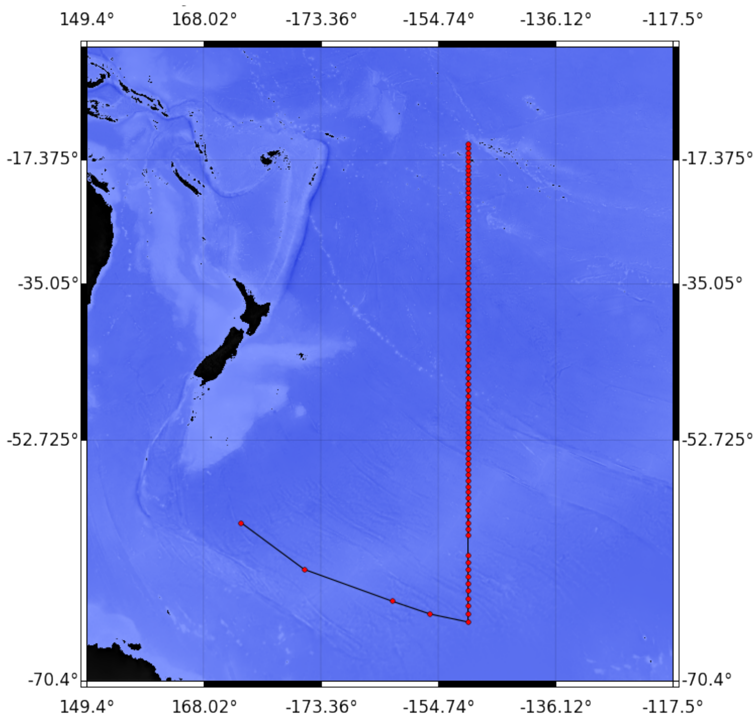
CRUISE REPORT: P16S

(Updated OCT 2017)



Highlights

Cruise Summary Information

Section Designation	**P16S**
Expedition designation (ExpoCodes)	**320620140320**
Chief Scientists	**Lynne Talley/SIO**
Dates	2014-MAR-20 - 2014-MAY-05
Ship	*RVIB Nathaniel B. Palmer*
Ports of call	Hobart, Tasmania, AUS - Papeete, Tahiti, French Polynesia
Geographic Boundaries	15° 01' S 174° 0.1' E 149° 57.18' W 66° 59.93' S
Stations	86
Floats and drifters deployed	30 drifters, 12 floats deployed
Moorings deployed or recovered	0

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Links To Select Topics

Shaded sections are not relevant to this cruise or were not available when this report was compiled.

Cruise Summary Information	**Hydrographic Measurements**
Description of Scientific Program	**CTD Data:**
Geographic Boundaries	Acquisition
Cruise Track (Figure): PI CCHDO	Processing
Description of Stations	Calibration
Description of Parameters Sampled	Temperature Pressure
Bottle Depth Distributions (Figure)	Salinities Oxygens
Floats and Drifters Deployed	**Bottle Data**
Moorings Deployed or Recovered	Salinity
	Oxygen
Principal Investigators	Nutrients
Cruise Participants	Carbon System Parameters
	CFCs
Problems and Goals Not Achieved	Helium / Tritium
Other Incidents of Note	Radiocarbon
Other Profiling Measurements	
LADCP	NASA
Underway Data Information	**References**
Navigation Bathymetry	Hydrography
Acoustic Doppler Current Profiler (ADCP)	CFCs
Thermosalinograph	Dissolved Inorganic Carbon
XBT and/or XCTD	pH
Meteorological Observations	Alkalinity
Atmospheric Chemistry Data	$\delta^{15}N\text{-}NO_3/\delta^{18}O\text{-}NO_3$
Data Processing Notes	

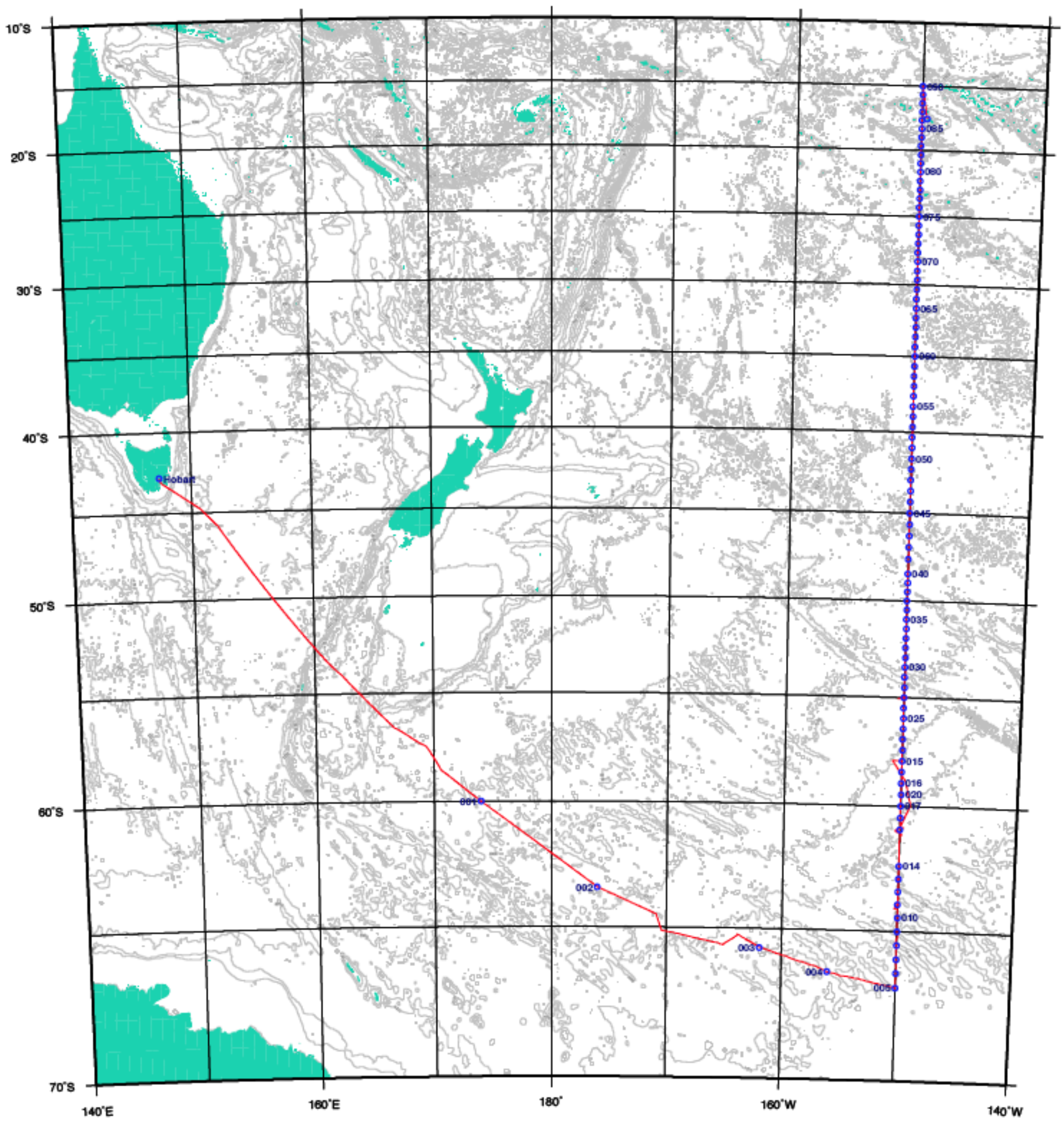
US-Repeat Hydrography (GO-SHIP) P16S

RVIB Nathaniel B. Palmer NBP1403

20 March 2014 - 5 May 2014
Hobart, Tasmania, AUS - Papeete, Tahiti, French Polynesia

Chief Scientist: Dr. Lynne Talley
Scripps Institution of Oceanography

Co-Chief Scientist: Dr. Brendan Carter
Princeton University



Cruise Report
5 May 2014
Rev. 31 July 2014

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Summary

The P16S quasi-decadal hydrographic survey was conducted from the Ross Sea through the Southern Ocean and finished in the South Pacific Ocean aboard the Edison Chouest RVIB Nathaniel B. Palmer vessel from 20 March 2014 - 5 May 2014. 86 of the 90 rosette/CTD/LADCP/chipod stations were occupied along the southernmost portion of the P16S starting at 67°S and running northward along longitude 150°W to 15°S. The first 4 stations were occupied as biogeochemical float calibration stations during the transit from Hobart to the beginning of P16S hydrographic transect.

Most CTD casts extended to within 10 meters of the seafloor, and up to 36 water samples were collected throughout the water column. CTDO (conductivity, temperature, pressure, oxygen), transmissometer, fluorometer, LADCP (lowered acoustic Doppler current profiler) and chipod (temperature diffusivity instrumentation) electronic data were collected; rosette water samples were collected from the rosette/CTD/LADCP/chipod package. 14 Hyperpro "Javelin" and 36 IOP Bio-optic casts were carried out by the NASA/CDOM group. 30 Global Drifter Program surface drifters were deployed on behalf of Rick Lumpkin of NOAA/AOML. 12 biogeochemical floats were deployed on behalf of Steve Riser (University of Washington) and Ken Johnson (MBARI).

Salinity and dissolved oxygen samples, drawn from most bottles on every full cast, were analyzed and used to calibrate the CTD conductivity and oxygen sensors. Water samples were also analyzed on board the ship for nutrients (silicate, phosphate, nitrate, nitrite), total CO_2/TCO_2 (aka dissolved inorganic Carbon/DIC), pH, total alkalinity, N_2O, and transient tracers (CFCs and SF_6).

Additional water samples were collected and stored for analysis onshore: ^{3}Helium / Tritium, ∂^{18}O, ^{13}C/ ^{14}C, dissolved organic Carbon and total dissolved Nitrogen (DOC / TDN), ∂^{15}N-NO_3, ∂^{18}O-NO_3, Calcium, HPLC, CDOM and ∂^{30}Si.

Discrete dissolved oxygen, pH, DIC, total alkalinity, salinity, and nutrient samples were drawn and analyzed from the ship's flow-through underway system. Continuous underway measurements included GPS navigation, multibeam bathymetry, ADCP, meteorological parameters, sea surface measurements (including temperature, conductivity/salinity, fluorescence), and gravity. In addition to the permanently installed RVIB Nathaniel B. Palmer systems, an underway pCO_2 system designed by Taro Takahashi (LDEO) collected data throughout the cruise.

1. P16S NARRATIVE - L. Talley, Chief Scientist

RVIB Nathaniel B. Palmer cruise NBP1403 had three major independent funded projects: 1. U.S. Repeat Hydrography/CLIVAR section P16S along 150°W, 67°S-15°S (NSF, NOAA) (90 stations completed); 2. Biogeochemical Argo-equivalent float deployments (12 floats, NSF/NOAA); 3. Ocean optical/pigment observations for satellite ocean color validation (NASA).

1.1. Sampling Programs

We sampled or deployed instruments for 18 different principal investigators, with NSF, NOAA, and NASA funding. In addition to the core set of funded projects, we also deployed 30 surface drifters in support of the Global Surface Velocity Program, and collected water samples for three unfunded experimental projects. Our science party of 29 included one postdoc (co-chief scientist) and 11 students (CFC, alkalinity, pH, DOC, C14, CTD watch standers).

The 90 P16S stations repeat two earlier transects, in 1991 (World Ocean Circulation Experiment) and 2005 (U.S. Repeat Hydrography). A segment of 150°W in the Ross Sea from 67°S to the Antarctic continent was occupied in 2011 on the RVIB Palmer as part of the S04P section, and can be considered part of this decades' repeat of 150°W.

The temperature/salinity profiling on the 12 BGC floats is part of the global Argo float array, profiling every 10 days to 2000 m depth. The group of floats is the first set of fully-equipped Southern Ocean biogeochemical profiling floats, measuring oxygen, nitrate, fluorescence and backscatter, and newly-developed pH. The southernmost group has sea ice avoidance software.

The NASA optical program included (a) profiling to 200 m for inherent optical properties (IOP) almost every day of operations and (b) hand-held casts for apparent optical properties (AOP) close to noon on the 14 days when the weather and sea conditions were favorable.

The work began with a 6 day transit from Hobart, Tasmania to the first station. The first four stations were along the great circle route to the 150°W section. These stations were for the purpose of BGC float deployments, and were accompanied by a CTD/rosette profile with nutrient, salt, oxygen, carbon and fluorescence measurements for purposes of float calibration/validation. To test all equipment and sampling, and because full-depth stations take little additional time compared with 2000 m stations necessary for the floats, three of these stations were occupied to the ocean bottom. Station 3 was to 2000 m due to weather (see "slowdown" comments below).

On day 11 (31 March), we reached the southernmost end of the P16S section at 67°S and began working northward at 30 nm spacing for P16S. Station spacing was increased to 40 nm starting at Station 39 (49°S) because of time lost to weather and wire problems. The last station was completed on 4 May 2014. NASA bio-optical sampling (IOP) was done once a day when sampling (CTD/rosette) was possible, and AOP sampling on 14 days when conditions permitted.

Samples were filled from a 36 bottle sampling rosette with seawater collected from depths ranging from the ocean surface to ~5600 m. Samples for various analyses were collected from the rosette in the following order:

1. CFCs, N_2O, CCl_4
2. Helium
3. Dissolved oxygen
4. Total dissolved inorganic carbon
5. pH
6. Total alkalinity
7. Carbon isotopes ($\delta^{14}C$, $\delta^{13}C$)
8. Dissolved organic carbon
9. Nutrients
10. $\delta^{15}N$-NO_3/$\delta^{18}O$-NO_3
11. $\delta^{18}O$
12. Salinity
13. Colored dissolved organic matter
14. $\delta^{30}Si$
15. Pigments

1.2. Successes and challenges

The cruise can be judged mostly successful. 90 stations were completed, 81 of them to the ocean bottom, and all with excellent data. 12 biogeochemical floats were deployed and all have returned their initial profiles and one or two subsequent profiles prior to June, 2014 (5- and 10-day timing separation between profiles). The NASA biooptical program was able to operate casts most days, collecting the farthest south ever Apparent Optical Property profile for satellite cal/val.

The intricate operation of the many sampling programs and laboratory analyses worked extremely well, due to the professionalism, experience and high standards of the science party. The Antarctic Support Contractor (ASC) personnel were central to the success of daily operations, from planning and supporting all deck operations with knowledgeable and creative solutions to challenges. The Edison Chouest Offshore (ECO) ship operation was highly professional and easy to work with. Daily teamwork between the three groups (ECO, ASC and science) is central to successful scientific operations. When major challenges arose (CTD wire change; Hyperpro loss), the 3-way collaboration worked well.

Delays and incomplete science resulted from weather (many delays prior to Station 39), malfunctioning of the CTD conducting wire (affecting Stations 31-39), and from loss of a Hyperpro IOP package for the NASA ocean color mission (section 19).

1.2.1. Weather

About half of our stations were located south of 50°S, where wind and seas (March and April) were very rough. The ship spent 68 hours waiting on weather based on engine room logs. In addition to work stoppage, rough conditions affected wire tension, ship speed, and ability to sample while underway after Station 39 when the rosette was moved to the outside main deck/backup wire. Our average wire speed for the cruise was on the order of 45 m/min, with slow starts at each station, ramping up to 60 m/min far into the cast. Ship steaming speed was often less than 9 knots. The net impact was a reduction in total number of stations from the projected 105 stations to 90, a gap in stations between 61°S and 62°30'S, and expansion of station spacing to 40 nm from 49°S to 15°S. The cruise request was based on an assumption of 4 hours per station and 9 knots steaming speed, plus two days for weather. On the 150°W section, our station time (CTD in the water) averaged 3.5 hours, wirespeed averaged 38 m/min and steaming speed averaged 7.7 knots (including positioning, and waiting for sampling). South of 50°S, our station time averaged 2.9 hours. Wirespeed averaged 41 m/min and steaming speed averaged 7.1 knots.

Overall, wirespeeds were less than optimal because of restrictions due to wire tension requiremets (see Section 16).

Severe weather affecting Station 3 and float 7567. Severe weather resulted in a shift of Station 3 and its float deployment somewhat to the east along the great circle transit to the P16S line. The requirement for stations 1 through 4 was to reach 2000 m but we sampled to the bottom on Stations 1, 2 and 4 as the additional time was minimal and this provided both full water-column profiles for the carbon algorithm to be used with the floats, and the opportunity to test all shipboard and laboratory equipment prior to the start of P16S line. Station 3 was occupied only to 2000 m because of the extremely rough deployment conditions. Float 7567, deployed under rough conditions, was the only float of the 12 with compromised data return, although it appears to have recovered and is reporting good data (as of Jan 2015).

Severe weather affecting Station 10 through 23 (64°S to 57°S; April 2-9, 2014; 52.43 hours of Wait-on-Weather). To minimize work stoppage/slow-downs due to extremely rough conditions that began at 64°S, and with a weather forecast for even more protracted "wait-on-weather", we steamed northward from 62°30'S (Station 14) to 58°S (thus becoming station 15), and then occupied stations back southward at 1° spacing, to 61°S (Station 19). Because of time and the negative weather forecast, we abandoned the stations at 62°S and 61°30'S. We then proceeded northward, filling in the 0.5° stations to 57°30'S (Station 22), and then recommenced regular 30 nm spacing, in order to best capture this important set of stations across the Antarctic Circumpolar Current.

Weather affecting Stations 24 through 34 (57°S to 51°S; April 10-13, 2014; 16 hours of Wait-on-Weather). Weather stoppages and slowdowns affected these stations only by slowing the rate, but did not result in any changes in cruise plan. North of 51°S, we were slowed for weather several additional times (stations 55-56, 65-66, 75-77) but there were no work stoppages.

1.2.2. CTD wire problems

Affecting Stations 31-38, and 39 (April 12-15, 2014). Stations 31-38 were truncated at 4100 to 4200 m wire out. Multiple outer strand breakages on the Baltic Room CTD wire were first noted at ˜4200 m wire out at Station 30. While Stations 1, 5 and 6 were deeper, the problem was not noted then, although it was noticed at Station 1 that the wire was increasingly rusty farther down in the spool. (This was surprising as the wire was reportedly only two years old). After Station 30, it was determined that it was too risky to use the wire beyond 4100 / 4200 m. The upper waterfall winch (UWW) wire was spooled out to 3000 m with a lead weight attached, and was judged to be in excellent condition, even though we were told that the wire was 16 years old. (We have raised a question, currently unresolved, about the accuracy of the ASC's CTD wire log information since the "new" wire on the Baltic Room winch had all of the characteristics of a very well-used wire, including significant rust and very little rotation associated with unwinding, whereas the "old" wire on the UWW had the characteristics of a new wire, with very little wear, and extremely large rotation/unwinding on the first several casts, settling into lesser but still large rotation on all remaining casts.). Because of previous time losses due to weather, the Chief Scientist decided to continue with Stations 31-38 to just ˜4100 m on the Baltic Room winch while ASC and ECO carefully considered the various options for switching to the backup wire. The height off the bottom for these 8 casts over rough topography ranged from 77 to 847 m, averaging 378 m (see Section 2.1).

Station 39 depth was > 4900 m, with a long set of stations thereafter deeper than 5000. It was scientifically important to ensure switching to the UWW CTD wire prior to Station 39 rather than continue with truncated stations. The possibility of spooling the wire from the UWW to the Baltic Room winch was considered in great detail, but was determined to be possible only in excellent weather conditions, which were highly unlikely.

It was decided to go ahead and use the UWW winch and wire, although the incorrect sheave had been mounted on the starboard A-frame prior to departure from Hobart. The crane operation necessary for switching sheaves was ruled out because of the suboptimal weather conditions. The smooth and efficient rosette transfer took place between Stations 38 and 39, which was coincidentally a day of calmer seas and lower wind than usual. The CTD was attached to both the Baltic room and Upper Waterfall Winch wires, lowered into the surface water from the Baltic Room, and then swung over and landed on the main deck in front of the latter winch. From that point onward, all CTD and sampling operations were outdoors on the main deck.

Station 39, the first with the Upper Waterfall Winch, was undertaken with very slow winch speed (6.4 hour station time) because there was little information about the wire and its condition, and to minimize large tension spikes. Station 39 nevertheless had significant electrical problems, traced to the winch. A number of winch electrical modifications were made between Stations 39 and 40. Station 40 and stations thereafter were excellent and we were able to resume normal operations.

Slowdowns associated with this operation added up to about 12.2 hours. These CTD wire problems significantly compromised data for 9 of our total of 86 stations along P16S.

1.2.3. Loss of NASA Hyperpro instrument (AOP measurements)

The hand-deployed NASA Hyperpro instrument was lost during a cast at Station 80, when the wire was caught in the propeller. Circumstances were extensively documented by ECO, ASC and the NASA scientists, and are described in the NASA cruise report (Section 19 below). The backup instrument was employed on May 1. Lack of deployment of the backup on May 2 was requested by the ECO home office, but permission was obtained to deploy a final station on May 3, the last day for sampling (see Section 19.1).

1.2.4. Laboratory Conditions

The laboratories were spacious and well appointed with shelving and storage space. The computer laboratories provided excellent working conditions for our large group of computer-based scientists. The ASC IT and MLT support for the labs was excellent.

There were two compromising laboratory issues. The DIC laboratory van was installed on the main deck, which was often secured due to bad weather, as the low-to-the-water deck is routinely awash in even the normal (high) sea state of the Southern Ocean. A large wave damaged the DIC van, after which the DIC analysis was moved into the aft dry lab. It would have been very helpful if ASC had advised in advance that all active laboratory vans be located on upper decks (the location of the CFC van), but the extensive administrative planning process somehow failed to recognize this important issue (see Section 4).

Temperatures in the aft dry lab, which hosted four chemistry lab groups, ranged from 14° to 31°C through the cruise, which was unsatisfactory (see Section 4). The higher temperatures, encountered near the end of the cruise because of the high ambient seawater temperatures used for cooling on the Palmer, resulted in reduced numbers of analyses that could be processed. The ECO engineers and ASC staff worked hard to bring the temperatures under control, but the problem was only partially alleviated. "Cold" water in the taps and showers was as hot as 113°F over the last three days of the cruise. As this is a structural problem for the Palmer, improved laboratory temperature regulation as well as provision of cool water may require renovation; meanwhile we recommend that deployments in tropical regions be limited.

1.3. Preliminary results

The Ross Sea bottom waters continue to warm, with a monotonic increase over the 4 WOCE/CLIVAR surveys thus far: 1992, 2005, 2011, and now 2014. The bottom 1000 m thick layer is nearly adiabatic (well mixed with lower temperature variance than the abyssal thermocline above it), and can be easily compared from one survey to the next. Additionally, we note that the entire deep temperature structure has shifted from cooler to warmer, and hence it appears that the warming of the bottom layer is partly a function of warming of the deep layer from 2500 to 4500 m.

An energetic subthermocline eddy or internal wave was observed at 45°S (Station 45), with westward flow of>30 cm/sec at 1200-1800m, and 300 m isopycnal deflections. This extremely anomalous feature had a weak anticyclonic surface expression, and was located well north of the most energetic part of the ACC's eddy field. The feature was principally an isopycnal deflection with only weak property anomalies along isopycnals through the feature. It was clear in the deep-reaching SADCP velocity. Diapycnal diffusivity calculated from fine-structure parameterization using the CTD and LADCP profile data, was enhanced above and below the feature. Vertical velocities processed from the LADCP data by A Thurnherr (LDEO) showed signatures of high frequency internal waves in the high stratification above and below the stretched isopycnals at the core of the feature. Several mechanisms for generation of this feature are being explored.

Principal Investigators for US-Repeat Hydrography(GO-SHIP) P16S

Program	Affiliation*	Principal Investigator	email
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*Affiliation abbreviations listed on page 11

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*Affiliation abbreviations are listed on page 11

KEY to Institution Abbreviations	
ANU	Australian National University
CASPO	Climate Atmospheric Sciences and Physical Oceanography(SIO)
CCHDO	CLIVAR/Carbon Hydrographic Data Office (SIO)
GDP	Global Drifter Program
LDEO	Lamont-Doherty Earth Observatory (Columbia University)
MPL	Marine Physical Laboratory (SIO)
MBARI	Monterey Bay Aquarium Research Institute
MCG	Marine Chemistry and Geochemistry (SIO)
NASA	National Aeronautic and Space Administration
NOAA	National Oceanic and Atmospheric Administration
ODF	Oceanographic Data Facility (SIO/STS)
OSU	Oregon State University
PMEL	Pacific Marine Environmental Laboratory (NOAA)
RT	Research Technicians (SIO/STS)
SIO	Scripps Institution of Oceanography(UCSD)
SOMTS	Ship Operations and Marine Technical Support (SIO)
STS	Shipboard Technical Support (SIO)
TAMU	Texas Agricultural and Mechanical Engineering University
UBO	Universite` de Bretagne Occidentale (France)
U. Concepción	Universidad of Concepción(Chile)
UCSD	University of California, San Diego
UCSB	University of California, Santa Barbara
U.Hawaii	University of Hawaii
USAP	United States Antarctic Program
U. Texas	University of Texas at Austin
U. Washington	University of Washington
WHOI	Woods Hole Oceanographic Institution

2. Core Hydrographic Measurements: CTD Data, Salinity, Oxygen and Nutrients

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The US-Repeat Hydrography(GO-SHIP) P16S repeat hydrographic line was reoccupied for the United States Repeat Hydrograph Carbon Program from 20 March 2014 -5May 2014 aboard RVIB Nathaniel B. Palmer during a survey consisting of rosette/CTD/LADCP/chipod stations and a variety of underway measurements. The ship departed Hobart, Tasmania, AUS on 20 March 2014 and arrived Papeete, Tahiti, French Polynesia on 5 May 2014 (UTC dates).

A sea-going science team gathered from 15 oceanographic institutions participated on the cruise. The programs and PIs, and the shipboard science team and their responsibilities, are listed in the Narrative section.

A total of 90 stations were occupied with one rosette/CTD/LADCP/chipod cast completed at each. 2 aborted cast(s) were not reported. CTDO data and water samples were collected on each rosette/CTD/LADCP/chipod cast, usually to within 10 meters of the bottom. Water samples measured on board or stored for shore analysis are tabulated in the Bottle Sampling section.

Pressure, temperature, conductivity/salinity, dissolved oxygen, fluorometer and transmissometer data were recorded from CTD profiles. Current velocities were measured by the LADCP. Core hydrographic measurements consisted of salinity, dissolved oxygen and nutrient water samples taken from each rosette cast. The distribution of samples is shown in the following figures.

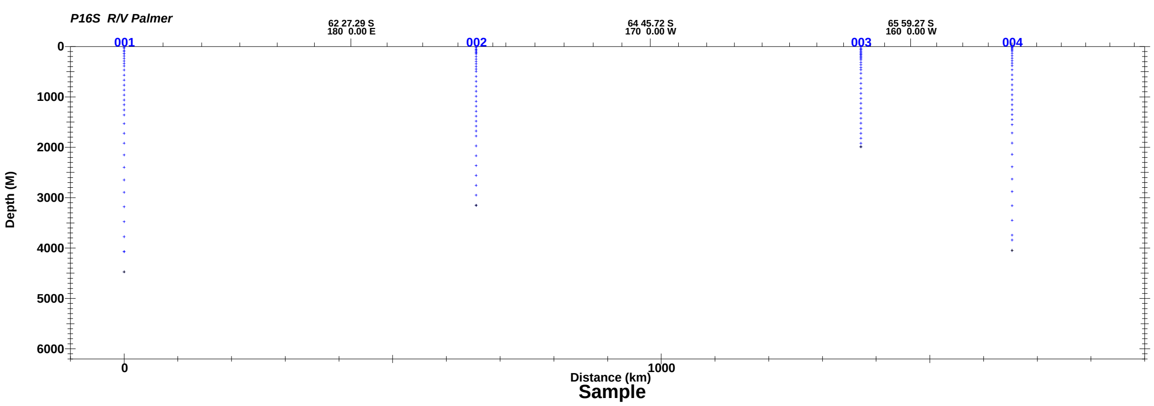

Figure 2.0 P16S Sample Distribution, Stations 1-4

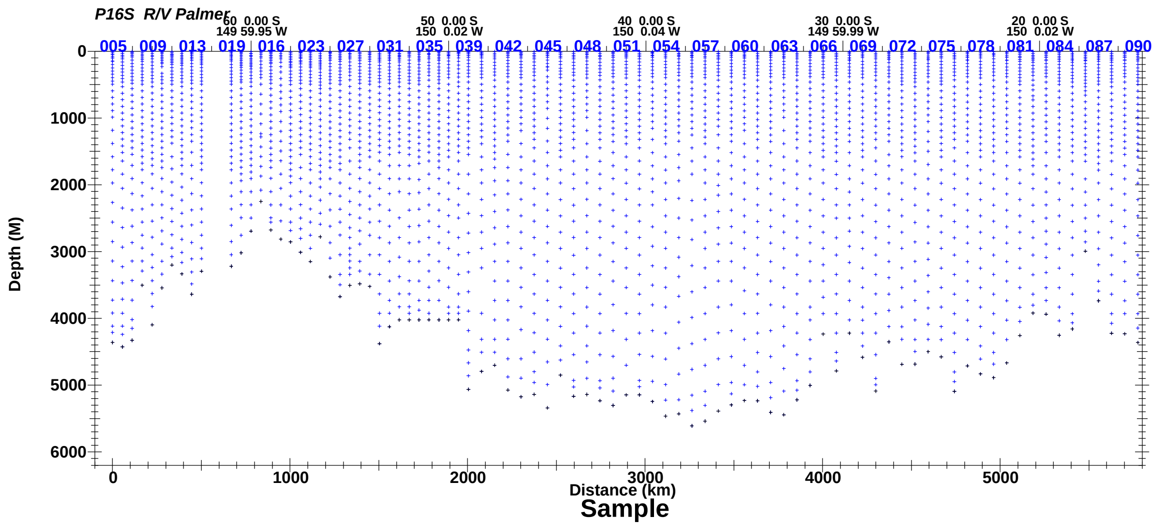

Figure 2.1 P16S Sample Distribution, Stations 5-90

2.1. Water Sampling Package

Rosette/CTD/LADCP/chipod casts were performed with a package consisting of a 36-bottle rosette frame (SIO/STS), a 36-place carousel (SBE32) and 10.0L Bullister-style bottles (SIO/STS) with an absolute volume of 10.4L. Underwater electronic components consisted of a Sea-Bird Electronics SBE9*plus* CTD with dual pumps (SBE5), dual temperature sensors (SBE3*plus*), dual conductivity sensors (SBE4C), dissolved oxygen (SBE43), chlorophyll fluorometer (Seapoint), transmissometer (WET Labs), altimeter (Tritech), reference temperature (SBE35RT), LADCP (RDI) and 3 chipods (JFE).

The CTD was mounted vertically in an SBE CTD cage attached to the bottom of the rosette frame and located to one side of the carousel. The SBE4C conductivity, SBE3*plus* temperature and SBE43 Dissolved oxygen sensors and their respective pumps and tubing were mounted vertically in the CTD cage, as recommended by SBE. Pump exhausts were attached to the CTD cage on the side opposite from the sensors and directed downward. The transmissometer was mounted horizontally, and the fluorometer was mounted vertically near the bottom of the rosette frame. The altimeter was mounted on the inside of the bottom frame ring. The 150 KHz downward-looking Broadband LADCP (RDI) was mounted vertically on one side of the frame between the bottles and the CTD. Its battery pack was located on the opposite side of the frame, mounted on the bottom of the frame. The two upward facing chipods were mounted to the top of the rosette opposite one another. The one downward facing chipod was mounted to the LEFT side of the downward facing LADCP. A chipod pressure-case was mounted next to the downward facing chipod containing the memory storage and battery pack. Rosette images are featured at in the appendix section of the report. Table 2.1.0 shows height of the sensors referenced to the bottom of the frame:

Instrument	Height in cm
Pressure Sensor, inlet to capillary tube	20
Temperature (probe tip at TC duct inlet)	10
SBE35RT (centered between T1/T2 on same plane)	15
Rinko DO	20
Transmissometer	10.5
Fluorometer	11.5
Altimeter	10
LADCP (downward paddle center)	10.5
LADCP (upward paddle center)	188
chipod (downward facing)	3.5
chipod (upward A facing)	213
chipod (upward B facing)	213
Outer-ring (odd #s) bottle centerline	122
Inner-ring (even #s) bottle centerline	112
Reference (Surface Zero tape on wire)	262

Table 2.1.0 Heights referenced to bottom of rosette frame

The rosette system was suspended from a UNOLS-standard three-conductor 0.322" electro-mechanical sea cable. The sea cable was terminated at the beginning of P16S. On station 02 weather events and swells caused a low tension event near recovery resulting in a "bird-nested" wire about 15m above package. A re-termination was performed after sampling.

The RVIB Nathaniel B. Palmer's Markey DESH-5 (starboard Baltic room) winch was used for the first 38 station casts. At the bottom of station cast 031/01 Meghan King, the MT on duty in the Baltic room, noted the exposed outer wire on the winch-drum appeared to have broken or rusted strands. It was later determined the wire was in had not been damaged during the current cruise. ODF electronic technician, John Calderwood, and the ACS deck group agreed rosette/CTD/LADCP/chipod operations would not exceed 4031m wire-out with damaged wire. Stations 31-38 were carried out at most approximately 900m short of the multibeam reported bottom depth. After station 38, optimal weather, swell and wind speed allowed for the package to be transferred to outside winch to complete full profile casts under the starboard A-frame.

Stations 39-90 were completed from Markey DESH-5.5 dual-drum (01 starboard A-frame) winch. Station cast 039/01 was canceled at 300m wire-out after 300 plus missed frames. The package was recovered and winch wire was re-terminated after cast. Station cast 039/02 was terminated after 800m and 700 plus missed frames. Package was recovered and the Markey DESH-5.5 dual-drum (01 starboard A-frame) winch slip-ring was replaced with the Markey DESH-5 (starboard Baltic room) winch slip-ring. Station cast 039/03 signal was improved enough to complete with winch speed held at 30mpm down-cast and 60mpm on up-cast. George Aukon, ASC Electronics Technician, cleaned slip-ring housing, removed extraneous wiring, replaced ground-wire and electrically re-terminated the package. Stations 40-90 continued with a clean signal and without incident using the Markey DESH-5.5 dual-drum (01 starboard A-frame) winch.

The deck watch prepared the rosette 20-30 minutes prior to each cast. The bottles were cocked and all valves, vents and lanyards were checked for proper orientation. Once stopped on station, and the bridge and deck were ready for deployment, the CTD was powered-up and the data acquisition system started from the computer lab. The rosette was unstrapped from the deck and syringes were removed from CTD intake ports. The winch operator was directed by the USAP marine technician (MT) to raise the package.

The rosette deployments took place by either extending the Baltic room squirt-boom or the starboard A-frame outboard and lowering the package quickly into the water. The package was lowered to 10-20 meters depending on position and turbidity of water from the bow thruster. Once the console operator determined that the sensor pumps had turned on and the sensors were stable, the MT was notified and then directed the winch operator to bring the package back to the surface. At the surface, the wire-out reading was re-zeroed before descent.

Most rosette casts were lowered to within 10 meters of the bottom, using the CTD depth multibeam echosounder depth to estimate the distance, and the altimeter and wire-out to direct the final approach. Stations 31-38 were held at 4031m wire-out to prevent the compromised wire from parting and losing the package.

For each up-cast, the winch operator was directed to stop the winch at up to 36 predetermined sampling depths. These standard depths were staggered every station using 3 sampling schemes. To ensure package shed wake had dissipated, the CTD console operator waited 30 seconds prior to tripping sample bottles. An additional 10 seconds elapsed before moving to the next consecutive trip depth, to allow the SBE35RT time to take its readings. The MT directed the package to the surface for the last bottle trip.

Recovering the package at the end of the deployment was essentially the reverse of launching, with the MT directing the winch operator to maneuver the package inboard. The rosette was secured on the deck for sampling. The bottles and rosette were examined before samples were taken, and anything unusual was noted on the sample log.

Each bottle on the rosette had a unique serial number, independent of the bottle position on the rosette. Sampling for specific programs was outlined on sample log sheets prior to cast recovery or at the time of collection.

Routine CTD maintenance included soaking the conductivity and oxygen sensors with fresh deionized water between casts as well as once every 10-20 casts with 1% Triton-X solution to maintain sensor stability and eliminate accumulated bio-films. Rosette maintenance was performed on a regular basis. Valves and o-rings were inspected for leaks. The rosette, CTD and carousel were rinsed with fresh water as part of the routine maintenance.

2.2. Navigation and Bathymetry Data Acquisition

Navigation data were acquired at 1-second intervals from the ship's Seapath 330 GPS located on the foward bow mast. Navigation was recorded with a Linux system beginning 20 March 2014 at 0350z, as the RVIB Nathaniel B. Palmer left the dock in Hobart, Tasmania, AUS. It was noted by Steve Howell that the Seapath 330 was ~23m from the ship's Trimble 20636-00SM navigation used by the LADCP for GPS data located in the center mast of the ship.

Center-beam bathymetric and hull-depth correction data from the Kongsberg EM-122 multibeam echosounder system were acquired by the ship, and fed into the ODF Linux systems through a serial data feed. The ships hull offset of 7.3m was applied to all multibeam data. Bathymetry and navigation data were merged and stored on the ODF systems, and data were made available as displays on the ODF acquisition system during casts. Bottom depths associated with rosette casts were recorded on the Console Logs during deployments.

Multibeam malfunctioned a number of times during the cruise. Extended use of bow thruster on station caused the multibeam to report erratically in most cases. The ship's secondary Seapath failed at the beginning of station 27 until just after bottom of cast. On station 86 the multibeam settings were out of range resulting in readings reported 1000m deeper than CTD depth at bottom of cast. If otherwise not resolved, bathymetry signal loss around cast events were stored as -999 in the system database.

Corrected multibeam center depths are reported for each cast event in the WOCE and Exchange format files.

2.3. CTD Data Acquisition and Rosette Operation

The CTD data acquisition system consisted of an SBE-11*plus* (V2) deck unit and four networked generic PC workstations running CentOS-5.10 Linux. The systems each had a Comtrol Rocketport PCI multiple port serial controller providing 8 additional RS-232 ports. The systems were interconnected through the ship's network. These systems were available for real-time operational and CTD data displays, and provided for CTD and hydrographic data management.

One of the workstations was designated the CTD console and was connected to the CTD deck unit via RS-232. The CTD console provided an interface and operational displays for controlling and monitoring a CTD deployment and closing bottles on the rosette. Another of the workstations was designated the website and database server and maintained the hydrographic database for P16S. Redundant backups were managed automatically.

The SBE9*plus* CTD supplied a standard SBE-format data stream at a data rate of 24 frames/second. The sensors and instruments used during US-Repeat Hydrography (GO-SHIP) P16S, along with pre-cruise laboratory calibration information, are listed below in Table 2.3.0. Copies of the pre-cruise calibration sheets for various sensors are included in Appendix 2.D.

Instrument/Sensor*	Mfr.§/Model	Serial Number	CTD Channel	Stations Used	Pre-Cruise Calibration Date	Pre-Cruise Calibration Facility§
Carousel Water Sampler	SBE32 (36-place)	3213290-0113		1-90		
Reference Temperature	SBE35	3528706-0035		1-90	15-Jan-2014	SIO/STS
CTD	SBE9*plus* SIO	09P41717-0831		1-90		
Pressure	Paroscientific Digiquartz 401K-105	99677	Freq.2	1-90	02-Jan-2014	SIO/STS
Primary Pump Circuit						
Temperature (T1)	SBE3*plus*	03P-5046	Freq.0	1-14	07-Jan-2014	SIO/STS
Temperature (T1)	SBE3*plus*	03P-4953	Freq.0	15-90	07-Jan-2014	SIO/STS
Conductivity (C1)	SBE4C	04-3429	Freq.1	1-90	19-Nov-2013	SBE
Dissolved Oxygen	SBE43	43-1138	Aux2/V2	1-34	07-Dec-2013	SBE
Dissolved Oxygen	SBE43	43-0185	Aux2/V2	35	07-Dec-2013	SBE
Secondary Pump Circuit						
Temperature (T2)	SBE3*plus*	03P-4953	Freq.3	1-14	07-Jan-2014	SIO/STS
Temperature (T2)	SBE3*plus*	03P-5046	Freq.3	15-27	24-Jan-2013	SIO/STS
Temperature (T2)	SBE3*plus*	03P-4213	Freq.3	28-90	02-Jan-2014	SIO/STS
Conductivity (C2)	SBE4C	04-3057	Freq.4	1-14	19-Dec-2013	SBE
Conductivity (C2)	SBE4C	04-2115	Freq.4	15-90	14-Dec-2013	SBE
Dissolved Oxygen	SBE43	43-0185	Aux2/V2	36-85	07-Dec-2013	SBE
Dissolved Oxygen	SBE43	43-1071	Aux2/V2	85-90	19-Dec-2013	SBE
Chlorophyll Fluorometer	Seapoint	SCF2748	Aux1/V0	1-90		Seapoint
Transmissometer (TAMU)	WET Labs C-Star	CST-1636DR	Aux1/V1	1-90	08-Oct-2013	WET Labs
Altimeter (200m range)	Tritech LPA200	221666	Aux3/V4	1		Tritech
Altimeter (200m range)	Tritech LPA200	244480	Aux3/V4	2-90		Tritech
Deck Unit (NBP)	SBE11*plus* V2	11P47914-0768		1-90		SBE

* All sensors belong to SIO/STS, unless otherwise noted.
§ SBE = Sea-Bird Electronics

Table 2.3.0 US-Repeat Hydrography (GO-SHIP) P16S Rosette Underwater Electronics.

An SBE35RT reference temperature sensor was connected to the SBE32 carousel and recorded a temperature for each bottle closure. These temperatures were used as additional CTD calibration checks. The SBE35RT was utilized using Sea-Bird Electronics' recommendations (*http://www.seabird.com*).

The SBE9*plus* CTD was connected to the SBE32 36-place carousel, providing for sea cable operation. Power to the SBE9*plus* CTD and sensors, SBE32 carousel and Simrad altimeter was provided through the sea cable from the SIO/STS SBE11*plus* deck unit in the main lab.

CTD deployments were initiated by the console watch after the ship stopped on station. The acquisition program was started and the deck unit turned on at least 3 minutes prior to package deployment. The watch maintained a console operations log containing a description of each deployment, a record of every attempt to close a bottle and any relevant comments. The deployment and acquisition software presented a short dialog instructing the operator to turn on the deck unit, to examine the on-screen CTD data displays and to notify the deck watch that this was accomplished.

Once the deck watch had deployed the rosette, the winch operator lowered it to 10 meters, or deeper in heavier seas. The CTD sensor pumps were configured with a 5-second start-up delay after detecting seawater conductivities. The console operator checked the CTD data for proper sensor operation and waited for sensors to stabilize, then instructed the winch operator to bring the package to the surface and descend to a specified target depth, based on CTD pressure available on the winch display.

The CTD profiling rate was at most 30m/min to 100m and up to 60m/min deeper than 100m, depending on sea cable tension and sea state. As the package descended toward the target depth, the rate was reduced to 40m/min at 100m from the bottom and again to 20m/min at 50m from the bottom.

The progress of the deployment and CTD data quality were monitored through interactive graphics and operational displays. Bottle trip locations were transcribed onto the console and sample logs. The sample log was used later as an inventory of samples drawn from the bottles. The altimeter channel, CTD depth, winch wire-out and bathymetric depth were all monitored to determine the distance of the package from the bottom, allowing a safe approach to 8-10 meters. A bottom contact switch was attached to the CTD as an additional safety measure requested by the USAP team.

Bottles were closed on the up-cast by operating an on-screen control. The expected CTD pressure was reported to the winch operator for every bottle trip. Bottles were tripped 30-40 seconds after the package stopped to allow the rosette wake to dissipate and the bottles to flush. The winch operator was instructed to proceed to the next bottle stop no sooner than 10 seconds after closing bottles to ensure that stable CTD data were associated with the trip and to allow the SBE35RT temperature sensor to measure bottle trip temperature.

It was necessary at some stations in higher sea states to close shallower bottles (normally only the shallowest bottle) "on the fly" due to the need to keep tension on the CTD cable. Such closures were always noted on the CTD Console Log Sheet.

The package was directed to the surface by the deck for the last bottle closure, then the package was brought on deck. The console operator terminated the data acquisition, turned off the deck unit after SBE35 data had been recovered and assisted with rosette sampling.

2.4. CTD Cable Tension on Deep Casts

As US-Repeat Hydrography (GO-SHIP) P16S progressed into deeper and deeper water, significant science operations issues hinged on actual CTD cable tension and cast time performance on very deep CTD casts (maximum cast depths deeper than 5000 meters). Although all the U.S. work for this program since it began in 2003 had transpired without CTD cable parting or functionality loss, new UNOLS/NSF cable tension rules went into effect shortly before this cruise. It was thought pre-cruise, by some at the operator and agency level, that the maximum CTD cable tensions on deep casts on this cruise would exceed the new rules. Two questions in particular loomed in planning: (1) under what conditions would CTD cable tensions exceed 5000 lbs., and (2) what would be the impacts on P16S station times and operations due to efforts to keep maximum observed CTD cable tension less than 5000 lbs.? The cruise had a waiver permitting CTD operations to continue under some conditions if higher CTD cable tensions were observed, but there was general concurrence that sustained P16S CTD operations with cable tensions above 5000 lbs. should be avoided if possible.

All precautions taken to adhere to "Appendix B: UNOLS Overboard Handling Systems Design Standards" by ACS and the science party. It is important to note that most 5000-6000 meter casts during P16S took place in good weather (winds 10-20 knots; low swell) and at all times all precautions were observed to maintain winch wire safety practices. That being said, tension spikes were noted under unusual circumstances. On station cast 010/01 a tension spike of 6965lbs was recorded just before recovery of the package at about 9m wire out. Sea state and ship motion did not explain the relatively high tension spike near the surface. Wire-out and angle of package with swell, documented damage to one of the upward-facing chipods and a slightly bent rosette indicate contact with the ship may have caused this particular tension spike. In addition, during the first 38 station casts, increased ship motion normally associated with high tension events, there were several casts where cable tensions approached 5000 lbs but did not exceed 5000 lbs. While on the Markey DESH-5 (starboard Baltic room) winch , under high sea state conditions winch speeds were held at 20 meters per minute until well over 500m and 40 meters per minute until well over 1000m depth. However, under similar conditions with maximum cable deployed and despite lower haul-up speeds, the tension(s) reported by the Markey DESH-5.5 dual-drum (01 starboard A-frame) winch to regularly exceeded 5000lbs. Tension readings from the package during recovery also indicated that the calibration for the Markey DESH-5.5 dual-drum (01 starboard A-frame) winch was not accurate. In such circumstances excessive tensions were unavoidable despite best efforts.

2.5. CTD Data Processing

Shipboard CTD data processing was performed automatically during and after each deployment using SIO/STS CTD processing software v.5.1.6.

During acquisition, the raw CTD data were converted to engineering units, filtered, response-corrected, calibrated and decimated to a more manageable 0.5-second time series. Pre-cruise laboratory calibrations for pressure, temperature and conductivity were also applied at this time. The 0.5-second time series data were used for real-time graphics during deployments, and were the source for CTD pressure and temperature data associated with each rosette bottle. Both the raw 24 Hz data and the 0.5-second time series were stored for subsequent processing. During the deployment, the raw data were backed up to another Linux workstation every 5 minutes.

At the completion of a deployment a sequence of processing steps was performed automatically. The 0.5-second time series data were checked for consistency, clean sensor response and calibration shifts. A 2-decibar pressure series was generated from the down cast data. The pressure-series data were used by the web service for parameter plots, sections and CTD data distribution. Time-series data were also available for distribution through the website.

CTD data were routinely examined for sensor problems, calibration shifts and deployment or operational problems. On-deck pressure values were monitored at the start and end of each cast for potential drift. Alignment of temperature and conductivity sensor data (in addition to the default 0.073-second conductivity "advance" applied by the SBE11*plus* deck unit) was optimized for each pump/sensor combination to minimize salinity spiking, using data from multiple casts of various depths after acquisition. If the pressure offset or conductivity "advance" values were altered after data acquisition, the CTD data were re-averaged from the 24Hz stored data.

The primary and secondary temperature sensors (SBE3*plus*) were compared to each other and to the SBE35 temperature sensor. CTD conductivity sensors (SBE4C) were compared to each other, then calibrated by examining differences between CTD and check-sample conductivity values. CTD dissolved oxygen sensor data were calibrated to check-sample data.

As bottle salinity and oxygen results became available, they were used to refine shipboard conductivity and oxygen sensor calibrations. Theta-Salinity and theta-O_2 comparisons were made between down and up casts as well as between groups of adjacent deployments.

A total of 90 casts were made using the 36-place rosette/CTD/LADCP/chipod rosette. Further elaboration of CTD procedures specific to this cruise are found in the next section.

2.6. CTD Acquisition and Data Processing Details

Sta/Cast	Comment
Start	Full (electrical + mechanical) retermination of both wires.
1/2	No test cast. Altimeter did not come on. Pumps were not operating until 3200db. Primary conductivity signal reading -9 until 3200db. Bottle 35 tripped out of the water. After cast replaced primary conductivity cable, secondary pump and altimeter. Knudsen and multibeam are unstable due to bow thruster holding station. Signal drops skewed data which required fitting temperature and conductivity specific to this station. Used secondary sensors for reporting. Numerous pump shut-offs during upcast affected oxygen signal, very noisy.
4/2	Bottom contact switch interferes with pump status on deck. Once package was lifted off-deck pump status on deck-unit read 0010. Package came partially out of water at start of cast. Conductivity stabilized late on down cast. Chose start time that coinsides with approximately 12db.
5/3	Primary temperature cut out at 2836-2834db on upcast. Replaced primary temperature cable after cast. Signal drops skewed data which required fitting temperature and conductivity specific to this station. Used secondary sensors for reporting.
10/1	Poor weather conditions, high seas state caused deployment tensions near 0. On recovery tensions spiked to 6965lbs. Proximity to ship, wire out 9m, lack of ship heave or roll to cause such a spike indicate the package may have hit the ship. This caused a change in winch protocol. MTs direct surface deployment to 10m or 20m. In high seas package will not come to surface for start of cast. Interpolating best near surface value to surface.
13/1	Down casts started at 9.4m due to poor weather condition (wind speed & swell). Surface bottle at 5db will not match up with downcast. Advised co-chief, start of downcast should be where we trip last bottle.
14/1	Replaced secondary conductivity after cast due to large drift. Swapped more stable secondary temperature for primary temperature.

Sta/Cast	Comment
15/1	Station casts 15-21 TC duct disconnected from primary line. Noisy high gradient region in primary sensors used secondary sensors for reporting.
20/1	Improved sea state allows surface start of cast.
21/1	TC duct found disconnected on primary sensors. Replaced screw that held TC duct in place. Secondary sensors used in reporting for stations 15-21.
25/1	Bottom contact switch was replaced. Appears to be operating correctly now. Deck-unit turned off before SBE35 data could finish writing file. Next cast over wrote last 12 bottle trips SBE35 data.
26/1	Secondary sensors dropped out from 900-1960db upcast. Temperature cable replaced after cast.
27/1	Secondary sensors dropped out from 730-2140db upcast. Replaced primary temperature sensor after cast. Multibeam dropped out from beginning of cast until just after bottom approach.
31/1	ASC MT noted broken wire strands on winch wire at approximately 4100m wire out.
32/1	Station casts 32-38 stopped at 4031m wire-out.
33/1	Winch LCI90 screen stopped working at 1800m. Continued down to 660m then came to full stop. LCI90 restarted and cast continued. On downcast spiking was noted again in primary sigma theta and salinity. Replaced primary pump after cast. Used secondary sensors for reporting.
34/1	Up-cast O2 and salinity signals very noisy on primary plumb line. Sensors back to normal by 2650db. Secondary good. Used secondary sensors for reporting. Flushed plumb lines with Triton-X, replaced pump cable and oxygen cable after cast.
35/1	O2 sensor looks bad beyond 3500m on down cast. O2 and primary good signal from 2800m upcast to surface. Sensors back to normal by 2650db. Secondary good. Used secondary sensors for reporting.
36/1	Replaced oxygen sensor and cable before cast. Downcast O2 and primary clean signal. Upcast very noisy. Spiking has stopped.
37/1	Moved O2 sensor to secondary plumb line and replaced primary pump. Signal improved both up and down cast. Moved secondary sensors to primary reporting signal.
39/1	Moved Rosette out of Baltic room to starboard A-frame. Using waterfall winch instead of Baltic room winch. Initial cast lost around 300 frames in 300m. Canceled cast and recovered package. Cut off some wire and reterminated package after cast. Cast not reported.
39/2	600 frames lost in 350m. Canceled cast and recovered package. Replaced slip-ring with Baltic-room-winch slip-ring.
39/3	Missed frames started at about 500m and continued through out cast. Not as many as on first 2 casts. Frames missed increased as winch speed increased. Resulting in the downcast carried out at 30m/min and upcast at increased speeds. All bottle stops observed for good data. Used primary sensor for reporting this cast. Signal drops skewed data which required fitting temperature and conductivity specific to this station. Sampling outside after package repositioned under starboard a-frame. Heavy rain and wind noted for outside sampling under tarp.
40/2	Before cast re-termination, removed extraneous wires from slip-ring housing, checked/fixed grounding, cleaned slip-ring, and fixed meter wheel.
79/1	88 missed frames on down-cast. Signals despiked and coded.
80/3	388 missed frames from 1200db to bottom of cast. Package wire re-terminated after cast. Signals despiked and coded.
85/1	Odd SBE43 DO sensor trace. Replaced sensor and cable after cast.

2.7. CTD Sensor Laboratory Calibrations

Laboratory calibrations of the CTD pressure, temperature, conductivity and dissolved oxygen sensors were performed prior to US-Repeat Hydrography (GO-SHIP) P16S. The sensors and calibration dates are listed in Table 2.3.0. Copies of the calibration sheets for Pressure, Temperature, Conductivity, and Dissolved Oxygen sensors, as well as factory and deck calibrations for the TAMU Transmissometer, are in Appendix 2.D.

2.8. CTD Shipboard Calibration Procedures

One SBE9*plus* CTD was used for all rosette/CTD/LADCP/chipod casts during US-Repeat Hydrography (GO-SHIP) P16S: S/N 831. The CTDs were deployed with all sensors and pumps aligned vertically, as recommended by SBE.

The SBE35RT Digital Reversing Thermometer (S/N 3528706-0035) served as an independent calibration check for T1 and T2 sensors. *In situ* salinity and dissolved O_2 check samples collected during each cast were used to calibrate the conductivity and dissolved O_2 sensors.

2.8.1. CTD Pressure

The Paroscientific Digiquartz pressure transducer (S/N 831-99677) was calibrated in Jan 2014 at the SIO/STS Calibration Facility. The calibration coefficients provided on the reports were used to convert frequencies to pressure. The SIO/STS pressure calibration coefficients already incorporate the slope and offset term usually provided by Paroscientific.

The initial deck readings for pressure indicated a pressure offset was needed, typically because CTDs are calibrated horizontally but deployed vertically. The optimal offset was found to be -0.2 decibars.

Residual pressure offsets (the difference between the first and last submerged pressures, after the offset corrections) varied from -0.4 to 0.0 decibars. Pre- and post-cast on-deck/out-of-water pressure offsets varied from 0.7 to 0.0 decibars before the casts, and 0.6 to 0.0 decibars after the casts. The in/out pressures within a cast were very consistent.

2.8.2. CTD Temperature

Two temperature sensor changes were made through out P16S. After the first 14 stations, the primary SBE3*plus* temperature sensor (T1: 03P-5046) was traded with the secondary temperature sensor (T2: 03P-4953). The secondary sensor was replaced once again after station 27 with (T2: 03P-4213). Calibration coefficients derived from the pre-cruise calibrations, plus shipboard temperature corrections determined during the cruise, were applied to raw primary and secondary sensor data during each cast.

A single SBE35RT (3528706-0035) was used as a tertiary temperature check. It was located equidistant between T1 and T2 with the sensing element aligned in a plane with the T1 and T2 sensing elements. The SBE35RT Digital Reversing Thermometer is an internally-recording temperature sensor that operates independently of the CTD. It is triggered by the SBE32 carousel in response to a bottle closure. According to the manufacturer's specifications, the typical stability is 0.001°C/year. The SBE35RT on P16S was set to internally average over 5 sampling cycles (a total of 6.6 seconds).

Two independent metrics of calibration accuracy were examined. At each bottle closure, the primary and secondary temperature were compared with each other and with the SBE35RT temperatures.

Temperature sensors were first examined for drift with time, using the more stable SBE35RT at a smaller range of deeper trip levels (2000-5000 decibars).

Station 1, the pumps shut off on the downcast; this skewed temperatures and required an independent fit for T1 and T2. Similar circumstances occurred on station 5. Both station 1 and 5 have the same initial second order fit with respect to pressure, before they were incorporated with other stations for an over-all fit. The replacement of temperature sensors and plumbing circulatory issues required alternating primary and secondary sensors for reporting. Therefore the temperature sensors were grouped as follows for fitting purposes: Stations 1-14, 15-21, 22-27, 28-32 and 33-90. A second order fit with respect to pressure and a first order fit with respect to temperature were applied to each station grouping in both T1 and T2. Finally, a time-dependent drifts in temperature sensors were noted and corrected for deep-data (2000-5000 decibars) in all stations.

The final corrections for T1 temperature data reported on P16S are summarized in Appendix 2.A. Corrections made to both temperatures had the form:

$$T_{ITS90} = T + tp2 * P^2 + tp1 * P + t1 * T + t0$$

Residual temperature differences after correction are shown in figures 2.8.2.0 through 2.8.2.8.

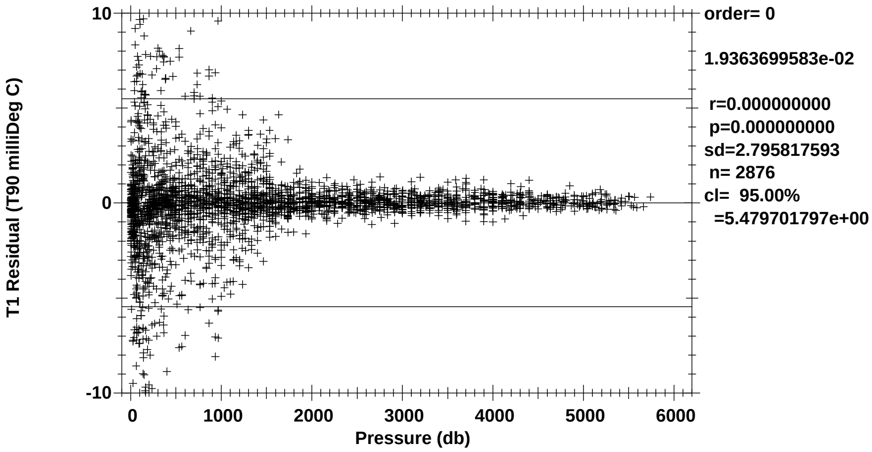

Figure 2.8.2.0 SBE35RT-T1 by pressure (-0.01°C≤T1 – T2≤0.01°C).

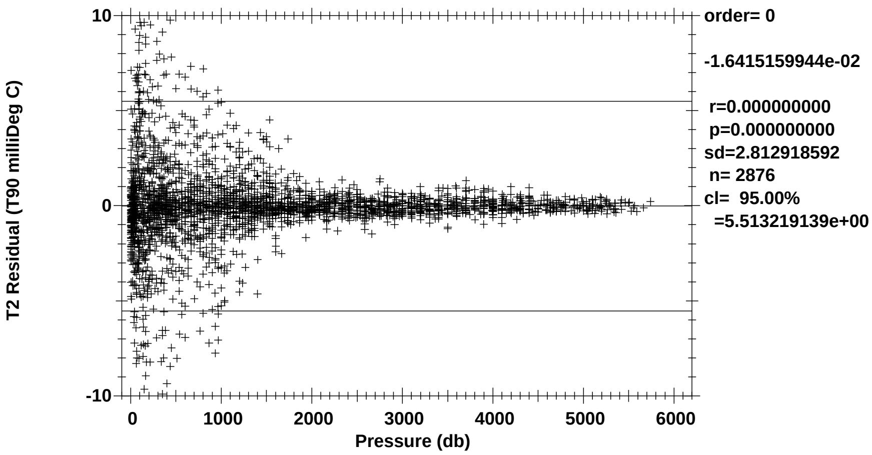

Figure 2.8.2.1 SBE35RT-T2 by pressure (-0.01°C≤T1 – T2≤0.01°C).

