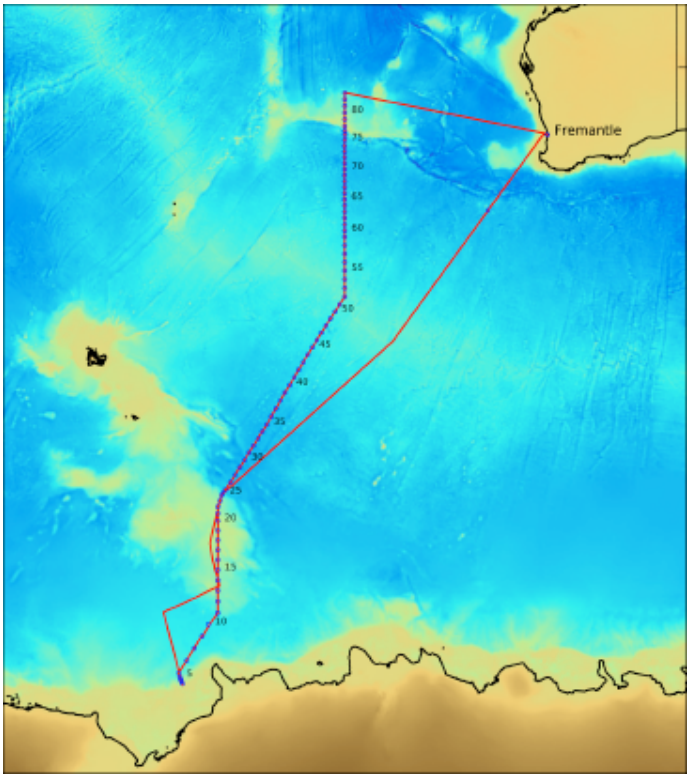
# CRUISE REPORT: I08S

*(Updated NOV 2016)*




## Highlights

### Cruise Summary Information

| | |
|---|---|
| Section Designation | **I08S** |
| Expedition designation (ExpoCodes) | **33RR20160208** |
| Chief Scientists | **Alison Macdonald/WHOI** |
| Dates | 2016 FEB 08 – 2016 MAR 16 |
| Ship | *R/V Roger Revelle* |
| Ports of call | Fremantle, Australia - Fremantle, Australia |
| Geographic Boundaries | 28° 19' 4.8" S<br>78° 0' 36.72" E 95° 0' 46.44" E<br>66° 36' 9.72" S |
| Stations | 83 |
| Floats and drifters deployed | 6 SOCCOM floats, 10 NOAA drifters deployed |
| Moorings deployed or recovered | 0 |

**Contact Information:**

Alison M. Macdonald

Mailstop 21 • Woods Hole Oceanographic Institution • Clark 344A • Woods Hole, MA • 02543

Work: 508 289 3507 • amacdonald@whoi.edu

## 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 |
| | |
| **Underway Data Information** | **References** |
| Navigation Bathymetry | |
| Acoustic Doppler Current Profiler (ADCP) | |
| Thermosalinograph | |
| XBT and/or XCTD | |
| Meteorological Observations | **Acknowledgments** |
| Atmospheric Chemistry Data | |
| | |
| **Lowered Acoustic Doppler Current Profiler (LADCP)** | |
| | |
| **Data Processing Notes** | |


# Cruise Report of the 2016 I08S US GO-SHIP Reoccupation

***Release Draft 1***

**Alison Macdonald**

July 29, 2016

CHAPTER

# ONE

# GO-SHIP I08S 2016 HYDROGRAPHIC PROGRAM

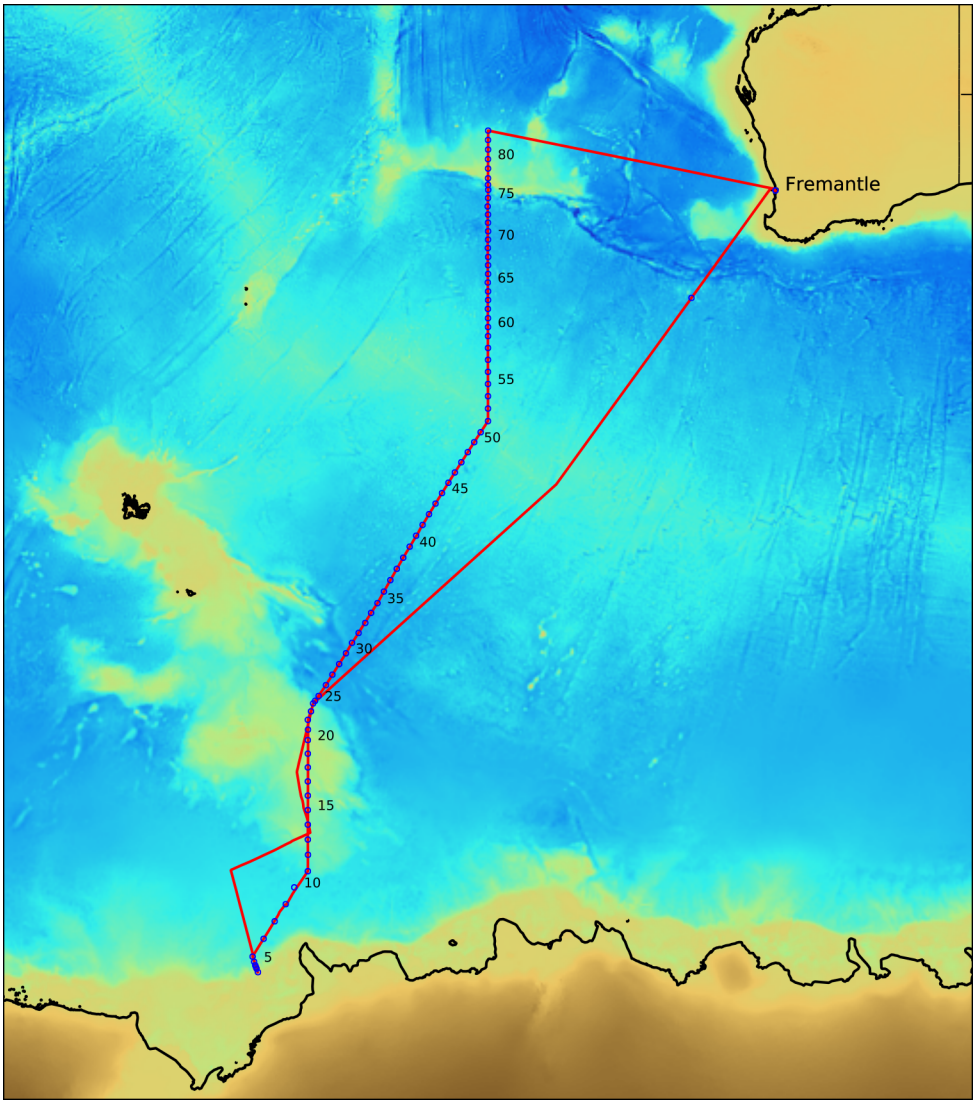



Fig. 1.1: Figure: *I08S Cruise Track of 2016*

The Southern Indian Ocean I08S repeat hydrographic line was reoccupied for the US Global Ocean Carbon and Repeat Hydrography Program. Reoccupation of the I08S transect, seen in the *Figure: I08S Cruise Track of 2016* figure, occurred on the R/V Roger Revelle from February 8th, 2016 to March 16th, 2016. The survey of I08S consisted of

*CTDO*, rosette, *LADCP*, chipod, water samples and underway measurements. The ship departed and returned to the port of Fremantle, Western Australia.

A total of 83 stations were occupied with 2 CTDO/rosette/LADCP/chipod packages and the vertical sampling section profiles can be seen in the following two figures *Figure: Sample Profile Section: Stations 1-45* and *Figure: Sample Section Profile: Stations 45-83*. 1 test station and 83 stations performed, for the most part, a reoccupation of I08S-2007. Stations 1-13 were completed with the initial primary package. While deploying the package on station 14, our primary instrument was lost. A second package was used from stations 14-83.

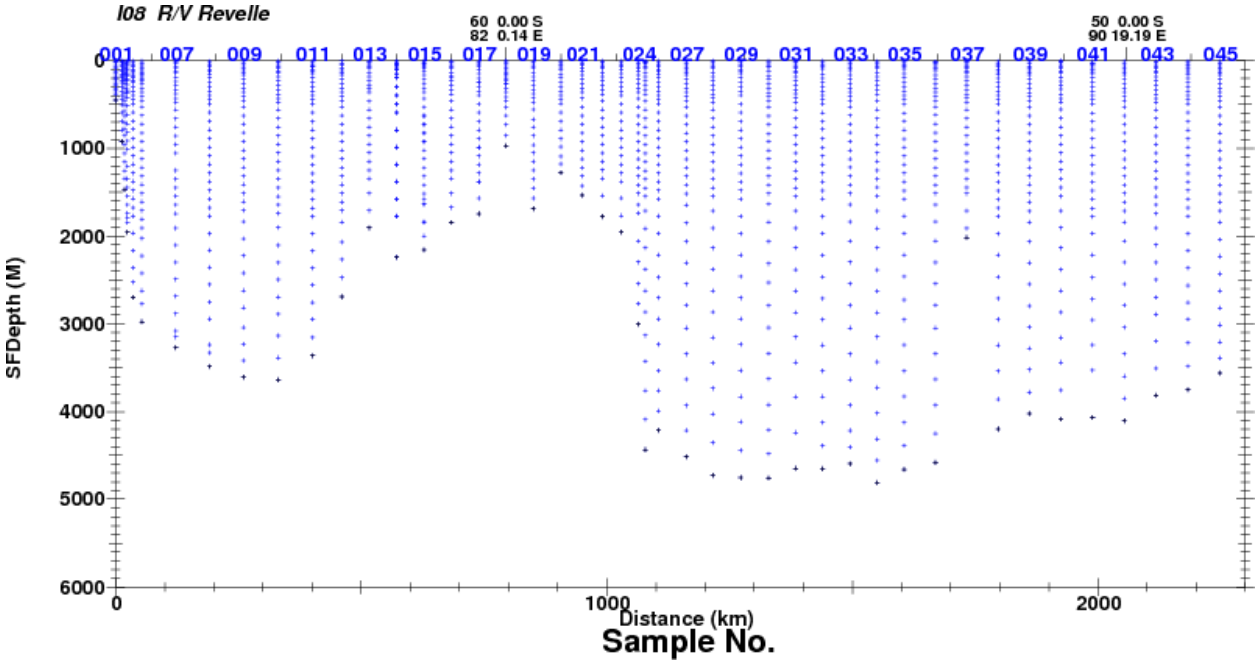



Fig. 1.2: Figure: *Sample Profile Section: Stations 1-45*

CTDO data and water samples were collected on each CTDO, rosette, LADCP and chipod cast, usually within 10 meters of the bottom. Water samples were measured on board for salinity, dissolved oxygen, nutrients, *DIC*, pH, total alkalinity and *CFCs*/*SF6*. Additional water samples were collected and stored for shore analyses of $\delta O^{18}$, $\delta N^{15}$ and $\delta O^{18}$ in $NO^3$, *DOC*/*TDN*, 13C/14C, *CDOM*, phytoplankton pigments, *POC*, *HPLC* and *AP*.

## 1.1 Programs and Principal Investigators

A sea-going science team assembled from 13 different institutions participated in the collection and analysis of this data set. The programs, affiliations, science team, responsibilities, instrumentation, analysis and analytical methods are outlined in the following cruise documents.

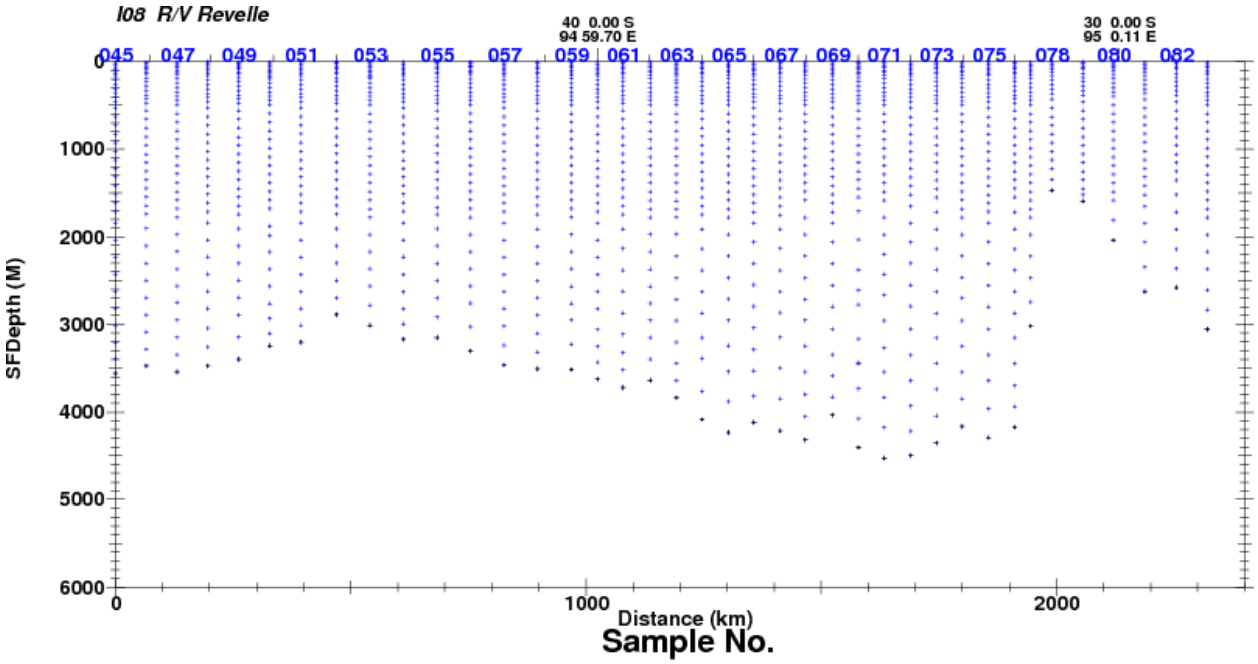



Fig. 1.3: Figure: *Sample Section Profile: Stations 45-83*

| Program | Affiliation | Principal Investigator | Email |
|---|---|---|---|
| *CTDO* Data, Salinity, Nutrients, Dissolved $O_2$ | *UCSD*, *SIO* | Susan Becker, Jim Swift | sbecker@ucsd.edu, jswift@ucsd.edu |
| Total $CO_2$ (DIC), Underway $pCO_2$ | *AOML*, *NOAA* | Rik Wanninkhof | Rik.Wanninkhof@noaa.gov |
| Total Alkalinity, pH | *UCSD*, *SIO* | Andrew Dickson | adickson@ucsd.edu |
| ADCP | *UH* | Jules Hummon | Hummon@hawaii.edu |
| *LADCP* | *LDEO*, *UH* | Andreas Thurnherr, William Smethie, David Ho | ant@ldeo.columbia.edu, bsmeth@ldeo.columbia.edu, ho@hawaii.edu |
| *CFCs*, $SF_6$ | *RSMAS* | Jim Happel | jhappell@rsmas.miami.edu |
| DOC, TDN | *UCSB* | Craig Carlson | carlson@lifesci.ucsb.edu |
| Transmissometry | *TAMU* | Wilf Gardner | wgardner@ocean.tamu.edu |
| Chipod | *OSU*, *UCSD* | Jonathan Nash, Jen Mackinnon | nash@coas.oregonstate.edu, jmackinnon@ucsd.edu |
| *CDOM*, *HPLC*, *POC* | *UCSB* | Norm Nelson | norm@icess.ucsb.edu |
| 13C/14C | *WHOI*, *Princeton* | Ann McNichol, Robert Key | amcnichol@whoi.edu, key@princeton.edu |
| $\delta O^{18}$ | *LDEO* | Peter Schlosser | schlosser@ldeo.columbia.edu |
| $\delta N^{15}$ and $\delta O^{18}$ in $NO^3$ | *VUB* | Francois Fripiat | ffripiat@ulb.ac.be |
| *NOAA* Drifters | *AOML* | Shaun Dolk | shaun.dolk@noaa.gov |
| *SOCCOM* Floats | *UW*, *MBARI*, *SIO* | Stephen Riser, Ken Johnson, Lynne Talley | riser@ocean.washington.edu, johnson@mbari.org, ltalley@ucsd.edu |
| *SOCCOM* Optical Sensors | *Princeton* | Emmanuel Boss | emmanuel.boss@maine.edu |
| Bathymetry, Underway Thermosalinograph | *UCSD*, *SIO* | Bruce Applegate | bapplegate@ucsd.edu |

## 1.2 Science Team and Responsibilities

| Duties | Name | Affiliation | Email Address |
|---|---|---|---|
| Chief Scientist | Alison Macdonald | *WHOI* | amacdonald@whoi.edu |
| Co-Chief Scientist | Viviane Menezes | *WHOI* | vmenezes@whoi.edu |
| CTD Watchstander, *SOCCOM* floats | Earle Wilson | *UW* | earlew@uw.edu |
| CTD Watchstander | Natalie Freeman | *U Colorado* | Natalie.Freeman@Colorado.edu |
| CTD Watchstander | David Webb | *UNSW* | d.webb@unsw.edu.au |
| CTD Watchstander | Seth Travis | *UH* | stravis3@hawaii.edu |
| CTD Watchstander | Hannah Dawson | U of Western Australia | 20517368@student.uwa.edu.au |
| Res Tech | Josh Manger | *UCSD* | jmanger@ucsd.edu |
| Computer Tech | Mary Huey | *UCSD* | mhuey@ucsd.edu |
| Nutrients, *ODF* supervisor, *SOCCOM* floats | Susan Becker | *UCSD ODF* | sbecker@ucsd.edu |
| Nutrients | John Ballard | *UCSD ODF* | jrballar@ucsd.edu |
| CTDO Processing, Database Management | Courtney Schatzman | *UCSD ODF* | cschatzman@ucsd.edu |
| Salts, ET, Deck | John Calderwood | *UCSD ODF* | jkc@ucsd.edu |
| Salts, ET, Deck | Sergey Tepyuk | *UCSD ODF* | sergey1@ucsd.edu |
| Dissolved $O_2$, Database Management | Andrew Barna | *UCSD ODF* | abarna@gmail.com |
| Dissolved $O_2$, Database Support | Joseph Gum | *UCSD ODF* | jgum@ucsd.edu |
| SADCP, *LADCP* | Philip A. Mele | *LDEO* | pmele@ldeo.columbia.edu |
| *DIC*, underway pCO2 | Charles Featherstone | *AOML* | charles.featherstone@noaa.gov |
| *DIC* | Dana Greeley | *PMEL* | dana.greeley@noaa.gov |
| *CFCs*, SF6 | Jim Happell | *RSMAS* | jhappell@rsmas.miami.edu |
| *CFCs*, SF6 | Charlene Grall | *RSMAS* | cgrall@rsmas.miami.edu |
| *CFCs*, SF6 student | Sarah Bercovici | *RSMAS* | sBercovici@rsmas.miami.edu |
| Total Alkalinity | David Cervantes | *UCSD* | d1cervantes@ucsd.edu |
| Total Alkalinity | Heather Page | *UCSD* | hnpage@ucsd.edu |
| pH | Michael Fong | *UCSD* | mbfong@ucsd.edu |
| *CDOM* | Norm Nelson | *UCSB* | norm@icess.ucsb.edu |
| *CDOM* | Cara Nissen | *ETHZ* | cara.nissen@usys.ethz.ch |
| *DOC*, *TDN* | Maverick Carey | *UCSB* | maverickcarey@gmail.com |

## 1.3 Underwater Sampling Package

CTDO/rosette/LADCP/chipod casts were performed with a package consisting of a 36 bottle rosette frame, a 36-place carousel and 36 Bullister style bottles with an absolute volume of 10.4L. Underwater electronic components primarily consisted of a SeaBird Electronics pressure sensor and housing unit with dual exhaust, dual pumps, dual temperature, a reference temperature, dual conductivity, dissolved oxygen, transmissometer, chlorophyll fluorometer and altimeter. The RINKOII optode, CDOM fluorometer and turbidity sensor were unique non-standard instruments that were not replaceable after loss of initial rosette package. LADCP and chipods instruments were deployed with the CTD/rosette package in most cases and their use is outlined in sections of this document specific to their analysis.

| Equipment | Model | S/N | Cal Date | Sta | Resp Party |
|---|---|---|---|---|---|
| Rosette | 36-place | Orange | _ | 1-13 | *STS*/*ODF* |

Continued on next page

Table 1.1 – continued from previous page

| Equipment | Model | S/N | Cal Date | Sta | Resp Party |
|---|---|---|---|---|---|
| Rosette | 36-place | Yellow | _ | 14-83 | *STS*/*ODF* |
| CTD | SBE9+ | 401 | _ | 1-13 | *STS*/*ODF* |
| Pressure Sensor | Digiquartz | 59916 | Nov 17, 2015 | 1-13 | *STS*/*ODF* |
| CTD | SBE9+ | 831 | _ | 14-83 | *STS*/*ODF* |
| Pressure Sensor | Digiquartz | 99677 | Nov 17, 2015 | 14-83 | *STS*/*ODF* |
| Primary Temperature | SBE3+ | 34213 | Nov 12, 2015 | 1-13 | *STS*/*ODF* |
| Primary Temperature | SBE3+ | 32166 | Nov 17, 2015 | 14-83 | *STS*/*ODF* |
| Primary Conductivity | SBE4C | 43176 | Nov 10, 2015 | 1-13 | *STS*/*ODF* |
| Primary Conductivity | SBE4C | 43057 | Nov 10, 2015 | 14-30 | *STS*/*ODF* |
| Primary Conductivity | SBE4C | 43399 | Nov 10, 2015 | 31-83 | *STS*/*ODF* |
| Primary Pump | SBE5 | _ | _ | 1-13 | *STS*/*ODF* |
| Primary Pump | SBE5 | _ | _ | 14-83 | *STS*/*ODF* |
| Secondary Temperature | SBE3+ | 32165 | Nov 17, 2015 | 1-13 | *STS*/*ODF* |
| Secondary Temperature | SBE3+ | 34226 | Nov 17, 2015 | 14-83 | *STS*/*ODF* |
| Secondary Conductivity | SBE4C | 42036 | Nov 10, 2015 | 1-13 | *STS*/*ODF* |
| Secondary Conductivity | SBE4C | 43023 | Dec 1, 2015 | 14-56 | *STS*/*ODF* |
| Secondary Conductivity | SBE4C | 41919 | Nov 10, 2015 | 57-83 | *STS*/*ODF* |
| Secondary Pump | SBE5 | _ | _ | 1-13 | *STS*/*ODF* |
| Secondary Pump | SBE5 | _ | _ | 14-83 | *STS*/*ODF* |
| Transmissometer | Cstar | CST-327DR | Jun 3, 2015 | 1-13 | *TAMU* |
| Transmissometer | Cstar | CST-492DR | _ | 14-83 | *STS*/*ODF* |
| Fluorometer CDOM | ECO CDOM | FLCDRTD-3177 | May 13, 2013 | 1-13 | U Maine |
| Fluorometer Chlora | ECO Chlor | FLBBRTD-3697 | Sep 9, 2014 | 1-13 | *UCSB* |
| Fluorometer Chlora | ChlorA | SCF-2958 | _ | 14-83 | *STS*/*ODF* |
| Scattering Meter | WL 700nm | FLBBRTD-3697 | Sep 9, 2014 | 1-13 | *UCSB* |
| Altimeter | LPA200 | 92147.24448 | _ | 1-13 | *STS*/*ODF* |
| Dissolved Oxygen | SBE43 | 431129 | Dec 8, 2015 | 1-13 | *STS*/*ODF* |
| Dissolved Oxygen | SBE43 | 431138 | Nov 19, 2015 | 14-83 | *STS*/*ODF* |
| Dissolved Oxygen | RINKOII | 143 | Jan 1, 2014 | 1-13 | *STS*/*ODF* |
| Temperature | RINKOII | 143 | Jan 1, 2014 | 1-13 | *STS*/*ODF* |
| Carousel | SBE32 | _ | _ | 1-13 | *STS*/*ODF* |
| Carousel | SBE32 | _ | _ | 14-83 | *STS*/*ODF* |
| Referense Temperature | SBE35 | _ | _ | 1-13 | *STS*/*ODF* |
| Referense Temperature | SBE35 | _ | _ | 14-83 | *STS*/*ODF* |
| LADCP (Up) | WH300 | 13330 | _ | 1-13 | *LDEO*/*UH* |
| LADCP (Down) | WH300 | 149 | _ | 1-13 | *LDEO*/*UH* |
| LADCP (Down) | WH300 | 150 | _ | 28-83 | *LDEO*/*UH* |

CTD was housed in the recommended SBE cage, mounted vertically for stations 1-13 and mounted horizontally for stations 14-83. Both cages were mounted to one side of the bottom of the rosette frame. The temperature, conductivity, dissolved oxygen, respective pumps and exhaust tubing were mounted to the CTD housing as recommended by SBE. The reference temperature sensor was mounted between the primary and secondary temperature sensors at the same level as the intake tubes for the exhaust lines. The transmissometers were mounted horizontally. The fluorometers and altimeters were mounted vertically inside the bottom ring of the rosette frames. The 300 KHz bi-directional Broadband LADCP (RDI) units, when in use, were mounted vertically on the top and bottom sides of the frame. The LADCP battery pack was also mounted on the bottom of the 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 I08S-2016. A full re-termination was completed after the package was replaced on station 14. Another full re-termination was performed prior to station 59. The CAST6 aft winch deployment system cast used for test, 1-13 and 38-83 stations. The Markey DESH-5 forward winch was used for

stations 14-37.

The deck watch prepared the rosette 10-30 minutes prior to each cast. The bottles were cocked and all valves, vents and lanyards were checked for proper orientation. LADCP technician would check for LADCP battery charge, prepare instrument for data acquisition and disconnect cables. The chipod battery was monitored for charge and connectors were checked for fouling and connectivity. Every 20 stations, the transmissometer windows were cleaned and an on deck blocked and un-blocked voltage readings were recorded prior to the cast. Once stopped on station, the Marine Technician would check the sea state prior to cast and decide if conditions were acceptable for deployment.

Recovering the package at the end of the deployment was essentially the reverse of launching. The rosette, CTD and carousel were rinsed with fresh water frequently. CTD maintenance included rinsing de-ionized water through both plumbed sensor lines between casts. On average, once every 20 stations, 1% Triton-x solution was also rinsed through both conductivity sensors. The rosette was routinely examined for valves and o-rings leaks, which were maintained as needed.

CHAPTER

TWO

# CRUISE NARRATIVE

## 2.1 Summary

A hydrographic survey in the southern Indian Ocean that included CTD/rosette/LADCP/Chi-pods/ Fluorometer/Transmissometer casts and bio-optical casts, underway shipboard ADCP and $pCO_2$/T/S/XX/YY measurements, as well as SOCCOM biochemical floats and drifter deployments were carried out between early February and mid-March 2016. After MOB (February 4th – 8th), the *R/V Revelle* departed Fremantle, Australia on February 8th at 16:06 (local). The southern end of the occupation took a western route to avoid ice. Sampling began on Febru-ary 19th on the Antarctica shelf in less than 500 m of water. After leaving the shelf, sampling continued generally northeastward until reaching 82°E where it began following the track of the 2007 occupation. At station 14 the pri-mary rosette and all associated instrumentation was lost. The spare rosette and instrument replacements were used the remainder of the line.

A total of 83 stations were occupied: 83 CTD/rosette/fluorometer/transmissometer casts; 13 included both upward and downward looking LADCP and 56 included downward looking-only LADCP; 66 included two upward looking chi-pods, 9 included two downward looking chi-pods and 53 included 1 downward looking chi-pod; and 13 included a second fluorometer with a backscatter sensor. With a couple of exceptions, casts were made to within 10-15 m of the bottom. Water samples (up to 36) were collected in 10 L Bullister bottles at all stations providing water samples for CFCs/$SF_6$, Total DIC, Total Alkalinity, pH, dissolved oxygen, nutrients, salinity, DOC, $DI^{13/14}C$, $DO^{14}C$, CDOM, Chl-A, HPLC, AP, POC, $\delta^{18}O$, and Nitrate $\delta^{15}N/\delta^{18}O$. Once a day when weather, sea state and satellite flyovers were conducive to sampling a spectro-radiometer cast was performed. Underway surface $pCO_2$, temperature, salinity, dissolved oxygen, (OTHERS?) multi-beam bathymetry and meteorological measurements were collected. Six biochemical floats were deployed for the SOCCOM program and 10 surface drifters for the Global Drifter Program. XBTs provided upper water column temperature profiles for calibration of the multi-beam on all days that CTD casts were not performed. The cruise ended in Fremantle, Australia on March 16th, 2016 with deMOB occurring on March 17th.

## 2.2 Cruise Narrative

Following the tracks of the WOCE 1994 and CLIVAR 2007 occupations, 2016 GO-SHIP expedition marks the third complete repeat of the IO8S transect from Antarctica to 28°S. It is first leg of I08S/I09N 95°E meridional transect in the Indian Ocean. The *R/V Revelle* arrived in Fremantle on 3 February having completed a suite of successful tests of the CAST-6 (primary) and DESH-5 (backup) winches in mid-January. Between 4 February and 8 February, vans (SIO/ODF storage van, working AOML/DICE van), equipment and supplies were loaded onto the ship in Fremantle.

On 8 February, before leaving port, R. Rupan (U.W.) provided a tutorial on the instrumentation on and deployment of the SOCCOM (http://soccom.princeton.edu/) floats that we would be deploying. Our CTD-watchstander, Earle Wilson was in charge of SOCCOM floats as well as writing a blog for the SOCCOM program outreach (http://floatdispenser.blogspot.com/). Trained by A. Pickering while in port, watchstander Hannah Dawson was in

charge of running the chi-pods for the non-sailing OSU group. With all hands on board at 14:00, Josh Manger (res-tech) provided an extended safety brief and Mary Huey (computer tech) gave us the basics of computer and Internet access on the ship. With ODF busy setting up the data management for the cruise and creating cheat sheets for the CTD-watch, the electronic web-based event logger was started for RR1603 and the various different types of casts and event were created for the cruise. The first event was the departure of the Revelle from a sunny and hot (106°F) Fremantle at 16:06 with 28 scientists from 13 different institutions aboard, representing some XX PIs from YY institutions .

Underway sampling of ($pCO_2$, oxygen, nutrients and chlorophyll-A, XX) began at 20:00 local (12:00 UTC) and continued every 4 hours thereafter. In spite of rain overnight, the following day (Tuesday 9 February) turned out to be sunny, if somewhat bumpy (seas 4-6 ft, with 6-8 swell and wind at 22 kt). The time for the test cast was determined. We wanted at least 3000 m of water, to be outside the Australian EEZ and to have it occur during the middle of the day. CTD-watch was tutored on console duties and the rosette. We had our first drills and obtained our first of our XBT profile. XBT profiles were taken every day while in transit to update the sound speed profile used by the multi-beam. Anyone who wanted the experience could sign up to deploy an XBT.

The test cast took place on 10 February at 10:00. There was a hitch at the start with a miscommunication between computer and the winch. The computer's coms check was interpreted as a signal that lab was ready, but it was not. Deck could individually hear and speak to the winch, but there was no direct communication between lab and deck; a point that was not understood at the start of the cast. On later stations, the Computer Lab often had a radio on in the lab to help mitigate this issue. The first time the rosette went into the water, there were no numbers coming out the CTD. Once this was finally relayed to deck the rosette was brought out, by which time the CTD had started take readings. It was deployed a second time. The test cast proceeded with no further issues. Once complete, the CDOM group deployed the spectro-radiometer, and sampling at the rosette began. The CTD-watchstanders were taught to sample-cop and to sample for TAlk and salts.

The following day as winds picked up it became obvious that a cold/flu had come aboard with us. The combination of strong winds with 8-12 ft seas and flu symptoms continued for at least a week - making our transit of the Southern Ocean difficult. Nevertheless, for the most part, spirits remained high with cribbage games and birthday celebrations coming in a seemingly endless stream. Two of the CTD-watchstanders (Seth Travis and Natalie Freeman) created a handy piece of software that would allow us to track our position on the weather forecast maps.

