - qp) Siemens/meter

f = temperature [°C]; p = pressure [decibars]; S = CTemp; q = CPTcor

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



POST CRUISE CALIBRATION

Conductivity # 2

Serial # 2561

SEA-BIRD ELECTRONICS, INC.

1808 136th Place N.E., Bellevue, Washington, 98005 USA

Phone: (425) 643 - 5865 Fax: (425) 643 - 9054 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 2561
CALIBRATION DATE: 18 Jan 08

SHIP CONDUCTIVITY CALIBRATION DATA
PSS 1978, C(35), S(0) = 4.2914 Siemens/meter

GIE COEFFICIENTS

g = -1.07101210e+001
h = -1.03117039e+000
i = -1.07107070e+000
j = -3.0010499e+004
ktemp = -8.7713e-008 (mho/m) / (mho/m) / (Celsius)
kpres = -1.2713e-006 (mho/m) / (mho/m) / (decibars)

ABCDM COEFFICIENTS

a = -1.36871953e-005
b = -1.67191647e-000
c = -1.06222879e+001
d = -1.00000445e+005
m = 4.7
CPres = -6.0700e-008 (mho/m) / (mho/m) / (decibars)

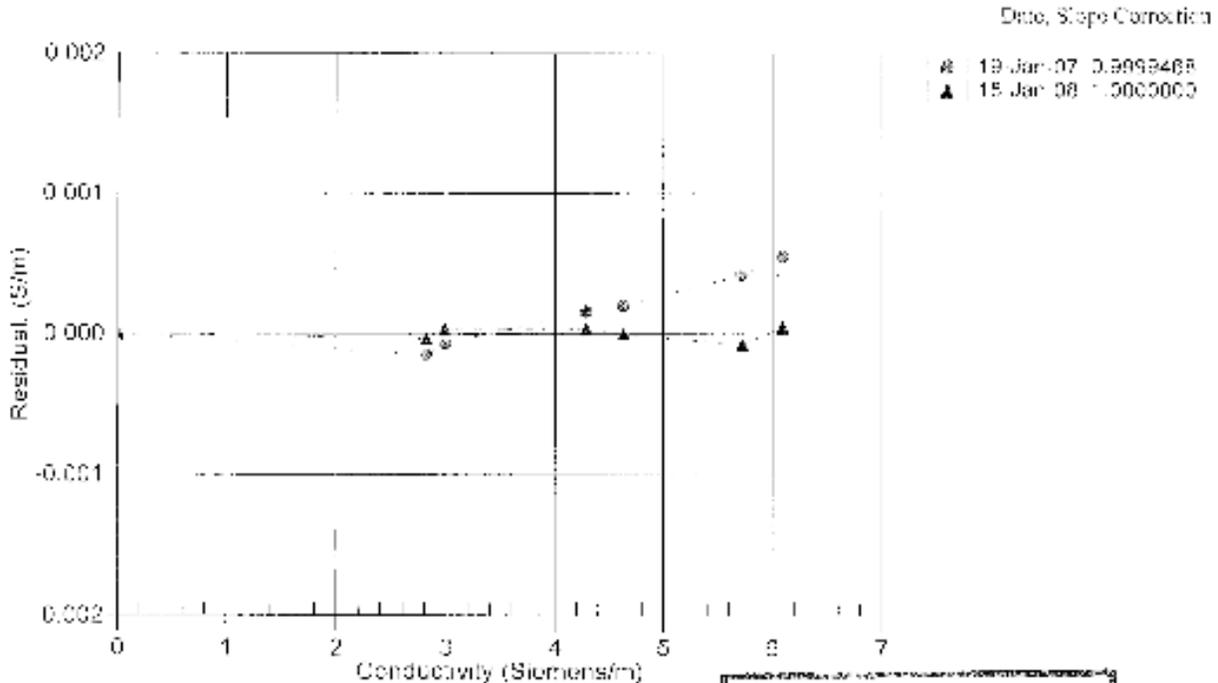
| BATH TEMP (IPS-90) | BATH SAL (PSU) | BATH COND (Siemens/m) | INST FREQ (kHz) | INST COND (Siemens/m) | RESIDUAL (Siemens/m) |
|--------------------|----------------|-----------------------|-----------------|-----------------------|----------------------|
| 0.0000 | 0.0000 | 0.00000 | 2.34142 | 0.00000 | 0.00000 |
| -1.0000 | 30.9337 | 2.91825 | 4.64880 | 3.81451 | -0.00000 |
| 1.0000 | 30.9337 | 3.92516 | 4.64878 | 2.90817 | 0.00000 |
| 1.0000 | 34.9347 | 4.28454 | 3.71538 | 4.28458 | 0.00000 |
| 18.0000 | 34.9339 | 4.63228 | 0.00204 | 0.63228 | -0.00000 |
| 19.0000 | 34.9293 | 0.71374 | 6.00024 | 0.71367 | 0.00000 |
| 30.0000 | 34.9198 | 6.09789 | 6.01408 | 6.09094 | 0.00000 |

Conductivity = (g + T² + T³ + j) * C(0) * (1 + k) Siemens/meter

Conductivity = (aT^m + bTⁿ + c + d * p) * C(0) * (1 + k) Siemens/meter

T = (temp[IPS]-90) / 5 (Celsius); p = pressure[decibars]; k = C(Temp); k = C(Pres)

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



Oxygen

Serial # 0458

SEA-BIRD ELECTRONICS, INC.