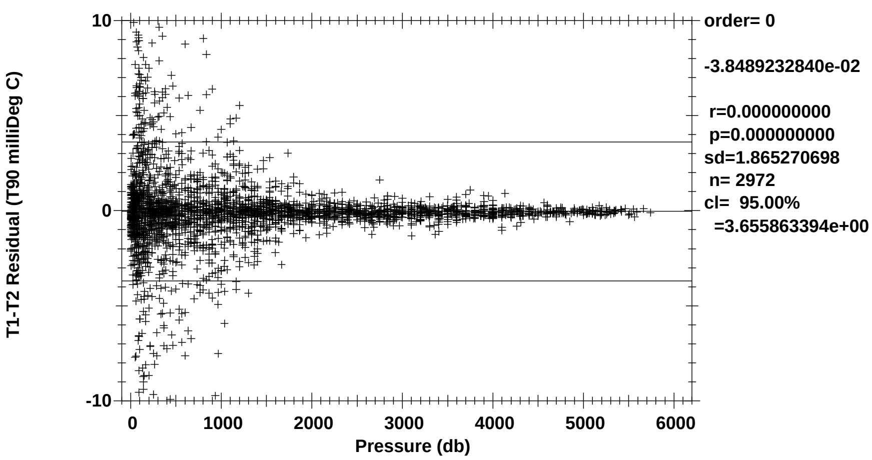

Figure 2.8.2.2 T1-T2 by pressure (-0.01°C≤T1 – T2≤0.01°C).

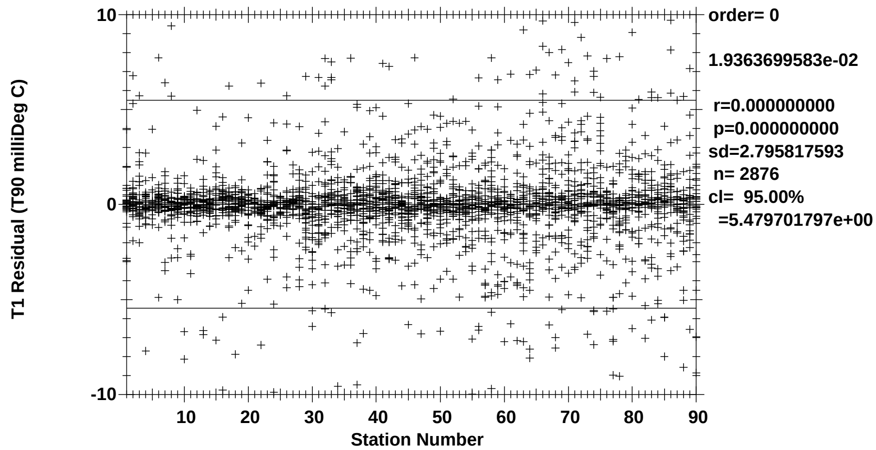

Figure 2.8.2.3 SBE35RT-T1 by station (-0.01°C≤T1 – T2≤0.01°C).

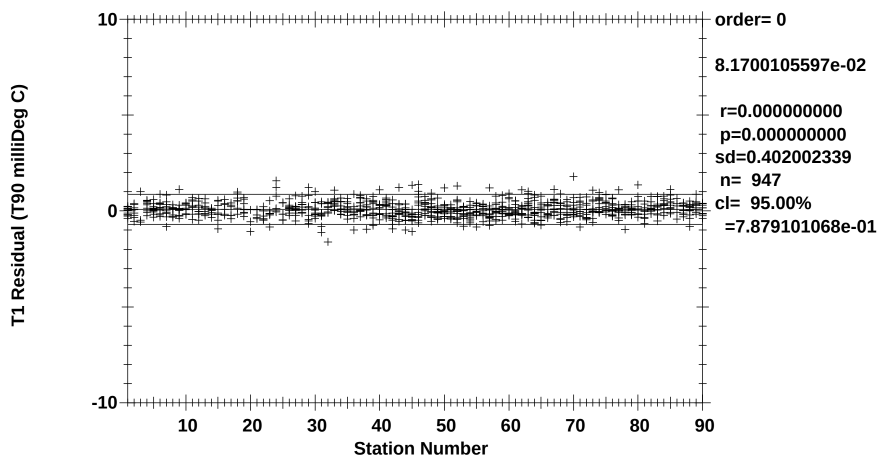

Figure 2.8.2.4 Deep SBE35RT-T1 by station (Pressure >= 1800 dbars).

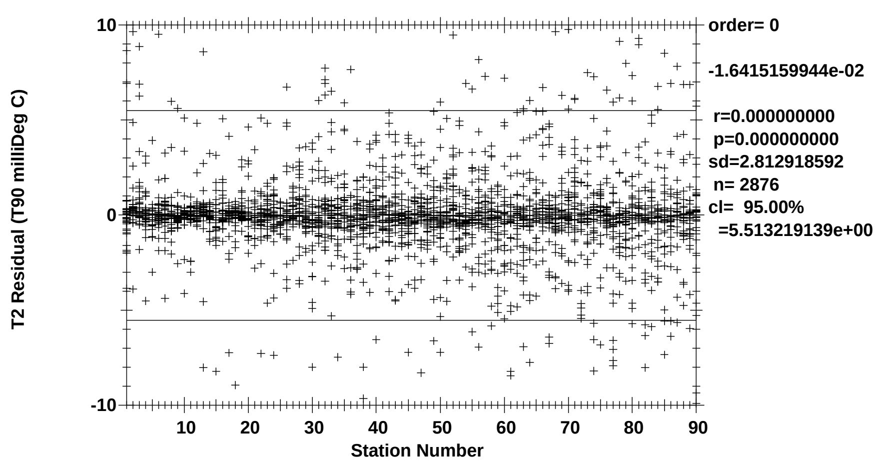

Figure 2.8.2.5 SBE35RT-T2 by station (-0.01°C≤T1 – T2≤0.01°C).

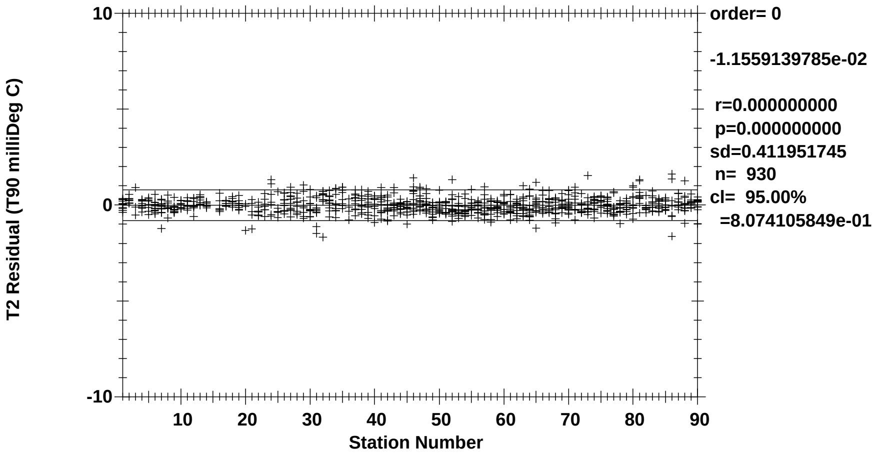

Figure 2.8.2.6 Deep SBE35RT-T2 by station (Pressure >= 1800 dbars).

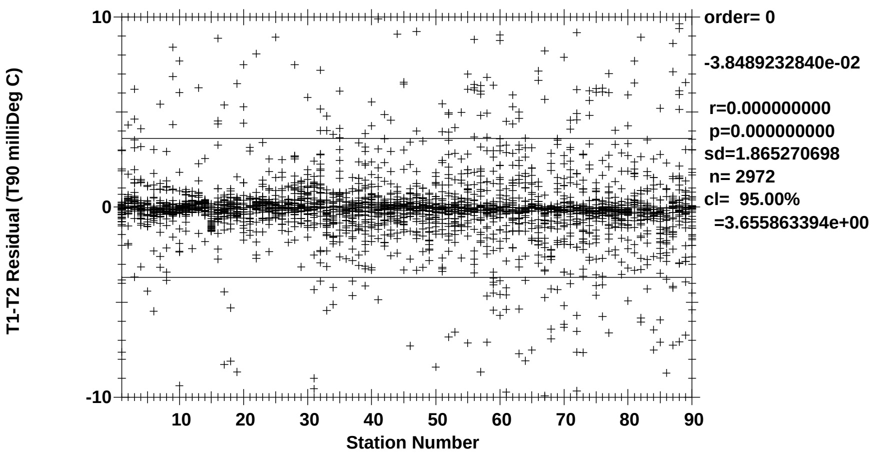

Figure 2.8.2.7 T1-T2 by station (-0.01°C≤T1 – T2≤0.01°C).

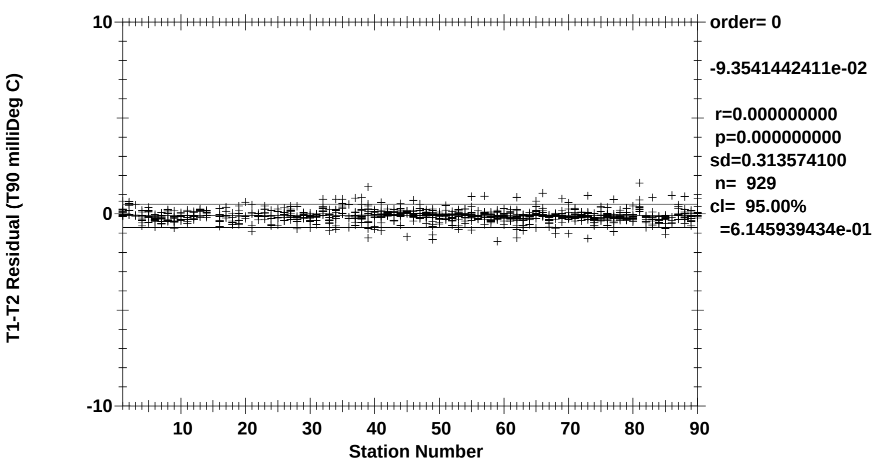

Figure 2.8.2.8 Deep T1-T2 by station (Pressure >= 1800 dbars).

The 95% confidence limit for deep temperature residuals (where pressure > 1800 db) is ±0.000788°C with a standard deviation of ±0.000402°C for SBE35RT-T1 and ±0.000615°C with a standard deviation of ±0.000313°C for T1-T2.

2.8.3. CTD Conductivity

A single SBE4C primary conductivity sensor (C1/04-3429) and two secondary conductivity sensors were used during P16S. Stations 1-14 the secondary sensor was C2:04-3057 and stations 15-90 C2:04-2155. Calibration coefficients derived from the pre-cruise calibrations were applied to convert raw frequencies to conductivity. Shipboard conductivity corrections, determined during the cruise, were applied to primary and secondary conductivity data for each cast.

Corrections for both CTD temperature sensors were finalized before analyzing conductivity differences. Two independent metrics of calibration accuracy were examined. At each bottle closure, the primary and secondary conductivity were compared with each other. Each sensor was also compared to conductivity calculated from check sample salinities using CTD pressure and temperature.

The differences between primary and secondary temperature sensors were used as filtering criteria for all conductivity fits to reduce the contamination of conductivity comparisons by package wake. The coherence of this relationship is shown in figure 2.8.3.0.

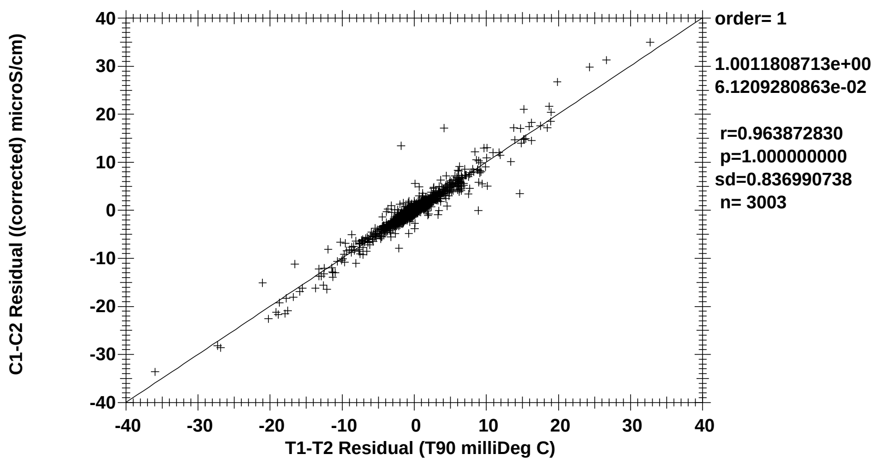

Figure 2.8.3.0 Coherence of conductivity differences as a function of temperature differences.

Uncorrected conductivity comparisons are shown in figures 2.8.3.1 through 2.8.3.3.

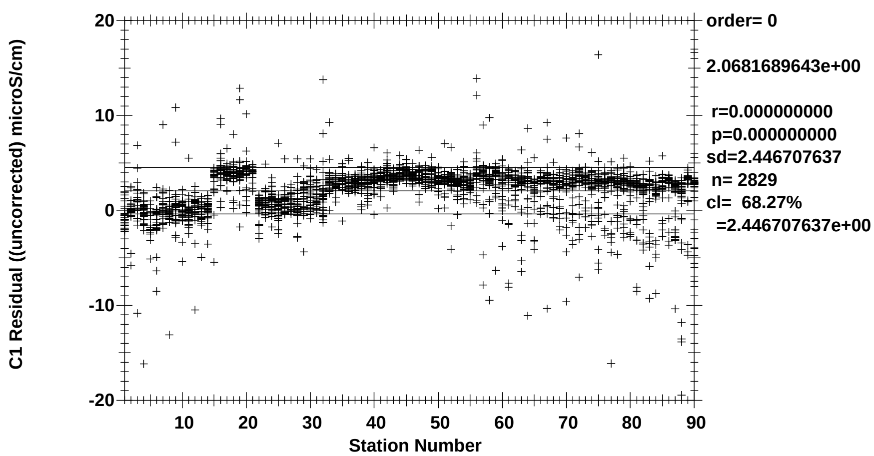

Figure 2.8.3.1 Uncorrected $C_{Bottle} - C1$ by station (-0.01°C≤T1 – T2≤0.01°C).

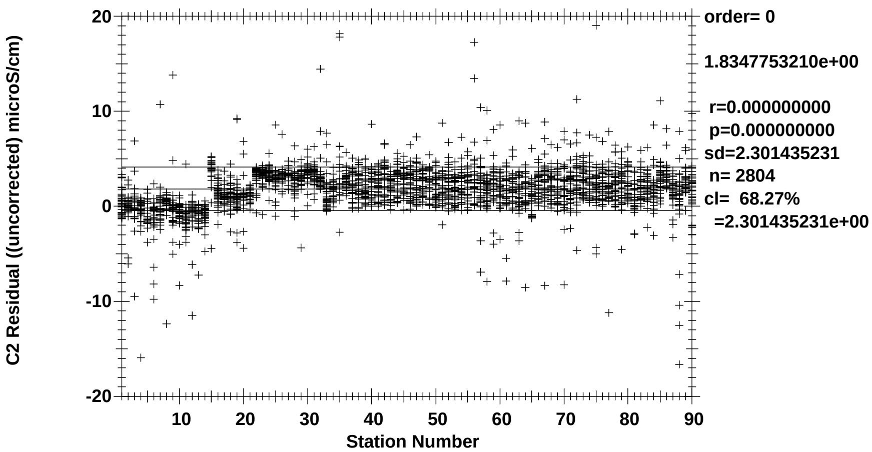

Figure 2.8.3.2 Uncorrected $C_{Bottle} - C2$ by station (-0.01°C≤T1 – T2≤0.01°C).

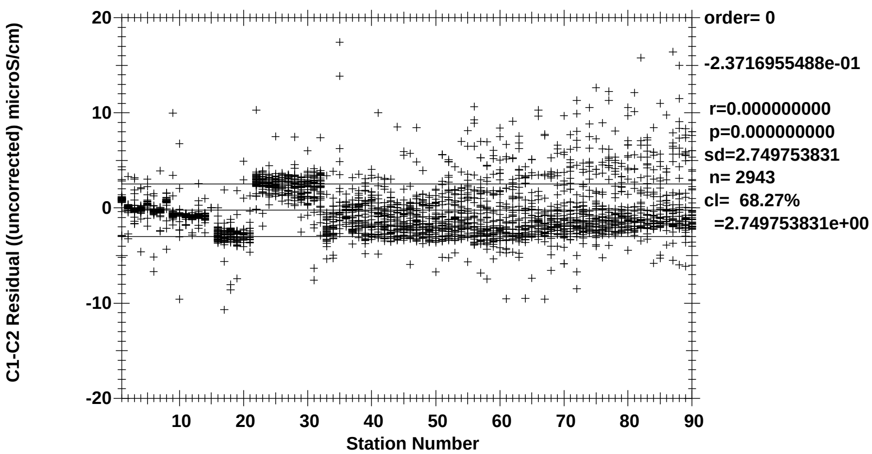

Figure 2.8.3.3 Uncorrected C1 – C2 by station (-0.01°C≤T1 – T2≤0.01°C).

Offsets for each C sensor were evaluated for drift with time using $C_{Bottle} - C_{CTD}$ differences from deeper pressures (more than 1800 decibars). C1 and both C2 offsets had a steady, slow shift with time

On station 1 the pumps shut off on the downcast which skewed temperatures and conductivity. Similar circumstances occurred on station 5. Both station 1 and 5 have the same initial second order fit with respect to pressure. After which both stations 1 and 5 were incorporated with other stations for an over-all fit. The replacement of conductivity sensors and plumbing circulatory issues required alternating primary and secondary sensors for reporting. Therefore the conductivity sensors were grouped as follows for fitting purposes: Stations 1-14, 15-21, 22-27, 28-32 and 33-90. A second order fit with respect to pressure was applied to each station grouping. Second order fit with respect to temperature was applied to stations 2-4, 6-14 and 33-90. A first order fit with respect to temperature only was applied to C1 and C2 for stations 15-21. A second order fit with respect to conductivity was applied to stations 33-90. First order fit with respect to conductivity only was applied to C1 and C2 for stations 2-4, 6-21. Finally, a time-dependent drifts in conductivity sensors were noted and corrected for deep-data (2000-5000 decibars) for all stations.

The residual conductivity differences after correction are shown in figures 2.8.3.4 through 2.8.3.15.

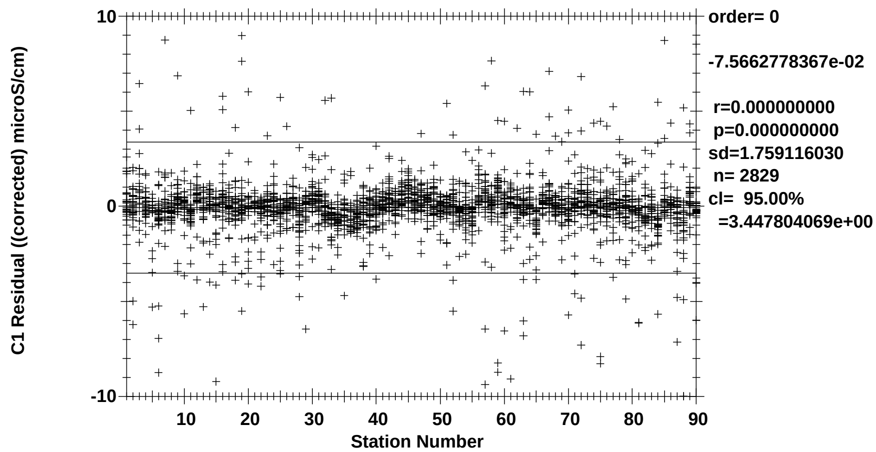

Figure 2.8.3.4 Corrected C_{Bottle} – C1 by station (-0.01°C≤T1 – T2≤0.01°C).

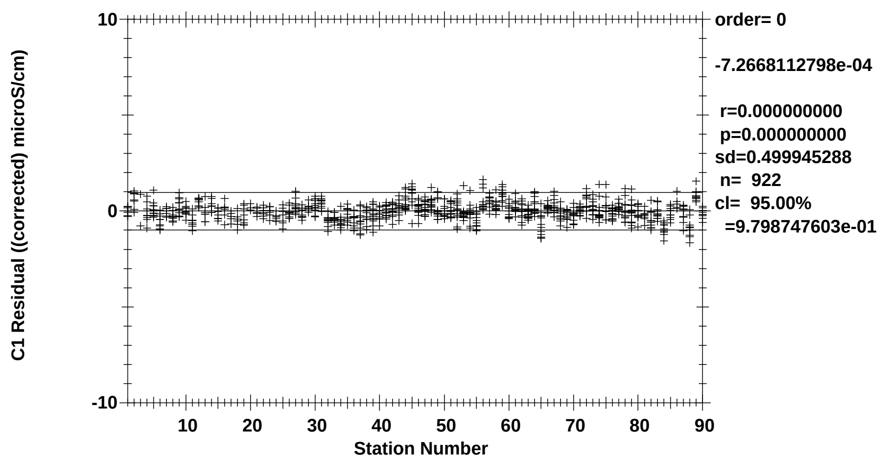

Figure 2.8.3.5 Deep Corrected C_{Bottle} – C1 by station (Pressure >= 1800 dbars).

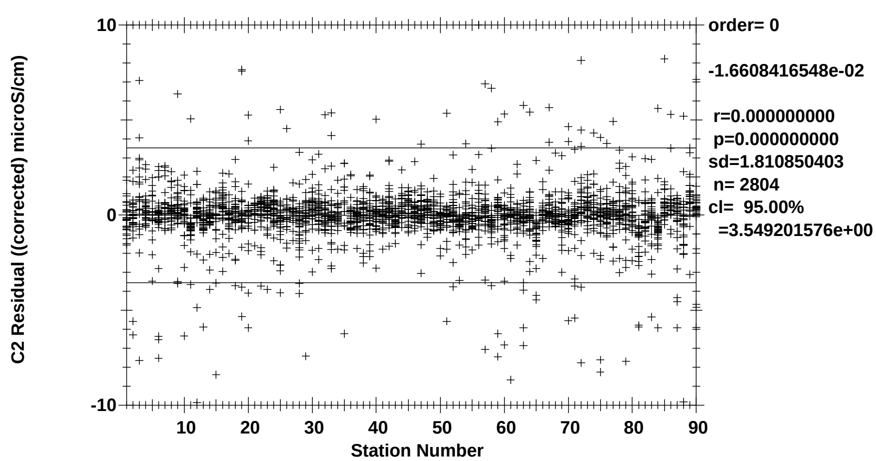

Figure 2.8.3.6 Corrected C_{Bottle} – C2 by station (-0.01°C≤T1 – T2≤0.01°C).

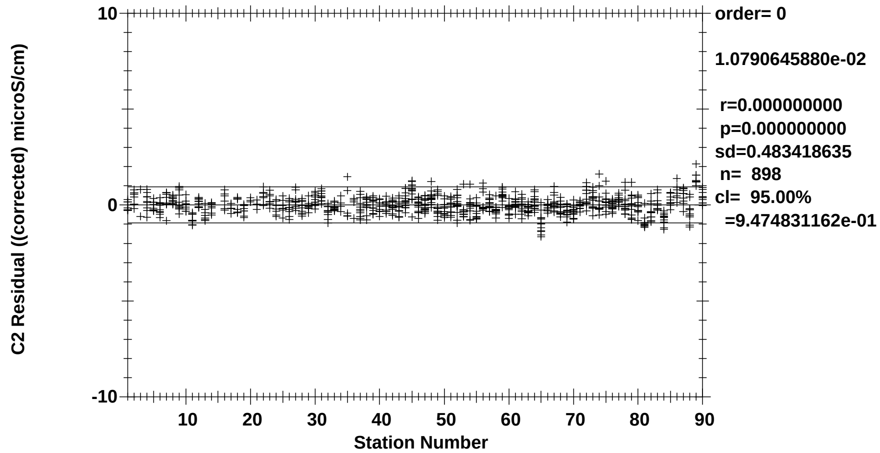

Figure 2.8.3.7 Deep Corrected C_{Bottle} – C2 by station (Pressure >= 1800 dbars).

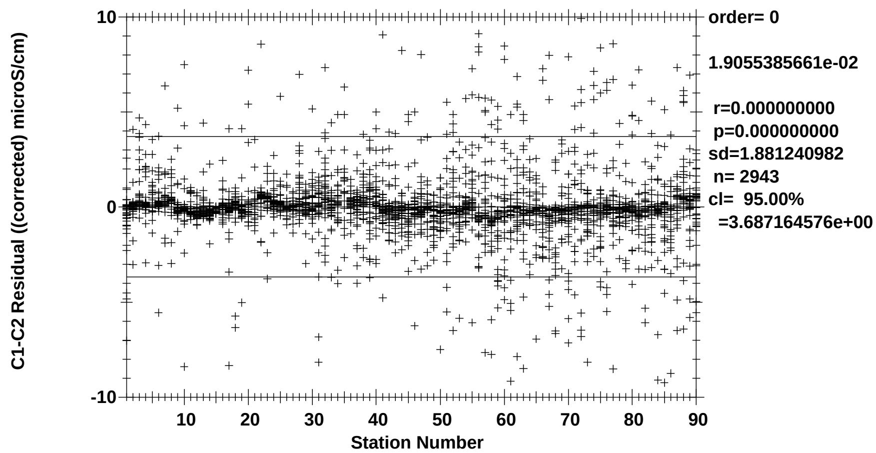

Figure 2.8.3.8 Corrected C1 – C2 by station (-0.01°C≤T1 – T2≤0.01°C).

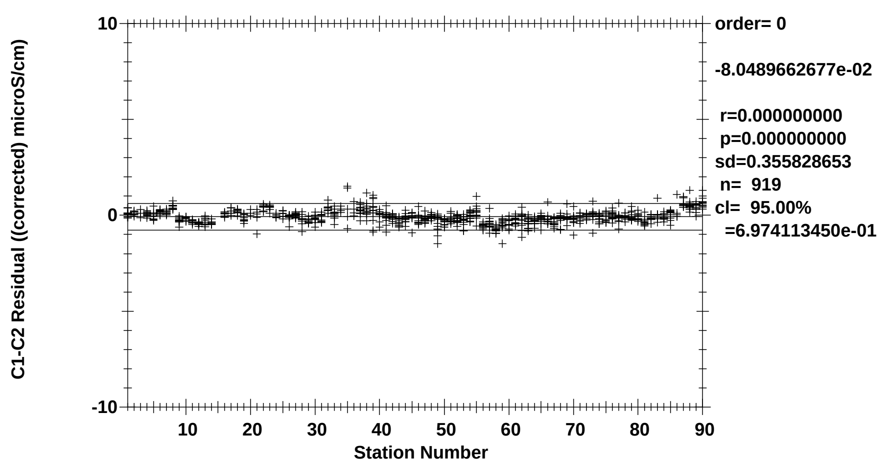

Figure 2.8.3.9 Deep Corrected C1 – C2 by station (Pressure >= 1800 dbars).

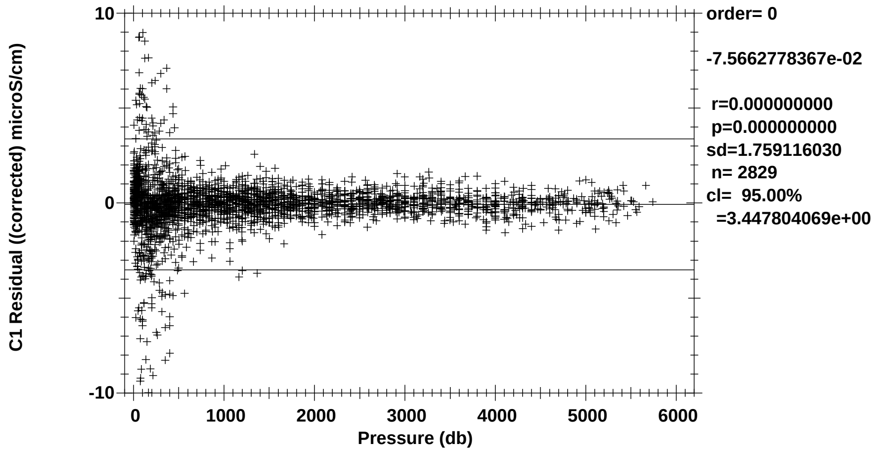

Figure 2.8.3.10 Corrected C_{Bottle} – C1 by pressure (-0.01°C≤T1 – T2≤0.01°C).

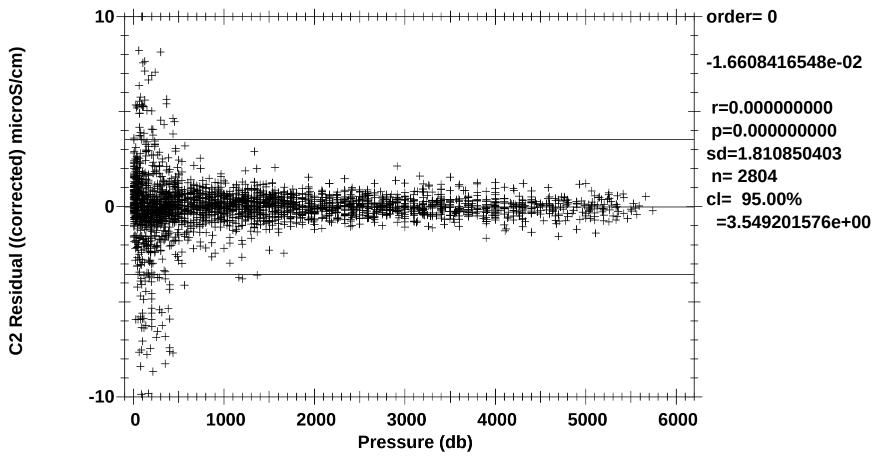

Figure 2.8.3.11 Corrected C_{Bottle} – C2 by pressure (-0.01°C≤T1 – T2≤0.01°C).

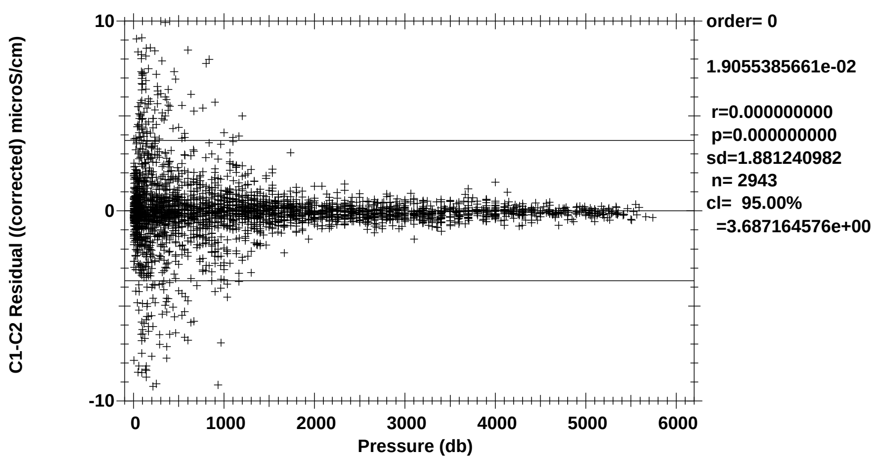

Figure 2.8.3.12 Corrected C1 – C2 by pressure (-0.01°C≤T1 – T2≤0.01°C).

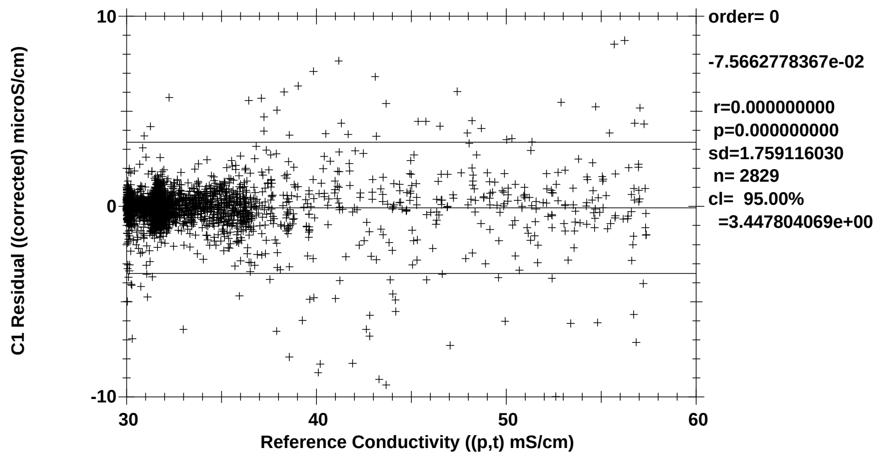

Figure 2.8.3.13 Corrected C_{Bottle} – C1 by conductivity (-0.01°C≤T1 – T2≤0.01°C).

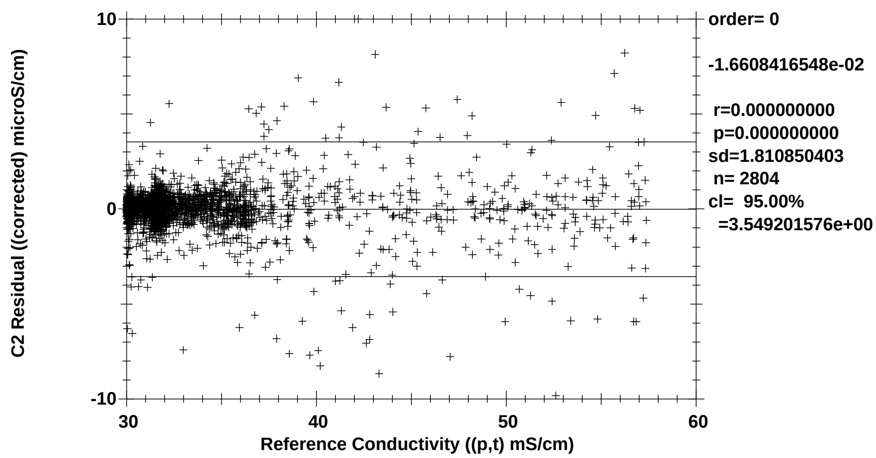

Figure 2.8.3.14 Corrected C_{Bottle} – C2 by conductivity (-0.01°C≤T1 – T2≤0.01°C).

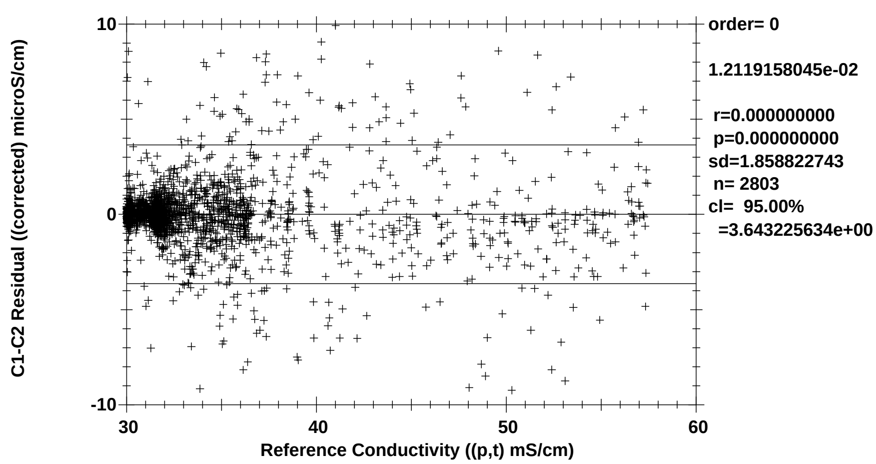

Figure 2.8.3.15 Corrected C1 – C2 by conductivity (-0.01°C≤T1 – T2≤0.01°C).

The final corrections for the sensors used on P16S are detailed in Appendix 2.A. Corrections made to each conductivity sensor had the form:

$$C_{cor} = C + cp2 * P^2 + cp1 * P + ct2 * T^2 + ct1 * T + c2 * C^2 + c1 * C + c0$$

Salinity residuals after applying shipboard P/T/C corrections are summarized in figures 2.8.3.16 through 2.8.3.18. Only CTD and bottle salinity data with "acceptable" quality codes are included in the differences.

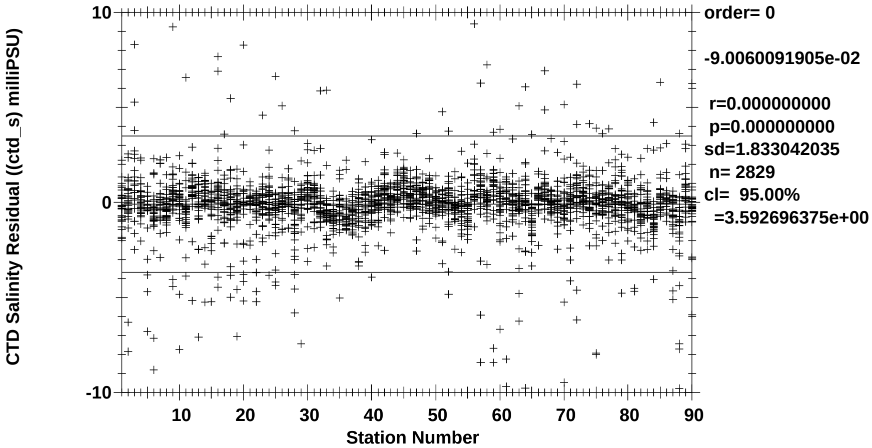

Figure 2.8.3.16 Salinity residuals by station (-0.01°C≤T1 – T2≤0.01°C).

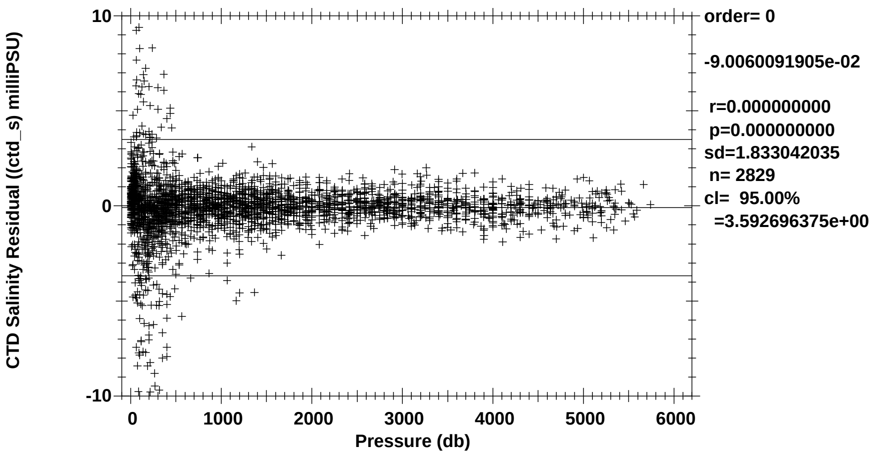

Figure 2.8.3.17 Salinity residuals by pressure (-0.01°C≤T1 – T2≤0.01°C).

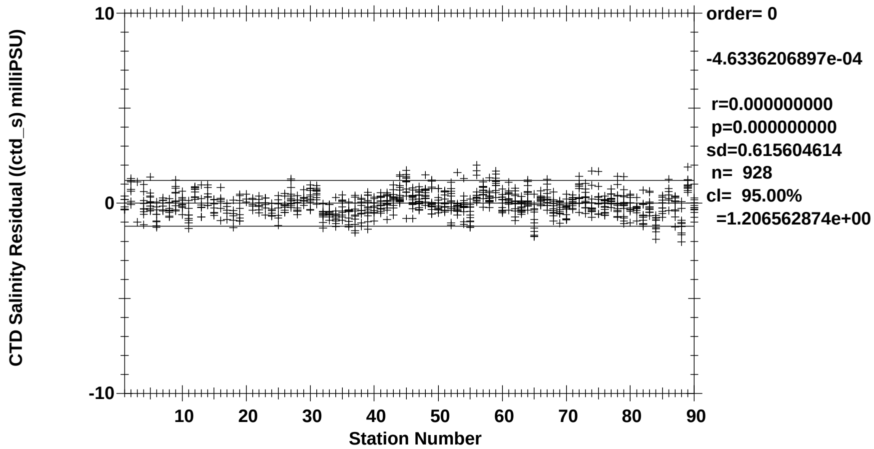

Figure 2.8.3.18 Deep Salinity residuals by station (Pressure >= 1800 dbars).

Figures 2.8.3.17 and 2.8.3.18 represent estimates of the salinity accuracy and precision of P16S. The 95% confidence limits are ±0.00125 PSU with a standard deviation of ±0.000616 PSU relative to bottle salinities for deep salinities, where pressure is more than 1800 decibars.

2.8.4. CTD Dissolved Oxygen

Three SBE43 dissolved O_2 sensors (DO/43-1138 for stations 1-35, DO/43-0185 for stations 36-85, and DO/43-1071 for stations 86-90) were used during P16S. The dissolved O_2 sensor was plumbed into the primary T1/C1 pump circuit after C1 for stations 1-36, and into the secondary T2/C2 pump circuit after C2 for stations 37-90.

Pressure-series data were fit for stations 1-35, and time-series down and up cast data were used together for stations 36-90 to determine the fits. Time-series fitting is a more recent addition to fitting options for the program. Only station 1 was an up cast pressure-series; the rest were down casts.

The SBE43 DO sensors were calibrated to dissolved O_2 bottle samples taken at bottle stops by matching the down cast CTD data to the up cast trip locations on isopycnal surfaces, then calculating CTD dissolved O_2 using a DO sensor response model and minimizing the residual differences from the bottle samples. A non-linear least-squares fitting procedure was used to minimize the residuals and to determine sensor model coefficients, and was accomplished in three stages.

The time constants for the lagged terms in the model were first determined for the sensors. These time constants can be sensor-specific; but the same ones were used for each sensor on this cruise. Next, casts were fit individually to bottle sample data. Consecutive casts were compared on plots of Theta vs O_2 to verify consistency over the course of P16S.

At the end of the cruise, standard and blank values for bottle oxygen data were smoothed for stations 1-67, and the bottle oxygen values were recalculated. Stations 68-90 bottle oxygens were intentionally not smoothed due to a 5+°C change over the last few days of the cruise. The changes to bottle oxygen values were less than 0.01 ml/l for most stations. CTD O_2 data were re-calibrated to the smoothed bottle values at the end of the cruise, but only where the bottle values changed by more than 0.005 ml/l.

Final CTD dissolved O_2 residuals are shown in figures 2.8.4.0-2.8.4.2.

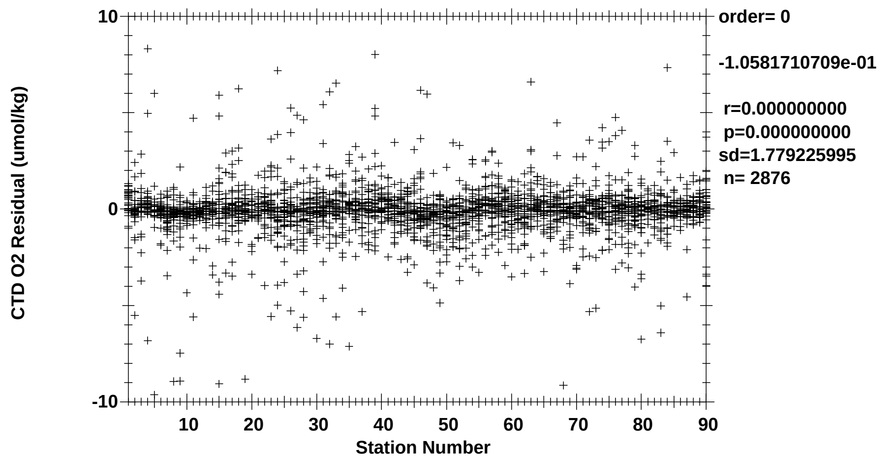

Figure 2.8.4.0 O_2 residuals by station (-0.01°C≤T1 − T2≤0.01°C).

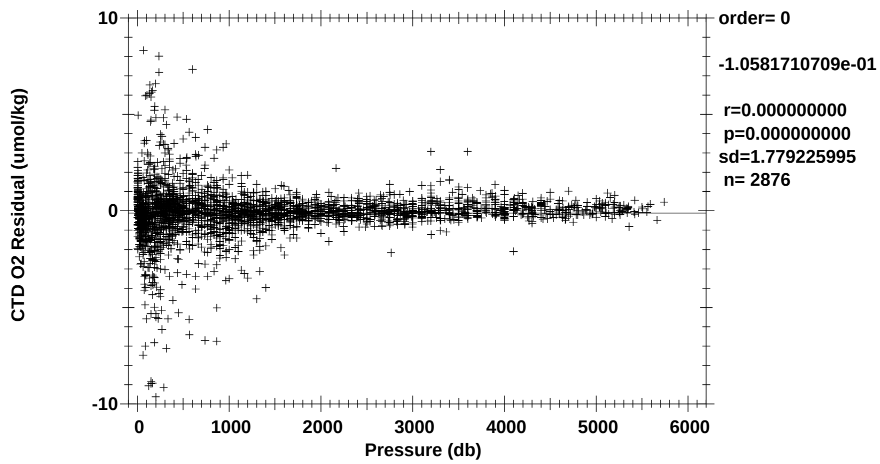

Figure 2.8.4.1 O_2 residuals by pressure (-0.01°C≤T1 − T2≤0.01°C).

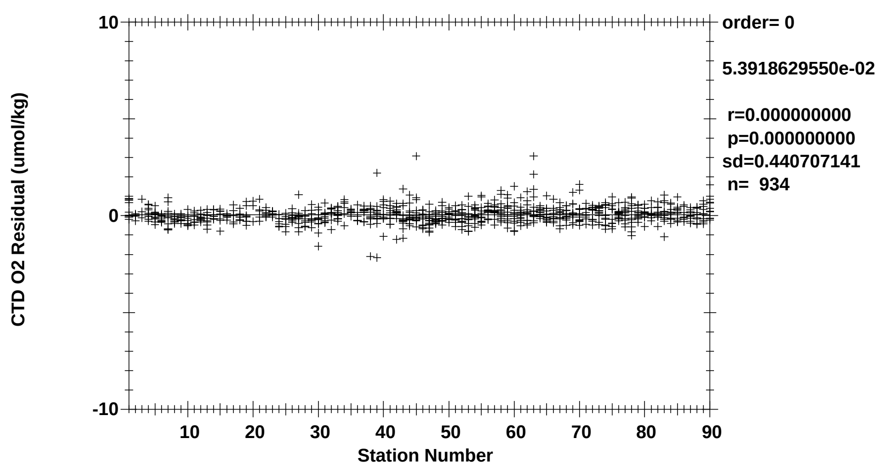

Figure 2.8.4.2 Deep O_2 residuals by station (Pressure >= 1800 dbars).

The standard deviations of 1.779 μmol/kg for all oxygens and 0.441 μmol/kg for deep oxygens are only presented as general indicators of goodness of fit. SIO/STS makes no claims regarding the precision or accuracy of CTD dissolved O_2 data.

The general form of the SIO/STS DO sensor response model equation for Clark-style cells follows Brown and Morrison [Brow78], Millard [Mill82] and Owens & Millard [Owen85]. SIO/STS models DO sensor responses with lagged CTD data. *In situ* pressure and temperature are filtered to match the sensor responses. Time constants for the pressure response (τ_p), a slow (τ_{Tf}) and fast (τ_{Ts}) thermal response, package velocity (τ_{dP}), thermal diffusion (τ_{dT}) and pressure hysteresis (τ_h) are fitting parameters. Once determined for a given sensor, these time constants typically remain constant for a cruise. The thermal diffusion term is derived by low-pass filtering the difference between the short response (T_s) and long response (T_l) temperatures. This term is intended to correct non-linearity in sensor response introduced by inappropriate analog thermal compensation. Package velocity is approximated by low-pass filtering 1st-order pressure differences, and is intended to correct flow-dependent response. Dissolved O_2 concentration is then calculated:

$$O_2ml/l = [C_1 \cdot V_{DO} e^{(C_2 \cdot \frac{P_h}{5000})} + C_3] \cdot f_{sat}(T,P) \cdot e^{(C_4 \cdot T_l + C_5 \cdot T_s + C_7 \cdot P_l + C_6 \cdot \frac{dO_c}{dt} + C_8 \cdot \frac{dP}{dt} + C_9 \cdot dT)} \quad (2.8.4.0)$$

where:

O_2ml/l	Dissolved O_2 concentration in ml/l;
V_{DO}	Raw sensor output;
C_1	Sensor slope
C_2	Hysteresis response coefficient
C_3	Sensor offset
$f_{sat}(T,P)$	O_2 saturation at T,P (ml/l);
T	*in situ* temperature (°C);
P	*in situ* pressure (decibars);
P_h	Low-pass filtered hysteresis pressure (decibars);
T_l	Long-response low-pass filtered temperature (°C);
T_s	Short-response low-pass filtered temperature (°C);
P_l	Low-pass filtered pressure (decibars);
$\frac{dO_c}{dt}$	Sensor current gradient (μamps/sec);
$\frac{dP}{dt}$	Filtered package velocity (db/sec);
dT	low-pass filtered thermal diffusion estimate (T_s - T_l).
$C_4 - C_9$	Response coefficients.

CTD O_2 ml/l data are converted to μmol/kg units on demand.

Manufacturer information on the SBE43 DO sensor, a modification of the Clark polarographic membrane technology, can be found at *http://www.seabird.com/application_notes/AN64.htm.*

A faster-response JFE Advantech Rinko III ARO-CAV Optical DO sensor, with its own oxygen temperature thermistor, was installed on the rosette and integrated with the ODF CTD from station 25 onward. ODF intends to evaluate it side-by-side with the SBE43 data, considering its possible use for future expeditions. Please contact ODF (odfdata@sts.ucsd.edu) for further information. Manufacturer information about the Rinko III sensor can be found at *http://www.jfe-advantech.co.jp/eng/ocean/rinko/rinko3.html*.

2.9. Bottle Sampling

At the end of each rosette deployment water samples were drawn from the bottles in the following order:

- CFC-12, CFC-11, SF_6, and N_2O
- ^{3}He
- Dissolved O_2
- Dissolved Inorganic Carbon (DIC)
- pH
- Total Alkalinity
- ^{13}C and ^{14}C
- Dissolved Organic Carbon (DOC) and Total Dissolved Nitrogen (TDN)
- Tritium
- Nutrients
- $\delta^{15}N\text{-}NO_3$ / $\delta^{18}O\text{-}NO_3$
- Salinity
- Dissolved Calcium
- Pigments HPLC
- CDOM
- $\delta^{30}Si$

Bottle serial numbers were assigned at the start of P16S, and corresponded to their rosette/carousel position. Aside from various repairs to bottles along the way, no bottles were replaced during this transect.

The correspondence between individual sample containers and the rosette bottle position (1-36) from which the sample was drawn was recorded on the sample log for the cast. This log also included any comments or anomalous conditions noted about the rosette and bottles. One member of the sampling team was designated the *sample cop*, whose sole responsibility was to maintain this log and ensure that sampling progressed in the proper drawing order.

Normal sampling practice included opening the drain valve and then the air vent on the bottle, indicating an air leak if water escaped. This observation together with other diagnostic comments (e.g., "lanyard caught in lid", "valve left open") that might later prove useful in determining sample integrity were routinely noted on the sample log. Drawing oxygen samples also involved taking the sample draw temperature from the bottle. The temperature was noted on the sample log and was sometimes useful in determining leaking or mis-tripped bottles.

Once individual samples had been drawn and properly prepared, they were distributed for analysis. Oxygen, nutrient and salinity analyses were performed on computer-assisted (PC) analytical equipment networked to the data processing computer for centralized data management.

2.10. Bottle Tripping Issues

Few bottle trip issues were encountered during P16S. In all cases either the carousel or bottle was fixed after issue was reported. On station 4, bottle 2 carousel trigger was stuck and bottle did not close. On station 5, the bottom endcap lanyard hung up and bottle 32 did not trip close. On station 17, carousel trigger stuck and bottle 35 did not trip close. On station 65, data indicated a mis-trip on bottle 7. On station 81, data indicated a mis-trip on bottle 1. Numerous other minor bottle tripping and/or carousel issues occurred during P16S. Most of these problems were resolved by re-aligning the lanyards during cocking to avoid obstructions or snagging points. Individual mis-tripped bottles have been quality-coded 4. Samples taken from them have been quality-coded by appropriate analytical groups. More detailed comments with respect to ODF analysis appear in Appendix 2.C.

2.11. Bottle Data Processing

Water samples collected and properties analyzed shipboard were centrally managed in a relational database (PostgreSQL NBP1403) running on a Linux system. A web service (OpenACS 5.5.0 and AOLServer 4.5.1) front-end provided ship-wide access to CTD and water sample data. Web-based facilities included on-demand arbitrary property-property plots and vertical sections as well as data uploads and downloads.

The sample log information and any diagnostic comments were entered into the database once sampling was completed. Quality flags associated with sampled properties were set to indicate that the property had been sampled, and sample container identifications were noted where applicable (e.g., oxygen flask number). Acquisition and sampling details were also made available on the ODF shipboard website post-cast with scanned versions of the Console and Sample logs.

Analytical results were provided on a regular basis by the various analytical groups and incorporated into the database. These results included a quality code associated with each measured value and followed the coding scheme developed for the World Ocean Circulation Experiment Hydrographic Programme (WHP) [Joyc94].

Table 2.11.0 shows the number of samples drawn and the number of times each WHP sample quality flag was assigned for each basic hydrographic property:

Rosette Samples Stations 1- 90								
	Reported levels	WHP Quality Codes 1	2	3	4	5	7	9
Bottle	3211	0	3186	12	6	1	0	6
CTD Salt	3211	0	3207	4	0	0	0	0
CTD Oxy	3123	0	3105	0	17	0	1	88
Salinity	3127	0	3053	57	17	2	0	82
Oxygen	3122	0	3111	3	8	6	0	83
Silicate	3129	0	3119	1	9	0	0	82
Nitrate	3129	0	3120	0	9	0	0	82
Nitrite	3129	0	3120	0	9	0	0	82
Phosphate	3129	0	3118	1	10	0	0	82

Table 2.11.0 Frequency of WHP quality flag assignments.

Additionally, data investigation comments are presented in Appendix 2.C.

Various consistency checks and detailed examination of the data continued throughout the cruise. Chief Scientist, Dr. Lynne Talley, reviewed the data and compared it with historical data sets.

2.12. Salinity Analysis

Equipment and Techniques

One salinometer, a Guildline Autosal 8400B (S/N 65-740), was used throughout P16S. A spare 8400B (S/N 65-743) was maintained at 21C, but not used for sample analysis during this expedition. These salinometers utilized the typical National Instruments interface to decode Autosal data and communicate with a Windows-based acquisition PC. The original heat exchanger coil for this unit is replaced with a longer coil to increase heat transfer between the bath and the sample. All discrete salinity analyses were done in the RVIB Nathaniel B. Palmer's Salinity Lab.

Samples were analyzed after they had equilibrated to laboratory temperature, usually within 6-20 hours after collection. The salinometer was standardized for each group of analyses (typically 1 cast, sometimes 2; up to 72 samples) using two fresh vials of standard seawater per group. In instances when 2 stations were run as a group, a third standard vial was run between the two stations.

Salinometer measurements were made by a computer using LabVIEW software developed by SIO/STS. The software maintained an Autosal log of each salinometer run which included salinometer settings and air and bath temperatures. The air temperature was monitored via digital thermometer and displayed on an up-to 48-hour strip-chart via LabVIEW in order to observe cyclical changes. The program guided the operator through the standardization procedure and making sample measurements. The analyst was prompted to change samples and flush the cell between readings.

Standardization procedures included flushing the cell at least 2 times with a fresh vial of Standard Seawater (SSW), setting the flow rate to a low value during the last fill, and monitoring the STD dial setting. If the STD dial changed by 10 units or more since the last salinometer run (or during standardization), another vial of SSW was opened and the standardization procedure repeated to verify the setting.

Each salt sample bottle was agitated to minimize stratification before reading on the salinometer. Samples were run using 2 flushes before the final fill. The computer determined the stability of a measurement and prompted for additional readings if there appeared to be drift. The operator could annotate the salinometer log, and would routinely add comments about cracked sample bottles, loose thimbles, salt crystals or anything unusual in the amount of sample in the bottle.

Sample Collection, Equilibration and Data Processing

A total of 3129 rosette salinity samples were measured. An additional 58 underway samples were taken and analyzed between Hobart and the start of the 150W line. 185 vials of standard seawater (IAPSO SSW) were used.

Salinity samples were drawn into 200 ml Kimax high-alumina borosilicate bottles, which were rinsed three times with the sample prior to filling. The bottles were sealed with custom-made plastic insert thimbles and kept closed with Nalgene screw caps. This assembly provides very low container dissolution and sample evaporation. Prior to sample collection, inserts were inspected for proper fit and loose inserts replaced to ensure an airtight seal.

After samples were brought back to the analysis lab, the full case was placed on a shelf projecting from the workbench supporting the Autosal. Salt bottle storage boxes have either an open grid pattern material or have holes drilled between bottle locations to facilitate air circulation between the bottles from bottom to top. A fan circulated air down through the salt case.

A thermometer was placed between two bottles that represent cooler but not the coldest temperatures, typically bottles 9 and 15 for the square cases and alongside bottle 3, on the inner side, for the rectangular cases. Ambient air circulated through the case until indicated glass temperature was within 1°C of bath temperature. The fan was removed from the case, which was allowed to stand for 10 to 30 minutes before analyzing the salinities. Equilibration times were logged for all casts and laboratory temperatures were logged at the beginning and end of each run.

PSS-78 salinity [UNES81] was calculated for each sample from the measured conductivity ratios. The difference between the initial vial of standard water and the next one run as an unknown was applied as a linear function of elapsed run time to the measured ratios. The corrected salinity data were then incorporated into the cruise database.

Data processing included double checking that the station, sample and box number had been correctly assigned, and reviewing the data and log files for operator comments. Discrete salinity data were compared to CTD salinities and were used for shipboard sensor calibration.

Laboratory Temperature

The salinometer water bath temperature was maintained at 24°C. Except for one day, when the temperature control failed and was repaired, the ambient laboratory air temperature varied from 21 to 25.5°C, typically between 23 and 25°C.

Standards

IAPSO Standard Seawater Batch P-156 was used to standardize all stations.

Analytical Problems

No analytical problems were encountered on US-Repeat Hydrography (GO-SHIP) P16S.

2.13. Oxygen Analysis

Equipment and Techniques

Dissolved oxygen analyses were performed with an SIO/ODF-designed automated oxygen titrator using photometric end-point detection based on the absorption of 365nm wavelength ultra-violet light. The titration of the samples and the data logging were controlled by PC LabVIEW software. Thiosulfate was dispensed by a Dosimat 665 buret driver fitted with a 1.0 mL burette. ODF used a whole-bottle modified-Winkler titration following the technique of Carpenter [Carp65] with modifications by Culberson *et al.* [Culb91], but with higher concentrations of potassium iodate standard (approximately 0.012N) and thiosulfate solution (approximately 55 gm/l). Pre-made liquid potassium iodate standards were run every day (approximately every 2-4 stations), unless changes were made to the system or reagents. Reagent/distilled water blanks were determined every day or more often if a change in reagents required it to account for presence of oxidizing or reducing agents.

Sampling and Data Processing

3128 oxygen measurements were made from rosette samples. Another 58 measurements were made from samples taken every ~4 hours on the transit from Hobart to the 150W line.

Samples were collected for dissolved oxygen analyses soon after the rosette was brought on board. Six different cases of 24 flasks each were rotated by station to minimize any potential flask calibration issues. Using a Tygon and silicone drawing tube, nominal 125mL volume-calibrated iodine flasks were rinsed 3 times with minimal agitation, then filled and allowed to overflow for at least 3 flask volumes. The sample drawing temperatures were measured with an electronic thermocouple temperature detector (TRACEABLE™ Model 89094-738) embedded in the drawing tube. These temperatures were used to calculate μmol/kg concentrations, and as a diagnostic check of bottle integrity. Reagents ($MnCl_2$ then NaI/NaOH) were added to fix the oxygen before stoppering. The flasks were shaken twice (10-12 inversions) to assure thorough dispersion of the precipitate, once immediately after drawing, and then again after about 30-40 minutes. A water seal was applied to the rim of each bottle after shaking.