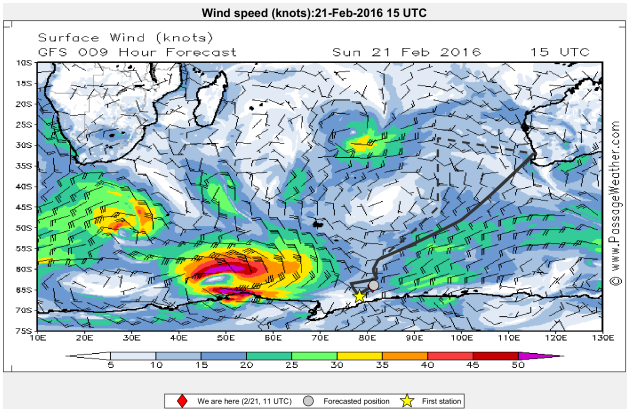



Fig. 2.1: Maps

Example of the weather maps used on the cruise from 21 February 2016 15:00 UTC. Wind map for the Southern Indian Ocean from passageweather.com overlaid with our position at the time the figure as made (red diamond); our first station (yellow star); the track prior to the forecast date (black line); our planned position at the time of the forecast (gray diamond). (S. Travis and N. Freeman)

We were grateful to see that in spite of the sea state we were experiencing, we were missing the worst of the storm. Although it took some of the science party the entire transit to get their sea legs, we were treated to science talks by many of the participants and we all managed to be on our feet for the first station.

To create a sequential line from Antarctica to the northern Bay of Bengal we began the 2016 I08S line at the southern end. The intention was to follow track of the 2007 repeat as closely as possible. Therefore, initially we steamed directly southwest towards what had been the 2007 station 10 at 63.525°S, 82.000°E. This would place us midway between the 2007 shelf stations and our best guess at a 2016 ice-free route onto the shelf. S. Escher at SIO provided us with daily updates on ice conditions in the form of ice concentration maps based on data from NSIDC averaged over 0.5°x0.5° bins.

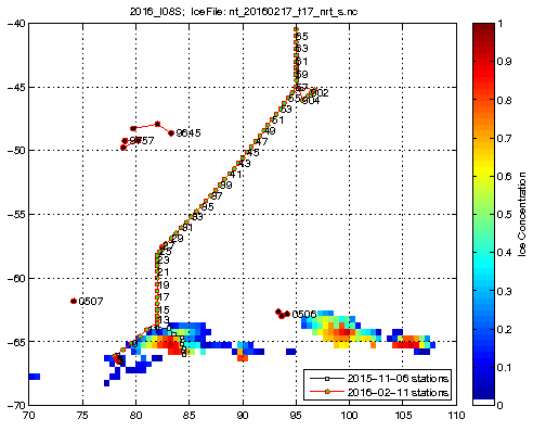



Fig. 2.2: Ice-Concentration

Example of the ice maps used on the cruise. Color shading indicates ice-concentration from NSIDC. Both the 2007 and planned 2016 tracks are plotted along with presently floats in the region. (Courtesy of S. Escher)

Andrew Constable onboard the Aurora Australis (currently in the region performing their K-AXIS observations) also provided us (via Steve Rintoul) with hand-annotated maps of the ice-conditions they were seeing. It was obvious before reaching our first waypoint that in spite of some melting and shifting, the 2007 shelf stations were under ice. Therefore, we chose to sample the shelf to the west of the 2007 line. Under the expert navigational advice of Captain Curl we approached the shelf from the west. There was some risk in this decision in that we would need extra time this approach and track that would have to be made up by efficient sampling and steaming as well as the possibility of some extension of the nominal GO-SHIP 30 nm station spacing for later stations. Nevertheless, it was considered important to get the shelf stations, particularly because of the other work going on in the region (K-AXIS) and decisions concerning spacing were left for the future when we would have a better handle on station timing.

As we headed south we were treated to displays of the Southern Lights, Aurora Australis. A sign up list for aurora wake up calls was started so that no one would have to miss what for some of us was a once in a life time opportunity to see the spectacle. On February 19th, 11 days after leaving Fremantle, approaching from the west to avoid ice, we reached our first station at 66.6°S, 78.4°E in Prydz Bay. To everyone's delight we were just south of the Antarctic Circle at the time was at 66.5°S. In ~460 m of water station 001/01 occurred without incident.

Our track took us on a line perpendicular to the slope, northwestward from our first station on the shelf to station 007 at 66.15°S, 78.01°E. The close station spacing (3.2 to 9.4 nm) provided bottom depth changes between stations of order 500 m. We then began a series of stations approximately 37-38 nm apart to bring us around the regions of high ice-concentration back to the northward track of the 2007 line at 82°E. Although always kept at a safe distance, we were accompanied by isolated icebergs as we sampled our way across the Princess Elizabeth Trough. At more than one point we had to change our transit heading to avoid ice, and once we had to shift a station position because an iceberg had arrived there before us. Nevertheless, the ice-concentration maps were a great help because we only traveled through regions with less than 10% ice-cover giving us plenty of space and time to stay well away from the potential ice hazards. Occasionally, sightings were reported of penguins sitting en masse on these bergs. However, not even the many zoom lenses carried with us managed to actually capture these penguineries. We were, however, met by the occasional penguin or two in the water, along with whales, albatross and petrels all of which were subject to our cameras, phones and Go-Pros. In fact, very little occurred on this cruise that was not subject to one or more forms of

image capture.

We proceeded to work our way through stations ironing out short-term surmountable issues. At station 2, the solution in the syringes placed on the CTD intake froze. It was decided that until temperatures warmed up we would rinse the CTD with the syringes and then remove them. It was found that for stations 001-003 although conductivity was correct, there was a problem with the conversion to salinity. A software solution was found. Another issue that followed us throughout the cruise was the source of seawater intake. During our transit, the uncontaminated seawater intake was switched from the bow to the portside sea chest because the rough weather was causing bubbles. However, on Feb 19th, trash was found in the uncontaminated seawater. It was therefore requested that trash not be dump on the portside. Later in the cruise, when the weather calmed, intake was switched back to the bow, and switched back and forth yet again as the weather changed and when a problem with the sea chest pump occurred. On station 005 the wire stopped paying out at 1368 m. Evidently a surge from the generator caused the ship to have to shut down power. The power came back after a few minutes and the cast continued without further incident. The multi-beam began having difficulties before even arriving at our southernmost point, at the start of station 006 it was shut down for maintenance. Luckily our altimeter was working flawlessly coming in 200 m above the bottom.

By the time we reached station 010 it was obvious that particularly with short station spacing coming off the shelf, the day shift CTD watch was being overwhelmed by the extra sampling for non-sailing participants that included both $\delta^{18}$O and Nitrate $\delta^{15}$N/$\delta^{18}$O. The watchstander students were also sampling salts and TAlk, and Hannah was in charge of the chi-pods downloads and maintenance. It was therefore, decided that the $\delta^{18}$O and Nitrate $\delta^{15}$N/$\delta^{18}$O sampling would only occur on the night shift which had 3 watchstander students. On the night watch, Natalie Freeman and David Webb also helped with the radiocarbon sampling.

To stagger the bottle spacing throughout the water column and across stations we used three rotating schema designed for a 36 bottle rosette. The particular pressures at which bottles would be tripped were based on bottom depth and scheme. To alleviate the pressure on the analysis teams it was decided that when in shallower waters (less than 3000 meters) and particularly during times of close station spacing the number of bottles to be tripped would be predetermined. The schema would still be used, but in such a way that the pressures at which samples were taken were set by the number of bottles to be tripped rather than the bottom depth. To keep some consistency, when stations positions matched, the number of bottles used in 2007 would be considered in this decision.

Stations 007 to 0010 had taken us eastward across deepest stations in the Princess Elizabeth Trough and we began to head up the slope southeast of the Banzare Bank (part of the larger Kerguelen Plateau). On 21 February, at station 011 (82°E) we arrived back at the 2007 line. We reverted back to our nominal 30 nm spacing and we had our first SOCCOM float deployment. These deployments were done in conjunction with extra sampling for HPLC and POC from the rosette at the chlorophyll-A maximum and at the surface. At one of these two depths we would trip two bottles, so that duplicates of the 2.2L HPLC and POC samples could be taken. As it turned out, it was only at the other depth (where only 1 bottle was tripped) that we ran into issues with water availability. At all subsequent casts where these samples were taken we either tripped two bottles at both the surface and chlorophyll maximum, or made sure that HPLC/POC and nutrients obtained water before salts and any non-level 1 sampling. The float deployments are discussed in a separate section of this report.

During our first few days of sampling we had overcome the expected variety of small issues as they had come up, and with the now longer station spacing, we were just getting into the swing of deployments, recoveries, sampling and analysis when we came to station 014 (62.0°S, 82.0°E) just after lunch on 22 February. All appeared to be going well, the CAST-6 boom had extended out over the water for deployment just as it had done on every other cast when the CTD package was unceremoniously dumped into 2250 m of water.

A detailed report on this incident, along with loss of instrumentation and science impact has been submitted and the particulars are not discussed here. Calls to shore were made and a decision was quickly reached not to drag for the lost rosette along with all our primary instrumentation as a) there would be too much time lost with little hope of recovery and b) setting up dragging would involve the same personnel needed to prep the spare CTD/rosette and the hydro-boom, DESH-5 winch.

Along with ODF/STS and the day shift science personnel who got the replacement rosette together quickly and efficiently, the ship crew did a wonderful job getting us up and running again. The teamwork involved on what was a very cold in the Southern Ocean was outstanding. This efficiency and the subsequent fast transit speeds gave us

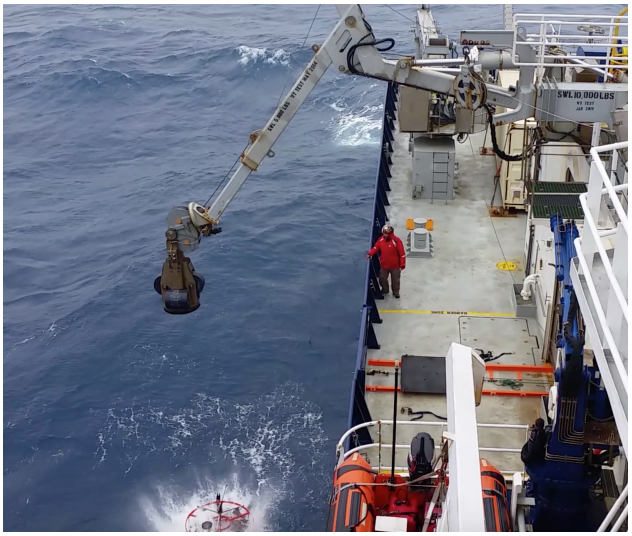



Fig. 2.3: Rosette loss
The primary rosette going in for the last time on station 014 cast 01 (photo courtesy of M. Carey).

as much time as possible to make up for the loss and truly minimized the overall impact on science. The chief and co-chief want to personally thank everyone involved, and my particular thanks go to Captain Chris Curl, Res-tech Josh Manger, Techs John Calderwood and Susan Becker who kept the whole situation in perspective and motivated a positive solution, and to science personnel Hannah Dawson, Seth Travis, Maverick Cary and Phil Mele who did whatever was asked of them to assist. Surprisingly, there were some bonuses to this disaster. These included a) the chance for the day watch students to not only see how a rosette is put together, but actually help in the building of it; b) the reversion back to the DESH-5 gave all the students a chance to participate in deck work; and c) keeping our sense of humor here, it provided the chief and co-chief scientists the chance to fire a few bottles and gave a number of the other members of the science party a chance to work at the console or on the deck. Within less than 9 hours we were up and running again. Generally speaking, every 4 hours of time lost is equivalent to losing one 4000 m station. Loss of stations means a loss of horizontal resolution which was particularly important to us for resolving the ACC fronts and eddy field to the north of the Kerguelen Plateau.

At station 014, the first with our new rosette, we double fired all bottles to check for problems. Not wishing to lose any more time, we continued up the slope and onto station 015. We continued to deal with small issues with the Bullister bottles that meant we lost some data to misfires and leaks. We continued to double fire at depths where we were using "untrustworthy" bottles. As we were in fairly shallow waters (< 2200 m) we had bottles to spare for this process of working out the kinks. One loss over these days was that we did not yet have either our remaining LADCP or 3 chi-pods installed. Both had to wait for the engineers to design additions to the rosette frame for mounting of the instruments and batteries.

Station 015 also presented another issue that plagued us as long as we used the DESH-5. The winch was unable to properly zero out the meter. Initially this just created offset headaches for the console operators, but eventually, after a number of attempts to fix the problem, the inability to zero correctly escalated to a software "feature" that required the winch to zero out the meter before 1400 m of wire-out; otherwise it would revert to negative 1400 and start counting backwards. So, beginning at station 028, every one-thousand meters the console would give the winch a heads up and the meter would be zeroed out on the fly. Interestingly this actually made the console operators job easier because they only had to deal with the last 3 digits on the offset between wire-out and pressure.

On the 23 February at station 19 we deployed the first of 10 surface drifters for the Global Drifter Program at approximate 59.5°S, 82°E. Over the course of the cruise most of the CTD watch had a chance to deploy a drifter or two as it basically entailed nothing more than dropping them off the back of the ship and noting the time and position.

We maintained 30 nm spacing or better between 63°S and 54°S and the stations once again began to roll by as we crossed the Kerguelen Plateau and over the sharp ridge on the northern side into the Labuan Basin, home to our deepest

casts. The chi-pods (2 upward and 1 downward) and LADCP (downward only) went on the rosette at station 028. The replacement LADCP appeared to have issues with the tilt of the rosette, but nothing could be done about this as there did not seem to be any way to re-weight the rosette or to re-seat the LADCP system. These problems continued until the incident at station 59 – but more about that later.

By the time we reached station 032 (54.9°S, 86.6°E) the winds had picked up again and we were reminded that we were once again crossing the Southern Ocean. By station 033, we decided to start firing bottles on the fly to minimize the amount of the time in the water. At station 034 the winch was forced not to exceed 30 m/min to avoid high tensions, and after a long delay due to strong winds, much of the down cast for station 35 (4600 m) was done at 10 m/min. Still we persevered. At station 36, unidentified noises started coming from the winch, which stopped at 4370 m wire-out for some investigation. The station continued, but on the next (037) the DESH-5 seized. After going down at 30 m/min due to tension spikes, the console was informed of mechanical issues and the cast was stopped at 2010 m wire-out. The rosette was brought up at 4 m/min and bottles were fired on the fly. The internals of the DESH-5 system had seized and it was not possible correct the issue at sea. Everyone was left somewhat mystified at all these winch issues as both the CAST-6 and DESH-5 had been completely overhauled just prior to the start of this cruise. Nevertheless, ours is not to reason why. Ours is to figure out what to do and get back to sampling. We moved off station 037 with only half a profile and moved on to the station 038.

On the transit and once on station the CAST-6 winch was once again prepared for use and the wire was re-terminated. As we no longer had a rosette with a frame designed for docking, our chief engineer, the res- techs and winch operators worked out a way to use the CAST-6 as a boom. Tests were performed with a weight and the rosette so that between them winch operators and deck would have control of the package. It was decided that a third person would be needed to provide an extra tagline. It was also found that with this new setup negative tensions on the downcast could be an issue when the ship rolled, so it became common practice to start descent at 30 m/min, move on to 45 m/min and then only once the package was 200-500 m deep accelerate to 60 m/min. Station 038 proceeded without major incidents, but the level wind failed somewhere near the bottom. Since the engineers were not confident enough with the system to re-lay the wire with the rosette on it, we stopped at a point between stations 038 and 039 that was deeper than 038, put a weight on the wire and sent it down to below the point that level wind had failed. With the wire wound onto the spool correctly we continued on to station 039.

At 53.5°S we went to 35 nm spacing, a compromise between the need to make up time and the desire to have closer station in the rich eddy field created by the Polar Front as it passes to the north of Kerguelen and Heard Islands and the plateau. Before even arriving at this region, our co-chief, Vivianne Menezes was creating mean fields of these eddies along with one day a real-time image.

This region, and in particular the pathway of the Polar Front, are subjects of CTD-watchstander Natalie Freemans thesis research. She provided us with maps of mean frontal position (~station 034) and we hope to see real time figures once we get back to shore. Being in the Southern Ocean has the big disadvantage that our Internet bandwidth is low, making real-time anything difficult to obtain. One exception is weather. Our LADCP tech, Phil Mele, directed us to a website where we could download small (kbyte) 3-hour forecasts of winds and waves (Passageweather.com/download.htm). It was these maps that Seth Travis overlaid our track on, and these maps that kept us diligently moving northward as we worked to avoid a massive storm that would have caused even more delays.

At stations 039 and 040 we again had some issues with wire readout. We now found that the numbers in the lab were not the same as those seen by the winch. It was a initially thought that this particular problem could be fixed by a software reset, but to varying extents it continued throughout the rest of the cruise. As it got too confusing, it helped when the winch used LCI readout that lab could also see. Likewise, there were occasional glitches when winch's wire-out readout would fail completely. There was one other winch "feature" that began occurring regularly which was that on descent the winch would have to stop in order to slow down. This meant that console had to be particularly diligent in being early to give the slow down signal for the bottom approach.

At station 41 with 1.5 knots of current under us, and a lot of wire out, we had the ship go off station to correct the problem. But as we headed northward out of the Furious Fifties into the Roaring Forties, for the most part the casts went by uneventfully and we began to make up time as deck and winch grew more skillful with deployments and recoveries. Air tests were performed on the secondary transmissometer on stations 14, 37, 57 and 78. The computer running the Seabird software, which had been rebooted at station 020 (2/23) when dealing with an issue with the computer mouse, had to be rebooted again at station 049 (3/3) after it froze near the surface on the ascent. This same

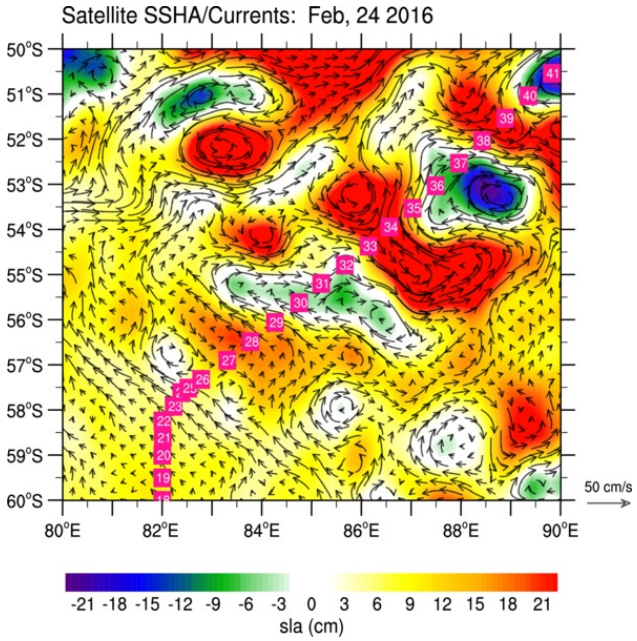



Fig. 2.4: Real-time image
Satellite sea surface anomaly and absolute geostrophic currents for Feb 24, 2016 (stations 021-026) based on near real-time altimetry data from IMOS. Pink squares show the I08S station positions. (V. Menezes)

freezing up of the console occurred at station 077 (3/10). We would suggest that in the future the computer be rebooted every day to avoid the issue.

On March 4, after station 054, the hangar was found to be slippery. We tried to clean it up but could not alleviate the problem, which only appeared to be getting worse. Once daylight was with us the engineers determined that it was a leak from a loose fitting on the CAST-6 hydraulics on the deck above. Both DOC and CDOM were carefully to clean all spigots before sampling. The crew to get the deck and hangar cleaned up.

In the first week of March as we moved into warmer climes the hydro-lab began having issues with rising temperatures. On 5 March the ship turned the air conditioning back on and appeared to have solved the issue. It certainly cooled off the computer lab.

On March 6th, by station 058 the wire was beginning to look damaged – showing small curve and raised strand outer armor. Using an abundance of caution as requested from land, the wire was mechanically reterminated. On station 059 recovery the Evergrip used in the termination slipped, the packaged slid down the wire hitting the boards and then teetering on the rail as the winch attempted to bring it in. It was brought under control and brought onboard. The students on the deck did a great job of holding the lines and the winch managed to pick it up and get it safely on the deck. A complete retermination was done before Station 60. Not only did all sensors check out after this incident, but the LADCP actually started working properly again. Also, this time it was night watchstanders who got the chance to learn about and participate in a retermination. We consider ourselves lucky as the glass salinity sensors could have easily broken and the two we still had available were not as good as those on the rosette.

We had started doing 40 nm spacing at station 051 (45.6°S), but the efficiency of the work as we continued using the CAST-6 system meant that we were making up time, allowing us to revert back to the 30 nm spacing or less until station 078. The captain gave us a drop-dead time of 06:00 (local) on 12 March for completing our final station. We finished up the last few subtropical casts using 36 nm spacing, making it through our final planned station at 28.3°S with 25 minutes to spare. The one loss on these few days of sampling was for CFCs, whose system broke down due to an overflow. Nevertheless, they got it up and running again and were able to fully sample the last few stations.

During our copious free time, along with maps of tracks and bottle spacing, we started to produce section plots. These

indicate strong CFC and SF6 signals in bottom and intermediate waters (see section plots). We also began some preliminary comparisons to the previous occupations of this line. Consistent with large-scale studies, there are strong warming and freshening signals visible in the bottom waters.

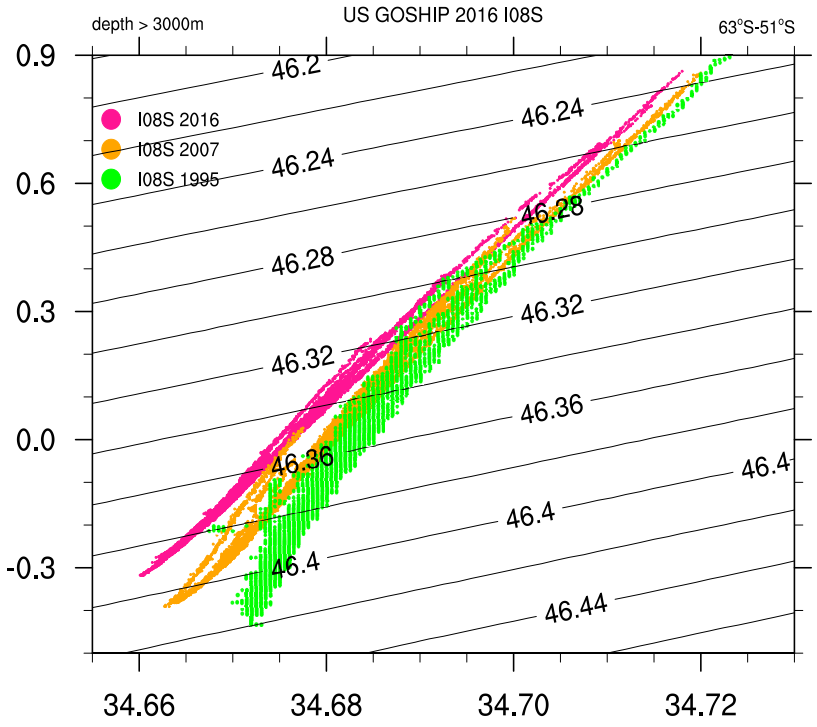



Fig. 2.5: Property-Property

Potential Temperature versus Salinity plot comparing data from the previous two occupations of I08s to the 2016 occupation. The data indicate strong warming and freshening between 63°S and 51°S (contours $\sigma 4$).

Our co-chief, Viviane Menezes put a substantial effort into a preliminary analysis of the temperature and salinity changes and we hope to have these results in the published literature soon.

As this report is being written we are in the midst of the 4–day transit back to Fremantle. Yesterday we had red-nose testing for those for whom this was the first Antarctic Circle crossing. In full penguin regalia the red-noses cleaned the refrigerators and galley, and made pizzas for lunch. Two penguins deployed XBTS and all penguins joined in a rousing rendition of the hit song, ICEBERG, written and arranged by our very own res-tech Josh Manger. By unanimous vote of a two-person panel the winning penguin was declared to be Mary Huey, a rock-hopper with pink feet and a uniquely slippery coat.

Along with writing documentation, we are once again deploying XBTs each day and will be doing some rearrangements of the lab spaces so make room for the new groups arriving with I9N. We are expecting to arrive outside Fremantle on the evening of the 15th, which should allow us to start unloading on 16 March as intended.

This cruise presented us all with challenges. We would like thank the officers and crew of the R/V Revelle who have

gone above and beyond to support the science of this expedition. They have worked with us every step of the way, to fix everything from the smallest detail to the greatest problems, all the while speeding us along so that we could sample the full line with minimal loss of data.

CHAPTER

THREE

# CTDO AND HYDROGRAPHIC ANALYSIS

## 3.1 CTDO and Bottle Data Acquisition

The CTD data acquisition system consisted of an SBE-11+ (V2) deck unit and a networked generic PC workstation running Windows 7 2009 SBE SeaSave v.7.18c software was used for data acquisition and to close bottles on the rosette.

CTD deployments were initiated by the console watch after the ship had stopped on station. The watch maintained a CTD Cast logs for each attempted cast containing a description of each deployment event.

Once the deck watch had deployed the rosette, the winch operator would lower it to 10 meters. The CTD exhaust line pumps were configured with a 10 second startup delay in addition to the necessity that salt water be present in the conductivity cells, and were usually on by this time. The console operator checked the CTD data for proper sensor operation, waited for sensors to stabilize, and then instructed the winch operator to bring the package to the surface in good weather and up to 5 meters below the surface in high seas. The winch was then instructed to lower the package to the initial target wire-out at no more than 30m/min to 100m and no more than 60m/min after 100m depending on sea cable tension and the sea state.

The console watch monitored the progress of the deployment and quality of the CTD data through interactive graphics and operational displays. The altimeter channel, CTD pressure, wire-out and center multibeam depth were all monitored to determine the distance of the package from the bottom. The winch was directed to slow decent rate to 30m/min 100m from the bottom and 10m/min 30m from the bottom. The maximum depth of the CTD cast was usually within 10-20 meters of the bottom depth determined by the altimeter data. For each up-cast, the winch operator was directed to stop the winch at up to 36 predetermined sampling pressures. These standard depths were staggered every station using 3 sampling schemes. The CTD console operator waited 30 seconds prior to tripping sample bottles, to ensure package shed-wake had dissipated. An additional 15 seconds elapsed before moving to the next consecutive trip depth, which allowed for the SBE35RT to record bottle trip temperature.

After the last bottle was closed, the console operator directed winch to recover the rosette. Once the rosette was on deck, the console operator terminated the data acquisition, turned off the deck unit and assisted with rosette sampling.

Additionally, the watch created a sample log for each deployment. Sample logs are used to record the depths of bottles tripped and serve as correspondence between rosette bottles and analytical samples drawn.

Normally the CTD sensors were rinsed after each station using syringes fitted with Tygon tubing and filled with a fresh solution of dilute Triton-X in de-ionized water. The syringes were left on the CTD between casts, with the temperature and conductivity sensors immersed in the rinsing solution.

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. The bottles and rosette were examined before samples were drawn. Any abnormalities were noted on the sample log, stored in the cruise database and reported in the APPENDIX.

## 3.2 CTDO Data Processing

Shipboard CTD data processing was performed after deployment using SIO/ODF CTD processing software v.5.1.0. CTD acquisition data were copied onto the Linux system and database, then processed to a 0.5-second time-series. CTD data at bottle trips were extracted, and a 2-decibar down-cast pressure series created. The pressure series data set was submitted for CTD data distribution.

A total of 88 CTD casts were made including one test cast, 4 aborted casts and 83 successful CTD casts. The 36-place (CTD #401) rosette was used on the test station 998 and from station 1 to station 13. The 36-place (CTD #831) rosette was used from station 14 to station 83

CTD data were examined at the completion of each deployment for clean corrected sensor response and any calibration shifts. As bottle salinity and oxygen results became available they were used to refine shipboard conductivity and oxygen sensor calibrations.

Temperature, salinity and dissolved $O_2$ comparisons were made between down and up casts as well as between groups of adjacent deployments. Vertical sections of measured and derived properties from sensor data were checked for consistency.

A number of issues were encountered during I08S-2016 that directly impacted CTD analysis. Low surface air temperatures caused total ice blockage in primary plumb line of CTD on station/cast 2/2. Station/cast 2/2 was terminated to clear plumb lines and the station work resumed with 2/3. A similar partial ice blockage occurred on station 4/1 and cleared a few hundred meters from the surface. The loss of our primary rosette system (CTD #401) occurred during recovery of the package on station 14. Deployments resumed from the Markey DESH-5 winch deployment system after a back-up package (CTD #831) could be constructed on station 14. The LCI-90i interface and DESH-5 system was used from station 14-38 and that system had communication issues as well as possible drum slip issues on station/cast 038/01 at 4450-4470 dbar. The cast 038/01 was paused to analyze the LCI-90 and DESH-5 communications, which compromised the stability of the CTDO signal and that section of data was coded questionable. Winch stops on CTDO down-cast were also noted on several stations where the CAST6 system was put back into use. The CAST6 system was frequently stopped between on bottom approach from 60m/min to 30 m/min transition to put the automated control into manual mode. Only station 059/01 from 3530-3590 and station 065/02 from 4000-4040 appeared to have compromised data sections due to the auto manual transition, and those sections were also coded questionable. One station had a sizable signal inversion in oxygen and conductivity from 2350 to 2390 dbar. The inversion was filtered and coded on the data as well. High seas and negative winch tensions during operations prompted CTD acquisition team to trip bottles without the standard delay observed at trip levels ("tripping on the fly") on the up-cast for stations 33-37. Trip levels that appeared to be negatively impacted by "tripping on the fly" were quality flagged and recorded in APPENDIX.

## 3.3 Pressure Analysis

Laboratory calibrations of CTD pressure sensors were performed prior to the cruise. Dates of laboratory calibration are recorded on the underway sampling package table and calibration documents are provided in the APPENDIX.

The Paroscientific Digiquartz pressure transducer S/N: 401-59916 and S/N: 831-99677 were both calibrated on November 17th, 2015 at the SIO/ Calibration Facility. The lab calibration coefficients provided on the report were used to convert frequencies to pressure. Initially SIO/ pressure lab calibration slope and offsets coefficients were applied to cast data. A shipboard calibration offset was applied to the pressure signal during each cast. These offsets were determined by the on-deck pre- and post-cast pressure offsets. The pressure offsets were applied per configuration cast sets.

- CTD Serial 401-59916; Station Set 1-13

| | Start P (dbar) | End P (dbar) |
|---|---|---|
| Min | -0.2 | -0.3 |
| Max | 2.5 | -0.1 |
| Average | 0.164286 | -0.214286 |
| Applied Offset | | -0.06 |

- CTD Serial 831-99677; Station Set 14-83

| | Start P (dbar) | End P (dbar) |
|---|---|---|
| Min | -0.5 | -0.5 |
| Max | 0.3 | 0.5 |
| Average | -0.0695652 | -0.114493 |
| Applied Offset | | 0.1 |

Pre- and post-cast on-deck pressure offsets for CTD 401 varied from -0.2 to +2.5 dbar before the casts, and -0.3 to -0.1 dbar after the casts. An offset of -0.06 was applied to every cast performed by CTD 401. Pre- and post-cast on-deck pressure offsets for CTD 831 varied from -0.5 to +0.3 dbar before the casts, and -0.5 to +0.5 dbar after the casts. An offset of 0.1 was applied to every cast performed by CTD 831.

## 3.4 Temperature Analysis

Laboratory calibrations of temperature sensors were performed prior to the cruise at the SIO/ Calibration Facility. Dates of laboratory calibration are recorded on the 'Underway Sampling Package' table and calibration documents are provided in the APPENDIX.

The pre-cruise laboratory calibration coefficients were used to convert SBE3plus frequencies to 90 temperature. Additional shipboard calibrations were performed to correct sensor bias. Two independent metrics of calibration accuracy were used to determine sensor bias. At each bottle closure, the primary and secondary temperature were compared with each other and with a SBE35RT reference temperature sensor.

The SBE35RT Digital Reversing Thermometer is an internally-recording temperature sensor that operates independently of the CTD. The SBE35RT was located equidistant between the two SBE3plus temperature sensors. 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(deC/year. The SBE35RT was set to internally average over a 5 second period.