1808 136th Place N.E., Bellevue, Washington, 98005 USA

Phone: (425) 643 - 9866 Fax (425) 643 - 9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 0458
CALIBRATION DATE: 12-Dec-07p

SBE 43 OXYGEN CALIBRATION DATA

COEFFICIENTS

Soc = 0.4060

Boc = 0.0000

Voffset = -0.4927

TCor = 0.0006

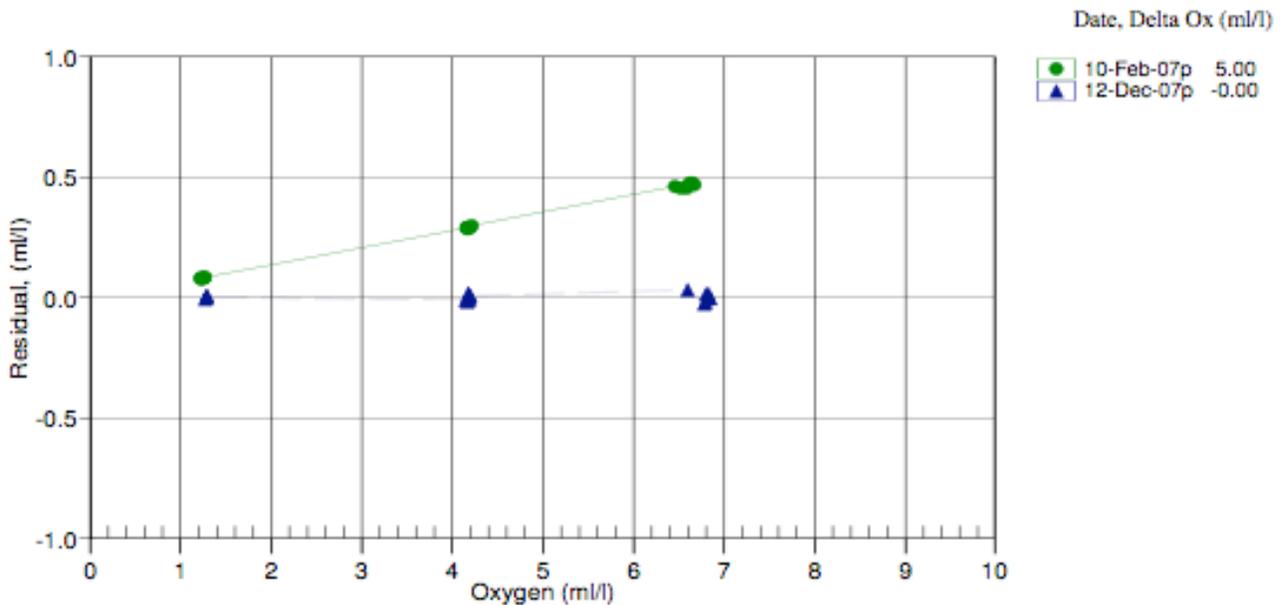
PCor = 1.350e-04

| BATH OX (ml/l) | BATH TEMP ITS-90 | BATH SAL PSU | INSTRUMENT OUTPUT(VOLTS) | INSTRUMENT OXYGEN(ml/l) | RESIDUAL (ml/l) |
|-------------------|---------------------|-----------------|-----------------------------|----------------------------|--------------------|
| 1.27 | 20.00 | 0.01 | 0.979 | 1.27 | -0.01 |
| 1.28 | 26.00 | 0.01 | 1.037 | 1.27 | -0.01 |
| 1.28 | 12.00 | 0.01 | 0.909 | 1.28 | 0.00 |
| 1.28 | 2.00 | 0.00 | 0.820 | 1.28 | 0.00 |
| 1.29 | 6.00 | 0.00 | 0.858 | 1.29 | 0.01 |
| 1.29 | 30.00 | 0.01 | 1.085 | 1.29 | 0.00 |
| 4.15 | 26.00 | 0.01 | 2.265 | 4.13 | -0.01 |
| 4.16 | 20.00 | 0.01 | 2.083 | 4.15 | -0.02 |
| 4.17 | 12.00 | 0.01 | 1.847 | 4.17 | 0.00 |
| 4.18 | 30.00 | 0.01 | 2.419 | 4.19 | 0.02 |
| 4.19 | 2.00 | 0.00 | 1.556 | 4.18 | -0.01 |
| 4.19 | 6.00 | 0.00 | 1.677 | 4.20 | 0.01 |
| 6.59 | 30.00 | 0.01 | 3.535 | 6.62 | 0.03 |
| 6.78 | 20.00 | 0.01 | 3.082 | 6.75 | -0.03 |
| 6.79 | 26.00 | 0.01 | 3.397 | 6.77 | -0.02 |
| 6.80 | 12.00 | 0.01 | 2.706 | 6.81 | 0.01 |
| 6.82 | 6.00 | 0.00 | 2.420 | 6.83 | 0.01 |
| 6.84 | 2.00 | 0.00 | 2.234 | 6.84 | -0.00 |

$$\text{oxygen (ml/l)} = (\text{Soc} * (\text{V} + \text{Voffset})) * \exp(\text{TCor} * \text{T}) * \text{Oxsat}(\text{T},\text{S}) * \exp(\text{PCor} * \text{P})$$

V = voltage output from SBE43, T = temperature [deg C], S = salinity [PSU]

Oxsat(T,S) = oxygen saturation [ml/l], P = pressure [dbar], Residual = instrument oxygen - bath oxygen



Fluorometer

Serial # 088234

CERTIFICATE OF CALIBRATION

All test equipment and standards used are of known accuracy and are traceable to national standards. Details of test equipment and standards relevant to this certificate are available upon request.



| | |
|---------------|-----------------------------------|
| Date of issue | 06 March 2007 |
| Description | Mk III Aquatracka (Chlorophyll-a) |
| Serial Number | 088234 |
| Part No | 3598C |

Chelsea
Technologies
Group

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Tel: +44 (0)20 8481 9000
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www.chelsea.co.uk

REPORT

The fluorimeter was exposed to various concentrations of Chlorophyll-a dissolved in acetone in addition to pure water and pure acetone. The following formula was derived from the readings to relate instrument output to chlorophyll-a concentration.

$$\text{Conc.} = (0.00779 \times 10^{\text{Output}}) - 0.0211$$

Where -

Conc. = fluorophor concentration in µg/l
Output = Aquatracka output in volts

The above formula can be used in the range 0 - 100 microgrammes per litre to an uncertainty of 0.02 microgrammes per litre plus 5% of value.