The samples were analyzed within 2-14 hours of collection, and the data incorporated into the cruise database.

Thiosulfate normalities were calculated from each standardization and corrected to 20°C. The 20°C normalities and the blanks were plotted versus time and were reviewed for possible problems. The blanks and thiosulfate normalities for each batch of thiosulfate were smoothed (linear fits) in two groups (stations 1-36 and stations 37-67) during the cruise, and the oxygen values recalculated. The last batch of thiosulfate (stations 68-90) was intentionally not smoothed. The laboratory had a rapid temperature rise for the last few days of the cruise, which is believed to have caused the changes seen in the thio normalities. All differences between the original and "smoothed" data were less than ±0.25%.

After the data were uploaded to the database, bottle oxygen was graphically compared with CTD oxygen and adjoining stations. Any points that appeared erroneous were reviewed and comments made regarding the final outcome of the investigation. These investigations and final data coding are reported in Appendix 2.C.

Volumetric Calibration

Oxygen flask volumes were determined gravimetrically with degassed deionized water to determine flask volumes at ODF's chemistry laboratory. This is done once before using flasks for the first time and periodically thereafter when a suspect volume is detected. The volumetric flasks used in preparing standards were volume-calibrated by the same method, as was the 10 mL Dosimat buret used to dispense standard iodate solution.

Standards

Liquid potassium iodate standards were prepared in 6 liter batches and bottled in sterile glass bottles at ODF's chemistry laboratory prior to the expedition. The normality of the liquid standard was determined by calculation from weight. The standard was supplied by Alfa Aesar (lot B05N35) and has a reported purity of 99.4-100.4%. All other reagents were "reagent grade" and were tested for levels of oxidizing and reducing impurities prior to use.

Problems Encountered

Around station 37, the thiosulfate was topped off and began to degrade with high variability in the thio normality. A new 1L batch was made and used from station 37 to 67. Samples for stations 37 and 38 waited for approximately 12 hours before being run.

The thermocouple wire on the primary thermometer probe used during sampling broke twice, requiring backup temp probes to be used. The backup probes had a slower response than the thermocouple, possibly causing less accurate readings. The backup temperature probes were used for sampling stations 43 through 50 and stations 80 and 81.

Additionally, several samples were lost due to simple operator errors such as forgetting the stir bar, or accidentally dumping a sample before being analyzed. A summary of these lost samples can be found in Appendix 2.C.

2.14. Nutrient Analysis

Summary of Analysis

3129 samples from 90 ctd stations, and 58 from the underway system. The cruise started with new pump tubes and they were changed after stations 12, 29, 51, and 70. 5 sets of Primary/Secondary standards were made up over the course of the cruise. The cadmium column efficiency was checked periodically and ranged between 92%-100%. The column was replaced when efficiency was less than 97%.

Equipment and Techniques

Nutrient analyses (phosphate, silicate, nitrate plus nitrite, and nitrite) were performed on a Seal Analytical continuous-flow AutoAnalyzer 3 (AA3). The analytical methods used are described by Gordon *et al.* [Gord92], Hager *et al.* [Hage68] and Atlas *et al.* [Atla71]. The details of modification of analytical methods used for this cruise are also compatible with the methods described in the nutrient section of the GO-SHIP repeat hydrography manual [Hyde10].

Nitrate/Nitrite Analysis

A modification of the Armstrong *et al.* [Arms67] procedure was used for the analysis of nitrate and nitrite. For nitrate analysis, a seawater sample was passed through a cadmium column where the nitrate was reduced to nitrite. This nitrite was then diazotized with sulfanilamide and coupled with N-(1-naphthyl)-ethylenediamine to form a red dye. The sample was then passed through a 10mm flowcell and absorbance measured at 520nm. The procedure was the same for the nitrite analysis but without the cadmium column.

REAGENTS

Sulfanilamide

Dissolve 10g sulfanilamide in 1.2N HCl and bring to 1 liter volume. Add 2 drops of 40% surfynol 465/485 surfactant. Store at room temperature in a dark poly bottle.

Note: 40% Surfynol 465/485 is 20% 465 plus 20% 485 in DIW.

N-(1-Naphthyl)-ethylenediamine dihydrochloride (N-1-N)

Dissolve 1g N-1-N in DIW, bring to 1 liter volume. Add 2 drops 40% surfynol 465/485 surfactant. Store at room temperature in a dark poly bottle. Discard if the solution turns dark reddish brown.

Imidazole Buffer

Dissolve 13.6g imidazole in ˜3.8 liters DIW. Stir for at least 30 minutes to completely dissolve. Add 60 ml of $CuSO_4$ + NH_4Cl mix (see below). Add 4 drops 40% Surfynol 465/485 surfactant. Let sit overnight before proceeding. Using a calibrated pH meter, adjust to pH of 7.83-7.85 with 10% (1.2N) HCl (about 20-30 ml of acid, depending on exact strength). Bring final solution to 4L with DIW. Store at room temperature.

NH_4Cl + $CuSO_4$ mix

Dissolve 2g cupric sulfate in DIW, bring to 100 m1 volume (2%). Dissolve 250g ammonium chloride in DIW, bring to l liter volume. Add 5ml of 2% $CuSO_4$ solution to this NH_4Cl stock. This should last many months.

Phosphate Analysis

Ortho-Phosphate was analyzed using a modification of the Bernhardt and Wilhelms [Bern67] method. Acidified ammonium molybdate was added to a seawater sample to produce phosphomolybdic acid, which was then reduced to phosphomolybdous acid (a blue compound) following the addition of dihydrazine sulfate. The sample was passed through a 10mm flowcell and absorbance measured at 820nm. The 820nm bulb was only used for stations 1-10 and then changed to 880nm.

REAGENTS

Ammonium Molybdate

H_2SO_4 solution: Pour 420 ml of DIW into a 2 liter Erlenmeyer flask or beaker, place this flask or beaker into an ice bath. SLOWLY add 330 ml of concentrated H_2SO_4. This solution gets VERY HOT!! Cool in the ice bath. Make up as much as necessary in the above proportions.

Dissolve 27g ammonium molybdate in 250ml of DIW. Bring to 1 liter volume with the cooled sulfuric acid solution. Add 3 drops of 15% DDS surfactant. Store in a dark poly bottle.

Dihydrazine Sulfate

Dissolve 6.4g dihydrazine sulfate in DIW, bring to 1 liter volume and refrigerate.

Silicate Analysis

Silicate was analyzed using the technique of Armstrong *et al.* [Arms67] Acidified ammonium molybdate was added to a seawater sample to produce silicomolybdic acid which was then reduced to silicomolybdous acid (a blue compound) following the addition of stannous chloride. The sample was passed through a 10mm flowcell and measured at 660nm.

REAGENTS

Tartaric Acid

Dissolve 200g tartaric acid in DW and bring to 1 liter volume. Store at room temperature in a poly bottle.

Ammonium Molybdate

Dissolve 10.8g Ammonium Molybdate Tetrahydrate in ~ 900ml DW. Add 2.8ml H_2SO_4* to solution, then bring volume to 1000ml.

Add 3-5 drops 15% SDS surfactant per liter of solution.

Stannous Chloride stock (as needed)

Dissolve 40g of stannous chloride in 100 ml 5N HCl. Refrigerate in a poly bottle.

NOTE: Minimize oxygen introduction by swirling rather than shaking the solution. Discard if a white solution (oxychloride) forms.

Working (every 24 hours): Bring 5 ml of stannous chloride stock to 200 ml final volume with 1.2N HCl. Make up daily - refrigerate when not in use in a dark poly bottle.

Sampling

Nutrient samples were drawn into 40 ml polypropylene screw-capped centrifuge tubes. The tubes and caps were cleaned with 10% HCl and rinsed 2-3 times with sample before filling. Samples were analyzed within 1-3 hours after sample collection, allowing sufficient time for all samples to reach room temperature. The centrifuge tubes fit directly onto the sampler.

Data collection and processing

Data collection and processing was done with the software (AACE ver. 6.07) provided with the instrument from SEAL Analytical. After each run, the charts were reviewed for any problems during the run, any blank was subtracted, and final concentrations (μM) were calculated, based on a linear curve fit. Once the run was reviewed and concentrations calculated a text file was created. That text file was reviewed for possible problems and then converted to another text file with only sample identifiers and nutrient concentrations that was merged with other bottle data.

Standards and Glassware calibration

Primary standards for silicate (Na_2SiF_6), nitrate (KNO_3), nitrite ($NaNO_2$), and phosphate (KH_2PO_4) were obtained from Johnson Matthey Chemical Co. and/or Fisher Scientific. The supplier reports purities of >98%, 99.999%, 97%, and 99.999 respectively.

All glass volumetric flasks and pipettes were gravimetrically calibrated prior to the cruise. The primary standards were dried and weighed out to 0.1 mg prior to the cruise. The exact weight was noted for future reference. When primary standards were made, the flask volume at 20°C, the weight of the powder, and the temperature of the solution were used to buoyancy correct the weight, calculate the exact concentration of the solution, and determine how much of the primary was needed for the desired concentrations of secondary standard. Primary and secondary standards were made up every 7-10 days. The new standards were compared to the old before use.

All the reagent solutions, primary and secondary standards were made with fresh distilled deionized water (DIW).

Standardizations were performed at the beginning of each group of analyses with working standards prepared prior to each run from a secondary. Working standards were made up in low nutrient seawater (LNSW). Two different batches of LNSW were used on the cruise, the first for stations 1-40 and the second for the remainder, stations 41-90. Both were collected off shore of coastal California and treated in the lab. The water was first filtered through a 0.45 micron filter then re-circulated for ˜8 hours through a 0.2 micron filter, passed a UV lamp and through a second 0.2 micron filter. The actual concentration of nutrients in this water was empirically determined during the standardization calculations.

Batch	μM N+N	μM PO_4	μM SiO_3	μM NO_2
0)	0.0	0.0	0.0	0.0
3)	15.50	1.2	60	0.50
5)	31.00	2.4	120	1.0
7)	46.50	3.6	180	1.5

Table 2.14.0 US-Repeat Hydrography (GO-SHIP) P16S Concentration of working standards used in micro-moles per liter.

Quality Control

All data were reported in μM (micromoles/liter). NO_3, PO_4, and NO_2 were reported to two decimal places and SiO_3 to one. Accuracy is based on the quality of the standards; the levels were:

Parameter	Accuracy (μM)
NO_3	0.05
PO_4	0.004
SiO_3	2-4
NO_2	0.05

Table 2.14.1 US-Repeat Hydrography (GO-SHIP) P16S Nutrient Accuracy

All final data was reported in micro-moles/kg after it has been merged with the CTD trip information in the bottle file.

As is standard ODF practice, a deep calibration "check" sample was run with each set of samples to estimate precision within the cruise. The data are tabulated below.

As is standard ODF practice, a deep calibration *check* sample was run with each set of samples and the data are tabulated below.

Parameter	Concentration (μM)
NO_3	32.90 +/- 0.18
PO_4	2.27 +/- 0.02
SiO_3	127.0 +/- 0.71
NO_2	0.01 +/- 0.009

Table 2.14.2 US-Repeat Hydrography (GO-SHIP) P16S Deep Calibration Values.

SIO/ODF has been using Reference Materials for Nutrients in Seawater (RMNS) on repeat Hydrography cruises as another estimate of accuracy and precision for each cruise since 2009. The accuracy and precision (standard deviation) for this cruise were measured by analysis of a RMNS with each run.

The RMNS preparation, verification, and suggested protocol for use of the material are described by Aoyama *et al.* [Aoya06] [Aoya07] [Aoya08] and Sato *et al.* [Sato10]. RMNS batch BX was used on this cruise, with each bottle being used twice before being discarded and a new one opened. Data are tabulated below.

Parameter	Concentration (μmol kg^{-1})	Assigned	Diff
NO_3	43.05 +/- 0.21	43.00	-0.05
PO_4	2.89 +/- 0.026	2.907	0.017
SiO_3	138.1 +/- 0.69	136.0	-2.1
NO_2	0.039 +/- 0.006	0.034	-0.005

Table 2.14.3 US-Repeat Hydrography (GO-SHIP) P16S Concentration of RMNS standard.

Analytical Problems

There was significant loss of column efficiency that required frequent columns changes at the beginning of the cruise. It was tracked down to inaccurate adjusting of the pH of the imidazole buffer. The buffer preparation was changed to adding 10 mls of 10 percent hydrochloric acid without checking the pH. The column efficiency was stable and the columns lasted longer after this practice was implemented.

There was significant noise in the phosphate signal and baseline at the start of the cruise. The photometer was loose and was not staying in place. A new photometer/flowcell/light source combination was put on prior to station 11. The phosphate signal was much better after that change. Occasional baseline drops were still a problem but monitoring of the deep check sample and the RMNS values allowed for detection of problems and corrections to be implemented so the data quality did not suffer.

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Appendix 2.A

US-Repeat Hydrography (GO-SHIP) P16S: CTD Temperature and Conductivity Corrections Summary

ITS-90 Temperature Coefficients

$corT = tp2*corP^2 + tp1*corP + t1*T + t0$

Sta/ Cast	tp2	tp1	t1	t0
1/2	8.08415e-12	1.29654e-07	2.40000e-04	-0.00041253
2/1	-3.92977e-11	-1.26878e-07	5.37384e-05	-0.00077777
3/1	-3.92977e-11	-1.26878e-07	5.37384e-05	-0.00077777
4/3	-3.92977e-11	-1.26878e-07	5.37384e-05	-0.00077777
5/3	8.08415e-12	-1.89214e-08	2.40000e-04	-0.00064658
6/1	-3.92977e-11	-1.26878e-07	5.37384e-05	-0.00077777
7/1	-3.92977e-11	-1.26878e-07	5.37384e-05	-0.00077777
8/1	-3.92977e-11	-1.26878e-07	5.37384e-05	-0.00077777
9/1	-3.92977e-11	-1.26878e-07	5.37384e-05	-0.00077777
10/1	-3.92977e-11	-1.26878e-07	5.37384e-05	-0.00077777
11/1	-3.92977e-11	-1.26878e-07	5.37384e-05	-0.00077777
12/1	-3.92977e-11	-1.26878e-07	5.37384e-05	-0.00077777
13/1	-3.92977e-11	-1.26878e-07	5.37384e-05	-0.00077777
14/1	-3.92977e-11	-1.26878e-07	5.37384e-05	-0.00077777
15/1	-1.70942e-10	3.85216e-07	2.78977e-04	-0.00149899
16/1	-1.70942e-10	3.85216e-07	2.78977e-04	-0.00149899
17/2	-1.70942e-10	3.85216e-07	2.78977e-04	-0.00149899
18/1	-1.70942e-10	3.85216e-07	2.78977e-04	-0.00149899
19/1	-1.70942e-10	3.85216e-07	2.78977e-04	-0.00149899
20/1	-1.70942e-10	3.85216e-07	2.78977e-04	-0.00149899
21/1	-1.70942e-10	3.85216e-07	2.78977e-04	-0.00149899
22/1	-5.34418e-11	3.16085e-07	2.23999e-04	-0.00067781
23/1	-5.34418e-11	3.16085e-07	2.23999e-04	-0.00067781
24/1	-5.34418e-11	3.16085e-07	2.23999e-04	-0.00067781
25/1	-5.34418e-11	3.16085e-07	2.23999e-04	-0.00067781
26/1	-5.34418e-11	3.16085e-07	2.23999e-04	-0.00067781
27/1	-5.34418e-11	3.16085e-07	2.23999e-04	-0.00067781
28/1	4.09003e-11	-5.83485e-08	3.71046e-04	-0.00064631
29/1	4.09003e-11	-5.83485e-08	3.71046e-04	-0.00064631
30/1	4.09003e-11	-5.83485e-08	3.71046e-04	-0.00064631
31/1	4.09003e-11	-5.83485e-08	3.71046e-04	-0.00064631
32/1	4.09003e-11	-5.83485e-08	3.71046e-04	-0.00064631
33/1	8.08415e-12	-5.81235e-08	2.40000e-04	-0.00047796
34/1	8.08415e-12	-5.81235e-08	2.40000e-04	-0.00047796
35/1	8.08415e-12	-5.81235e-08	2.40000e-04	-0.00047796
36/1	8.08415e-12	-5.81235e-08	2.40000e-04	-0.00047796
37/2	8.08415e-12	-5.81235e-08	2.40000e-04	-0.00047796
38/1	8.08415e-12	-5.81235e-08	2.40000e-04	-0.00047796
39/3	8.08415e-12	-5.81235e-08	2.40000e-04	-0.00047796
40/2	8.08415e-12	-5.81235e-08	2.40000e-04	-0.00047796
41/1	8.08415e-12	-5.81235e-08	2.40000e-04	-0.00047796

ITS-90 Temperature Coefficients

$corT = tp2*corP^2 + tp1*corP + t1*T + t0$

Sta/ Cast	tp2	tp1	t1	t0
42/1	8.08415e-12	-5.81235e-08	2.40000e-04	-0.00047796
43/3	8.08415e-12	-5.81235e-08	2.40000e-04	-0.00047796
44/1	8.08415e-12	-5.81235e-08	2.40000e-04	-0.00047796
45/1	8.08415e-12	-5.81235e-08	2.40000e-04	-0.00047796
46/1	8.08415e-12	-5.81235e-08	2.40000e-04	-0.00047796
47/1	8.08415e-12	-5.81235e-08	2.40000e-04	-0.00047796
48/3	8.08415e-12	-5.81235e-08	2.40000e-04	-0.00047796
49/1	8.08415e-12	-5.81235e-08	2.40000e-04	-0.00047796
50/1	8.08415e-12	-5.81235e-08	2.40000e-04	-0.00047796
51/3	8.08415e-12	-5.81235e-08	2.40000e-04	-0.00047796
52/1	8.08415e-12	-5.81235e-08	2.40000e-04	-0.00047796
53/1	8.08415e-12	-5.81235e-08	2.40000e-04	-0.00047796
54/1	8.08415e-12	-5.81235e-08	2.40000e-04	-0.00047796
55/1	8.08415e-12	-5.81235e-08	2.40000e-04	-0.00047796
56/2	8.08415e-12	-5.81235e-08	2.40000e-04	-0.00047796
57/1	8.08415e-12	-5.81235e-08	2.40000e-04	-0.00047796
58/3	8.08415e-12	-5.81235e-08	2.40000e-04	-0.00047796
59/1	8.08415e-12	-5.81235e-08	2.40000e-04	-0.00047796
60/1	8.08415e-12	-5.81235e-08	2.40000e-04	-0.00047796
61/1	8.08415e-12	-5.81235e-08	2.40000e-04	-0.00047796
62/1	8.08415e-12	-5.81235e-08	2.40000e-04	-0.00047796
63/3	8.08415e-12	-5.81235e-08	2.40000e-04	-0.00047796
64/1	8.08415e-12	-5.81235e-08	2.40000e-04	-0.00047796
65/1	8.08415e-12	-5.81235e-08	2.40000e-04	-0.00047796
66/2	8.08415e-12	-5.81235e-08	2.40000e-04	-0.00047796
67/1	8.08415e-12	-5.81235e-08	2.40000e-04	-0.00047796
68/1	8.08415e-12	-5.81235e-08	2.40000e-04	-0.00047796
69/1	8.08415e-12	-5.81235e-08	2.40000e-04	-0.00047796
70/1	8.08415e-12	-5.81235e-08	2.40000e-04	-0.00047796
71/1	8.08415e-12	-5.81235e-08	2.40000e-04	-0.00047796
72/1	8.08415e-12	-5.81235e-08	2.40000e-04	-0.00047796
73/1	8.08415e-12	-5.81235e-08	2.40000e-04	-0.00047796
74/2	8.08415e-12	-5.81235e-08	2.40000e-04	-0.00047796
75/1	8.08415e-12	-5.81235e-08	2.40000e-04	-0.00047796
76/1	8.08415e-12	-5.81235e-08	2.40000e-04	-0.00047796
77/3	8.08415e-12	-5.81235e-08	2.40000e-04	-0.00047796
78/1	8.08415e-12	-5.81235e-08	2.40000e-04	-0.00047796
79/1	8.08415e-12	-5.81235e-08	2.40000e-04	-0.00047796
80/3	8.08415e-12	-5.81235e-08	2.40000e-04	-0.00047796
81/1	8.08415e-12	-5.81235e-08	2.40000e-04	-0.00047796
82/1	8.08415e-12	-5.81235e-08	2.40000e-04	-0.00047796
83/3	8.08415e-12	-5.81235e-08	2.40000e-04	-0.00047796
84/1	8.08415e-12	-5.81235e-08	2.40000e-04	-0.00047796
85/1	8.08415e-12	-5.81235e-08	2.40000e-04	-0.00047796
86/2	8.08415e-12	-5.81235e-08	2.40000e-04	-0.00047796

ITS-90 Temperature Coefficients

$corT = tp2*corP^2 + tp1*corP + t1*T + t0$

Sta/ Cast	tp2	tp1	t1	t0
87/1	8.08415e-12	-1.89276e-08	2.40000e-04	-0.00053832
88/1	8.08415e-12	-1.89276e-08	2.40000e-04	-0.00053832
89/3	8.08415e-12	-1.89276e-08	2.40000e-04	-0.00053832
90/1	8.08415e-12	-1.89276e-08	2.40000e-04	-0.00053832

Conductivity Coefficients

$corC = cp2*corP^2 + cp1*corP + ct2*corT^2 + ct1*corT + c2*C^2 + c1*C + c0$

Sta/ Cast	cp2	cp1	ct2	ct1	c2	c1	c0
1/2	1.75480e-10	-1.21353e-06	0.00000e+00	0.00000e+00	0.00000e+00	0.00000e+00	0.00020477
2/1	-1.69141e-11	-4.83210e-07	1.89170e-06	-5.47861e-05	0.00000e+00	1.97380e-04	-0.00529380
3/1	-1.69141e-11	-4.83210e-07	1.89170e-06	-5.47861e-05	0.00000e+00	1.97380e-04	-0.00529428
4/3	-1.69141e-11	-4.83210e-07	1.89170e-06	-5.47861e-05	0.00000e+00	1.97380e-04	-0.00529448
5/3	1.08624e-10	-1.03741e-06	0.00000e+00	0.00000e+00	0.00000e+00	0.00000e+00	0.00038806
6/1	-1.69141e-11	-4.83210e-07	1.89170e-06	-5.47861e-05	0.00000e+00	1.97380e-04	-0.00518231
7/1	-1.69141e-11	-4.83210e-07	1.89170e-06	-5.47861e-05	0.00000e+00	1.97380e-04	-0.00518439
8/1	-1.69141e-11	-4.83210e-07	1.89170e-06	-5.47861e-05	0.00000e+00	1.97380e-04	-0.00518650
9/1	-1.69141e-11	-4.83210e-07	1.89170e-06	-5.47861e-05	0.00000e+00	1.97380e-04	-0.00518897
10/1	-1.69141e-11	-4.83210e-07	1.89170e-06	-5.47861e-05	0.00000e+00	1.97380e-04	-0.00519103
11/1	-1.69141e-11	-4.83210e-07	1.89170e-06	-5.47861e-05	0.00000e+00	1.97380e-04	-0.00519657
12/1	-1.69141e-11	-4.83210e-07	1.89170e-06	-5.47861e-05	0.00000e+00	1.97380e-04	-0.00519884
13/1	-1.69141e-11	-4.83210e-07	1.89170e-06	-5.47861e-05	0.00000e+00	1.97380e-04	-0.00520262
14/1	-1.69141e-11	-4.83210e-07	1.89170e-06	-5.47861e-05	0.00000e+00	1.97380e-04	-0.00520461
15/1	-2.25428e-10	7.40449e-07	0.00000e+00	9.07661e-05	0.00000e+00	-2.49290e-04	0.01087920
16/1	-2.25428e-10	7.40449e-07	0.00000e+00	9.07661e-05	0.00000e+00	-2.49290e-04	0.01090440
17/2	-2.25428e-10	7.40449e-07	0.00000e+00	9.07661e-05	0.00000e+00	-2.49290e-04	0.01093340
18/1	-2.25428e-10	7.40449e-07	0.00000e+00	9.07661e-05	0.00000e+00	-2.49290e-04	0.01095510
19/1	-2.25428e-10	7.40449e-07	0.00000e+00	9.07661e-05	0.00000e+00	-2.49290e-04	0.01097160
20/1	-2.25428e-10	7.40449e-07	0.00000e+00	9.07661e-05	0.00000e+00	-2.49290e-04	0.01100470
21/1	-2.25428e-10	7.40449e-07	0.00000e+00	9.07661e-05	0.00000e+00	-2.49290e-04	0.01102670
22/1	4.22399e-11	-5.95999e-07	0.00000e+00	0.00000e+00	0.00000e+00	0.00000e+00	0.00139734
23/1	4.22399e-11	-5.95999e-07	0.00000e+00	0.00000e+00	0.00000e+00	0.00000e+00	0.00139525
24/1	4.22399e-11	-5.95999e-07	0.00000e+00	0.00000e+00	0.00000e+00	0.00000e+00	0.00139330
25/1	4.22399e-11	-5.95999e-07	0.00000e+00	0.00000e+00	0.00000e+00	0.00000e+00	0.00139024
26/1	4.22399e-11	-5.95999e-07	0.00000e+00	0.00000e+00	0.00000e+00	0.00000e+00	0.00138794
27/1	4.22399e-11	-5.95999e-07	0.00000e+00	0.00000e+00	0.00000e+00	0.00000e+00	0.00138175
28/1	2.12355e-10	-1.57686e-06	0.00000e+00	0.00000e+00	0.00000e+00	0.00000e+00	0.00269719
29/1	2.12355e-10	-1.57686e-06	0.00000e+00	0.00000e+00	0.00000e+00	0.00000e+00	0.00269525
30/1	2.12355e-10	-1.57686e-06	0.00000e+00	0.00000e+00	0.00000e+00	0.00000e+00	0.00269300
31/1	2.12355e-10	-1.57686e-06	0.00000e+00	0.00000e+00	0.00000e+00	0.00000e+00	0.00269086
32/1	2.12355e-10	-1.57686e-06	0.00000e+00	0.00000e+00	0.00000e+00	0.00000e+00	0.00269078
33/1	1.82849e-10	-1.30110e-06	6.27235e-06	-2.24446e-04	-8.31047e-06	4.57817e-04	-0.00030450
34/1	1.82849e-10	-1.30110e-06	6.27235e-06	-2.24446e-04	-8.31047e-06	4.57817e-04	-0.00031293
35/1	1.82849e-10	-1.30110e-06	6.27235e-06	-2.24446e-04	-8.31047e-06	4.57817e-04	-0.00032040
36/1	1.82849e-10	-1.30110e-06	6.27235e-06	-2.24446e-04	-8.31047e-06	4.57817e-04	-0.00032921

Conductivity Coefficients

$corC = cp2*corP^2 + cp1*corP + ct2*corT^2 + ct1*corT + c2*C^2 + c1*C + c0$

Sta/ Cast	cp2	cp1	ct2	ct1	c2	c1	c0
37/2	1.82849e-10	-1.30110e-06	6.27235e-06	-2.24446e-04	-8.31047e-06	4.57817e-04	-0.00033775
38/1	1.82849e-10	-1.30110e-06	6.27235e-06	-2.24446e-04	-8.31047e-06	4.57817e-04	-0.00034648
39/3	1.82849e-10	-1.09777e-06	6.27235e-06	-2.24446e-04	-8.31047e-06	4.57817e-04	-0.00096041
40/2	1.82849e-10	-1.30110e-06	6.27235e-06	-2.24446e-04	-8.31047e-06	4.57817e-04	-0.00037703
41/1	1.82849e-10	-1.30110e-06	6.27235e-06	-2.24446e-04	-8.31047e-06	4.57817e-04	-0.00038733
42/1	1.82849e-10	-1.30110e-06	6.27235e-06	-2.24446e-04	-8.31047e-06	4.57817e-04	-0.00039673
43/3	1.82849e-10	-1.30110e-06	6.27235e-06	-2.24446e-04	-8.31047e-06	4.57817e-04	-0.00040846
44/1	1.82849e-10	-1.30110e-06	6.27235e-06	-2.24446e-04	-8.31047e-06	4.57817e-04	-0.00041834
45/1	1.82849e-10	-1.30110e-06	6.27235e-06	-2.24446e-04	-8.31047e-06	4.57817e-04	-0.00042790
46/1	1.82849e-10	-1.30110e-06	6.27235e-06	-2.24446e-04	-8.31047e-06	4.57817e-04	-0.00044056
47/1	1.82849e-10	-1.30110e-06	6.27235e-06	-2.24446e-04	-8.31047e-06	4.57817e-04	-0.00045014
48/3	1.82849e-10	-1.30110e-06	6.27235e-06	-2.24446e-04	-8.31047e-06	4.57817e-04	-0.00046137
49/1	1.82849e-10	-1.30110e-06	6.27235e-06	-2.24446e-04	-8.31047e-06	4.57817e-04	-0.00047126
50/1	1.82849e-10	-1.30110e-06	6.27235e-06	-2.24446e-04	-8.31047e-06	4.57817e-04	-0.00048071
51/3	1.82849e-10	-1.30110e-06	6.27235e-06	-2.24446e-04	-8.31047e-06	4.57817e-04	-0.00049162
52/1	1.82849e-10	-1.30110e-06	6.27235e-06	-2.24446e-04	-8.31047e-06	4.57817e-04	-0.00050111
53/1	1.82849e-10	-1.30110e-06	6.27235e-06	-2.24446e-04	-8.31047e-06	4.57817e-04	-0.00051064
54/1	1.82849e-10	-1.30110e-06	6.27235e-06	-2.24446e-04	-8.31047e-06	4.57817e-04	-0.00052211
55/1	1.82849e-10	-1.30110e-06	6.27235e-06	-2.24446e-04	-8.31047e-06	4.57817e-04	-0.00053509
56/2	1.82849e-10	-1.30110e-06	6.27235e-06	-2.24446e-04	-8.31047e-06	4.57817e-04	-0.00055024
57/1	1.82849e-10	-1.30110e-06	6.27235e-06	-2.24446e-04	-8.31047e-06	4.57817e-04	-0.00056142
58/3	1.82849e-10	-1.30110e-06	6.27235e-06	-2.24446e-04	-8.31047e-06	4.57817e-04	-0.00057325
59/1	1.82849e-10	-1.30110e-06	6.27235e-06	-2.24446e-04	-8.31047e-06	4.57817e-04	-0.00058299
60/1	1.82849e-10	-1.30110e-06	6.27235e-06	-2.24446e-04	-8.31047e-06	4.57817e-04	-0.00059243
61/1	1.82849e-10	-1.30110e-06	6.27235e-06	-2.24446e-04	-8.31047e-06	4.57817e-04	-0.00060279
62/1	1.82849e-10	-1.30110e-06	6.27235e-06	-2.24446e-04	-8.31047e-06	4.57817e-04	-0.00061207
63/3	1.82849e-10	-1.30110e-06	6.27235e-06	-2.24446e-04	-8.31047e-06	4.57817e-04	-0.00062292
64/1	1.82849e-10	-1.30110e-06	6.27235e-06	-2.24446e-04	-8.31047e-06	4.57817e-04	-0.00063245
65/1	1.82849e-10	-1.30110e-06	6.27235e-06	-2.24446e-04	-8.31047e-06	4.57817e-04	-0.00064300
66/2	1.82849e-10	-1.30110e-06	6.27235e-06	-2.24446e-04	-8.31047e-06	4.57817e-04	-0.00065415
67/1	1.82849e-10	-1.30110e-06	6.27235e-06	-2.24446e-04	-8.31047e-06	4.57817e-04	-0.00066348
68/1	1.82849e-10	-1.30110e-06	6.27235e-06	-2.24446e-04	-8.31047e-06	4.57817e-04	-0.00067341
69/1	1.82849e-10	-1.30110e-06	6.27235e-06	-2.24446e-04	-8.31047e-06	4.57817e-04	-0.00068344
70/1	1.82849e-10	-1.30110e-06	6.27235e-06	-2.24446e-04	-8.31047e-06	4.57817e-04	-0.00069238
71/1	1.82849e-10	-1.30110e-06	6.27235e-06	-2.24446e-04	-8.31047e-06	4.57817e-04	-0.00070180
72/1	1.82849e-10	-1.30110e-06	6.27235e-06	-2.24446e-04	-8.31047e-06	4.57817e-04	-0.00071164
73/1	1.82849e-10	-1.30110e-06	6.27235e-06	-2.24446e-04	-8.31047e-06	4.57817e-04	-0.00072079
74/2	1.82849e-10	-1.30110e-06	6.27235e-06	-2.24446e-04	-8.31047e-06	4.57817e-04	-0.00073028
75/1	1.82849e-10	-1.30110e-06	6.27235e-06	-2.24446e-04	-8.31047e-06	4.57817e-04	-0.00073997
76/1	1.82849e-10	-1.30110e-06	6.27235e-06	-2.24446e-04	-8.31047e-06	4.57817e-04	-0.00074891
77/3	1.82849e-10	-1.30110e-06	6.27235e-06	-2.24446e-04	-8.31047e-06	4.57817e-04	-0.00075928
78/1	1.82849e-10	-1.30110e-06	6.27235e-06	-2.24446e-04	-8.31047e-06	4.57817e-04	-0.00076820
79/1	1.82849e-10	-1.30110e-06	6.27235e-06	-2.24446e-04	-8.31047e-06	4.57817e-04	-0.00077736
80/3	1.82849e-10	-1.30110e-06	6.27235e-06	-2.24446e-04	-8.31047e-06	4.57817e-04	-0.00078753

Conductivity Coefficients

$$corC = cp2*corP^2 + cp1*corP + ct2*corT^2 + ct1*corT + c2*C^2 + c1*C + c0$$

Sta/ Cast	cp2	cp1	ct2	ct1	c2	c1	c0
81/1	1.82849e-10	-1.30110e-06	6.27235e-06	-2.24446e-04	-8.31047e-06	4.57817e-04	-0.00079640
82/1	1.82849e-10	-1.30110e-06	6.27235e-06	-2.24446e-04	-8.31047e-06	4.57817e-04	-0.00080506
83/3	1.82849e-10	-1.30110e-06	6.27235e-06	-2.24446e-04	-8.31047e-06	4.57817e-04	-0.00081551
84/1	1.82849e-10	-1.30110e-06	6.27235e-06	-2.24446e-04	-8.31047e-06	4.57817e-04	-0.00082403
85/1	1.82849e-10	-1.30110e-06	6.27235e-06	-2.24446e-04	-8.31047e-06	4.57817e-04	-0.00083252
86/2	1.82849e-10	-1.30110e-06	6.27235e-06	-2.24446e-04	-8.31047e-06	4.57817e-04	-0.00084297
87/1	1.82849e-10	-1.30110e-06	6.27235e-06	-2.24446e-04	-8.31047e-06	4.57817e-04	-0.00085114
88/1	1.82849e-10	-1.30110e-06	6.27235e-06	-2.24446e-04	-8.31047e-06	4.57817e-04	-0.00085952
89/3	1.82849e-10	-1.30110e-06	6.27235e-06	-2.24446e-04	-8.31047e-06	4.57817e-04	-0.00086957
90/1	1.82849e-10	-1.30110e-06	6.27235e-06	-2.24446e-04	-8.31047e-06	4.57817e-04	-0.00087813

Appendix 2.B

Summary of US-Repeat Hydrography (GO-SHIP) P16S CTD Oxygen Time Constants

(time constants in seconds)

Pressure Hysteresis (τ_h)	Temperature Long(τ_{Tl})	Temperature Short(τ_{Ts})	Pressure Gradient (τ_p)	O_2 Gradient (τ_{og})	Velocity (τ_{dP})	Thermal Diffusion (τ_{dT})
50.0	300.0	4.0	0.50	8.00	200.00	300.0

US-Repeat Hydrography (GO-SHIP) P16S: Conversion Equation Coefficients for CTD Oxygen

(refer to Equation 1.9.4.0)

Sta/ Cast	O_cSlope (c_1)	Offset (c_3)	$P_h$coeff (c_2)	$T_l$coeff (c_4)	$T_s$coeff (c_5)	$P_l$coeff (c_6)	$\frac{dO_c}{dt}$coeff (c_7)	$\frac{dP}{dt}$coeff (c_8)	T_{dT}coeff (c_9)
001/02	7.358e-04	-0.3511	-0.0337	-2.328e-02	-8.635e-03	-2.602e-03	-8.206e-03	-2.602e-03	3.877e-02
002/01	5.956e-04	-0.2493	-0.1365	6.878e-03	7.639e-05	-9.694e-03	6.431e-03	-9.694e-03	-7.624e-03
003/01	6.442e-04	-0.3115	-0.2424	9.438e-03	-1.010e-03	-1.102e-02	7.546e-03	-1.102e-02	1.116e-02
004/03	6.417e-04	-0.3139	-0.0200	7.522e-03	1.943e-03	8.263e-03	9.116e-03	8.263e-03	5.286e-03
005/03	6.193e-04	-0.2673	-0.0621	2.820e-03	5.925e-04	-1.203e-02	1.931e-02	-1.203e-02	-5.949e-03
006/01	5.918e-04	-0.2209	-0.1002	9.758e-03	-1.920e-02	-1.424e-02	1.467e-02	-1.424e-02	4.271e-03
007/01	5.918e-04	-0.2209	-0.1002	9.758e-03	-1.920e-02	-1.424e-02	1.467e-02	-1.424e-02	4.271e-03
008/01	6.444e-04	-0.3160	-0.0489	7.209e-03	1.196e-02	-3.509e-03	2.940e-03	-3.509e-03	1.114e-03
009/01	6.377e-04	-0.3031	-0.0631	1.479e-02	4.202e-03	-1.002e-02	4.891e-03	-1.002e-02	2.469e-03
010/01	6.116e-04	-0.2576	-0.1387	5.742e-03	-5.424e-03	-1.666e-02	1.861e-03	-1.666e-02	-3.020e-03
011/01	5.950e-04	-0.2223	-0.0954	-1.098e-02	-8.250e-04	-1.745e-02	7.675e-03	-1.745e-02	-4.154e-02
012/01	6.512e-04	-0.3481	-0.1331	1.019e-02	4.051e-02	-9.357e-03	1.075e-02	-9.357e-03	9.326e-03
013/01	6.072e-04	-0.2329	0.1193	9.075e-03	-3.781e-02	4.076e-03	1.527e-02	4.076e-03	1.470e-02
014/01	6.105e-04	-0.3046	-0.2496	2.154e-02	4.616e-02	-2.006e-02	1.234e-02	-2.006e-02	3.559e-03
015/01	5.808e-04	-0.2718	-0.3506	-7.944e-03	5.230e-02	-2.375e-02	9.679e-03	-2.375e-02	1.123e-02
016/01	6.003e-04	-0.2527	-0.0899	1.296e-02	-3.141e-04	-7.524e-03	5.302e-03	-7.524e-03	6.079e-04
017/02	6.220e-04	-0.2857	-0.3045	-1.242e-02	1.604e-02	-5.126e-03	5.280e-03	-5.126e-03	3.377e-03
018/01	5.973e-04	-0.2567	-0.1305	1.114e-02	1.305e-02	-1.053e-02	1.087e-03	-1.053e-02	-2.823e-02
019/01	5.958e-04	-0.2607	-0.2528	2.096e-02	1.328e-02	-1.806e-02	1.022e-02	-1.806e-02	9.825e-03
020/01	5.989e-04	-0.2589	-0.5488	1.465e-02	1.034e-02	-4.955e-02	3.625e-03	-4.955e-02	-7.896e-03
021/01	6.239e-04	-0.3512	-0.3249	8.490e-03	7.291e-02	-5.875e-02	-1.049e-02	-5.875e-02	6.674e-04
022/01	6.048e-04	-0.2591	-0.1815	-3.402e-03	1.013e-02	-1.010e-02	5.584e-03	-1.010e-02	-4.495e-03
023/01	5.909e-04	-0.2657	-0.1621	2.248e-03	2.303e-02	-1.124e-02	3.848e-03	-1.124e-02	-7.897e-03
024/01	4.490e-04	-0.1179	0.0338	3.827e-02	1.129e-02	-2.348e-02	6.709e-03	-2.348e-02	-1.068e-01
025/01	5.670e-04	-0.2172	-0.1706	4.650e-03	4.799e-03	-1.241e-02	-2.498e-04	-1.241e-02	-1.960e-02
026/01	5.937e-04	-0.2446	-0.1490	4.369e-03	-3.693e-04	-9.830e-03	5.738e-03	-9.830e-03	4.872e-03
027/01	5.886e-04	-0.2389	-0.1535	3.051e-03	2.085e-04	-5.912e-03	7.088e-03	-5.912e-03	1.822e-03
028/01	5.658e-04	-0.2195	-0.2255	1.206e-02	-3.426e-03	-1.894e-02	-1.871e-03	-1.894e-02	-5.422e-03
029/01	6.297e-04	-0.2596	0.0116	1.683e-04	-4.762e-03	-4.325e-03	4.071e-03	-4.325e-03	2.472e-02
030/01	6.494e-04	-0.2881	0.1526	-7.320e-03	2.151e-03	7.906e-03	5.634e-03	7.906e-03	8.586e-03
031/01	7.561e-04	-0.3940	0.4940	-1.294e-02	-1.785e-03	4.288e-03	-4.816e-04	4.288e-03	9.810e-03
032/01	7.562e-04	-0.3843	0.2189	-1.350e-02	-2.182e-03	4.442e-03	3.560e-03	4.442e-03	1.786e-02
033/01	5.965e-04	-0.2353	-0.0109	2.939e-03	-3.398e-03	-1.863e-03	-3.852e-05	-1.863e-03	8.972e-03
034/01	5.925e-04	-0.2409	-0.0769	5.806e-03	-4.425e-03	-1.462e-02	2.229e-03	-1.462e-02	2.007e-03
035/01	7.505e-04	-0.3560	0.3201	2.630e-03	-1.822e-02	-3.557e-02	-3.261e-03	-3.557e-02	1.994e-02
036/01	6.489e-04	-0.2567	0.0210	-6.008e-03	5.803e-03	-1.167e-02	-4.903e-03	-1.167e-02	-5.203e-03

Sta/ Cast	O_c Slope (c_1)	Offset (c_3)	P_h coeff (c_2)	T_l coeff (c_4)	T_s coeff (c_5)	P_l coeff (c_6)	$\frac{dO_c}{dt}$ coeff (c_7)	$\frac{dP}{dt}$ coeff (c_8)	T_{dT} coeff (c_9)
037/02	6.202e-04	-0.2333	-0.0893	-2.637e-03	5.244e-03	-1.181e-02	-4.437e-04	-1.181e-02	-3.117e-03
038/01	6.382e-04	-0.2507	-0.1133	1.901e-03	-9.189e-04	-1.144e-02	1.735e-03	-1.144e-02	3.827e-05
039/03	6.231e-04	-0.2238	-0.0644	2.163e-03	-8.537e-04	-2.590e-02	-2.345e-04	-2.590e-02	1.771e-03
040/02	6.286e-04	-0.2450	-0.1344	3.154e-03	-6.574e-04	-1.753e-02	-9.528e-05	-1.753e-02	-1.466e-04
041/01	6.425e-04	-0.2531	-0.0942	-1.864e-03	2.638e-03	-1.547e-02	7.142e-04	-1.547e-02	-4.542e-03
042/01	6.318e-04	-0.2425	-0.0942	-2.734e-04	2.267e-03	-2.023e-02	2.404e-03	-2.023e-02	-5.154e-03
043/03	6.346e-04	-0.2429	-0.1090	3.053e-04	1.031e-03	-1.879e-02	-3.225e-03	-1.879e-02	-2.464e-03
044/01	6.313e-04	-0.2442	-0.1167	2.413e-04	1.854e-03	-1.807e-02	1.361e-03	-1.807e-02	-3.237e-03
045/01	6.320e-04	-0.2426	-0.1161	2.852e-05	2.216e-03	-2.044e-02	-7.217e-04	-2.044e-02	-5.873e-03
046/01	6.420e-04	-0.2498	-0.0787	-1.155e-03	2.105e-03	-1.510e-02	-3.527e-03	-1.510e-02	-1.718e-03
047/01	6.316e-04	-0.2419	-0.1155	5.868e-04	1.870e-03	-1.780e-02	-2.521e-03	-1.780e-02	-3.255e-03
048/03	6.300e-04	-0.2388	-0.1157	-1.458e-03	3.644e-03	-2.026e-02	-2.610e-03	-2.026e-02	-4.974e-03
049/01	6.301e-04	-0.2423	-0.1219	5.647e-04	1.910e-03	-2.044e-02	2.462e-03	-2.044e-02	-5.102e-03
050/01	6.290e-04	-0.2413	-0.1149	9.763e-04	1.638e-03	-2.016e-02	8.025e-04	-2.016e-02	-4.229e-03
051/03	6.365e-04	-0.2429	-0.0739	4.527e-04	9.690e-04	-1.943e-02	7.171e-04	-1.943e-02	-2.909e-03
052/01	6.378e-04	-0.2481	-0.1036	9.735e-05	1.523e-03	-1.724e-02	-6.076e-04	-1.724e-02	-2.894e-03
053/01	6.346e-04	-0.2405	-0.0963	2.612e-04	1.254e-03	-1.900e-02	4.723e-03	-1.900e-02	-3.029e-03
054/01	6.385e-04	-0.2423	-0.0804	-1.261e-03	1.953e-03	-1.938e-02	-2.099e-03	-1.938e-02	-2.757e-03
055/01	6.343e-04	-0.2418	-0.1104	-1.041e-03	2.368e-03	-1.951e-02	1.516e-04	-1.951e-02	-3.726e-03
056/02	6.331e-04	-0.2423	-0.1109	-5.368e-04	1.823e-03	-2.132e-02	1.481e-03	-2.132e-02	-2.660e-03
057/01	6.438e-04	-0.2509	-0.0708	8.505e-04	-2.891e-04	-1.941e-02	-1.238e-03	-1.941e-02	-1.164e-03
058/03	6.370e-04	-0.2419	-0.1104	-1.196e-03	2.089e-03	-1.874e-02	-3.365e-04	-1.874e-02	-3.215e-03
059/01	6.484e-04	-0.2540	-0.0622	6.090e-04	-1.700e-04	-1.686e-02	1.495e-03	-1.686e-02	-1.362e-03
060/01	6.380e-04	-0.2430	-0.0986	6.257e-04	1.702e-04	-1.689e-02	-2.750e-03	-1.689e-02	-5.422e-04
061/01	6.315e-04	-0.2429	-0.1449	-2.039e-03	3.599e-03	-2.016e-02	1.375e-03	-2.016e-02	-5.062e-03
062/01	6.339e-04	-0.2441	-0.1257	-4.055e-06	1.416e-03	-1.811e-02	-2.211e-03	-1.811e-02	-2.179e-03
063/03	6.343e-04	-0.2398	-0.1248	2.878e-03	-2.093e-03	-1.920e-02	-1.607e-03	-1.920e-02	8.789e-04
064/01	6.410e-04	-0.2480	-0.1091	1.675e-03	-1.026e-03	-1.696e-02	2.768e-03	-1.696e-02	-2.436e-05
065/01	6.391e-04	-0.2475	-0.1159	3.507e-04	6.373e-04	-1.557e-02	5.054e-03	-1.557e-02	-1.663e-03
066/02	6.391e-04	-0.2451	-0.1267	1.914e-03	-1.186e-03	-1.456e-02	7.092e-04	-1.456e-02	5.849e-04
067/01	6.394e-04	-0.2460	-0.1189	8.735e-04	-8.279e-05	-1.520e-02	-2.963e-04	-1.520e-02	-1.691e-04
068/01	6.346e-04	-0.2434	-0.1413	3.451e-04	6.264e-04	-1.531e-02	-1.859e-04	-1.531e-02	-9.591e-04
069/01	6.338e-04	-0.2440	-0.1608	-3.949e-04	1.530e-03	-1.672e-02	5.192e-03	-1.672e-02	-2.228e-03
070/01	6.377e-04	-0.2457	-0.1114	6.544e-04	1.944e-04	-1.701e-02	1.092e-03	-1.701e-02	-1.058e-03
071/01	6.389e-04	-0.2467	-0.1127	-1.614e-06	7.798e-04	-1.576e-02	3.296e-04	-1.576e-02	-1.391e-03
072/01	6.322e-04	-0.2417	-0.1656	-1.811e-04	1.299e-03	-1.752e-02	2.513e-03	-1.752e-02	-1.412e-03
073/01	6.421e-04	-0.2543	-0.1486	-9.059e-04	1.677e-03	-1.697e-02	-3.665e-03	-1.697e-02	-2.073e-03
074/02	6.359e-04	-0.2460	-0.1425	2.953e-04	6.122e-04	-1.459e-02	7.203e-04	-1.459e-02	-7.036e-04
075/01	6.417e-04	-0.2492	-0.1257	3.586e-04	2.046e-04	-1.468e-02	7.210e-03	-1.468e-02	-7.148e-04
076/01	6.402e-04	-0.2457	-0.0928	3.630e-04	-1.975e-05	-1.614e-02	1.211e-03	-1.614e-02	5.795e-06
077/03	6.405e-04	-0.2452	-0.0818	-8.819e-04	1.363e-03	-1.489e-02	-6.022e-04	-1.489e-02	-1.857e-03
078/01	6.373e-04	-0.2422	-0.0712	3.185e-04	2.953e-04	-1.597e-02	1.503e-03	-1.597e-02	-5.463e-04
079/01	6.406e-04	-0.2483	-0.1077	-1.405e-03	2.123e-03	-1.644e-02	-4.784e-04	-1.644e-02	-3.438e-03
080/03	6.423e-04	-0.2519	-0.1326	-5.229e-04	1.167e-03	-1.599e-02	-9.524e-04	-1.599e-02	-2.326e-03
081/01	6.659e-04	-0.2665	0.1716	1.169e-03	-1.941e-03	-7.454e-03	2.493e-03	-7.454e-03	1.358e-03
082/01	6.391e-04	-0.2437	-0.0586	-7.560e-04	1.128e-03	-1.080e-02	-4.299e-04	-1.080e-02	-6.957e-04
083/03	6.325e-04	-0.2389	-0.1253	-1.627e-03	2.118e-03	-1.077e-02	-4.437e-05	-1.077e-02	-1.030e-03
084/01	6.978e-04	-0.3001	0.6100	-9.146e-04	-7.276e-04	-1.961e-03	-2.224e-04	-1.961e-03	-8.339e-04

Sta/ Cast	O_c Slope (c_1)	Offset (c_3)	P_h coeff (c_2)	T_l coeff (c_4)	T_s coeff (c_5)	P_l coeff (c_6)	$\frac{dO_c}{dt}$ coeff (c_7)	$\frac{dP}{dt}$ coeff (c_8)	T_{dT} coeff (c_9)
085/01	6.409e-04	-0.2494	-0.1284	3.033e-04	6.631e-05	-1.278e-02	8.381e-04	-1.278e-02	-1.290e-05
086/02	5.783e-04	-0.2383	-0.1683	-1.219e-03	1.205e-03	-1.071e-02	-1.936e-03	-1.071e-02	-1.452e-03
087/01	5.791e-04	-0.2401	-0.1916	-3.827e-04	2.949e-04	-1.328e-02	-1.777e-04	-1.328e-02	-6.686e-04
088/01	5.565e-04	-0.2138	-0.1578	-1.206e-03	1.926e-03	-1.240e-02	-1.508e-03	-1.240e-02	-1.179e-03
089/03	5.177e-04	-0.1783	-0.2455	-9.707e-04	3.547e-03	-1.397e-02	-7.403e-04	-1.397e-02	-1.590e-03
090/01	5.726e-04	-0.2337	-0.1819	-6.584e-04	7.412e-04	-1.344e-02	6.538e-05	-1.344e-02	-2.790e-04

Appendix 2.C

US-Repeat Hydrography (GO-SHIP) P16S: Bottle Quality Comments

Comments from the Sample Logs and the results of STS/ODF's data investigations are included in this report. The sample number is the cast number times 100 plus the bottle number. Investigation of data may include comparison of bottle salinity and oxygen data with CTD data, review of data plots of the station profile and adjoining stations, and re-reading of peaks (i.e. nutrients).

Station	Sample No.	Property	Quality Code	Comment
1/2	202	bottle	9	Bottle tripped for deep-water nutrient check.
1/2	204	salt	3	Salinity value does not fit profile.
1/2	205	salt	3	Salinity value does not fit profile.
1/2	207	salt	3	Salinity value does not fit profile.
1/2	208	reft	3	SBE35 did not equilibrate.
1/2	216	salt	3	Salinity value does not fit profile.
1/2	228	bottle	2	Bottle loose.
2/1	103	bottle	3	SAMPLE LOG: "Large leak". O-ring unseated from top end cap.
2/1	108	salt	3	Salinity value does not fit profile.
2/1	109	salt	3	Salinity value does not fit profile.
3/1	101	salt	3	Salinity value does not fit profile.
3/1	109	salt	3	Salinity value does not fit profile.
3/1	110	salt	3	Salinity value does not fit profile.
3/1	111	salt	3	Salinity value does not fit profile.
3/1	115	salt	3	Salinity value does not fit profile.
3/1	116	salt	3	Salinity value does not fit profile.
3/1	117	salt	3	Salinity value does not fit profile.
3/1	129	no2	4	Mis-trip
3/1	129	no3	4	Mis-trip
3/1	129	o2	4	O2 is 57 umol/kg high vs CTDO profile, mis-trip.
3/1	129	po4	4	Mis-trip
3/1	129	salt	4	Mis-trip
3/1	129	sio3	4	Mis-trip
3/1	131	reft	3	SBE35 did not equilibrate.
4/3	301	salt	3	Salinity value does not fit profile.
4/3	329	bottle	5	Bottle did not trip. Carousel trigger stuck.
4/3	329	reft	4	SBE35 did not equilibrate. Note bottle trip issue.
4/3	332	reft	3	SBE35 did not equilibrate.
5/3	314	salt	4	Mis-sampled. Drawn from 12.
5/3	332	bottle	9	Niskin 32 did not close. Bottom end cap hung up in bottom lanyard of niskin 31.
6/1	103	bottle	4	Sample Log: "Niskin 3 is leaking". Top cap O-ring was unseated.
6/1	103	no2	4	Sample bad, see other parameters.
6/1	103	no3	4	Sample bad, see other parameters.
6/1	103	o2	4	O2 value 5umol/kg low. Niskin leaking.
6/1	103	po4	4	Sample bad, see other parameters.
6/1	103	salt	4	Mis-Sampled
6/1	103	sio3	4	Silicate value high.
6/1	104	salt	3	Salinity value does not fit profile.
6/1	114	salt	4	Mis-sampled. Drawn from Niskin 11.
6/1	132	reft	3	SBE35 did not equilibrate.
7/1	101	salt	3	

Station	Sample No.	Property	Quality Code	Comment
7/1	103	salt	3	Salinity value does not fit profile.
7/1	104	salt	3	
7/1	114	salt	3	
7/1	115	salt	3	
7/1	118	salt	3	
7/1	121	o2	5	O2 titration flat-lined at 1.7v, no end point; sample lost.
8/1	114	salt	3	Salinity value does not fit profile.
8/1	133	reft	3	SBE35 did not equilibrate.
9/1	105	salt	3	Salinity value does not fit profile.
9/1	114	salt	3	Salinity value does not fit profile.
9/1	124	salt	3	Salinity value does not fit profile.
9/1	125	salt	3	Salinity value does not fit profile.
9/1	129	salt	3	Salinity value does not fit profile.
10/1	114	salt	3	
10/1	131	reft	3	Unstable temperatures.
11/1	109	salt	3	
11/1	114	salt	3	
11/1	117	o2	3	O2 value 3 umol/kg low, sio3 also slightly low; similar to btl 18 values.
11/1	117	salt	3	
11/1	117	sio3	3	SiO3 value lower than expected, no analytical errors noted.
11/1	131	bottle	3	"Niskin 31 has no seal". Vent was tight, top appeared to be seated correctly.
12/1	114	salt	3	Salinity value does not fit profile.
12/1	131	reft	3	SBE35 did not equilibrate.
13/1	101	salt	3	
13/1	103	salt	3	
13/1	114	salt	3	
13/1	119	salt	3	
13/1	122	po4	3	PO4 value lower than expected, no analytical errors noted.
13/1	129	reft	3	SBE35 did not equilibrate.
13/1	131	o2	2	Low battery on o2 thermometer starting niskin 31. Readings ok.
14/1	114	salt	3	Salinity value does not fit profile.
15/1	110	bottle	2	Niskin 10 is leaking at spigot before venting: vent tight, tried resealing top lid. JKC: no obvious reason.
15/1	117	o2	2	Bottle o2 matches upcast feature not seen on downcast.
15/1	126	o2	2	Bottle o2 matches upcast feature not seen on downcast.
15/1	132	reft	3	SBE35 did not equilibrate.
16/1	123	o2	2	Bottle o2 matches upcast feature not seen on downcast.
16/1	128	reft	3	SBE35 did not equilibrate.
16/1	132	reft	3	SBE35 did not equilibrate.
17/2	201	salt	4	Mis-sample from bottle 3.
17/2	217	o2	2	Bottle o2 matches upcast feature not seen on downcast.
17/2	218	o2	2	Bottle o2 matches upcast feature not seen on downcast.
17/2	231	reft	3	Unstable temperatures.
17/2	235	bottle	9	Niskin 35 did not trip; no obvious reason why. JKC: sticky carousel latch, disassembled and cleaned.
18/1	106	salt	4	Conductivity cell not completely filled during analysis.
18/1	109	bottle	3	Niskin 9 leaking because vent knob was not closed properly.
18/1	120	o2	2	Bottle o2 matches upcast feature not seen on downcast.
18/1	124	o2	2	Bottle o2 matches upcast feature, similar feature deeper on downcast.
18/1	132	reft	3	Unstable temperatures.
18/1	132	salt	3	Salinity value does not fit profile.

Station	Sample No.	Property	Quality Code	Comment
19/1	131	bottle	3	Slight leak. O-ring not seated correctly in top end cap.
22/1	129	reft	3	SBE35 did not equilibrate.
22/1	132	reft	3	Unstable temperatures.
23/1	133	reft	3	SBE35 did not equilibrate.
25/1	107	reft	3	SBE35 did not equilibrate.
25/1	117	bottle	3	Bottle leak. Top o-ring not seated correctly.
25/1	121	reft	3	SBE35 did not equilibrate.
25/1	122	salt	5	Salinity sample 22 lost.
26/1	110	salt	3	Salinity value does not fit profile.
27/1	104	salt	3	Salinity value does not fit profile.
27/1	122	salt	4	Sample 22 was drawn from niskin 23.
27/1	131	reft	2	Unstable temperatures.
27/1	132	reft	3	SBE35 did not equilibrate.
28/1	122	reft	3	SBE35 did not equilibrate.
29/1	109	bottle	3	Niskin 9 leak. Vent left slightly open.
29/1	123	reft	3	SBE35 did not equilibrate.
29/1	131	bottle	3	Niskin 31 leak. O-ring not seated correctly.
30/1	133	reft	2	SBE35 not equilibrated. Not used in fit.
31/1	122	reft	3	SBE35 did not equilibrate.
31/1	132	reft	3	SBE35 did not equilibrate.
31/1	132	salt	3	Salinity value does not fit profile.
31/1	133	salt	4	Analytical error.
32/1	124	salt	3	Salinity value does not fit profile.
32/1	130	reft	3	SBE35 did not equilibrate.
33/1	121	o2	5	O2 UV detector a/d disconnected after sample switched to plot mode. Sample lost. USB connector re-seated in laptop, solved the problem for the rest of the run.
33/1	134	reft	3	SBE35 did not equilibrate.
34/1	101	ctdc2	4	This plumb line went bad. Replaced pump and cables after cast.
34/1	102	ctdc2	4	This plumb line went bad. Replaced pump and cables after cast.
34/1	103	ctdc2	4	This plumb line went bad. Replaced pump and cables after cast.
34/1	104	ctdc2	4	This plumb line went bad. Replaced pump and cables after cast.
34/1	105	ctdc2	4	This plumb line went bad. Replaced pump and cables after cast.
34/1	109	ctdc2	4	This plumb line went bad. Replaced pump and cables after cast.
34/1	114	reft	3	Unstable temperatures.
35/1	101	ctdc2	4	This plumb line was noisy on upcast. Replaced cables and pumps after cast.
35/1	103	ctdc2	4	This plumb line was noisy on upcast. Replaced cables and pumps after cast.
35/1	104	ctdc2	4	This plumb line was noisy on upcast. Replaced cables and pumps after cast.
35/1	105	ctdc2	4	This plumb line was noisy on upcast. Replaced cables and pumps after cast.
35/1	106	ctdc2	4	This plumb line was noisy on upcast. Replaced cables and pumps after cast.
35/1	107	ctdc2	4	This plumb line was noisy on upcast. Replaced cables and pumps after cast.
35/1	117	ctdc2	4	This plumb line was noisy on upcast. Replaced cables and pumps after cast.
35/1	118	ctdc2	4	This plumb line was noisy on upcast. Replaced cables and pumps after cast.
35/1	119	ctdc2	4	This plumb line was noisy on upcast. Replaced cables and pumps after cast.
35/1	119	reft	3	SBE35 did not equilibrate.
35/1	120	ctdc2	4	This plumb line was noisy on upcast. Replaced cables and pumps after cast.
35/1	121	ctdc2	4	This plumb line was noisy on upcast. Replaced cables and pumps after cast.
35/1	122	ctdc2	4	This plumb line was noisy on upcast. Replaced cables and pumps after cast.
35/1	123	ctdc2	4	This plumb line was noisy on upcast. Replaced cables and pumps after cast.
35/1	124	ctdc2	4	This plumb line was noisy on upcast. Replaced cables and pumps after cast.
36/1	119	reft	3	SBE35 did not equilibrate.
36/1	132	reft	3	SBE35 did not equilibrate.