A functioning SBE3plus sensor typically exhibit a consistent predictable well modeled response. The response model is second order with respect to pressure, a first order with respect to temperature and a first order with respect to time. The functions used to apply shipboard calibrations are as follows.

$$T_{cor} = T + D_1 P_2 + D_2 P + D_3 T_2 + D_4 T + \text{Offset}$$

$$T_{90} = T + tp_1 P + t_0$$

$$T_{90} = T + aP_2 + bP + cT_2 + dT + \text{Offset}$$

Corrected temperature differences are shown in figures *SBE35RT-T1 by station (-0.01°C T1-T2 0.01°C).* through *T1-T2 by pressure (-0.01°C T1-T2 0.01°C).*

The 95% confidence limits for the mean low-gradient (where -0.01°C $\leq$ T1-T2 $\leq$ 0.01°C) differences are $\pm$0.0049°C for SBE35RT-T1, $\pm$0.0052°C for SBE35RT-T2 and $\pm$0.0042°Cfor T1-T2. The 95% confidence limits for the deep temperature residuals (where pressure $\geq$ 2000dbar) are $\pm$0.00083°C for SBE35RT-T1, $\pm$0.00096°C for SBE35RT-T2 and $\pm$0.00088°C for T1-T2.

No problems were encountered with the temperature sensors used for this cruise. The SBE35RT memory bank was full for stations 75/1 bottle 36 to station 78/1 bottle 21. Data was not reported from the SBE35RT for that section.

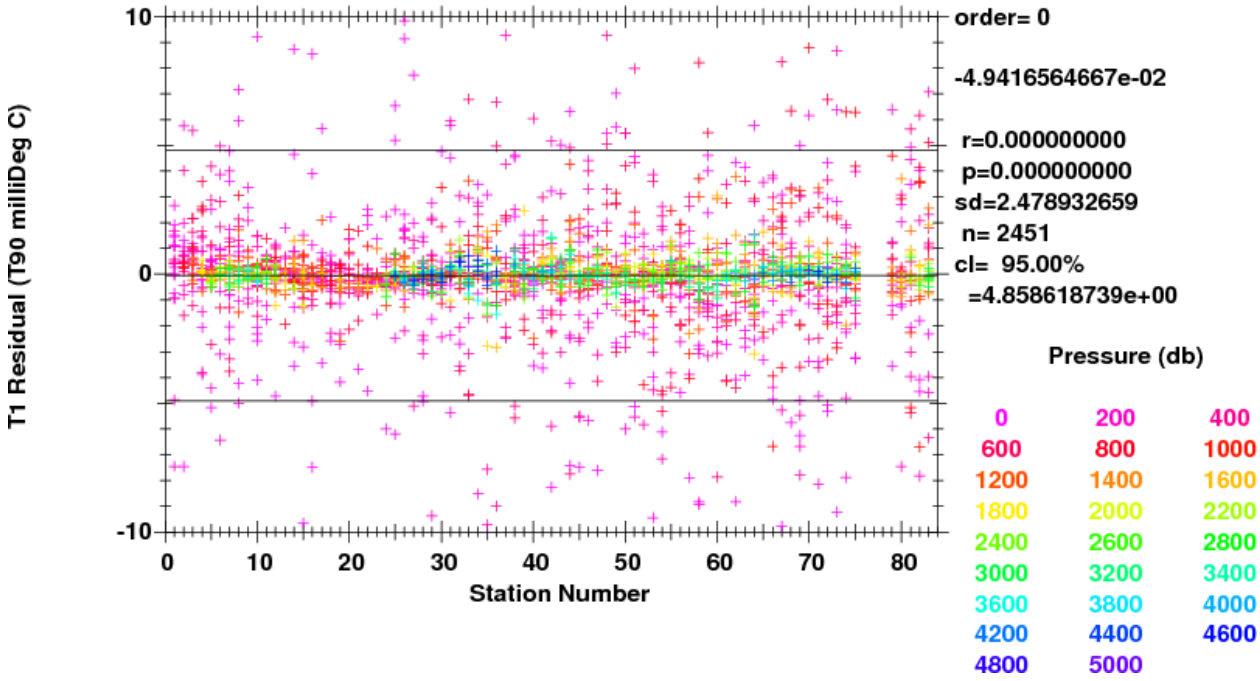



Fig. 3.1: SBE35RT-T1 by station (-0.01°C $\leq$ T1-T2 $\leq$ 0.01°C).

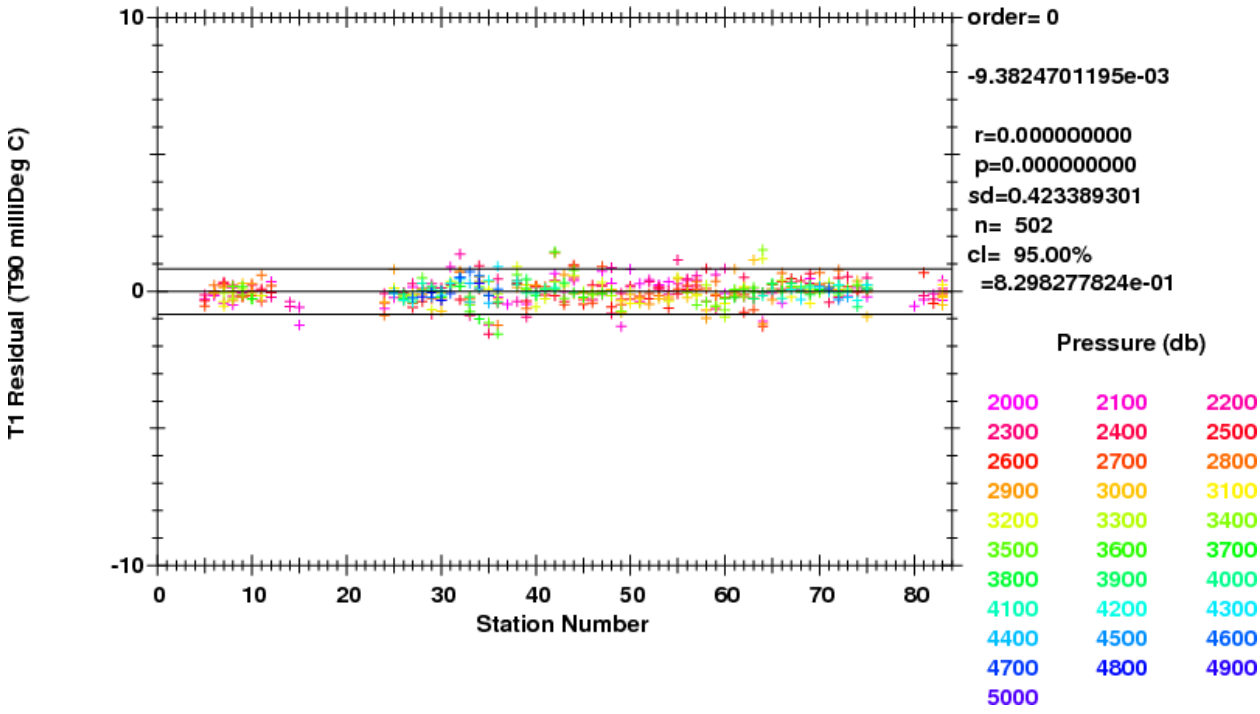



Fig. 3.2: Deep SBE35RT-T1 by station (Pressure $\geq$ 2000dbar).

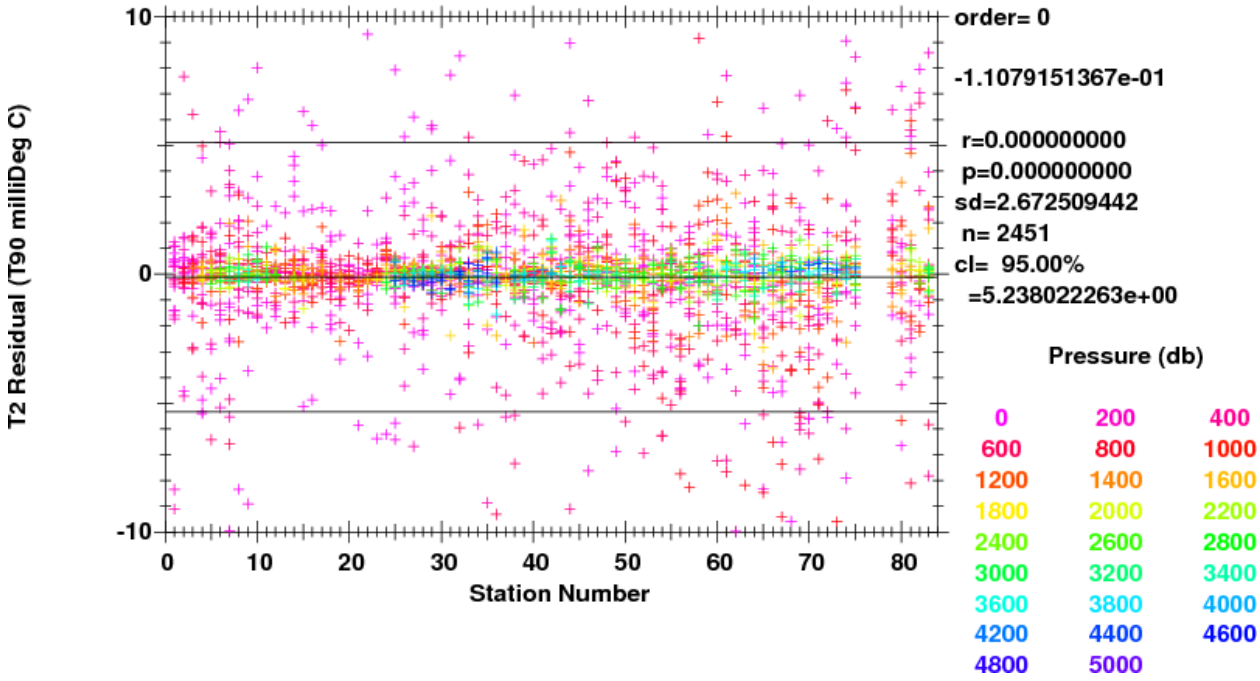



Fig. 3.3: SBE35RT-T2 by station (-0.01°C $\leq$ T1-T2 $\leq$ 0.01°C).

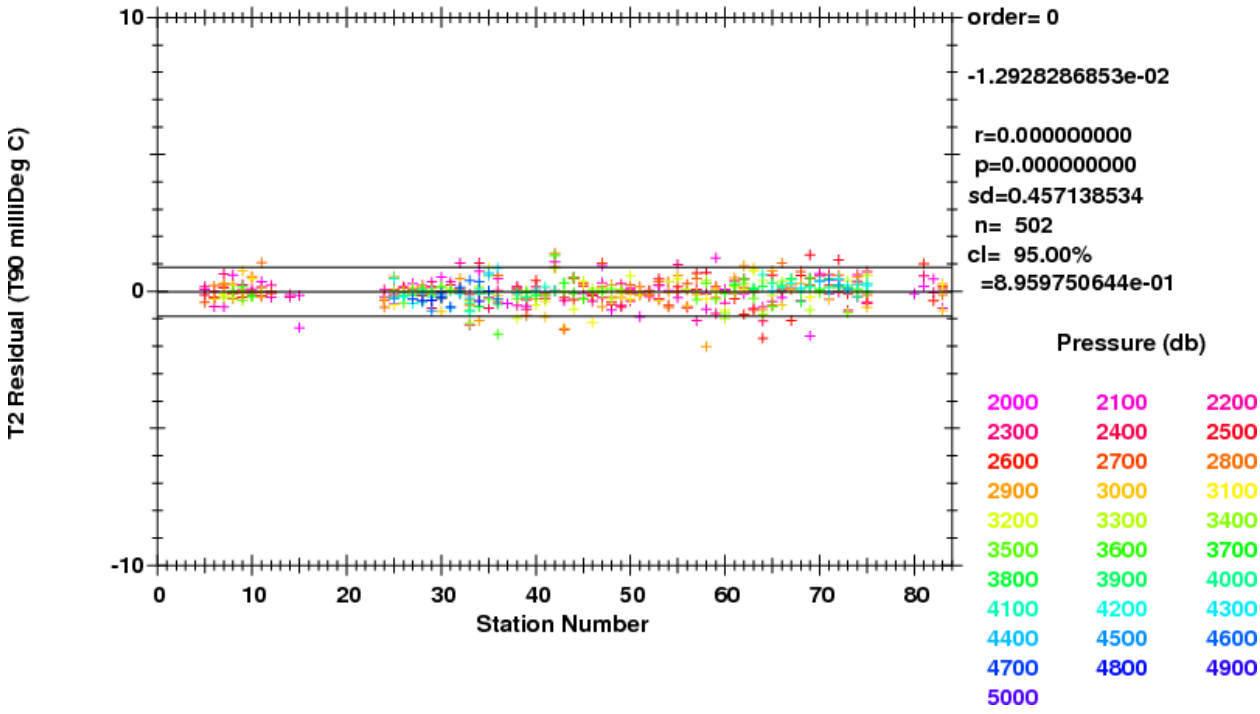



Fig. 3.4: Deep SBE35RT-T2 by station (Pressure $\geq$ 2000dbar).

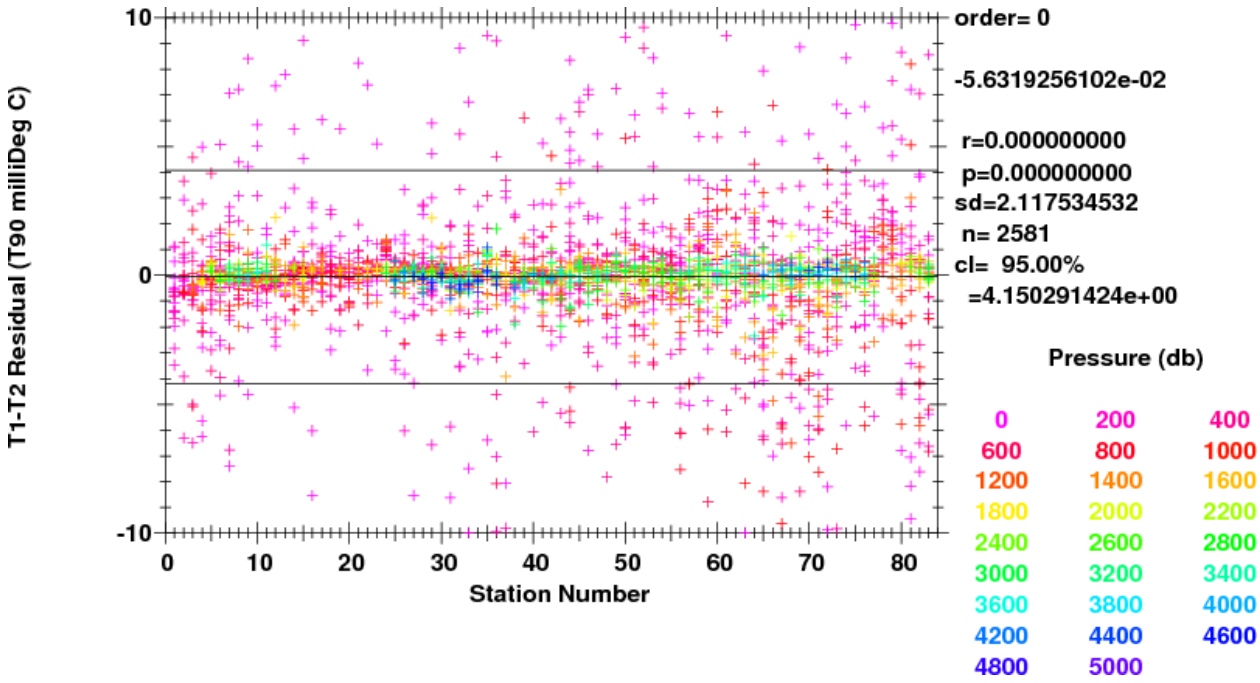



Fig. 3.5: T1-T2 by station (-0.01°C $\leq$ T1-T2 $\leq$ 0.01°C).

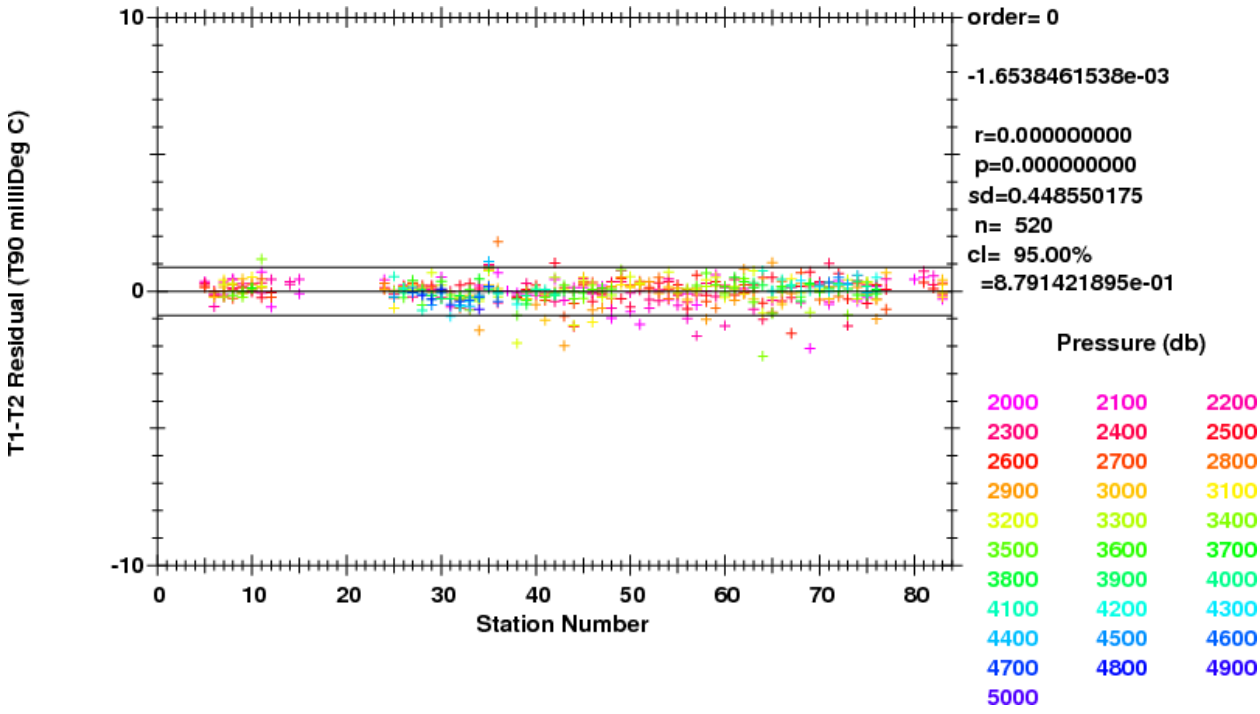



Fig. 3.6: Deep T1-T2 by station (Pressure $\geq$ 2000dbar).

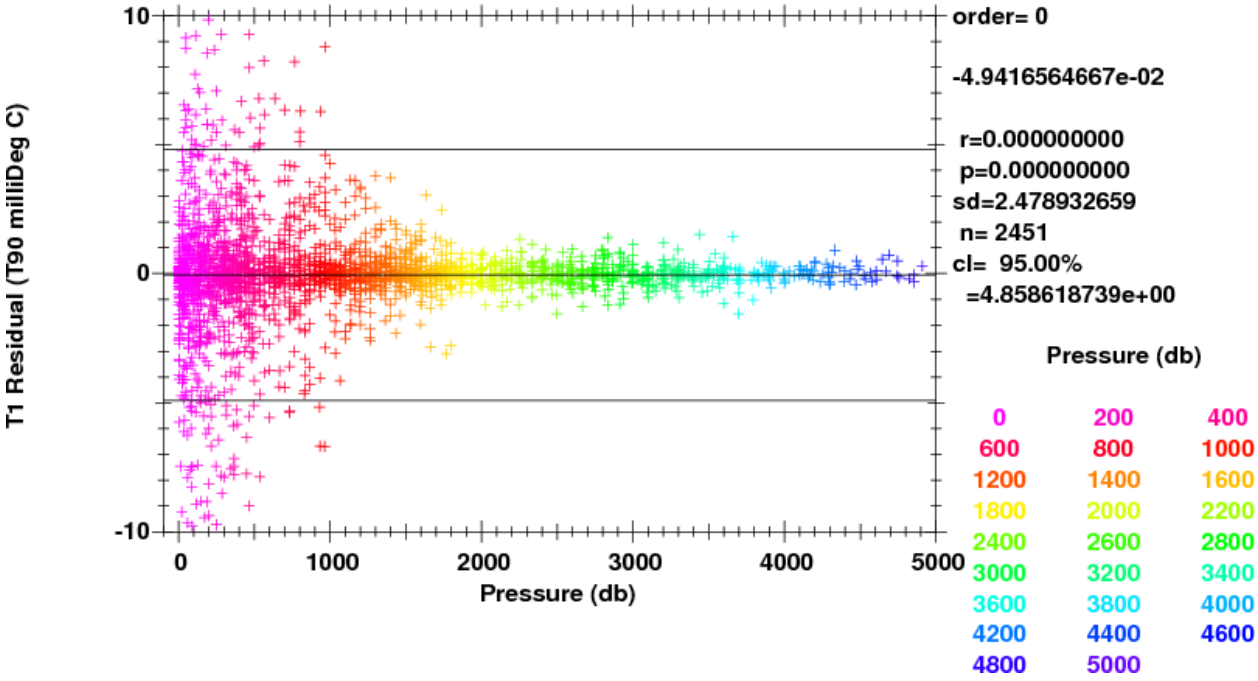



Fig. 3.7: SBE35RT-T1 by pressure (-0.01°C ≤ T1-T2 ≤ 0.01°C).

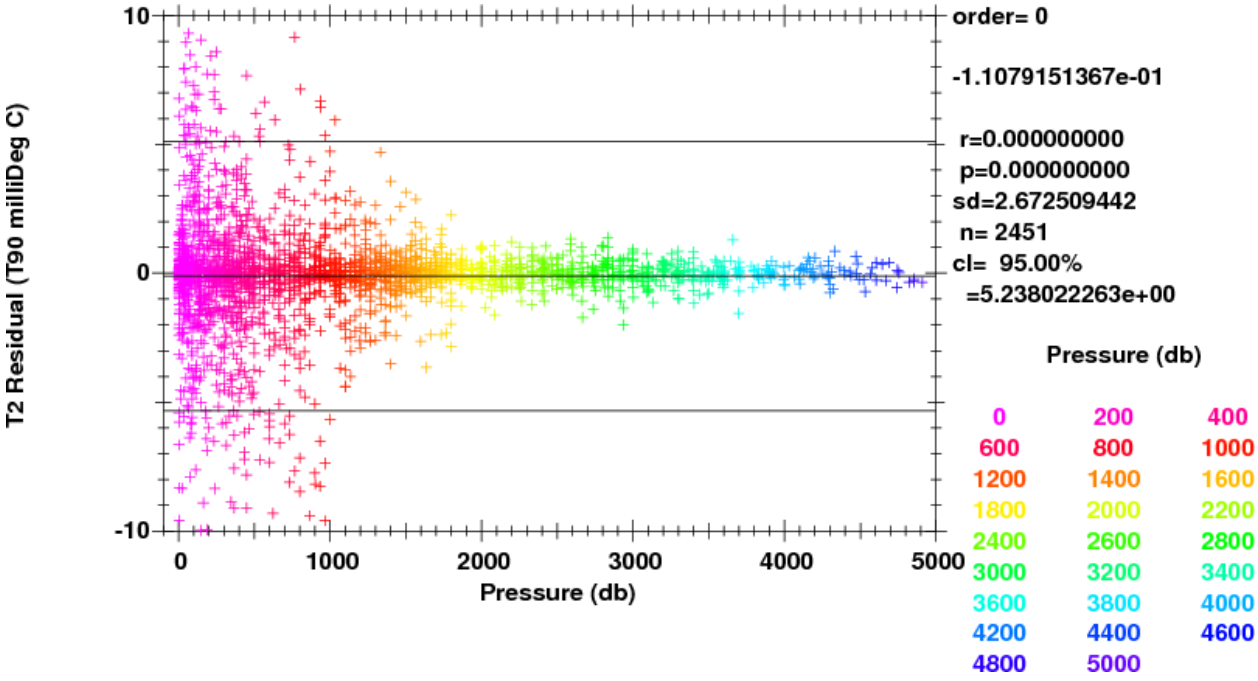



Fig. 3.8: SBE35RT-T2 by pressure (-0.01°C ≤ T1-T2 ≤ 0.01°C).

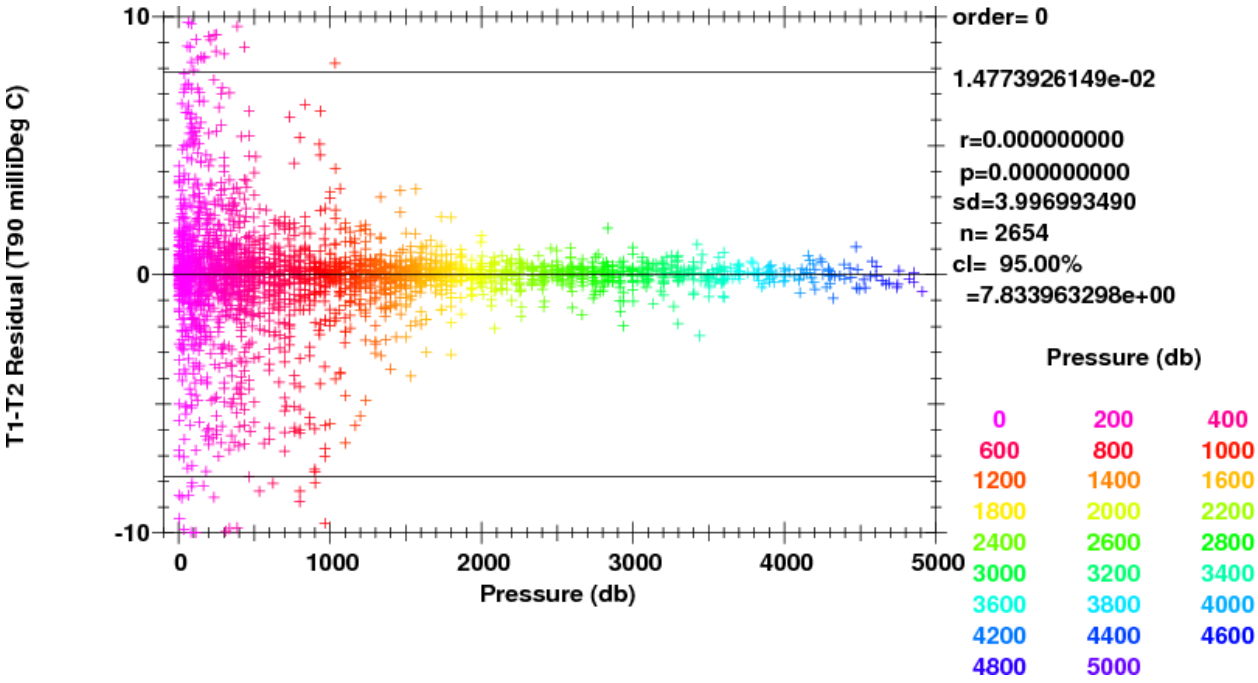



Fig. 3.9: T1-T2 by pressure (-0.01°C $\leq$ T1-T2 $\leq$ 0.01°C).

## 3.5 Conductivity Analysis

Laboratory calibrations of conductivity sensors were performed prior to the cruise at the SeaBird Calibration Facility. Dates of laboratory calibrations are recorded on the underway sampling package table and calibration documents are provided in the APPENDIX.

The pre-cruise laboratory calibration coefficients were used to convert SBE4C frequencies to mS/cm conductivity values. Additional shipboard calibrations were performed to correct sensor bias. Corrections for both pressure and 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 to reduce the contamination of conductivity comparisons by package wake. The coherence of this relationship is shown in the following figure.

Uncorrected conductivity comparisons are shown in figures *Uncorrected CBottle - C1 by station (-0.01°C T1-T2 0.01°C).* through *Uncorrected C1-C2 by station (-0.01°C T1-T2 0.01°C).*.

A functioning SBE4C sensor typically exhibit a predictable modeled response. Offsets for each C sensor were determined using $C_{Bottle}$ - $C_{CTD}$ differences in a deeper pressure range (500 or more dbars). After conductivity offsets were applied to all casts, response to pressure, temperature and conductivity were examined for each conductivity sensor. The response model is second order with respect to pressure, a first order with respect to temperature, first order with respect to conductivity and a first order with respect to time. The functions used to apply shipboard calibrations are as follows.

The residual conductivity differences after correction are shown in figures *Corrected CBottle - C1 by station (-0.01°C T1-T2 0.01°C).* through *Corrected C1-C2 by conductivity (-0.01°C T1-T2 0.01°C).*.

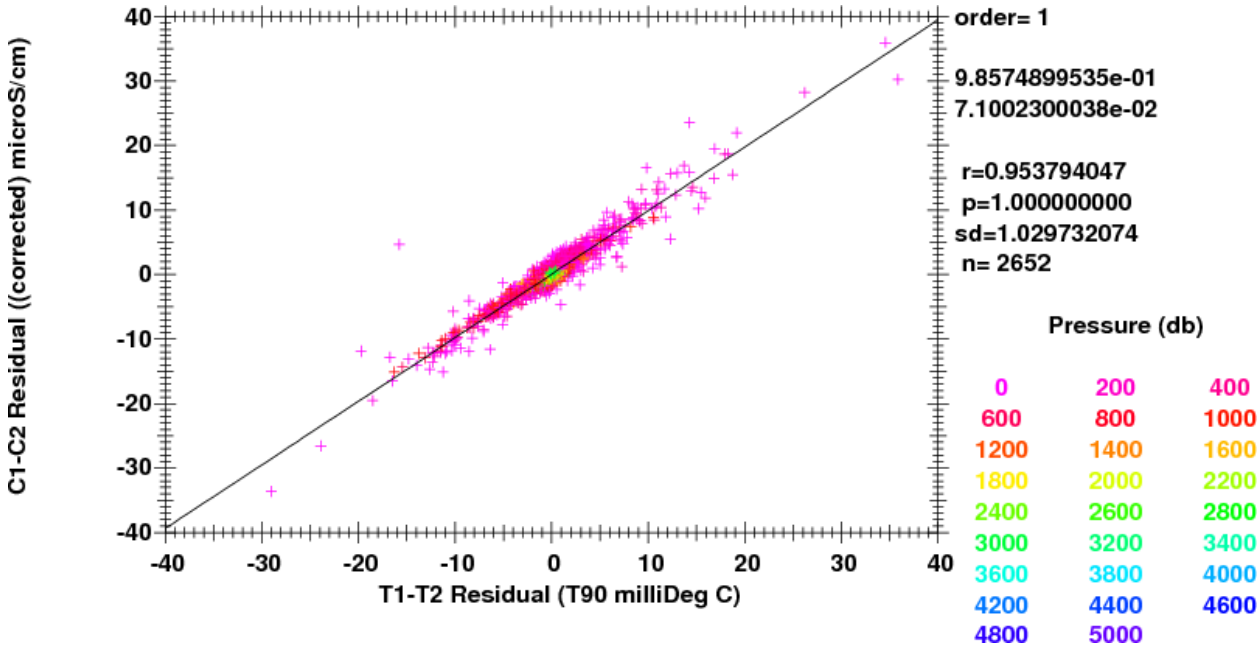



Fig. 3.10: Coherence of conductivity differences as a function of temperature differences.

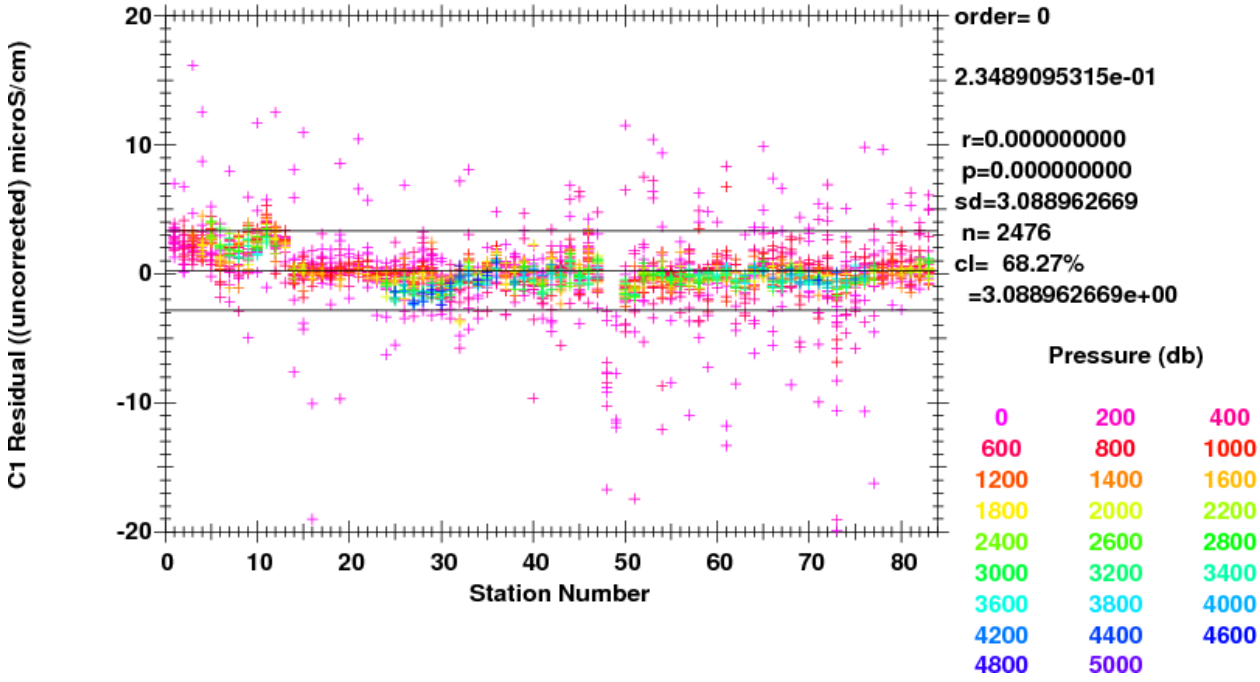



Fig. 3.11: Uncorrected $C_{Bottle}$ - C1 by station (-0.01°C $\leq$ T1-T2 $\leq$ 0.01°C).