Notes

The above formula has been derived using Chlorophyll-a dissolved in acetone. No guarantee is given as to the performance of the instrument to biologically active chlorophyll in sea-water.

The zero offset has been determined in the laboratory using purified water from a reverse osmosis/ion exchange column. It is possible that purer water may be found in clean deep ocean conditions. Under these conditions, the offset shown in the above formula should be replaced by the antilogarithm of the Aquatracka output in the purest water found, multiplied by the scale factor.

Serial number 88234 Page 1 of 2

**Group Companies**

Chelsea Technologies Ltd
Chelsea Instruments Ltd
Chelsea Environmental Ltd
Marine Acoustics Ltd

Transmisometer

Serial # CST-390DR

PO Box 518
620 Applegate St.
Philomath, OR 97370



(541) 929-565
Fax (541) 929-527
www.wetlabs.com

C-Star Calibration

| | | | | | |
|-------|-------------------|----------|----------------|------------|-------|
| Date | February 27, 2007 | Customer | US Coast Guard | Work order | 004 |
| Job # | 0012004 | S/N# | CST-390DR | Pathlength | 25 cm |

| | |
|-----------|---------------------|
| | Analog meter |
| V_d | 0.058 V |
| V_{air} | 4.788 V |
| V_{ref} | 4.707 V |

| | |
|--|---------|
| Temperature of calibration water | 18.8 °C |
| Ambient temperature during calibration | 23.4 °C |

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

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.

PAR

Serial # 70115

Calibration Date: 01/09/07 Job No.: L9514
 Model Number: QSP2300
 Serial Number: 70115
 Operator: TPC
 Standard Lamp: F-853(9/30/05)
 Operating Voltage Range: 6 to 15 VDC (+)

Note: The QSP-2300 output is a voltage that is proportional to the log of the incident irradiance. To calculate irradiance, use this formula:

$$\text{Irradiance} = \text{Calibration factor} * (10^{\wedge}\text{Light Signal Voltage} - 10^{\wedge}\text{Dark Voltage})$$

Dry Calibration Factor: 3.22E+12 quanta/cm²-sec per volt 5.34E-06 μ Einsteins/cm²-sec per volt
 Wet Calibration Factor: 5.42E+12 quanta/cm²-sec per volt 9.00E-06 μ Einsteins/cm²-sec per volt

Sensor Test Data and Results²⁾

| Sensor Supply Current (Dark): | | 3.5 mA | | | | | |
|---------------------------------|-----------------------|--------------------------------------|----------------|--|-----------------|------------------------|---|
| Supply Voltage: | | 6 Volts | | | | | |
| Lamp Integrated PAR Irradiance: | | 9.43E-15 quanta/cm ² -sec | | 0.01566 μ Einsteins/cm ² -sec | | | |
| SC3 Immersion Coefficient: | | 0.594 | | | | | |
| Nominal Filter OD | Expected Transmission | Calibrated Trans. | Sensor Voltage | Expected Voltage | Measured Trans. | Transmission Error (%) | Test Irrad. (quanta/cm ² -sec) |
| No Filter | 100% | 100.00% | 3.467 | 3.467 | 100.00% | 0.0 | 9.43E+15 |
| 0.3 | 50% | 36.10% | 3.007 | 3.024 | 34.66% | 4.2 | 3.27E+15 |
| 0.5 | 32% | 27.60% | 2.897 | 2.908 | 26.87% | 2.7 | 2.54E+15 |
| 1 | 10% | 9.27% | 2.478 | 2.434 | 10.22% | -9.3 | 9.66E+14 |
| 2 | 1% | 1.11% | 1.608 | 1.512 | 1.35% | -17.7 | 1.30E+14 |
| 3 | 0.10% | 0.05% | 0.500 | 0.194 | 0.07% | -27.4 | 1.02E+13 |

Dark Before: 0.003 Volts
 Light - No Filter Hldr.: 3.467 Volts
 Dark After - NFH: 0.003 Volts
 Average Dark 0.00274 Volts

Notes:

1. Annual calibration is recommended.
- 2) This section is for internal use and for more advanced analysis

Gravity Meters

Serial # 221

BGM-3 PLATFORM TESTS

Sensor Subsys. S/N 221
 C.P.S. S/N 324
 Platform S/N 324

ZERO DAMP period (SPEC: 533 SEC +/- 5)

11 Feb 08

ROLL (R49)
2157 Z 531 sec.
 _____ sec.
 _____ sec.

PITCH (R65)
530 sec. 220 ± Z
 _____ sec.
 _____ sec.

TILT TEST (SPEC: +/- 0.7 MRAD)

2343 Z NOMINAL 979 318.03
 POS 316.95 mgal.
 NEG 317.00 mgal.
 .36 (POS - NEG) -0.05 -0.018 mrad
 Adjustments NONE

PITCH (R56)
317.16 mgal. ^{12 Feb 08} 0001
316.62 mgal.
0.194 mrad
NONE

12 Feb 08 of 0114 NOMINAL 979 317.94
 POS _____ mgal.
 NEG _____ mgal.
 .36 (POS - NEG) _____ mrad
 Adjustments _____

NOMINAL _____
 POS _____ mgal.
 NEG _____ mgal.
 .36 (POS - NEG) _____ mrad
 Adjustments _____

NOMINAL _____
 POS _____ mgal.
 NEG _____ mgal.
 .36 (POS - NEG) _____ mrad
 Adjustments _____

NOMINAL _____
 POS _____ mgal.
 NEG _____ mgal.
 .36 (POS - NEG) _____ mrad
 Adjustments _____