Station	Sample No.	Property	Quality Code	Comment
37/2	216	bottle	2	Bottle 16 vent not closed properly. No leak. No analytical issues noted.
37/2	228	bottle	2	Bottle 28 vent not closed properly. No leak. No analytical issues noted.
37/2	230	reft	3	SBE35 did not equilibrate.
38/1	117	salt	4	Mis-sampled from bottle 16.
39/3	301	o2	2	Voltage a bit high for this sample, but value is fine.
39/3	302	o2	2	Replaced flask 1762 (box W) after station run. Cracked rim and label falling off - did not affect sample.
39/3	308	o2	3	O2 value is 4 umol/kg high vs CTDO and nearby casts. Nutrients are in line.
40/2	230	reft	3	Unstable temperatures.
41/1	133	reft	3	Unstable temperatures.
42/1	108	bottle	2	Bottle 8 vent not closed properly.
42/1	110	bottle	2	Green paint on bottle 10 nozzle.
42/1	133	reft	3	SBE35 did not equilibrate.
44/1	119	reft	3	SBE35 did not equilibrate.
44/1	134	reft	3	Unstable temperatures.
45/1	131	reft	3	SBE35 did not equilibrate.
45/1	131	salt	3	Salinity value does not fit profile.
45/1	132	reft	3	SBE35 did not equilibrate.
46/1	120	reft	3	SBE35 did not equilibrate.
46/1	132	reft	3	SBE35 did not equilibrate.
47/1	121	reft	3	SBE35 did not equilibrate.
47/1	135	reft	3	SBE35 did not equilibrate.
48/3	314	no2	4	Mis-sampled, likely from bottle 16.
48/3	314	no3	4	Mis-sampled, likely from bottle 16.
48/3	314	po4	4	Mis-sampled, likely from bottle 16.
48/3	314	salt	4	Mis-sampled, likely from bottle 16.
48/3	314	sio3	4	Mis-sampled, likely from bottle 16.
48/3	331	reft	3	SBE35 did not equilibrate.
49/1	108	reft	3	SBE35 did not equilibrate.
49/1	112	salt	3	Salinity value does not fit profile.
50/1	120	no2	4	Mis-sampled, likely from bottle 19.
50/1	120	no3	4	Mis-sampled, likely from bottle 19.
50/1	120	po4	4	Mis-sampled, likely from bottle 19.
50/1	120	sio3	4	Mis-sampled, likely from bottle 19.
51/3	317	reft	3	SBE35 did not equilibrate.
51/3	331	reft	3	Unstable temperatures.
51/3	332	reft	3	Unstable temperatures.
52/1	124	salt	3	Salinity value does not fit profile.
52/1	131	reft	3	SBE35 did not equilibrate.
52/1	133	reft	3	SBE35 did not equilibrate.
53/1	126	o2	2	correct typo
53/1	127	reft	3	SBE35 did not equilibrate.
53/1	130	reft	3	SBE35 did not equilibrate.
53/1	131	reft	3	SBE35 did not equilibrate.
53/1	132	reft	3	Unstable temperatures.
53/1	136	o2	5	Analytical error, sample lost.
56/2	212	o2	4	Bottle o2 4 umol/kg high vs CTDO.
56/2	224	salt	3	Salinity value does not fit profile.
56/2	231	reft	3	SBE35 did not equilibrate.
56/2	232	reft	4	Required wait time for SBE35 equilibration was not observed.
56/2	233	reft	3	Unstable temperatures.

Station	Sample No.	Property	Quality Code	Comment
57/1	112	bottle	4	Mis-trip. See parameters.
57/1	112	no2	4	Mis-trip
57/1	112	no3	4	Mis-trip
57/1	112	o2	4	O2 does not fit profile or CTD, Mis-trip.
57/1	112	po4	4	Mis-trip
57/1	112	salt	4	Mis-trip
57/1	112	sio3	4	Mis-trip
57/1	131	salt	3	Salinity value does not fit profile.
57/1	134	reft	3	Unstable temperatures.
57/1	134	salt	4	Contaminated sample.
58/3	333	reft	3	Unstable temperatures.
59/1	110	bottle	3	Niskin 10 top cap was not secure, CFC and carbon samples skipped.
59/1	112	bottle	2	Niskin 12 bottom cap could close after cocking for next station; adjusted lanyard guide ring up to take up excess lanyard before station 60. This may have affected some previous casts.
59/1	120	reft	3	Unstable temperatures.
59/1	128	bottle	3	Niskin 28 top vent was not fully closed, CFC and carbon samples skipped.
59/1	129	reft	3	SBE35 did not equilibrate.
59/1	131	reft	3	SBE35 did not equilibrate.
60/1	128	salt	2	Suppression switch too low.
60/1	129	salt	2	Suppression switch too low.
60/1	130	reft	3	SBE35 did not equilibrate.
60/1	131	reft	3	SBE35 did not equilibrate.
60/1	131	salt	2	Suppression switch too low.
60/1	133	salt	2	Suppression switch too low.
60/1	134	salt	2	Suppression switch too low.
60/1	135	salt	2	Suppression switch too low.
60/1	136	salt	2	Suppression switch too low.
61/1	110	bottle	3	Bottle leak. See other parameters.
61/1	110	no2	4	Bottle leak
61/1	110	no3	4	Bottle leak.
61/1	110	o2	4	Bottle value does not fit profile
61/1	110	po4	4	Bottle leak.
61/1	110	salt	4	Bottle leak.
61/1	110	sio3	4	Bottle leak.
61/1	129	reft	3	Unstable temperatures.
61/1	133	reft	3	SBE35 did not equilibrate.
62/1	101	o2	3	bottom o2 value 2 umol/kg high vs CTDO and nearby casts.
62/1	110	bottle	4	Bottle leak. See other parameters. Fixed after cast.
62/1	110	no2	4	Bottle leak
62/1	110	no3	4	Bottle leak.
62/1	110	o2	4	Bottle value does not fit profile.
62/1	110	po4	4	Bottle leak.
62/1	110	salt	4	Bottle leak.
62/1	110	sio3	4	Bottle leak.
62/1	115	salt	3	Salinity value does not fit profile.
62/1	119	reft	3	SBE35 did not equilibrate.
62/1	128	reft	3	Unstable temperatures.
62/1	129	salt	2	Suppression switch too low.
62/1	130	salt	2	Suppression switch too low.
62/1	131	salt	2	Suppression switch too low.

Station	Sample No.	Property	Quality Code	Comment
62/1	132	salt	2	Suppression switch too low.
62/1	133	reft	3	Unstable temperatures.
62/1	133	salt	2	Suppression switch too low.
62/1	134	salt	2	Suppression switch too low.
62/1	135	salt	2	Suppression switch too low.
62/1	136	salt	2	Suppression switch too low.
64/1	117	reft	3	SBE35 did not equilibrate.
64/1	120	reft	3	Unstable temperatures.
64/1	126	reft	3	Unstable temperatures.
64/1	128	reft	3	SBE35 did not equilibrate.
64/1	129	reft	3	SBE35 did not equilibrate.
65/1	107	bottle	4	O2 Draw temp high, bottle o2 does not fit profile, mis-trip.
65/1	107	no2	4	Mis-trip
65/1	107	no3	4	Mis-trip
65/1	107	o2	4	Bottle o2 does not fit profile, mis-trip.
65/1	107	po4	4	Mis-trip
65/1	107	salt	4	Mis-trip
65/1	107	sio3	4	Mis-trip
65/1	120	reft	3	SBE35 did not equilibrate.
65/1	127	o2	5	Analytical error, sample lost
65/1	129	reft	3	SBE35 did not equilibrate.
65/1	131	reft	3	SBE35 did not equilibrate.
65/1	133	reft	3	SBE35 did not equilibrate.
66/2	203	reft	3	SBE35 did not equilibrate.
66/2	225	reft	3	SBE35 did not equilibrate.
66/2	228	reft	3	Unstable temperature.
66/2	232	reft	3	Unstable temperatures.
66/2	233	reft	3	Unstable temperatures.
66/2	234	bottle	2	Spigot pushed in (not leaking).
67/1	101	ph	2	pH redo after total alkalinity on niskin 1.
67/1	101	salt	3	Salinity value does not fit profile.
67/1	131	o2	5	Forgot to add stir bar, too much thio to recover with OT. Sample lost.
67/1	133	reft	3	Unstable temperatures.
69/1	126	reft	3	SBE35 did not equilibrate.
69/1	132	reft	3	SBE35 did not equilibrate.
70/1	107	bottle	9	Niskin 7 did not close; JKC removed and checked latch, no problem found; bottle shifted higher before next cast.
70/1	116	bottle	9	Niskin 16 did not close; JKC removed and checked latch, no problem found; bottle shifted higher before next cast.
70/1	118	o2	5	Forgot to add stir bar, too much thio to recover with OT. Sample lost.
71/1	116	reft	3	Unstable temperatures
71/1	123	reft	3	SBE35 did not equilibrate.
71/1	129	reft	3	SBE35 did not equilibrate.
72/1	123	reft	3	SBE35 did not equilibrate.
73/1	121	reft	3	SBE35 did not equilibrate.
74/2	222	reft	3	Unstable temperatures.
74/2	233	reft	2	Unstable temperatures..
75/1	134	reft	3	SBE35 did not equilibrate.
76/1	130	reft	3	SBE35 did not equilibrate.
76/1	132	reft	3	SBE35 did not equilibrate.
77/3	322	salt	4	Mis-sampled

Station	Sample No.	Property	Quality Code	Comment
77/3	324	reft	3	SBE35 did not equilibrate.
78/1	107	reft	3	SBE35 did not equilibrate.
78/1	126	reft	3	SBE35 did not equilibrate.
79/1	131	reft	3	SBE35 did not equilibrate.
79/1	133	reft	3	SBE35 did not equilibrate.
80/3	309	doc	2	Nutrient jumped ahead of DOC in sampling and contaminated nozzle with hand.
80/3	325	reft	3	SBE35 did not equilibrate.
80/3	326	reft	3	SBE35 did not equilibrate.
80/3	331	o2	2	O2 thermocouple meter change out to thermistor for Niskin 31 to 36.
81/1	101	bottle	4	Bottom o2 value similar to bottle 103, nutrients as well. Appears to be a mis-trip.
81/1	101	no2	4	Mis-trip
81/1	101	no3	4	Mis-trip
81/1	101	o2	4	Bottle o2 6 umol/kg low vs CTDO, apparent mis-trip near same depth as niskin 3.
81/1	101	po4	4	Mis-trip
81/1	101	salt	4	Mis-trip. See other parameters.
81/1	101	sio3	4	Mis-trip
81/1	112	o2	2	O2 temps jump 4 degrees between 11/12, drop back 1 degree between 16/17. "slow" backup therm read similarly high on bottle 12, so continued to use half-fast therm for entire sampling. Check umol/kg conversion after analysis come in.
81/1	113	o2	2	O2 temps jump 4 degrees between 11/12, drop back 1 degree between 16/17. "slow" backup therm read similarly high on bottle 12, so continued to use half-fast therm for entire sampling. Check umol/kg conversion after analysis come in.
81/1	114	o2	2	O2 temps jump 4 degrees between 11/12, drop back 1 degree between 16/17. "slow" backup therm read similarly high on bottle 12, so continued to use half-fast therm for entire sampling. Check umol/kg conversion after analysis come in.
81/1	115	o2	2	O2 temps jump 4 degrees between 11/12, drop back 1 degree between 16/17. "slow" backup therm read similarly high on bottle 12, so continued to use half-fast therm for entire sampling. Check umol/kg conversion after analysis come in.
81/1	116	o2	2	O2 temps jump 4 degrees between 11/12, drop back 1 degree between 16/17. "slow" backup therm read similarly high on bottle 12, so continued to use half-fast therm for entire sampling. Check umol/kg conversion after analysis come in.
81/1	123	ctdc2	4	TC duct displaced.
81/1	124	reft	3	Unstable temperatures.
81/1	126	reft	3	Unstable temperatures.
81/1	128	ctdc2	4	TC duct displaced.
81/1	133	reft	3	SBE35 did not equilibrate.
82/1	115	reft	3	SBE35 did not equilibrate.
82/1	126	reft	3	SBE35 did not equilibrate.
83/3	316	bottle	2	While prepping rosette, CTD watch noted vent knob had sheared from shaft.
83/3	317	reft	3	SBE35 did not equilibrate.
83/3	324	reft	3	SBE35 did not equilibrate.
83/3	326	reft	3	SBE35 did not equilibrate.
83/3	331	bottle	3	"#31 is leaker." Bottle leaking water on deck. O-ring reseated.
83/3	331	reft	3	SBE35 did not equilibrate.
83/3	335	salt	3	Salinity value does not fit profile.
84/1	118	reft	3	SBE35 did not equilibrate.
84/1	123	reft	3	Unstable temperatures.
84/1	129	reft	3	Unstable temperatures.
85/1	102	salt	3	Salinity value does not fit profile.
85/1	121	salt	3	Salinity value does not fit profile.
85/1	124	reft	3	SBE35 did not equilibrate.

Station	Sample No.	Property	Quality Code	Comment
85/1	134	reft	3	SBE35 did not equilibrate.
86/2	213	reft	3	SBE35 did not equilibrate.
86/2	224	reft	3	SBE35 did not equilibrate.
86/2	225	reft	3	Unstable temperatures.
86/2	226	po4	4	Value much higher than expected, suspect sampling contamination.
86/2	233	reft	3	Unstable temperatures.
87/1	114	reft	3	SBE35 did not equilibrate.
87/1	117	reft	3	SBE35 did not equilibrate.
87/1	123	reft	3	SBE35 did not equilibrate.
87/1	125	reft	3	SBE35 did not equilibrate.
87/1	128	reft	3	SBE35 did not equilibrate.
87/1	129	reft	3	SBE35 did not equilibrate.
87/1	133	reft	3	SBE35 did not equilibrate.
88/1	107	bottle	9	Niskin bottom end-cap did not close until it was on deck; empty.
88/1	124	reft	3	SBE35 did not equilibrate.
88/1	127	reft	3	SBE35 did not equilibrate.
88/1	128	reft	3	SBE35 did not equilibrate.
88/1	132	reft	3	SBE35 did not equilibrate.
89/3	321	reft	3	SBE35 did not equilibrate.
89/3	321	salt	3	Salinity value does not fit profile.
89/3	323	reft	3	SBE35 did not equilibrate.
89/3	324	reft	3	Unstable temperatures..
89/3	327	reft	3	Unstable temperatures..
89/3	328	reft	3	SBE35 did not equilibrate.
89/3	330	reft	3	SBE35 did not equilibrate.
89/3	333	salt	3	Salinity value does not fit profile.
90/1	106	salt	5	Salinity sample dropped during analysis. Sample lost.

Appendix 2.D

US-Repeat Hydrography (GO-SHIP) P16S: Pre-Cruise Sensor Laboratory Calibrations

Table of Contents

Pressure Calibration Report
STS/ODF Calibration Facility

SENSOR SERIAL NUMBER: 0831
CALIBRATION DATE: 02-JAN-2014
Mfg: SEABIRD Model: 09P CTD Prs s/n: 99677

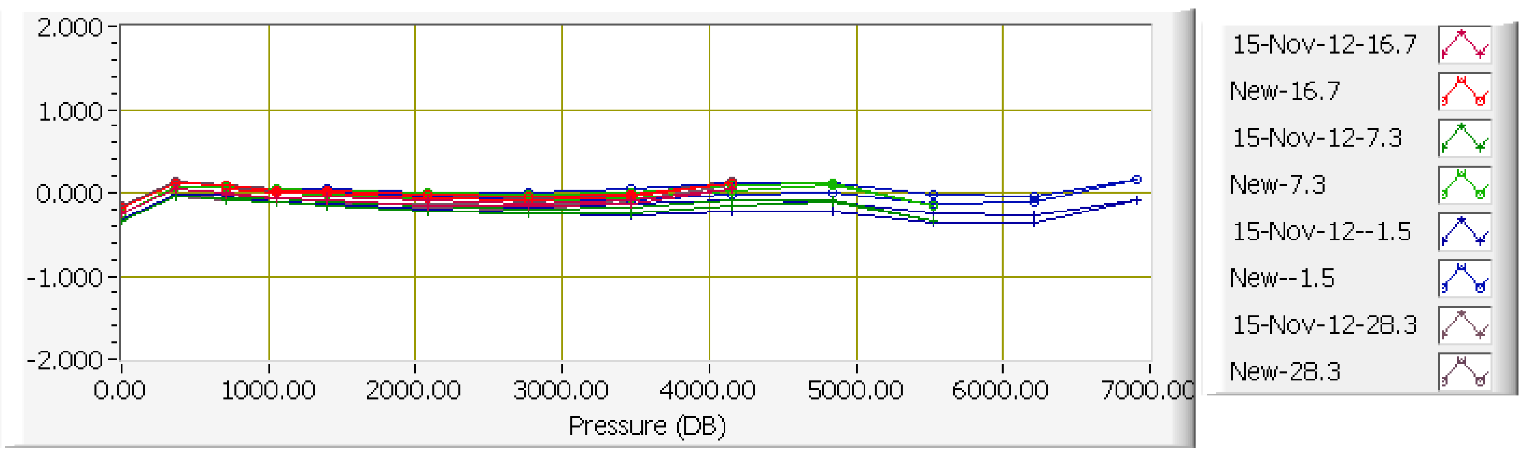
C1= -4.346374E+4
C2= -3.002636E-1
C3= 1.123365E-2
D1= 3.308025E-2
D2= 0.000000E+0
T1= 3.004621E+1
T2= -4.407214E-4
T3= 3.664094E-6
T4= 1.262619E-8
T5= 0.000000E+0
AD590M= 1.28916E-2
AD590B= -8.23481E+0
Slope = 1.00000000E+0
Offset = 0.00000000E+0

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

Sensor Output	Standard	Sensor New_Coefs	Standard-Sensor Prev_Coefs	Standard-Sensor NEW_Coefs	Sensor_Temp	Bath_Temp
33295.357	0.16	0.34	-0.26	-0.19	18.25	16.724
33497.066	364.95	364.83	0.04	0.12	18.25	16.725
33686.299	709.13	709.05	0.00	0.08	18.25	16.726
33874.342	1053.30	1053.28	-0.06	0.02	18.25	16.727
34061.220	1397.56	1397.54	-0.05	0.02	18.25	16.728
34431.523	2086.04	2086.06	-0.10	-0.02	18.27	16.729
34797.353	2774.57	2774.62	-0.12	-0.05	18.27	16.730
35158.859	3463.19	3463.21	-0.09	-0.02	18.28	16.731
35516.144	4151.89	4151.79	0.04	0.11	18.30	16.732
35158.883	3463.19	3463.24	-0.13	-0.05	18.30	16.733
34797.385	2774.57	2774.66	-0.17	-0.09	18.30	16.734
34431.557	2086.04	2086.10	-0.15	-0.07	18.30	16.735
34061.253	1397.56	1397.57	-0.09	-0.01	18.30	16.736
33874.365	1053.30	1053.29	-0.07	0.01	18.30	16.736
33686.331	709.13	709.08	-0.02	0.06	18.30	16.737
33497.099	364.95	364.86	0.02	0.09	18.30	16.738
33291.944	0.16	0.40	-0.34	-0.24	8.94	7.262

Sensor Output	Standard	Sensor New_Coefs	Standard-Sensor Prev_Coefs	Standard-Sensor NEW_Coefs	Sensor_Temp	Bath_Temp
33493.627	364.95	364.88	-0.04	0.07	8.94	7.262
33682.820	709.12	709.06	-0.06	0.07	8.94	7.260
33870.815	1053.29	1053.24	-0.08	0.05	8.94	7.260
34057.683	1397.55	1397.52	-0.11	0.03	8.94	7.259
34427.932	2086.01	2086.02	-0.16	-0.00	8.94	7.259
34793.722	2774.55	2774.58	-0.19	-0.03	8.94	7.259
35155.187	3463.17	3463.17	-0.18	-0.00	8.94	7.259
35512.438	4151.85	4151.76	-0.10	0.09	8.94	7.259
35865.672	4840.60	4840.48	-0.08	0.11	8.94	7.258
36215.116	5529.40	5529.55	-0.35	-0.15	8.94	7.258
35865.683	4840.60	4840.51	-0.10	0.09	8.94	7.258
35512.467	4151.85	4151.82	-0.16	0.03	8.93	7.257
35155.208	3463.17	3463.23	-0.24	-0.06	8.92	7.257
34793.744	2774.55	2774.63	-0.25	-0.08	8.91	7.256
34427.959	2086.02	2086.09	-0.22	-0.07	8.91	7.256
34057.695	1397.55	1397.56	-0.15	-0.01	8.91	7.256
33870.827	1053.29	1053.28	-0.12	0.01	8.91	7.255
33682.826	709.13	709.09	-0.08	0.03	8.91	7.255
33493.622	364.95	364.89	-0.05	0.06	8.91	7.255
33287.889	0.16	0.41	-0.32	-0.25	-0.06	-1.545
33489.555	364.95	364.87	-0.01	0.08	-0.05	-1.544
33678.734	709.13	709.06	-0.03	0.07	-0.05	-1.543
33866.722	1053.30	1053.25	-0.07	0.05	-0.05	-1.542
34053.564	1397.56	1397.51	-0.08	0.05	-0.05	-1.542
34423.796	2086.03	2086.03	-0.15	-0.00	-0.04	-1.541
34789.557	2774.57	2774.57	-0.17	-0.00	-0.03	-1.540
35150.978	3463.19	3463.14	-0.14	0.05	-0.02	-1.539
35508.222	4151.88	4151.78	-0.09	0.11	-0.02	-1.538
35861.439	4840.63	4840.52	-0.11	0.11	-0.02	-1.537
36210.794	5529.44	5529.47	-0.26	-0.03	-0.02	-1.536
36556.272	6218.32	6218.36	-0.27	-0.04	-0.02	-1.535
36897.941	6907.25	6907.10	-0.10	0.15	-0.02	-1.533
36556.311	6218.32	6218.44	-0.35	-0.12	-0.02	-1.533
36210.846	5529.44	5529.56	-0.36	-0.12	-0.02	-1.532
35861.505	4840.63	4840.64	-0.23	-0.01	-0.02	-1.532
35508.296	4151.88	4151.91	-0.23	-0.03	-0.02	-1.531
35151.056	3463.20	3463.28	-0.27	-0.08	-0.02	-1.530
34789.609	2774.58	2774.66	-0.26	-0.09	-0.02	-1.530
34423.842	2086.04	2086.08	-0.20	-0.04	-0.01	-1.529
34053.609	1397.56	1397.55	-0.12	0.01	-0.01	-1.528
33866.769	1053.30	1053.29	-0.11	0.01	0.00	-1.528
33678.775	709.13	709.08	-0.06	0.05	0.01	-1.527
33489.586	364.95	364.88	-0.02	0.07	0.01	-1.526
33298.399	0.16	0.32	-0.33	-0.16	29.56	28.318
33500.146	364.95	364.82	-0.03	0.13	29.57	28.318

Sensor Output	Standard	Sensor New_Coefs	Standard-Sensor Prev_Coefs	Standard-Sensor NEW_Coefs	Sensor_Temp	Bath_Temp
33689.412	709.13	709.04	-0.06	0.09	29.59	28.319
33877.483	1053.30	1053.26	-0.11	0.04	29.60	28.319
34064.406	1397.55	1397.55	-0.13	0.01	29.61	28.320
34434.756	2086.03	2086.05	-0.15	-0.03	29.62	28.320
34800.653	2774.56	2774.63	-0.16	-0.07	29.63	28.321
35162.198	3463.19	3463.20	-0.09	-0.01	29.64	28.322
35519.515	4151.88	4151.73	0.10	0.14	29.66	28.323
35162.219	3463.19	3463.23	-0.12	-0.04	29.67	28.324
34800.683	2774.56	2774.67	-0.20	-0.11	29.67	28.325
34434.784	2086.03	2086.08	-0.17	-0.05	29.68	28.326
34064.436	1397.56	1397.57	-0.15	-0.01	29.69	28.327
33877.506	1053.30	1053.26	-0.12	0.03	29.70	28.328
33689.451	709.13	709.06	-0.09	0.07	29.71	28.329
33500.182	364.95	364.83	-0.04	0.12	29.72	28.330
33298.435	0.16	0.32	-0.34	-0.17	29.73	28.331



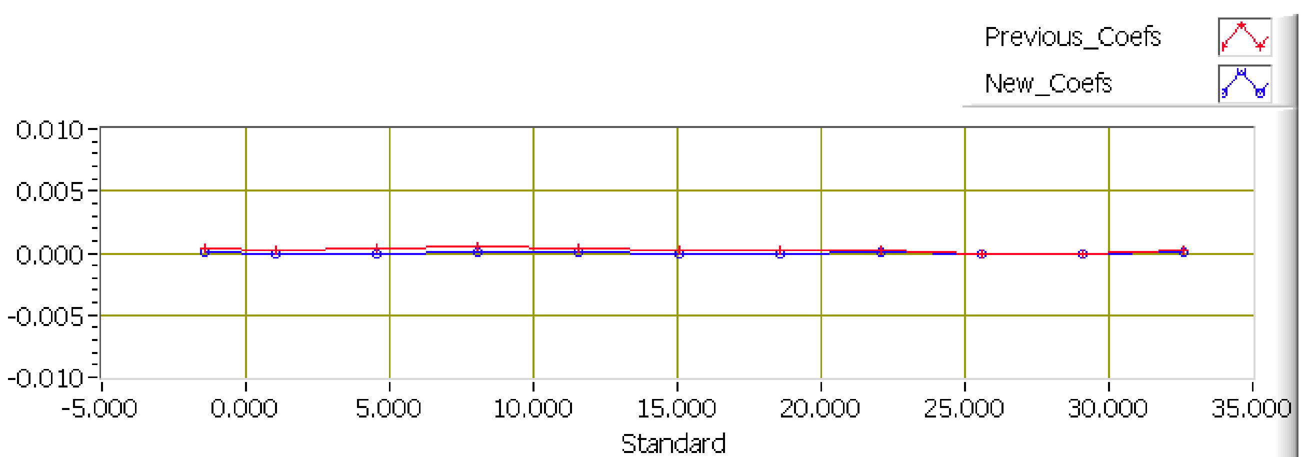
Temperature Calibration Report
STS/ODF Calibration Facility

SENSOR SERIAL NUMBER: 5046
CALIBRATION DATE: 07-Jan-2014
Mfg: SEABIRD Model: 03
Previous cal: 20-Aug-13
Calibration Tech: CAL

ITS-90_COEFFICIENTS	IPTS-68_COEFFICIENTS ITS-T90	
g = 4.41730139E-3	a = 4.41751937E-3	
h = 6.45937577E-4	b = 6.46153852E-4	
i = 2.37505541E-5	c = 2.37831272E-5	
j = 2.31036294E-6	d = 2.31187244E-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)
Temperature IPTS-68 = 1/{a+b[ln(f0/f)]+c[ln2(f0/f)]+d[ln3(f0/f)]} - 273.15 (°C)
T68 = 1.00024 * T90 (-2 to -35 Deg C)

SBE3 Freq	SPRT ITS-T90	SBE3 ITS-T90	SPRT-SBE3 OLD_Coefs	SPRT-SBE3 NEW_Coefs
3274.4722	-1.4609	-1.4610	0.00042	0.00010
3463.4980	1.0410	1.0412	0.00027	-0.00013
3741.2316	4.5443	4.5444	0.00040	-0.00004
4034.6519	8.0480	8.0480	0.00046	0.00005
4344.2531	11.5529	11.5528	0.00040	0.00005
4669.5436	15.0493	15.0493	0.00024	-0.00003
5012.6414	18.5558	18.5559	0.00017	-0.00001
5372.7964	22.0605	22.0603	0.00025	0.00014
5750.2992	25.5623	25.5624	-0.00004	-0.00010
6145.7028	29.0641	29.0641	-0.00002	-0.00009
6559.6169	32.5680	32.5679	0.00021	0.00007



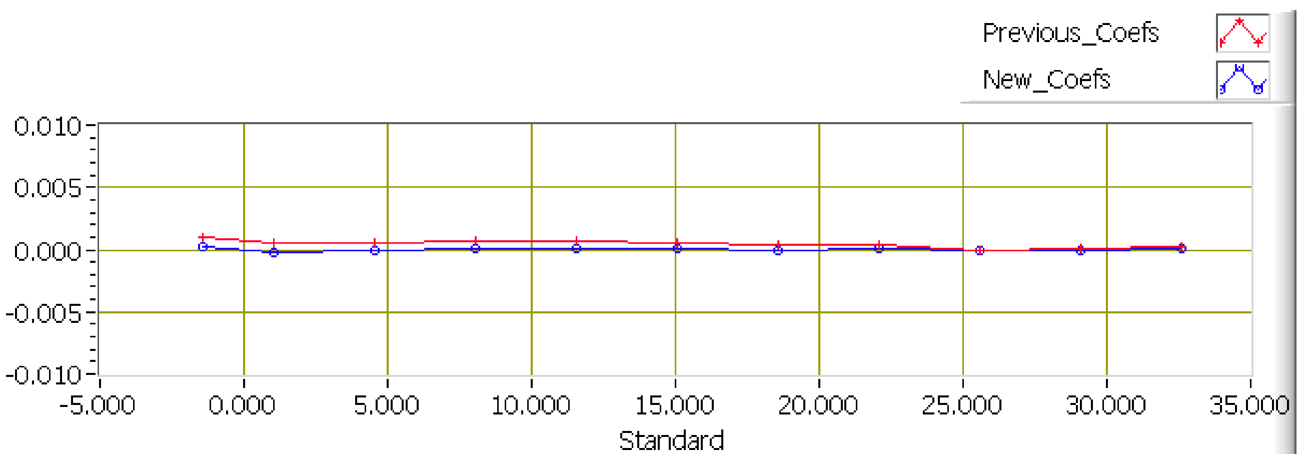
Temperature Calibration Report
STS/ODF Calibration Facility

SENSOR SERIAL NUMBER: 4953
CALIBRATION DATE: 07-Jan-2014
Mfg: SEABIRD   Model: 03
Previous cal: 30-Jul-13
Calibration Tech: CAL

ITS-90_COEFFICIENTS	IPTS-68_COEFFICIENTS ITS-T90	
g = 4.36142499E-3	a = 4.36162472E-3	
h = 6.31196043E-4	b = 6.31403988E-4	
i = 1.99805635E-5	c = 2.00117066E-5	
j = 1.40393039E-6	d = 1.40528736E-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)
Temperature IPTS-68 = 1/{a+b[ln(f0/f)]+c[ln2(f0/f)]+d[ln3(f0/f)]} - 273.15 (°C)
T68 = 1.00024 * T90 (-2 to -35 Deg C)

SBE3 Freq	SPRT ITS-T90	SBE3 ITS-T90	SPRT-SBE3 OLD_Coefs	SPRT-SBE3 NEW_Coefs
3048.8242	-1.4609	-1.4611	0.00093	0.00019
3227.1230	1.0410	1.0412	0.00054	-0.00022
3489.3193	4.5443	4.5445	0.00058	-0.00014
3766.6180	8.0480	8.0480	0.00071	0.00005
4059.5444	11.5529	11.5528	0.00068	0.00012
4367.6831	15.0493	15.0492	0.00049	0.00005
4693.0918	18.5558	18.5558	0.00033	-0.00000
5035.1090	22.0605	22.0604	0.00031	0.00008
5394.0568	25.5623	25.5625	0.00000	-0.00015
5770.5254	29.0641	29.0642	0.00003	-0.00010
6165.1595	32.5680	32.5679	0.00025	0.00011



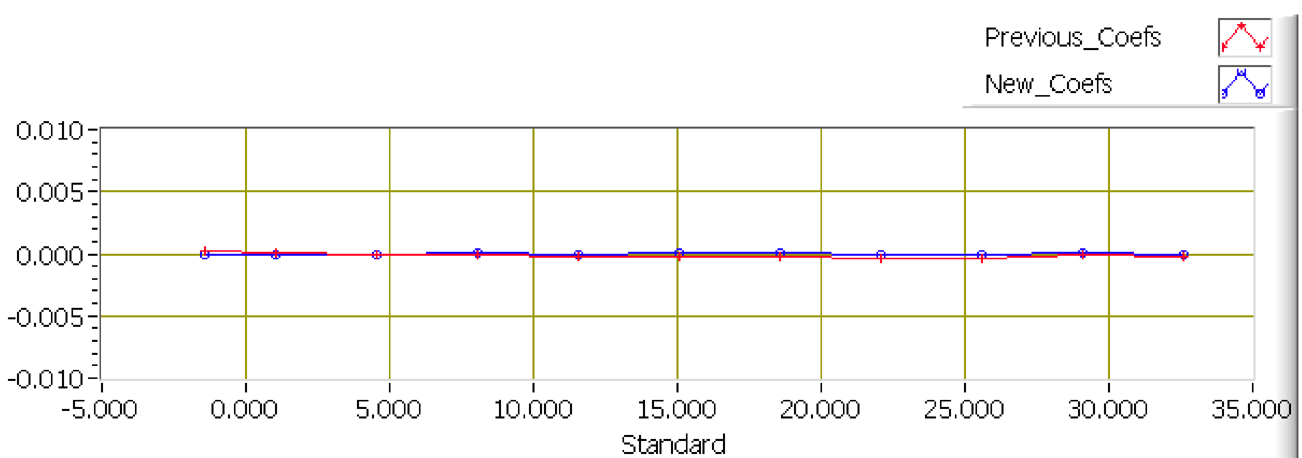
Temperature Calibration Report
STS/ODF Calibration Facility

SENSOR SERIAL NUMBER: 4213
CALIBRATION DATE: 02-Jan-2014
Mfg: SEABIRD   Model: 03
Previous cal: 20-Aug-13
Calibration Tech: CAL

ITS-90_COEFFICIENTS	IPTS-68_COEFFICIENTS ITS-T90	
g = 4.32186185E-3	a = 4.32204860E-3	
h = 6.25984057E-4	b = 6.26187083E-4	
i = 1.97785170E-5	c = 1.98090679E-5	
j = 1.52992507E-6	d = 1.53126321E-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)
Temperature IPTS-68 = 1/{a+b[ln(f0/f)]+c[ln2(f0/f)]+d[ln3(f0/f)]} - 273.15 (°C)
T68 = 1.00024 * T90 (-2 to -35 Deg C)

SBE3 Freq	SPRT ITS-T90	SBE3 ITS-T90	SPRT-SBE3 OLD_Coefs	SPRT-SBE3 NEW_Coefs
2876.7902	-1.4610	-1.4610	0.00025	0.00000
3045.8353	1.0421	1.0421	0.00014	0.00000
3294.3018	4.5439	4.5440	-0.00002	-0.00002
3557.2866	8.0480	8.0480	-0.00005	0.00005
3835.1349	11.5529	11.5530	-0.00024	-0.00007
4127.4919	15.0499	15.0498	-0.00017	0.00005
4436.2710	18.5566	18.5566	-0.00024	0.00002
4760.6823	22.0593	22.0594	-0.00031	-0.00003
5101.5675	25.5633	25.5633	-0.00037	-0.00010
5458.9798	29.0655	29.0654	-0.00014	0.00013
5833.6458	32.5690	32.5691	-0.00027	-0.00004



Temperature Calibration Report
STS/ODF Calibration Facility

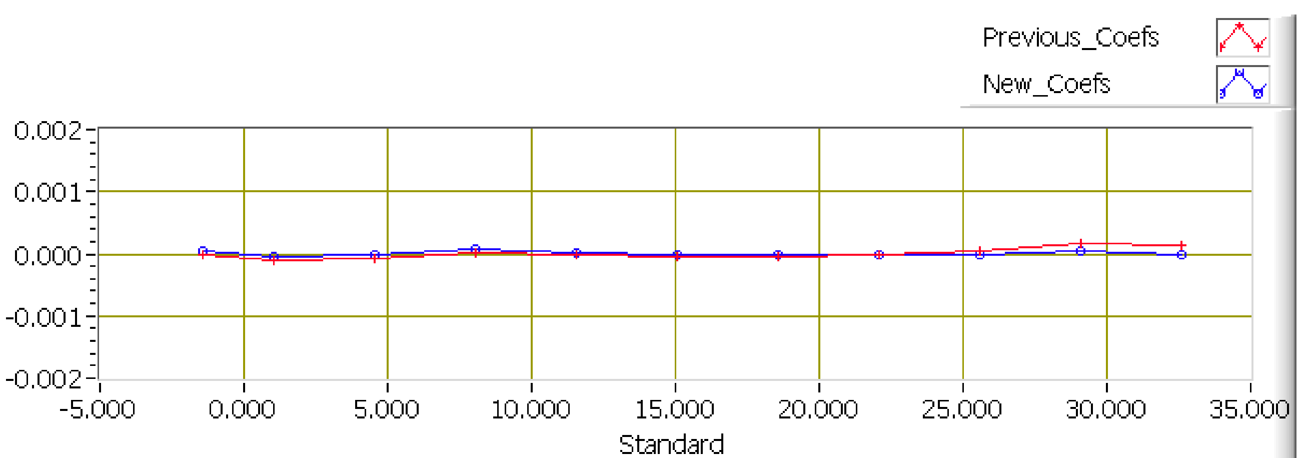
SENSOR SERIAL NUMBER: 0035
CALIBRATION DATE: 15-Jan-2014
Mfg: SEABIRD Model: 35
Previous cal: 18-Jun-13
Calibration Tech: CAL

ITS-90_COEFFICIENTS
a0 = 3.927281381E-3
a1 = -1.037150759E-3
a2 = 1.634334722E-4
a3 = -9.184815311E-6
a4 = 1.986797340E-7
Slope = 1.000000 Offset = 0.000000
Calibration Standard: Mfg: ASL Model: F18 s/n: 245-5149

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

Temperature ITS-90 = 1/{a0+a1[ln(f)]+a2[ln2(f)]+a3[ln3(f)]+a4[ln4(f)} - 273.15 (°C)

SBE35 Count	SPRT ITS-T90	SBE35 ITS-T90	SPRT-SBE35 OLD_Coefs	SPRT-SBE35 NEW_Coefs
657640.1765	-1.4583	-1.4584	-0.00001	0.00004
589381.1624	1.0431	1.0432	-0.00010	-0.00006
506707.0552	4.5463	4.5464	-0.00007	-0.00003
436795.5730	8.0507	8.0506	0.00003	0.00007
377548.8988	11.5551	11.5551	-0.00001	0.00003
327329.4239	15.0512	15.0512	-0.00005	-0.00001
284422.2912	18.5581	18.5581	-0.00005	-0.00003
247847.5604	22.0594	22.0594	-0.00003	-0.00003
216504.1183	25.5646	25.5646	0.00005	0.00000
189632.1110	29.0664	29.0663	0.00016	0.00006
166499.1570	32.5698	32.5698	0.00013	-0.00003



Sea-Bird Electronics, Inc.

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SENSOR SERIAL NUMBER: 3429
CALIBRATION DATE: 19-Nov-13

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

GHIJ COEFFICIENTS

```
g = -9.80394533e+000
h =  1.50801204e+000
i = -1.83800754e-003
j =  2.29831365e-004
CPcor = -9.5700e-008 (nominal)
CTcor =  3.2500e-006 (nominal)
```

ABCDM COEFFICIENTS

```
a =  2.48339495e-006
b =  1.50340843e+000
c = -9.79511999e+000
d = -8.25604584e-005
m =  5.6
CPcor = -9.5700e-008 (nominal)
```

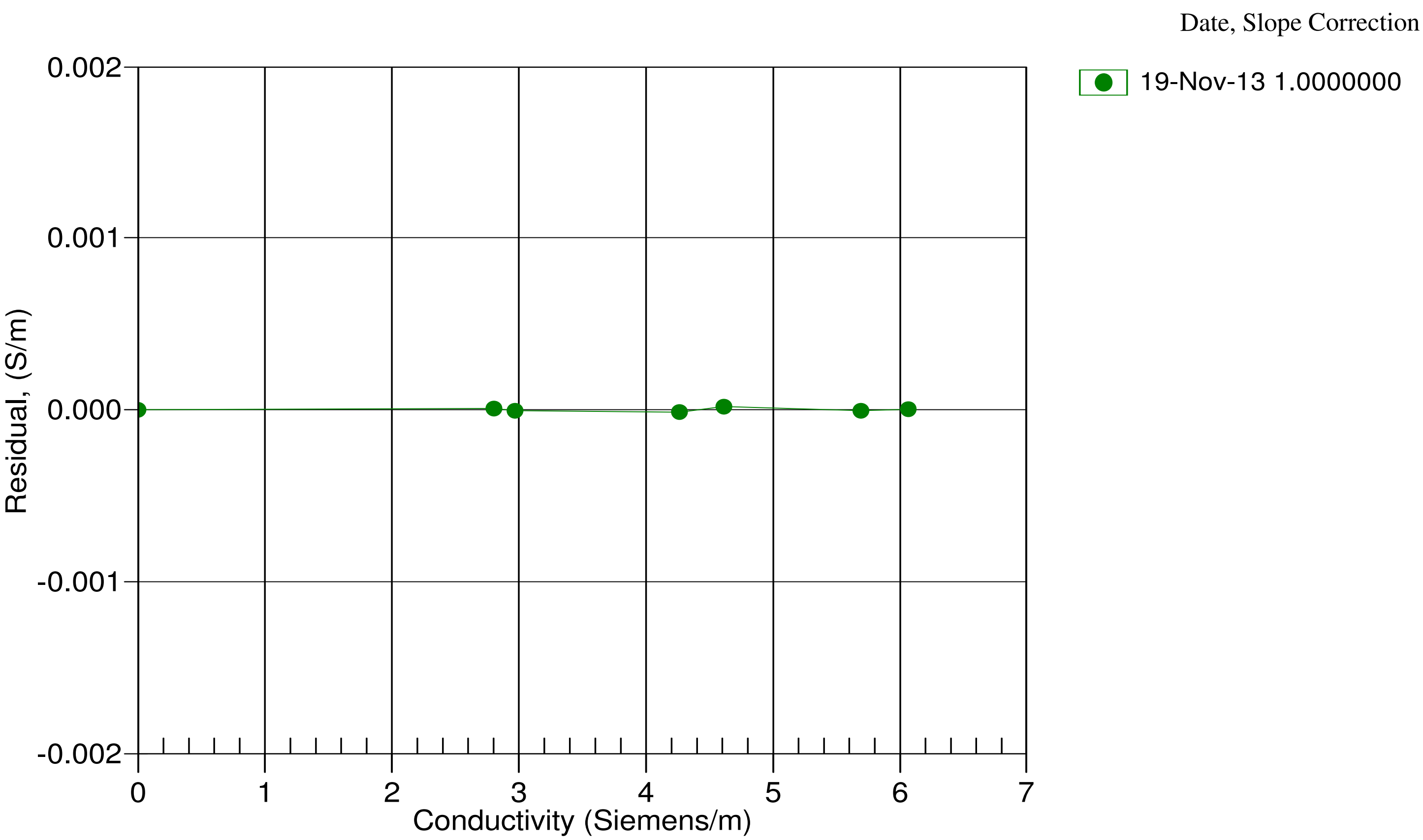
BATH TEMP (ITS-90)	BATH SAL (PSU)	BATH COND (Siemens/m)	INST FREQ (kHz)	INST COND (Siemens/m)	RESIDUAL (Siemens/m)
0.0000	0.0000	0.00000	2.55246	0.00000	0.00000
-1.0000	34.7448	2.79935	5.01216	2.79936	0.00001
1.0000	34.7455	2.97049	5.12428	2.97048	-0.00001
15.0000	34.7467	4.26398	5.90285	4.26396	-0.00001
18.5000	34.7459	4.61004	6.09419	4.61005	0.00002
29.0000	34.7444	5.69187	6.65652	5.69186	-0.00001
32.5001	34.7378	6.06386	6.83907	6.06386	0.00000

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

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

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

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



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SENSOR SERIAL NUMBER: 3057
CALIBRATION DATE: 19-Dec-13

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

GHIJ COEFFICIENTS

g = -1.02044015e+001
h = 1.28537138e+000
i = 4.10065605e-004
j = 2.58419169e-005
CPcor = -9.5700e-008 (nominal)
CTcor = 3.2500e-006 (nominal)

ABCDM COEFFICIENTS

a = 3.10846275e-004
b = 1.28556745e+000
c = -1.02046696e+001
d = -8.53416924e-005
m = 3.3
CPcor = -9.5700e-008 (nominal)

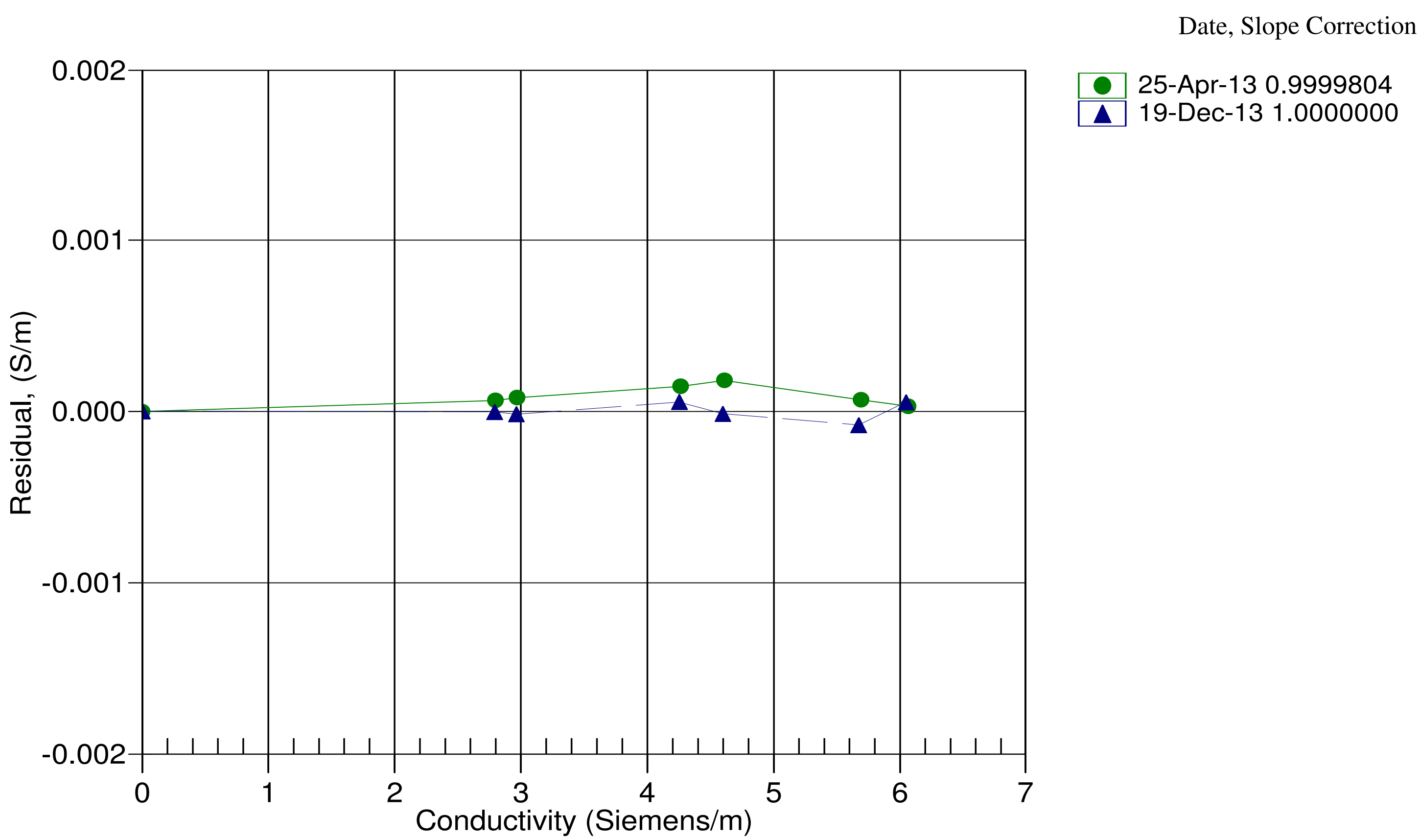
BATH TEMP (ITS-90)	BATH SAL (PSU)	BATH COND (Siemens/m)	INST FREQ (kHz)	INST COND (Siemens/m)	RESIDUAL (Siemens/m)
0.0000	0.0000	0.00000	2.81611	0.00000	0.00000
-1.0000	34.6232	2.79047	5.43869	2.79046	-0.00000
1.0000	34.6239	2.96108	5.55892	2.96107	-0.00002
15.0000	34.6233	4.25044	6.39466	4.25049	0.00006
18.5000	34.6229	4.59547	6.60024	4.59546	-0.00001
29.0000	34.6212	5.67395	7.20496	5.67387	-0.00008
32.5000	34.6145	6.04477	7.40149	6.04482	0.00005

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

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

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

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



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SENSOR SERIAL NUMBER: 2115
CALIBRATION DATE: 14-Dec-13

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

GHIJ COEFFICIENTS

g = -9.88681014e+000
h = 1.42958230e+000
i = -1.74896449e-003
j = 2.07715195e-004
CPcor = -9.5700e-008 (nominal)
CTcor = 3.2500e-006 (nominal)

ABCDM COEFFICIENTS

a = 1.34789425e-006
b = 1.42507263e+000
c = -9.87782542e+000
d = -8.48856510e-005
m = 5.8
CPcor = -9.5700e-008 (nominal)

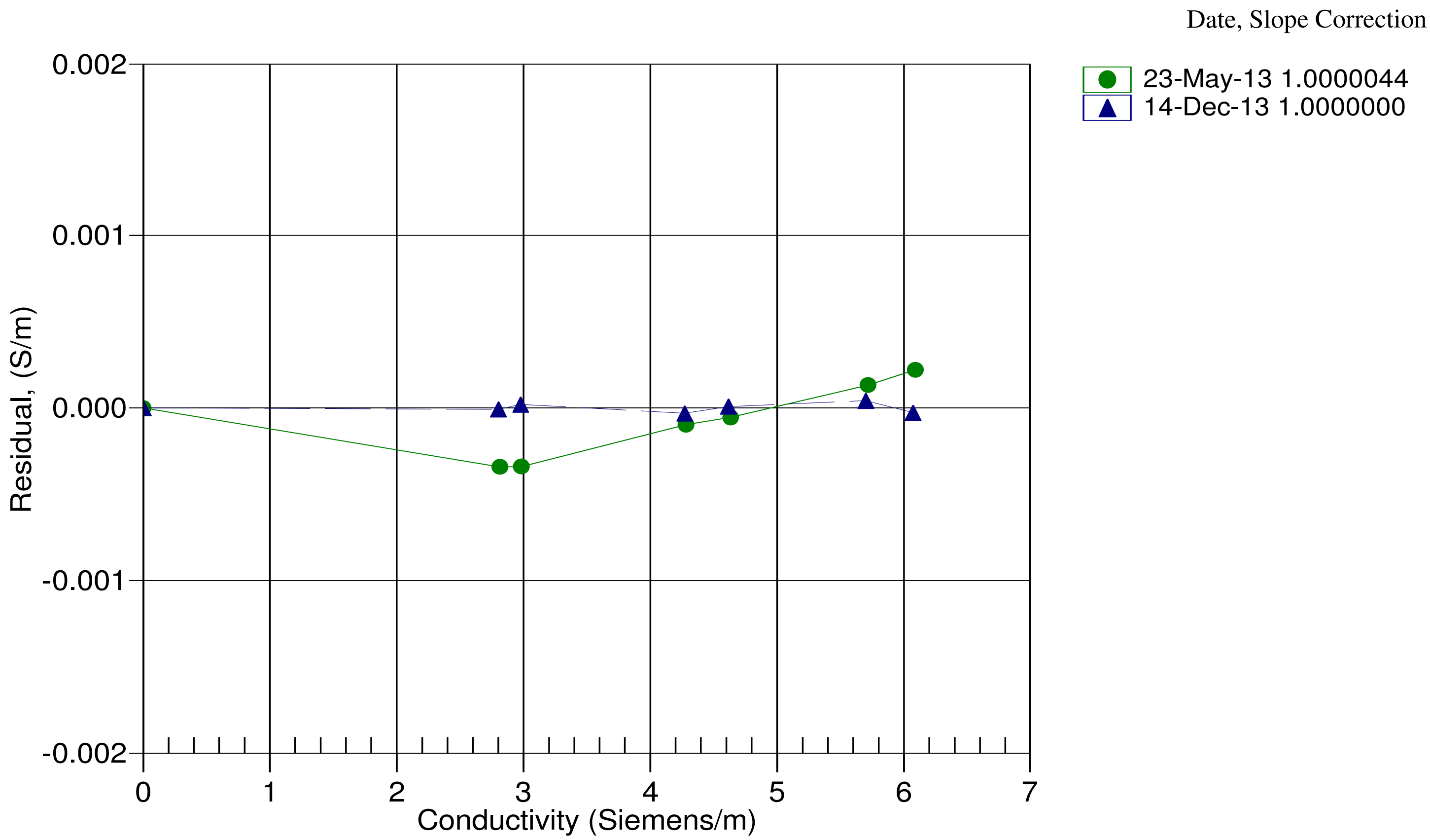
BATH TEMP (ITS-90)	BATH SAL (PSU)	BATH COND (Siemens/m)	INST FREQ (kHz)	INST COND (Siemens/m)	RESIDUAL (Siemens/m)
0.0000	0.0000	0.00000	2.63272	0.00000	0.00000
-1.0000	34.7932	2.80289	5.15627	2.80288	-0.00001
1.0000	34.7931	2.97417	5.27139	2.97419	0.00002
15.0000	34.7944	4.26921	6.07098	4.26918	-0.00003
18.5000	34.7940	4.61573	6.26755	4.61574	0.00001
29.0000	34.7926	5.69887	6.84523	5.69891	0.00004
32.5001	34.7880	6.07162	7.03289	6.07160	-0.00003

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

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

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

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



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SENSOR SERIAL NUMBER: 1138
CALIBRATION DATE: 07-Dec-13

SBE 43 OXYGEN CALIBRATION DATA

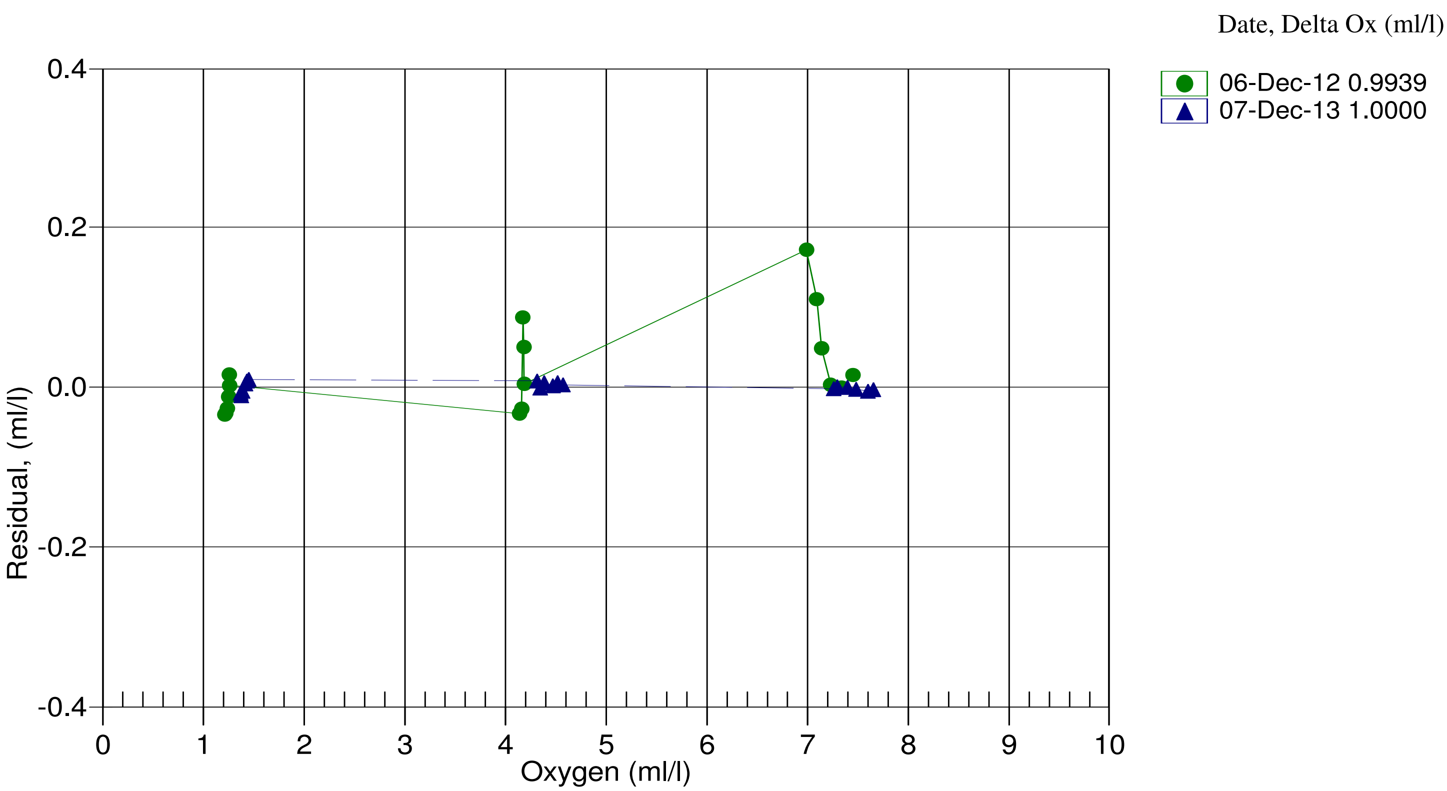
COEFFICIENTS
Soc = 0.4962
Voffset = -0.5213
Tau20 = 2.33

A = -3.5410e-003
B = 1.6754e-004
C = -2.4783e-006
E nominal = 0.036

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

BATH OX (ml/l)	BATH TEMP ITS-90	BATH SAL PSU	INSTRUMENT OUTPUT(VOLTS)	INSTRUMENT OXYGEN(ml/l)	RESIDUAL (ml/l)
1.37	2.00	0.00	0.807	1.36	-0.01
1.38	6.00	0.00	0.843	1.37	-0.01
1.39	12.00	0.00	0.899	1.38	-0.01
1.41	20.00	0.00	0.982	1.42	0.00
1.43	26.00	0.00	1.045	1.44	0.01
1.45	30.00	0.00	1.089	1.46	0.01
4.31	2.00	0.00	1.427	4.32	0.01
4.34	6.00	0.00	1.542	4.34	-0.00
4.38	12.00	0.00	1.721	4.39	0.01
4.47	20.00	0.00	1.971	4.47	0.00
4.52	26.00	0.00	2.163	4.52	0.01
4.57	30.00	0.00	2.304	4.57	0.00
7.26	2.00	0.00	2.041	7.25	-0.00
7.30	6.00	0.00	2.236	7.30	0.00
7.39	12.00	0.00	2.542	7.39	-0.00
7.48	20.00	0.00	2.947	7.48	-0.00
7.60	26.00	0.00	3.277	7.59	-0.01
7.65	30.00	0.00	3.502	7.65	-0.00