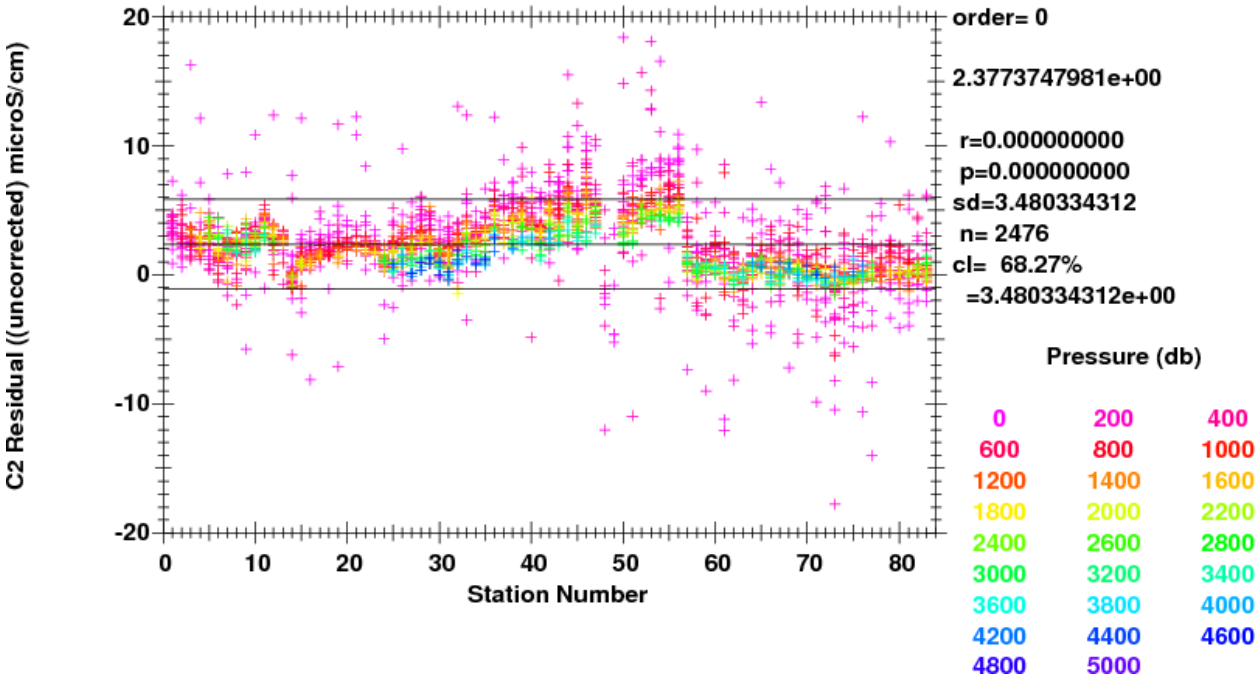



Fig. 3.12: Uncorrected $C_{Bottle}$ - C2 by station (-0.01°C $\leq$ T1-T2 $\leq$ 0.01°C).

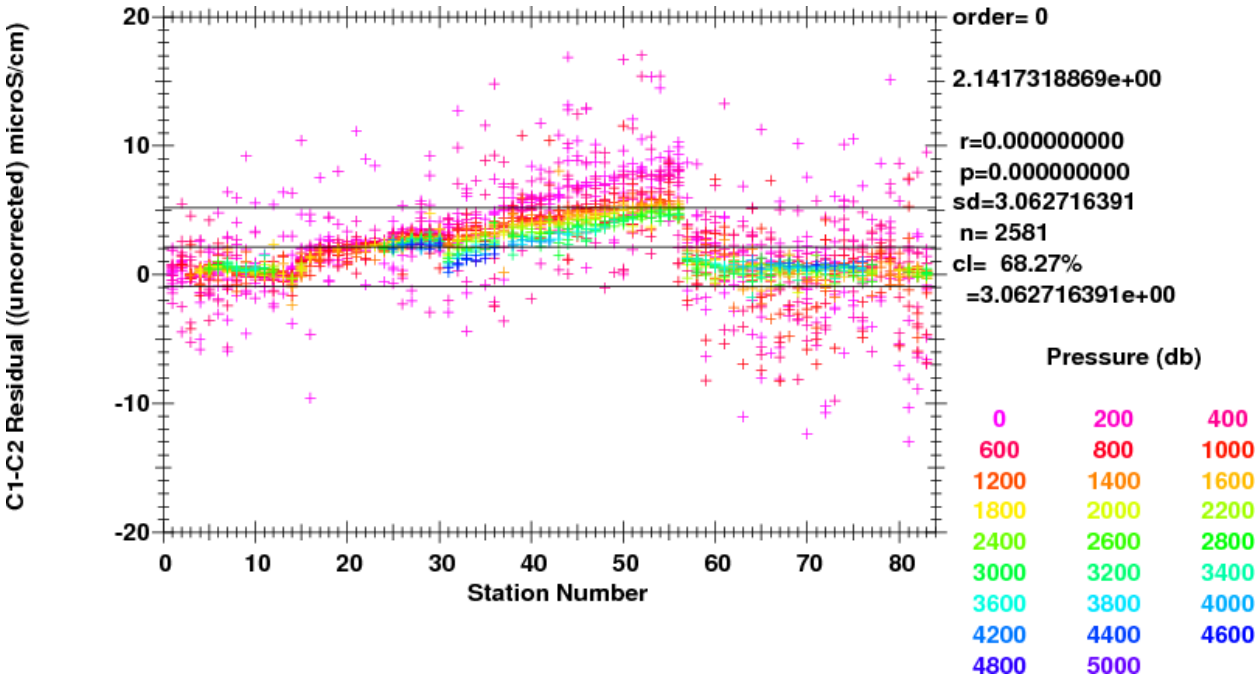



Fig. 3.13: Uncorrected C1-C2 by station (-0.01°C $\leq$ T1-T2 $\leq$ 0.01°C).

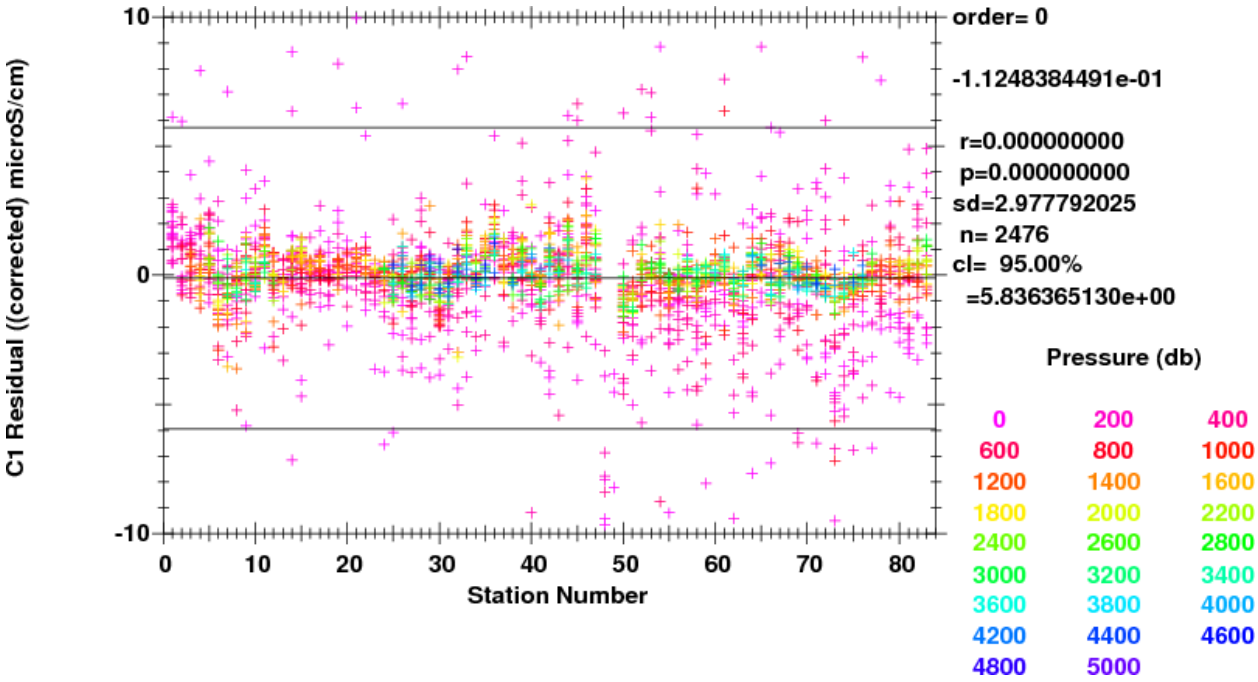



Fig. 3.14: Corrected $C_{Bottle}$ - C1 by station (-0.01°C $\leq$ T1-T2 $\leq$ 0.01°C).

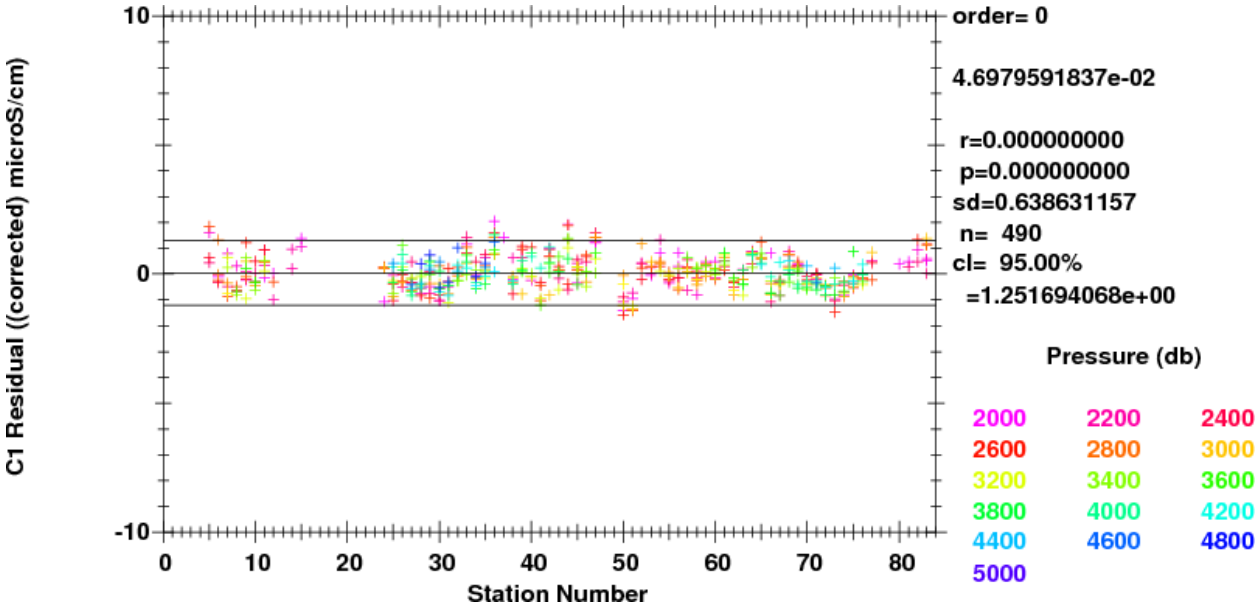



Fig. 3.15: Deep Corrected $C_{Bottle}$ - C1 by station (Pressure >= 2000dbar).

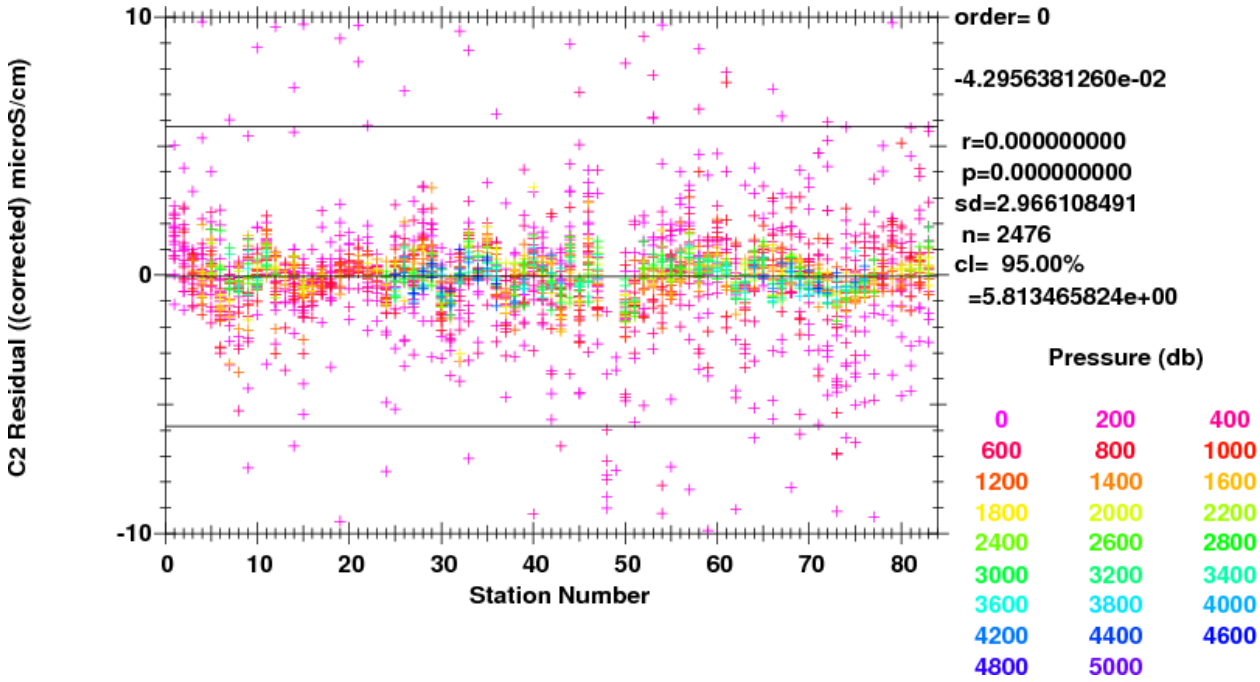



Fig. 3.16: Corrected $C_{Bottle}$ - C2 by station (-0.01°C $\leq$ T1-T2 $\leq$ 0.01°C).

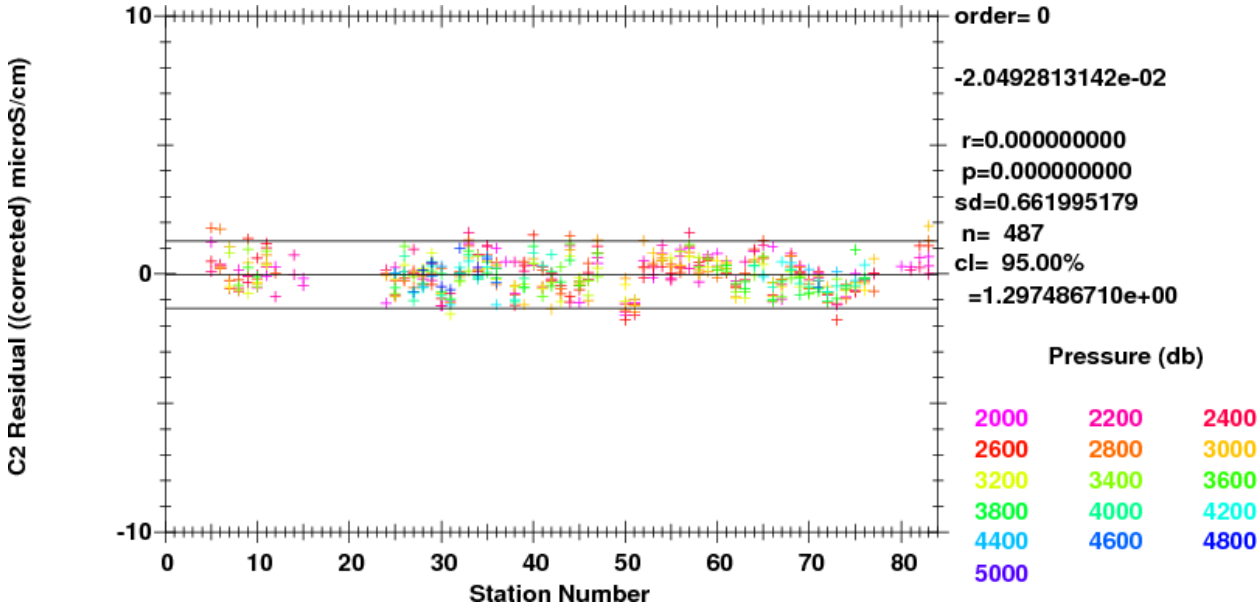



Fig. 3.17: Deep Corrected $C_{Bottle}$ - C2 by station (Pressure >= 2000dbar).

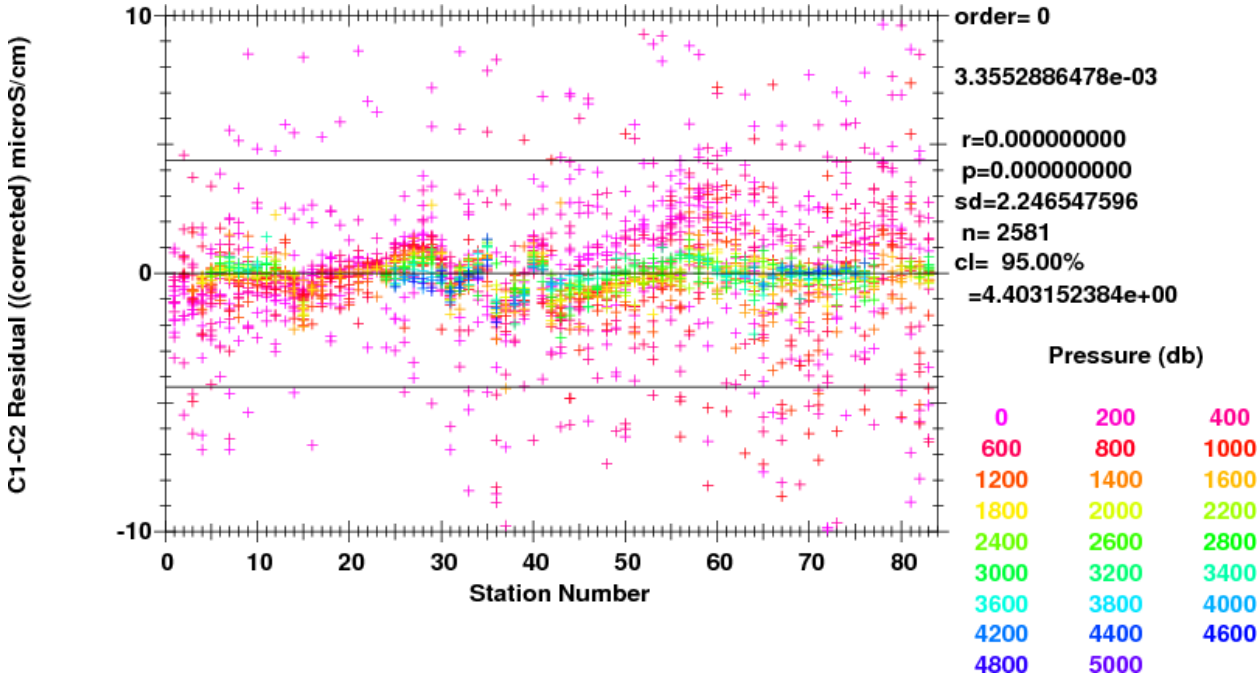



Fig. 3.18: Corrected C1-C2 by station (-0.01°C $\leq$ T1-T2 $\leq$ 0.01°C).

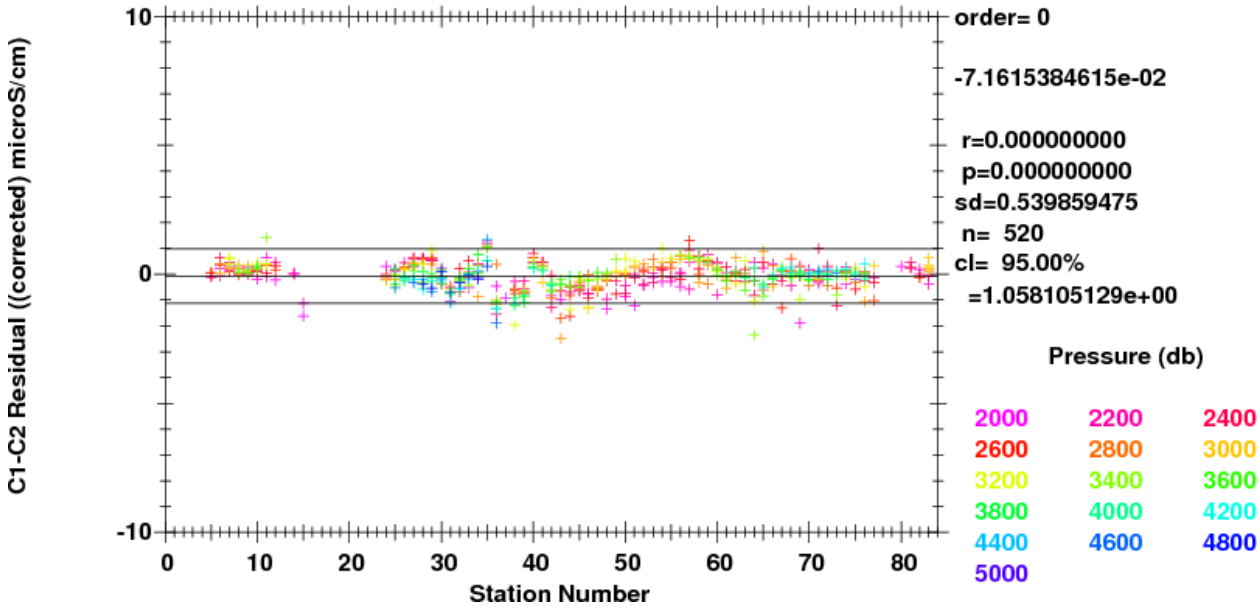



Fig. 3.19: Deep Corrected C1-C2 by station (Pressure >= 2000dbar).

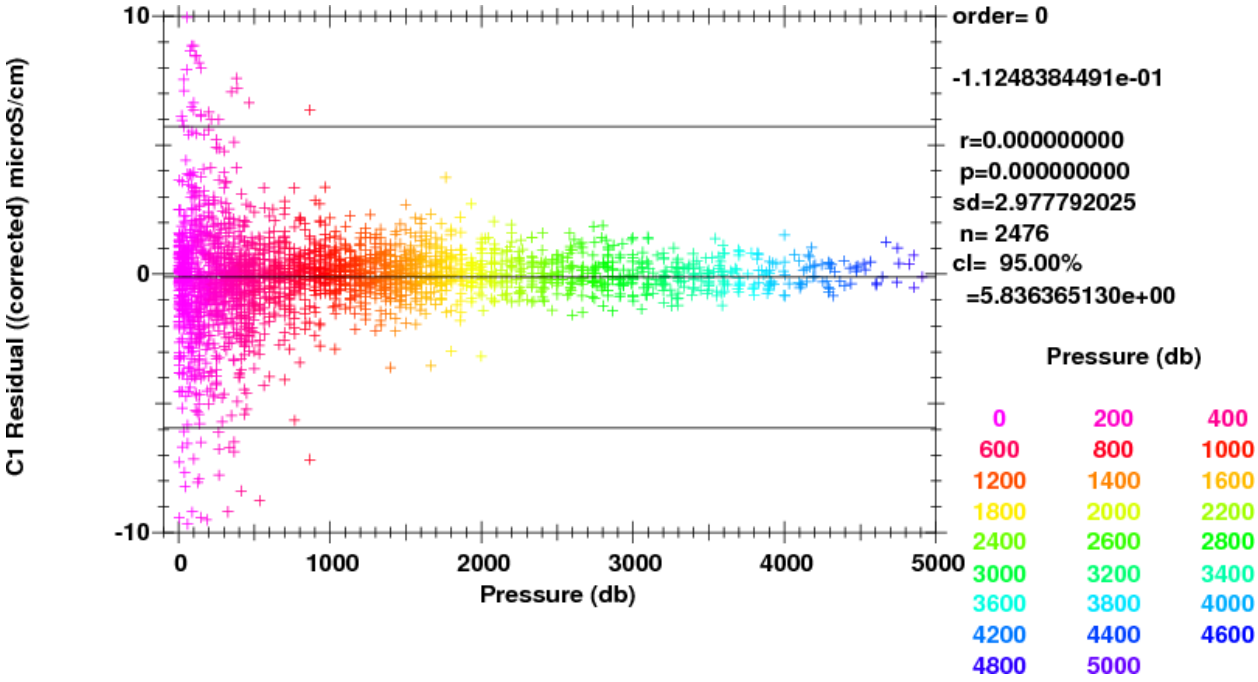



Fig. 3.20: Corrected $C_{Bottle}$ - C1 by pressure (-0.01°C $\leq$ T1-T2 $\leq$ 0.01°C).

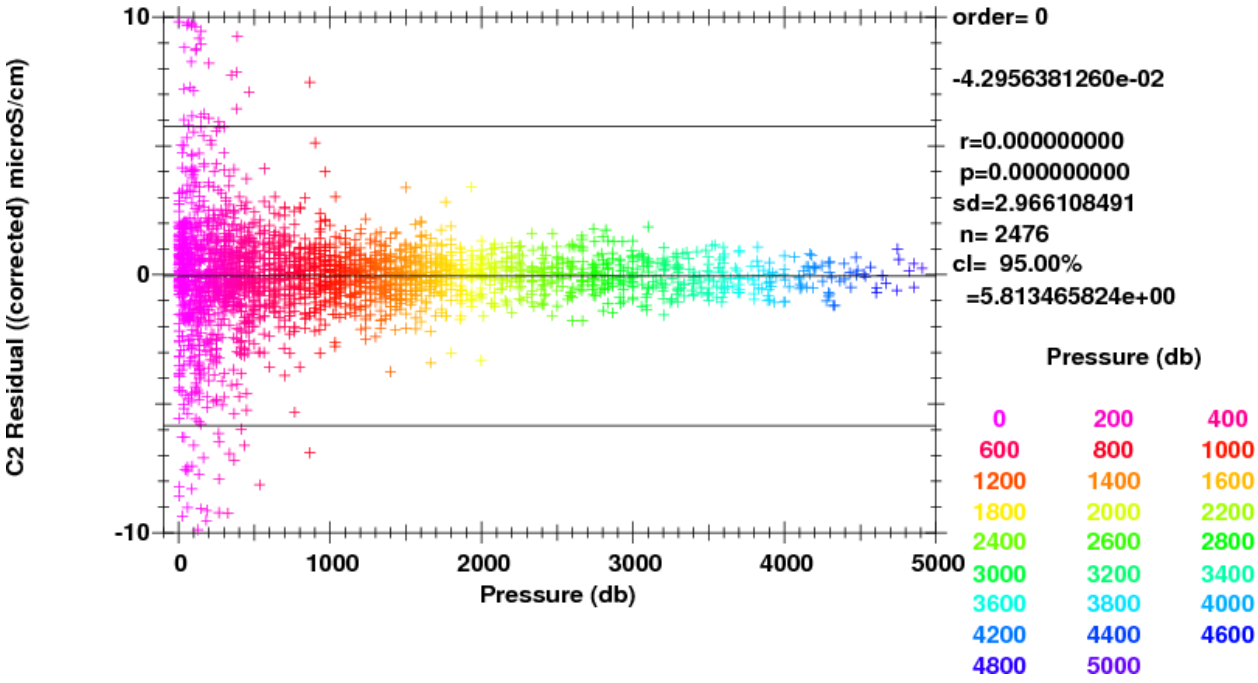



Fig. 3.21: Corrected $C_{Bottle}$ - C2 by pressure (-0.01°C $\leq$ T1-T2 $\leq$ 0.01°C).

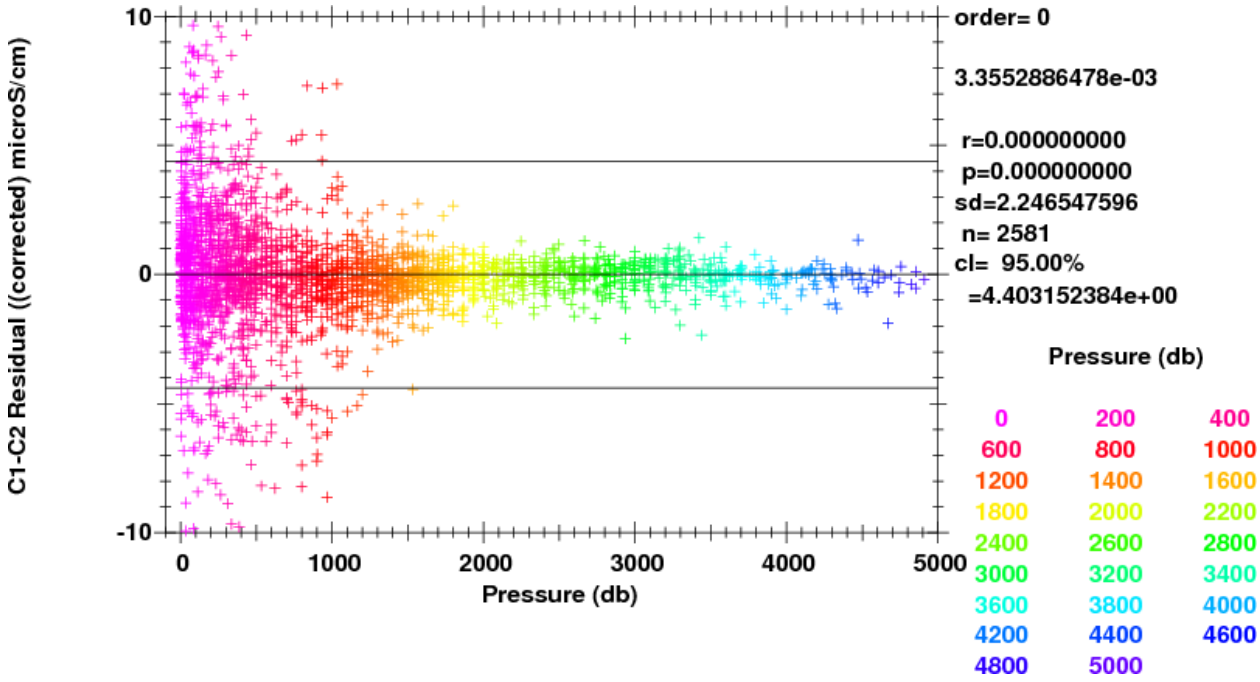



Fig. 3.22: Corrected C1-C2 by pressure (-0.01°C $\leq$ T1-T2 $\leq$ 0.01°C).