NOMINAL _____

| PRE-SHIPMENT SYSTEM CHECKOUT | | | |
|------------------------------|-------------|-------------|-----------|
| SENSOR S/N | 221 | DATE | 12 FEB 08 |
| CPS S/N | 324 | TIME (Z) | 0020 |
| PLATFORM S/N | 324 | | |
| SCALE FACTOR | 5.017387349 | | |
| B.IAS | 855285.8361 | | |
| SENSOR TEST POINTS | | CPS MONITOR | |
| 1 | 30.08 | 1 | 14.80 |
| 2 | 27.98 | 2 | 10.02 |
| 3 | 18.50 | 3 | 1.006 |
| 4 | 17.62 | 4 | 0.00 |
| 5 | 15.09 | 5 | 0.00 |
| 6 | -15.00 | 6 | -0.02 |
| 7 | — | 7 | 0.727 |
| 8 | 5.02 | 8 | -0.045 |
| 9 | 13.67 | 9 | 0.025 |
| 10 | 17.68 | | |
| 11 | 6.50 | | |
| 12 | -0.07 | | |
| 13 | 5.0 - 0 | | |
| 14 | -17.95 | | |
| 15 | -6.92 | | |
| 16 | 0.00 | | |
| ACCEL OVEN | 80 | | |
| PRC OVEN | 50 | | |
| BPTC OVEN | .65 | | |
| BAT VOLTAGE | 28.0 | | |
| ELEX VOLTAGE | 29.4 | | |
| ELEC CURRENT | .16A | | |
| CHGR CURRENT | .03A | | |

AARU SYSTEM

| POST INSTALLATION SYSTEM CHECKOUT | | | |
|-----------------------------------|-------------|-------------|-----------|
| SENSOR S/N | 221 | DATE | 28 FEB 08 |
| CPS S/N | 324 | TIME (Z) | 1700 |
| PLATFORM S/N | 324 | | |
| SCALE FACTOR | 5.017387349 | | |
| BIAS | 855285.84 | | |
| SENSOR TEST POINTS | | CPS MONITOR | |
| 1 | 29.95 | 1 | 14.82 |
| 2 | 27.87 | 2 | 10.04 |
| 3 | 18.41 | 3 | 1.005 |
| 4 | 17.55 | 4 | 0.00 |
| 5 | 15.03 | 5 | 0.00 |
| 6 | -14.93 | 6 | 1.22 |
| 7 | - | 7 | -0.076 |
| 8 | 5.00 | 8 | -0.053 |
| 9 | 13.60 | 9 | .024 |
| 10 | 17.60 | | |
| 11 | 6.47 | | |
| 12 | .005 | | |
| 13 | 0/c | | |
| 14 | -17.87 | | |
| 15 | -6.90 | | |
| 16 | 0.000 | | |
| ACCEL OVEN | 75 | | |
| PRC OVEN | 44 | | |
| BPTC OVEN | .64 | | |
| BAT VOLTAGE | 28.5 | | |
| ELEX VOLTAGE | 29.5 | | |
| ELEC CURRENT | .16 | | |
| CHGR CURRENT | .02 | | |

Post-installation

AARV SYSTEM

BGM-3 PLATFORM TESTS

28 FEB 08

180 SECOND FILTER

Sensor Subsys. S/N 221
 C.P.S. S/N 324
 Platform S/N 324

ZERO DAMP period (SPEC: 533 SEC +/- 5)

| | | |
|---------------|---------------------------|----------------------------------|
| | ROLL (R49) | PITCH (R65) |
| <i>1720 Z</i> | <u>530</u> sec. <i>OK</i> | <u>526</u> sec. <i>1732 Z</i> |
| | _____ sec. | _____ sec. <i>2654 CCW</i> |
| | _____ sec. | <u>534</u> sec. <i>1833 Z OK</i> |

TILT TEST (SPEC: +/- 0.7 MRAD)

| | ROLL (R41) | PITCH (R56) |
|---------------|----------------------------------|----------------------------------|
| | NOMINAL <u>179 730.50</u> | |
| <i>1800 Z</i> | POS <u>29.85</u> mgal. | <u>29.55</u> mgal. <i>1815 Z</i> |
| | NEG <u>29.21</u> mgal. <i>OK</i> | <u>29.59</u> mgal. <i>OK</i> |
| | .36 (POS - NEG) <u>.64</u> | <u>-0.04</u> mrad |
| | Adjustments <u>NONE</u> | <u>NONE</u> |
| <i>1846 Z</i> | NOMINAL <u>979 730.50</u> | |
| | POS _____ mgal. | _____ mgal. |
| | NEG _____ mgal. | _____ mgal. |
| | .36 (POS - NEG) _____ mrad | _____ mrad |
| | Adjustments _____ | _____ |
| | NOMINAL _____ | |
| | POS _____ mgal. | _____ mgal. |
| | NEG _____ mgal. | _____ mgal. |
| | .36 (POS - NEG) _____ mrad | _____ mrad |
| | Adjustments _____ | _____ |
| | NOMINAL _____ | |
| | POS _____ mgal. | _____ mgal. |
| | NEG _____ mgal. | _____ mgal. |
| | .36 (POS - NEG) _____ mrad | _____ mrad |
| | Adjustments _____ | _____ |
| | NOMINAL _____ | |
| | POS _____ mgal. | _____ mgal. |
| | NEG _____ mgal. | _____ mgal. |
| | .36 (POS - NEG) _____ mrad | _____ mrad |
| | Adjustments _____ | _____ |
| | NOMINAL _____ | |

BASE CALIBRATION READINGS

BGM S/N: 221 / AARV SURVOPS: _____ ACC NO: _____
 SHIP: HEALY SURVOPS DATES: _____ TO: _____
 PORTS: SEATTLE, WA TO: _____
 PERSONNEL: HERR