Oxygen (ml/l) = Soc * (V + Voffset) * (1.0 + A * T + B * T^2 + C * T^3) * OxSol(T,S) * exp(E * P / K)
V = voltage output from SBE43, T = temperature [deg C], S = salinity [PSU], K = temperature [Kelvin]
OxSol(T,S) = oxygen saturation [ml/l], P = pressure [dbar], Residual = instrument oxygen - bath oxygen



Sea-Bird Electronics, Inc.
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Phone: (+1) 425-643-9866 Fax (+1) 425-643-9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 0185
CALIBRATION DATE: 31-Dec-13

SBE 43 OXYGEN CALIBRATION DATA

COEFFICIENTS

Soc = 0.5352
Voffset = -0.5047
Tau20 = 1.48

A = -3.2374e-003
B = 1.3084e-004
C = -2.1473e-006
E nominal = 0.036

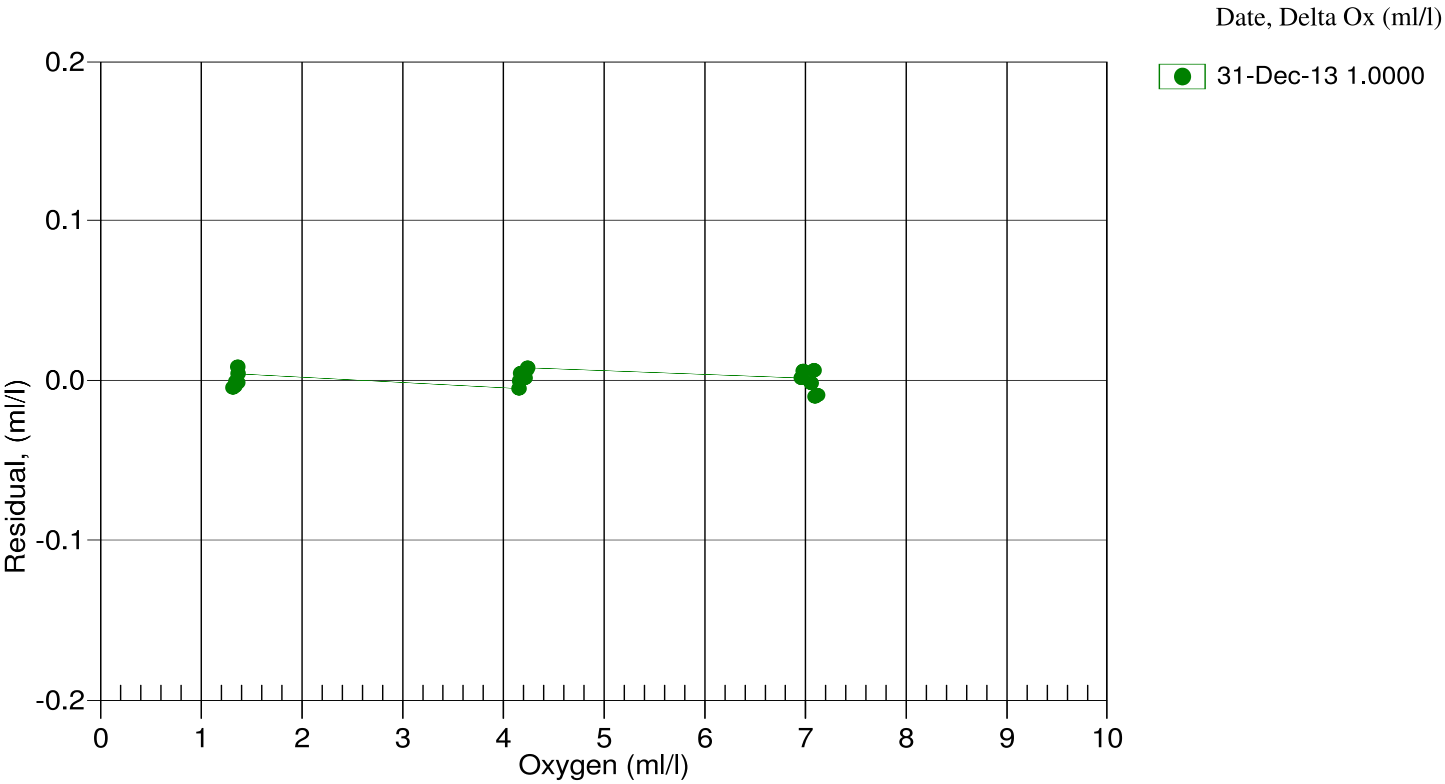
NOMINAL DYNAMIC COEFFICIENTS

D1 = 1.92634e-4
D2 = -4.64803e-2

H1 = -3.30000e-2
H2 = 5.00000e+3
H3 = 1.45000e+3

BATH OX (ml/l)	BATH TEMP ITS-90	BATH SAL PSU	INSTRUMENT OUTPUT(VOLTS)	INSTRUMENT OXYGEN(ml/l)	RESIDUAL (ml/l)
1.32	2.00	0.00	0.759	1.31	-0.00
1.34	6.00	0.00	0.795	1.33	-0.00
1.34	12.00	0.00	0.846	1.34	-0.00
1.36	20.00	0.00	0.916	1.36	-0.00
1.36	30.00	0.00	1.008	1.37	0.01
1.37	26.00	0.00	0.971	1.37	0.00
4.15	2.00	0.00	1.310	4.15	-0.01
4.16	6.00	0.00	1.410	4.16	-0.00
4.17	12.00	0.00	1.565	4.18	0.00
4.21	20.00	0.00	1.780	4.21	0.00
4.23	30.00	0.00	2.061	4.24	0.01
4.24	26.00	0.00	1.950	4.25	0.01
6.96	2.00	0.00	1.856	6.96	0.00
6.98	6.00	0.00	2.026	6.99	0.01
7.06	12.00	0.00	2.296	7.06	-0.00
7.08	26.00	0.00	2.919	7.09	0.01
7.10	30.00	0.00	3.104	7.09	-0.01
7.12	20.00	0.00	2.657	7.11	-0.01

Oxygen (ml/l) = Soc * (V + Voffset) * (1.0 + A * T + B * T^2 + C * T^3) * OxSol(T,S) * exp(E * P / K)
V = voltage output from SBE43, T = temperature [deg C], S = salinity [PSU], K = temperature [Kelvin]
OxSol(T,S) = oxygen saturation [ml/l], P = pressure [dbar], Residual = instrument oxygen - bath oxygen



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SENSOR SERIAL NUMBER: 1071
CALIBRATION DATE: 21-Jul-12

SBE 43 OXYGEN CALIBRATION DATA

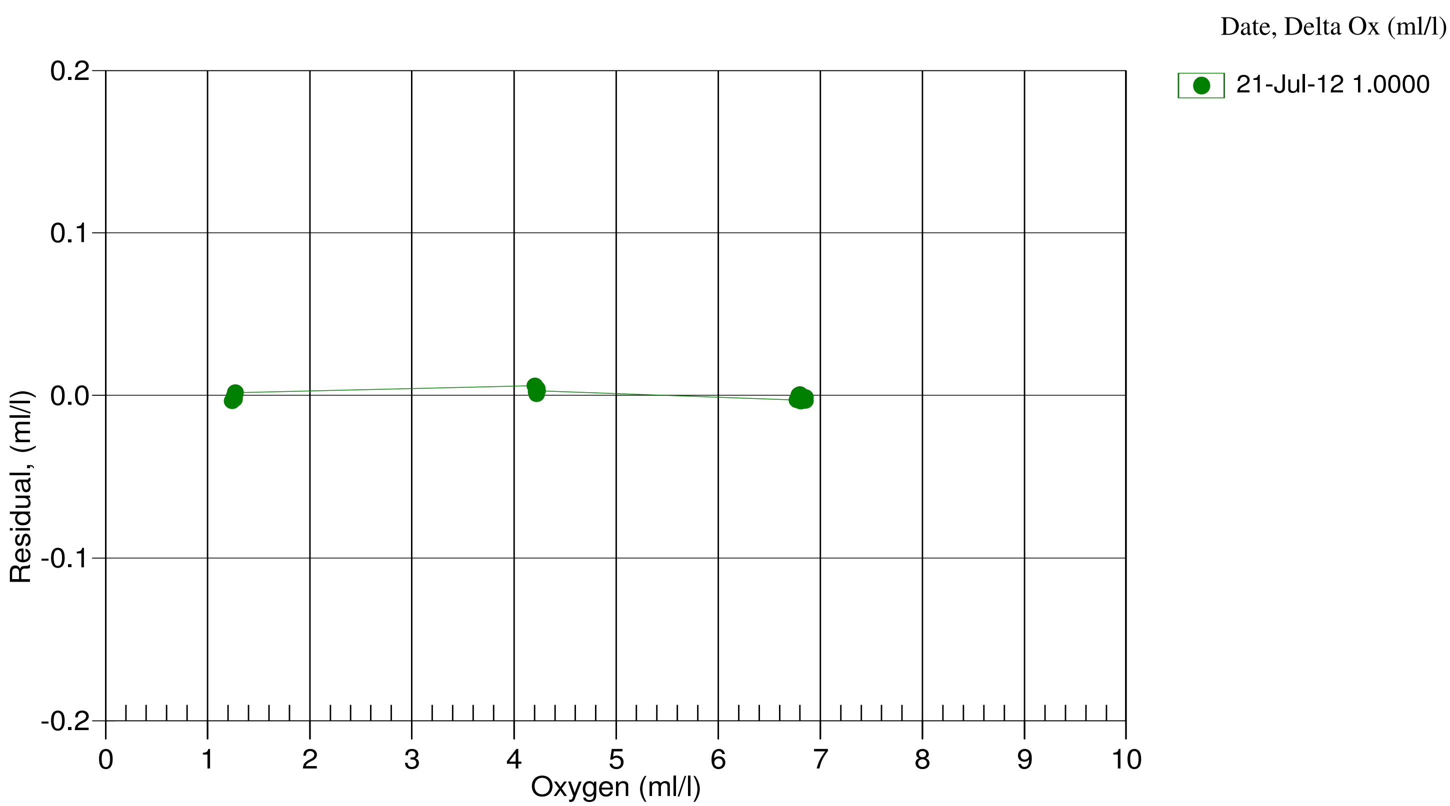
COEFFICIENTS
Soc = 0.4611
Voffset = -0.5086
Tau20 = 1.25

A = -1.6343e-003
B = 3.9125e-005
C = -8.4413e-007
E nominal = 0.036

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

BATH OX (ml/l)	BATH TEMP ITS-90	BATH SAL PSU	INSTRUMENT OUTPUT(VOLTS)	INSTRUMENT OXYGEN(ml/l)	RESIDUAL (ml/l)
1.24	2.00	0.05	0.787	1.24	-0.00
1.25	6.00	0.05	0.822	1.25	-0.00
1.26	12.00	0.04	0.875	1.26	-0.00
1.27	20.00	0.04	0.950	1.26	-0.00
1.27	26.00	0.04	1.009	1.27	0.00
1.27	30.00	0.04	1.052	1.28	0.00
4.20	2.00	0.05	1.455	4.21	0.01
4.21	6.00	0.05	1.568	4.22	0.00
4.22	20.00	0.04	1.983	4.22	0.00
4.23	30.00	0.04	2.311	4.23	0.00
4.23	12.00	0.04	1.745	4.23	0.00
4.24	26.00	0.04	2.181	4.24	0.00
6.77	12.00	0.04	2.486	6.77	-0.00
6.79	20.00	0.04	2.880	6.79	0.00
6.80	6.00	0.05	2.217	6.80	0.00
6.81	2.00	0.05	2.038	6.80	-0.00
6.85	30.00	0.04	3.424	6.85	-0.00
6.86	26.00	0.04	3.211	6.85	-0.00

Oxygen (ml/l) = Soc * (V + Voffset) * (1.0 + A * T + B * T^2 + C * T^3) * OxSol(T,S) * exp(E * P / K)
V = voltage output from SBE43, T = temperature [deg C], S = salinity [PSU], K = temperature [Kelvin]
OxSol(T,S) = oxygen saturation [ml/l], P = pressure [dbar], Residual = instrument oxygen - bath oxygen



3. P16S_2014 CHLOROFLUOROCARBON (CFC), SULFUR HEXAFLUORIDE (SF_6), AND NITROUS OXIDE (N_2O)*

PI: Mark J. Warner, University of Washington (warner@u.washington.edu)
Samplers and Analysts: Mark J. Warner, University of Washington
Patrick Mears, University of Texas
Katie Kirk, Woods Hole Oceanographic Institute

* Note that N_2O measurements are a Level 3 measurement. The concentrations were measured on the same water samples collected for the Level 1 CFC/SF_6 measurements. The N_2O analysis is still under development. Please contact the PI for any use of these data.

3.1. Measurements

Samples for the analysis of dissolved CFC-11, CFC-12, SF_6, and N_2O were collected from approximately 2100 of the Niskin water samples during the expedition. When taken, water samples for CFC analysis were the first samples drawn from the 10-liter bottles. Care was taken to coordinate the sampling of CFCs with other samples to minimize the time between the initial opening of each bottle and the completion of sample drawing. In most cases, dissolved oxygen, dissolved inorganic carbon, and pH samples (and He-3 when sampled) were collected within several minutes of the initial opening of each bottle. To minimize contact with air, the CFC samples were collected from the Niskin bottle petcock into 250-cc ground glass syringes through plastic 3-way stopcocks. The syringes were stored in large ice chest in the laboratory at 3.5° - 6°C until 30-45 minutes before analysis to reduce the degassing and bubble formation in the sample. At that time, they were transferred to a water bath at approximately 35°C in order to increase the stripping efficiency.

Concentrations of CFC-11, CFC-12, SF_6, and N_2O in air samples, seawater and gas standards were measured by shipboard electron capture gas chromatography (EC-GC). This system from the University of Washington was located in a portable laboratory on the heli-deck. Samples were introduced into the GC-EC via a purge and trap system. Approximately 200-ml water samples were purged with nitrogen and the compounds of interest were trapped on a Porapak Q/Carboxen 1000/Molecular Sieve 5A trap cooled by an immersion bath to -60°C. During the purging of the sample (6 minutes at 200 ml min-1 flow), the gas stream was stripped of any water vapor via a Nafion trap in line with an ascarite/magnesium perchlorate dessicant tube prior to transfer to the trap. The trap was isolated and heated by direct resistance to 175°C. The desorbed contents of the trap were back-flushed and transferred onto the analytical pre-columns. The first precolumn was a 40-cm length of 1/8-in tubing packed with 80/100 mesh Porasil B. This precolumn was used to separate the CFC-11 from the other gases. The second pre-column was 13 cm of 1/8-in tubing packed with 80/100 mesh molecular sieve 5A. This pre-column separated the N_2O from CFC-12 and SF_6. Three analytical columns in three gas chromatographs with electron capture detectors were used in the analysis. CFC-11 was separated from other compounds by a long column consisting of 30 cm of Porasil B and 130 cm of Porasil C maintained at 80°C. CFC-12 and SF_6 were analyzed using a column consisting of 100 cm Porasil B and 2.33 m of molecular sieve 5A maintained at 80°C. The analytical column for N_2O was 30 cm of molecular sieve 5A in a 220°C oven. The carrier gas for this column was instrumental grade P-5 gas (95% Ar / 5% CH4) that was directed onto the second precolumn and into the third column for the N_2O analyses.

The analytical system was calibrated frequently using a standard gas of known gas composition. Gas sample loops of known volume were thoroughly flushed with standard gas and injected into the system. The temperature and pressure was recorded so that the amount of gas injected could be calculated. The procedures used to transfer the standard gas to the trap, precolumns, main chromatographic columns and EC detectors were similar to those used for analyzing water samples. Three sizes of gas sample loops were used. Multiple injections of these loop volumes could be made to allow the system to be calibrated over a relatively wide range of concentrations. Air samples and system blanks (injections of loops of CFC-free gas) were injected and analyzed in a similar manner. The typical analysis time for samples was 750 sec.

For atmospheric sampling, a ~100 meter length of 3/8-in OD Dekaron tubing was run from the portable laboratory to the bow of the ship. A flow of air was drawn through this line to the main laboratory using an Air Cadet pump. The air was compressed in the pump, with the downstream pressure held at ~1.5 atm. using a back-pressure regulator. A tee allowed a flow (100 ml min-1) of the compressed air to be directed to the gas sample valves of the CFC/SF_6/N_2O

analytical system, while the bulk flow of the air (>7 l min-1) was vented through the back-pressure regulator. Air samples were generally analyzed when the relative wind direction was within 100 degrees of the bow of the ship to reduce the possibility of shipboard contamination. The pump was run for approximately 30 minutes prior to analysis to insure that the air inlet lines and pump were thoroughly flushed. The average atmospheric concentrations determined during the cruise (from a set of 4 measurements analyzed when possible, n=16) were 230.8 +/- 6.0 parts per trillion (ppt) for CFC-11, 516.9 +/- 12.5 ppt for CFC-12, 8.0 +/- 0.9 ppt for SF_6, and 329.6 +/- 15.4 parts per billion for N_2O. Note that a larger aliquot was required for higher precision N_2O analysis.

Concentrations of the CFCs in air, seawater samples and gas standards are reported relative to the SIO98 calibration scale (Cunnold, et. al., 2000). Concentrations in air and standard gas are reported in units of mole fraction in dry gas, and are typically in the parts per trillion (ppt) range for CFCs and SF_6 and parts per billion (ppb) for N_2O. Dissolved CFC concentrations are given in units of picomoles per kilogram seawater (pmol kg^{-1}), SF6 in femtomoles per kilogram seawater (fmol kg^{-1}), and N_2O in nanomoles per kilogram seawater (nmol kg^{-1}). CFC concentrations in air and seawater samples were determined by fitting their chromatographic peak areas to multi-point calibration curves, generated by injecting multiple sample loops of gas from a working standard (UW WRS 32399) into the analytical instrument. Full-range calibration curves were run at the beginning and end of the cruise, and they were supplemented with occasional injections of multiple aliquots of the standard gas at more frequent time intervals. Single injections of a fixed volume of standard gas at one atmosphere were run much more frequently (at intervals of 2 hours) to monitor short-term changes in detector sensitivity. The SF_6 peak was often on a small bump on the baseline, resulting in a large dependence of the peak area on the choice of endpoints for integration. Estimated accuracy is +/- 3%. Estimated limit of detection is 1 fmol kg^{-1} for CFC-11, 6 fmol kg^{-1} for CFC-12 and 0.05 fmol kg^{-1} for SF_6.

The efficiency of the purging process was evaluated at every other station by re-stripping water samples and comparing the residual concentrations to initial values. These re-strip values were less than 1% for CFC-11 and essentially zero for CFC-12 and SF_6. For N_2O, the re-strip values were complicated by the apparent production of N_2O within the re-stripped sample within the sparging chamber for a subset of the samples. See the discussion below. Based on the re-strips of numerous samples from the deep ocean, the mean values were approximately 4%.

Based upon samples with very low CFC-12 concentrations and the ratio to CFC-11, there appears to be a sampling blank associated with CFC-11. A preliminary estimate for this blank of 0.003 pmol kg^{-1} has been applied to the CFC-11 concentrations. No sampling blanks were applied to the other gases.

On this expedition, based on the analysis of 40 duplicate samples, we estimate precisions (1 standard deviation) of 2.1% or 0.006 pmol kg^{-1} (whichever is greater) for dissolved CFC-11, 0.97% or 0.004 pmol kg^{-1} for CFC-12 measurements, 0.03 fmol kg^{-1} or 3.4% for SF_6, and 0.35 nmol kg^{-1} or 1.6% for N_2O.

3.2 Analytical Difficulties

On this expedition, the ratio of CFC-11 to CFC-12 is too high for samples with low concentrations of both compounds. Two possible explanations for this finding are 1) a sampling blank associated with CFC-11 and 2) poorly constrained calibration curves as peak areas approach 0. Post-cruise processing will be necessary to determine which of these possibilities are more likely. The calibration curve run at the end of the cruise will hopefully be useful in sorting this out. The re-strip values for N_2O in near-surface samples from Stations 17-33 (at least, after that we re- stripped deep samples) were greater than 10% and increased to as high as 40%. Since the stripper blank remained about the same and none of the other gases showed similar trends, we did experiments to show that N_2O was being produced within the stripper during the 13 minutes between analyses. Some microbe took advantage of the anoxic environment and the plentiful nutrients to produce nitrous oxide at a relatively high rate. We will review our data to determine whether this might affect our calculated concentrations for these water samples - if the microbes could actually begin to generate N_2O during the first strip of the sample. When we tried the experiment later in the cruise, at Station 64, the re-strips were the expected 3-4%.

3.3. References

Prinn, R. G., Weiss, R.F., Fraser, P.J., Simmonds, P.G., Cunnold, D.M., Alyea, F.N., O'Doherty, S., Salameh, P., Miller, B.R., Huang, J., Wang, R.H.J., Hartley, D.E., Harth, C., Steele, L.P., Sturrock, G., Midgley, P.M., McCulloch, A., 2000. A history of chemically and radiatively important gases in air deduced from ALE/GAGE/AGAGE. Journal of Geophysical Research, 105, 17,751-17,792

4. DISSOLVED INORGANIC CARBON (DIC)

PI: Richard A. Feely (NOAA/PMEL)
Technicians: Dana Greeley (NOAA/PMEL) and Charles Featherstone (NOAA/AOML)

4.1. Sample collection:

Samples for DIC measurements were drawn (according to procedures outlined in the PICES Publication, Guide to Best Practices for Ocean CO_2 Measurements) from Niskin bottles into 310 ml borosilicate glass flasks using silicone tubing. The flasks were rinsed once and filled from the bottom with care not to entrain any bubbles, overflowing by at least one-half volume. The sample tube was pinched off and withdrawn, creating a 6 ml headspace and 0.12 ml of saturated $HgCl_2$ solution was added as a preservative. The sample bottles were then sealed with glass stoppers lightly covered with Apiezon-L grease. DIC samples were collected from variety of depths with approximately 10% of these samples taken as duplicates.

4.2. Equipment:

The analysis was done by coulometry with two analytical systems (PMEL1 and PMEL2) used simultaneously on the cruise. Each system consisted of a coulometer (5011 UIC Inc) coupled with a Dissolved Inorganic Carbon Extractor (DICE). The DICE system was developed by Esa Peltola and Denis Pierrot of NOAA/AOML and Dana Greeley of NOAA/PMEL to modernize a carbon extractor called SOMMA (Johnson et al. 1985, 1987, 1993, and 1999; Johnson 1992).

The two DICE systems (PMEL-1 and PMEL-2) were set up in a seagoing container modified for use as a shipboard laboratory on the aft main working deck of the *RVIB Nathaniel B. Palmer*. During the 11 day transit, from Hobart to the P16S line along 150°W, the outside air conditioning unit for the container was flooded with water and quit operating. For this reason, and the fact that the deck was awash during much of the transit, it was decided to move the 2 DICE systems into the aft end of the dry lab near the pH and Alkalinity equipment, thus completing the carbon trifecta. This trifecta shared the 1036 sq. ft. aft dry lab of the Palmer with seven refrigerators and freezers and the crew from NASA. This lab was conveniently located just forward of the Baltic Room.

4.3. Calibration, Accuracy, and Precision:

The stability of each coulometer cell solution was confirmed three different ways.

1) Gas loops were run at the beginning and end of each cell;
2) CRM's supplied by Dr. A. Dickson of SIO, were measured near the beginning; and
3) Duplicate samples were typically run throughout the life of the cell solution.

Each coulometer was calibrated by injecting aliquots of pure CO_2 (99.999%) by means of an 8-port valve (Wilke et al., 1993) outfitted with two calibrated sample loops of different sizes (~1ml and ~2ml). The instruments were each separately calibrated at the beginning of each cell with a minimum of two sets of these gas loop injections and then again at the end of each cell to ensure no drift during the life of the cell. Even though we experienced a large temperature fluctuation in the aft dry lab (14°C to 31°C) these standard loops were well insulated and consistent throughout the cruise.

The accuracy of the DICE measurement is determined with the use of standards (Certified Reference Materials (CRMs), consisting of filtered and UV irradiated seawater) supplied by Dr. A. Dickson of Scripps Institution of Oceanography (SIO). The CRM accuracy is determined manometrically on land in San Diego and the DIC data reported to the data base have been corrected to this batch 135 CRM value. The CRM certified value for this batch is 2036.91 $\mu mol/kg^{-1}$.

The precision of the two DICE systems can be demonstrated via the replicate samples. Approximately 10% of the niskins sampled were duplicates taken as a check of our precision. These replicate samples were interspersed throughout the station analysis for quality assurance and integrity of the coulometer cell solutions. The average absolute difference from the mean of these replicates is 0.44 $\mu mol/kg^{-1}$ No systematic differences between the replicates were observed[2].

4.4. Summary

The overall performance of the analytical equipment was very good during the cruise. Once the station spacing went to 40 NM we were able to sample every niskin made available to us. It was only at the end of the cruise, when the lab temperature rose significantly and cut down on the efficiency of our equipment, that we started to cut back on our coverage. At the very start of the cruise, pinch valve #7 failed on PMEL1 but was replaced immediately and without complications. The display for the UIC 5011 coulometer on PMEL1 froze on a few occasions but fortunately not during analysis of a water sample. Near the end, when the lab temperature went above 28°C, one of the water bath's temperature sensors failed and was replaced with a spare. The major problem that was hurdled stemmed from the poor location of the container on the aft main deck. During the past 10 years this same container has been on (11) oceanographic cruises in all the world's oceans on (8) different UNOLS ships without major issue due to the seas. However during this trip, the main deck of the Palmer was awash much of the transit forcing the closure of the deck to scientific personnel. Unfortunately this sea water was enough to both kill the air conditioner and make its way through the hinge side of the double dogged water tight door on the container converted to lab van. In hindsight the helo deck (or 02 level up two decks) next to where the CFC container was located would've been a much more appropriate location for this container.

On a much more positive note, many thanks are given to Joe Tarnow, one of the two ship's IT personnel, for recovering the hard drive from one of the pc computers that also took on some water (during the transit) in the van on the main deck. Joe was able to transfer the drive to another pc and PMEL1 was (thanks to his hard work) seamlessly back in operation.

Including the duplicates, over 3,000 samples were analyzed for dissolved inorganic carbon which means that there is a DIC value for more than 85% of the niskins tripped. The total dissolved inorganic carbon data reported to the database directly from the ship are to be considered preliminary until a more thorough quality assurance can be completed shore side.

Calibration data during this cruise:

SYSTEM	Large Loop	Small Loop	Pipette Volume	Ave CRM[1]	Duplicate[2]
PMEL1	1.9842 ml	1.0006 ml	27.571 ml	2035.19	0.44
PMEL2	1.9885 ml	0.9857 ml	26.363 ml	2036.11	0.45

4.5. References:

Dickson, A.G., Sabine, C.L. and Christian, J.R. (Eds.), (2007): Guide to Best Practices for Ocean CO_2 Measurements. PICES Special Publication 3, 191 pp.

Feely, R.A., R. Wanninkhof, H.B. Milburn, C.E. Cosca, M. Stapp, and P.P. Murphy (1998): "A new automated underway system for making high precision pCO_2 measurements aboard research ships." Anal. Chim. Acta, 377, 185-191.

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Johnson, K.M. (1992): Operator's manual: "Single operator multiparameter metabolic analyzer (SOMMA) for total carbon dioxide (CT) with coulometric detection." Brookhaven National Laboratory, Brookhaven, N.Y., 70 pp.

Johnson, K.M., K.D. Wills, D.B. Butler, W.K. Johnson, and C.S. Wong (1993): "Coulometric total carbon dioxide analysis for marine studies: Maximizing the performance of an automated continuous gas extraction system and coulometric detector." Mar. Chem., 44, 167-189.

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Wilke, R.J., D.W.R. Wallace, and K.M. Johnson (1993): "Water-based gravimetric method for the determination of gas loop volume." Anal. Chem. 65, 2403-2406

5. DISCRETE pH ANALYSES

PI: Dr. Andrew Dickson (SIO/UCSD)
Ship technician: J. Adam Radich (SIO/UCSD)

5.1. Sampling

Samples were collected in 300 mL Pyrex glass bottles and sealed using grey butyl rubber stoppers held in place by aluminum crimped caps. Each bottle was rinsed three times and allowed to overflow by one additional bottle volume. Prior to sealing, each sample was given a 1% head-space and poisoned with 0.02% saturated mercuric chloride ($HgCl_2$). Samples were collected only from the Niskin bottles sampled by both total alkalinity or dissolved inorganic carbon in order to generate a complete characterize the carbon system. This was ended in an overall coverage of greater than 75%. Additionally duplicate bottles were taken (2-4) on random Niskins for each station throughout the course of the cruise. All data should be considered preliminary.

5.2. Analysis

pH was measured on the total hydrogen scale using an Agilent 8453 spectrophotometer outlined in the methods paper by Carter et al. 2012. A Thermo NESLAB RTE-7 recirculating water bath was used to maintain spectrophotometric cell temperature at 20.0°C during the analyses. A custom 10cm flow through jacketed cell was filled autonomously with samples using a Kloehn V6 syringe pump. The sulfonephthalein indicator m-cresol purple (mCp) was used to measure the absorbance of light measured at two different wavelengths (434 nm, 578 nm) corresponding to the maximum absorbance peaks for the acidic and basic forms of the indicator dye. A baseline absorbance was also measured and subtracted from these wavelengths. The baseline absorbance was determined by averaging the absorbances from 725-735nm. The ratios of the absorbances were then used to calculate pH on the total scales using the equations outlined in Liu et al., 2011. The salinity data used was obtained from the conductivity sensor on the CTD. The salinity data was later corroborated by shipboard measurements. Temperature of the samples was measured immediately after spectrophotometric measurements using a YSI 4600 thermometer.

5.3. Reagents

The mCp indicator dye was made up to a concentration of 2.0mM and a total ionic strength of 0.7 mol/kg. A total of 3 batches were used during the cruise. The pHs of these batches were adjusted to approximately 7.8 using dilute solutions of HCl and NaOH and a pH meter calibrated using NBS buffers. The indicator was provided by Dr. Robert Byrne of the University of South Florida, and was purified using the HPLC technique described by Liu et al., 2011.

5.4. Standardization/Results

The precision of the data was accessed from measurements of duplicate analyses, certified reference material (CRM) Batch 135 (provided by Dr. Andrew Dickson, UCSD), and TRIS buffer Batch 20 (provided by Dr. Andrew Dickson, UCSD). CRMs were measured twice a day and bottles of TRIS buffer were measured once a day over the course of the cruise. The preliminary precision obtained from duplicate analyses was found to be ±0.0003.

5.5. Data Processing

The addition of an indicator dye perturbs the pH of the sample and the degree to which pH is affected is a function of the differences between the pH of the seawater and the pH of the indicator. Therefore, a correction is applied to all samples measured for a given batch of dye. To determine this correction samples of varying pH and water composition were randomly run with a single injection of dye and then again with a double injection of dye on a single bottle. To determine this correction the change in the measured absorbance ratio R where R =(A578-Abase) / (A434-Abase) is divided by the change in the isosbestic absorbance (Aiso at 488nm) observed from two injections of dye to one (R''-R') / (Aiso''-Aiso') is plotted against the measured R value for the single injection of dye is then plotted and fitted with a linear regression. From this fit the slope and y- intercept (b and a respectively) are determined by:

$\Delta R/\Delta A\text{iso} = \text{b.i}' + \text{a}$ (1)

From this the corrected ratio (R) corresponding to the measured absorbance ratio if no indicator dye were present can be determined by:

$R = R' - \text{Aiso}' (\text{b}R' + \text{a})$ (2)

Preliminary data have not been corrected for the perturbation.

5.6. References

Carter, B.R., Radich, J.A., Doyle, H.L., and Dickson, A.G., "An Automated Spectrometric System for Discrete and Underway Seawater pH Measurements," Limnology and Oceanography: Methods, 2013.

Liu, X., Patsvas, M.C., Byrne R.H., "Purification and Characterization of meta Cresol Purple for Spectrophotometric Seawater pH Measurements," Environmental Science and Technology, 2011.

6. ALKALINITY

PI: Andrew G. Dickson, Marine Physical Laboratory, Scripps Institution of Oceanography
Technicians: David Cervantes and Ellen Briggs (SIO/UCSD)

6.1. Sample Collection

Samples for alkalinity measurements were taken at all P16S Stations (1-90). The Niskin bottles chosen for sampling matched those chosen for Dissolved Inorganic Carbon measurements. Two Niskins at each station were sampled twice for duplicate measurements. Using silicone tubing, the alkalinity samples were drawn from Niskin bottles into 250 mL Pyrex bottles, making sure to rinse the bottles and Teflon sleeved glassed stoppers at least twice before the final filling. A headspace of approximately 5 mL was removed and 0.12 mL of saturated mercuric chloride solution was added to each sample for preservation. After sampling was completed, each sample's temperature was equilibrated to approximately 20°C using a Thermo Scientific RTE water bath.

6.2. Summary

Samples were dispensed using a Sample Dispensing System (SDS) consisting of a volumetric pipette and various relay valves and air pumps controlled using LabVIEW 2012. Before filling the jacketed cell with a new sample for measurement, the volumetric pipette was cleared of any residual from the previous sample with the aforementioned air pumps. The pipette is then rinsed with new sample and then filled, allowing for overflow and time for the sample temperature to equilibrate. The temperatures inside the drawing bottle and pipette were measured using a DirecTemp thermistor probe inside the drawing bottle and DirecTemp surface probe placed on the pipette. These temperature measurements were used to convert the sample volume to mass for analysis.

During instrument set up it was discovered that the Pipette A SDS board was dispensing more than the calibrated volume due to a weak valve. This was confirmed by running titrations using a calibrated manual pipette to dispense reference seawater of known alkalinity and measuring correct alkalinity values while the Pipette A SDS board was providing incorrect alkalinity values with the same reference seawater. As a result, the Pipette B SDS board was switched in and maintained its calibrated volume of 92.190 mL for the entire P16S Line.

Samples were analyzed using an open cell titration procedure using two 250 mL jacketed cells. One sample was undergoing titration while the second was being prepared and equilibrating to 20°C for analysis. After an initial aliquot of approximately 2.3-2.4 mL of standardized hydrochloric acid (~0.1M HCl in ~0.6M NaCl solution), the sample was stirred for 5 minutes and had air bubbled into it at a rate of 200 scc/m to remove any liberated carbon dioxide gas. A Metrohm 876 Dosimat Plus was used for all standardized hydrochloric acid additions. After equilibration, 19 aliquots of 0.04 ml were added. Between the pH range of 3.5 to 3.0, the progress of the titration was monitored using a pH glass electrode/reference electrode cell, and the total alkalinity was computed from the titrant volume and e.m.f. measurements using a nonlinear least-squares approach (Dickson, et.al., 2007). An Agilent 34970A Data Acquisition/Switch Unit with a 34901A multiplexer was used to read the voltage measurements from the electrode and monitor the temperatures from the sample, acid, and room. The calculations for this procedure were performed automatically using LabVIEW 2012.

6.3. Quality Control

Dickson laboratory Certified Reference Material (CRM) Batch 135 was used to determine the accuracy of analysis. The certified alkalinity value for Batch 135 is 2226.33 ± 0.63 µmol kg^{-1} . This reference material was analyzed 208 times throughout P16S. The preliminary average B135 measured value for P16S is 2225.84 ± 0.76

Twice per station, a single Niskin was sampled twice to conduct duplicate analyses. A total of 178 Niskins were sampled for Duplicate analyses and gave a pooled standard deviation of 0.67 µmol kg^{-1} .

2749 Niskins were sampled for alkalinity analyses. The data should be considered preliminary since the correction for the difference between the CRMs stated and measured values has yet to be finalized and applied. The correction for the mercuric chloride addition has yet to be applied. And finally, the correction for any shifts in total volume dispensed per volume has yet to be applied.

Throughout P16S, empty pre-weighed glass bottles with rubber stoppers and metal caps were filled with deionized water and then crimped shut. These sealed bottles will be weighed once they return to the lab to detect any possible subtle shifts in volume dispensing.

Finally, each P16S 2014 station's alkalinity measurements were compared to measurements taken from the neighboring P16S 2014 stations and the P16S 2005 stations of similar if not identical coordinates.

6.4. Reference

Dickson, Andrew G., Chris Sabine and James R. Christian, editors, "Guide to Best Practices for Ocean CO^2 Measurements", Pices Special Publication 3, IOCCP Report No. 8, October 2007, SOP 3b, "Determination of total alkalinity in sea water using an open-cell titration"

7. DI^{13C} / DI^{14C} (CARBON ISOTOPES IN SEAWATER [DIC])

PIs: Ann P. McNichol, Al R. Gagnon (Woods Hole Oceanographic Institution)
Technician: Nicholas Huynh (Marine Science Institute, University of California, Santa Barbara)

Samples of the stable (DI^{13C}) and radio-isotopic (DI^{14C}) content of seawater dissolved inorganic carbon were collected for future analyses that will estimate the extent of the bomb-produced ^{14}C pool and quantify the decrease of $\delta^{13}C$ in the Southern Ocean.

Sample collection was targeted for stations that correspond to previously carbon isotope- sampled stations during the 1996 and 2005 P16S CLIVAR cruises. However, the locations of these target stations were slightly modified to accommodate changes in the master sampling scheme, which were caused by weather and winch repair delays.

A total of 29 stations were sampled, 17 of which captured full profiles (approx. 32 samples), four of which captured shallow profiles (approx. 16 samples in the upper 3000 m of the water column), and eight of which captured a single random depth. At these eight stations, one set of duplicate samples was collected from one randomly selected Niskin bottle for future quality control purposes. At every station sampled, samples were only taken at depths sampled by the alkalinity team. 558 total samples were taken.

Each sample was collected in a 500 ml Pyrex glass bottle using silicone tubing. The bottles were rinsed twice with seawater (approx. 50 ml for each rinse), filled, and overflown with about half the bottle volume. Once collected, a small volume was poured out to leave a headspace between the waterline and neck of each bottle. After drying the neck of a bottle with a laboratory wipe, the water in the bottle was fixed using ~120 ul of saturated $HgCl_2$ (mercuric chloride) solution. Fixed bottles were then sealed with a M-Apiezon greased glass stoppers and secured with rubber bands before being stowed.

All samples were shipped to Woods Hole Oceanographic Institution to be analyzed by the AMS lab.

8. DISSOLVED ORGANIC CARBON AND TOTAL DISSOLVED NITROGEN

PI: Craig Carlson (Marine Science Institute, University of California, Santa Barbara)
Technician: Nicholas Huynh (Marine Science Institute, University of California, Santa Barbara)

Dissolved Organic Carbon (DOC) and Total Dissolved Nitrogen (TDN) samples were collected for land-based measurements that will help strengthen bulk estimates of how carbon and nitrogen cycling in the Southern Ocean and ultimately, in the global ocean, have changed and may change with time.

Samples were taken at every other station to profile a water column at every degree of latitude along the cruise transect. 34-36 Niskin bottles were sampled at each station, with one to four of those Niskins sampled twice. A total of 1680 samples were collected.

Each sample was collected in a 60 ml high-density polyethylene (HDPE) bottle, which was rinsed thrice before being filled. Prior to the cruise, bottles were cleaned with 10% HCl solution and rinsed thrice with deionized water.

Water drawn from Niskins that were fired at depths lower than 500 m was not filtered prior to collection. Contrastingly, water drawn from depths higher than 500 m was filtered through reusable inline cartridges holding disposable 0.2 µm combusted glass fiber filters (GF/F). The reusable cartridges rinsed with deionized water after every use and were cleaned with 10% HCl roughly every four to five stations. Filtration is performed for the upper 500 m of the water column in order to prevent the inclusion of particulate organic matter in dissolved organic matter measurements.

Filled bottles were immediately frozen and stored at -20° in an onboard freezer.

All frozen DOC samples were shipped back to UC Santa Barbara for analysis by the High Temperature Combustion method. TDN will be determined from the same samples in the upper 300 m of the water column.

9. TRITIUM, HELIUM AND ^{18}O

PI: Peter Schlosser (Lamont-Doherty Earth Observatory/Columbia U.)
Technician: Anthony Dachille (LDEO/Columbia U.)

Helium samples were taken from designated Niskins in 90 cc 316 type stainless steel gas tight vessels with valves. The samples were then extracted into aluminum silicate glass storage vessels within 24 hours using the at sea gas extraction system. The helium samples are to be shipped to the Lamont-Doherty Earth Observatory of Columbia University Nobel Gas Lab for mass spectrometric measurements. A corresponding one-liter water sample was collected from the same Niskin as the helium sample in a preprocessed glass bottle for degassing back at the shore based laboratory and subsequent tritum determination by ^{3}He in-growth method. ^{18}O samples were collected and shipped to LDEO for analysis. During P16S, 18 stations were sampled, collecting 371 samples for tritium, 442 samples for helium and 310 samples for ^{18}O analysis. No duplicate samples were taken.

10. $\delta^{15}N$-NO_3/$\delta^{18}O$-NO_3

PI: Daniel Sigman (Princeton U.)
Sampling: Brendan Carter (Princeton U.)

10.1. Overview

Seawater samples were collected for $\delta^{15}N$-NO_3/$\delta^{18}O$-NO_3 analysis aboard the RV Nathaniel B. Palmer on the 2014 GO-SHIP reoccupation of the P16S line in the South Pacific, extending from 67°S to 15°S along 150°W. The 640 samples were collected from 623 distinct locations in the ocean. They were returned to the laboratory of Daniel Sigman in Princeton, NJ, USA for analysis by mass spectrometer.

10.2 Sample Collection

Sampling procedures recommended by Sigman were followed by the seven individuals involved in $\delta^{15}N$-NO_3/$\delta^{18}O$-NO_3 sample collection:

Tonia Capauno,
Brendan Carter,
Tyler Hennon,
Eric Sanchez Munoz,
Elizabeth Simons,
Isabella Rosso,
and Veronica Tamsitt.

Nitrate isotope sample bottles and caps were rinsed three times with sample seawater before filling. Bottles were filled with slightly less than 50 mL of seawater. Once filled, sample bottle numbers were recorded with their associated rosette bottle numbers on the hydrocast sampling log sheets. Samples were stored in a -20°C freezer within two hours of collection. Carter added inserts to the frozen sample bottles within one week of freezing. Inserts were rinsed with purified water (18.3 MΩ resistance) three times prior to insertion, and care was taken to avoid touching the surfaces of the inserts that could come in contact with frozen sample seawater. Powder free latex laboratory gloves were worn while adding inserts. Samples remained in the -20°C freezer between two days and four weeks, after which they were moved to a -80°C freezer to prepare for shipping. Samples remained in the -80°C freezer for at least 72 hours before shipping.

Filtered samples
At 15 stations, a single $\delta^{15}N$-NO_3/ $\delta^{18}O$-NO_3 sample was collected from the 2μm filters used to collect $\delta^{30}Si$ samples. Sampling protocols were identical for these samples as for the unfiltered samples, aside from using filtered sample seawater and the collection of these samples alongside the $\delta^{30}Si$ samples in the sampling order noted above.

Details on sample filtration: At least 5 L of seawater was flushed through each filter before it was used for sampling the first time. Collection of filtered isotopic samples from the rosette began with the seawater from the surface ocean and ended with the seawater from the deep ocean to minimize the risk of sample cross contamination affecting the measured isotopic ratios. Six further steps were taken before collecting filtered seawater to ensure the sample seawater coming from the filter was uncontaminated by seawater from previous samples:

1. The tube connecting the filter assembly to the rosette bottle was emptied, as was the dead space between the tube and the filter portion of the filter assembly.
2. The sample tube and the dead space within the filter assembly was filled with sample seawater. The sample seawater was then passed through the filter gravitationally for 10 seconds.
3. The sample tube was disconnected from the rosette bottle and connected to an oil-free pump. The pump was used to force the sample seawater in the sample tube and the assembly dead space through the filter at low pressure.
4. Step 2 was repeated.
5. Step 1 was repeated.
6. Step 2 was repeated.

Following sample collection, steps 1 through 6 were repeated using purified water. A filter was sometimes used for deeper depths before it was used for shallower depths. When bottles were sampled out of order in this fashion, the filter was cleaned by following by steps 1 through 6 with purified water between the deeper and the shallower samples as a precautionary measure against sample cross contamination.

Sampling mistakes
Some collected samples were lost due to mishandling:

The most common sampling problem was sample bottle overfilling. This problem was dealt with in two ways. When the sample was filled to the extent that sample seawater was lost from the sample bottle during freezing, the sample was thawed and dumped, and the bottle was rinsed for reuse at a later station. When the sample was too full to insert a sample bottle insert without extruding brine, the insert was not inserted and the bottle cap was labeled "NITF" for "No Insert; Too Full" with a permanent marker. Inserts were added to ~6 samples which were possibly too full for inserts, and a droplet of water was noted around the edge of the insert following insertion. It is not clear that these samples were compromised because the inserts sometimes had small amounts of purified water remaining on their sides from the rinsing procedure. These samples were not dumped, instead they were placed in labeled plastic bags for shipping.

Bottles from station 31 remained unfrozen for ~10 hours following collection. These samples were dumped and the sample bottles reused at a later station (the sample bottles were first labeled "FL" for “Frozen Late” but these labels can be ignored since the problematic sample seawater was ultimately dumped). Samples that were sampled improperly and dumped for reuse are flagged 9 (meaning: “not collected”) in the cruise databases. Therefore no missing value indicator needs to be reported for these samples.

Sampling plan
The sampling plan provided by Sigman was followed wherever possible. The following table indicates where the sampling plan called for samples and where samples were ultimately collected. The comments explain any discrepancies between sample planning and collection.

Lat.(°S)	Station #	*Planned* Normal	Filtered	*Collected* Normal	Filtered	Comments
68	--	36	0	0	0	Our southernmost station was at 67°S
67	5	0	0	32	0	*, One rosette bottle failed to close, so sample bottle 30 was reused on station 23.
65	9	36	1	0	0	Bottles overfilled. Washed and reused later.
64	11	36	0	34	1	*
63	13	0	0	18	0	
62	--	24	0	0	0	We skipped this station due to weather
61	19	0	0	18	0	Station numbering due to weather
60	17	36	1	34	1	*, Station numbering due to weather
59	16	12	1	12	1	Station numbering due to weather
58	15	24	1	24	1	Station numbering due to weather
57	23	12	1	12	1	
56	25	36	1	34	1	*
55	27	12	1	12	1	
54	29	24	1	24	1	
53	31	12	1	0	0	Bottles not frozen. Washed and reused later.
52	33	36	1	36	1	
51	35	12	1	12	1	
50	37	24	1	24	1	
48	40	36	1	34	1	*, Collected at 48° 20'
46	43	24	1	24	1	Collected at 46° 20'
44	46	36	1	36	1	Collected at 44° 20'
42	49	24	0	24	0	Collected at 42° 20'
40	52	36	0	36	0	Collected at 40° 20'
35	60	0	0	24	1	
30	67	36	0	36	0	Collected at 30° 20'
25	75	0	0	24	0	
20	82	24	0	24	0	Collected at 20° 20'
18	85	36	0	37	0	Collected at 18° 20', one replicate
Total		624	15	625	15	

*indicates that 2 rosette bottles were reserved for pigment samples, so only 34 of 36 planned bottles were filled.

10.3 Sample Measurement

These samples will be analyzed for nitrate nitrogen and oxygen isotopic analysis by bacterial reduction to nitrous oxide followed by automated nitrous oxide extraction, purification, and analysis on a stable isotope ratio mass spectrometer (Sigman et al., 2001, Analytical Chemistry; Casciotti et al., 2002, Analytical Chemistry). For samples from the upper ~500 m of the water column, analysis will be performed with and without prior removal of nitrite by sulfamic acid addition (Granger and Sigman, 2009, Rapid Communications in Mass Spectrometry).

10.4 References

Casciotti, K. L., Sigman, D. M., Hastings, M. G., Böhlke, J. K., & Hilkert, A. (2002). Measurement of the oxygen isotopic composition of nitrate in seawater and freshwater using the denitrifier method. *Analytical Chemistry*, *74*(19), 4905-4912.

Granger, J., & Sigman, D. M. (2009). Removal of nitrite with sulfamic acid for nitrate N and O isotope analysis with the denitrifier method. *Rapid Communications in Mass Spectrometry*, *23*(23), 3753-3762.

Sigman, D. M., Casciotti, K. L., Andreani, M., Barford, C., Galanter, M., & Böhlke, J. K. (2001). A bacterial method for the nitrogen isotopic analysis of nitrate in seawater and freshwater. *Analytical chemistry*, *73*(17), 4145-4153.

11. δ^{30}Si

PI: Gregory DeSouza, (Princeton U.) gfds@princeton.edu
Sampling: Brendan Carter, (Princeton U.) brendan.carter@gmail.com

11.1. Overview

Seawater samples were collected for δ^{30}Si analysis aboard the RV Nathaniel B. Palmer on the 2014 GOSHIP reoccupation of the P16S line in the South Pacific, extending from 67°S to 15°S along 150°W. The 200 samples were collected from 168 distinct locations in the ocean. They will be returned to the laboratory of Dr. Florian Wetzel in Zurich, Switzerland for analysis by mass spectrometer.

This research cruise left port from Hobart, Tasmania on March 20th 2014 and arrived in Pape'ete, Tahiti on May 5th 2014. The full cruise report can be found at http://ushydro.ucsd.edu.

11.2. Sample collection

Sampling procedures provided by DeSouza and Carter were followed by the seven individuals who collected δ^{30}Si samples:

Tonia Capauno,
Brendan Carter,
Tyler Hennon,
Eric Sanchez Munoz,
Elizabeth Simons,
Isabella Rosso,
and Veronica Tamsitt.

At least 5 L of seawater was flushed through each 0.2 µm filter before it was used for sampling the first time. Collection of filtered isotopic samples from the rosette began with the seawater from the surface ocean and ended with the seawater from the deep ocean to minimize the risk of sample cross contamination affecting the measured isotopic ratios. Six further steps were taken before collecting seawater to ensure the sample seawater coming from the filter was uncontaminated by seawater from previous samples:

1. The tube connecting the filter assembly to the rosette bottle was emptied, as was the dead space between the tube and the filter portion of the filter assembly.
2. The sample tube and the dead space within the filter assembly was filled with sample seawater.
   The sample seawater was then passed through the filter gravitationally for 10 seconds.
3. The sample tube was disconnected from the rosette bottle and connected to an oil-free pump. The pump was used to force the sample seawater in the sample tube and the assembly dead space through the filter at low pressure.
4. Step 2 was repeated.
5. Step 1 was repeated.
6. Step 2 was repeated.

Sample bottles and caps were rinsed three times with filtered sample seawater before filling. Bottles were filled with slightly less than 50 mL of seawater. Upon filling, sample bottle numbers were recorded with their associated rosette bottle numbers on the hydrocast sample log sheets. For a subset of shallow high latitude samples, a second sample bottle was filled (to provide double the volume for low Si concentration seawater measurement). Following sample collection, steps 1 through 6 were repeated using purified water (18.3 MΩ) system. A filter was sometimes used for deeper depths before it was used for shallower depths. When used in this fashion, the filter was cleaned by following by steps 1 through 6 with purified water between the deeper and the shallower samples as a precautionary measure against sample cross contamination. Samples were stored in a 4 °C refrigerator within one hour of collection, where they remained for between 1 to 5 weeks prior to being shipped to Zurich.

The sampling plan provided by DeSouza was followed where possible. The following table indicates where the sampling plan called for samples and where samples were collected.

		Planned		*Collected*		
Lat.(°S)	Station #	Normal	Second bottles	Normal	Second bottles	Comments
65	9	7		7		
60	17	10		10		Station numbering due to weather
59	16	7		7		Station numbering due to weather
58	15	7		7		Station numbering due to weather
57	23	7		7		
56	25	7		7		
55	27	13		13		
54	29	6		6		
53	31	6	3	6	3	
52	33	6	3	6	3	
51	35	6	3	6	3	
50	37	14	4	14	4	
48	40	12	4	12	4	Collected at 48° 20'
46	43	12	4	12	4	Collected at 46° 20'
44	46	15	4	14	5	Collected at 44° 20'
40	52	12	2	12	2	Collected at 40° 20'
35	60	12	2	11	2	
30	67	11	2	11	2	Collected at 30° 20'
Total	170	31	168	32		

11.3 Sample measurement

Samples were shipped for analysis to:

Dr. Florian Wetzel
Institute of Geochemistry and Petrology
ETH Zurich, NW C81.1
Clausiusstrase 25
8092 Zurich,
Switzerland

12. CALCIUM SAMPLING

PI: Todd Martz, Scripps Institution of Oceanography/UCSD
Sampler: Ellen Briggs (SIO/UCSD)

Seawater samples were collected at 15 stations along the 150° W P16S transect at approximately 5° latitude spacing. 15 - 16 Niskin bottles were sampled at each station ranging from the surface to the greatest depth following those that were also sampled for Total Alkalinity. Two duplicate samples were taken at 250 m and 2500 m. The sampling procedure entailed rinsing 100 mL plastic bottles three times before the final filling and tightly securing the cap for storage during transit to Scripps Institution of Oceanography for analysis of calcium concentration. The plastic bottles were specifically ordered to reduce any leeching of materials into the samples that would interfere with analysis.

13. TRANSMISSOMETER SHIPBOARD PROCEDURES

PI: Wilford D. Gardner, Texas A&M Department of Oceanography, wgardner@ocean.tamu.edu
Shipboard Responsibility: John Calderwood, SIO STS/RT

13.1. Instrument: WET Labs C-Star Transmissometer - S/N CST-1636DR

13.2. Air Calibration:

- Calibrated the transmissometer on deck at beginning of the cruise.
- Washed and dried the windows with Kim wipes and distilled water.
- Recorded the final values for unblocked and blocked voltages plus air temperature on the Transmissometer Calibration/Cast Log.
- Compared the output voltage with the Factory Calibration data.
- Computed updated calibration coefficients.

13.3. Deck Procedures:

- Washed the transmissometer windows before every calibration. Rinsed both windows with a distilled water bottle that contains 2-3 drops of liquid soap. This was the last procedure before the CTD went in the water.
- Rinse instrument with fresh water at end of cruise.

13.4. Summary:

Deck calibrations were carried out 3 times during P16S - at the start of the cruise, about a month into the cruise on station 53, and the morning after the last station was completed. Results of the pre-cruise laboratory calibration, and deck calibrations done during this cruise, appear at the end of Appendix D with the other instrument/sensor laboratory calibrations.

After preparing the transmissometer for deployment (see Deck Procedures above), CST1636DR was sent with the rosette for every CTD cast during P16S on RVIB Nathaniel B Palmer. Data were reported through a CTD a/d channel, then converted to raw voltages without applying any corrections. The data were averaged into half-second blocks with the CTD data, and later converted into 2-dbar block-averaged data files. The raw voltage data will be reported to Wilf Gardner for further processing post- cruise, and later merged in with the CTD data at CCHDO.

No problems were encountered with the transmissometer during this leg.

14. LOWERED ACOUSTIC DOPPLER CURRENT PROFILER (LADCP) DATA

PIs: Eric Firing (PI), François Ascani, and Julia Hummon (all U. Hawaii)
Shipboard operators: Steven Howell, UH and Veronica Tamsitt, SIO

14.1. System description

The University of Hawaii (UH) ADCP group used a two Teledyne/RDI Workhorse Lowered Acoustic Doppler Current Profilers (LADCPs) to measure full-depth ocean currents during the 2014 CLIVAR/GOSHIP P16S cruise from Hobart, Australia, to Papeete, Tahiti aboard the *RVIB Nathaniel B. Palmer*.

A 150 kHz instrument (WH150, serial number 16283, firmware 50.40, with beams 20° from vertical) was deployed on every cast. It was mounted near the base of the rosette by an anodized aluminum collar connected to three struts that were in turn bolted to the rosette frame.

Beginning at station 63, a 300 kHz instrument (WH300, model WHS-I-UG300, serial no. 12734, firmware 50.40) was mounted in a collar at the top of the rosette with beams facing upward. It collected data on every subsequent station, except during station 78, when a serial communications issue kept it from sampling.

From station 4 to station 63, an Inertial Motion Processor (IMP), was mounted to the floor of the rosette. This was the second cruise this new instrument has been used on. It was made by Andreas Thurnherr, of the Lamont- Doherty Earth Observatory and contains accelerometers for tilt and roll and magnetic flux gate compasses. The idea is to improve on similar measurements made by the LADCPs to better determine the orientation of the rosette while the LADCPs are sampling. This is particularly important near the Earth's magnetic poles, where the compasses on LADCPs have often proved unreliable. The IMP contains a Raspberry Pi computer running Arch Linux and measures accelerations and magnetic flux at 100 Hz. It communicates via a WiFi interface.

There were numerous other instruments mounted on the rosette. A rough schematic of positions of the LADCP and other devices is shown in Figure 14.1. Particularly worth noting are the altimeter, a possible source of acoustic interference, and the bottom contact switch, which had a weight dangling 10 m below. That was within the blanking interval of the WH150 so probably had little effect, though it certainly was visible to the altimeter.

Power for the LADCPs and IMP was provided by a Deep Sea Power & Light sealed oil-filled marine battery (model SB-48V/18A, serial number 01527). It sat in a custom-made stainless-steel basket in the rosette frame. Figure 14.1 shows the arrangement of instruments in the rosette.

Between casts, a single power/communications cable connected each LADCP and battery to a computer and a DC power supply to initialize the LADCP, collect data after casts, and recharge the battery. Communication with the instrument was managed by a custom serial communication package.

Operating parameters

The WH150 used nominal 16 m pulses and 8 m receive intervals (assuming a standard 1500 m s^{-1} speed of sound). The blanking interval (distance to first usable data) was 16 m.

A staggered pinging pattern was used, with alternating 1.2 s and 1.6 s periods between pings. This was to avoid a problem referred to as Previous Ping Interference (PPI), which happens when a strong echo off the bottom from a previous ping overwhelms the weak scattering signal from the water column. PPI occurs at a distance above the ocean floor of $\Delta z = \frac{1}{2} c \Delta t \cos \theta$ where Δt is the period between pings, c is the speed of sound, and θ is the beam angle from vertical. With constant ping rates, the artifact hits a single depth, essentially invalidating all data at that depth. By alternating delays, we lose half the data at two depths, but have some data through the entire column.