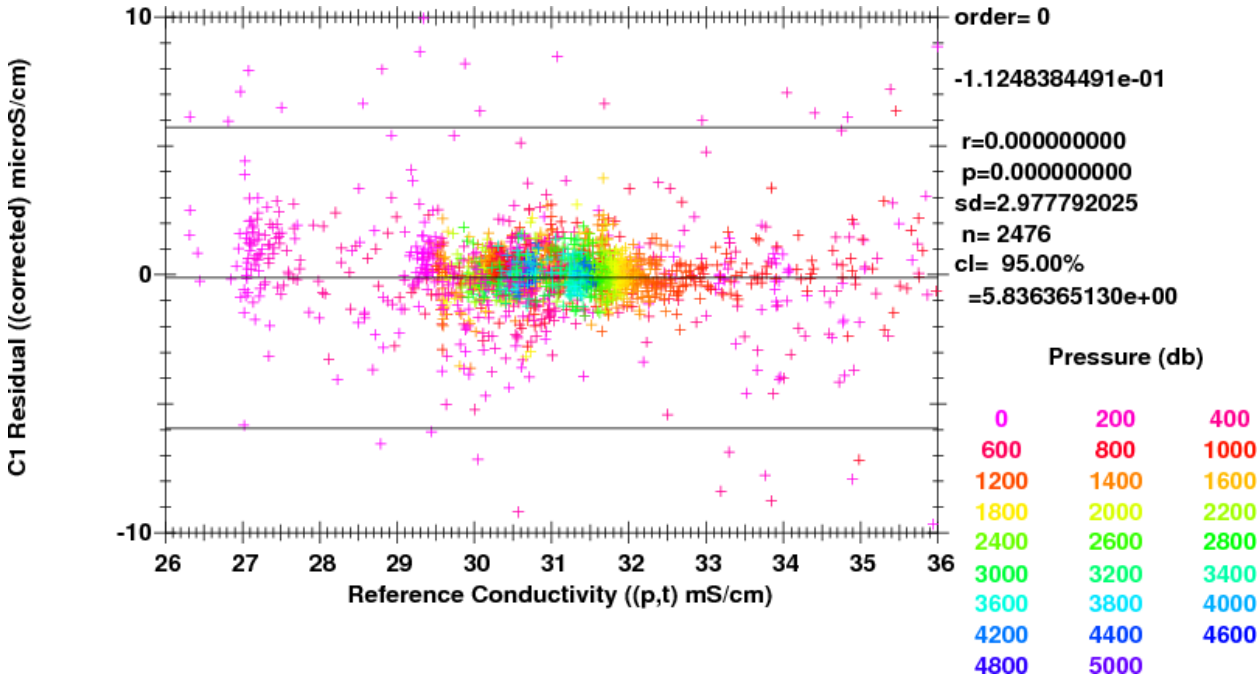



Fig. 3.23: Corrected $C_{Bottle}$ - C1 by conductivity (-0.01°C $\leq$ T1-T2 $\leq$ 0.01°C).

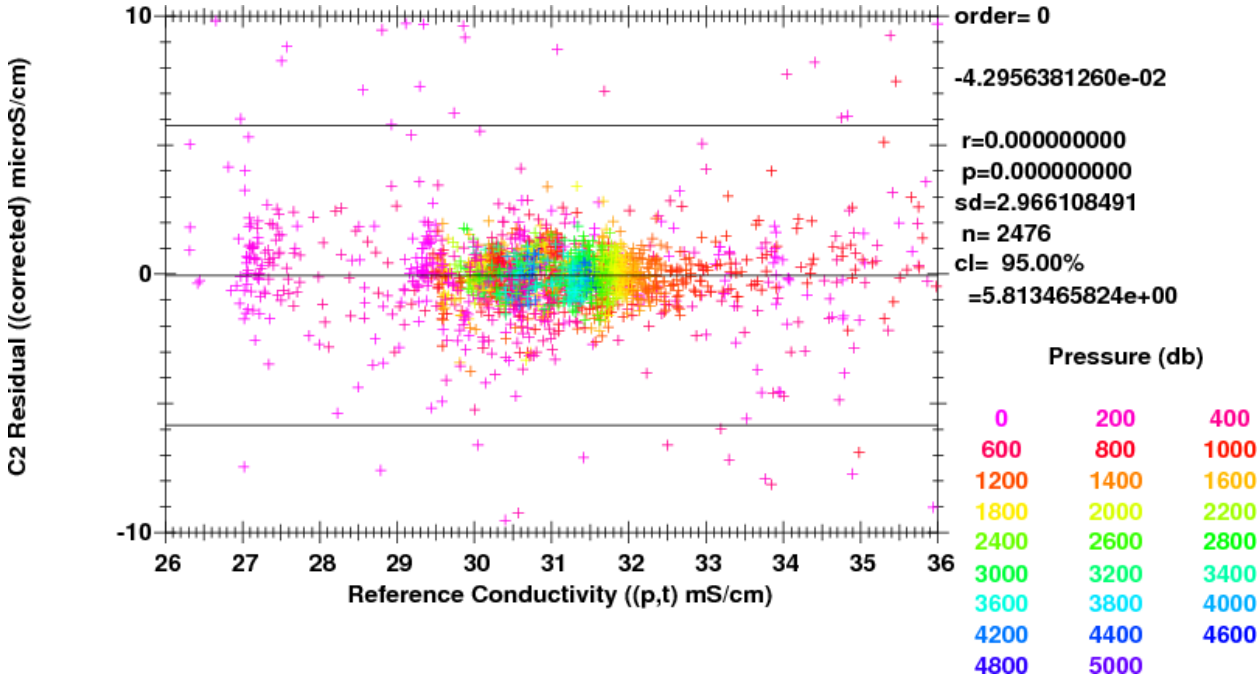



Fig. 3.24: Corrected $C_{Bottle}$ - C2 by conductivity (-0.01°C $\leq$ T1-T2 $\leq$ 0.01°C).

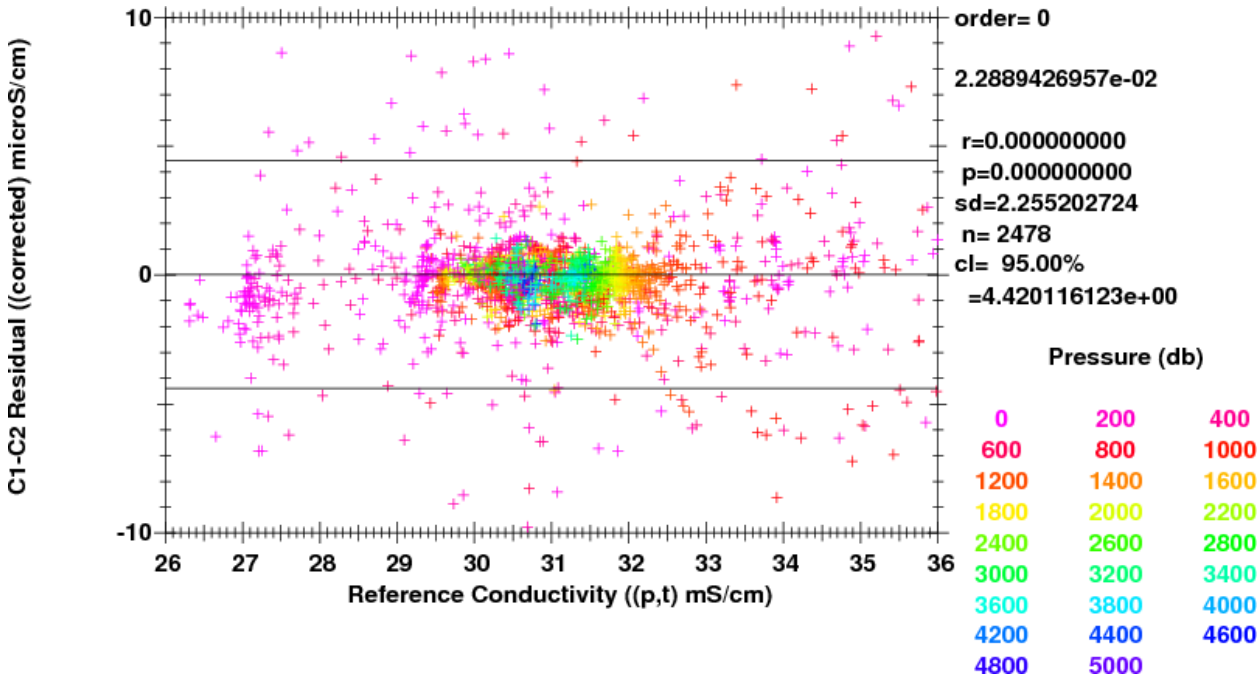



Fig. 3.25: Corrected C1-C2 by conductivity (-0.01°C $\leq$ T1-T2 $\leq$ 0.01°C).

Corrections made to all conductivity sensors had the form:

$$C \ : sub : `cor` = C + cp \ : sub : `2` P \ : sup : `2` + cp \ : sub : `1` P + c \ : sub : `1` C + c \ : sub : `0`$$

Salinity residuals after applying shipboard P/T/C corrections are summarized in the following figures. Only CTD and bottle salinity data with "acceptable" quality codes are included in the differences. Quality codes and comments are also published in APPENDIX.

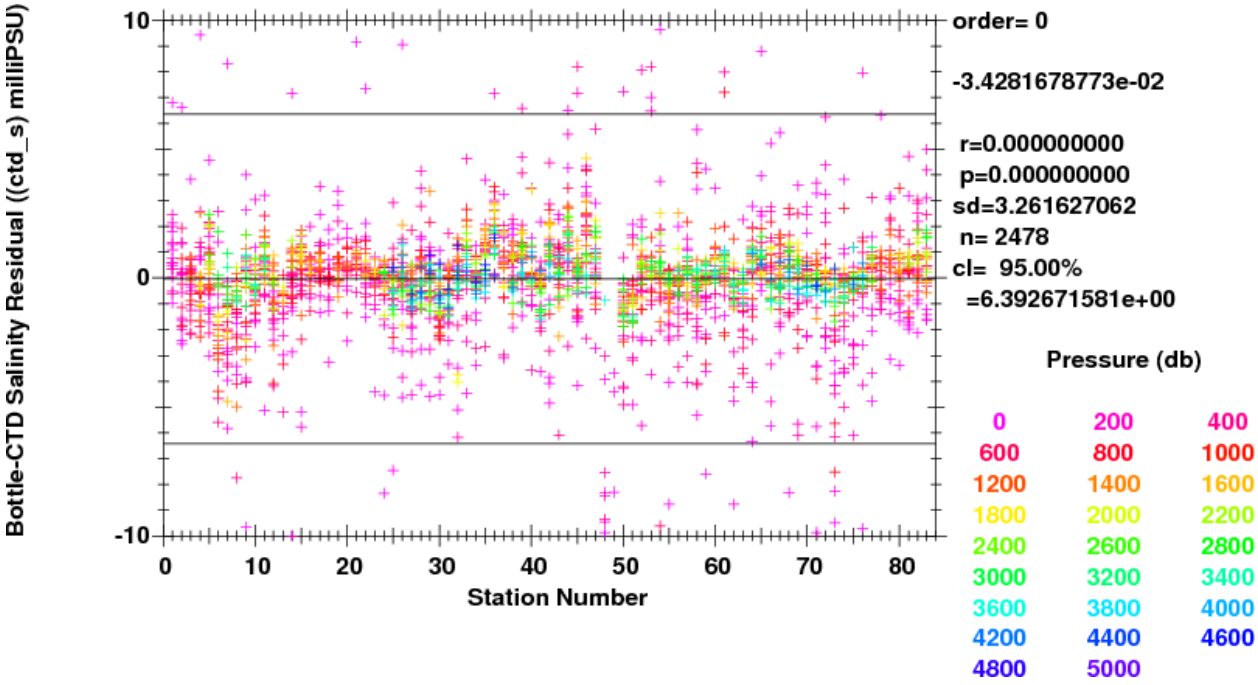



Fig. 3.26: Salinity residuals by station (-0.01°C $\leq$ T1-T2 $\leq$ 0.01°C).

The 95% confidence limits for the mean low-gradient (where -0.01°C $\leq$ T1-T2 $\leq$ 0.01°C) differences are $\pm$0.0064°C for salnity-C1. The 95% confidence limits for the deep salinity residuals (where pressure $\geq$ 2000dbar) are $\pm$0.00016 for salinity-C1.

A number of issues affected conductivity and calculated CTD salinities during this cruise. After the loss of the initial package on station 14 a new package was constructed with new instrumentation. The secondary conductivity (SBE4C: 42023) was used from station 14-56. C2:42023 was replaced after its data drifted at a non-linear rate that was not in accordance with manufacturing specifications. As the cruise progressed North the temperatures in the Hydro-Lab, where discrete salinity samples were analyzed, became unstable. Samples data from station 48 bottle 2 through bottle 23 and station 49 bottle 1 through bottle 29 were considered unusable for comparison.

## 3.6 CTD Dissolved Oxygen

Laboratory calibrations of the dissolved oxygen sensors were performed prior to the cruise at the SeaBird Calibration Facility. Dates of laboratory calibration are recorded on the underway sampling package table and calibration documents are provided in the APPENDIX.

The pre-cruise laboratory calibration coefficients were used to convert SBE43 frequencies to µmol/kg oxygen values for acquisition only. Additional shipboard fittings were performed to correct for the sensors non-linear response. Corrections for pressure, temperature and conductivity sensors were finalized before analyzing dissolved oxygen data. The SBE43 sensor data were compared to dissolved $O_2$ check samples taken at bottle stops by matching the down cast

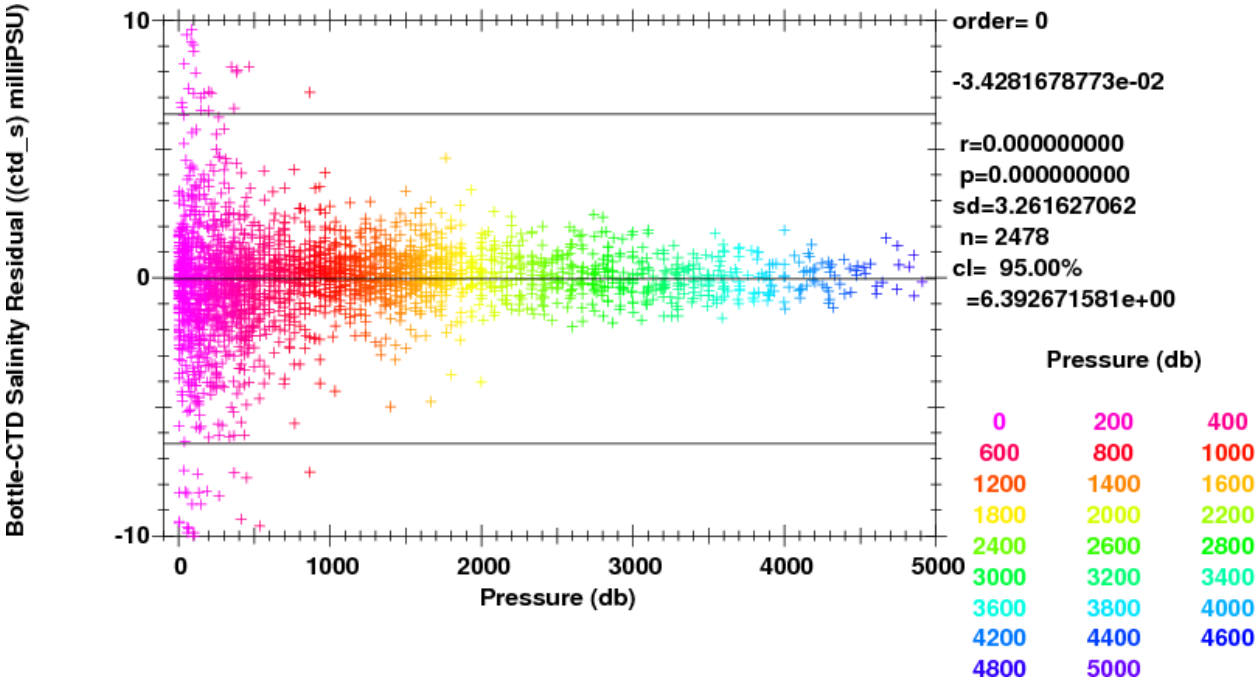



Fig. 3.27: Salinity residuals by pressure (-0.01°C $\leq$ T1-T2 $\leq$ 0.01°C).

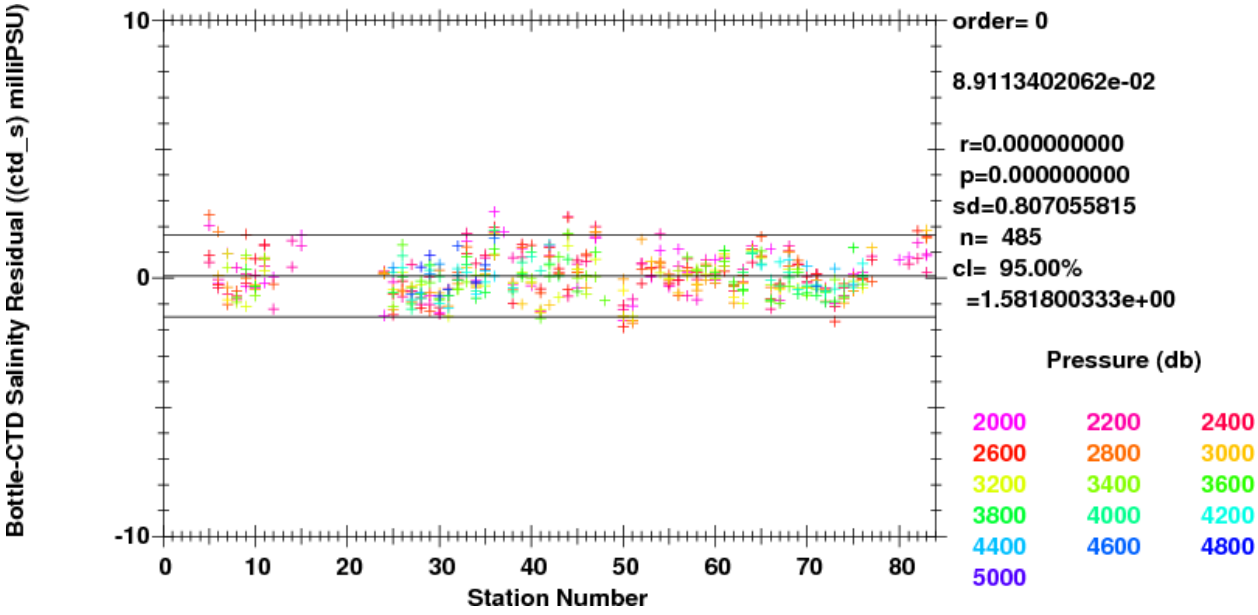



Fig. 3.28: Deep Salinity residuals by station (Pressure >= 2000dbar).

CTD data to the up cast trip locations along isopycnal surfaces. CTD dissolved $O_2$ was then calculated using Clark Cell MPOD $O_2$ sensor response model for Beckman/Sensormedics and SBE43 dissolved $O_2$ sensors. The residual differences of bottle check value versus CTD dissolved $O_2$ values are minimized by optimizing the SIO DO sensor response model coefficients with a Levenberg-Marquardt non-linear least-squares fitting procedure.

The general form of the SIO DO sensor response model equation for Clark cells follows Brown and Morrison *[Mill82]* and Owens *[Owen85]* SIO models DO sensor secondary responses with lagged CTD data. In-situ pressure and temperature are filtered to match the sensor responses. Time constants for the pressure response ($\tau_p$), a slow $\tau_{Tf}$ and fast $\tau_{Ts}$ thermal response, package velocity $\tau_{dP}$, thermal diffusion $\tau_{dT}$ and pressure hysteresis $\tau_h$ 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 fast response $T_s$ and slow response $T_l$ temperatures. This term is intended to correct non-linearities 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:

$$O_2\text{ml/l} = \left[C_1 \cdot V_{\text{DO}} \cdot e^{C_2 \frac{P_h}{5000}} + C_3\right] \cdot f_{\text{sat}}(T, P) \cdot e^{\left(C_4 t_l + C_5 t_s + C_7 P_l + C_6 \frac{dO_c}{dT} + C_8 \frac{dP}{dTt} + C_9 dT\right)}$$

Where:

- $O_2$ ml/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 )|O2| 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)
- $dO_c$ / dt Sensor current gradient (µamps/sec)
- 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 dissolved $O_2$ residuals are shown in figures *O2 residuals by station (-0.01°C T1-T2 0.01°C).* through *Deep O2 residuals by station (Pressure >= 2000dbar).*

The standard deviations of 2.98 (µmol/kg) for all oxygens and 0.69 (µmol/kg) for deep oxygens are only presented as general indicators of goodness of fit. SIO makes no claims regarding the precision or accuracy of CTD dissolved $O_2$ data.

A few minor problems with acquisition of data complicated the CTD dissolved oxygen fits. The primary pumps were partially blocked on station 4. This resulted in the use of the up-cast for data reporting instead of the standard down-cast profile. On stations 3, 36, 59 and 65 the winch stopped on CTD decent. This caused the data from the oxygen sensor to report different values at the same pressure depth. These data were coded questionable for those perspective pressure depth regions. For a number of near surface bottle values, the down-casts did not match the bottle value, however the up-cast did match. These samples were comment on in the bottle quality comments and coded good, but

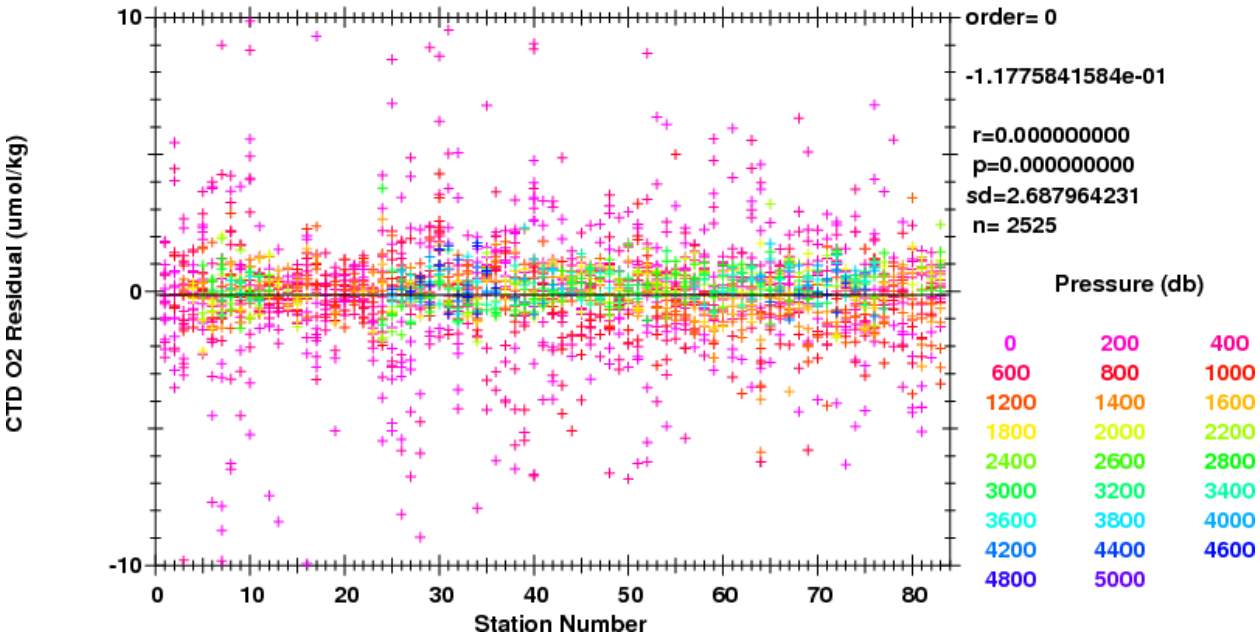



Fig. 3.29: $O_2$ residuals by station (-0.01°C $\leq$ T1-T2 $\leq$ 0.01°C).

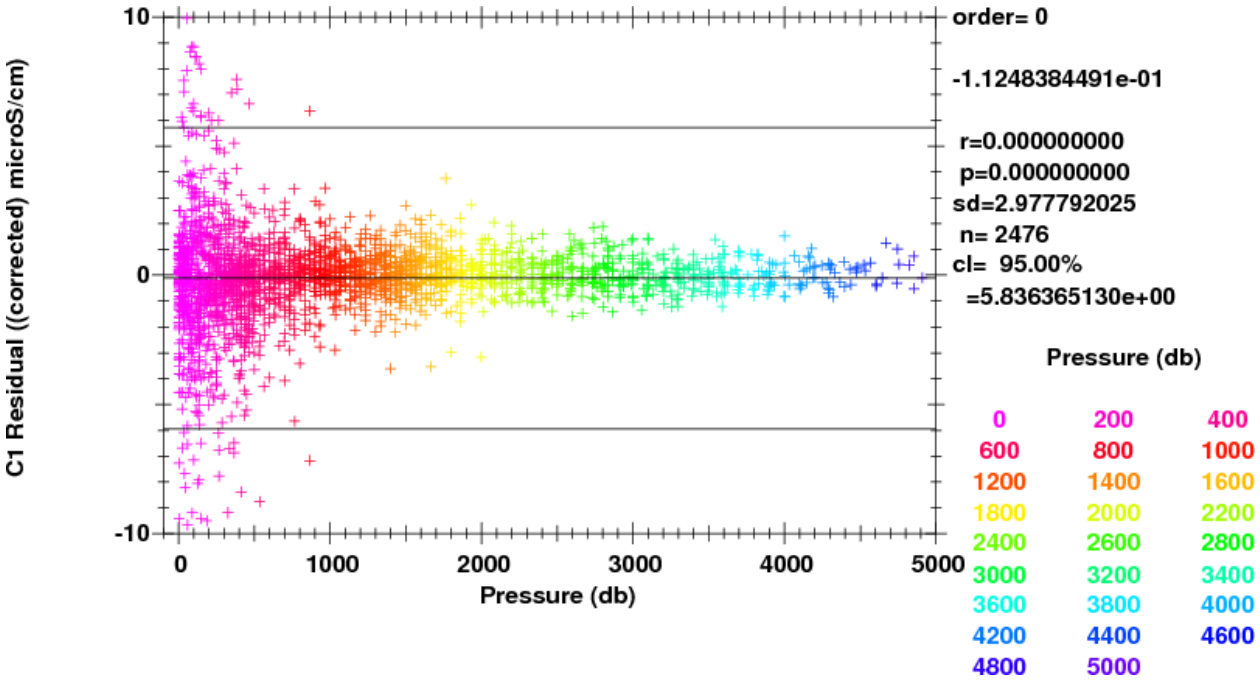



Fig. 3.30: $O_2$ residuals by pressure (-0.01°C $\leq$ T1-T2 $\leq$ 0.01°C).

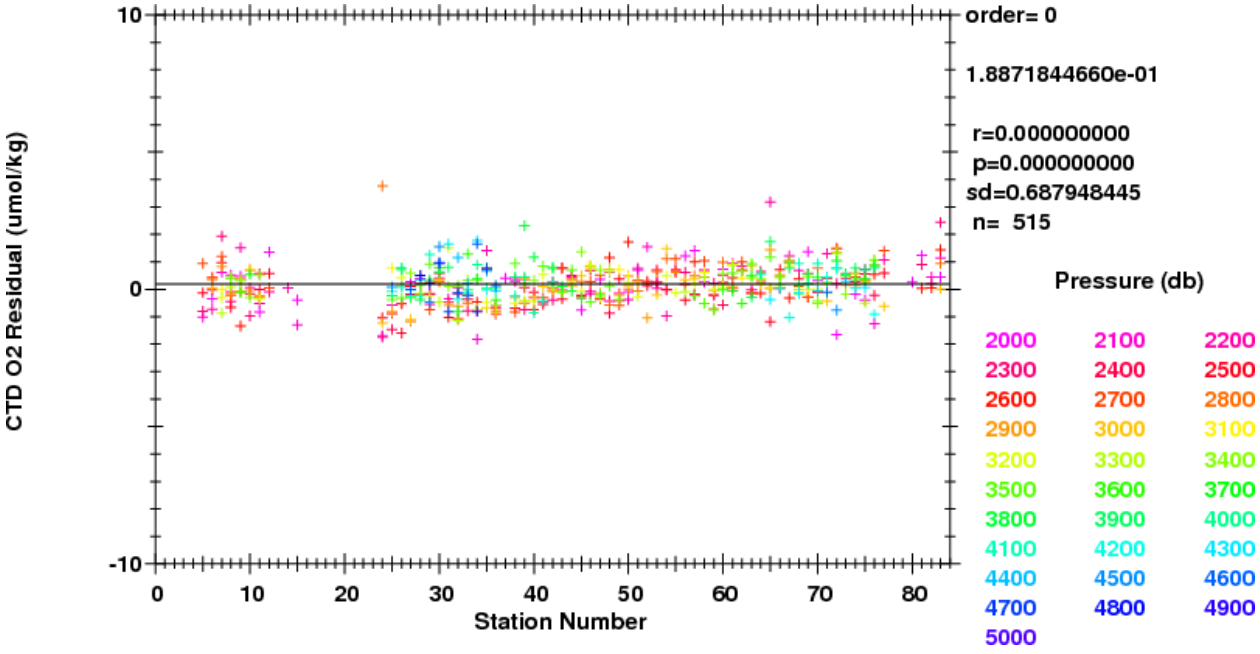



Fig. 3.31: Deep $O_2$ residuals by station (Pressure >= 2000dbar).

the data associated with those trips were weighted 0 in the non-linear least squares fitting algorithm and not used for the fit.

CHAPTER

FOUR

# SALINITY

## 4.1 Equipment and Techniques

A single Guildline Autosal, model 8400B salinometer (S/N 65-740) located in salinity analysis room, was used for all salinity measurements. The autosal was recently calibrated before this cruise, I08S. The salinometer readings were logged on a computer using in-house LabView program developed by Carl Mattson. This is to ensure stabilize reading values and improve accuracy. Salinity analyses were performed after samples had equilibrated to laboratory temperature, usually 8 hours after collection. The salinometer was standardized for each group of samples analyzed (usually 2 casts and up to 72 samples) using two bottles of standard seawater: one at the beginning and end of each set of measurements. The salinometer output was logged to a computer file. The software prompted the analyst to flush the instrument's cell and change samples when appropriate. Prior to each run a sub-standard flush, approximately 200 ml, of the conductivity cell was conducted to flush out the DI water used in between runs. For each calibration standard, the salinometer cell was initially flushed 6 times before a set of conductivity ratio reading was taken. For each sample, the salinometer cell was initially flushed at least 3 times before a set of conductivity ratio readings were taken.

IAPSO Standard Seawater Batch P-158 was used to standardize all casts.

## 4.2 Sampling and Data Processing

The salinity samples were collected in 200 ml Kimax high-alumina borosilicate bottles that had been rinsed at least three times with sample water prior to filling. The bottles were sealed with custom-made plastic insert thimbles and 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 insure an airtight seal. Laboratory temperature was also monitored electronically throughout the cruise. PSS-78 salinity *[UNESCO1981]* was calculated for each sample from the measured conductivity ratios. The offset between the initial standard seawater value and its reference value was applied to each sample. Then the difference (if any) between the initial and final vials of standard seawater was applied to each sample as a linear function of elapsed run time. The corrected salinity data was then incorporated into the cruise database.

As the cruise progressed north temperatures in the lab became warmer, which affected analysis for station data 48 and 49. Samples were flagged in the database and reflected in the quality comments documented for this report APPENDIX.