DEPARTURE BASE CALIBRATION READINGS

DATE: 29 FEB 08 J.D. 060 TIME GMT: 1700 TO: 1800 MEAN: 1730
 STA.#: _____
 STA. NAME: PIER 36 STA GRAV @ PIER LEVEL 980728.35 MGALS
 PIER STA HGT 7.4' X .094 + .70 MGALS
 BASE g @ WATER LEVEL 980729.05 MGALS
 S.F.: 5.017387 BGM OBS GRAV 980729.34 MGALS
 CORR. BIAS: 855284.64 OBS g - BASE g + 0.29 MGALS
 DRIFT CORR. ENTERED: N/A

ARRIVAL BASE CALIBRATION READINGS

DATE: _____ J.D.: _____ TIME GMT: _____ TO: _____ MEAN: _____
 STA.#: _____
 STA. NAME: _____ STA GRAV @ PIER LEVEL _____ MGALS
 PIER STA HGT _____ X .094 + _____ MGALS
 BASE g @ WATER LEVEL _____ MGALS
 S.F.: _____ BGM OBS GRAV _____ MGALS
 CORR. BIAS: _____ OBS g - BASE g _____ MGALS

LAND METER NO. _____

DEPARTURE J. D.: _____ TIME GMT: _____ VALUE: _____ C.D. = _____ MGALS
 ARRIVAL J. D.: _____ TIME GMT: _____ VALUE: _____ C.D. = _____ MGALS
 DIFFERENCE: _____ MGALS
 STA.GRAV @ PIER LEVEL DIFFERENCE: _____ MGALS
 MISTIE: _____ MGALS

BCR BY: _____

CHECKED BY: _____

Serial # 222

BGM-3 PLATFORM TESTS

Sensor Subsys. S/N 222
 C.P.S. S/N 325
 Platform S/N 325

ZERO DAMP period (SPEC: 533 SEC +/- 5)

11 FEB 08

| | | |
|--------|-----------------|-------------------------------|
| | ROLL (R49) | PITCH (R65) |
| 2222 Z | <u>533</u> sec. | <u>534</u> sec. <u>2286 Z</u> |
| | _____ sec. | _____ sec. |
| | _____ sec. | _____ sec. |

TILT TEST (SPEC: +/- 0.7 MRAD)

| | | |
|------------------------------|---------------------------------|--|
| | ROLL (R41) | PITCH (R56) |
| 2343 Z | NOMINAL <u>979.515.24</u> | <u>312.06</u> mgal. ^{12 Feb 08} <u>0001</u> |
| | POS <u>312.18</u> mgal. | <u>312.30</u> mgal. |
| | NEG <u>312.21</u> mgal. | <u>-0.0864</u> mrad |
| .36 (POS - NEG) <u>-0.03</u> | <u>-0.0108</u> mrad <u>-.24</u> | <u>NONE</u> |
| Adjustments | <u>NONE</u> | <u>NONE</u> |

| | | |
|-----------------|---------------------------|-------------|
| 12 Feb 08 0014 | NOMINAL <u>979.513.31</u> | |
| | POS _____ mgal. | _____ mgal. |
| | NEG _____ mgal. | _____ mgal. |
| .36 (POS - NEG) | _____ mrad | _____ mrad |
| Adjustments | _____ | _____ |
| | NOMINAL _____ | |
| | POS _____ mgal. | _____ mgal. |
| | NEG _____ mgal. | _____ mgal. |
| .36 (POS - NEG) | _____ mrad | _____ mrad |
| Adjustments | _____ | _____ |
| | NOMINAL _____ | |
| | POS _____ mgal. | _____ mgal. |
| | NEG _____ mgal. | _____ mgal. |
| .36 (POS - NEG) | _____ mrad | _____ mrad |
| Adjustments | _____ | _____ |
| | NOMINAL _____ | |
| | POS _____ mgal. | _____ mgal. |
| | NEG _____ mgal. | _____ mgal. |
| .36 (POS - NEG) | _____ mrad | _____ mrad |
| Adjustments | _____ | _____ |
| | NOMINAL _____ | |

| PRE-SHIPMENT SYSTEM CHECKOUT | | | |
|------------------------------|-------------|-------------|-----------|
| SENSOR S/N | 222 | DATE | 12 FEB 08 |
| CPS S/N | 325 | TIME (Z) | 0015 |
| PLATFORM S/N | 325 | | |
| SCALE FACTOR | 4.949006443 | | |
| BIAS | F56735.6953 | | |
| SENSOR TEST POINTS | | CPS MONITOR | |
| 1 | 30.23 | 1 | 14.50 |
| 2 | 28.06 | 2 | 9.90 |
| 3 | 18.54 | 3 | 0.985 |
| 4 | 17.74 | 4 | 0.05 |
| 5 | 15.04 | 5 | 0.05 |
| 6 | -14.98 | 6 | -0.691 |
| 7 | — | 7 | 1.013 |
| 8 | 5.04 | 8 | -0.071 |
| 9 | 13.86 | 9 | -0.012 |
| 10 | 18.03 | | |
| 11 | 4.52 | | |
| 12 | -.04 | | |
| 13 | 5.0 - 0 | | |
| 14 | -18.23 | | |
| 15 | -6.94 | | |
| 16 | .02 | | |
| ACCEL OVEN | 100 | | |
| PRC OVEN | 45 | | |
| BPTC OVEN | .65 | | |
| BAT VOLTAGE | 26.5 | | |
| ELEX VOLTAGE | 27.8 | | |
| ELEC CURRENT | .15 A | | |
| CHGR CURRENT | .02 A | | |