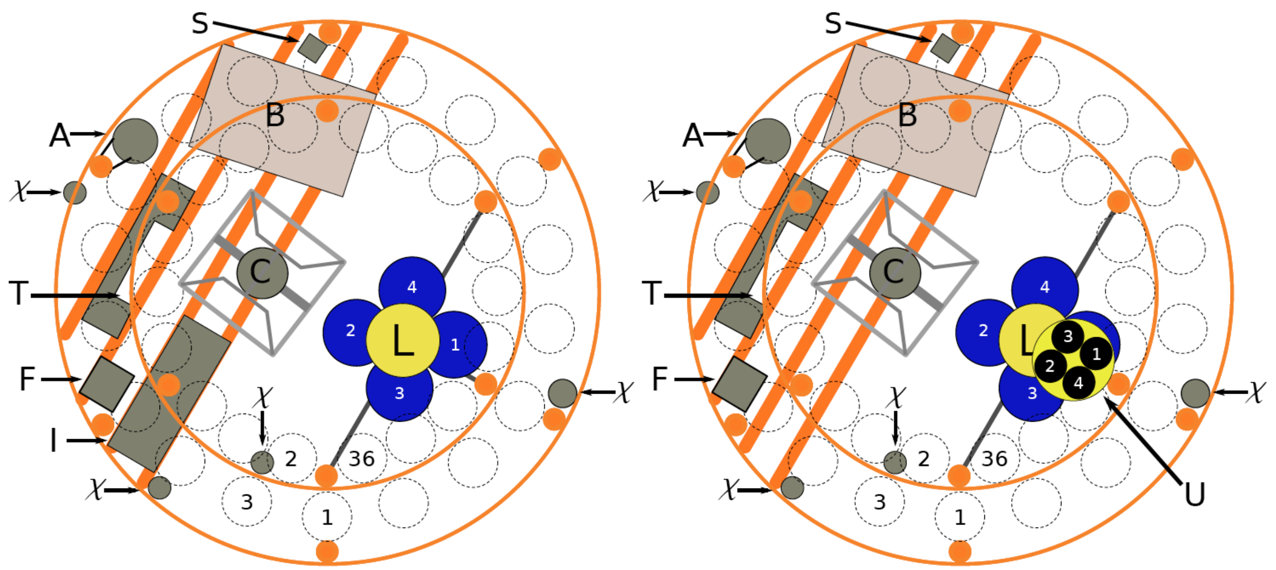

Figure 14.1: *Schematic plan view of instrument and bottle locations on the rosette before (left) and after the upward-looking WH300 was mounted. Orange elements are parts of the rosette frame. Bottle locations are indicated by dashed circles and numbers. Instruments are identified by letters: L, LADCP (WH150); U, Up-looking LADCP (WH300); B, Battery for LADCP/IMP power; I, IMP; S, bottom contact Switch; C, CTD;A, Altimeter (120 kHz Benthos echosounder); T, transmissometer; F, Fluorometer for chlorophyll-A; and , elements of the -pod fast temperature system. White numerals show ADCP beam positions.*

The WH150 control file

```
CR1  # factory defaults
PS0  # Print system serial number and other info.
WM15 # sets LADCP mode; WB -> 1, WP -> 001, TP -> 000100, TE -> 00000100
TC2  # 2 ensembles per burst
TB 00:00:02.80 ### also try old BB settings, 2.6 and 1.0
TE 00:00:01.20
TP 00:00.00
WN40   # 40 cells, so blank + 320 m with 8-m cells
WS0800 # 8-m cells
WT1600 # 16-m pulse
WF1600 # Blank, 16-m
WV330  # 330 is max effective ambiguity velocity for WB1
EZ0011101 # Soundspeed from EC (default, 1500)
EX00100   # No transformation (middle 1 means tilts would be used otherwise)
CF11101   # automatic binary, no serial
LZ30,230  # for LADCP mode BT; slightly increased 220->230 from Dan Torres
CL0       # don't sleep between pings (CL0 required for software break)
```

The WH300 used 8 m pings, blanking intervals, and receive ranges. For stations 63 to 67, the instrument was set to listen through 20 depth bins of 8 m each, for a total range of 168 m. That proved excessive, as signal strength was usually too weak beyond 5 bins. Starting as station 68, the number of depth bins were reduced to 10, and the period between pings shortened to 0.53 s.

The WH300 control file (stations 68 and higher)

```
CR1  # Factory defaults
PS0  # Print system serial number and configuration
WM15 # Sets LADCP mode WP->1; WB->1; TE->00:00:01; TP->00:01
TC1  # 1 ensemble per burst
TB 00:00:00.53 # Time between bursts
TE 00:00:00.00 # Minimum time between ensembles
TP 00:00.00 # Minimum time between pings
WP 1      # 1 ping per ensemble
WN10      # 10 cells. That’s beyond the useful range for most of the cast.
WS0800    # 8 m cells (No WT command means transmit length also 8 m)
WF0800    # 8 m blank
WV330     # Ambiguity velocity
EZ0011101 # Manual sound speed, depth, salinity; others from ADCP sensors
EX00100   # No transformation (middle 1 means tilts would be used otherwise)
CF11101
```

Data processing

Data were processed using version IX.8 of Andreas Thurnherr's implementation of Martin Visbeck's LADCP inversion method, developed at the Lamont-Doherty Earth Observatory of Columbia University. The LDEO code is written in Matlab, and performs a long chain of calculations, including transforming the raw LADCP data to Earth coordinates; editing out suspect data; meshing with CTD data from the cast and simultaneous shipboard ADCP and GPS data; then running both an inverse method and a shear-based algorithm to obtain ocean currents throughout the profile. The shear-based calculation is used as a check on the inverse method-if they agree, confidence in the solution is enhanced. The LDEO code is available at ftp://ftp.ldeo.columbia.edu/pub/LADCP.

Only preliminary data processing was performed during the cruise; full processing takes more time than was available. The automatic data editing is not completely adequate, as ocean bottom reflections are not always edited out and the algorithms for detecting and discarding PPI require more work. When the data are fully processed, they will be made available on the UH ADCP website, http://currents.soest.hawaii.edu as part of the CLIVAR ADCP archive.

The IMP is still an experimental device; processing routines are still being worked on and no significant analysis was attempted beyond ensuring that the data were intake and made some sense.

14.2. Data gathered

WH150 data were successfully obtained in every cast at each station. WH300 data were gathered during stations 63 to 77 and 79 through 90. IMP data Preliminary vertical profile plots of each station were made available on the ship's website within 12 hours of each cast.

Problems encountered

We had no major hardware or software problems during the cruise. The biggest issue is one that always plagues deep LADCP profiles in oligotrophic regions: the acoustic signal relies on backscatter from mm-to cm-sized particles, and there are too few to get much range from the instruments. The WH150 had an effective range of 320 m near the surface, but was reduced to about 80 m at depth. The WH300 was added to increase the data available to the inversion, but only managed 8 m to 16 m at depth. That was a significant addition to the data, particularly since it pinged almost 3X as often as the WH150, so the quality of the profiles clearly improved.

Whether they improved enough to be oceanographically useful is still open to question. Preliminary analysis by Tonia Capuano found suspiciously high diffusivities in the deep ocean north of Station 60 or so, implying that the currents are exaggerated, even after the addition of the WH300. Work is ongoing to improve the inversion, but we may just be facing a limitation of available instrumentation. The end of the cruise appeared mildly better, with more signal at depth.

This was the first deployment of the WH150, and it started out with all 4 beams equally strong. As the cruise progressed, beam 3 weakened relative to the others, until its useful range was only 65% of the other beams. Curiously, it appeared to recover somewhat, rising back to about 85% by the end of the cruise. It may be that it suffered more than the other beams from the very small signals.

There was considerable acoustic noise sensed by both instruments, though the source was not obvious. The Benthos 120 kHz altimeter is an obvious candidate, since it was on the rosette. The ship's multibeam and depth sounders could be responsible. The shipboard ADCPs are also possible sources of noise, but those frequencies are absorbed by seawater, so should not have much effect when the package is a few kilometers down. There was an odd noise signature that was only visible part of the time in the WH300 data, implying either an irregular source, or a highly directional one.

In any case, acoustic noise affected a small fraction of the data and is usually easy to edit out, so it should have little effect on the overall data quality.

Sample data plots

We made both vertical profiles of individual plots and contour plots along the cruise track available on the ship's network. A contour plot of data from the entire cruise (autoref fig:contour) may be the best capsule summary of the preliminary data.

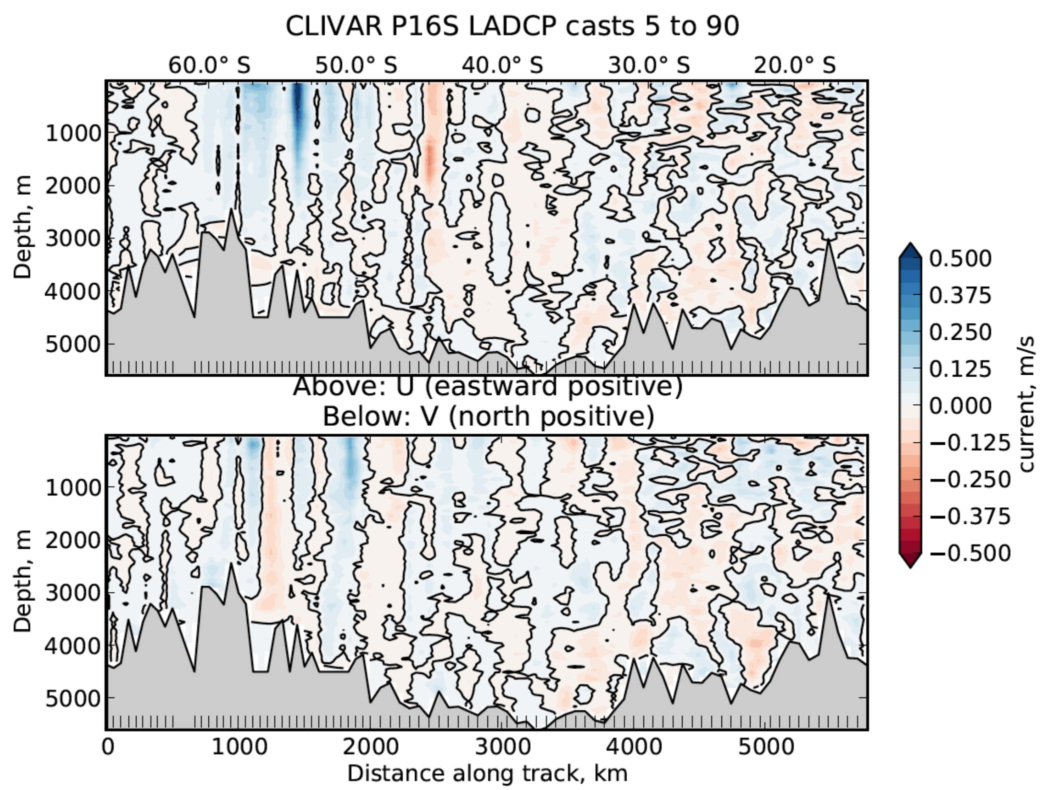

Figure 14.2: *Contour plot of P16 stations along 150°W. Tick marks along the bottom of each plot are station locations.*

The strongest current was the Antarctic Circumpolar Current (ACC), at 54°S. Rather surprising was the second strongest current,at 45°S moving west at 0.3 ms^{-1} at a depth of 1500 m. A profile of the currents at 45°S is shown in Figure 14.3, together with CTD traces from that station and the previous one. An eddy shed by the interaction of the ACC and Antarctic-Pacific Ridge is the obvious source of such a current, but eddies usually bring in water from different regions, whereas the water in station 45 seemed identical to 44, but the features around 1400 m were thicker. That seems like an internal wave. Andreas Thurnherr of LDEO (who was also responsible for the IMP), found vertical currents above and below the high-velocity core that changed from upward as the rosette was going down to downward as the rosette was pulled back up.

Currents through the rest of the basin are much weaker, though it is striking that current features south of about 40°show a much greater vertical extent than they do father north.

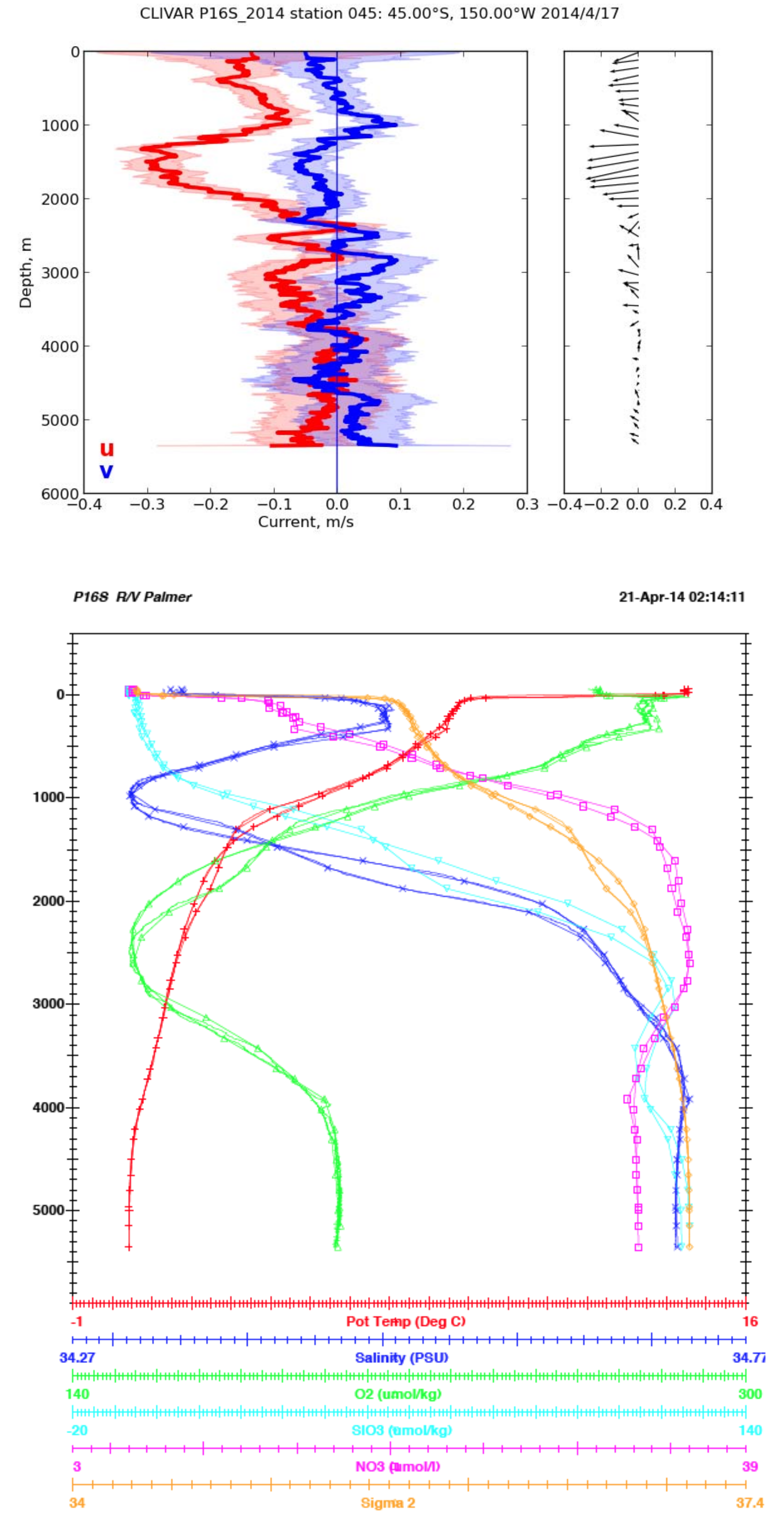

Figure 14.3: *LADCP profile(left) of station 45 at 45°S and CTD profiles at stations 44 and 45. Station 45 traces can be identified by the inflections in the curves at 1500 m.*

15. CHIPODS.

PIs: Jonathan Nash (OSU, nash@coas.oregonstate.edu),
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Jennifer MacKinnon (Scripps Shipboard Operation, jmackinn@ucsd.edu).
Tyler Hennon: (U. of Washington, thennon@uw.edu).

Turbulent mixing is traditionally obtained by measuring microscale shear variance, which must be gathered from a platform that profiles smoothly through the water column with minimal vibration. As a result, there is a dearth of direct deep-ocean mixing estimates, totaling only *O*(1,000) globally. This is because tethered free falling instruments that measure mixing cannot reach abyssal depths, and autonomous profilers require dedicated efforts for deployment and recovery on every cast. It is advantageous to develop methods though which turbulence can be measured from the standard shipboard CTD, since there are many efforts underway to obtain a broad distribution of CTD data. In the current effort, we seek to measure microscale temperature variance (using devices we call "chipods") from which mixing is inferred. The measurement of "chi," the dissipation rate of temperature variance is less susceptible to contamination from platform vibration, so is possible to obtain from traditional CTD. In the current effort, chipods are attached to the CTD, and therefore require no extra time on repeat hydrography cruises. P16S is the second of the repeat hydrography cruises to include CTD-chipods, and represent one part of a larger effort to increase the number of direct observations of mixing by an order of magnitude. Hennon was tasked with data collection and maintenance of the chipods for the duration of the P16S cruise.

Chipods are equipped with very sensitive thermistors and accelerometers that sample at 100 Hz. The thermistors are extremely fragile, so are prone to failure from extreme pressure cycling, temperature shocks, or physical impact. The voltage from the thermistors is converted into temperature by calibration with the raw CTD temperature data (many thanks to Courtney Schatzman for providing these). The CTD pressure and chipod accelerometers are used to remove any data in contaminated water caused by loops in pressure.

The synthesis of the chipod and CTD data culminate in the computation of χ, the dissipation rate of temperature variance. Through χ, the turbulent dissipation and diffusivities are estimated.

For redundancy, we attached four chipod thermistors to the CTD. The locations of the thermistors were chosen so that they would sample water unperturbed by the CTD rosette, although there is the possibility of contamination from the wire for the upward looking thermistors, and by a "bottom-contact" weight that hangs 10 m beneath the CTD and used as a mechanical altimeter. The initial setup had two RBR pressure cases each connected to and individual thermistor (one upward looker and one downward looker) and one larger pressure case connected to two thermistors (both upward looking).

We are only in the beginning stages of making these type of measurements during routine CTD profiling, so we are still learning many lessons. Overall, the chipods returned good data. Although some individual instruments had temporary electrical or mechanical failure, the redundancy of using four thermistors on 3 separate loggers allowed us to obtain at least one clean set of data for nearly every one of the 90 stations on P16S.

The downward looking RBR collected an excellent dataset with few problems. The upward looking RBR had occasional short-lived problems, but for most stations returned good data. Unfortunately, the large pressure case with two upward looking thermistors had a series of logging problems, which we are still sorting out. Repeated attempts at replacing thermistors, thermistor housings, and cables did not seem to significantly improve the quality of the data. On April 28th (perhaps overdue), Hennon replaced it with another RBR attached to a single upward looking thermistor, reducing the total thermistors on the CTD to three.

Based off of preliminary processing at sea, the chipod data look reasonable with the exception of a possible high bias in the lower ~1000 m of the ocean at many stations, possibly resulting from regions with extremely low temperature gradients where our automated processing scripted may need to be revised. Diffusivity values here range from about 10^2 to 100 m^2s^{-1}. While there is likely some degree of bottom intensification, these extreme estimates are probably biased by very weak vertical temperature gradients. Further work will be needed to tease out the actual mixing rates at the bottom.

16. A NOTE ON WIRE TENSION DURING CLIVAR/GOSHIP P16S 2014

Steven Howell, University of Hawaii

As part of an effort to extend the life of cables on its oceanographic vessels, NSF has determined that the standard 0.322" CTD cable used in hydrographic surveys should not be exposed to tensions in excess of 5000 lbs[1]. This was a concern on P16S, particularly since the 36-bottle rosette used is one of the largest and heaviest in routine use. CLIVAR/CARBON P02E 2013, on *R/V Melville* was one of the first cruises under the new tension limits, so close attention was paid to winch tension. We established that casts as deep as 6000 m using the same rosette as P16S 2014 can be done without exceeding the 5000 lb limit. However, those casts were under relatively calm conditions, and the chief scientist, Jim Swift, wrote in the cruise report that "the main cause of cable tension spikes is ship motion (ship roll and heave)" and noted that high sea states like those found in the Southern Ocean would likely be a problem.

Since I had participated in the wire tension analyses during P02 2013, I was curious to see how it changed in higher seas on a different ship. P16S 2014 used the same rosette, but had a bit of additional instrumentation, including the χ-pod system from Oregon State and an Inertial Motion Processor (IMP) from Lamont used as an adjunct sensor for the LADCP. These add a little mass, probably some buoyancy, and a bit of drag to the package.

RVIB Nathaniel B. Palmer underway data are routinely submitted to the NSF Rolling Deck to Repository gateway, so the data used here, from the LCI-90 winch monitors and the Seapath 200, should become available at their website,

`http://www.rvdata.us .`

Station 1

During the first part of the cruise, the rosette was deployed from the Baltic Room. It had an LCI-90 tension measurement system like that on the Melville, reporting at 20 Hz. The first station, on March 26 at 60°S, 174°E, was a good test, as the CTD reached 4484 m depth, the deepest cast until station 31.

Simply plotting tension as a function of wire out and doing a linear regression is instructive (Figure 16.1). The slope of the line is the weight in water per unit length of cable. According to the manufacturer, the weight in seawater is 212 kg km^{-1} or 0.467 lb/m. I do not know the manufacturing tolerance or how precise the LCI-90 calibrations are supposed to be, but the 4% difference is reassuring that the winch tension, or at least the slope, is accurate to within a few percent.

The intercept of 1187 lbs represents the weight of the package in water.

The tension while the rosette was dangling in the air during the launch was 1910 lbs. At recovery, it was 2730 lbs, an 820 lb difference. The difference must be due primarily to seawater in the sample bottles. Two bottles failed to trip, so there were 34 with ~10.5 L of seawater each. At a density of about 1.028 kg L^{-1}, there should be 809 lbs of water. This is within 2% of the winch measurement.

For comparison, for P02 2013 station 56, a 5960 m cast on April 23, a similar regression yielded t = 1185(1) lbs + w x 0.5082(3) lbs/m. The weight of the rosette in water was almost identical to that in P16S station 1, while the slope was about 9% higher than expected (if the wire on the Melville was made to the same specifications). Tension in the air during launch was 2036 lbs and at recovery was 2952 lbs. The difference of 916 lbs is about 7% high.

Winch speed and acceleration also have some effect on tension and are the only things that can actually be controlled during the cast. From Figure 16.2, it appears that the drag of the package is 5.3 lbs/(m/min). There is no particular reason to expect a linear relationship, but this plot gives little indication that drag goes with the square or cube of the speed, at least within the ±1 m s^{-1} winch speeds we used. This package drag agrees reasonable well with the crude estimate from P02W 2013 of 4 to 5 lbs/(m/min).

---

[1] I apologize for the mixed units. The winch tension is calibrated in pounds(force), while wire out is in meters. Since those are the numbers we see during the cruise, I'll continue to use them.

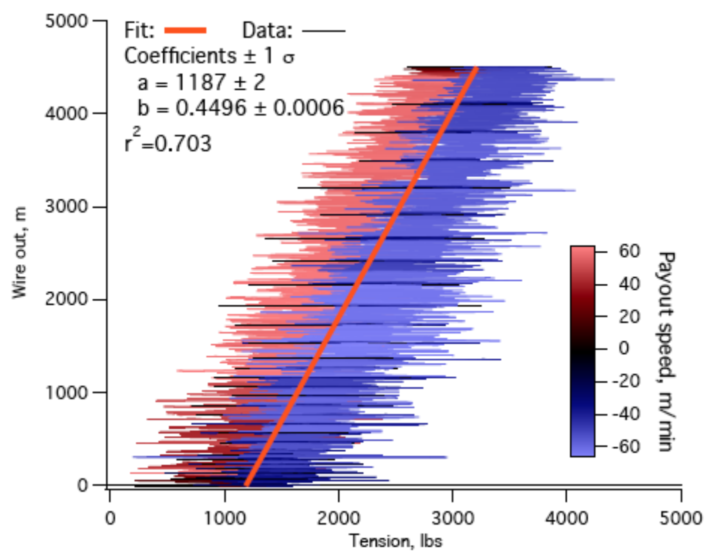


Figure 16.1: *Tension vs wire out during station 1.*

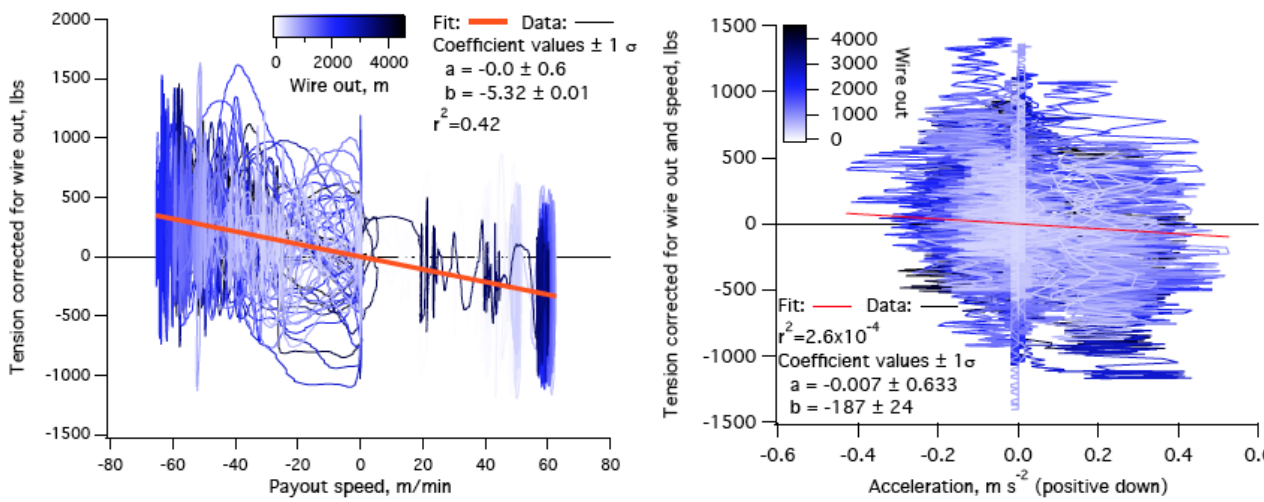


Figure 16.2: *Left: Effects of winch speed on tension during station 1 after correcting for wire out. Right: (Lack of) effect of winch acceleration on tension after corrections for wire out and winch speed.*

There is also little indication that the amount of wire out has much effect on drag, which implies that the drag of the wire is small compared to the package. A crude calculation bears that out. According to the Nbpedia, a 2011 dump of Wikipedia, the drag equation is

$$F_D = ½\rho u^2 C_D A \qquad (1)$$

where F_D is the drag force, ρ is the density of the fluid, u is the velocity through the fluid, C_D is the coefficient of drag, and A is the area exposed to the fluid. The choice of C_D isn't quite obvious, as there's no entry for a rod. Most appropriate seems to be a flat plate parallel to the fluid motion, with $A = \pi dw = \pi 0{:}322"w = 0.026\ m^2\ m^{-1}$ being surface area. C_D for such a plate is 0.001 in laminar flow to 0.005 in turbulent flow. I don't know whether the flow is turbulent or how to deal with the roughness of the cable. $\rho = 1030\ kg\ m^{-3}$. Assuming winch speed $u = 60\ m\ min^{-1} = 1\ m\ s^{-1}$ and

C_D =0:001, Equation 1 yields 0.013 n m^{-1}, or 3 lb km^{-1}. If I haven't made a major mistake, this is only 75 lbs even if C_D is a factor of 5 too low and there are 5 km of wire out.

As the right hand plot in Figure 16.2 shows, winch acceleration plays a very small role in wire tension, even after subtracting the influences of wire out and winch speed. Typical winch acceleration upward was 0.2 m s^{-2}, though it was occasionally double that. Given the mass of the rosette and F = ma, F = 860 kg x 0.2 m s^{-2} = 172 n = 39 lb. Each kilometer of cable adds F = 257 kg x 0.2 m s^{-2} = 51 n = 12 lb. The rosette alone is pretty close to the 38 lb from the fit in Figure 16.2, despite the terrible correlation. I'm surprised the order of magnitude is right.

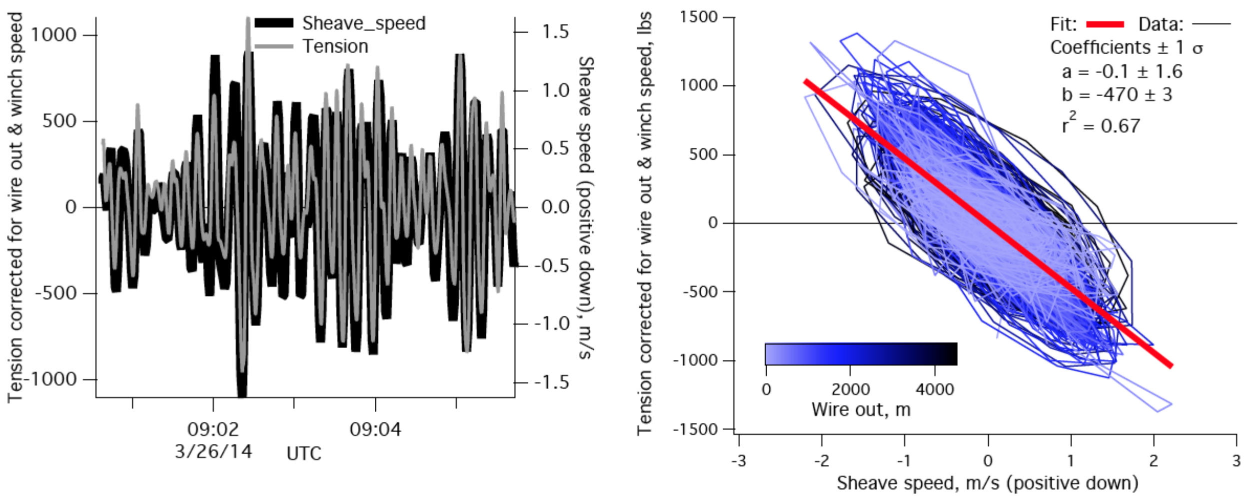


Figure 16.3: *Left: Time series of tension and sheave velocity calculated from heave and roll. Right: Correlation between sheave velocity and tension during station 1. The effects of wire out and winch speed from Figure 16.1 and Figure 16.2 have been removed in both plots.*

On the *Palmer*, a Kongsberg Seatex Seapath 200 monitors heave, roll, pitch, and heading. Its output is at 1 Hz. I used the Seapath data to crudely calculate the position and velocity of the sheave. I ignored pitch, since the Baltic Room is pretty near amidships. The boom extends about 40 feet/12.2 m from the centerline of the ship, so the sheave position z is

$$z = z_0 + h + 12{:}2 \sin(\pi r / 180) \qquad (2)$$

where h is heave and r is roll in degrees. These are defined a bit counterintuitively; heave is positive downward and a roll to starboard is positive, so z goes up as the sheave descends. Taking the differential gives an approximation for weave velocity. A short timeseries (left side of Figure 16.3) shows that sheave motion is closely related to tension, but actually performing a linear correlation reveals that the correlation coefficient is only 0.67 (right panel of Figure 16.3). The loops around the best-fit line indicate that tension is somewhat out of phase with sheave velocity, so some other factor is important. The obvious candidate is a spring effect, either from the stretchiness of the cable (0.4% at 2500 lbs is the manufacturer's specification) or from curves in the wire imposed by currents and package motion. I have not extended my analysis to include either factor; the former would be straightforward, while the latter might be a challenge.

As it turned out, roll had very little influence on sheave motion, despite the 12 m lever arm. That is because during the cast, the ship faced into the wind and seas, and therefore roll was minimized. Heave, on the other hand, cannot be avoided.

The slope of the tension vs. sheave speed plot is 470 lbs/(m/s) considerably higher than that from the winch speed, which works out to 320 lbs/(m/s). This could reflect either the spring effects or perhaps the drag of the rosette through the water has a quadratic relationship with speed at the higher speeds imposed by the sheave.

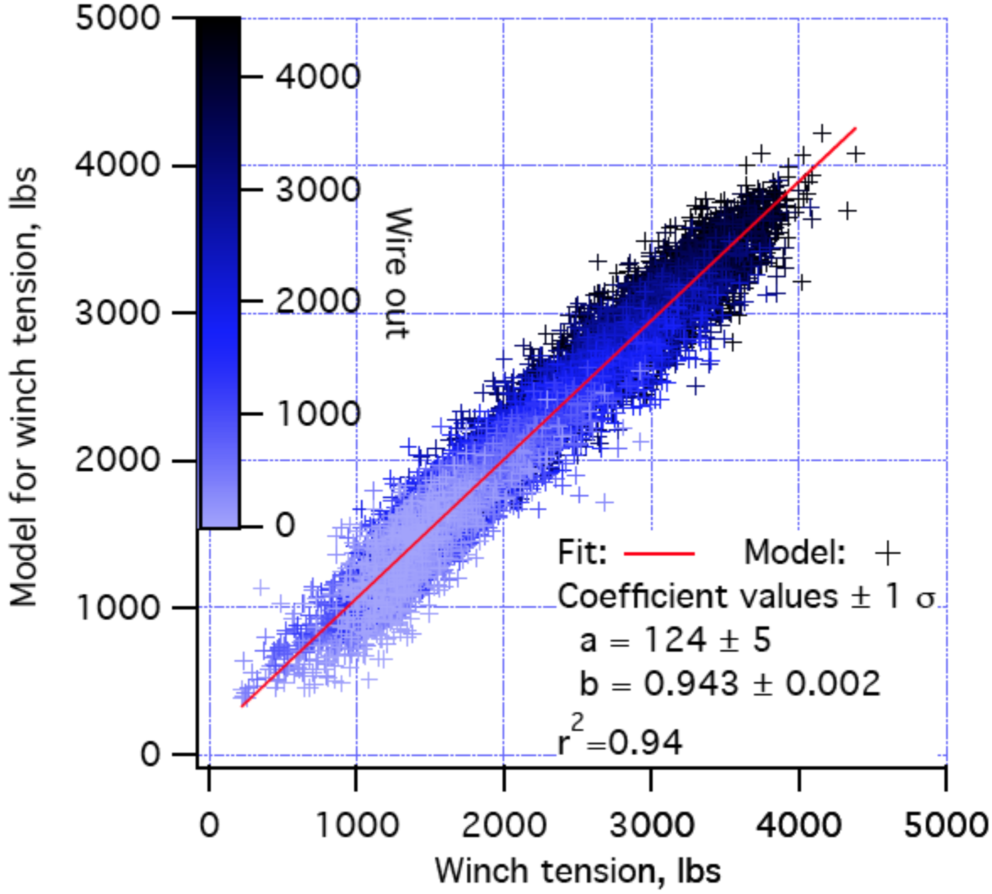


Figure 16.4: *Wire tension calculated from wire out, winch speed, and sheave velocity vs measured tension during station 1.*

This analysis is not altogether satisfactory. Although these correlations, when combined, explain about 94% of the variations in tension (Figure 16.4), the peak tensions are poorly represented. Part of that is due to the relatively slow data from the Seapath, but the springiness of the system is probably more important. However, it did establish that under the sea states where we could actually conduct CTD operations, we were unlikely to exceed the 5000 lb limit, given the cast depths anticipated. Given other obligations on the cruise, I did not pursue a more complete analysis.

Station 6

As a test of repeatability, I did an analysis like that in Figure 16.1, for station 6, a 4433 m cast on April 1 at 66.5°S, 150°W. The results, shown in Figure 16.5, are almost identical to station 1. The least-squares fit for tension vs wire out is subtly different, as I only used data from when the winch was stopped. That gave a much higher correlation, but not significantly different results.

Station 43

During station 30, a cast to 4389 m on April 12, the marine tech monitoring the cast noticed that there were some broken strands in the outer armor of the cable at around 4200 m. At that point, rather than risk losing the rosette, we limited cast depth to about 4100 m until we could either replace the cable or transfer operations to another winch. Beginning on Station 39, we began using the upper waterfall winch for CTD operations. That turned out to be a difficult cast, as there were electrical problems that put hundreds of spikes into the CTD data and the tension measurements broke down altogether. It turned out that the bracket holding the metering sheave that measures tension and cable motion had detached from the fairlead assembly. It was reattached and the cast continued, but reported tensions were much higher than expected, frequently exceeding the 5000 lb limit. High reported tensions continued until the techs had a chance to recalibrate the LCI-90 on April 16th between stations 42 and 43.

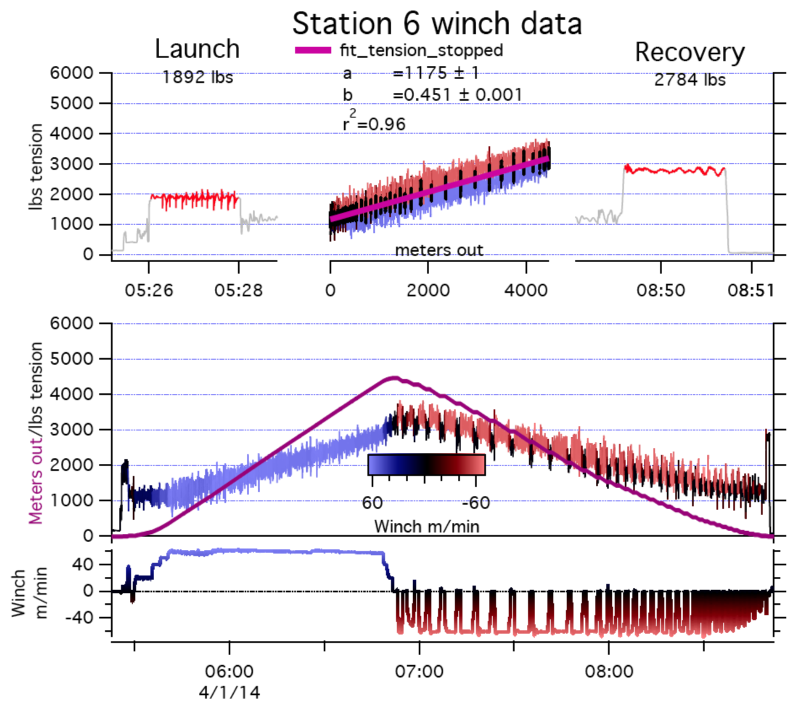


Figure 16.5: *Wire tension during station 6.*

The recalibration brought reported tensions down, but were still higher than those from the Baltic Room winch. I repeated the station 6 analysis for station 43 (Figure 16.6) and found that the slope of the tension vs wire out had jumped to 0.547 lbs/m, 17% higher than the wire specifications, and the 1086 lb difference between launch and recovery weights was 27% higher than it should have been. I have more confidence in the conclusion based on wire out, even though the water mass method has a firmer theoretical basis. (It is unlikely, but conceivable that the cable on the upper waterfall winch is much heavier than that on the Baltic Room winch and the Melville.) The wire out regression is based on a large number of points over a wide range of tensions, while the data on weights before and after launch are short periods with noisy data over a much smaller tension span. Either way, the tensions reported by the waterfall winch are too high.

It is probably a coincidence that the zero intercept, representing the rosette weight in water, was very similar at station 43 to the values at stations 1 and 6 and the Melville.

A striking feature of the tension time series in Figure 6 is the pattern of tension variation. Variability rises sharply when the rosette starts to be pulled back up. That cannot be explained by sheave motions. Could it be due to a straighter cable having less give as the tension rises? Maximum tension variability appears to be between 500 M and 3000 m. The reasons for that are not clear, but may have to do with the springiness of the winch/sheave/wire/rosette system. This pattern is present, though often less obvious, in all of the casts.

Station 56

The deepest cast of the cruise was station 56, to 5628 m, at 37°40´S on April 22. It was almost identical to station 46, except the weight of the package leaving the water was 100 lbs higher. It looks as though either the winch/A-frame operator did a smoother job during 46 or the marine techs recovering the rosette were pulling down harder during 56.

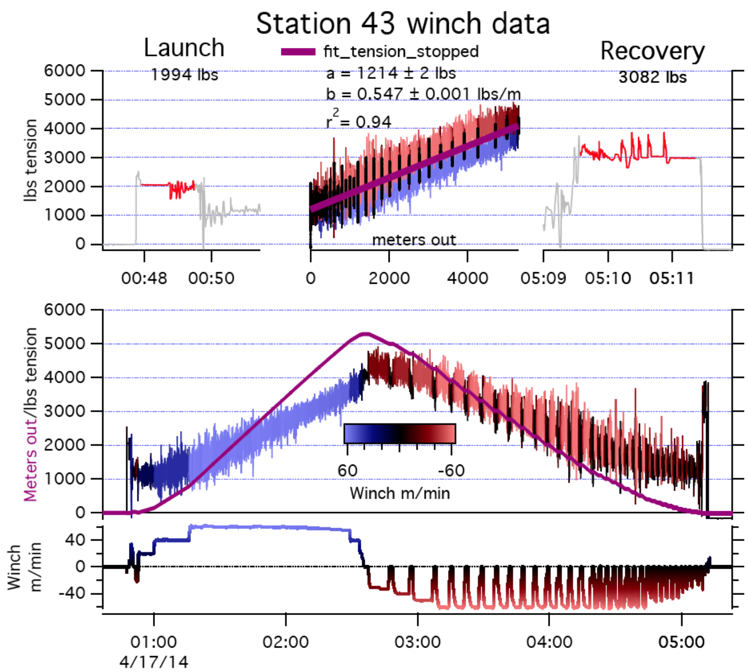


Figure 16.6: *Wire tension during station 43. This cast was the first after recalibration of the upper waterfall winch tension.*

If the tension measurements are accurate at 1200 lbs and the 17% difference between the slope and the manufacturer's specification of the weight in water is entirely due to measurement error, then the peak reported tension of 5200 lbs is closer to 4620 lbs. The waterfall winch would have to have been beyond about 5650 lbs for the 5000 lb tension limit to have been exceeded. After the April 16th winch recalibration, the maximum tension recorded was 5394 lbs on April 18th at 07:11:39 UTC during station 46.

Before the recalibration the maximum tension recorded was 5555 lbs at 07:46:31 UTC on April 16th, during station 41. At that time, reported tensions were even more excessive. I should note here that while NSF's tension limit was never exceeded on the waterfall winch cable, some damage may have been done by the 16 inch WHOI mooring block sheave, which had a wider groove than recommended for 0.322 inch cable. Sea conditions were too rough to allow the techs to mount the proper sheave on the A-frame.

Station 10

The highest recorded tension during the cruise was at 13:14:45 on April 2nd, during recovery of the rosette from station 10. The tension spiked to 6965 lbs with 7 m of wire out. No one seemed to notice the spike as it was happening.

The spike occurred when the package was about 10 m below the surface, after bottle 35 was tripped at 20 m, and before bottle 36 was tripped on the fly at 5 m (conditions were too rough for stopping at the surface).

The tension peak lasted about 2.1 s, with a 3/4 s rise to a sharp peak, roughly a second at about 6400 lbs, then a rapid drop followed by some ringing. As the tension peaked, the winch wire out stopped. Curiously, the winch speed took a couple of seconds before stopping. The winch remained stopped for 7 s before resuming the upcast.

This is not a case of a swell lifting the package, then dropping it. The package was still 10 m down. In addition, the lift would have reduced tension before the spike, rather than after.

It doesn't look like an electrical glitch. The peak lasted too long, and the ringing after the peak looks mechanical to me.

This isn't a sudden swell increasing tension. No unusual rolling or heaving was going on, and those motions are smoother and take longer.

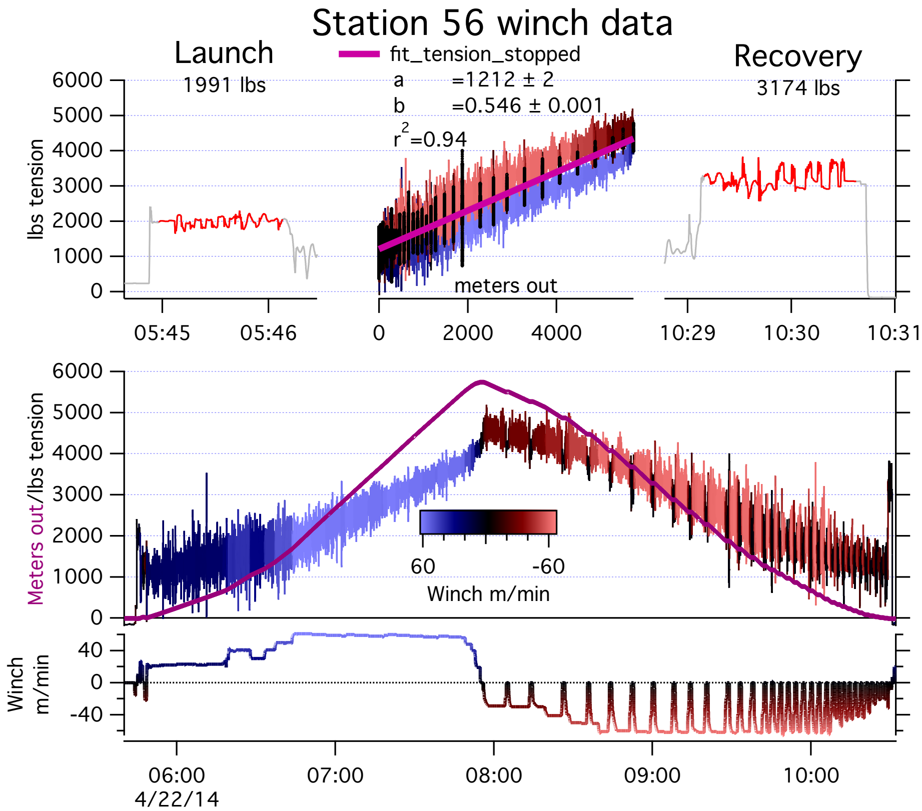


Figure 16.7: *Wire tension during station 56. This was the deepest cast during P16S 2014.*

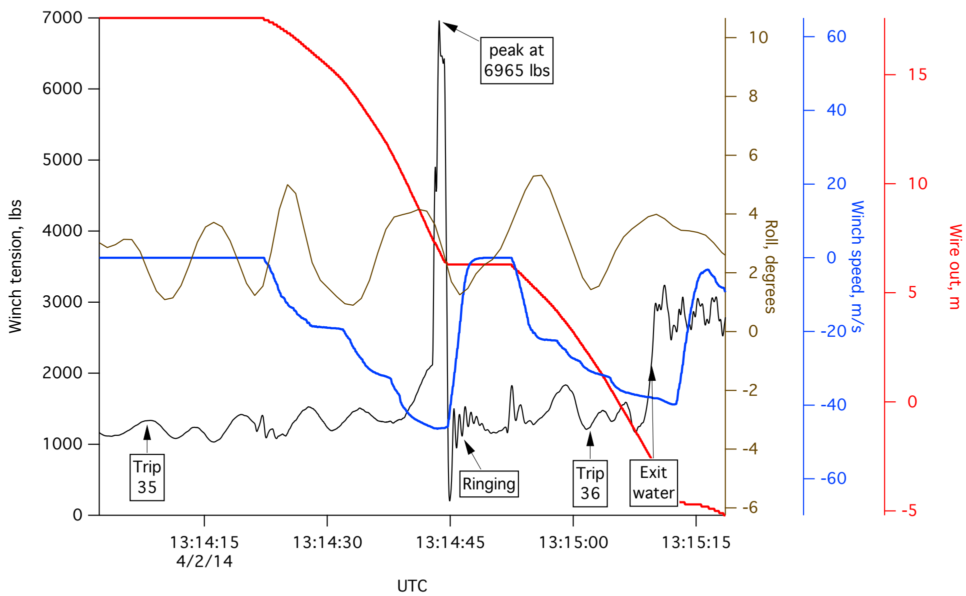


Figure 16.8: *The tension spike during recovery from Station 10. This was the highest tension recorded in P16S 2014. Also plotted are wire out, winch speed and roll from the Seapath 200.*

The conclusion we reached was that the package had hit the bottom of the ship. Its not clear what else could have caused the spike. At first we had only indirect evidence; the rosette frame was a bit bent, and there was some paint missing, but no one was sure those were new. The rosette is almost 2 m tall; the bottom of the ship is 7 m, so the depth was about right. Later on, we learned that one of the thermistors in the chipod fast-temperature package had been crushed. It stopped reporting at exactly that time.

Given the 10 000 lb nominal breaking strength of the cable, we were probably lucky not to lose the rosette.

Figure 16.9: *The only direct evidence of contact between the hull and the rosette. This was crushed at the end of station 10.*

17. SURFACE DRIFTERS (GLOBAL SURFACE VELOCITY PROGRAM)

PI: Rick Lumpkin (NOAA/AOML)
PI: Shaun Dolk (NOAA/AOML affiliate)
Shipboard operations: Elizabeth Simons (FSU), Isa Rosso (ANU)

Thirty Southern Ocean GDP drifters were deployed without incident. Two primary deployers, Elizabeth Simons (EGS) and Isa Rosso (IR) split deployments between the two CTD watchstander shifts (day shift and night shift). Secondary assistance was provided by ASC Marine Technicians, Meghan King, Julia Carleton, and Mackenzie Habermann as well as the other CTD watchstanders. When a deployment called for pair or triplet releases, thirty (30) second deployment spacing was enacted to limit the possibility of drifters' drogues entangling. As of 25/4/2014 all 30 drifters are reporting data.

Drifter ID	Deployment Date (dd/mm/yyyy)	Time	P16S STA #	Latitude	Longitude	Deployer	Notes on Deployment:
114536	05/04/2014	06:57	15	60 55.2372 S	149 54.3642 W	EGS	
114533	05/04/2014	06:57	15	60 55.1904 S	149 54.4206 W	EGS	
114665	06/04/2014	20:54	16	58 59.6736 S	149 59.9100 W	IR	
114645	07/04/2014	07:40	17	59 59.4360 S	150 1.4514 W	EGS	
114661	09/04/2014	10:54	23	56 59.9952 S	150 0.1254 W	IR	
114680	09/04/2014	10:54	23	56 59.9952 S	150 0.1272 W	IR	
116269	09/04/2014	10:53	23	57 0.0108 S	150 0.0642 W	IR	
116263	10/04/2014	04:33	25	55 59.9526 S	150 0.0954 W	EGS	
114644	10/04/2014	04:34	25	55 59.9346 S	150 0.1782 W	EGS	
114540	10/04/2014	04:34	25	55 59.9340 S	150 0.1788 W	EGS	
114678	11/04/2014	09:36	27	55 0.3732 S	150 1.1604 W	EGS	Cap off of thermistor when deployed
114673	11/04/2014	09:36	27	55 0.3732 S	150 1.1616 W	EGS	
114654	11/04/2014	09:37	27	55 0.3900 S	150 1.2480 W	EGS	
116454	11/04/2014	23:25	29	54 0.3918 S	149 54.5772 W	EGS	
114532	11/04/2014	23:25	29	54 0.3918 S	149 54.5778 W	EGS	Cap off of thermistor when deployed
116456	11/04/2014	23:26	29	54 0.3918 S	149 54.6282 W	EGS	Cap off of thermistor when deployed
114664	12/04/2014	14:12	31	53 0.0000 S	150 0.0426 W	IR	
116264	12/04/2014	14:13	31	52 59.9994 S	150 0.0432 W	IR	
114539	12/04/2014	14:13	31	52 59.9988 S	150 0.0438 W	IR	
114676	13/04/2014	23:41	35	51 0.0534 S	149 59.9130 W	EGS	
114677	13/04/2014	23:41	35	51 0.0528 S	149 59.9118 W	EGS	Cap off of thermistor when deployed
114683	13/04/2014	23:42	35	51 0.0552 S	149 59.8884 W	EGS	Cap off of thermistor & stem when deployed
114588	15/04/2014	15:31	39	48 59.9832 S	150 0.0138 W	IR	
116380	15/04/2014	15:32	39	48 59.9430 S	150 0.0282 W	IR	
114536	16/04/2014	18:50	42	46 59.9658 S	150 0.0762 W	IR	
116373	16/04/2014	18:50	42	46 59.9646 S	150 0.0768 W	IR	
114668	18/04/2014	01:06	45	44 58.4202 S	149 59.5488 W	EGS	Cap off of thermistor & stem when deployed
114541	18/04/2014	01:07	45	44 58.3320 S	149 59.5140 W	EGS	Cap off of thermistor when deployed
114684	19/04/2014	04:21	48	42 57.0444 S	150 0.0462 W	EGS	Cap off of thermistor when deployed
116377	20/04/2014	06:40	51	40 58.1214 S	150 0.0192 W	EGS	

18. ARGO AND ARGO-EQUIVALENT BIOGEOCHEMICAL FLOATS.

PIs: Ken Johnson (MBARI) and Stephen Riser (U. Washington).
Shipboard operations: Tyler Hennon (UW) and Lynne Talley (SIO)
Float funding sources: NSF OPP (Rapid grant) and NOPP

18.1. Deployments from *RVIB NB Palmer* (extracted from the complete P16S cruise report)

Twelve Argo-equivalent floats equipped with various combinations of state-of-the-art biogeochemical instrumentation and sea ice-avoidance software were deployed during the RVIB NB Palmer cruise (chief scientist Lynne Talley), 20 March - 5 May, 2014 (Table 18.1 and Figure 18.1). 4 of the floats were deployed along the great-circle transit from Hobart, Tasmania, to the initial station of the P16S section (67°S, 150°W), and the remaining 8 were deployed along 150°W from 67°S to 39°40'S. Six of the 7 floats along 150°W that included pH sensors were funded through an NSF Rapid grant; the high resolution T/S data are reported to Argo. The other 6 are Argo floats that have been outfitted with additional sensors through a NOPP grant. Tyler Hennon, a U. Washington graduate student (advisor co-PI S. Riser), was responsible for all deployments and record-keeping on the cruise, with assistance from the Palmer's marine technicians for all deployments. The two SIO Oceanographic Data Facility nutrient technicians (S. Becker and M. Miller) and the SIO alkalinity technician (D. Cervantes from the A. Dickson laboratory) also assisted with several deployments to gain experience in the event that they will be on ships that deploy such biogeochemical floats in the future.

Table 18.1. *Deployment and profile Information as of 14 May 2014*

	Float ID	P16S Sta. #	WMO number (Argo)	Equipped Sensors*	Reporting Sensors*	Deployment date (UTC)	Lat.	Lon.	Days/ cycle	Max p	Number of profiles 5/11/14
1	6091	1	5904179	IONF	OF	26/03/2014	60 0.0 S	173 57.8 E	10	2000	5
2	7557	2	5904181	IONF	ONF	28/03/2014	60 29.27 S	176 00.66 W	10	1500	5
3	7567	3	5904182	IONF	OF	30/03/2014	65 41.17 S	161 55.34 W	10	1800	2 (4/21 most recent**)
4	7613	4	5904180	IONF	ONF	31/03/2014	66 30.64 S	155 59.47 W	10	1600	2 (4/11 most recent**)
5	7614	5	5904183	IONF	ONF	01/04/2014	67 00.82 S	149 59.97 W	10	1600	3 (4/22 most recent**)
6	9091	11	5904184	IONFp	ONFp	03/04/2014	63 59.55S	150 01.36 W	10	1400	4
7	9092	17	5904185	IONFp	ONFp	07/04/2014	59 59.54 S	150 01.18 W	10	1600	4
8	9031	27	5904396	ONFp	ONFp	11/04/2014	55 0.34 S	150 01.04 W	5	1500	7
9	9018	32	5904186	Op	Op	13/04/2014	52 29.33 S	150 0.61 W	5	1600	8
10	9095	37	5904188	ONFp	ONFp	14/04/2014	49 59.23 S	149 59.44 W	5	1600	6
11	9101	45	5904187	Op	Op	18/04/2014	44 58.43 S	149 59.55 W	5	1700	5
12	9254	53	5904395	ONFp	ONFp	20/04/2014	39 39.40 S	149 58.96 W	5	1600	5

*Sensors: I = ice enabled (software) O = oxygen N = nitrate F = FLbb p = pH
** Most likely ice-covered thereafter, will report after emerging from ice

Typical deployment procedure was relatively simple. After finishing the CTD cast at a deployment location, the Palmer would relocate to ~1 km off station and then proceed at about 1-2 knots in whatever direction offered the most shelter to the deployment. Hennon, along with one NBP ASC marine technician and one additional assistant (either a second MT or an SIO chemistry technician), then would lower the float from the stern to the water with a rope. This proved to be moderately challenging, given that the sea state was usually quite rough. Following deployment, the ship made a wide arc back to its steaming direction, ensuring that it did not pass over the deployment location.

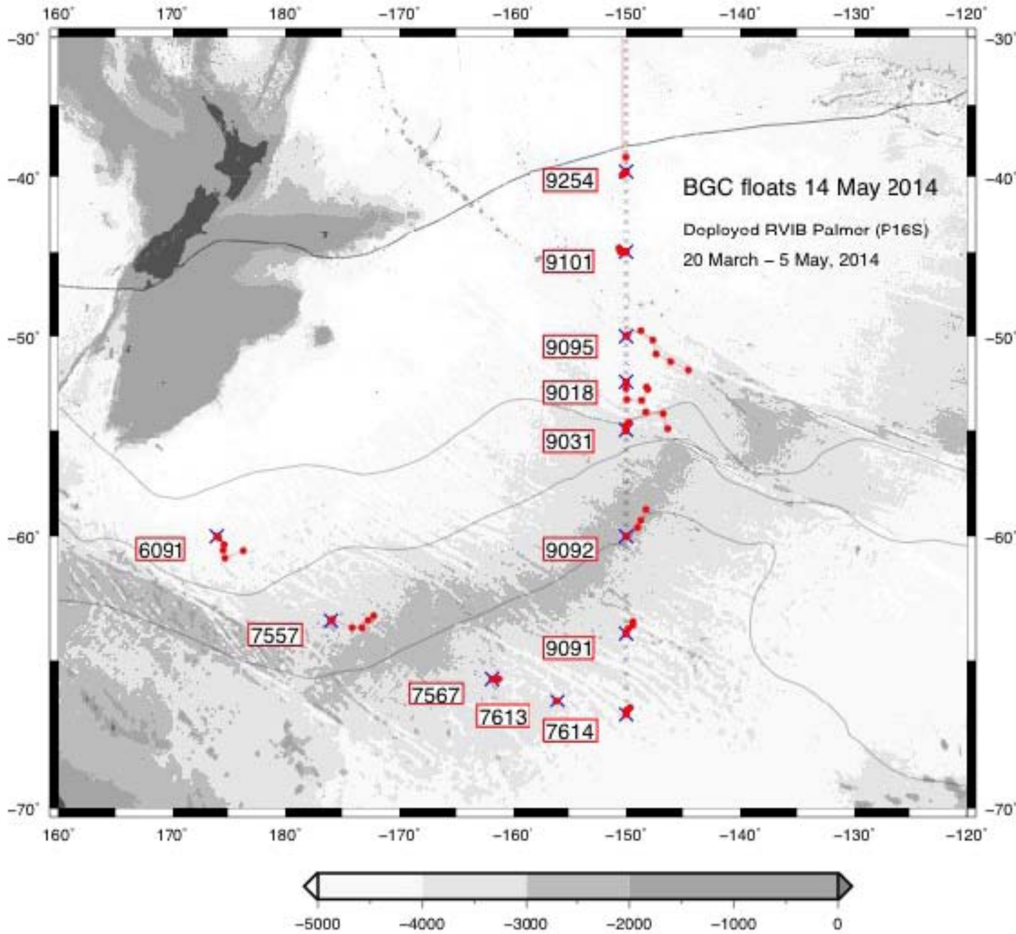


Figure 18.1: *RVIB N.B. Palmer (NBP1403) float deployment locations and subsequent tracks (red), with P16S CLIVAR stations (black x's) (20 March - 5 May, 2014). Float ID numbers are listed in Table 1; WMO numbers for access to data on the Argo servers are listed in Table 1. Light curves are the standard Orsi fronts (subtropical, subantarctic, polar and southern boundary, from north to south). The Ross Sea lies south of the southern boundary, and sea ice has already advanced over the southernmost 3 floats.*

All 12 floats reported their first profiles on time and several profiles thereafter, with information and data posted on both http://www.mbari.org/chemsensor/floatviz.htm (biogeochemical site, plots, data sets) and http://runt.ocean.washington.edu/ (float tracking, engineering data, profiles). All oxygen, pH and FLbb sensors and 8 of the 10 ISUS nitrate sensors (exceptions are floats 6091, 7567) are producing good data. Of the 49 floats with nitrate sensors built at MBARI, these are the first two that did not respond on deployment. Engineering data indicate that the nitrate sensor on float 7567 is not responding because the persistent power interface (PPI) on the float is not operating properly and the nitrate sensor is not receiving power. This float appears to have had a significant shock on launch, as several other subsystems operated abnormally on the first profile. Operation of the other subsystems was restored, with the exception of the PPI. Loss of the nitrate sensor on 6091 has not been understood, at this time. The sensor communicated properly during predeployment tests. All systems in the float itself are operating normally after deployment, but there are no communications being received from the sensor.

Individual float deployment concerns (no issues for floats not listed):

6091: The Palmer was steaming close to 3-4 knots to try to protect the back deck (deployment location) from bad weather. The nitrate sensor did not work for unknown reasons.

7567: A wave pushed float 7567 against the ship when the float was still attached to the deployment line. Initially this didn't cause concern, as there was not a violent collision. However, the data returned from the first profile (~12 hours after deployment) indicated severe problems and possible entry of saltwater into the float. Fortunately the 2nd profile was normal, with the exception of a nonfunctional nitrate sensor. Currently, it is unclear what caused the problems or if the float will continue operating normally. It is now presumably under ice along with two of the other floats and we will only learn more in the austral spring when they emerge.