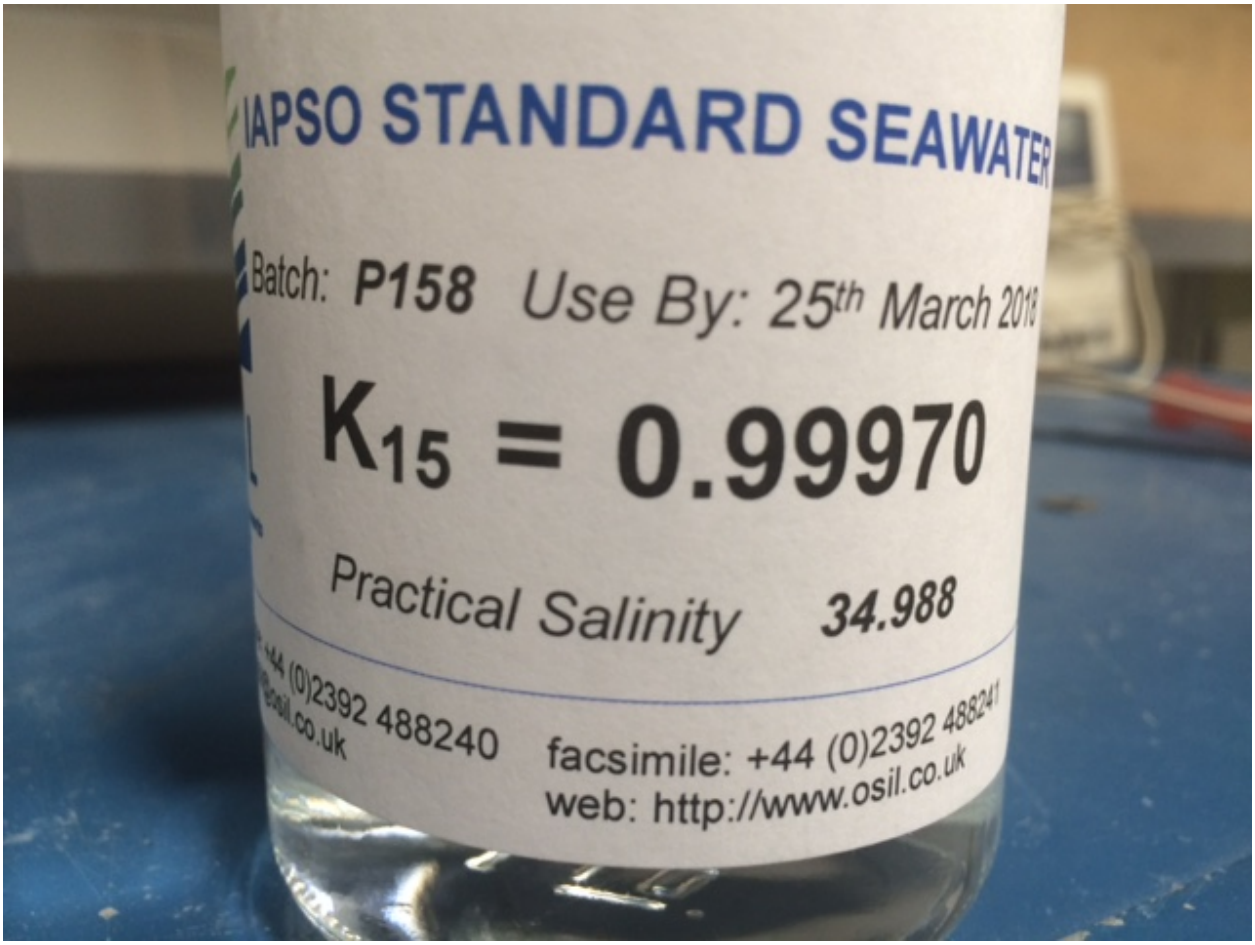



Fig. 4.1: Salinity standard IAPSO Batch P-158

CHAPTER

FIVE

# NUTRIENTS

**PIs**

- Susan Becker
- James Swift

**Technicians**

- Susan Becker
- John Ballard

## 5.1 Summary of Analysis

- 2723 samples from 83 ctd stations
- The cruise started with new pump tubes and they were changed prior to stations 31 and 60.
- 4 sets of nitrate, phosphate, and silicate Primary/Secondary standards were made up over the course of the cruise.
- 2 sets of Primary and 26 sets of Secondary nitrite and ammonia standards were made up over the course of the cruise.
- The cadmium column efficiency was check periodically and ranged between 96%-100%. A new column was put on if the efficiency fell below 97%.

## 5.2 Equipment and Techniques

Nutrient analyses (phosphate, silicate, nitrate+nitrite, nitrite and ammonia) were performed on a Seal Analytical continuous-flow AutoAnalyzer 3 (AA3). The methods used are described by Gordon et al *[Gordon1992]* Hager et al. *[Hager1972]*, and Atlas et al. *[Atlas1971]*. Details of modification of analytical methods used in this cruise are also compatible with the methods described in the nutrient section of the GO-SHIP repeat hydrography manual (Hydes et al., 2010) *[Hydes2010]*.

## 5.3 Nitrate/Nitrite Analysis

A modification of the Armstrong et al. (1967) *[Armstrong1967]* 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 540nm. The procedure was the same for the nitrite analysis but without the cadmium column.

**REAGENTS**

**Sulfanilamide** Dissolve 10g sulfamilamide 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 CuSO4 + NH4Cl 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 10 ml of acid, depending on exact strength). Bring final solution to 4L with DIW. Store at room temperature.

**NH4Cl + CuSO4 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% CuSO4 solution to this NH4Cl stock. This should last many months.

## 5.4 Phosphate Analysis

Ortho-Phosphate was analyzed using a modification of the Bernhardt and Wilhelms (1967) *[Bernhardt1967]* 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 (880nm after station 59, see section on analytical problems for details).

**REAGENTS**

**Ammonium Molybdate H2SO4 sol'n** Pour 420 ml of DIW into a 2 liter Ehrlenmeyer flask or beaker, place this flask or beaker into an ice bath. SLOWLY add 330 ml of conc H2SO4. 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 sol'n. Add 3 drops of 15% DDS surfactant. Store in a dark poly bottle.

**Dihydrazine Sulfate** Dissolve 6.4g dihydazine sulfate in DIW, bring to 1 liter volume and refrigerate.

## 5.5 Silicate Analysis

Silicate was analyzed using the basic method of Armstrong et al. (1967). 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 1000ml dilute H2SO4. (Dilute H2SO4 = 2.8ml conc H2SO4 or 6.4ml of H2SO4 diluted for PO4 moly per liter DW) (dissolve powder, then add H2SO4) 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.

## 5.6 Ammonium Analysis

**Fluorometric method** Ammonia is analyzed using the method described by Kerouel and Aminot *[Kerouel1997]*. The sample is combined with a working reagent made up of ortho-phthalaldehyde, sodium sulfite and borate buffer and heated to 75degC. Fluorescence proportional to the NH4 concentration is emitted at 460nm following excitation at 370nm.

**REAGENTS**

**Ortho-phthalaldehyde stock (OPH):** Dissolve 8g of ortho-phthalaldehyde in 200mls ethanol and mix thoroughly. Store in a dark glass bottle and keep refrigerated.

**Sodium sulfite stock:** Dissolve 0.8g sodium sulfite in DIW and dilute up to 100ml. Store in a glass bottle, replace weekly.

**Borate buffer** Dissolve 120g disodium tetraborate in DIW and bring up to 4L volume.

**Working reagent:** In the following order and proportions combine: 1L borate buffer 20ml stock orthophthalaldehyde, 2 ml stock sodium sulfite, 4 drops 40% Surfynol 465/485 surfactant and mix. Store in a glass bottle and protect from light. Replace weekly. Make this up at least one day prior to use. Store in dark bottle and protect from outside air/nh4 contamination.

## 5.7 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.

## 5.8 Data collection and processing

Data collection and processing was done with the software (ACCE ver 6.10) 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 (micro moles/liter) 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.

## 5.9 Standards and Glassware calibration

Primary standards for silicate (Na2SiF6), nitrate (KNO3), nitrite (NaNO2), and phosphate (KH2PO4) 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 0.1mg prior to the cruise. The exact weight was noted for future reference. When primary standards were made, the flask volume at 20C, 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 7-10days. 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, used for initial underway and stations 001-054, was 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. The second batch of LNSW, used for stations 055-083, was collected off shore of coastal California, filtered, and UV treated in the same manner described for batch one. The concentrations in micro-moles per liter of the working standards used were:

| - | N+N (uM) | PO4 (uM) | SiO3 (uM) | NO2 (uM) | NH4 (uM) |
|---|---|---|---|---|---|
| 0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 3 | 15.50 | 1.2 | 60 | 0.50 | 2.0 |
| 5 | 31.00 | 2.4 | 120 | 1.00 | 4.0 |
| 7 | 46.50 | 3.6 | 180 | 1.50 | 6.0 |

## 5.10 Quality Control

All final data was reported in micro-moles/kg. NO3, PO4, and NO2 were reported to two decimals places and SIL to one. Accuracy is based on the quality of the standards the levels are:

| | |
|---|---|
| NO3 | 0.05 µM (micro moles/Liter) |
| PO4 | 0.004 µM |
| SIL | 2-4 µM |
| NO2 | 0.05 µM |
| NH4 | 0.03 µM |

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.

| Parameter | Concentration (µM) | stddev |
|---|---|---|
| NO3 | 31.20 | 0.12 |
| PO4 | 2.16 | 0.02 |
| SIL | 99.3 | 0.51 |

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 *[Aoyama2006] [Aoyama2007]*, *[Aoyama2008]* and Sato *[Sato2010]*. RMNS batch BV 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 | stddev | assigned conc | diff |
|---|---|---|---|---|
| - | (µmol/kg) | - | (µmol/kg) | - |
| NO3 | 35.29 | 0.12 | 35.36 | 0.07 |
| PO4 | 2.50 | 0.02 | 2.498 | -0.002 |
| Sil | 101.9 | 0.63 | 102.2 | 0.32 |
| NO2 | 0.05 | 0.006 | 0.047 | -0.002 |

## 5.11 Analytical problems

Distilled deionized water was checked for all nutrients during cruise after reporting a POC filter change warning. All nutrient levels were below detection limit and good for duration of cruise.

Sulfite reagent was replaced once due to degradation in detected in OPA working reagent. Occasional phosphate baseline drifts and jumps were mitigated with periodic soap and bleach cleaning.

Nitrate and nitrite detector gains were reset at station 045 due to an increased sensitivity and high standard readings slightly above the set ranges within the software.

CHAPTER

SIX

# OXYGEN ANALYSIS

**PIs**

- Susan Becker
- James Swift

**Technicians**

- Andrew Barna
- Joseph Gum

## 6.1 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 765 buret driver fitted with a 1.0 ml burette. ODF used a whole-bottle modified-Winkler titration following the technique of Carpenter (Carpenter 1965) with modifications by Culberson (Culberson 1991) 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 4-5 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.

## 6.2 Sampling and Data Processing

2699 oxygen measurements were made. Samples were collected for dissolved oxygen analyses soon after the rosette was brought on board. Using a 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 resistance temperature detector (RTD) embedded in the drawing tube. These temperatures were used to calculate umol/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.

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

Thiosulfate normalities were calculated for each standardization and corrected to 20 deg C. The 20 deg 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 stable enough that no smoothing was necessary.

## 6.3 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.

## 6.4 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 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.

## 6.5 Narrative

Initial setup and reagent preparation occurred while in the port of Fremantle, WA on 2016-02-05. Setup was smooth, with no issues.

Standards were run about every 24 hours during the transit to station 1 to monitor thiosulfate stability. Underway samples were also being collected and analyzed at during the transit.

After station 25, the thiosulfate was topped off from the working stock. A subsequent standardization showed an out of spec jump in the thiosulfate normality. Standardizations performed in the following 24 hours showed this new normality to be stable.

Around station 65 problems with the UV Detector box occurred. The behavior observed was a rising zero offset when the detector was completely blocked. Swapping to the spare detector box appeared to solve the issue.

On station 74, the initial estimates of how much $MnCl_2$ and NaI/NaOH were needed proved to be incorrect. New batches of both reagents were made and were in use by station 75. No analytical issues were noted due to the new reagents.

No samples were lost due to analytical error.

CHAPTER

SEVEN

# TOTAL ALKALINITY

**PI**

- Andrew G. Dickson – Scripps Institution of Oceanography

**Technicians**

- David Cervantes
- Heather Page (Graduate Student)

## 7.1 Total Alkalinity

The total alkalinity of a sea water sample is defined as the number of moles of hydrogen ion equivalent to the excess of proton acceptors (bases formed from weak acids with a dissociation constant K $\leq$ 10–4.5 at 25°C and zero ionic strength) over proton donors (acids with K > 10–4.5) in 1 kilogram of sample.

## 7.2 Total Alkalinity Measurement System

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

Samples are analyzed using an open cell titration procedure using two 250 mL jacketed cells. One sample is undergoing titration while the second is 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 is stirred for 5 minutes while air is bubbled into it at a rate of 200 scc/m to remove any liberated carbon dioxide gas. A Metrohm 876 Dosimat Plus is used for all standardized hydrochloric acid additions. After equilibration, ~19 aliquots of 0.04 ml are added. Between the pH range of 3.5 to 3.0, the progress of the titration is monitored using a pH glass electrode/reference electrode cell, and the total alkalinity is computed from the titrant volume and e.m.f. measurements using a non-linear least-squares approach (*[Dickson2007]*). An Agilent 34970A Data Acquisition/Switch Unit with a 34901A multiplexer is used to read the voltage measurements from the electrode and monitor the temperatures from the sample, acid, and room. The calculations for this procedure are performed automatically using LabVIEW 2012.

## 7.3 Sample Collection

Samples for total alkalinity measurements were taken at all I08 Stations (1-83). Two Niskin bottles at each station were sampled twice for duplicate measurements except for stations where 15 or less Niskin bottles were sampled. Using silicone tubing, the total alkalinity samples were drawn from Niskin bottles into 250 mL Pyrex bottles, making sure to rinse the bottles and Teflon sleeved glass stoppers at least twice before the final filling. A headspace of approximately 3 mL was removed and 0.06 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.

## 7.4 Problems and Troubleshooting

Normally after samples are collected, they are placed into a water bath to equilibrate the sample temperature near 20°C. For I08, this caused a problem for our SDS. Heating the samples to 20°C resulted in too much gas being released from the samples. The SDS tubing and pipette began to fill with such a large amount of gas bubbles from the sample that the SDS pipette failed to fill completely resulting in inaccurate sample sizes. To remedy this problem, we began equilibrating our samples to 11°C and increased the pipette filling time from 70 seconds to 80 seconds. The amount of gas bubbles forming in the SDS immensely decreased and the SDS pipette began to fill normally.

Throughout I08, the Agilent 34970A Data Acquisition/Switch Unit and the LabVIEW software occasionally displayed an error when beginning a titration. A software communication error is suspected but this cannot be confirmed at sea. When this error occurs, the Agilent Unit will immediately beep and an error message will be visible on the Agilent Unit's display. A LabVIEW error message appears on the computer after approximately 1.65 mL of standardized hydrochloric acid is added during the titration's initial aliquot. If this error message is noticed and attended to immediately, the Agilent Unit will "reset" itself and begin to process the titration normally, resulting in a reliable total alkalinity measurement. If the error is not caught in time, the total alkalinity measurement is unacceptable. One sample was lost because the operator was unable to notice the Agilent Unit's error in time.

## 7.5 Quality Control

Dickson laboratory Certified Reference Material (CRM) Batch 152 was used to determine the accuracy of the total alkalinity analyses. The certified total alkalinity value for Batch 152 is 2216.94 $\pm$ 0.60 mol kg:sup'-1'. This reference material was analyzed 108 times throughout I08 at least once for every station. The preliminary B152 measured value average for I08 is 2216.53 $\pm$ 0.70 mol $kg^{-1}$.

Throughout I08, empty pre-weighed glass bottles with rubber stoppers and aluminum caps were filled with deionized water from the SDS and then crimped shut. These sealed bottles will be weighed again once they return to shore to detect (or confirm) any possible or suspected shifts in volume dispensing throughout the cruise that could have caused reference material, and therefore sample, value shifts.

If greater than 15 Niskin bottles were sampled at a station, two Niskin bottles on that station were sampled twice to conduct duplicate analyses. If 15 or less Niskin bottles were sampled at a station, only one Niskin on that station was sampled twice for duplicate analyses. A total of 138 Niskin bottles were sampled for duplicate measurements and gave an average difference of 0.01 $\pm$ 1.01 mol $kg^{-1}$.

Each I08 station's total alkalinity measurements were compared to measurements taken from the neighboring I08 2016 stations and the I08 2007 stations of similar if not identical coordinates.

1811 total alkalinity values were submitted out of 1812 sampled Niskin bottles. Corrections have already been applied for the Certified Reference Material comparison and also for the mercuric chloride dilution. A normalized total alkalinity plot was analyzed to aid in identifying any possible inaccurate measurements. Although most corrections have been made and it is unlikely that additional ones will need to be performed, this data should be considered

preliminary until the correction for any shifts in total volume dispensed per sample is checked, confirmed and applied. This assessment cannot be accomplished until the pre-weighed bottles of filled deionized water are reweighed back on land.

CHAPTER

EIGHT

# DISSOLVED INORGANIC CARBON (DIC)

**PI's**

- Rik Wanninkhof (NOAA/AOML)
- Richard A. Feely (NOAA/PMEL)

**Technicians**

- Charles Featherstone (NOAA/AOML)
- Dana Greeley (NOAA/PMEL)

## 8.1 Sample collection

Samples for DIC measurements were drawn (according to procedures outlined in the PICES Publication, *Guide to Best Practices for Ocean CO2 Measurements* *[Dickson2007]*) from Niskin bottles into 294 ml borosilicate glass bottles 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, followed by 0.16 ml of saturated $HgCl_2$ solution which was added as a preservative. The sample bottles were then sealed with glass stoppers lightly covered with Apiezon-L grease and were stored at room temperature for a maximum of 12 hours.

The analysis was done by coulometry with two analytical systems (AOML 3 and AOML 4) used simultaneously on the cruise. Each system consisted of a coulometer (CM5015 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 (*[Johnson1985]*, *[Johnson1987]*, *[Johnson1993]*, *[Johnson1992]*, *[Johnson1999]*).

The two DICE systems (AOML 3 and AOML 4) were set up in a seagoing container modified for use as a shipboard laboratory on the aft main working deck of the R/V Roger Revelle.

## 8.2 DIC Analysis

In coulometric analysis of DIC, all carbonate species are converted to $CO_2$ (gas) by addition of excess hydrogen ion (acid) to the seawater sample, and the evolved $CO_2$ gas is swept into the titration cell of the coulometer with pure air or compressed nitrogen, where it reacts quantitatively with a proprietary reagent based on ethanolamine to generate hydrogen ions. In this process, the solution changes from blue to colorless, triggering a current through the cell and causing coulometrical generation of $OH^-$ ions at the anode. The $OH^-$ ions react with the $H^+$ and the solution turns blue again. A beam of light is shone through the solution, and a photometric detector at the opposite side of the cell senses the change in transmission. Once the percent transmission reaches its original value, the coulometric titration is stopped, and the amount of $CO_2$ that enters the cell is determined by integrating the total change during the titration.

## 8.3 DIC Calculation

Calculation of the amount of CO2 injected was according to the CO2 handbook *[DOE1994]*. The concentration of CO2 ([CO2]) in the samples was determined according to:

$$[CO_2] = \text{Cal. Factor} * \frac{(\text{Counts} - \text{Blank} * \text{Run Time}) * K\mu\text{mol/count}}{\text{pipette volume} * \text{density of sample}}$$

where Cal. Factor is the calibration factor, Counts is the instrument reading at the end of the analysis, Blank is the counts/minute determined from blank runs performed at least once for each cell solution, Run Time is the length of coulometric titration (in minutes), and K is the conversion factor from counts to micromoles.

The instrument has a salinity sensor, but all DIC values were recalculated to a molar weight (µmol/kg) using density obtained from the CTD's salinity. The DIC values were corrected for dilution due to the addition of 0.16 ml of saturated $HgCl_2$ used for sample preservation. The total water volume of the sample bottles was 288 ml (calibrated by Esa Peltola, AOML). The correction factor used for dilution was 1.00055. A correction was also applied for the offset from the CRM. This additive correction was applied for each cell using the CRM value obtained at the beginning of the cell. The average correction was 1.82 µmol/kg for AOML 3 and 3.18 µmol/kg for AOML 4.

The coulometer cell solution was replaced after 25 – 28 mg of carbon was titrated, typically after 9 – 12 hours of continuous use. Normally the blank is less than 30, but we were forced to run them with blanks in the 12 – 48 range.

## 8.4 Calibration, Accuracy, and Precision

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

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

Each coulometer was calibrated by injecting aliquots of pure CO2 (99.999%) by means of an 8-port valve *[Wilke1993]* 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.

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 152 CRM value. The CRM certified value for this batch is 2020.88 µmol/kg1.

The precision of the two DICE systems can be demonstrated via the replicate samples. Approximately 12% 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 1.51 µmol/kg - No major systematic differences between the replicates were observed.

The pipette volume was determined by taking aliquots of distilled water from volumes at known temperatures. The weights with the appropriate densities were used to determine the volume of the pipettes.

Calibration data during this cruise:

| UNIT | L Loop | S Loop | Pipette | Ave CRM1 | Std Dev1 | Dupes2 |
|---|---|---|---|---|---|---|
| AOML 3 | 1.002367 | 1.000603 | 27.927 ml | 2019.15, N=40 | 1.29 | 1.56 |
| AOML 4 | 1.000058 | 0.998393 | 29.306 ml | 2016.28, N=42 | 3.18 | 1.45 |

## 8.5 Underway DIC Samples

Underway samples were collected from the flow thru system in the forward Main Lab during transit. Discrete DIC samples were collected approximately every 4 hours with duplicates every fifth sample. A total of 80 discrete DIC samples including duplicates were collected while underway. The average difference for replicates of underway DIC samples was 1.24 µmol/kg and the average STDEV was 0.88.

## 8.6 Summary

The overall performance of the analytical equipment was good during the cruise. During setup of the DICE Lab van it was discovered that the AOML 4 cooler housing the 8-port valve outfitted with two calibrated sample loops of different sizes (~1ml and ~2ml) was filled with water, which apparently leak from the hatch in the roof above during shipment to Fremantle. The 8-port valve and two positon actuator control module was replaced with a new one and the two sample loops were removed from the old 8-port valve and connected to the new valve. The gas calibrations seemed to vary throughout the cruise on AOML 4, but did not affect the data. Several small leaks were fixed in the HSG and compressed air lines at the beginning of the cruise.

Including the duplicates, over 2013 samples were analyzed from 83 CTD casts for dissolved inorganic carbon (DIC) which means that there is a DIC value for approximately 66% of the niskins tripped. The DIC 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.

CHAPTER

NINE

# DISCRETE PH ANALYSES

**PI** Dr. Andrew Dickson

**Cruise Participant** Michael B. Fong

## 9.1 Sampling

Samples were collected in 250 mL Pyrex glass bottles and sealed using grey butyl rubber stoppers held in place by aluminum-crimped caps. Each bottle was rinsed two times and allowed to overflow by one additional bottle volume. Prior to sealing, each sample was given a 1% headspace and poisoned with 0.02% of the sample volume of saturated mercuric chloride ($HgCl_2$). Samples were collected only from Niskin bottles that were also being sampled for both total alkalinity and dissolved inorganic carbon in order to completely characterize the carbon system. Additionally, two duplicate samples were collected from almost all stations for quality control purposes.

## 9.2 Analysis

pH was measured spectrophotometrically on the total hydrogen scale using an Agilent 8453 spectrophotometer and in accordance with the methods outlined by Carter et al., 2013 *[Carter2013]*. A Kloehn V6 syringe pump was used to autonomously fill, mix, and dispense sample through the custom 10cm flow-through jacketed cell. A Thermo NESLAB RTE-7 recirculating water bath was used to maintain the cell temperature at 25.0°C during analyses, and a YSI 4600 precision thermometer and probe were used to monitor and record the temperature of each sample immediately after the spectrophotometric measurements were taken. The indicator meta-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 ratio of the absorbances was then used to calculate pH on the total scale using the equations outlined in Liu et al., 2011 *[Liu2011]*. The salinity data used was obtained from the conductivity sensor on the CTD. The salinity data was later corroborated by shipboard measurements.

## 9.3 Reagents

The mCP indicator dye was made up to a concentration of approximately 2.0mM and a total ionic strength of 0.7 M. A total of 2 batches were used during Leg 1 of the cruise. The pHs of these batches was adjusted with 0.1 M solutions of HCl and NaOH (in 0.6 M NaCl background) to approximately 7.3, measured with a pH meter calibrated with NBS buffers. The indicator was obtained from Dr. Robert Byrne at the University and Southern Florida and was purified using the flash chromatography technique described by Patsavas et al., 2013 *[Patsavas2013]*.

## 9.4 Data Processing

An indicator dye is itself an acid-base system that can change the pH of the seawater to which it is added. Therefore it is important to estimate and correct for this perturbation to the seawater's pH for each batch of dye used during the cruise. To determine this correction, multiple bottles from each station were measured twice, once with a single addition of indicator dye and once with a double addition of indicator dye. The measured absorbance ratio (R) and an isosbestic absorbance ($A_{\text{iso}}$) were determined for each measurement, where:

$$R = \frac{A_{578} - A_{\text{base}}}{A_{434} - A_{\text{base}}}$$

and

$$A_{\text{iso}} = A_{488} - A_{\text{base}}$$

The change in R for a given change in $A_{\text{iso}}$, $\Delta R/\Delta A_{\text{iso}}$, was then plotted against the measured R-value for the normal amount of dye and fitted with a linear regression. From this fit the slope and y-intercept (b and a respectively) are determined by:

$$\Delta R/\Delta A_{\text{iso}} = bR + a$$

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

$$R' = R - A_{\text{iso}}(bR + a)$$

## 9.5 Standardization/Results

The precision of the data was assessed from measurements of duplicate analyses, replicate analyses (two successive measurements on one bottle), certified reference materials (CRMs) from Batch 152 (provided by Dr. Andrew Dickson, UCSD). CRMs were measured twice a day over the course of the cruise.

The overall precision determined from duplicate analyses was ±0.00039 (n=161). The overall precision determined from replicate analyses was ±0.00029 (n=161). Additionally, 98 measurements were made on 49 bottles of Certified Reference Materials, which were found to have a pH of 7.8708 ±0.00063 (n=98) and a within-bottle standard deviation of ±0.00041 (n=98).

The pH of the entire transect is shown as a section in *pH Section*.

## 9.6 Problems

Many of the samples had high dissolved gas content and degassed when brought to room temperature. This could be clearly seen in the formation of bubbles inside the sealed sample bottles and in the spectrophotometric pH system (Kloehn syringe pump, sample tubing, and the 10 cm cell). Bubbles were especially difficult to eliminate in the Kloehn syringe pump, which would accumulate large bubbles at the top after running a number of samples in each station. Efforts were made to reduce bubble formation by verifying all pump fittings were tight, slowing down the speed of the syringe pump, holding samples below 25°C, and analysis at a lower temperature (10°C). Bubbles were cleared from the syringe after every station by flushing with ethanol, followed by DI water. The potential for the bubbles to alter the sample pH was a concern, and the significance of this error was evaluated by examining a handful of duplicates which were run after the accumulation of large bubbles in the syringe and immediately after clearing bubbles from the syringe. The difference of these duplicates suggested there was no significant effect of the bubbles on sample pH. Samples for two stations (Stations 25 and 26) were held and measured at 10°C in an attempt to reduce bubble formation, but no dramatic improvement in bubble formation was observed. Furthermore, the baseline absorbances

at 10°C were consistently high (as high as 0.006). The decision was therefore made to continue running samples at 25°C.

Bubbles also occasionally formed in the water bath that controls the measurement temperature. In one instance, an extremely large bubble in the tubing stopped the circulation of water around the 10 cm cell and caused a sudden drop in temperature. This appeared to affect the pH of one sample, which deviated from a typical profile and was flagged as questionable in the preliminary data. All water bath fittings were readjusted and retightened afterwards to prevent bubble formation.

The Labview program that controls our automated pH system crashed once during the cruise, resulting in the loss of data for one sample.

Our $HgCl_2$ dispenser became clogged due to the cold temperatures in the staging bay and eventually became unusable by the middle of the cruise. As the dispenser was failing, the volume of $HgCl_2$ dispensed into some of the samples was variable, although no effect on the pH was detected. After the dispenser failed completely, we used an Eppendorf pipette to deliver 60 µL of saturated $HgCl_2$ solution into the samples.

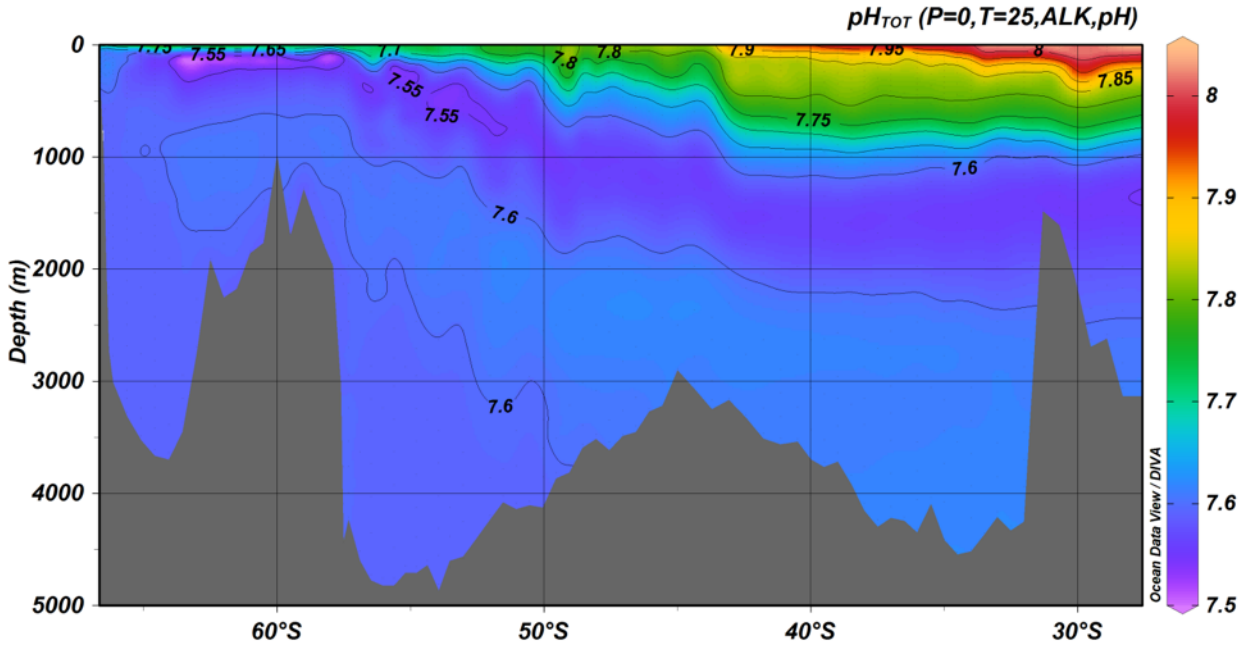



Fig. 9.1: pH Section

Section of pH on the total scale along I08S (Stations 1 to 83). Data were DIVA-gridded, and a few contours are shown. Because measurements at Station 25 and 26 were at 10°C, as opposed to 25°C for all the other stations, the pH data shown here have been recalculated at 25°C from the measured pH and total alkalinity, using the constants of Lueker et al. (2000) *[Lueker2000]*.

CHAPTER

TEN

# CFC-11, CFC-12, CFC-113, AND $SF_6$

**Analysts**

- Jim Happell
- Charlene Grall
- Sarah Bercovici

## 10.1 Sample Collection

All samples were collected from depth using 10.4 liter Niskin bottles. None of the Niskin bottles used showed a CFC contamination throughout the cruise. All bottles in use remained inside the CTD hanger between casts.

Sampling was conducted first at each station, according to WOCE protocol. This avoids contamination by air introduced at the top of the Niskin bottle as water was being removed. A water sample was collected from the Niskin bottle petcock using viton tubing to fill a 300 ml BOD bottle. The viton tubing was flushed of air bubbles. The BOD bottle was placed into a plastic overflow container. Water was allowed to fill BOD bottle from the bottom into the overflow container. The stopper was held in the overflow container to be rinsed. Once water started to flow out of the overflow container the overflow container/BOD bottle was moved down so the viton tubing came out and the bottle was stoppered under water while still in the overflow container. A plastic cap was snapped on to hold the stopper in place. One duplicate sample was taken on every other station from random Niskin bottles. Air samples, pumped into the system using an Air Cadet pump from a Dekoron air intake hose mounted high on the foremast, were run when time permitted. Air measurements are used as a check on accuracy.

## 10.2 Equipment and Technique

CFC-11, CFC-12, CFC-113, and $SF_6$ were measured on 78 0f 83 stations for a total of 2100 samples. Salt water flooded the analytical system just after sampling station 76, which caused us to not analyzing samples from Stations 75, 77, 78, 79, and 81. Analyses were performed on a gas chromatograph (GC) equipped with an electron capture detector (ECD). Samples were introduced into the GC-EDC via a purge and dual trap system. 202 ml water samples were purged with nitrogen and the compounds of interest were trapped on a main Porapack N/Carboxen 1000 trap held at ~ -20°C with a Vortec Tube cooler. After the sample had been purged and trapped for 6 minutes at 250ml/min flow, the gas stream was stripped of any water vapor via a magnesium perchlorate trap prior to transfer to the main trap. The main trap was isolated and heated by direct resistance to 150°C. The desorbed contents of the main trap were back-flushed and transferred, with helium gas, over a short period of time, to a small volume focus trap in order to improve chromatographic peak shape. The focus trap was Porapak N and is held at ~ -20°C with a Vortec Tube cooler. The focus trap was flash heated by direct resistance to 180°C to release the compounds of interest onto the analytical pre-columns. The first precolumn was a 5 cm length of 1/16" tubing packed with 80/100 mesh molecular sieve 5A. This column was used to hold back N2O and keep it from entering the main column. The second precolumn was the first 5 meters of a 60 m Gaspro capillary column with the main column consisting of the remaining 55

meters. The analytical pre-columns were held in-line with the main analytical column for the first 50 seconds of the chromatographic run. After 35 seconds, all of the compounds of interest were on the main column and the pre-column was switched out of line and back-flushed with a relatively high flow of nitrogen gas. This prevented later eluting compounds from building up on the analytical column, eventually eluting and causing the detector baseline signal to increase.