HEALY SYSTEM

| POST INSTALLATION SYSTEM CHECKOUT | | | |
|-----------------------------------|--------------------------------|-------------|-----------|
| SENSOR S/N | 222 | DATE | 28 FEB 08 |
| CPS S/N | 325 | TIME (Z) | 1710 |
| PLATFORM S/N | 325 | | |
| SCALE FACTOR | 4.949006443 | | |
| BIAS | 855285.84 856735.70 | | |
| SENSOR TEST POINTS | | CPS MONITOR | |
| 1 | 30.01 | 1 | 14.47 |
| 2 | 27.95 | 2 | 9.92 |
| 3 | 18.45 | 3 | -985 |
| 4 | 17.66 | 4 | .04 |
| 5 | 14.95 | 5 | 105 |
| 6 | -14.95 | 6 | .373 |
| 7 | - | 7 | .281 |
| 8 | 4.99 | 8 | -.073 |
| 9 | 13.77 | 9 | -.010 |
| 10 | 17.93 | | |
| 11 | 6.47 | | |
| 12 | .016 | | |
| 13 | 0/C | | |
| 14 | -18.18 | | |
| 15 | -6.94 | | |
| 16 | 0.000 | | |
| ACCEL OVEN | 95 | | |
| PRC OVEN | 45 | | |
| BPTC OVEN | .65 | | |
| BAT VOLTAGE | 26.9 | | |
| ELEX VOLTAGE | 28.0 | | |
| ELEC CURRENT | .17 | | |
| CHGR CURRENT | .02 | | |

POST-INSTALLATION
HEAVY SYSTEM

BGM-3 PLATFORM TESTS

28 FEB 68

Sensor Subsys. S/N 222
 C.P.S. S/N 325
 Platform S/N 325

ZERO DAMP period (SPEC: 533 SEC +/- 5)

| | | |
|-------|---------------------------|------------------------------|
| | ROLL (R49) | PITCH (R65) <i>OK</i> |
| 1930Z | <u>532</u> sec. <i>OK</i> | <u>535</u> sec. <i>1945Z</i> |
| | _____ sec. | _____ sec. |
| | _____ sec. | _____ sec. |

TILT TEST (SPEC: +/- 0.7 MRAD)

| | ROLL (R41) | PITCH (R56) |
|-----------------------------|------------------------------|---------------------------------|
| 1843Z | NOMINAL <u>979 724.92</u> | |
| | POS <u>23.82</u> mgal. | <u>24.03</u> mgal. <i>1859Z</i> |
| | NEG <u>24.16</u> mgal. | <u>23.92</u> mgal. |
| .36 (POS - NEG) <i>-.32</i> | <u>-.115</u> mrad <i>.11</i> | <u>.039</u> mrad |
| Adjustments | <u>NONE</u> <i>OK</i> | <u>NONE</u> <i>OK</i> |
| | NOMINAL _____ | |
| | POS _____ mgal. | _____ mgal. |
| | NEG _____ mgal. | _____ mgal. |
| .36 (POS - NEG) | _____ mrad | _____ mrad |
| Adjustments | _____ | _____ |
| | NOMINAL _____ | |
| | POS _____ mgal. | _____ mgal. |
| | NEG _____ mgal. | _____ mgal. |
| .36 (POS - NEG) | _____ mrad | _____ mrad |
| Adjustments | _____ | _____ |
| | NOMINAL _____ | |
| | POS _____ mgal. | _____ mgal. |
| | NEG _____ mgal. | _____ mgal. |
| .36 (POS - NEG) | _____ mrad | _____ mrad |
| Adjustments | _____ | _____ |
| | NOMINAL _____ | |
| | POS _____ mgal. | _____ mgal. |
| | NEG _____ mgal. | _____ mgal. |
| .36 (POS - NEG) | _____ mrad | _____ mrad |
| Adjustments | _____ | _____ |
| | NOMINAL _____ | |

BASE CALIBRATION READINGS

BGM S/N: 222/HEALY SURVOPS: _____ ACC NO: _____
 SHIP: HEALY SURVOPS DATES: _____ TO: _____
 PORTS: SEATTLE, WA TO: _____
 PERSONNEL: HEAR

DEPARTURE BASE CALIBRATION READINGS

DATE: 29 FEB 08 J.D. 060 TIME GMT: 1700 TO: 1800 MEAN: 1730
 STA.#: _____
 STA. NAME: PIER 36 STA GRAV @ PIER LEVEL 980728.35 MGALS
 PIER STA HGT 7.4' X .094 + .70 MGALS
 BASE g @ WATER LEVEL 980729.05 MGALS
 S.F.: 4.949006 BGM OBS GRAV 980729.26 MGALS
 CORR. BIAS: 856740.23 OBS g - BASE g +0.21 MGALS
 DRIFT CORR. ENTERED: N/A

ARRIVAL BASE CALIBRATION READINGS

DATE: _____ J.D.: _____ TIME GMT: _____ TO: _____ MEAN: _____
 STA.#: _____
 STA. NAME: _____ STA GRAV @ PIER LEVEL _____ MGALS
 PIER STA HGT _____ X .094 + _____ MGALS
 BASE g @ WATER LEVEL _____ MGALS
 S.F.: _____ BGM OBS GRAV _____ MGALS
 CORR. BIAS: _____ OBS g - BASE g _____ MGALS

LAND METER NO. _____

DEPARTURE J. D.: _____ TIME GMT: _____ VALUE: _____ C.D. = _____ MGALS
 ARRIVAL J. D.: _____ TIME GMT: _____ VALUE: _____ C.D. = _____ MGALS
 DIFFERENCE: _____ MGALS
 STA.GRAV @ PIER LEVEL DIFFERENCE: _____ MGALS
 MISTIE: _____ MGALS
 BCR BY: _____ CHECKED BY: _____