7614: The line tangled during deployment. After a couple minutes we were able to shake the float free, but there were incidents of low speed (~10 cm/s) contacts between the iridium antenna and the ship's hull. The float has since reported back and is fully functional.

9031: Deployed in big swell, but there was no contact with ship to cause concern. The Palmer was steaming 4-5 knots during the deployment to protect the back deck from incoming waves. The bad conditions also prevented the ship from steaming off the CTD station until all the sampling was completed in order to limit the wash upon the deck (CTD sampling was outdoors at this point). This caused the float to be deployed about 2.5 hours after the conclusion of the CTD cast, but this is not a concern as the location was close, and the first float profiles are normally 12 to 24 hours later in any case.

Deployment Information (Original Log)

P16S 2014 Floats (NSF Eager, Pre-SOCOM, Argo)
U.Washington (S. Riser) and K. Johnson (MBARI)

	Nominal location (°S)	Float ID	Sen-sors*	P16S sta. #	Deploy-ment Date	Deploy-ment Time (GMT)	Lat.	Lon.	Name (deployer)
1	174E	6091	IONF	1	26/03/2014	12:43:00	60 0.0 S	173 57.86 E	Herman
2	176W	7557	IONF	2	28/03/2014	04:45:00	60 29.271 S	176 00.695 W	Herman
3	165.3W	7567	IONF	3	30/03/2014	07:54:19	65 [illegible] S	161 55.7791 W	Herman
4	158.3W	7613	IONF	4	31/03/2014	05:46:50	66 35.6372 S	155 59.4811 W	Herman
5	67S	7614	IONF	5	01/04/2014	[illegible]	67 00.824 S	149 59.9720 W	Herman
6	64S	9091	IONFp	11	03/04/2014	08:34:03	63 59.55 S	150 01.280 W	Herman
7	60S	9092	IONFp	17	07/04/2014	07:33:00	59 59.9475 S	150 01.1901 W	Herman
8	55S	9031	ONFp	27	11/04/2014	09:30	55 0.34 S	150 01.04	Herman
9	52.5S	9018	Op	32	13/04/2014	01:15	52 29.33 S	150 0.61 W	Herman
10	50S	9095	ONFp	37	14/04/2014	14:00	49 59.23 S	149 59.44 W	Herman
11	45S	9101	Op	45	18/04/2014	1:00	44 59.47 S	149 59.55 W	Herman
12	40S	9254	ONFp	53	20/04/2014	22:55	39 59.40 S	149 58.96 W	Herman

I = ice enabled
O = oxygen sensor
N = nitrate sensor
F = FLbb
p = pH

Final 22-Mar-14

float	UW #	ice	O2 -3830	O2 -4330	NO3	FLBB	pH	Lon W	Lat
1	6091	✓	✓		✓	✓		(173.5E)	-60
2	7557	✓		✓	✓	✓		176	-63.5
3	7567	✓		✓	✓	✓		165.3	-65.6
4	7613	✓	✓		✓	✓		158.3	-66.5
5	7614	✓		✓	✓	✓		150	-67
6	9091	✓		✓	✓	✓	✓	150	-64
7	9092	✓		✓	✓	✓	✓	150	-60
10	9031			✓	✓	✓	✓	150	-55
8	9018			✓			✓	150	-52.5
11	9095			✓	✓	✓	✓	150	-50
9	9101			✓			✓	150	-45
13	9254			✓	✓	✓	✓	150	-40

18.2 Float data and engineering information (14 May 2014)

The data and performance information from the 12 floats deployed on NBP1403 are available in near real-time and delayed mode from four servers, each with a unique purpose (Table 18.2).

Table 18.2: *Profiling float data servers*

Server	url	Purpose
U. Washington Argo float server	http://runt.ocean.washington.edu	U.W. float summaries, diagnostics, engineering data, profiles
Floatviz (MBARI)	http://www.mbari.org/chemsensor/floatviz.htm	Float profile data including all sensors, quality controlled data
U.S. GODAE Argo GDAC	http://www.usgodae.org	Real-time and delayed-mode Argo data server (U.S.), high resolution T/S
JCOMMOPS Argo data server	http://argo.jcommops.org/ (links to US GODAE for data access)	Real-time and delayed-mode Argo data server (international), high resolution T/S

18.2.a. Temperature/salinity profiles reporting to Argo data servers

The high resolution temperature/salinity data (2 m vertical resolution above 1000 m) from all 12 floats are available according to Argo protocols from the U.S. GODAE and JCOMMOPS servers, listed in Table 2. (The U.S. GODAE server is the U.S. mirror site for JCOMMOPS.) The WMO numbers for each float are provided above in Table 1, and are also listed on the floatviz.htm website.

18.2.b. Float information and statistics to U. Washington data server

The U. Washington profiling float website tracks each of the Apex floats that have been built at U. Washington. This NBP1403 group of 12 is displayed with the Southern Ocean floats. Information about each float can be accessed by clicking on the float ID (Table 1 and Figure 1). This website provides plots (trajectories, profiles, and a large amount of additional information about each float's performance, that are not provided by the Argo data server websites. The U.W. website does not provide the data sets themselves.

18.2.c. T, S, oxygen, nitrate, pH, fluorescence (chlorophyll) and backscatter data to MBARI floatviz data server

The MBARI floatviz.htm website provides both the data sets and visualization tools for the biogeochemical and physical parameters collected by these floats, as well as many other floats outfitted by MBARI (K. Johnson). The complete data sets at the lower resolution of the chemistry data (~70 vertical samples on each profile) for each of the 12 floats are posted and are public.

There are two versions of each data set: non-QC (raw data) and QC (adjusted data, with quality control flags). International and U.S. Argo are just beginning to decide how to work with and format data other than temperature and salinity; eventually the chemistry data posted at floatviz will be available through Argo.

18.3 Data quality

We have just begun assessing the quality of the new data sets. The NB Palmer P16S CLIVAR observations included a full suite of carbon-related measurements (DIC, alkalinity, pH), nutrients, oxygen, temperature and salinity, and many other chemical and physical quantities, all measured at the highest possible international standards of accuracy and precision. The pH and nitrate data from the floats are already being checked against the shipboard measurements. The CTD/rosette profiling included a fluorescence sensor, which can be used for comparison with the float fluorescence data. A full optical program was also aboard from NASA, for ocean color satellite validation, and therefore high quality in situ data in the upper 200 m are also available for comparison with the float optical sensors (Wetlabs FLbb); water samples were collected for pigment analysis.

As discussed in Appendix 18A, it appears that the pH sensors were likely coated with TBT anti-foulant that biased the calibration and first profile of each float. The TBT was rapidly removed and subsequent profiles have been extremely stable. Surface pH values on profiles subsequent to the first are stable to about +/-0.005 pH (1 std. deviation for all data in the upper 50 m) for up to 6 profiles and one month in the water, as shown in Figure 18.3.

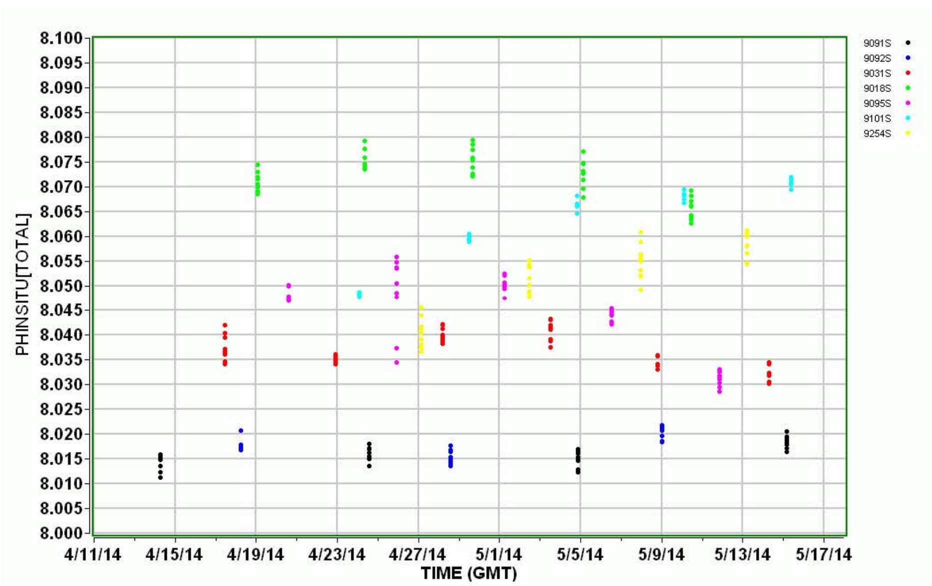


***Fig. 18.2**: In situ pH values in the upper 50 m for all float profiles except the first, from all 7 floats with pH sensors. The plot was generated from the FloatViz web site. Cooling without deep mixing drives pH up, while deep mixing lowers pH.*

A full set of plots comparing the float and P16S inset observations of oxygen, nitrate and pH is available as a PowerPoint; an example for one float is shown in Figure 18.3. The profile shapes are excellent. Calibration offsets are being calculated and applied. As part of the learning curve, it appears that laboratory calibrations of the pH and nitrate sensors were affected by an inadvertent presence of antifoulant (see long email discussion from K. Johnson, Appendix 18A).

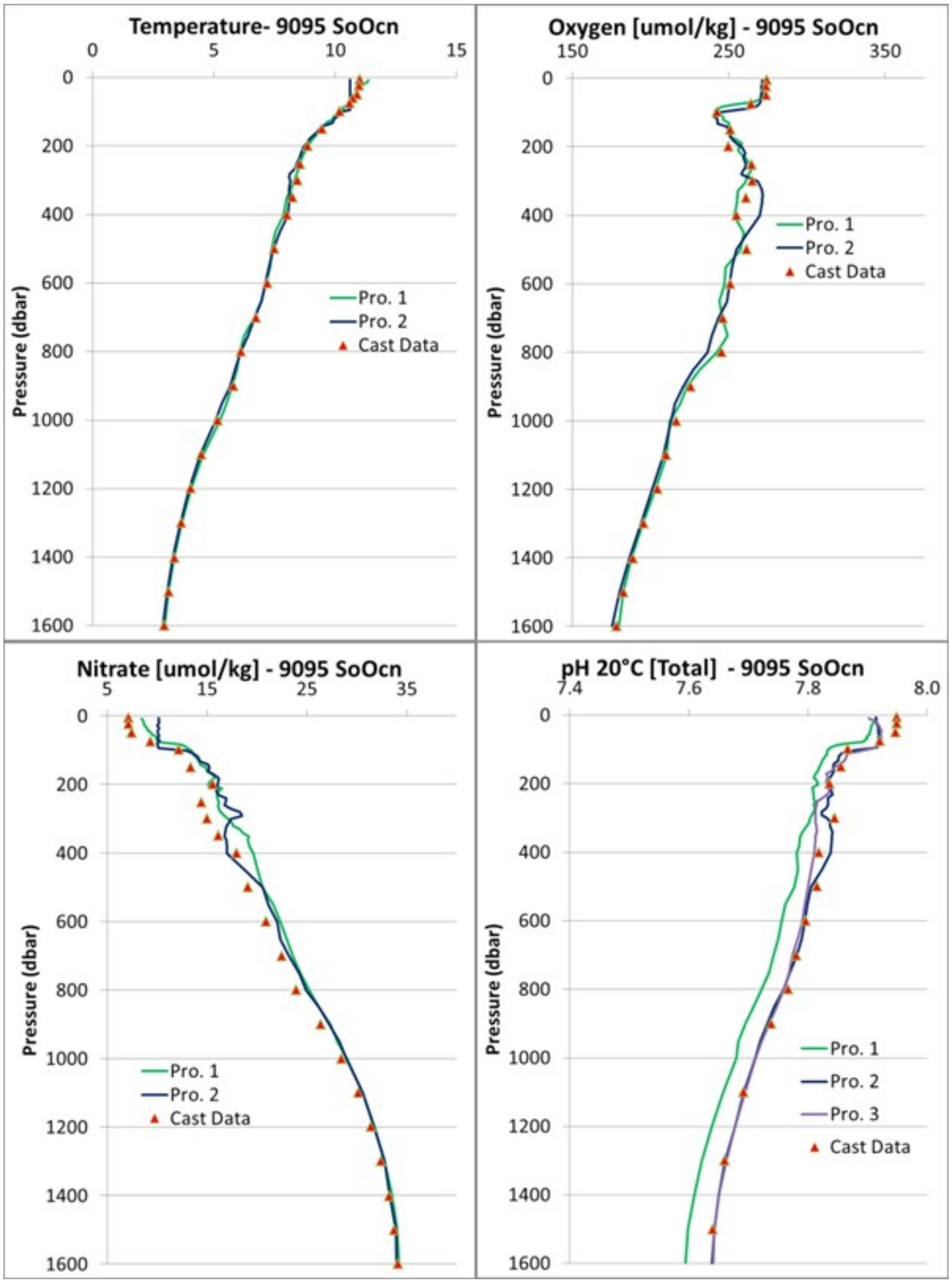


Figure 18.3*: Comparison of shipboard measurements ("cast data") and float measurements from the first two profiles of float 9095, as an example of the comparisons made as soon as profiles were available.*

Data were adjusted to match deep (1000-1600 m) data for nitrate and pH. Oxygen was adjusted so that the mean of all sensor measurements in air (one measurement is made on each profile) match air oxygen partial pressure. The first float profiles occur within 24 hours and several kilometers of the rosette cast. The initial offset of the pH profile is likely due to the presence of antifoulant during laboratory calibration and will not be an issue in the future.

Appendix 18.A

(Mis-) Calibration of the Deep-Sea DuraFET pH sensors (extracted and edited from an e-mail of May 7, 2014 from K. Johnson to P. Milne, L. Clough, L. Talley, J. Sarmiento)

There's a bit of a story about why our pH pre-deployment calibrations did not meet our expectations of being absolute. This is what we think happened. The float CTDs have a TBT anti-fouling plug in the circulating seawater line, which constantly pumps ambient seawater through the CTD. We do the final, absolute calibration of the sensor to pH with the whole sensor installed on the float endcap and plumbed into the CTD flow stream. Normally, the TBT antifouling plug on the CTD should be removed for pH/nitrate calibration because the flow stream is recirculated during lab calibration, with a dummy in its place. But a new employee didn't get the message and we received the CTD's with TBT loaded. That has been verified. It's hard for us to tell if the TBT is present because the dummy TBT plug would be installed to provide the same mass during ballasting at UW and it looks just like the real thing. In any case, the final calibration took place with a small volume of Tris buffer at pH 8.2 recirculating through the TBT plug and TBT concentrations would have been quite high. TBT is very surface active, it's an organic metal oxide with a strong affinity for the oxide on the gate of the pH sensor, and it would have coated the pH sensor, resulting in an offset calibration.

Coincidentally, we actually do two pH sensor calibrations. The first, for the sensor T and P response, is done in dilute HCl (the only solution we really know the proton activity properties of at high P) before the pH sensor is installed on the CTD and before the sensor would have seen TBT. The HCl and Tris calibrations normally produce very similar reference potentials for the sensor, but this time they did not. Unfortunately, we just did not do the comparison of the reference potential in HCl and Tris before we shipped the floats. It wasn't part of our protocol. The HCl calibration definitely has more error than the Tris calibration because its pH is so far from that of seawater (calibration at pH 2 to measure seawater pH near 8). When we applied the Tris calibration reference potential to the float data, the results for pH were way off, with large but constant offsets. But the HCl calibration gave pH values that were just about right on. In some cases, they're just right, in some case a little bit of adjustment is needed to bring sensor pH into agreement with the ship pH. The only way we can explain the weird Tris calibration is that something had coated the pH sensing surface and altered the sensor output during calibration.

One other bit of evidence for contamination by TBT during the pH sensor calibration was that the first profile for each sensor had an even larger offset, that went away after one profile. Just as if something like adsorbed TBT was dissolving off the sensor. This also impacted the nitrate sensor and the first nitrate profiles are a bit odd too, with constant offsets that have since gone away. Coincidentally, TBT has a strong UV absorbance, which would affect the ISUS's spectrophotometric nitrate measurement. Normally, the TBT is not a problem when the float is deployed because levels are low as water constantly flows through the system, but during our lab calibrations it just recirculates and concentrations can build up. We're kind of picking on TBT, but it was the one anomaly in the calibration process that we can identify and the effects makes sense.

So we're now processing the data using the HCl calibrations, in some cases with a small, constant offset added to account for non-linearities in sensor response that don't matter when calibrated near the pH it's measuring. Because of the TBT issue, we've ignored the first profile for all the floats and are only looking at profile 2 and on.

The pH delta for pH from TA/DIC minus spectrophotometric pH has a standard deviation around 0.002 to 0.003 pH on each profile. The pH delta for sensor minus spectrophotometric pH is larger, about 0.007. Partly, that larger standard deviation is due to the problem of matching profiles at different times and in the upper ocean where gradients can be pretty steep. But even in the deeper water where concentrations should be more nearly invariant, the scatter for the sensor pH delta is a bit larger than the pH delta derived from measurements on a seawater sample. So we likely don't quite have the precision that the shipboard measurements do, but CLIVAR shipboard laboratory measurements of all properties are the "gold standard" and no autonomous sensors on Argo floats match the accuracy of these highest quality benchmark measurements. On the other hand, these floats will be out there for 5 years and will provide the first complete annual cycles of pH observed anywhere in Antarctic waters over many years, thus demonstrating, as for other sensors, the value of the combination of (i) high accuracy shipboard measurements against which to compare autonomous sensors with (ii) the many years of autonomous measurements that cannot be made from ships.

19. NASA OCEAN BIOLOGY/BIOGEOCHEMISTRY PROGRAM

NASA Goddard Space Flight Center,
Ocean Ecology Branch, Field Support Group

Participating team members:

Joaquín E. Chaves
Scott A. Freeman
Michael G. Novak

The NASA Goddard Space Flight Center (GSFC), Field Support Group participated in the 2014 P16S CLIVAR Repeat Hydrography campaign on board the R/V Nathaniel B. Palmer. The campaign departed from the Australian port of Hobart, Tasmania, on March 20, 2014, and arrived in Papeete, French Polynesia, on May 5, 2014. Measurements were mainly conducted along 150° W from the Ross Sea section of the Southern Ocean at 67° S, to the tropical waters of the SW Pacific Ocean at approximately 16° S. In addition to the 150° W meridian sampling, NASA deployed during five stations between Hobart and 67° S immediately preceding biogeochemical ARGO float deployments. The floats were equipped with WET Labs Inc., backscattering and chlorophyll fluorescence sensors, which can be compared to instruments on our IOP package.

19.1. NASA Science Objectives

The P16S campaign presented a valuable opportunity to collect in-water optical measurements concurrently with phytoplankton pigments and other biogeochemical parameters to support NASA's satellite ocean color validation activities at GSFC.

Phytoplankton pigments, taxonomy, and biogeochemical measurements

Near-surface samples (~2 m) were collected for HPLC analysis of phytoplankton pigments, particulate organic carbon (POC), dissolved organic carbon (DOC), and spectral particulate (a_p), and CDOM (a_g) absorptions. Samples for the determination of phytoplankton taxonomy and cell abundance were also collected. For the parameters above, surface samples were collected with a peristaltic pump outfitted with an acid-clean silicon hose deployed over the side while on station. Additional subsurface samples from two depths within the photic zone (< 150 m) were collected from the CTD rosette at stations where concurrent optical measurements were conducted. The depths for these subsurface samples were chosen based on the location of the chlorophyll maximum. One sample was collected from the Niskin bottle nearest to the chlorophyll maximum, and one either above or below that feature. All filtration and cold sample preservation were conducted on board. Samples were transported to NASA-GSFC for further analyses. In addition to the samples processed and stored for on shore determination, ag was also measured on board on all CDOM samples shortly after collection on two UltraPath liquid waveguide systems (WPI, Inc.; Figure 19.1). An inventory of all samples collected for each parameter is presented in Table 19.1.

The NASA team also collected CDOM samples for Norm Nelson at UCSB. Samples were collected at 16 stations from the rosette casts along the P16S line. Samples were collected once daily every other day from the top 9 depths and from 9 additional depths down the bottom.

In-Water Optical Measurements (AOPs, IOPs)

The package to measure inherent optical properties (IOPs) was equipped with two attenuation and absorption spectrometers (ac-s, ac-9; WET Labs, Inc.). The ac-9 was equipped with a 0.2 um pre-filter to allow the in situ measurement of a_p. The IOP package also included two scattering meters (bb-9, VSF-9; WET Labs, Inc.), and a Sea Bird SBE 45 CTD. The ac-s and ac-9 meters measure absorption and attenuation (and total scattering by difference) at 90 and 9 wavelengths, respectively, between 400 and 740 nm, while the bb-9 measures backscatter at 9 wavelengths and 117°. The VSF-9 measures scattering at 9 angles from 60° to 170° at 532 nm. The package performed casts down to 200m depth at 37 stations during the campaign (Table 19.2).

Apparent optical properties (AOPs), both downwelling irradiance (Ed) and upwelling radiance (Lu), were measured using a Satlantic, Inc., HyperPro radiometer during 14 of the 16 stations where AOP measurements were conducted (Table 19.3). Unfortunately, during the deployment on station 80 the HyperPro was lost due to contact between the instrument cable and the ship propeller. For the last two stations where AOP deployments were possible, a Biospherical Instruments C-OPS system was used. For both instrument systems, incoming solar irradiance (E_s) was measured with a matching reference radiometer. The HyperPro system measured radiance and irradiance at 255 wavelengths between 305 and 1140 nm, while the C-OPS measured the same parameters at 19 wavelengths between 305 and 900 nm. AOP measurements were conducted once daily within ± 2 h of local solar noon when weather conditions permitted down to the 1% of surface light level.

Additionally, we conducted solar radiometry at six stations using a Microtops Sun Photometer. The Microtops is a small, handheld instrument, which measures solar radiance at five wavelengths. These data will be incorporated into the AERONET database.

Underway IOP Measurements

During the entire campaign, with the exception of the transit through the Australian EEZ, we conducted IOP measurements with an underway system that included an ac-s meter, a VSF-3 scattering meter, and two fluorometers for chlorophyll and CDOM, respectively. All the above instruments in the underway system are from WET Labs, Inc. In addition to the optical instruments, the system included a SeaBird SBE45 thermosalinograph and a Sequoia Inc. valve flow control unit, which switched hourly between whole seawater and 0.2 um filtered water to measure a_p. Three times per day, distilled water was run through the entire system to calibrate the ac-s and VSF-3. Because the same ac-s was used in the IOP package, the underway system was turned off while at stations. It performed very well throughout; however as the campaign progressed into warmer subtropical and tropical waters, biofouling from algae growth was noticeable in the lines that fed the ship clean seawater into the system. Further comparisons with other in situ measurements conducted during the cruise will be necessary to validate the data collected by the underway system, particularly during the second half of the campaign.

19.2. Tables and Figures

Table 19.1: *Biogeochemical samples collected during the P16S campaign by the NASA team.*

Parameter	Number of samples collected
HPLC Pigments	261
a_p	187
POC	357
a_g	143
DOC	513
Phytoplankton abundance, taxonomy	176
Total	1637

Table 19.2: *Inherent optical properties (IOPs) instrument casts during the P16S CLIVAR campaign.*

Date UTC, yyymmdd	Beg time, UTC	end time, UTC	Sta tion	Latitude, dec. deg.	Longitude, dec. deg.	Depth, m	Sky Conditions, %	Wind speed, m/s	Wind direction, deg.
20140326	7:05:03	7:14:59	1	-60.0013833	174.00135	4514	dark	15	300
20140326	7:42:55	8:18:29	1	-60.0013833	174.00135	4514	dark	15	300
20140328	3:52:14	4:24:03	2	-63.4997833	-176.000166	3275	100	17	105
20140330	6:53:04	7:27:20	3	-65.6917666	-161.894633	4096	dark	14	260
20140331	0:31:30	1:04:37	4	-66.4994166	-155.999933	4056	100	7	160
20140331	20:52:11	21:25:10	5	-67.0002833	-149.998583	4021	100	5	200
20140401	23:06:19	23:39:09	8	-65.48895	-150.019783	3275	100	9	320

20140403	7:43:44	8:13:41	11	-63.9984166	-150.000233	3268	dark	20	260
20140406	20:14:59	20:46:14	16	-58.9981833	-149.999583	2700	100	17	300
20140407	3:46:26	4:18:33	17	-60	-149.9996	2743	100	15	290
20140407	22:00:18	22:33:25	19	-61.00005	-150.000083	3200	100	11	300
20140409	4:24:22	4:44:14	22	-57.5001333	-149.998633	3364	dark	16	295
20140410	3:54:17	4:25:23	25	-55.9997666	-149.999366	3416	dark	16	273
20140411	7:56:28	8:27:08	27	-54.9995	-150.000916	3768	dark	10	220
20140411	8:40:07	9:09:31	27	-54.99955	-150.000916	3768	dark	10	220
20140411	22:26:07	22:58:46	29	-54.0067333	-149.999333	3255	100	10	295
20140412	21:11:42	21:45:46	32	-52.4994166	-149.998733	4661	100	14	330
20140413	22:57:00	23:30:11	35	-51.0005333	-150.000416	4951	100	14	110
20140414	9:47:42	10:20:42	37	-50.00121	-150.000198	4257	dark	10	41
20140414	21:25:05	21:48:38	38	-49.5000666	-150.000083	4177	100	8	335
20140415	20:18:22	20:45:39	40	-48.3336333	-149.999966	4865	100	13	310
20140416	23:55:33	0:25:27	43	-46.336345	-149.99083	5229	30	10	290
20140417	22:34:12	23:04:50	45	-44.99985	-150.000833	5310	60	17	212
20140418	22:44:23	23:13:46	48	-42.9957	-149.997866	5194	100	4	198
20140420	1:25:16	1:54:39	51	-41.0031	-149.999733	5622	90	5	64
20140420	23:09:36	23:37:35	53	-39.6671666	-149.9999	5269	100	15	80
20140422	5:04:07	5:34:03	56	-37.666615	-149.999893	5636	dark	15	80
20140423	1:16:55	1:48:57	58	-36.3290666	-149.992683	5855	70	10	263
20140423	22:59:56	23:27:24	60	-35.0000333	-150	5279	20	8	270
20140424	20:19:04	20:44:46	63	-33.0003833	-149.999916	5458	100	10.5	14
20140425	0:40:05	1:07:45	66	-31.0000333	-149.999366	4259	50	12	12
20140426	21:52:34	22:20:15	68	-29.6662166	-150.000566	4223	30	13	220
20140427	22:50:34	23:18:08	71	-27.6670833	-149.999633	4398	100	6	167
20140428	19:51:43	20:15:37	74	-25.6668	-150	4516	50	9	181
20140429	20:49:46	21:15:59	77	-23.66645	-149.9999	4737	40	11	157
20140430	21:52:21	22:20:43	80	-21.666683	-150.000166	4691	30	10	160
20140501	21:38:14	22:03:40	83	-19.6666333	-149.999833	3974	30	6	130
20140502	21:51:11	22:00:08	86	-17.6668666	-150.000066	5632	30	3	97
20140502	22:08:12	22:35:20	86	-17.6668666	-150.000066	5632	30	3	97
20140503	22:20:13	22:47:10	89	-15.666	-150.0082	4064	50	8	105

Table 19.3: *Apparent optical properties (AOPs) casts during the P16S CLIVAR campaign.*

Date UTC, yyymmdd	Beg time, UTC	end time, UTC	Sta tion	Latitude, dec. deg.	Longitude, dec. deg.	Depth, m	Sky Conditions, %	Wind speed, m/s	Wind direction, deg.
20140331	1:12:33	1:26:30	4	-66.4994	-155.9999	4056	100	7	160
20140331	21:49:37	22:02:07	5	-67.0002	-149.99858	4021	100	5	200
20140401	22:39:16	22:51:52	8	-65.4875	-150.02902	3275	100	9	320
20140411	23:07:33	23:19:52	29	-54.0064	-149.9104	3255	100	10	290
20140416	23:24:54	23:37:43	43	-46.336345	-149.9908	5229	30	10	290
20140418	22:14:10	22:26:34	48	-42.99955	-149.9997	5194	100	4	194
20140420	1:01:14	1:15:03	51	-41.0022	-149.999725	5622	90	5	64
20140423	0:46:18	1:01:46	58	-36.33223	-149.998183	5910	90	10	270
20140423	23:39:22	23:54:47	60	-34.999633	-149.998266	5248	20	8	262
20140424	20:57:20	21:02:47	63	-33.0035	-149.9998	5750	100	10	10
20140424	21:15:38	21:24:44	63	-33.0035	-149.9998	5750	100	10	10
20140427	23:27:15	23:40:16	71	-27.666183	-149.99923	4423	90	5	200
20140427	23:41:01	23:49:47	71	-27.66618	-149.9992	4423	90	5	200
20140428	23:52:35	23:57:21	74	-25.6667	-150.0001	4527	60	10	180
20140429	21:24:46	21:46:43	77	-23.666483	-149.9999	4737	60	11	157

20140430	22:28:07	22:40:16	80	-21.66668	-150.0003	4690	30	12	155
20140501	22:41:33	22:46:14	83	-19.664906	-149.99989	3991	30	5	125
20140501	22:49:37	22:52:52	83	-19.66490	-149.99989	3991	30	5	125
20140501	22:59:46	23:03:47	83	-19.664906	-149.99989	3991	30	5	125
20140501	23:05:20	23:08:14	83	-19.664906	-149.9998	3991	30	5	125
20140503	21:51:52	21:54:05	89	-15.6663	-150.0017	4217	50	8	120
20140503	22:00:13	22:04:35	89	-15.666366	-150.0017	4217	50	8	120
20140503	22:04:00	22:06:23	89	-15.6663666	-150.0017	4217	50	8	120

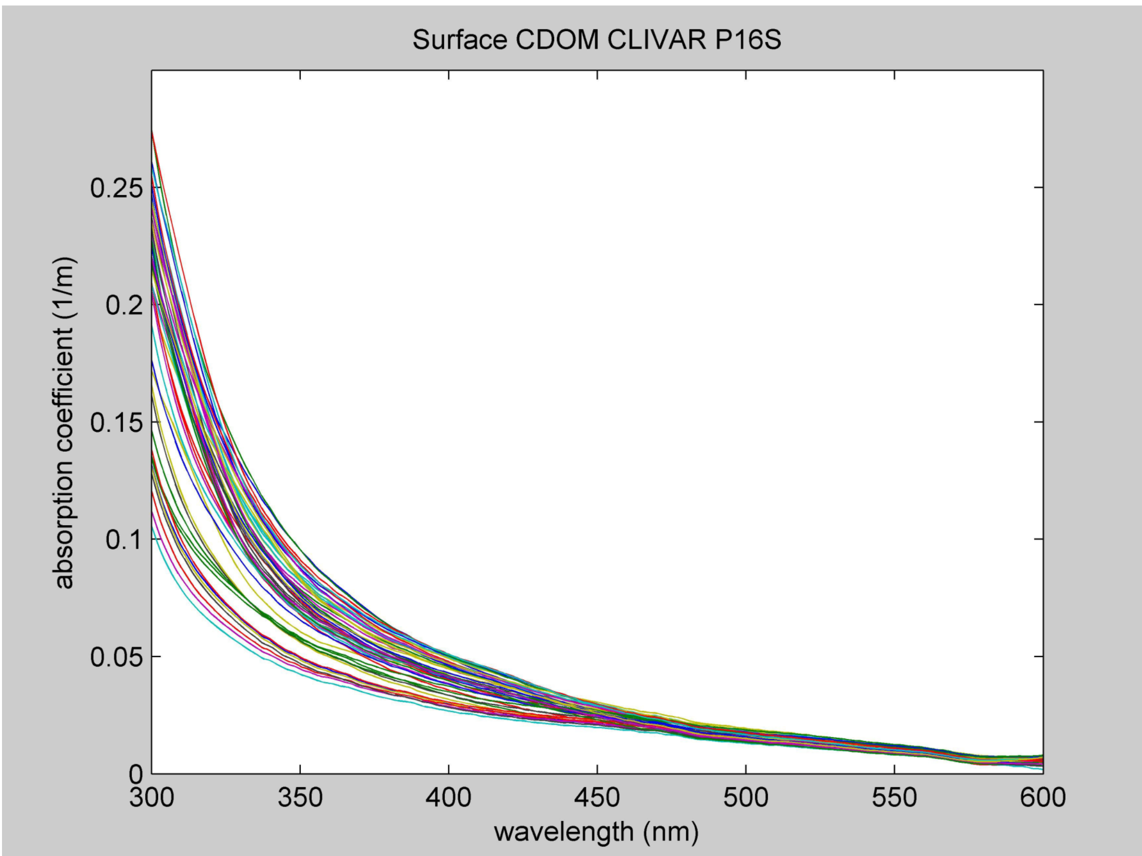
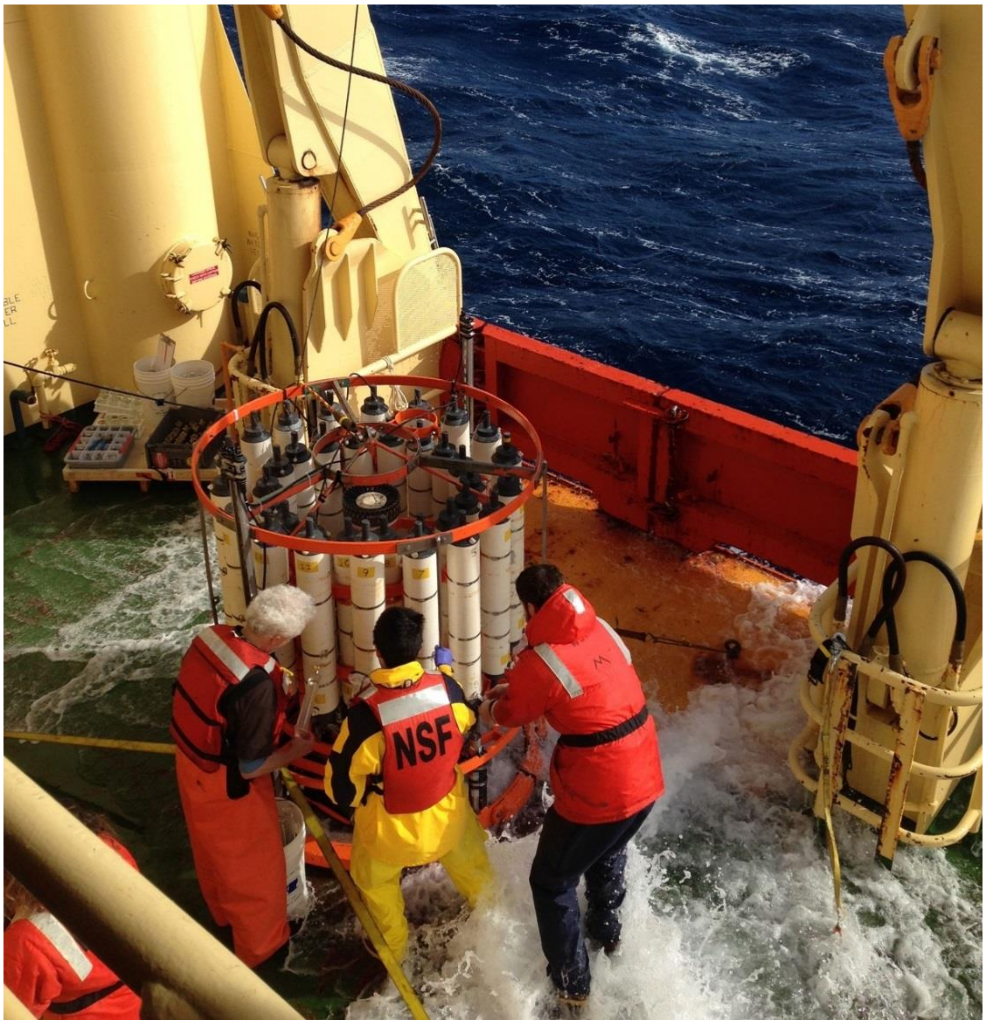


Figure 19.1: *Spectral absorption coefficient of CDOM from surface samples collected during the P16S CLIVAR campaign.*

20. Data Report NBP1403

March 20, 2014 - May 5, 2014



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United States Antarctic Program

Antarctic Support Contractor

Prepared by Joe Tarnow and Bryan Chambers

Table of Contents

20.1 Introduction

The NBP data acquisition systems continuously log data from the instruments used during the cruise. This document describes:

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

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

All the data has been compressed using Unix “gzip,” identified by the “.tz” extension. It has been copied to the distribution media in the Unix tar archive format, “.tar” extension. Tools are available on all platforms for uncompressing and de-archiving these formats: On Macintosh, one can use Stuffit Expander with DropStuff. On Windows operating systems, one can use WinZip or 7zip.

MultiBeam and raw ADCP data are distributed separately.

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

20.2 Distribution Contents at a Glance

Volume 1 of 1: NBP1403

File		Description
/		*Root level directory*
	NBP1403.trk	*Text file of cruise track (lat,lon)*
	NBP1403.mgd	*Full Cruise MGD77 data file*
	NBP1403.gmt	*GMT binary file of MGD77 data*
	INSTCOEF.TXT	*Instrument Coefficient File*
	1403DATA.docx	*Data Report NBP1403 (MS Word)*
	1403DATA.pdf	*Data Report NBP1403 (PDF format)*
/cal-sheets		*Calibration Sheets*
	NBP1403-Sensors.doc	*Sensor Calibration Sheet Reference*
	NBP1403-CalSheets.zip	*Sensor Calibration Sheet files*
/plots		*Cruise track plots*
	CruiseTrackMap.jpeg	*Cruise track plot (JPEG format)*
	WebCruiseTrackMap.jpeg	*Cruise track plot (PNG format)*
/process		*Processed data*
	1403JGOF.tz	*JGOFS format data files*
	1403QC.tz	*Daily RVDAS QC postcript plots*
	1403PCO2.tz	*Merged pCO2 data files*
	1403MGD.tz	*MGD Data*
	1403PROC.tz	*Other processed data*
/rvdas/nav		*Navigation data*
	1403dcp.tz	*ADCP Data Sets*
	1403gyr1.tz	*Gyro raw data*
	1403PCOD.tz	*Trimble P-code raw data*
	1403seap.tz	*Seapath data*
/rvdas/uw		*Underway data*
	1403Abwnc.tz	*Baltic winch data*
	1403Actdd.tz	*CTD depth data*
	1403Aeng1.tz	*Engineering data*
	1403Ahdas.tz	*HydroDAS raw data*
	1403Aknud.tz	*Knudsen raw data*
	1403Ambdp.tz	*Multibeam depth data*
	1403Amwx1.tz	*Meteorology raw data*
	1403Aoxyg.tz	*Oxygen sensor*
	1403Apco2.tz	*pCO2 raw data*
	1403Apguv.tz	*GUV raw data*
	1403Artmp.tz	*Sound velocity probe (in ADCP well)*
	1403Atsg1.tz	*Micro TSG data*
	1403Atsg2.tz	*2nd Micro TSG data*
/Imagery		*Satellite Imagery*
	1403Imagery.tz	*Collection of Imagery Files*
/ocean		
	1403ctd.tz	*Ocean data*
		CTD Data
		Raw multibeam data

Extracting Data

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

```
tar -czvf archive_filename files_to_archive
```

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

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

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

To extract the files from the archive:

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

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

```
gunzip filename.tz
```

20.3 Distribution Contents

Cruise Information

NBP1403 departed Hobart, Tasmania on March 20, 2014

Data logging was started on March 20, 2014 08:15 UTC

Data logging was ended on May 04, 2014 16:00 UTC

Cruise Track

The distribution DVD includes a GMT cruise track file (NBP1403.trk). It contains the longitude and latitude of the ship's position at one-minute intervals extracted from the NBP1403.gmt file.

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

Satellite Images

Satellite Images received for this cruise can be found in the file called /Imagery/1403Imagery.tar. Each type of image is contained in a .tz file within that file.

NBP Data Products

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

The data processing scripts used to produce JGOFS and MGD77 data sets create a lot of intermediate files. These files are included on the data distribution media in a file called /process/1403proc.tar. These files are not intended to be end-products. They are included to make re-processing easier in the event of an error, but no extensive detail of the formats is included in this document. If you have any questions, please contact itvessel@usap.gov.

JGOFS

The JGOFS data set can be found on the distribution media in the file /process/1403jgof.tar. The archive contains one file produced for each day named jgDDD.dat.tz, where DDD is the year-day the data was acquired. The ".tz" extension indicates that the individual files are compressed before archiving. Each daily file consists of 22 columnar fields in text format as described in the table below. The JGOFS data set is created from calibrated data decimated at one-minute intervals. Several fields are derived measurements from more than a single raw input. For example, Course Made Good (CMG) and Speed Over Ground (SOG) are calculated from gyro and GPS inputs. Daily plots during the cruise are produced from the JGOFS data set. Note: Null, unused, or unknown fields are indicated as "NAN" 9999 in the JGOFS data.

Field	Data	Units
01	UTC date	dd/mm/yy
02	UTC time	hh:mm:ss
03	SEAPATH latitude (negative is South)	tt.tttt
04	SEAPATH longitude (negative is West)	ggg.gggg
05	Speed over ground	Knots
06	GPS HDOP	-
07	Gyro Heading	Degrees (azimuth)
08	Course made good	Degrees (azimuth)
09	Mast PAR	μEinsteins/meter^2 sec
10	Sea surface temperature (remote)	°C
11	Sea surface conductivity (TSG1)	siemens/meter
12	Sea surface salinity (TSG1)	PSU
13	Sea depth (uncorrected, calc. sw sound vel. 1500 m/s)	meters
14	True wind speed (max speed windbird)	meters/sec
15	True wind direction (max speed windbird)	degrees (azimuth)
16	Ambient air temperature	°C
17	Relative humidity	%
18	Barometric pressure	mBars
19	Sea surface fluorometry	μg/l (mg/m^3)
20	Transmissometer	%
21	PSP	W/m^2
22	PIR	W/m^2

MGD77

The MGD77 data set is contained in a single file for the entire cruise. It can be found in the top level of the distribution data structure as NBP1403.mgd. The file NBP1403.gmt is created from the MGD77 dataset using the “mgd77togmt” utility. NBP1403.gmt can be used with the GMT plotting package.

The data used to produce the NBP1403.mgd file can be found on the distribution media in the file /process/1403proc.tar. The data files in the archive contain a day’s data and follow the naming convention Dddd.fnl.tz, where ddd is the year-day. These files follow a space-delimited columnar format that may be more accessible for some purposes. They contain data at one-second intervals rather than one minute and are individually “gzipped” to save space. Below is a detailed description of the MGD77 data set format. The other files in the archive contain interim processing files and are included to simplify possible reprocessing of the data using the RVDAS NBP processing scripts.

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

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

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

Science of Opportunity

ADCP

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

A data feed is sent from the ADCP system to RVDAS whenever a reference layer is acquired. This feed contains east and north vectors for ship’s speed, relative to the reference layer, and ship’s heading. Collected files (one per day) are archived in 1403adcp.tar in the directory /rvdas/nav.

pCO₂

The NBP carries a pCO2 measurement system from Lamont-Doherty Earth Observatory (LDEO). pCO2 data is recorded by RVDAS and transmitted to LDEO at the end of each cruise. You will find pCO2 data in a file named 1403pco2.tar in the /process directory, which contains the pCO2 instrument’s data merged with GPS, meteorological and other oceanographic measurements. For more information contact Colm Sweeney (csweeney@ldeo.columbia.edu).

Cruise Science

XBT

During the cruise, eXpendable BathyThermographs were used to obtain water column temperature profiles, providing corrections to the sound velocity profile for the multibeam system. The data files from these launches are included as 1403xbt.tar in the /ocean directory. No XBTs were collected on this cruise.

RVDAS

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

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

Sensors and Instruments

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

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

NBP[CruiseID][ChannelID].dDDD

Example: `NBP1403mwx1.d025`

- The CruiseID is the numeric name of the cruise, in this case, NBP1403.
- The ChannelID is a 4-character code representing the system being logged. An example is "mwx1," the designation for meteorology.
- DDD is the day of year the data was collected

Underway Sensors

Meteorology and Radiometry

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

Geophysics

Measurement	Channel ID	Collect. Status	Rate	Instrument
Gravimeter	grv1	continuous	1 sec	BGM-3
Magnetometer	mag1	continuous	15 sec	EG&G G-866
Bathymetry	knud	continuous	Varies	Knudsen 320B/R Knudsen 3260

Oceanography

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

Navigational Instruments

Measurement	Channel ID	Collect. Status	Rate	Instrument
Trimble GPS	PCOD	Continuous	1 sec	Trimble 20636-00SM
Gyro	gyr1	Continuous	0.2 sec	Yokogawa Gyro
SeaPath	seap	Continuous	1 sec	SeaPath 330

Data

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

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

where

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

All times are reported in UTC.

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

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

Underway Data /rvdas/uw

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

Sound Velocity Probe (svp1)

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

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

Meteorology (mwx1)

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

MET

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

PUS

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

SUS

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

MET string

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

*See page 21 for calculations.

PUS string

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

SUS string

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

Knudsen (knud)

```
99+099:00:18:19.775 3.5kHz,2540.55,0,12kHz,2540.55,,1500,-65.445954,-166.7773183
```

Field	Data	Units
1	RVDAS time tag	
2	LF = Low frequency flag (3.5 kHz)	
3	Low frequency depth	meters
4	LF quality	
5	HF = High frequency flag (12 kHz)	
6	High frequency depth	meters
7	HF quality	
8	Sound Speed	
9	Lat	
10	Lon	

Fluorometer (flr1)

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

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

Field	Data	Units
1	RVDAS time tag	
2	Marker 0 to 8	
3	4-digit index	
4	Date	mm/dd/yy
5	Time	hh:mm:ss
6	Signal	

Field	Data	Units
7	Signal units of measurement	
8	Cell temperature (if temperature compensation package is installed)	
9	Temperature units (if temperature compensation package is installed)	

pCO_2 (pco2)

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

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

Micro-TSG (tsg1)

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

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

Micro-TSG #2 (tsg2)

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

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

Gravimeter (grv1)

14+050:00:01:32.363 01:025415 00

Field	Data	Conversion	Units
1	RVDAS time tag		
2	01:		
3	Gravity count	mgal = count x 4.99407552 + bias	count
4	Error Flag		

Engineering (eng1)

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

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

*See page 24 for PIR calculations.

Hydro-DAS (hdas)

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

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

GUV Data (pguv)

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

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

Remote Temperature (rtmp)

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

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

Oxygen Data (oxyg)

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

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

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

Winch Data (bwnc, twnc, cwnc)

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

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

Navigational Data /rvdas/nav

Seapath GPS (seap)

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

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

GPZDA

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

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

GPGGA

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

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

GPVTG

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

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

GPHDT

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

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

PSXN,20

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

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

PSXN,22

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

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

PSXN,23

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

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

Trimble (P-Code) GPS (PCOD)

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

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

GGA: GPS Position Fix – Geoid/Ellipsoid

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

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

GLL: GPS Latitude/Longitude

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

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

VTG: GPS Track and Ground Speed

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

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

Gyro Compass (gyr1)

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

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

ADCP Course (adcp)

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

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

Processed Data /process/

pCO2-merged

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

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

Calculations

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

PAR

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

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

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

PSP

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

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

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

PIR

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

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

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

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

20.4 Acquisition Problems and Events

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

Start	End	Description
079.10.18		Start data collection
	080.08.15	Exit Australian EEZ 45 14.3 Lat 151 20.07 lon
082.03.49		Enter Australian EEZ 50 51.08 Lat 157 37.76 lon
	083.14.59	Exit Australian EEZ 55 30.63 Lat 164 36.02 Lon
118.09.42		Enter Tahitian EEZ 26 42.42 Lat 150 00.014 Lon
	124.16.00	Stop Data collection

20.5 Appendix: Sensors and Calibrations

Sensor	***Serial Number***	***Last Cal.***	***Comments***
Meteorology & Radiometers			
Stbd Anemometer (Gill US)	847014	9/29/2010	Installed 11/17/2010
Port Anemometer (Gill US)	924057	11/18/09	Installed 3/5/2010
Barometer	BP00872	11/29/2012	Installed 1/28/2014
Humidity/Wet Temp	06135	11/29/2012	Installed 9/11/2013
PIR	32845F3	7/17/2013	Installed 1/28/2014
PSP	32850F3	8/15/2013	Installed 1/28/2014
Mast PAR	6357	12/27/2012	Installed 9/11/2013
GUV (Mast)	25110203114	12/18/2012	Installed 9/11/2013
Underway			
Micro-TSG #1 (until 3/4/13)	4546167-0242	12/29/2012	Installed 5/9/2013
Micro-TSG #2	4566350-0389	10/20/2011	Installed 9/7/2012
Digital Remote Temp	3849120-0178	9/21/2012	Installed 5/9/2013
Oxygen Optode	3835-1424	10/21/2010	Installed12/30/2010
Fluorometer	AFL-016D	8/22/2012	Installed 9/11/2013
Transmissometer	CST-557DR	8/28/2013	Installed 1/28/2014
CTD			
CTD Fish	91480	12/18/2012	Installed 1/28/2014
CTD Fish Pressure	53952	12/18/2012	Installed 1/28/2014
CTD Deck Unit	11P19858-0768	N/A	Installed 1/28/2014
Slip-Ring Assembly	1.406	N/A	Installed 1/28/2014
Carousel Water Sampler	3214153-0140	N/A	Installed 1/28/2014
Pump (primary)	051627 3.0K	12/23/2012	Installed 1/28/2014
Pump (secondary)	051626 3.0K	12/23/2012	Installed 1/28/2014
Temperature (primary)	03P2308	6/28/2013	Installed 1/28/2014
Temperature (secondary)	03P2299	6/12/2013	Installed 1/28/2014
Conductivity (primary)	042513	2/26/2013	Installed 1/28/2014
Conductivity (secondary)	041798	6/21/2013	Installed 1/28/2014
Dissolved Oxygen (primary)	430161	6/12/2013	Installed 1/28/2014
Dissolved Oxygen (primary)	430080	2/13/2013	Installed 1/28/2014
Fluorometer	AFLD-0011	7/17/2013	Installed 1/28/2014
Transmissometer	CST-0889	9/5/13	Installed 1/28/2014
Altimeter	49432	N/A	Installed 1/28/2014

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

COPY

CALIBRATION REPORT
Barometric Pressure

Customer: *Lockheed Martin Maritime Systems & Sensors*

Test Number: 2060-01B
Test Date: 29 November 2012

Customer PO: 4900027957
Sales Order: 2973

Test Sensor:
Model: 61201
Serial Number: *BP00872*
Description: Barometric Pressure Sensor

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

Reference Pressure (hPa)	Voltage Output (millivolts)	Indicated (1) Pressure (hPa)
800.0	-1	800.0
875.0	1251	875.0
950.0	2501	950.0
1025.0	3749	1024.9
1100.0	4996	1099.7

(1) Calculated from voltage output

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

Reference Instrument	Serial #	NIST Test Reference
Druck Pressure Controller Model DPI515	51500497	UKAS Lab 0221
Fluke Multimeter Model 8060A	4865407	234027

Tested By: E Chenney

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

Mast Humidity Sensor

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

COPY

CALIBRATION REPORT

Relative Humidity

Customer: *Lockheed Martin Maritime Systems & Sensors*

Test Number: 2044-02R
Test Date: 29 November 2012

Customer PO: 4900027957
Sales Order: 2975

Test Sensor:
Model: 41372LC
Serial Number: *TS06135*
Description: Temperature/Relative Humidity Sensor

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

Reference Humidity (%)	Current Output (milliamps)	Indicated (1) Humidity (%)
10.0	5.9	12.1
30.0	9.0	31.2
50.0	12.4	52.3
69.9	15.4	71.0
89.9	18.1	88.1

(1) Calculated from voltage output

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

Reference Instrument	Serial #	NIST Test Reference
Vaisala Humidity Sensor Model 35AC	N475040	TN 266152
Fluke Multimeter Model 8060A	4865407	254027

Tested By: E Chenny

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

Mast Temperature Sensor

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

COPY

CALIBRATION REPORT

Temperature

Customer: *Lockheed Martin Maritime Systems & Sensors*

Test Number: 2044-02T
Test Date: 29 November 2012

Customer PO: 4900027957
Sales Order: 2973

Test Sensor:
Model: 41372LC Serial Number: *TS08135*
Description: Temperature/Relative Humidity Sensor

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

Bath Temperature (degrees C)	Current Output (milliamps)	Indicated (1) Temperature (degrees C)
-49.86	4.023	-49.66
0.03	12.008	0.05
50.18	20.029	50.18

(1) Calculated from current output

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

Reference Instrument	Serial #	NIST Test Reference
Brooklyn Thermometer Model 43-FC	8006-118	204365
Brooklyn Thermometer Model 22332-D5-FC	25071	249763
Brooklyn Thermometer Model 2X400-D7-FC	77532	228060
Keithley Multimeter Model 191	15232	234027

Tested By: E Chenney

METEOROLOGICAL INSTRUMENTS

Tel: 231-946-3980 Fax: 231-946-4772 Email: metsales@youngusa.com Website: youngusa.com

ISO 9001:2008 CERTIFIED

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

STANDARDIZATION OF EPPLEY PRECISION INFRARED RADIOMETER Model PIR

Serial Number: 32845F3

Resistance: 712 Ω at 23°C
Temperature Compensation Range: -20° to +40°C

This pyrgeometer has been compared against Eppley's Blackbody Calibration System under radiation intensities of approximately 200 watts meter^{-2} and an average ambient temperature of 30°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:

4.08×10^{-6} volts/watts meter^{-2}

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

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

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

Shipped to: LMP4 ISGS N.S.F.
Port Hueneme, CA

S.O. Number: 63850
Date: July 18, 2013

Remarks:

Date of Test: July 17, 2013

In Charge of Test: Debra L. Glenty

Reviewed by: Thomas D Kirk

EPLAB

THE EPPLEY LABORATORY, INC.

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

Calibration Certificate

Instrument:	Precision Spectral Pyranometer, Model PSP, Serial Number 32850F3	
Procedure:	This pyranometer was compared in Eppley's Integrating Hemisphere according to procedures described in ***ISO 9847 Section 5.3.1*** and Technical Procedure, TP01 of The Eppley Laboratory, Inc.'s Quality Assurance Manual on Calibrations.	
Transfer Standard:	Eppley Precision Spectral Pyranometer, Model PSP, Serial Number 21231F3	
Results:	**Sensitivity:**	**S = 7.68 μV / Wm^{-2}**
	Uncertainty:	U_{95} = ±0.91% (95% confidence level, k=2)
	Resistance:	706 Ω at 23°C
	Date of Test:	August 7, 2013
Traceability:	This calibration is traceable to the World Radiation Reference (WRR) through comparisons with Eppley's AHF standard self-calibrating cavity pyrheliometers which participated in the Eleventh International Pyrheliometric Comparisons (IPC XI) at Davos, Switzerland in September-October 2010. Unless otherwise stated in the remarks section below or on the Sales Order, the results of this calibration are "AS FOUND / AS LEFT".	
Due Date:	Eppley recommends a minimum calibration cycle of five (5) years but encourages annual calibrations for highest measurement accuracy.	
Customer:	LMP4 ISGS Port Hueneme, CA	
Signatures:	D.GIENTY In Charge of Test:	Thomas D Kirk Reviewed by:
Eppley SO	63884	
Date of Certificate	August 15, 2013	
Remarks:		

Biospherical Instruments Inc.

CALIBRATION CERTIFICATE

Calibration Date	12/27/2012
Model Number	QSR-240
Serial Number	6357
Operator	TPC
Standard Lamp	V-031(3/7/12)
Probe Excitation Voltage Range:	6 to 18 VDC(+)
Output Polarity:	Positive

Probe Conditions at Calibration(in air):

Calibration Voltage	6	VDC(+)
Probe Current:	7.2	mA

Probe Output Voltage:

Probe Illuminated	98.3	mV
Probe Dark	1.0	mV
Probe Net Response	97.3	mV
RG780	1.0	mV

Corrected Lamp Output:

Output In Air (same condition as calibration):

1.044E+16	quanta/cm²sec
0.01733	uE/cm²sec

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

Dry:	9.3240E-18	V/(quanta/cm²sec)
	5.6149E+00	V/(uE/cm²sec)

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

QSR240R 05/24/95

Biospherical Instruments Inc.

System Calibration Certificate

THE INSTRUMENTS REFERENCED BELOW WERE FACTORY TESTED AND CALIBRATED BY

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

Instruments: GUV-2511 No 25110203114

Optical Calibrations:

NIST Traceability. For wavelengths longer than 313 nm, the specific instruments cited here were calibrated using a 1000W FEL #V-031(3/7/12) following procedures and standards traceable to NIST Standard of Spectral Irradiance F616. Traceability paths and all procedures for all calibrated lamps and associated apparatus (shunts, power supplies, DMMs, etc) are maintained following calibration methodologies per National Bureau of Standards (US) (NBS) Special Publication 250-20 Spectral Irradiance Calibrations (1987) and NBS Publication 594–13 Optical Radiation Measurements: The 1973 Scale of Spectral Irradiance (1977).

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

Note that this certificate contains a subset of the information delivered in the calibration database 25110203114v7.mdb. This database is required for operation of this system using Biospherical Instruments Inc.'s Logger® software.

Biospherical Instruments Inc.

GUV-2511 Calibration Certificate

System Serial Number	25110203114	Date of Calibration	12/18/2012
Calibration database	25110203114v7.mdb	Date of Certificate	12/18/2012
DASSN	0069	Standard of Spectral Irradiance	V-031(3/7/12)
Microprocessor Tag Number	4	Operator	TC

Monochromatic Channels	Address	Wavelength [nm]	Responsivity [Amps per µW/(cm²·nm)]	ScaleSmall [Volts per µW/(cm²·nm)]	ScaleMedium [Volts per µW/(cm²·nm)]	ScaleLarge [Volts per µW/(cm²·nm)]	OffsetSmall [volts]	OffsetMedium [volts]	OffsetLarge [volts]	Measurement Units
Ed0320	2	320	2.3101E-10	2.3563E-05	6.6841E-03	2.1726E+00	6.8000E-05	7.1000E-05	5.8600E-04	µW/(cm²nm)
Ed0340	6	340	1.8298E-10	1.8664E-05	5.4528E-03	1.8705E+00	7.8000E-05	9.0000E-05	8.2900E-04	µW/(cm²nm)
Ed0313	8	313	2.3000E-10	2.3428E-05	6.8446E-03	2.4027E+00	9.2400E-04	9.2000E-04	-1.3310E-03	µW/(cm²nm)
Ed0305	10	305	1.0300E-11	1.0554E-06	3.0836E-04	1.0599E-01	3.6800E-04	3.7000E-04	1.1140E-03	µW/(cm²nm)
Ed0380	12	380	8.0945E-11	8.2564E-06	2.4122E-03	7.7368E-01	2.7800E-04	2.7600E-04	-1.0800E-04	µW/(cm²nm)
Ed0395	18	395	2.8798E-10	2.9374E-05	8.5818E-03	2.7127E+00	3.8900E-04	3.9300E-04	1.4470E-03	µW/(cm²nm)

Broadband Channels	Address	Wavelength [nm]	Responsivity [Amps per µE/(cm²·s)]	ScaleSmall [Volts per µE/(cm²·s)]	ScaleMedium [Volts per µE/(cm²·s)]	ScaleLarge [Volts per µE/(cm²·s)]	OffsetSmall [volts]	OffsetMedium [volts]	OffsetLarge [volts]	Measurement Units
Ed0PAR	13	400-700	1.7033E-05	1.7374E+00	5.0759E+02	1.7939E+05	5.7300E-04	5.7100E-04	-4.7800E-04	µE/(cm²sec)

Auxiliary Channels	Address	Wavelength	Responsivity	ScaleS	ScaleM	ScaleL	OffsetS	OffsetM	OffsetL	Measurement Units
Ed0Temp	22	0	1.0000E+00	1.0000E-02	1.0000E-02	1.0000E-02	0.0000E+00	0.0000E+00	0.0000E+00	C
Ed0VIn	27	0	1.0000E+00	-2.5000E-01	-2.5000E-01	-2.5000E-01	0.0000E+00	0.0000E+00	0.0000E+00	V

CALIBRATION CERTIFICATE

AANDERAA DATA INSTRUMENTS

Form No. 622, Dec 2005
Page 1 of 2

Sensing Foil Batch No: 5009
Certificate No:

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

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

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

Parameter: Internal Temperature:

Calibration points and readings:

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

Giving these coefficients

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

Parameter: Oxygen:

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

Calibration points and readings[2)]:

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

Giving these coefficients

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

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

AANDERAA DATA INSTRUMENTS AS

5051 BERGEN, NORWAY Tel. +47 55 60 48 00 Fax. +47 55 60 48 01 E-mail: info@aadi.no Web: http://www.aadi.no

CALIBRATION CERTIFICATE

AANDERAA DATA INSTRUMENTS

Form No. 622, Dec 2005
Page 2 of 2

Sensing Foil Batch No: 5009
Certificate No:

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

SR10 Scaling Coefficients:

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

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

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

Date: 22 October 2010

Sign:

Tor Ove Kvalvaag, Calibration Engineer

AANDERAA DATA INSTRUMENTS AS

5351 BERGEN, NORWAY Tel. +47 55 60 48 00 Fax. +47 55 60 48 01 E-mail: info@aadi.no Web: http://www.aadi.no

CALIBRATION CERTIFICATE

AANDERAA DATA INSTRUMENTS

Form No. 621, Dec 2005

Certificate No: 3853_5009_40331
Batch No: 5009

Product: O2 Sensing Foil PSt3 3853
Calibration Date: 2 June 2010

Calibration points and phase readings (degrees)

Temperature (°C)		3.97	10.93	20.15	29.32	38.39
Pressure (hPa)		977.00	977.00	977.00	977.00	977.00
O2 in % of O2+N2	0.00	73.18	72.63	71.62	70.72	69.77
	1.00	68.01	67.02	65.42	63.92	62.31
	2.00	64.39	63.16	61.20	59.44	57.57
	5.00	55.80	54.16	51.76	49.56	47.45
	10.00	46.27	44.47	41.97	39.75	37.69
	20.90	35.09	33.38	31.14	29.24	27.56
	30.00	29.85	28.30	26.31	24.64	23.19

Giving these coefficients [1)]

Index	0	1	2	3
C0 Coefficient	4.53793E+03	-1.62595E+02	3.29574E+00	-2.79285E-02
C1 Coefficient	-2.50953E+02	8.02322E+00	-1.58398E-01	1.31141E-03
C2 Coefficient	5.66417E+00	-1.59647E-01	3.07910E-03	-2.46265E-05
C3 Coefficient	-5.99449E-02	1.48326E-03	-2.82110E-05	2.15156E-07
C4 Coefficient	2.43614E-04	-5.26759E-06	1.00064E-07	-7.14320E-10

[1)] Ask for Form No 621S when this O2 Sensing Foil is used in Oxygen Sensor 3830 with Serial Numbers lower than 184.