The samples were stored at room temperature and analyzed within 24 hours of collection. Every 12 to 18 measurements were followed by a purge blank and a standard. The surface sample was held after measurement and was sent through the process in order to "restrip" it to determine the efficiency of the purging process.

## 10.3 Calibration

A gas phase standard, 33780, was used for calibration. The concentrations of the compounds in this standard are reported on the SIO 2005 absolute calibration scale. 5 calibration curves were run over the course of the cruise. Estimated accuracy is $\pm 2\%$. Precision for CFC-12, CFC-11, CFC-113 and $SF_6$ was less than $2\%$. Estimated limit of detection is 1 fmol/kg for CFC-11, 3 fmol/kg for CFC-12 and CFC-113, and 0.05 fmol/kg for $SF_6$.

CHAPTER

# ELEVEN

# UNDERWAY $PCO_2$ ANALYSIS

**PI's**

- Rik Wanninkhof (NOAA/AOML)
- Richard A. Feely (NOAA/PMEL)

**Technicians**

- Charles Featherstone (NOAA/AOML)
- Dana Greeley (NOAA/PMEL)

An automated underway $pCO_2$ system from AOML was installed in the Hydro Lab of the RV Roger Revelle. The design of the instrumental system is based on Wanninkhof and Thoning *[Wanninkhof1993]* and Feely et al. *[Feely1998]*, while the details of the instrument and of the data processing are described in Pierrot, et.al. *[Pierrot2009]*.

The repeating cycle of the system included 4 gas standards, 5 ambient air samples, and 100 headspace samples from its equilibrator every 3 hours. The concentrations of the standards range from 233 to 463 ppm $CO_2$ in compressed air. These field standards were calibrated with primary standards that are directly traceable to the WMO scale. A gas cylinder of ultra-high purity air was used every 18 hours to set the zero of the analyzer.

The system included an equilibrator where approximately 0.6 liters of constantly refreshed surface seawater from the bow or mid-ship intake was equilibrated with 0.8 liters of gaseous headspace. The water flow rate through the equilibrator was 1.5 to 2.2 liters/min.

The equilibrator headspace was circulated through a non-dispersive infrared (IR) analyzer, a LI-COR™ 6262, at 50 to 120 ml/min and then returned to the equilibrator. When ambient air or standard gases were analyzed, the gas leaving the analyzer was vented to the lab. A KNF pump constantly pulled 6-8 liter/min of marine air through 100 m of 0.95 cm (= 3/8") OD Dekoron™ tubing from an intake on the bow mast. The intake had a rain guard and a filter of glass wool to prevent water and larger particles from contaminating the intake line and reaching the pump. The headspace gas and marine air were dried before flushing the IR analyzer.

A custom program developed using LabView™ controlled the system and graphically displayed the air and water results. The program recorded the output of the IR analyzer, the GPS position, water and gas flows, water and air temperatures, internal and external pressures, and a variety of other sensors. The program recorded all of these data for each analysis.

The automated $pCO_2$ analytical system had several issues during the cruise with the seawater intakes:

1. February 4, 2016 - Start of cruise using the engine room pump (sea chest)
2. February 8, 2016 – Pump strainer cleaning flow thru shut down
3. February 21, 2016 – Engine room pump (sea chest) failure 11:30 GMT
4. February 21, 2016 – Started using Bow pump 13:30 GMT
5. February 21, 2016 – Turned off flow to flush system, turned back on 15:00 GMT

6. February 22, 2016 – Cleaned filter during gas calibration 20:20 GMT
7. February 27, 2016 – Bow pump failure 08:45 GMT
8. February 27, 2016 – Bow pump failure 10:20 GMT
9. February 28, 2016 – Switched to Engine room pump (sea chest)
10. March 5, 2016 – Switched to Bow pump 04:31 GMT
11. March 8, 2016 – Flow turned off, sink was backed up 21:44 GMT
12. March 8, 2016 – Switched to Engine room pump (sea chest) 23:00 GMT
13. March 11, 2016 – Engine room pump failure (sea chest) switched to Bow pump 01:58 GMT

The system worked well for the remainder of the cruise.

Table 11.1: Standard Gas Cylinders

| Cylinder# | ppm CO2 |
|---|---|
| JAO2646 | 233.46 |
| JAO2264 | 326.18 |
| JAO2285 | 406.05 |
| JAO2280 | 463.00 |

CHAPTER

# TWELVE

# NITRATE $\delta^{15}$N AND $\delta^{18}$N SAMPLING

Max-Planck Institute of Chemistry

**PI**

- Prof. Gerald Haug
- François Fripiat (ffpripiat@ulb.ac.be)

Samples for Nitrate $\delta$15N and $\delta$18N were taken by the CTD-watch for Haug and Fripiat. A total of 864 60 ml plastic bottles were used to collect 40 ml samples according to the protocol provided. Items in italics in the description below indicate an action that was not specifically indicated in the protocol.

1. The sample bottles came stored in annotated postal boxes (15x25x10 cm); with the annotation corresponding to the labels of the bottles inside; e.g. MPI 2016 Haug SO 00001 to 00049.
2. The container with the empty sample bottles and documentation was kept in the forward bio-lab. Usual before the return of the CTD to the deck, but sometimes afterward, the 24 bottle plastic rack was filled with the empty bottles. *To keep out the light, the bottles were covered with a black towel. Because timing was not always optimum, the black towel was kept over the sample bottles in the tray at all times prior to storage.*
3. Seawater was taken directly from the Bullister bottles. Sample bottles were rinsed 3 times with seawater from the Bullister prior to sampling. Each 60 ml sample bottle was filled with approximately 40 ml of seawater.
4. After sample 24 bottles were filled they were placed in their corresponding postal boxes and placed directly in the dark in a -20°C freezer[2].
5. The sample ID's, Bullister bottle numbers and date were recorded on the log sheet provided. After all sampling was complete this log sheet was converted to the electronic version, also provided.

The original sample plan asked for 24 stations x 36 bottles between 66°S and 38°S sampling every third station (using sampling scheme II). Assuming 30 nm spacing this would provide 1.0 to 1.2 degree (~90 nm) spacing. As we were limited by extended station spacing and when the samples could be taken (i.e. only the night-shift had the available manpower) the actual station sampling was less regular than the initial plan. Full profiles with samples from all available Bullister bottles were taken at 26 stations for a total of 851 samples. Station spacing ranged from 36 to 150 nm with an average of 97 nm covering latitudes 66.3°S to 23.3°S.

[2] On March 6th the engineers discovered that the walk-in freezer where the sample boxes were being stored had failed. The temperature had risen to -10.5°C by the time the samples were moved in their boxes (16:00 – 16:15 UTC) to an unused freezer in the science hold (temperature in this freezer was set to -20°C).

Table 12.1: Table of Nitrate Nitrogen Isotope Samples

| Station | # Samples | ID#s | Latitude (°N) | Longitude (°E) | Dist to Next Profile (nm) |
|---|---|---|---|---|---|
| 5 | 34 | 00001 - 00034 | -66.3 | 78.125 | 80.8 |
| 8 | 36 | 00035 - 00070 | -65.1 | 79.607 | 140.8 |
| 12 | 31 | 00071 - 00101 | -63.003 | 82.01 | 90.2 |
| 15 | 27 | 00102 - 00128 | -61.5 | 82 | 120 |
| 19 | 25 | 00129 - 00153 | -59.5 | 82 | 120.3 |
| 25 | 36 | 00154 - 00188 | -57.513 | 82.523 | 74 |
| 28 | 36 | 00189 - 00224 | -56.484 | 83.77 | 120.4 |
| 32 | 36 | 00225 - 00260 | -54.786 | 85.664 | 89.4 |
| 35 | 36 | 00261 - 00296 | -53.526 | 87.024 | 68.5 |
| 37 | 28 | 00297 - 00324 | -52.531 | 87.954 | 103.5 |
| 40 | 35 | 00325 -00359 | -51.037 | 89.35 | 104.4 |
| 43 | 36 | 00360 - 00395 | -49.543 | 90.747 | 140.5 |
| 47 | 35 | 00396 - 00430 | -47.551 | 92.609 | 142.1 |
| 51 | 34 | 00431 - 00464 | -45.559 | 94.47 | 151.2 |
| 55 | 34 | 00465 - 00498 | -43.068 | 95 | 115.4 |
| 58 | 36 | 00499 - 00534 | -41.144 | 95 | 129.2 |
| 62 | 36 | 00535 - 00570 | -38.991 | 94.992 | 59.5 |
| 64 | 36 | 00571 - 00606 | -37.999 | 95.004 | 90.1 |
| 67 | 36 | 00607 - 00642 | -36.498 | 95.003 | 89.8 |
| 70 | 25 | 00643 - 00677 | -35.001 | 95.002 | 89.6 |
| 73 | 36 | 00678 - 00713 | -33.508 | 95.001 | 90 |
| 76 | 36 | 00714 - 00748 | -32.009 | 95.013 | 78.6 |
| 79 | 24 | 00747 - 00772 | -30.699 | 95.004 | 71 |
| 81 | 27 | 00773 - 00799 | -29.515 | 95.006 | 36.2 |
| 82 | 27 | 00800 - 00826 | -28.911 | 95.002 | 35.6 |
| 83 | 33 | 00827 - 00830, 00841-00864 | -28.318 | 95.009 | |
| Total Samples | 851 | | | | |

CHAPTER

# THIRTEEN

# $\delta^{18}O$ SAMPLING

**PIs**

- Peter Schlosser (LDEO)
- Lynne Talley (SIO)

Samples for $\delta^{18}O$ were taken by the CTD-watch for Schlosser and Talley. A total of 1073 brown glass bottles were used to collect XX ml samples according to the protocol provided.

1. The sample bottles came stored in annotated boxes that were each labeled with a box number (1-20) as it was filled samples.
2. The container with the empty sample bottles and documentation was kept in the forward bio-lab. Before the return of the CTD to the deck, 36 bottles were prepared with Bullister bottle numbers written in the caps. The 24 bottle plastic rack, which sat in a plastic basin (both provided) was filled with the empty bottles. The 12 extra bottles were placed upright in the basin.
3. Seawater was taken directly from the Bullister bottles using the tube provided. Sample bottles were rinsed once with seawater from the Bullister prior to sampling.
4. After sampling the 36 bottles were taken back to the forward bio-lab where they were dried with paper towels, caps were tightened and wrapped in tape, and labels were filled out and applied.
5. The sample ID's, Bullister bottle numbers, date and box number were recorded on a log sheet provided. After all sampling was complete this log sheet was converted to the electronic version, which will be sent to the PIs.

The agreed upon sampling plan followed the basic outline of the I06S sampling provided by Robert Key (Princeton) with concentrated sampling at the southernmost stations and less concentrated to the north. The table below summarizes the sampling.

**Note:** Note there was a mix up in the assigning ID numbers so there are IDs 432A, B and C and 452A, and B.

| dO18 Box | dO18 ID | dO18 ID | STA# | CAST | DATE (UTC) | # SAM-PLES | LAT | LON | DEPTH (m) |
|---|---|---|---|---|---|---|---|---|---|
| START-END | START | END | | | | | | | |
| 1-1 | 1 | 19 | 1 | 1 | 19-Feb-16 | 19 | -66.6027 | 78.3815 | 468 |
| 1-1 | 20 | 40 | 2 | 3 | 19-Feb-16 | 21 | -66.4997 | 78.2986 | 953 |
| 1-2 | 41 | 67 | 3 | 1 | 19-Feb-16 | 27 | -66.45 | 78.2494 | 1497 |
| 2-2 | 68 | 98 | 4 | 1 | 19-Feb-16 | 31 | -66.4 | 78.1993 | 1979 |
| 2-3 | 99 | 132 | 5 | 1 | 20-Feb-16 | 34 | -66.2999 | 78.1253 | 2731 |
| 3-4 | 133 | 168 | 6 | 1 | 20-Feb-16 | 35 | -66.15 | 78.0102 | 3009 |
| 4 | 169 | 203 | 7 | 2 | 20-Feb-16 | 35 | -65.6248 | 78.8085 | 3313 |

Continued on next page

Table 13.1 – continued from previous page

| dO18 Box | dO18 ID | dO18 ID | STA# | CAST | DATE (UTC) | # SAM-PLES | LAT | LON | DEPTH (m) |
|---|---|---|---|---|---|---|---|---|---|
| 4-5 | 204 | 239 | 8 | 1 | 20-Feb-16 | 35 | -65.1 | 79.6066 | 3525 |
| 5-6 | 240 | 275 | 9 | 1 | 21-Feb-16 | 36 | -64.5799 | 80.3926 | 3667 |
| 6 | 276 | 311 | 10 | 1 | 21-Feb-16 | 36 | -64.05 | 81.2022 | 3700 |
| 6-7 | 312 | 347 | 11 | 1 | 21-Feb-16 | 35 | -63.535 | 82.0005 | 3450 |
| 7 | 348 | 378 | 12 | 1 | 21-Feb-16 | 31 | -63.003 | 82.0103 | 2748 |
| 8 | 379 | 402 | 13 | 1 | 22-Feb-16 | 23 | -62.5003 | 82.0002 | 1919 |
| 8 | 403 | 429 | 15 | 1 | 22-Feb-16 | 27 | -61.4999 | 82.0002 | 2175 |
| 8-9 | 430 | 451 | 16 | 1 | 22-Feb-16 | 24 | -61 | 82.0005 | 1858 |
| 9 | 452 | 475 | 19 | 2 | 23-Feb-16 | 25 | -59.5002 | 82.0003 | 1706 |
| 9-10 | 476 | 496 | 20 | 2 | 23-Feb-16 | 21 | -59.0001 | 82 | 1291 |
| 10 | 497 | 518 | 21 | 1 | 24-Feb-16 | 22 | -58.6101 | 82.0101 | 1549 |
| 11 | 519 | 553 | 25 | 1 | 24-Feb-16 | 35 | -57.5131 | 82.5226 | 4438 |
| 11 | 554 | 589 | 26 | 1 | 25-Feb-16 | 36 | -57.3209 | 82.7791 | 4240 |
| 11-12 | 590 | 625 | 29 | 1 | 25-Feb-16 | 36 | -56.058 | 84.2612 | 4822 |
| 12-13 | 626 | 661 | 32 | 1 | 26-Feb-16 | 36 | -54.7862 | 85.6644 | 4712 |
| 13 | 662 | 697 | 33 | 1 | 26-Feb-16 | 36 | -54.367 | 86.1421 | 4641 |
| 13-14 | 698 | 733 | 35 | 1 | 28-Feb-16 | 36 | -53.5264 | 87.0235 | 4602 |
| 14-15 | 734 | 761 | 37 | 1 | 28-Feb-16 | 28 | -52.531 | 87.954 | 4405 |
| 15 | 762 | 796 | 40 | 1 | 1-Mar-16 | 35 | -51.037 | 89.3503 | 4141 |
| 15-16 | 797 | 832 | 43 | 1 | 1-Mar-16 | 36 | -49.5429 | 90.7469 | 3868 |
| 16-17 | 833 | 868 | 44 | 1 | 2-Mar-16 | 36 | -49.0449 | 91.2121 | 3815 |
| 17 | 869 | 903 | 47 | 1 | 2-Mar-16 | 35 | -47.551 | 92.6087 | 3616 |
| 17-18 | 904 | 936 | 48 | 1 | 3-Mar-16 | 33 | -47.053 | 93.0739 | 3490 |
| 18 | 937 | 970 | 51 | 1 | 3-Mar-16 | 33 | -45.559 | 94.4702 | 3219 |
| 19 | 971 | 1003 | 52 | 1 | 3-Mar-16 | 33 | -44.992 | 95.0002 | 2903 |
| 19-20 | 1003 | 1037 | 55 | 1 | 4-Mar-16 | 34 | -43.068 | 95.0001 | 3168 |
| 20 | 1038 | 1073 | 58 | 1 | 5-Mar-16 | 36 | -41.1441 | 95.0003 | 3564 |

CHAPTER

# FOURTEEN

# CDOM

UCSB Global CDOM Group

- Norman Nelson, Earth Research Institute UCSB, PI
- Cara Nissen, ETH-Zürich, Volunteer Graduate Student

## 14.1 Chromophoric Dissolved Organic Matter (CDOM)

Sampling: We nominally sampled one cast per day, on the cast nearest the overpass times of the ocean color instrument bearing satellites Aqua (MODIS) and NPP (VIIRS). Each Niskin bottle would be sampled, with two randomly selected replicates.

Preparation: The standard method involves collecting 60 mL samples into glass EPA vials, then filtering the samples at low vacuum pressure (-0.05 MPa) through 25mm 0.2 micron Nuclepore filters which have been preconditioned with ultrapure water to remove organic contaminants. For the underway samples we used 0.2 micron nylon ZenPure cartridge filters to remove particles. Sample vials are rinsed with the filtrate and the filtrate is returned to the vial. Filtered samples are stored at 4 °C until analysis (*[Nelson2007]*, *[Nelson2009]*).

Original plan was to analyze samples at sea using the WPI UltraPath 200cm liquid waveguide cell spectrophotometer system. However the cell developed an air leak that I could not correct, so we opted to collect samples to return to UCSB for analysis on a functioning system rather than fight the heisenbug in the cell. We collected 16 samples and two replicates on each cast, filtered and stored them. The plan is to return the samples to UCSB from Fremantle.

We collected samples on 21 stations, for a total of 334 samples and 40 replicates.

Analysis: Filtered seawater samples are analyzed for absorption in the 250-734 nm range using a WPI UltraPath spectrophotometer system. The UltraPath is a single-beam spectrophotometer system consisting of a UV-Visible light source, a 200 cm liquid waveguide cell, and a diode array spectrometer. Samples (appx. 12 mL volume) are injected into the cell using a peristaltic pump. Light is introduced to the cell via a fiber-optic and travels the length of the cell because of total internal reflection, as in a fiber optic filament. Absorbance is calculated by computing the logarithm of the spectrum of transmitted light through a sample divided by the spectrum of transmitted light through a reference solution (in this case ultrapure water prepared each day with our Barnstead Nanopure Diamond UV system using potable water as input). Because of the difference in real refractive index between seawater and ultrapure water the raw data have an apparent negative absorbance signal that must be removed before computing absorption coefficient ($m^{-1}$) (as absorbance x 2.303/l, where l is the effective pathlength of the cell, *[Nelson2007]*).

On this expedition we are testing a new protocol for CDOM absorption spectra measurement and refractive index correction as part of a NASA methodological development effort. The protocol involves measuring standard solutions of Suwanee River Fulvic Acid ~0.25 mg/L and sodium chloride at 30 and 40 g/L to monitor instrument performance and obtain data for correction of apparent absorption due to refractive differences between ultrapure water and seawater.

Selected CDOM absorption data from discrete wavelengths will be submitted to CCHDO upon completion of quality control. More complete data sets including raw data and processing code will be available via the NASA bio-optical

field data SeaBASS (seabass.gsfc.nasa.gov).

## 14.2 Chlorophyll a

Sampling: We collected ~500mL samples from the top 6 depths (usually ~200m), one cast daily, total of approximately 126 samples.

Preparation: Samples were collected into 500mL brown HDPE bottles and were subsequently filtered onto 25mm 0.45$\mu$m pore nitrocellulose filters. The filters were placed in polypropylene Falcon tubes and extracted 48 hours at 4°C temperature in 10 mL of 90% acetone (with Barnstead Nanopure UV prepared water); and were shaken after 24 hours to ensure complete filter dissolution.

Analysis: The acetone extracts were analyzed using the acidification technique *[Mueller2003]* on a Turner Designs AU-10 fluorometer with the standard chlorophyll fluorescence set. The fluorescence (in relative units) was measured before (Rb) and after (Ra) acidification with two drops of 10% HCl. Chlorophylla was computed according to the standard formula:

$$\text{Chla}(\mu\text{g/l}) = (\tau/\tau - 1)\text{Fd}(\text{Rb} - \text{Ra})$$

Where $\tau$ is the fluorescence ratio of pure chlorophyll a to pure phaeophytin a and Fd is the calibration coefficient ($\mu$g/L). $\tau$ and Fd for each of the three sensitivity ranges of the instrument were determined in August 2014 by Janice Jones and Nathalie Guillocheau, UCSB; using solutions of pure Anacystis nidulans chlorophyll a (Sigma) in 90% acetone.

| | |
|---|---|
| HIGH Tau = | 1.9539 |
| MED Tau = | 1.9496 |
| LOW Tau = | 1.8885 |
| Med/High Tau = | 1.9520 |
| Low/Med Tau = | 1.9274 |
| overallavg Tau = | 1.9393 |

| | [Chla] Rb | [Chla] ((tau/(tau-1))*(Rb-Ra)) | Slope |
|---|---|---|---|
| HIGH Fd = | 0.138925422 | 0.138925422 | 0.142718147 |
| MED Fd = | 0.138626676 | 0.138626676 | 0.141249987 |
| LOW Fd = | 0.126879138 | 0.126879138 | 0.128316741 |
| Med/High Fd = | 0.1388 | 0.138794721 | 0.141417549 |
| Low/Med Fd = | 0.1344 | 0.134354844 | 0.141000945 |
| overallavgFd = | 0.1364 | 0.136411604 | 0.141201691 |

Instrument performance was checked daily with a Turner Designs solid fluorescence standard. No apparent trend was observed.

Preliminary Results: Preliminary quality control based on phaeophytin a to chlorophyll a ratios suggest almost all samples collected to date from shallower than 200m were good. Samples collected at 200m and below were effectively zero in most cases, putting a tentative lower limit for chlorophyll determination at 0.01 mg/m$^3$. Results show the expected high latitude shoaling and formation of a subsurface chlorophyll maximum in the subtropics. Surface chlorophyll concentrations at the surface at the northernmost part of the transect were below 0.04 milligrams per cubic meter, amongst the lowest concentrations of chlorophyll found in the ocean.

Problems: Two samples were possibly acid-contaminated and resulted in negative computed chlorophyll concentrations (flagged 4). One sample extract was too concentrated for the fluorometer sensitivity (station 010/1 sample 34) and the extract was diluted by 50% to get it in range (flagged 3). Four other samples were flagged as 3 because they didn't fit in the profile.

All collected CHLORA data were reported to CCHDO during the cruise. Additional data and raw data will be submitted to the NASA bio-optical field database SeaBASS (seabass.gsfc.nasa.gov).

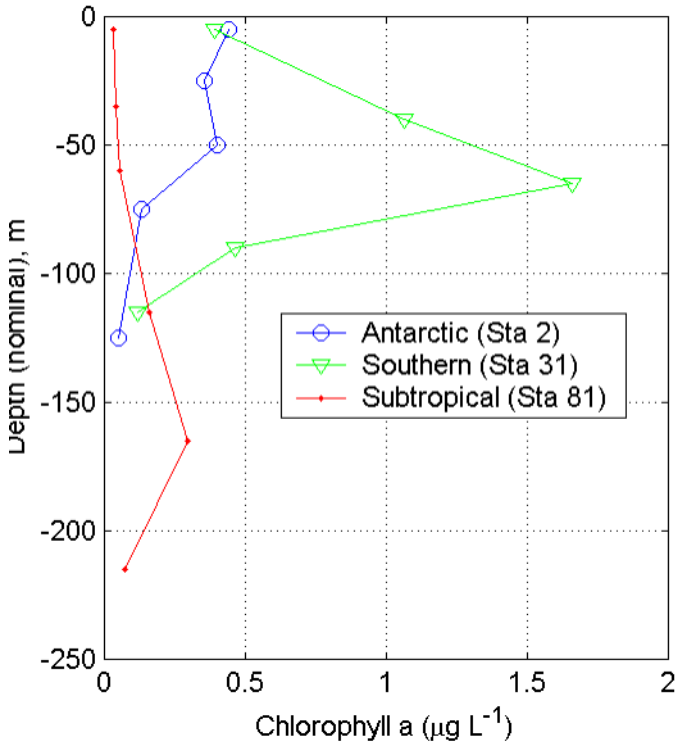



Fig. 14.1: Chlorophyll a profiles from Station 2 (65.6S), Station 31 (55.1S) and station 81 (29.5S).

## 14.3 CDOM Rosette Fluorometer

Equipment and Techniques: We deployed WETLabs ECO CDOM 6000m fluorometer FLCDRTD s/n 3117 on the rosette at the outset of the cruise. This was a replacement for a similar instrument that was lost with the rosette on Leg 1 of A16N in 2013. This instrument excites fluorescence with a 380 nm UV light source and monitors fluorescence at 420 nm.

Sampling and Analysis: Instrument data are saved as analog volts DC and are vicariously calibrated post cruise using laboratory-measured fluorescence spectra standardized to quinine sulfate fluorescence equivalents (ppb) of archived samples using a Horiba Jobin Yvon Fluoromax-4 (*[Nelson2009]*, *[Nelson2016]*).

Problems: The instrument suffered from data noise and an offset that occurred between 1200 and 1500 db pressure on each cast. This is similar to problems that occurred with the instrument on the A16S and P16N sections. Since those cruises the instrument returned to WETLabs for evaluation and they could find no problem with the instrument. The same problems occurred with different cables and different SeaBird CTD units, so the problem had to rest with the fluorometer itself. I currently suspect a mechanical issue, related to pressure, on the optical face of the instrument. This problem was encountered in the prototype fluorometer we first deployed in 2006, and apparently has returned.

The instrument was lost with the rosette on 22 February, so the mystery will remain unsolved.

## 14.4 Spectroradiometer casts

Acquisition: Each day near local noon (with one exception; see below) we deployed a Biospherical C-OPS profiling spectroradiometer system (system 023) off the port quarter. The instrument measures downwelling irradiance and upwelling radiance in 19 channels stretching from the UV-B to the NIR wavebands. The system includes a surface

reference unit with matching channels and a shadowband system for measuring direct and diffuse contributions to total irradiance. All instruments acquire data at 15 Hz. The profiler is hand deployed and recovered to allow drift away from the ship to avoid shadow influence. The maximum depth reached on every profile was approximately 100 m.

Data Processing: Collected data are subjected to quality control for tilt and surface irradiance change during the profile *[Mueller2003]* and derived products include attenuation coefficient spectra and water-leaving radiance reflectance (for ocean color remote sensing data validation). Resulting products will be made available via NASA's field bio-optics archive SeaBASS (seabass.gsfc.nasa.gov).

```
C-OPS cast summary to 02/29/16

Station 002/1
Cast Start: 19-Feb-2016 08:12:40 UT
Cast End  : 19-Feb-2016 08:26:45 UT
Max Depth : 55.1 m

Station 007/1
Cast Start: 20-Feb-2016 08:46:04 UT
Cast End  : 20-Feb-2016 09:04:27 UT
Max Depth : 124.6 m

Station 010/2
Cast Start: 21-Feb-2016 08:56:55 UT
Cast End  : 21-Feb-2016 09:19:13 UT
Max Depth : 120.8 m

Station 014/1
Cast Start: 22-Feb-2016 08:13:07 UT
Cast End  : 22-Feb-2016 08:32:05 UT
Max Depth : 118.1 m

Station 017/1
Cast Start: 23-Feb-2016 07:21:14 UT
Cast End  : 23-Feb-2016 07:36:35 UT
Max Depth : 117.8 m

Station 023/2
Cast Start: 24-Feb-2016 07:15:41 UT
Cast End  : 24-Feb-2016 07:31:44 UT
Max Depth : 98.2 m

Station 027/1
Cast Start: 25-Feb-2016 08:24:17 UT
Cast End  : 25-Feb-2016 08:38:27 UT
Max Depth : 85.3 m

Station 030/1
Abort (wind 33 kts)

*period of joyful weather here*

Station 042/1
Cast Start: 01-Mar-2016 08:33:36 UT
Cast End  : 01-Mar-2016 08:49:04 UT
Max Depth : 100.4 m

Station 045/2
Abort heavy current and high ship thrust
```

```
Station 049/2
Cast Start: 03-Mar-2016 07:53:19 UT
Cast End  : 03-Mar-2016 08:07:55 UT
Max Depth : 111.3 m

Cast 053/2
Cast Start: 04-Mar-2016 08:16:20 UT
Cast End  : 04-Mar-2016 08:30:35 UT
Max Depth : 114.7 m

Cast 057/2
Cast Start: 05-Mar-2016 09:52:55 UT
Cast End  : 05-Mar-2016 10:08:23 UT
Max Depth : 91.5 m

Cast 060/2
Cast Start: 06-Mar-2016 06:36:46 UT
Cast End  : 06-Mar-2016 06:52:50 UT
Max Depth : 111.0 m

Cast 065/1
Cast Start: 07-Mar-2016 08:38:21 UT
Cast End  : 07-Mar-2016 08:52:15 UT
Max Depth : 109.7 m

Cast 068/2
Cast Start: 08-Mar-2016 07:28:36 UT
Cast End  : 08-Mar-2016 07:44:22 UT
Max Depth : 85.8 m

Cast 072/1
Cast Start: 09-Mar-2016 06:20:04 UT
Cast End  : 09-Mar-2016 06:33:40 UT
Max Depth : 100.6 m

Cast 076/1
Cast Start: 10-Mar-2016 07:23:14 UT
Cast End  : 10-Mar-2016 07:37:22 UT
Max Depth : 104.9 m

Cast 081/1
Cast Start: 11-Mar-2016 08:47:13 UT
Cast End  : 11-Mar-2016 09:01:23 UT
Max Depth : 102.1 m
```

Problems: Several profiles shallow due to strong sub surface currents. Twisting in the cable was encountered during several of the casts which could be attributed to currents or the rate at which line was paid out.

At the outset of the cruise we had difficulty with the surface shadowband system. Apparently the temperature was too cold for effective stepper motor operation. We were able to correct this problem by increasing the working and rest voltages.