Instrument Locations on the Healy

Layout plot of instrument locations

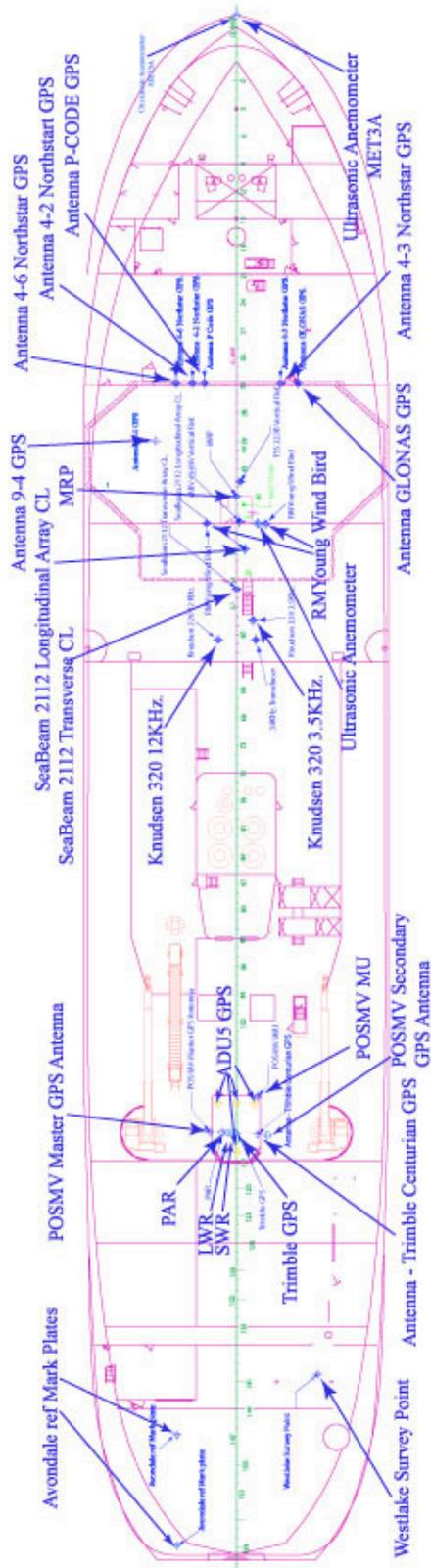


Table of Survey measurements

| Consolidated Survey Data | | | | | | |
|--|----------------------|-----------------------------------|--------------------------------------|---------------------|--------------------|-------------------------|
| | Elements of: | | | | | |
| | | Avondale Survey | | | | |
| | | Westlake Survey | | | | |
| | | Lamont Survey | | | | |
| | | | | | | |
| All Measurements in <u>Meters</u> relative to MRP unless otherwise stated | | | | | | |
| | | | | | | |
| X = fore & aft with + foreward | | | | | | |
| Y = port & starboard with + to starboard | | | | | | |
| Z= vertical with + upwards | | | | | | |
| | | | | | | |
| | | | | X | Y | Z |
| <u>Item</u> | <u>Survey</u> | <u>Description</u> | | <u>North</u> | <u>East</u> | <u>Elevation</u> |
| 1 | Avondale | MRP | See discussion Westlake Final Report | 34.30 | 0.00 | 9.15 |
| 2 | Westlake | MRP | by Definition | 0.00 | 0.00 | 0.00 |
| 3 | Westlake | Seabeam 2112 | | | | |
| | | Transverse Array | Centerline | -7.679 | 0.030 | 9.242 |
| | | Longitudinal Array | Centerline | -4.386 | 0.711 | 9.238 |
| 4 | Westlake | Transducers | | | | |
| | | Starboard - Forward to Aft | | | | |
| | | Transducer - | Bathy 2000 3.5 kHz | -10.252 | 1.362 | 9.243 |
| | | Transducer - | Bathy 1500 34 kHz * | -11.866 | 1.559 | 9.245 |
| | | Transducer - | Doppler Speed Log | -12.168 | 0.414 | 9.245 |
| | | Transducer - | Spare Transducer Well | -13.081 | 1.449 | 9.237 |
| 5 | Westlake | Port - Forward to Aft | | | | |

HLY0806 Data Synopsis

| | | | | | | |
|---|----------|---------------------|---------------------------------------|---------|--------|---------|
| | | Transducer - | VM 150 | -9.726 | -1.395 | 9.230 |
| | | Transducer - | Ocean Surveyor 75 kHz | -10.819 | -1.290 | 9.230 |
| | | Transducer - | Bathy 2000 12 kHz | -11.859 | -1.492 | 9.234 |
| | | Transducer - | Spare Transducer Well | -13.078 | -1.394 | 9.235 |
| 6 | Westlake | Gyros | | | | |
| | | Starboard Gyro | Centerline | 4.741 | 0.207 | -19.604 |
| | | | | | | |
| | | Port Gyro | Centerline | 4.746 | -0.207 | -19.609 |
| 7 | Westlake | Antennas | | | | |
| | | REF DWG TBD | Antenna 9-4 * - GPS Antenna (4.1.5) | 4.587 | -6.622 | -24.000 |
| | | | Antenna 4-6 * - Northstar GPS (4.1.1) | 9.374 | -4.970 | -23.406 |
| | | | Antenna 4-2 * - Northstar (4.1.2) | 9.362 | -3.617 | -23.451 |
| | | | P CODE GPS Antenna * | 9.368 | -2.645 | -23.609 |
| | | | Antenna 4-3 * - Northstar (4.1.4) | 9.355 | 3.638 | -23.363 |
| | | | GLONAS GPS Antenna * | 9.379 | 5.066 | -23.515 |
| | | | | | | |
| | | | Antenna base (4A) | -53.872 | -0.011 | -22.025 |
| | | | Antenna base (4B) | -49.758 | 0.038 | -22.010 |
| | | | Antenna base (4C) | -49.785 | 1.629 | -22.020 |
| | | | Antenna base (4D) | -49.771 | -1.546 | -22.008 |
| | | | | | | |
| | | | Trimble Centurion** | -52.726 | -1.717 | -21.113 |
| | | | Time Server ** | -52.671 | 1.838 | -21.115 |
| 8 | Westlake | Vertical Ref | | | | |
| | | | MRV-M-MV - | | | |
| | | | Measured at Top of mounting bracket | | | |