Date: 11/4/2010

Sign:

Tor Ove Kvalvaag, Calibration Engineer

AANDERAA DATA INSTRUMENTS AS

5351 BERGEN, NORWAY Tel. +47 55 60 48 00 Fax. +47 55 60 48 01 E-mail: info@aadi.no Web: http://www.aadi.no

Underway Micro-TSG number 1

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

SENSOR SERIAL NUMBER: 0242
CALIBRATION DATE: 29-Dec-12

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

COEFFICIENTS:

g = -9.992296e-001
h = 1.524743e-001
i = -4.722991e-004
j = 6.065458e-005

CPcor = -9.5700e-008
CTcor = 3.2500e-006
WBOTC = -0.0000e+000

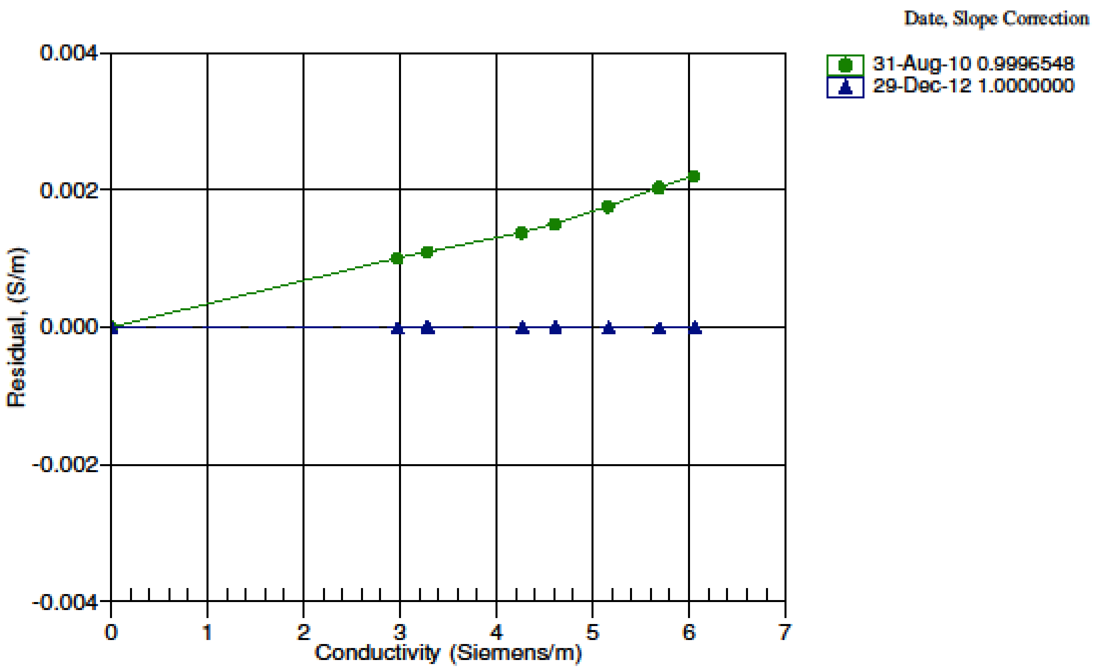
BATH TEMP (ITS-90)	BATH SAL (PSU)	BATH COND (Siemens/m)	INST FREQ (Hz)	INST COND (Siemens/m)	RESIDUAL (Siemens/m)
22.0000	0.0000	0.00000	2566.82	0.00000	0.00000
1.0000	34.8118	2.97562	5119.70	2.97561	-0.00001
4.5000	34.7917	3.28263	5313.24	3.28264	0.00001
15.0000	34.7487	4.26420	5888.60	4.26420	0.00000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

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

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

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

Residual = instrument conductivity - bath conductivity



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

SENSOR SERIAL NUMBER: 0242
CALIBRATION DATE: 29-Dec-12

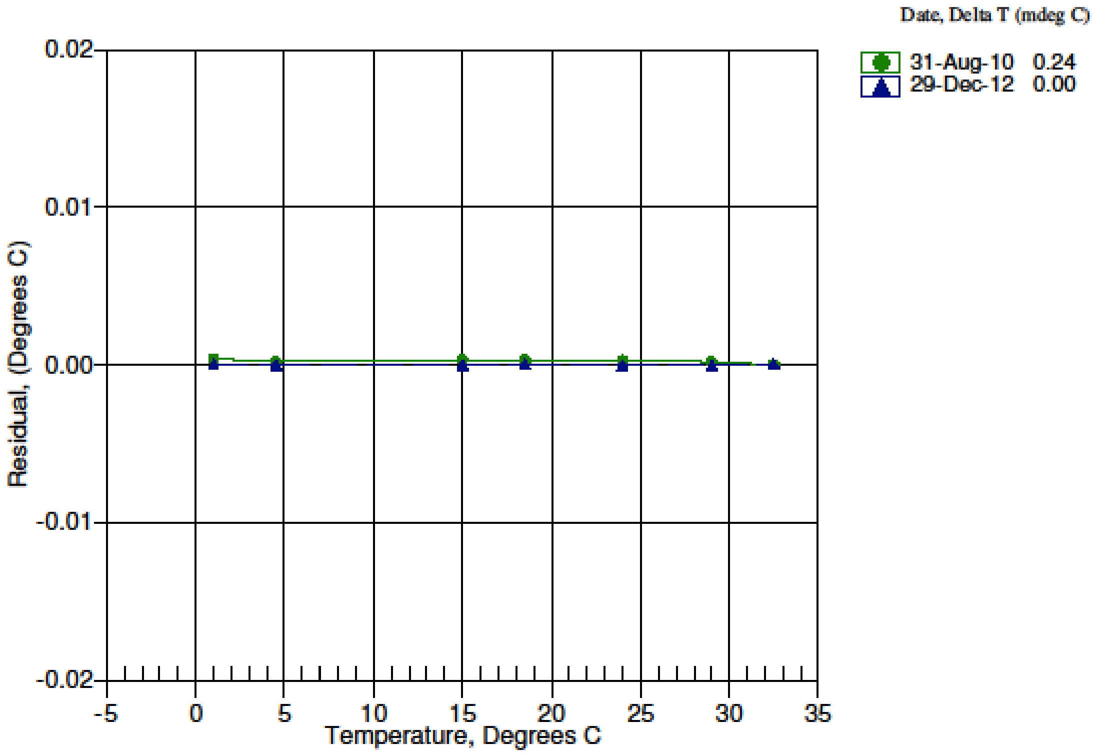
SBE 45 TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

ITS-90 COEFFICIENTS
a0 = 4.555848e-005
a1 = 2.733778e-004
a2 = -2.324224e-006
a3 = 1.499077e-007

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

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

Residual = instrument temperature - bath temperature



Underway Micro-TSG number 2

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Sea-Bird Electronics, Inc.

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

Micro TSG

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

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

COEFFICIENTS:

g = -9.860211e-001
h = 1.453849e-001
i = -4.022911e-004
j = 5.188313e-005

CPcor = -9.5700e-008
CTcor = 3.2500e-006
WBOTC = 1.2700e-007

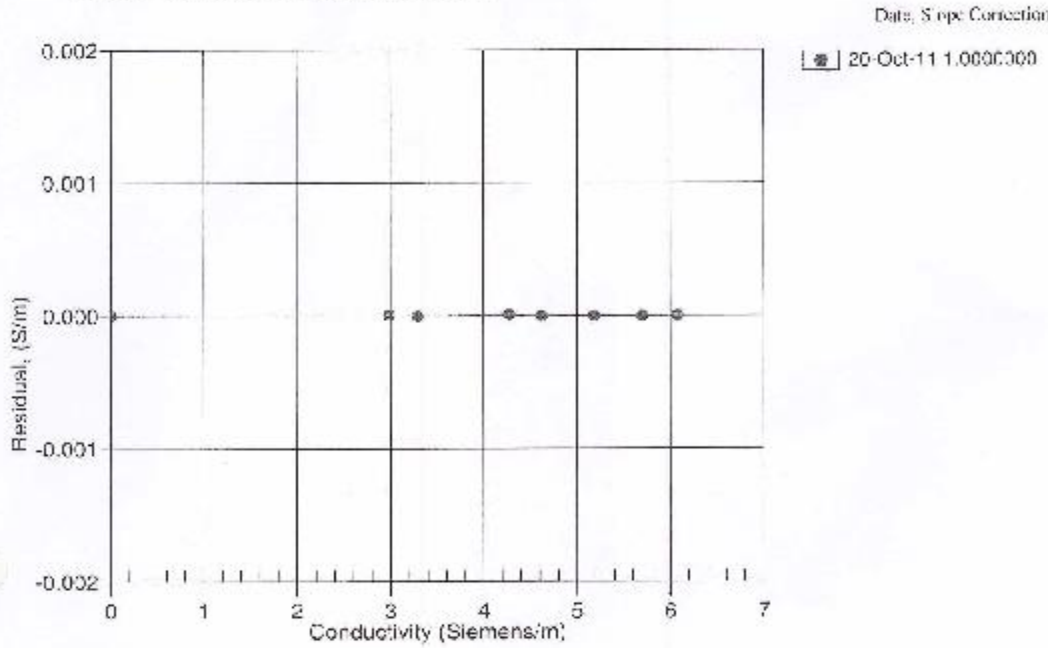
BATH TEMP (ITS-90)	BATH SAL (PSU)	BATH COND (Siemens/m)	INST FREQ (Hz)	INST COND (Siemens/m)	RESIDUAL (Siemens/m)
22.0000	0.0000	0.00000	2634.51	0.00000	0.00000
1.0000	34.9210	2.98605	5244.92	2.98606	0.00000
4.5000	34.9005	3.29188	5643.39	3.29188	-0.00000
14.9999	34.8564	4.27603	6033.44	4.27601	0.00001
18.4999	34.8467	4.62166	6227.28	4.62165	-0.00000
24.0000	34.8304	5.18115	6528.11	5.18115	-0.00000
29.0000	34.8277	5.70357	6795.07	5.70357	-0.00000
32.5000	34.8211	6.07673	6982.11	6.07673	0.00000

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

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

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

Residual = instrument conductivity - bath conductivity



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

Micro TSG

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

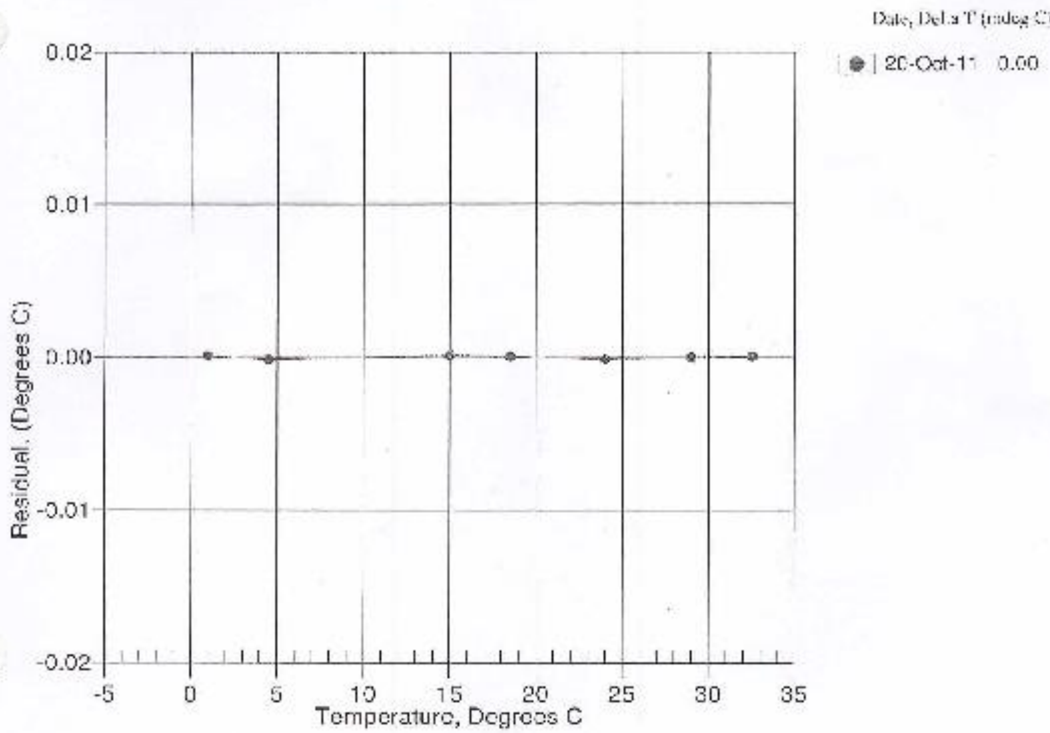
SBE 45 TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

ITS-90 COEFFICIENTS
a0 = 3.1[illegible]3853e-003
a1 = 2.856137e-004
a2 = -1.828637e-006
a3 = [illegible]e-007

BATH TEMP (ITS-90)	INSTRUMENT OUTPUT	INST TEMP (ITS-90)	RESIDUAL (ITS-90)
1.0000	828514.5	1.0001	0.0001
4.5000	706709.4	4.4998	-0.0002
14.9999	447335.7	15.0000	0.0001
18.4999	386307.6	18.5000	0.0001
24.0000	305342.[illegible]	23.9999	-0.0001
29.0000	253727.[illegible]	29.0000	-0.0000
32.5000	221749.8	32.5000	0.0000

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

Residual = instrument temperature - bath temperature



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

SENSOR SERIAL NUMBER: 0178
CALIBRATION DATE: 21-Sep-12

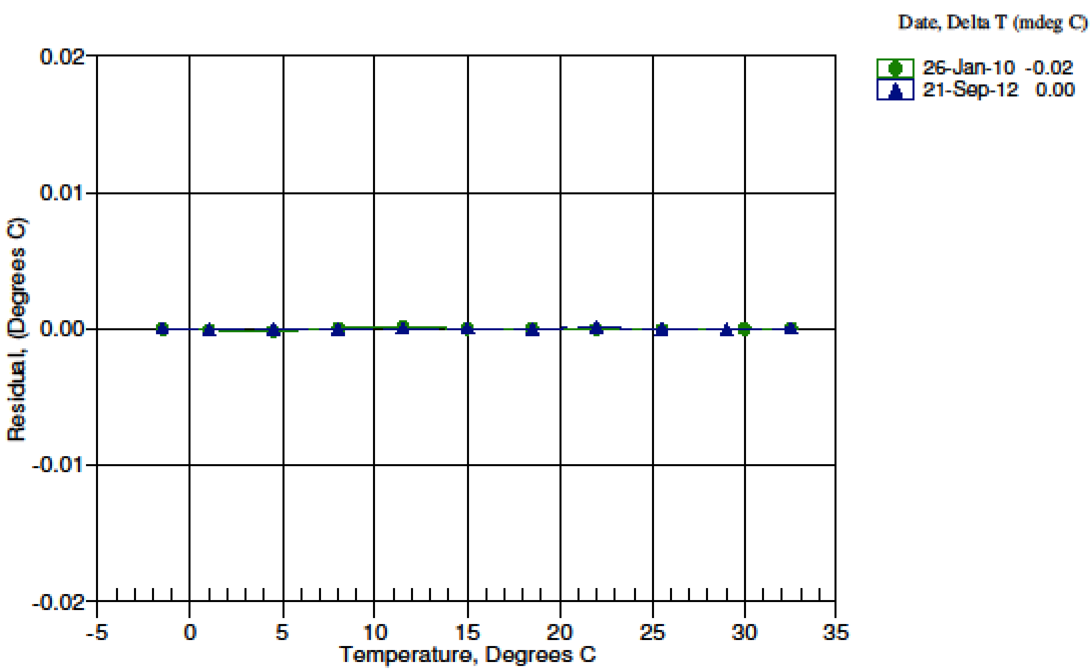
SBE 38 TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

ITS-90 COEFFICIENTS
a0 = -4.740793e-005
a1 = 2.820902e-004
a2 = -2.754939e-006
a3 = 1.681819e-007

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

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

Residual = instrument temperature - bath temperature



PO Box 518
620 Applegate St
Philomath OR 97370

WET Labs

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

Chlorophyll Fluorometer Characterization in Uranine liquid Proxy (new method)

Date:	**08/22/12**
Serial #:	AFL-016D
Tech:	dcm

Dark Counts	**0.152 volts**
CEV	**1.195 volts**
SF	**25.311**
FSV	**4.61 volts**
Linearity:	**0.999 R^2 (0–1.5 volts)** **0.995 R^2 (0– 5.45 volts)**

Notes:

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

CEV is the chlorophyll equivalent voltage. This value is the signal output of the fluorometer when using a Uranine dye fluorescent proxy that has been determined to be approximately equivalent to **26.4 µg/l** of a *Thalassiosira weissflogii* phytoplankton culture.

SF is the scale factor used to derive chlorophyll concentration from the signal voltage output of the fluorometer. The scale factor is determine by using the following equation: SF = (26.4) / (CEV – dark).

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

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

The relationship between fluorescence and chlorophyll-*a* concentrations in-situ is high variable. The scale factor listed on this document was determined by using a mono-culture of phytoplankton (*Thalassiosira weissflogii*). The population was assumed to be reasonably healthy and the concentration was determined by using the absorption method. To accurately determine chlorophyll concentration using a fluorometer you must perform secondary measurements on the populations of interest. This is typically done using extraction based measurement techniques on discrete samples. For additional information on determination of chlorophyll concentration see [Standard Methods For The Examination Of Water And Wastewater] part 10200 H published jointly by: American Public Health Association, American Water Works Association and Water Environment Federation.

PO Box 518
620 Applegate St.
Philomath, OR 97370

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www.wetlabs.com

WET Labs

C-Star Calibration

Date August 28, 2013 S/N# CST-557DR Pathlength 25cm

	Analog output	Digital output
V_d	0.009 V	0 counts
V_{air}	4.760 V	15596 counts
V_{ref}	4.700 V	15399 counts

Temperature of calibration water	21.2 °C
Ambient temperature during calibration	21.8 °C

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

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

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

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

Revision L 6/9/09

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

SENSOR SERIAL NUMBER: 1480
CALIBRATION DATE: 18-Dec-12

SBE9plus PRESSURE CALIBRATION DATA
10000 psia S/N 53952

DIGIQUARTZ COEFFICIENTS:

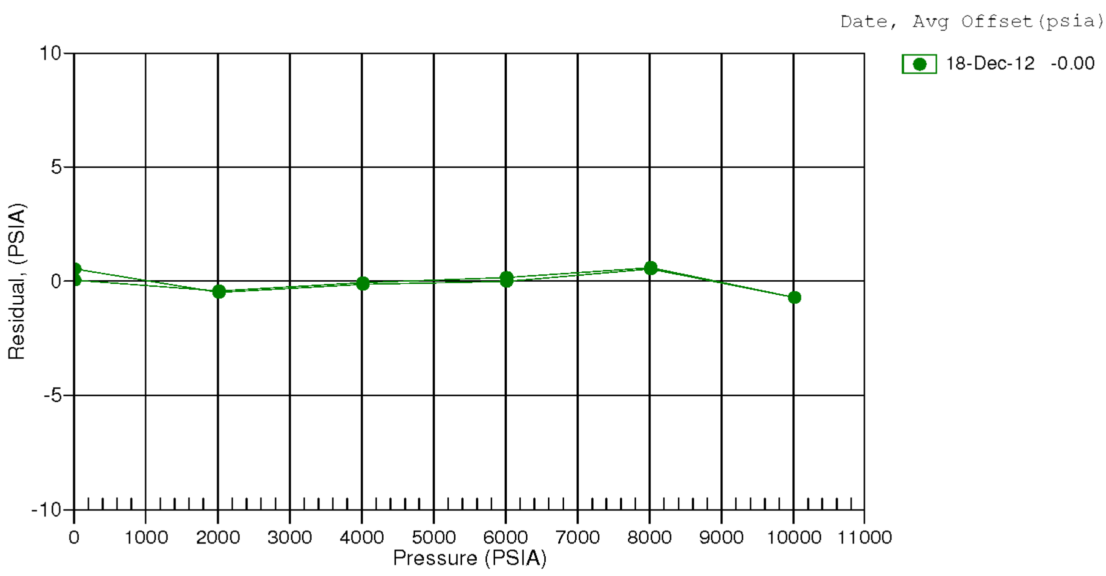
C1 = -5.561704e+004
C2 = 4.302402e-001
C3 = 1.582810e-002
D1 = 4.708200e-002
D2 = 0.000000e+000
T1 = 3.029296e+001
T2 = -2.122954e-004
T3 = 4.352450e-006
T4 = 2.626550e-009
T5 = 0.000000e+000

AD590M, AD590B, SLOPE AND OFFSET:

AD590M = 1.16300e-002
AD590B = -8.63457e+000
Slope = 0.99999
Offset = -3.0213 (dbars)

PRESSURE (PSIA)	INST OUTPUT(Hz)	INST TEMP(C)	INST OUTPUT (PSIA)	CORRECTED INST OUTPUT (PSIA)	RESIDUAL (PSIA)
14.547	33019.50	21.4	19.466	15.084	0.537
2014.689	33606.67	21.7	2018.592	2014.196	-0.493
4014.621	34182.17	21.8	4018.885	4014.476	-0.145
6014.640	34746.23	21.9	6019.053	6014.631	-0.009
8014.742	35299.59	21.9	8019.715	8015.280	0.537
10014.990	35842.18	22.0	10018.718	10014.268	-0.722
8014.780	35299.62	22.1	8019.806	8015.370	0.590
6014.719	34746.31	22.2	6019.301	6014.878	0.159
4014.689	34182.23	22.2	4019.027	4014.618	-0.070
2014.710	33606.71	22.3	2018.677	2014.281	-0.429
14.555	33019.38	22.4	18.981	14.598	0.043

Residual = corrected instrument pressure - reference pressure



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Phone: (+1) 425-643-9866 Fax (+1) 425-643-9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 2308
CALIBRATION DATE: 28-Jun-13

SBE3 TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

ITS-90 COEFFICIENTS
g = 4.34531719e-003
h = 6.44991551e-004
i = 2.35185807e-005
j = 2.23479362e-006
f0 = 1000.0

IPTS-68 COEFFICIENTS
a = 3.68121230e-003
b = 6.02583850e-004
c = 1.63930551e-005
d = 2.23636632e-006
f0 = 2906.476

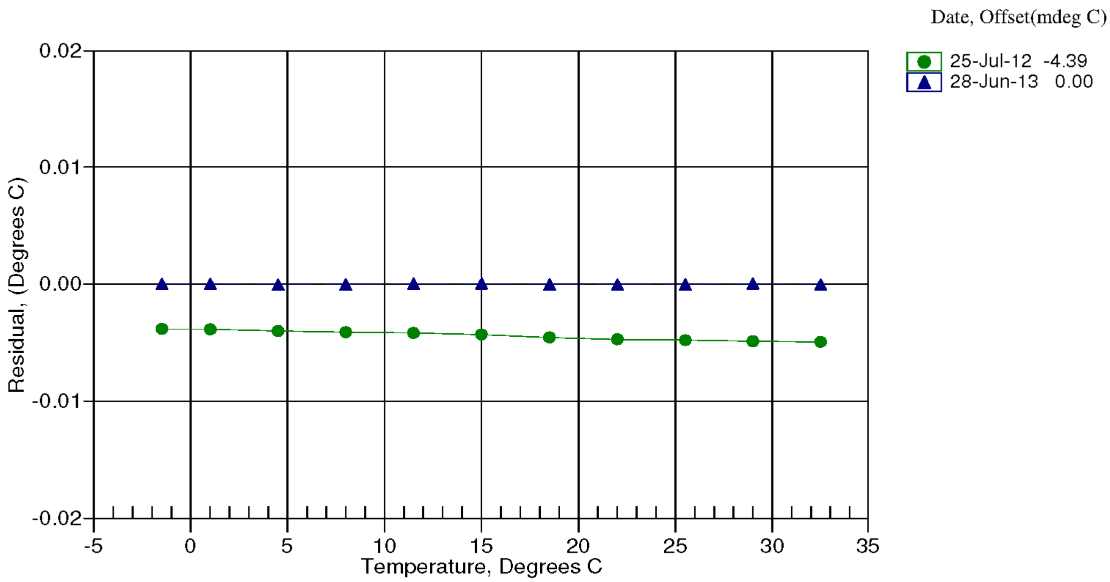
BATH TEMP (ITS-90)	INSTRUMENT FREQ (Hz)	INST TEMP (ITS-90)	RESIDUAL (ITS-90)
-1.5000	2906.476	-1.5000	0.00000
1.0000	3073.288	1.0000	0.00001
4.5000	3318.316	4.5000	-0.00001
8.0000	3577.096	8.0000	-0.00004
11.5000	3850.006	11.5000	0.00003
15.0000	4137.394	15.0001	0.00005
18.5000	4439.604	18.5000	-0.00001
22.0000	4756.983	22.0000	-0.00003
25.5000	5089.855	25.5000	-0.00003
28.9999	5438.527	28.9999	0.00005
32.5000	5803.307	32.5000	-0.00001

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



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Phone: (+1) 425-643-9866 Fax (+1) 425-643-9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 2299
CALIBRATION DATE: 12-Jun-13

SBE3 TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

ITS-90 COEFFICIENTS

g = 4.33219965e-003
h = 6.44461471e-004
i = 2.41492147e-005
j = 2.44706389e-006
f0 = 1000.0

IPTS-68 COEFFICIENTS

a = 3.68121247e-003
b = 6.02091743e-004
c = 1.64917777e-005
d = 2.44867224e-006
f0 = 2848.641

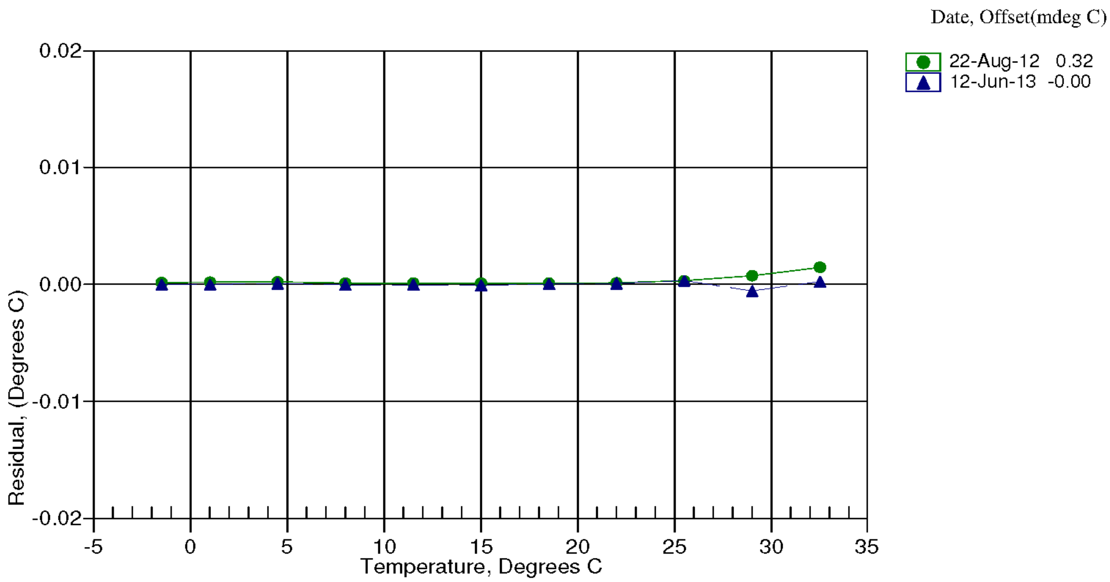
BATH TEMP (ITS-90)	INSTRUMENT FREQ (Hz)	INST TEMP (ITS-90)	RESIDUAL (ITS-90)
-1.5000	2848.641	-1.5000	-0.00001
1.0000	3012.273	1.0000	0.00000
4.4999	3252.647	4.5000	0.00007
8.0000	3506.532	7.9999	-0.00005
11.5000	3774.292	11.5000	-0.00003
15.0000	4056.268	14.9999	-0.00007
18.4999	4352.809	18.4999	0.00004
22.0000	4664.250	22.0001	0.00008
25.5000	4990.903	25.5003	0.00032
29.0000	5332.948	28.9994	-0.00057
32.5000	5690.953	32.5002	0.00023

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

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

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

Residual = instrument temperature - bath temperature



CTD Conductivity (Primary)

Sea-Bird Electronics, Inc.

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SENSOR SERIAL NUMBER: 2513
CALIBRATION DATE: 26-Jun-13

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

GHIJ COEFFICIENTS

g = -1.05846412e+001
h = 1.63289463e+000
i = -1.60820062e-003
j = 2.36014503e-004
CPcor = -9.5700e-008 (nominal)
CTcor = 3.2500e-006 (nominal)

ABCDM COEFFICIENTS

a = 7.40772717e-006
b = 1.62923614e+000
c = -1.05785259e+001
d = -8.60807664e-005
m = 5.2
CPcor = -9.5700e-008 (nominal)

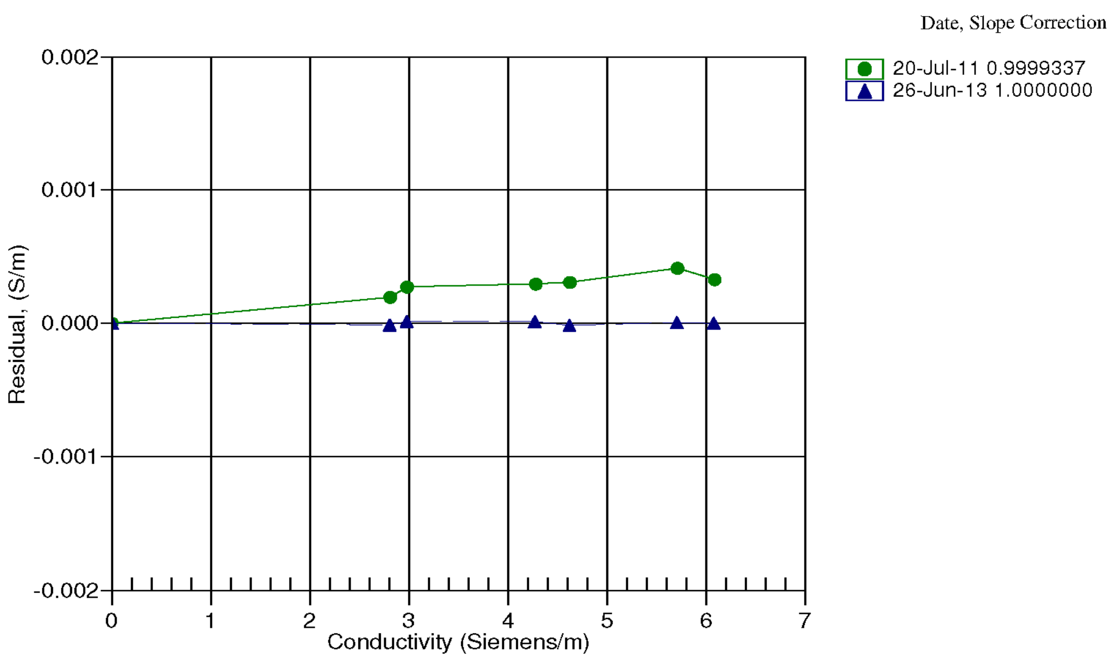
BATH TEMP (ITS-90)	BATH SAL (PSU)	BATH COND (Siemens/m)	INST FREQ (kHz)	INST COND (Siemens/m)	RESIDUAL (Siemens/m)
0.0000	0.0000	0.00000	2.54801	0.00000	0.00000
-1.0000	34.7933	2.80290	4.86617	2.80288	-0.00001
1.0000	34.7936	2.97421	4.97286	2.97422	0.00001
15.0000	34.7943	4.26920	5.71473	4.26921	0.00001
18.5000	34.7942	4.61575	5.89731	4.61574	-0.00002
29.0000	34.7933	5.69898	6.43437	5.69898	0.00001
32.5000	34.7892	6.07180	6.60900	6.07180	-0.00000

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

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

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

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



Sea-Bird Electronics, Inc.
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Phone: (+1) 425-643-9866 Fax (+1) 425-643-9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 1798
CALIBRATION DATE: 21-Jun-13

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

GHIJ COEFFICIENTS
g = -3.92941949e+000
h = 4.59841645e-001
i = -7.88790971e-004
j = 6.42017186e-005
CPcor = -9.5700e-008 (nominal)
CTcor = 3.2500e-006 (nominal)

ABCDM COEFFICIENTS
a = 5.86987503e-007
b = 4.56772457e-001
c = -3.91757440e+000
d = -7.11998198e-005
m = 5.4
CPcor = -9.5700e-008 (nominal)

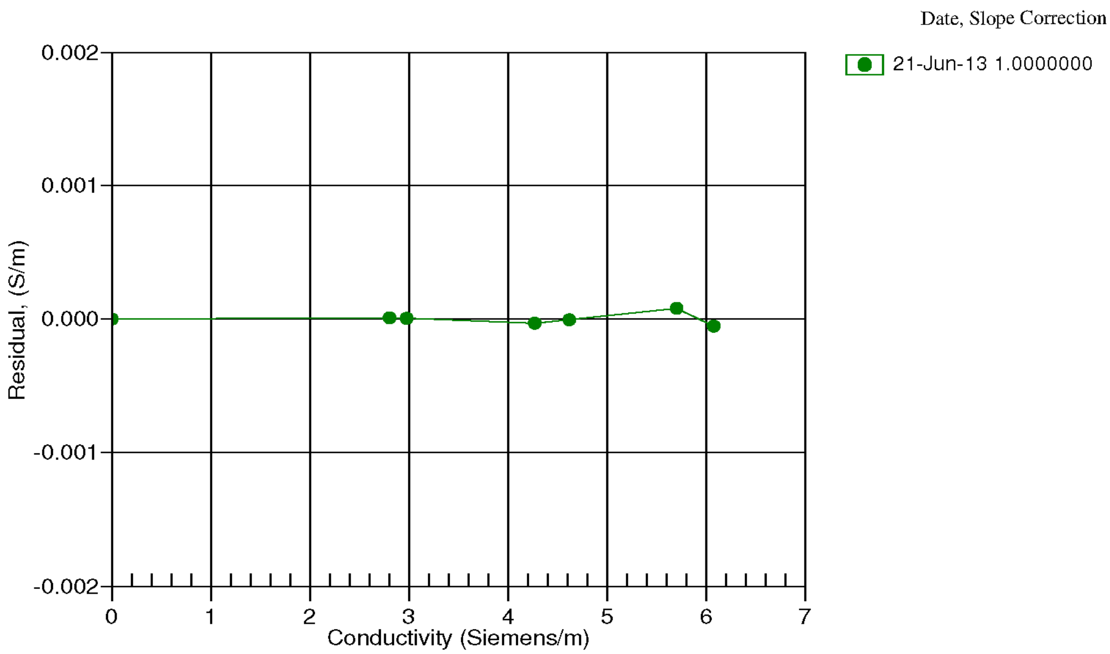
BATH TEMP (ITS-90)	BATH SAL (PSU)	BATH COND (Siemens/m)	INST FREQ (kHz)	INST COND (Siemens/m)	RESIDUAL (Siemens/m)
0.0000	0.0000	0.00000	2.92882	0.00000	0.00000
-1.0000	34.7942	2.80296	8.35585	2.80297	0.00001
1.0000	34.7951	2.97433	8.57635	2.97433	0.00001
15.0000	34.7956	4.26934	10.08504	4.26931	-0.00003
18.5000	34.7955	4.61591	10.45102	4.61590	-0.00001
29.0001	34.7944	5.69915	11.51780	5.69922	0.00008
32.5000	34.7889	6.07175	11.86157	6.07170	-0.00005

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

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

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

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



CTD Dissolved Oxygen Sensor (primary)

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

SENSOR SERIAL NUMBER: 0161
CALIBRATION DATE: 12-Jun-13

SBE 43 OXYGEN CALIBRATION DATA

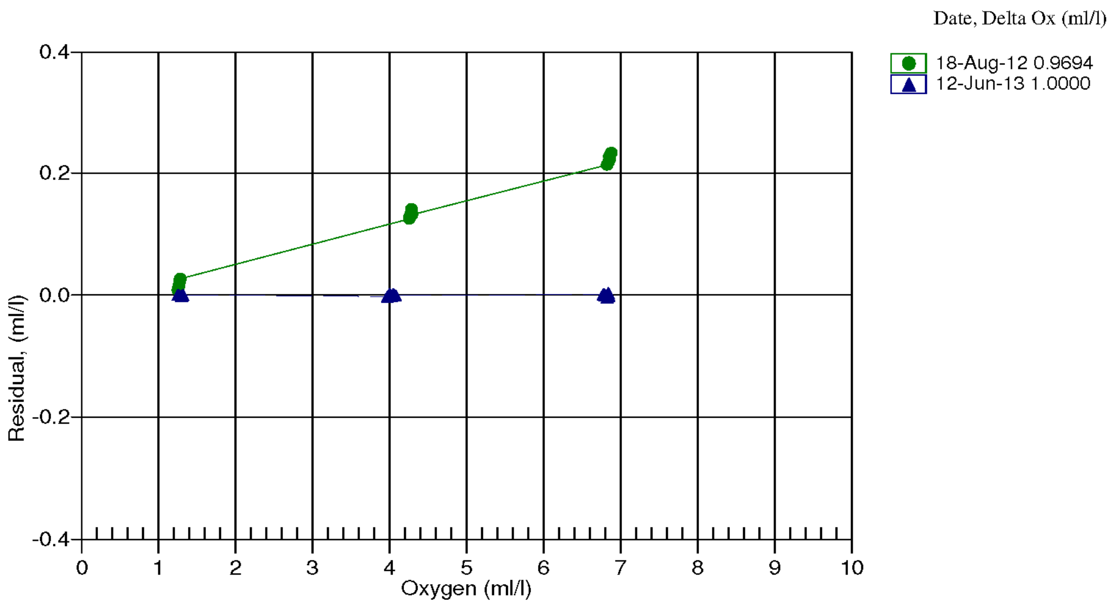
COEFFICIENTS
Soc = 0.5019
Voffset = -0.5162
Tau20 = 1.26

A = -2.3123e-003
B = 1.0028e-004
C = -2.1649e-006
E nominal = 0.036

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

BATH OX (ml/l)	BATH TEMP ITS-90	BATH SAL PSU	INSTRUMENT OUTPUT(VOLTS)	INSTRUMENT OXYGEN(ml/l)	RESIDUAL (ml/l)
1.25	2.00	0.00	0.775	1.25	0.00
1.26	12.00	0.00	0.856	1.26	0.00
1.27	6.00	0.00	0.810	1.27	0.00
1.30	20.00	0.00	0.931	1.29	-0.00
1.31	26.00	0.00	0.990	1.31	-0.00
1.32	30.00	0.00	1.031	1.32	0.00
3.97	2.00	0.00	1.337	3.97	-0.00
4.00	6.00	0.00	1.442	4.00	0.00
4.03	12.00	0.00	1.600	4.03	-0.00
4.05	20.00	0.00	1.814	4.05	0.00
4.05	26.00	0.00	1.983	4.05	0.00
4.07	30.00	0.00	2.111	4.07	-0.00
6.78	2.00	0.00	1.917	6.78	0.00
6.78	12.00	0.00	2.340	6.79	0.00
6.79	6.00	0.00	2.087	6.79	-0.00
6.82	20.00	0.00	2.703	6.82	-0.00
6.84	26.00	0.00	2.994	6.84	0.00
6.85	30.00	0.00	3.196	6.85	-0.00

Oxygen (ml/l) = Soc * (V + Voffset) * (1.0 + A * T + B * T^2 + C * T^3) * OxSol(T,S) * exp(E * P / K)
V = voltage output from SBE43, T = temperature [deg C], S = salinity [PSU], K = temperature [Kelvin]
OxSol(T,S) = oxygen saturation [ml/l], P = pressure [dbar], Residual = instrument oxygen - bath oxygen



CTD Dissolved Oxygen Sensor (secondary)

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

SENSOR SERIAL NUMBER: 0080
CALIBRATION DATE: 13-Feb-13

SBE 43 OXYGEN CALIBRATION DATA

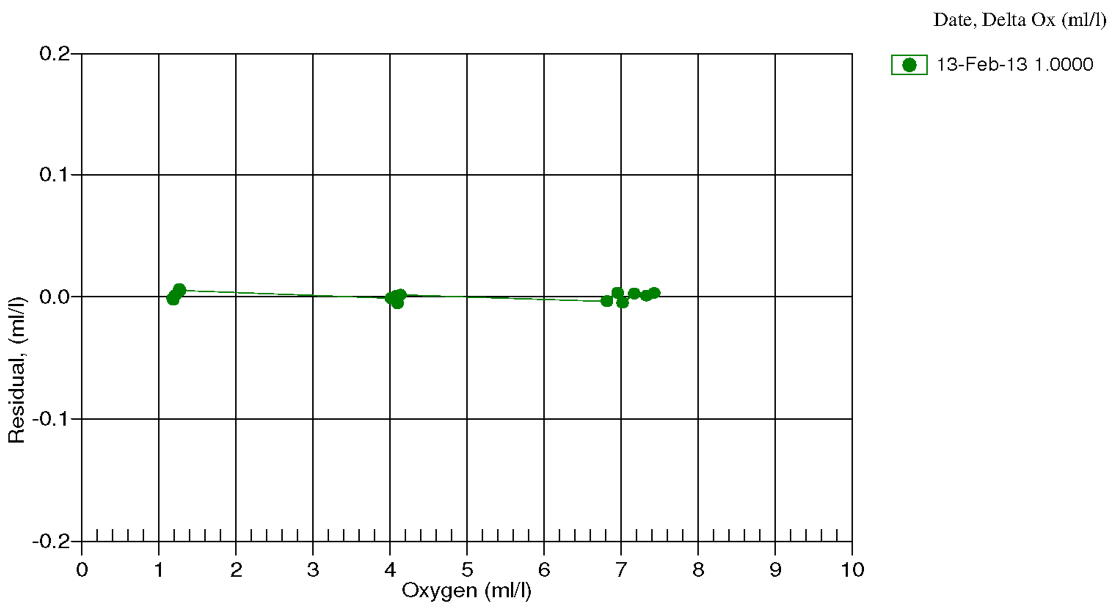
COEFFICIENTS
Soc = 0.4885
Voffset = -0.5049
Tau20 = 1.79

A = -3.0719e-003
B = 1.5019e-004
C = -2.7921e-006
E nominal = 0.036

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

BATH OX (ml/l)	BATH TEMP ITS-90	BATH SAL PSU	INSTRUMENT OUTPUT(VOLTS)	INSTRUMENT OXYGEN(ml/l)	RESIDUAL (ml/l)
1.18	2.00	0.07	0.756	1.18	-0.00
1.19	6.00	0.07	0.788	1.19	-0.00
1.20	12.00	0.06	0.839	1.20	0.00
1.23	20.00	0.06	0.909	1.23	0.00
1.27	26.00	0.06	0.977	1.27	0.01
1.28	30.00	0.06	1.018	1.28	0.01
4.01	6.00	0.07	1.461	4.01	-0.00
4.04	12.00	0.06	1.626	4.04	-0.00
4.08	20.00	0.06	1.849	4.08	0.00
4.10	2.00	0.07	1.376	4.09	-0.01
4.11	26.00	0.06	2.028	4.11	0.00
4.14	30.00	0.06	2.162	4.14	0.00
6.82	30.00	0.06	3.231	6.81	-0.00
6.95	26.00	0.06	3.084	6.95	0.00
7.02	20.00	0.06	2.817	7.01	-0.01
7.17	12.00	0.06	2.493	7.17	0.00
7.33	6.00	0.07	2.251	7.33	0.00
7.43	2.00	0.07	2.087	7.43	0.00

Oxygen (ml/l) = Soc * (V + Voffset) * (1.0 + A * T + B * T^2 + C * T^3) * OxSol(T,S) * exp(E * P / K)
V = voltage output from SBE43, T = temperature [deg C], S = salinity [PSU], K = temperature [Kelvin]
OxSol(T,S) = oxygen saturation [ml/l], P = pressure [dbar], Residual = instrument oxygen - bath oxygen



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WET Labs

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http://www.wetlabs.com

Chlorophyll Fluorometer Characterization in Uranine liquid Proxy (new method)

Date: **07/17/13**
Serial #: AFLD-011
Tech: K.C.

Dark Counts	**0.117volts**
CEV	**.682 volts**
SF	**32.743**
FSV	**4.61 volts**
Linearity:	**0.999 R^2 (0–1.5 volts)**
	0.995 R^2 (0– 5.45 volts)

Notes:

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

CEV is the chlorophyll equivalent voltage. This value is the signal output of the fluorometer when using a Uranine dye fluorescent proxy that has been determined to be approximately equivalent to **26.4 µg/l** of a *Thalassiosira weissflogii* phytoplankton culture.

SF is the scale factor used to derive chlorophyll concentration from the signal voltage output of the fluorometer. The scale factor is determine by using the following equation: SF = (18.3) / (CEV – dark).

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

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

The relationship between fluorescence and chlorophyll-*a* concentrations in-situ is high variable. The scale factor listed on this document was determined by using a mono-culture of phytoplankton (*Thalassiosira weissflogii*). The population was assumed to be reasonably healthy and the concentration was determined by using the absorption method. To accurately determine chlorophyll concentration using a fluorometer you must perform secondary measurements on the populations of interest. This is typically done using extraction based measurement techniques on discrete samples. For additional information on determination of chlorophyll concentration see [Standard Methods For The Examination Of Water And Wastewater] part 10200 H published jointly by: American Public Health Association, American Water Works Association and Water Environment Federation.

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Chlorophyll Fluorometer Characterization in Reflective Solid Proxy (old method)

Date: **07/17/13**
Serial #: AFLD-011
Tech: K.C.

Dark Counts	**0.117 volts**
CEV	**1.594 volts**
SF	**14.962**
FSV	**4.61 volts**
Linearity:	**0.999 R^2 (0–1.5 volts)** **0.995 R^2 (0– 5.45 volts)**

Notes:

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

CEV is the chlorophyll equivalent voltage. This value is the signal output of the fluorometer when using a Uranine dye fluorescent proxy that has been determined to be approximately equivalent to **21.6 µg/l** of a *Thalassiosira weissflogii* phytoplankton culture.

SF is the scale factor used to derive chlorophyll concentration from the signal voltage output of the fluorometer. The scale factor is determine by using the following equation: SF = (21.6) / (CEV – dark).

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

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

The relationship between fluorescence and chlorophyll-*a* concentrations in-situ is high variable. The scale factor listed on this document was determined by using a mono-culture of phytoplankton (*Thalassiosira weissflogii*). The population was assumed to be reasonably healthy and the concentration was determined by using the absorption method. To accurately determine chlorophyll concentration using a fluorometer you must perform secondary measurements on the populations of interest. This is typically done using extraction based measurement techniques on discrete samples. For additional information on determination of chlorophyll concentration see [Standard Methods For The Examination Of Water And Wastewater] part 10200 H published jointly by: American Public Health Association, American Water Works Association and Water Environment Federation.

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WET Labs

C-Star Calibration

Date September 5, 2013 S/N# CST-889DR Pathlength 25cm

	Analog output
V_d	**0.060 V**
V_{air}	**4.726 V**
V_{ref}	**4.624 V**

Temperature of calibration water	**23.1** °C
Ambient temperature during calibration	**21.2** °C

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

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

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

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

Revision M 7/26/11

Customer Alert: July, 2011

CHLa Scale Factors Shift

WET Labs calibration testing has revealed that our CHLa solid proxy used to calibrate our ECO and Wetstar fluorometers allows a large amount of instrument to instrument variability. Also, we have differences in scaling between Wetstar CHLa fluorometers and ECO CHLa Fluorometers because of differences in the solid proxy used to characterize these instruments. A new methodology using a liquid proxy has been implemented to assure stable calibrations between instruments and to match up the ECO FL and Wetstar FL corrected data outputs.

Instruments affected:

All CHLa ECO fluorometers built or calibrated before January 2011.

All CHLa Wetstar fluorometers built or calibrated before July 2011.

WET Labs' Actions:

New Instruments:

WET Labs has instituted a new calibration standard solution preparation methodology. All new ECO/Wetstar CHLa fluorometers delivered from this date forward will have range characteristics as per current specifications and scale factors**.**

Instruments returned for service and calibration:

Instruments returned for service and calibration will be calibrated using the new methodology. We are tuning all service instruments to this new liquid proxy to decrease instrument to instrument variability.

In some cases, we will not be able to achieve the previously stated range of an instrument. In these cases, we will strive for the highest resolution with the highest signal to noise ratio possible.

WET Labs service technicians will incorporate these improvements during service when practical. WET Labs' term for this service is 'retuning.' Accordingly, a serviced instrument may well have a better performance after retuning than when it was first built.

For instruments that are retuned, benefiting in either resolution or signal to noise ratio, WETLabs can provide pre calibration data to allow you to link your data sets prior to service with your data sets after the instrument is returned to you.

Recommended Customer Actions:

If you calibrate your instruments then you do not need to take any action. Continue to use your calibration.

If you report scaled or raw data, you should adjust your reported values.

For instruments returned for service, you will use the ratio between the previous scale factor and pre-service scale factor. This ratio will cover both the change in the methodology and any change in your instrument between the previous calibration and this servicing.

Use the post-service scale factor going forward.

CCHDO Data Processing Notes

Date	Person	Data Type	Action	Summary
2014-06-06	Schatzman, Courtney	CTD Exchange	Submitted	to go online
2014-06-06	Schatzman, Courtney	Bottle data file	Submitted	to go online
2014-06-06	Schatzman, Courtney	WOCE CTD	Submitted	to go online
2014-06-06	Schatzman, Courtney	CTD NetCDF	Submitted	to go online
2014-06-06	Schatzman, Courtney	WOCE Bottle Data	Submitted	to go online
2014-06-06	Schatzman, Courtney	WOCE Sum File	Submitted	to go online
2014-06-09	Staff, CCHDO	Bottle data file	Website Update	Available under 'Files as received'

The following files are now available online under 'Files as received', unprocessed by the CCHDO.

p16s_hy1.csv

Date	Person	Data Type	Action	Summary
2014-06-09	Staff, CCHDO	WOCE Bottle Data	Website Update	Available under 'Files as received'

The following files are now available online under 'Files as received', unprocessed by the CCHDO.

p16s.sea

Date	Person	Data Type	Action	Summary
2014-06-09	Staff, CCHDO	WOCE Sum File	Website Update	Available under 'Files as received'

The following files are now available online under 'Files as received', unprocessed by the CCHDO.

p16s.sum

Date	Person	Data Type	Action	Summary
2014-06-09	Staff, CCHDO	CTD Exchange	Website Update	Available under 'Files as received'

The following files are now available online under 'Files as received', unprocessed by the CCHDO.

P16S-2014-CTD-WHPEXCHNG.tar.gz

Date	Person	Data Type	Action	Summary
2014-06-09	Staff, CCHDO	WOCE CTD	Website Update	Available under 'Files as received'

The following files are now available online under 'Files as received', unprocessed by the CCHDO.

P16S-2014-CTD-WHP90.tar.gz

Date	Person	Data Type	Action	Summary
2014-06-09	Staff, CCHDO	CTD NetCDF	Website Update	Available under 'Files as received'

The following files are now available online under 'Files as received', unprocessed by the CCHDO.

P16S-2014-CTD-WHP90.tar.gz

P16S-2014-CTD-NETCDF.tar.gz

Date	Person	Data Type	Action	Summary
2014-06-16	Staff, CCHDO	SUM/CTD/BTL	Website Update	Available under 'Files as received'

The following files are now available online under 'Files as received', unprocessed by the CCHDO.

p16s_hy1.csv

p16s.sea

P16S-2014-CTD-WHP90.tar.gz

P16S-2014-CTD-NETCDF.tar.gz

p16s.sum

P16S-2014-CTD-WHPEXCHNG.tar.gz

Date	Person	Data Type	Action	Summary
2014-06-16	Schatzman, Courtney	SUM/CTD/BTL	Submitted	Resubmitting data reporting dates.
2014-06-17	Berys, Carolina	CTD-SUM-BTL	Website Update	Exchange, netCDF, and WOCE files online for CTD, BTL, and SUM.

2014-06-17	Lee, Rox	Map	Website Update	Maps created

```
==============================
320620140320 processing - Maps
==============================
2014-06-17
R Lee
.. contents:: :depth: 2
Process
=======
Changes
-------
- Map created from 320620140320_hy1.csv
Directories
===========
:working directory:
  /data/co2clivar/pacific/p16/320620140320/original/2014.06.17_Map_RJL
:cruise directory:
  /data/co2clivar/pacific/p16/320620140320
Updated Files Manifest
======================
==================== =====
file                 stamp
==================== =====
320620140320_trk.jpg
320620140320_trk.gif
==================== =====
```

2014-06-17	Schatzman, Courtney	BTL	Submitted	Updated
2014-06-19	Staff, CCHDO	SALNTY	Website Update	Available under 'Files as received'

The following files are now available online under 'Files as received', unprocessed by the CCHDO.

p16s_hy1.csv

2014-06-19	Berys, Carolina	SALNTY	Website Update	Exchange, netCDF, and WOCE files online. Bottle file updated SALNTY on station 25

```
================================================
P16S 2014 320620140320 processing - BTL/SALNTY
================================================
2014-06-19
C Berys
.. contents:: :depth: 2
Submission
==========
============ ================== ========== ========= ====
filename     submitted by       date       data type id
============ ================== ========== ========= ====
p16s_hy1.csv Courtney Schatzman 2014-06-17 SALNTY    1181
============ ================== ========== ========= ====
Process
=======
Changes
-------
320620140320_hy1.csv
~~~~~~~~~~~~~~~~~~~~
- SALNTY changed to fill value at station 25, cast 1, sample 22
Conversion
----------
```

```
======================= ==================== ========================
file                    converted from       software
======================= ==================== ========================
320620140320_nc_hyd.zip 320620140320_hy1.csv hydro 0.8.0-130-g9fe0afa
320620140320hy.txt      320620140320_hy1.csv hydro 0.8.0-130-g9fe0afa
======================= ==================== ========================
All converted files opened in JOA with no apparent problems.
Directories
===========
:working directory:
 /data/co2clivar/pacific/p16/320620140320/original/2014.06.19_SALNTY_CBG
:cruise directory:
 /data/co2clivar/pacific/p16/320620140320
Updated Files Manifest
======================
======================= ==================
file                    stamp
======================= ==================
320620140320hy.txt
320620140320_hy1.csv    20140619CCHSIOCBG
320620140320_nc_hyd.zip 20140619CCHSIOCBG
======================= ==================
```

2014-10-24 Courtney Schatzman BTL Submitted Updated CTD salinity station 001

2014-10-24 CCHDO Staff BTL/SALNTY Website Update Available under 'Files as received'
The following files are now available online under 'Files as received', unprocessed by the CCHDO. p16s_hy1.csv

2014-10-29 Courtney Schatzman BTL Submitted various correcteons
CTD salinity corrections Salinity flags added Bottom cast lat lon fixed

2014-10-29 CCHDO Staff BTL Website Update Available under 'Files as received'
The following files are now available online under 'Files as received', unprocessed by the CCHDO. p16s_hy1.csv

2014-10-31 Courtney Schatzman BTL Submitted Corrected headers

2014-10-31 CCHDO Staff BTL Website Update Available under 'Files as received'
The following files are now available online under 'Files as received', unprocessed by the CCHDO. p16s_hy1.csv

2014-11-10 Alex Kozyr TCARBN Submitted to go online
The TCARBN Data are submitted to CDIAC by Dick Feely/PMEL on 20141107. Additional QC preformed by Bob Key.

2014-11-12 CCHDO Staff TCARBN Website Update Available under 'Files as received'
The following files are now available online under 'Files as received', unprocessed by the CCHDO. 320620140320_TCARBN_final.exc.csv

2015-01-07 Carolina Berys TCARBN Website Update Updated TCARBN, bottle data online in all formats

P16S 2014 320620140320 processing - BTL/merge - TCARBN

2015-01-07

C Berys

Contents

- Conversion
- o Updated Files Manifest

Submission

filename
    320620140320_TCARBN_final.exc.csv
submitted by
    Alex Kozyr
date
    2014-11-10 00:00:00
data type
    data_suggestion
id
    5655

Parameters

320620140320_TCARBN_final.exc.csv
- o CTDPRS
- o TCARBN [1] [4]

[1] parameter has quality flag column
[2] parameter only has fill values/no reported measured data
[3] not in WOCE bottle file
[4] merged, see merge

Process

Merge

320620140320_TCARBN_final.exc.csv
Merged 320620140320_TCARBN_final.exc.csv into 320620140320_hy1.csv using hydro 0.8.2-40-g569f4c2.

Updated parameters:
    TCARBN, TCARBN_FLAG_W

All comment lines from original file copied back in following merge.
320620140320_hy1.csv opened in JOA with no apparent problems.

Conversion

file	converted from	software
320620140320_nc_hyd.zip	320620140320_hy1.zip	hydro 0.8.2-40-g569f4c2
320620140320hy.txt	320620140320_hy1.csv	hydro 0.8.2-40-g569f4c2

All converted files opened in JOA with no apparent problems.

Updated Files Manifest

file	stamp
320620140320_hy1.csv	20150106CCHSIOCBG
320620140320_nc_hyd.zip	20150106CCHSIOCBG
320620140320hy.txt	

2015-01-28 Carolina Berys Pigments Data available As Received
The following data are now available As Received, unprocessed by the CCHDO.
http://cchdo.ucsd.edu/cruise/320620140320
P16S_Pigments_report.csv pigments

2015-02-17	Kappa, Jerry	CrsRpt	Website Update	new PDF version online

I've put a new PDF version of the cruise report online.

It includes all the reports provided by the cruise PIs, summary pages and CCHDO data processing notes, as well as a linked Table of Contents and links to figures, tables and appendices.