HLY0806 Data Synopsis

| | | | | | | |
|----|-----------------|-----------------|--------------------------------------|----------|----------|----------|
| | | | Center (mid-point) - calculated | -2.100 | 0.291 | -0.775 |
| | | | | | | |
| | | | TSS 333B - Marine Motion Sensor - | | | |
| | | | scribe atop mounting plate | | | |
| | | | Center of TSS 333B | 1.210 | 0.329 | -0.013 |
| 9 | LDEO | POS/MV | | | | |
| | | From | TO | X | Y | Z |
| | | IMU | Port Antenna (Master) | -2.9719 | -3.9140 | -5.5310 |
| | | MRP | IMU | -49.5710 | 1.7110 | -16.7990 |
| | | MRP | Transmit array | -4.3860 | 0.7110 | 9.2380 |
| | | MRP | Port Antenna (Master) | -52.5429 | -2.2030 | -22.3300 |
| 10 | Westlake Raw | Fan Tail | | | | |
| | | | Aft/Port | -86.737 | -4.906 | -3.617 |
| | | | Forward/Port | -77.600 | -4.881 | -3.589 |
| | | | Forward/Starboard | -72.590 | 6.676 | -3.653 |

SBE 21 SEACAT Thermosalinograph Data Output Formats

This is extracted from page 33 of the SBE 21 SEACAT Thermosalinograph User's Manual (SeaBird Manual Version #022, 03/30/07).

The SBE 21 outputs data in raw, hexadecimal form as described below.

The inclusion of some output parameters is dependent on the system configuration - if the specified sensor is not enabled (see *Command Descriptions* above), the corresponding data is not included in the output data stream, shortening the data string.

- SBE 21 Format (**F1**) - ttttccccrrrrrruuuvvvwwxxx (use this format if you will be using SEASAVE to acquire real-time data and/or SBE Data Processing to process the data)
- SBE 16 Format (**F2**) - #ttttccccrrrrrruuuvvvwwxxxnnnn (custom format)

where

tttt = primary temperature

cccc = conductivity

rrrrrr = remote temperature (from SBE 38 or SBE 3 remote sensor)

uuu, vvv, www, xxx = voltage outputs 0, 1, 2, and 3 respectively

= attention character

nnnn = lineal sample count (0, 1, 2, etc.)

Data is output in the order listed, with no spaces or commas between parameters. Shown with each parameter is the number of digits.

Calculation of the parameter from the data is described below (use the decimal equivalent of the hex data in the equations).

1. Temperature

$$\text{temperature frequency (Hz)} = (\text{tttt} / 19) + 2100$$

2. Conductivity

$$\text{conductivity frequency (Hz)} = \text{square root} [(\text{cccc} * 2100) + 6250000]$$

3. SBE 3 secondary temperature (if **SBE3=Y**)

$$\text{SBE 3 temperature frequency (Hz)} = \text{rrrrrr} / 256$$

4. SBE 38 secondary temperature (if **SBE38=Y**)

$$\text{SBE 38 temperature } \textit{psuedo} \text{ frequency (Hz)} = \text{rrrrrr} / 256$$

5. External voltage 0 (if 1 or more external voltages defined with **SVx**)

$$\text{external voltage 0 (volts)} = \text{uuu} / 819$$

6. External voltage 1 (if 2 or more external voltages defined with **SVx**)

$$\text{external voltage 1 (volts)} = \text{vvv} / 819$$

7. External voltage 2 (if 3 or more external voltages defined with **SVx**)

$$\text{external voltage 2 (volts)} = \text{www} / 819$$

8. External voltage 3 (if 4 external voltages defined with **SVx**)

$$\text{external voltage 3 (volts)} = \text{xxx} / 819$$

Example: SBE 21 with SBE 38 and two external voltages sampled,

example scan = ttttccccrrrrrruuuvvv = A80603DA1B58001F5A21

- Temperature = tttt = A806 (43014 decimal);
 $\text{temperature frequency} = (43014 / 19) + 2100 = 4363.89 \text{ Hz}$
- Conductivity = cccc = 03DA (986 decimal);
 $\text{conductivity frequency} =$
 $\text{square root} [986 * 2100] + 6250000 = 2884.545 \text{ Hz}$
- SBE 38 = rrrrrr = 1B5800 (1,792,000 decimal)
 $\text{temperature pseudo frequency (Hz)} = (1,792,000 / 256) = 7000 \text{ Hz}$
- First external voltage = uuu = 1F5 (501 decimal);
 $\text{voltage} = 501 / 819 = 0.612 \text{ volts}$
- Second external voltage = vvv = A21 (2593 decimal);
 $\text{voltage} = 2593 / 819 = 3.166 \text{ volts}$

Note:

SBE 21 always outputs an even number of voltage characters. If you enable 1 or 3 voltages, it adds a 0 to the data stream before the last voltage, as shown below:

- Remote temperature and 1 voltage enabled –

ttttccccrrrrrr0uuu or
 #ttttccccrrrrrr0uuunnnn

- Remote temperature and 3 voltages enabled –

ttttccccrrrrrruuuvvv0www
 #ttttccccrrrrrruuuvvv0wwwnnnn

Notes:

- Sea-Bird’s software (SEASAVE and SBE Data Processing) uses the equations shown to perform these calculations; it then uses the calibration coefficients in the configuration (.con) file to convert the raw frequencies and voltages to engineering units. Alternatively, you can use the equations to develop your own processing software.
- See *Notes on SBE 38 Remote Temperature Data Output Format* below for details on how Sea-Bird handles SBE 38 data.