## 14.5 Underway optics system

Equipment and Techniques: We installed our underway inherent optical property measuring system in the hydro lab and supplied it with ship's uncontaminated seawater at appx 10 L/min. The system includes a computer-controlled

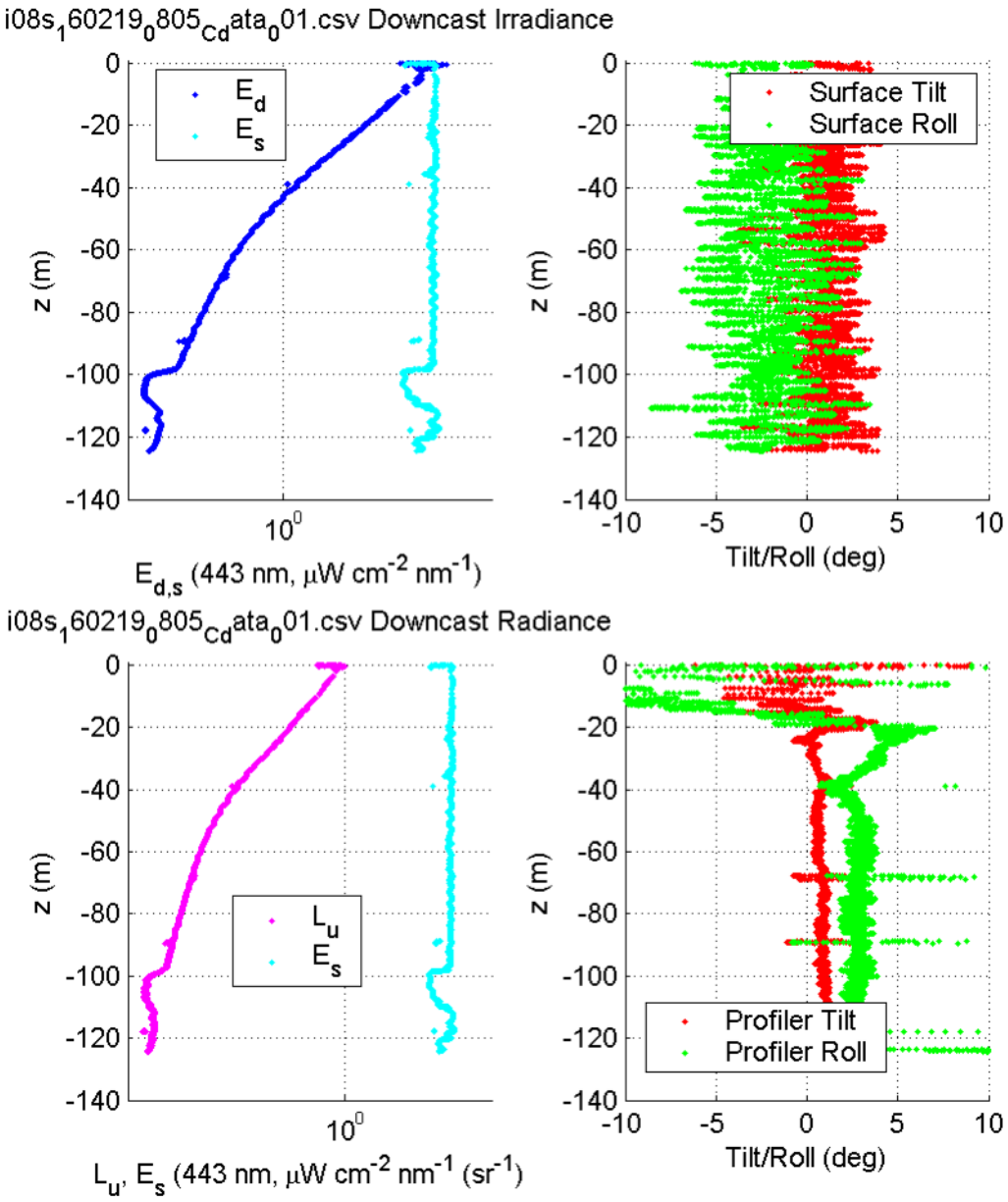



Fig. 14.2: C-OPS

443 nm downwelling irradiance (top left) and upwelling radiance (lower left), station 7, cast 1. 443 nm surface irradiance collected at the same moment is shown in cyan. Surface unit (ship) and profiler tilt and roll are shown in the righthand panels. The dip in the profiles near 100m is caused by a cloud passage, as can be seen in the surface reference data. Strong curvature in the profiles (shown on a logarithmic scale) are due to the presence of a chlorophyll maximum near 40m.

valve that switches between whole water and a 0.2 $\mu$m filter (ZenPure nylon cartridge) which feeds an MSRC vortex debubbler. The debubbled water is supplied through a PVC manifold to a SeaBird TSG and an array of optical instruments: a WETLabs ECO BB3 backscattering sensor installed in a custom light trap *[Slade2010]*, a WETLabs AC-S hyperspectral absorption and attenuation meter, a Sequoia Scientific LISST 100X type B laser diffraction particle counter/sizer, and a Satlantic in-situ FIRe in vivo fluorescence excitation/relaxation sensor.

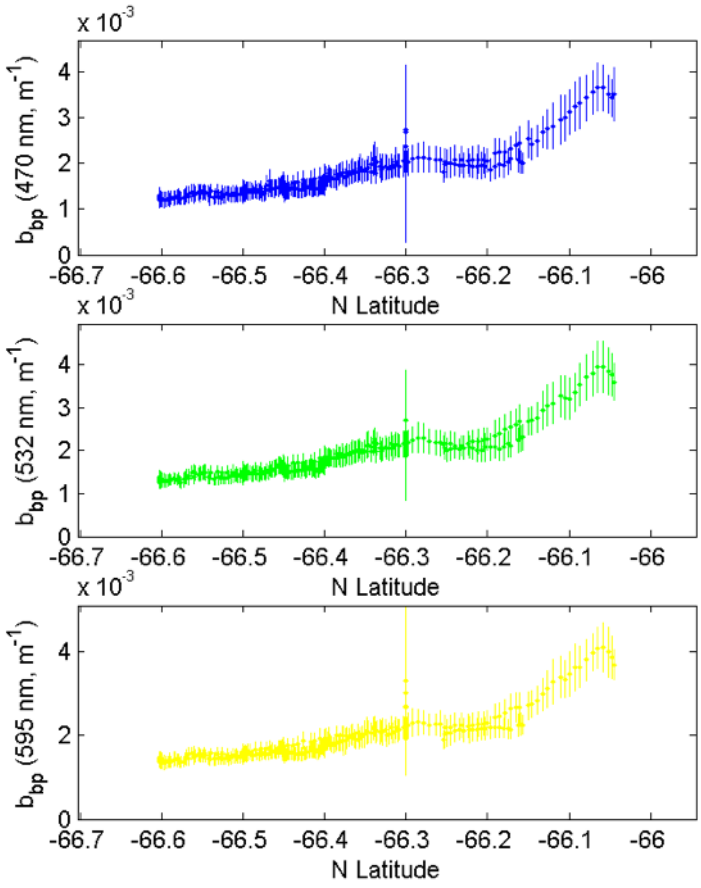



Fig. 14.3: Particulate backscattering coefficient from the southernmost end of the transit and beginning of the section. Note near exact overlap of the section south of 66.3S

Analysis: The system includes a computer-controlled data acquisition system that automatically switches between filtered and whole water supply to the instruments on a user-defined schedule. The filtered seawater baseline is used to correct the instrument data for calibration and offset drift, variable CDOM, and temperature effects *[Slade2010]*. With the system operating in unfiltered mode the instruments are sampled at 1 Hz and data are generally collected in one minute bins. It takes around 15 minutes to completely flush the system following a switch two or from filter mode, so no data collection takes place during this time period. Approximately five "filter" periods are scheduled each day. Instruments are also powered off for one minute in ten to mitigate overheating and to extend lamp life.

System optics were cleaned each day using isopropanol and the filter cartridge was changed on alternate days.

Data from the system require extensive post processing and quality control, which will be performed on land. Resulting data will be made available via NASA's field bio-optics archive SeaBASS (seabass.gsfc.nasa.gov).

## 14.6 SOCCOM sampling

Sampling: The ODF group collected samples for POC and HPLC phytoplankton pigment analysis on stations where SOCCOM bio-optical floats were deployed. ODF used our large volume HPLC/AP/POC filtration rig to filter the samples and the samples were stored in our liquid nitrogen Dewar during the cruise. We collected ~2 L samples into polyethylene sample bottles from the surface and chlorophyll maximum depths at each cast. Information on SOCCOM float deployments and sample collection is available elsewhere in the cruise report.

Preparation: Samples were filtered onto precombusted 25 mm GF/F glass fiber filters at <-0.05 MPa vacuum pressure. The filters were folded into foil packets and immediately frozen in liquid nitrogen. The samples will be returned to UCSB via liquid nitrogen dry shipper.

Analysis: POC samples will be analyzed for C and N content at the UCSB Marine Science Institute Analytical Laboratory. Samples are acidified, combusted at 100 °C and analyzed using a Control Equipment, Inc. CEC440HA elemental analyzer (http://msi.ucsb.edu/services/analytical-lab/instruments/organic-elemental-analyzer-chn). Detection limits are approximately 2 $\mu$g carbon and 5 $\mu$g nitrogen.

HPLC samples will be analyzed by Crystal Thomas at the NASA Goddard Spaceflight Center HPLC lab (Greenbelt, MD). The full suite of measurements, procedures, and quality control information is available at: http://oceancolor.gsfc.nasa.gov/cms/

## 14.7 Phytoplankton Pigments and Particulate Absorption

Sampling: Once daily, in approximate synchronization with our C-OPS casts and satellite overpasses we collected samples from the ship's uncontaminated seawater supply for shore analysis of phytoplankton pigments via HPLC and for particulate absorption spectra (AP). ~2 L samples were collected into polyethylene sample bottles.

Preparation: Samples were filtered onto 25 mm GF/F glass fiber filters and frozen in liquid nitrogen *[Mueller2003]*. The samples will be returned for analysis to UCSB (AP) and to NASA GSFC (HPLC).

Analysis: Particulate absorption spectra of the AP sample filters are measured a Shimadzu UV-2401 spectrophotometer with an integrating sphere attachment, using a moistened GF/F filter as a blank. Absorbance of filters is converted to absorption coefficient spectra using the Quantitative Filter Technique *[Mueller2003]* using multiple scattering corrections developed by Nelson et al. *[Nelson1998]*.

Samples for phytoplankton pigment analysis will be analyzed at NASA GSFC by the Ocean Ecology Laboratory Field Support Group (http://oceancolor.gsfc.nasa.gov/cms/hplc/). Acetone extracts of the particles collected on GF/F filters will be separated using an HP HPLC system with a C8 column, and detected using a diode array spectrophotometer system to confirm pigment identity. Resulting data will be made available via NASA's field bio-optics archive SeaBASS (seabass.gsfc.nasa.gov).

CHAPTER

# FIFTEEN

# DISSOLVED ORGANIC CARBON

**PI** Craig Carlson (UCSB)

**Technician** Maverick Carey

Dissolved Organic Carbon (DOC) samples were collected from all niskin bottles at all even numbered stations, as well as station 1. A total of 1415 samples were collected from 43 stations. At each sampled station, one duplicate sample was taken from a random depth. Samples from 500m and shallower in the water column were filtered through a 47mm in-line GF/F filter. All samples were rinsed 3 times with seawater, collected in 40 mL glass EPA vials, and stored at 4°C. 65µl of 4N Hydrochloric acid were added to preserve samples.

Sample vials were prepared for this cruise by soaking in 10% Hydrochloric acid, followed by 3 times rinse with DI water. The vials were then combusted at 450°C for 4 hours to remove any organic matter. Vial caps were cleaned by soaking in DI water overnight, followed by a 3 times rinse, and then left out to air dry.

Sampling goals for this cruise were to continue long term monitoring of DOC distribution throughout the water column, in order to help better understand biogeochemical cycling in global oceans.

CHAPTER

SIXTEEN

# LADCP

LADCP data were collected during CTD casts, stations 1-13 and 28-83 During stations 1-13 a dual head system was used consisting of a downlooker and an uplooker. From station 14-27 no data was collected due to loss of the CTD package at station 14. During stations 28-83 only a downlooker was available. Preliminary processing was performed onboard. All profiles were sent to A. Thurnherr for shore-based processing. A full QC will be carried out after the cruise.

The ADCPs and a lead acid battery pack were affixed to the CTD package. Three different ADCP WH300 instruments were used during the cruise.

| Stations | DownLooker | UpLooker |
|---|---|---|
| 1 - 13 | WH300 sn: 149 | WH300 sn: 13330 |
| 14 - 27 | | |
| 28 - 83 | WH300 sn: 150 | |

At the start of station 14 the package was lost. The secondary package was readied and deployed after a several hour delay. The backup LADCP was not installed until station 28, downlooker only. Compass problems within the unit from station 28 resulted in poor data. On station 59 the termination slipped and the package struck the side rail. The impact resulted in the compass to function properly.

ADCP programming and data acquisition were carried out using the LDEO acquire software running on a Mac computer.

Post-cruise processing is necessary and will be conducted at LDEO. At that point it will be determined which profiles are of sufficient quality for inclusion in the final CLIVAR ADCP archives.

CHAPTER

SEVENTEEN

# CHIPODS

## 17.1 System Configuration and Sampling

Initially, four Chipods were mounted on the rosette to measure temperature (T), its time derivative (dT/dt), and x and z (horizontal and vertical) accelerations at a sampling rate of 50 Hz. Two Chipods were oriented with sensors pointing upwards (circled in green in the figure below), and are referred to as *uplooking*. The other two pointed downwards and are referred to as *downlooking* (circled in blue at the bottom of the rosette in Figure below). The Chipod pressure case, containing the logger board and batteries, is circled in red in the figures below. Ideally, the chipod sensors need to sense an undisturbed stream of fluid passing over the thermistor tip. For this reason the uplooking sensors are mounted as far from the rosette as possible whilst the downlooking sensors are mounted as close to the bottom of the rosette as possible but still above the base frame so as to not be damaged on deployment and recovery. The downlooking chipods generally obtain better (less noisy) data on the downcast and the uplooking sensors record better data on the upcast. Chipod data was downloaded daily or every second day. Raw data was plotted for a quick quality check and to ensure chipods were working correctly. After the primary rosette was lost, three backup chipod loggers were installed on the backup rosette (one downlooking and two uplooking). This configuration is shown in *Chipod Figure 2*.

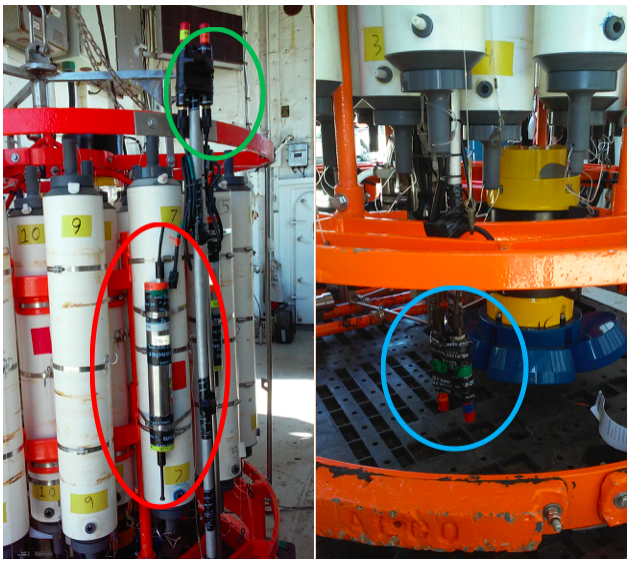


Fig. 17.1: Chipod Figure 1

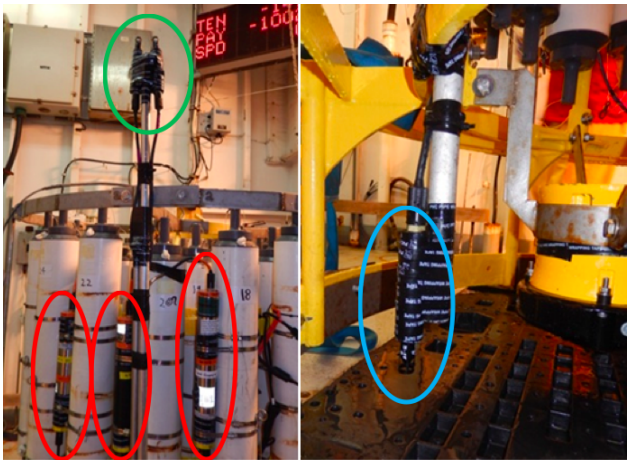


Fig. 17.2: Chipod Figure 2

## 17.2 Data Collection and Equipment Changes

A summary of the Chipod logger serial numbers, their associated sensor serial numbers and the station/cast range for which data was collected is provided in Table 1. In total, data from 66 stations was recorded by two uplooking Chipods whilst data from 9 stations was recorded by two downlooking Chipods and data from 53 stations was recorded by one downlooking Chipod. A more comprehensive summary is provided below.

Chipod loggers SN2003 and SN2020 were uplooking and recorded data from stations 1 to 10 (10 stations). Chipod logger SN2004 was downlooking and recorded data from stations 2 to 10. SN2004 was not logging data during the first station. This was rectified for station 2. Chipod logger SN2001 was downlooking and recorded data from stations 1 to 10. The last data download for these four chipods was on the 21th February after station 10. The rosette was lost on 22nd February, during deployment at station 14. Data from stations 11 to 13 was recorded by loggers but not downloaded and thus was lost with rosette. No data was collected by any Chipods during stations 14 to 27. The three remaining Chipod loggers were installed on 25th February prior to station 28. SN2002 was downlooking and recorded data from stations 28 to 30 and from 35 to 36. For an unknown reason SN2002 did not record any data during stations 31 to 34. The temperature derivative signal from the sensor (13-05 D) on SN2002 became noisy on 3rd March at approximately 10:00 UTC time. Sensor was swapped for 14-32 D on 8th March. This improved the noise signal in dT/dt data. SN2009 and SN1013 were both uplooking and recorded data from stations 28 to 83. The pole on which the uplooking sensors were mounted, was hit by the hangar door on recovery at station 33. The pole was bent outwards and for station 34 which means the sensors were not mounted vertically. This may impact data quality of SN2009 and SN1013 on that station. The sensors were remounted on a vertical pole prior to station 35. Sensor cable 24-4-2 (connected to SN2009) was caught on the hook during recovery at station 040 and was torn. Cable was replaced for 24-4-10 and data quality was not impacted.

Table 17.1: Chipod logger data showing serial numbers, orientation of logger and which stations data was collected from.

| Chipod Logger Serial Number | Sensor Serial Number | Sensor Cable Serial | Orientation | Station/Cast Range | Number of stations |
|---|---|---|---|---|---|
| SN2003 | 11-24 D | 24-04-3 | Uplooking | 00101 - 01001 | 10 |
| SN2020 | 14-28 D | 24-06-1 | Uplooking | 00101 - 01001 | 10 |
| SN2004 | 13-02 D | 24-06-7 | Downlooking | 00201 - 01001 | 9 |
| SN2001 | 10-01MP | 24-06-19 | Downlooking | 00101 - 01001 | 10 |
| SN2002 | 13-05 D | 24-06-19 | Downlooking | 02801 - 03001<br>03501 - 06801 | 37 |
| SN2002 | 14-32 D | 24-6-19 | Downlooking | 06901 - 08301 | 15 |
| SN2009 | 11-25 D | 24-04-2 | Uplooking | 02801 - 04001 | 13 |
| SN2009 | 11-25 D | 24-04-10 | Uplooking | 04101 - 08301 | 43 |
| SN1013 | 14-34 D | 24-04-11 | Uplooking | 02801 - 08301 | 56 |

CHAPTER

# EIGHTEEN

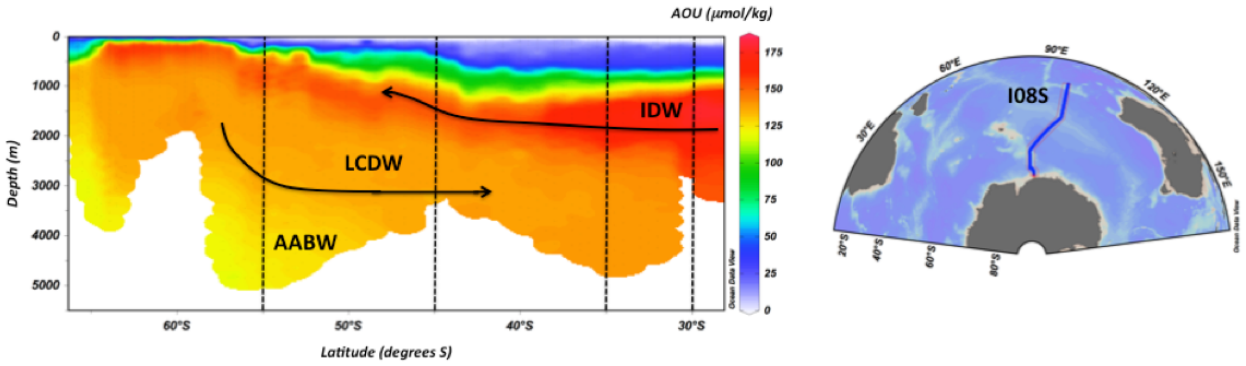
# STUDENT STATEMENTS

## 18.1 Sarah Bercovici

On the GO-SHIP I08S cruise, I was the student assistant for the on board analysis of chlorofluorocarbons (CFC) and sulfur hexafluoride (SF6), working for Jim Happell and Charlene Grall. As the CFC assistant, I learned technical and analytical skills, such as how to sample for CFCs on the CTD and how to run the samples on the gas chromatographer. I additionally was taught by my supervisors to recognize which compound was which on the resultant gas chromatogram, which allowed me to view trends in the data. From the large amount of data we were generating daily, I witnessed the ventilation of the different water masses near the Antarctic shelf slope and in the Southern Ocean. For example, I saw an increase of CFCs in the newly formed Antarctic Bottom Water (AABW) near the Amery shelf slope, while there were substantially less CFCs in the overlying circumpolar waters. These trends show that AABW has had more recent contact with the atmosphere (i.e. it shows that this AABW was derived from most likely the nearby Antarctic shelf waters). Through observing the data, I also recognized where intermediate and mode waters were being formed near the Polar Front, due to an influx of CFCs reaching down around 1000 m depth. I additionally saw that CFC concentrations in the surface waters south of the Polar Front were much higher than those as we reached lower latitudes due to the solubility of gases in the colder waters. Overall, running CFCs in the Southern Ocean was a rewarding experience that taught me about the exciting processes that are occurring in this remote region of the world.

In addition to being the CFC student assistant, I collected samples for radiocarbon of dissolved organic carbon (DOC), which is a student project that I proposed for this cruise. I brought enough bottles for four 12-point profiles, and chose to space the profiles out evenly throughout the transect at approximately 55°S, 45°S, 35°S, and 28°S (see 14C-DOC cruise report for exact sampling locations). This spacing is observed in the dashed lines on the figure below (data on figure is from the previous occupation of I08S) and will give a good representation of the different water masses present, including capturing the northward flowing lower circumpolar deep water (LCDW) /AABW which fills the basin of the Indian Ocean; and the southward flowing Indian Deep Water (IDW), derived from the mixing of upwelled LCDW with the anoxic intermediate waters near the bay of Bengal (as seen in the high apparent oxygen utilization

(AOU) signature of IDW in the figure below). These samples will be analyzed soon on shore using accelerator mass spectrometry.




## 18.2 Hannah Dawson

I've had a fantastic time participating in the 2016 occupation of I08S on the Revelle. It's been a great introduction to life at sea and in-the-field data collection. On this particular cruise I participated as a CTD watch-stander and chipod tech. The CTD watch-stander job involved prepping the rosette, operating the computer console during casts and taking water samples for various analyses including salinity, radiocarbon and $\delta$O18 isotope content. My other role involved downloading data from chipod instruments and providing maintenance where needed. Overall, the experience was a fantastic one with many highs and of course some lows.

We spent over a week transiting south to our first station just inside the Antarctic Circle. This was the first time I'd been on a ship in the open ocean for a long period of time and we had some rough weather which made the adjustment really tough. From the time we crossed 60°S however, everything improved (or perhaps I just became more accustomed to the rolling ocean...). We started to see an incredible array of wildlife including seabirds, whales and penguins. Seeing ice bergs inside the Antarctic Circle was really exciting and watching the Aurora Australis from the bridge of the ship

was definitely a highlight for me. Another one of my favourite moments was watching the giant albatross glide over the ocean waves without ever seeming to flap their wings.

Early on in the trip we lost the first rosette to the depths of the ocean. It was a pretty sad day but everyone on shift banded together and we had the backup one working and were on our way again, less than 8 hours later. Losing a rosette is not an experience that I'm eager to repeat but it was great to see everyone working together and it definitely solidified friendships. My fellow CTD watch-standers, scientists and crew members were fantastic people to be onboard a ship with. I really enjoyed meeting people from different universities all over the world and it was great to learn about the various research interests of everyone on board and how different samples are taken and analysed. It's been a great trip and I'm looking forward to the next opportunity to partake in a research cruise.

## 18.3 Natalie Freeman

What an amazing time I've had aboard the Revelle! These 6 weeks have flown by, full of experiences that far exceeded my expectations. As a CTD watch-stander, my 12-hour shifts were filled with a mix of hard work interspersed with moments of overwhelming appreciation of my surreal circumstances and surroundings. The thrilling anxiety that comes with playing 'sample cop' amid the backdrop of a sunrise in shades of pink and blue I had never seen before! Trying to keep pace with sampling for salts, alkalinity, nitrates, radiocarbon, and/or d18O, bobbing and weaving around others to/from the rosette, but with a near-constant smile from the joking and camaraderie among my fellow night-shifters. The pelting icy rain and gusty winds out on deck followed by the satisfaction of tying my first bowline knot and a successful 'hook' of the rosette. The necessity of working on various to-dos from 'back home' after/on top of a 12-hour shift but the excitement of getting the phone call from the bridge to come witness the dancing Aurora Australis! The butterflies during each 'bottom approach' or the worry of a misfired bottle but taking turns leaving the console to run out to take pictures of an iceberg or baby shark or penguin or rainbow or sea snake or flying fish... . Regretting the decision to go to bed much too late many nights but the elation I felt when there was STILL ripe cantaloupe at breakfast (right up until the last days of the leg!). The constant go-go-go associated with tightly spaced AND shallow stations and then getting that first real break and filling it with a quick game of cribbage/quiddler/scrabble, or that third cup of tea and a tasty pastry. The shock of losing a rosette to the sea followed by the unique opportunity to learn more about the bits/bobs, ins/outs of a rosette and getting to do 'deck work' after all.

Most certainly the ups and downs of I08S 2016 have taught me the dedication and resilience of the people that appreciate and observe our oceans. Thanks to all science and crew for their kindness and company and a special thanks to Alison Macdonald for sharing her wealth of knowledge and experience and helping make my participation possible. I will surely miss the sea – until next time...

## 18.4 Seth Travis

On this cruise, my primary responsibility was as a CTD watchstander. The tasks required for this position include preparing the rosette for deployment at roughly half an hour before each cast, monitoring the descent of the rosette and determining the stopping point for the maximum depth, and firing the rosette bottles during ascent for sample collection. Due to technical issues, CTD watchstander's also needed to be responsible for the guidelines on the rosette during the initial deployment, as well as hooking the rosette and using the guidelines during recovery of the rosette.

For my shift (the day shift), I was also responsible for sampling for the alkalinity group. This was as simple as taking samples on the bottles told to me by the alkalinity group. The sampling consisted of taking a sample bottle, filling and rinsing the bottle twice with sample water, refilling the bottle, and poisoning the sample with mercuric chloride. After these samples were taken, I helped to take salinity samples, which simply required me to rinse the sample bottles three times, and refill the bottle, leaving just a little head room at the top of the bottle.

Beyond these assigned responsibilities, I also worked to provide updated maps of wind and wave forecasts, with the current and future ship positions overlaid onto the maps. Once the Matlab program was developed, which does this task, the daily workload for this was fairly simple. I simply needed to update the files (forecast maps, completed ship

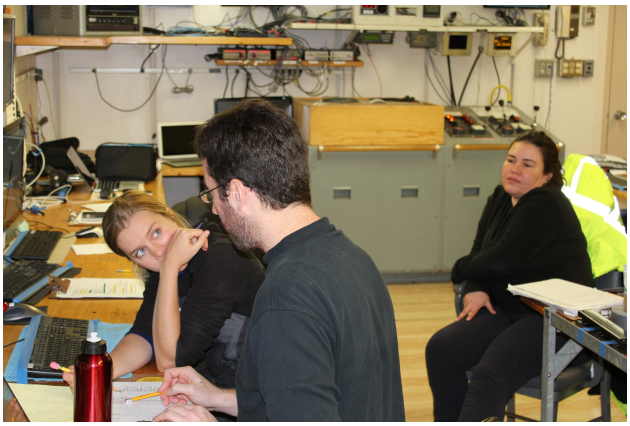


Fig. 18.1: During the CTD cast, monitoring the descent of the rosette. (Photo credit: J. Gum)

position, proposed ship track) each day, rerun the program, and print off a selected forecast map (I usually selected a time for each day which would be close to the change between the day and night shift).

This cruise was my first experience in being part of an extended research cruise. While I have had previous field and ship experience, this was my first of such length. I have definitely gained a greater appreciation for what goes on during field sampling and processing, and all the pitfalls involved. I now better understand the frantic energy of the situation when problems arise and how a steady hand is needed to direct that energy towards solving the problems; likewise, I also understand the preferred monotony of a smoothly running system. I was also able to observe the systems used for measurement and analysis of various oceanic parameters. While I was impressed by the systems, I must admit that I mostly did not know what each system did, or how they worked. While I was present for many sample collections, I knew little about the actual analysis was, and what happened to those samples after.

Overall, it has been a positive experience. I learned much about seagoing oceanography, the sampling process, all the challenges that can arise, and the impressive speed and perseverance of the whole team to come together to solve those challenges.

## 18.5 David Webb

I've had a great time onboard the Revelle and it has turned into one of the best experiences of my life. The scenery in itself was amazing; from the southern lights and spectacular sunsets above numerous icebergs, to the range of marine-life surrounding us and encroaching on the ship – including the bird that decided to fly into the back of my head when I turned to help deploy the rosette. Disregarding the aesthetically pleasing environment and kamikaze birds, the time

onboard was still an exciting experience. The first week was a little testing due to the cold that spread, on top of rough seas that amplified any sea-sickness that was felt. Although after a long transit of stomach hardening brutality things were only uphill in my personal experience.

My role on the cruise involved uploading and downloading data from the LADCP instruments sent down with the rosette, as well as standard CTD watch duties, and collection of water samples for various analysis testing for properties such as salinity, alkalinity and $\delta O^{18}$ isotope content. As a new student to physical oceanography (and being focused around modeling), it was great to gain some practical experience in the field and be a part of the ever so needed data collection while facing all the challenges that come with it. The loss of the first rosette along with numerous issues with the winch and a close call with the second rosette made for an interesting few weeks. Although these were obviously significant setbacks, it personally enhanced my experience because we had to adapt to the situation and in the process I have come out learning more than I would have otherwise.

Aside from work and scenery, it was a real pleasure to be in a shipmate environment – building strong working relationships and friendships, all whilst contributing to the larger scientific community. It is definitely something I would recommend and look forwards to doing again in the future.

## 18.6 Earle Wilson

Fig. 18.2: Photo credit: Cara Nissen

On this cruise, I mainly served as a CTD watch stander. In this role, I assisted with all stages of the rosette's launch, recovery and sampling. I was also the caretaker of six Argo floats, which I helped to deploy throughout the cruise. Additionally, I maintained a blog (https://floatdispenser.blogspot.com/) where I chronicled the events around me as well as my experiences onboard.

Overall, my time onboard the Revelle for the 2016 I08S cruise was an exciting and fulfilling experience. As someone who relies heavily on ocean data collected by others, I am thankful for the opportunity to witness and experience the challenges of doing fieldwork at sea. I don't think I will ever complain about gaps in my data again!

This cruise was not all sunshine and happiness though. There were stretches where we (the CTD watch) had to work long hours, for days on end, while fighting sea sickness and sleep deprivation. But in the end, I think the good overwhelmingly outweighed the bad. Never have I learned and accomplished so much over such a short period of time. Even the worst aspects of my experience can be viewed as positives in their own right. I believe those adversities helped to further my growth both as a scientist and as an individual.

Of all the things I am grateful for on this cruise, what I will cherish the most are my interactions with the people onboard. In particular, I am grateful to have met my fellow CTD watch standers. The bonds and friendships that I developed on this cruise are ones that I will hold dear for the rest of my life.

CHAPTER

# NINETEEN

# SOCCOM FLOAT DEPLOYMENT

On this cruise, we successfully deployed six [1] Argo floats for the Southern Ocean Carbon Climate Ocean and Modeling (SOCCOM) project. Each float is equipped with sensors to measure temperature, salinity, oxygen, nitrate, pH, chlorophyll and backscatter. With these measurements, we hope to further our understanding of the processes that contribute to carbon export in the Southern Ocean; this is one of the core missions of the SOCCOM project.

We released our floats at stations 11, 25, 36, 41, 48 and 56. The exact time and location of each deployment are summarized in the log table below. Each deployment was done at the end of their respective CTD cast, immediately after the rosette was secured onboard. We launched each float by lowering the instrument over the stern of the ship as the vessel was moving 1-2 knots over water. Each float was deployed with the assistance and supervision of the on-duty res-tech.

At each deployment station, we took samples for HPLC and POC analyses. These were 2-liter samples from the surface and the chlorophyll maximum, with duplicates at the surface (6 liters in total). These samples will be shipped to the US for analysis. Samples for pH, alkalinity, oxygen, salinity, and nutrients (including nitrate) were also collected and analyzed on-board by personnel from SIO in the Dickson lab and STS/ODF. Additionally, DIC samples were collected and analyzed by personnel from AOML and PMEL.

We have now received at least one profile from all of the floats we deployed on this cruise. These data are preliminary, but each float appears to be functioning properly. As an example, we have included a plot that compares the first profile from Float 9602 with CTD/bottle data from station 36.

We would like to express our gratitude to all the members of the science party and shipboard crew who facilitated our deployments. We extend special thanks to chief scientist Alison Macdonald for ensuring that our floats were deployed within a few nautical miles of their target deployment locations, despite all the delays and setbacks we encountered on this cruise.

[1] We had originally planned to deploy seven floats for the cruise, but one float was deemed “dead on arrival” while we were in port. This float (UW ID 9642) was shipped back to Seattle prior to the cruise.

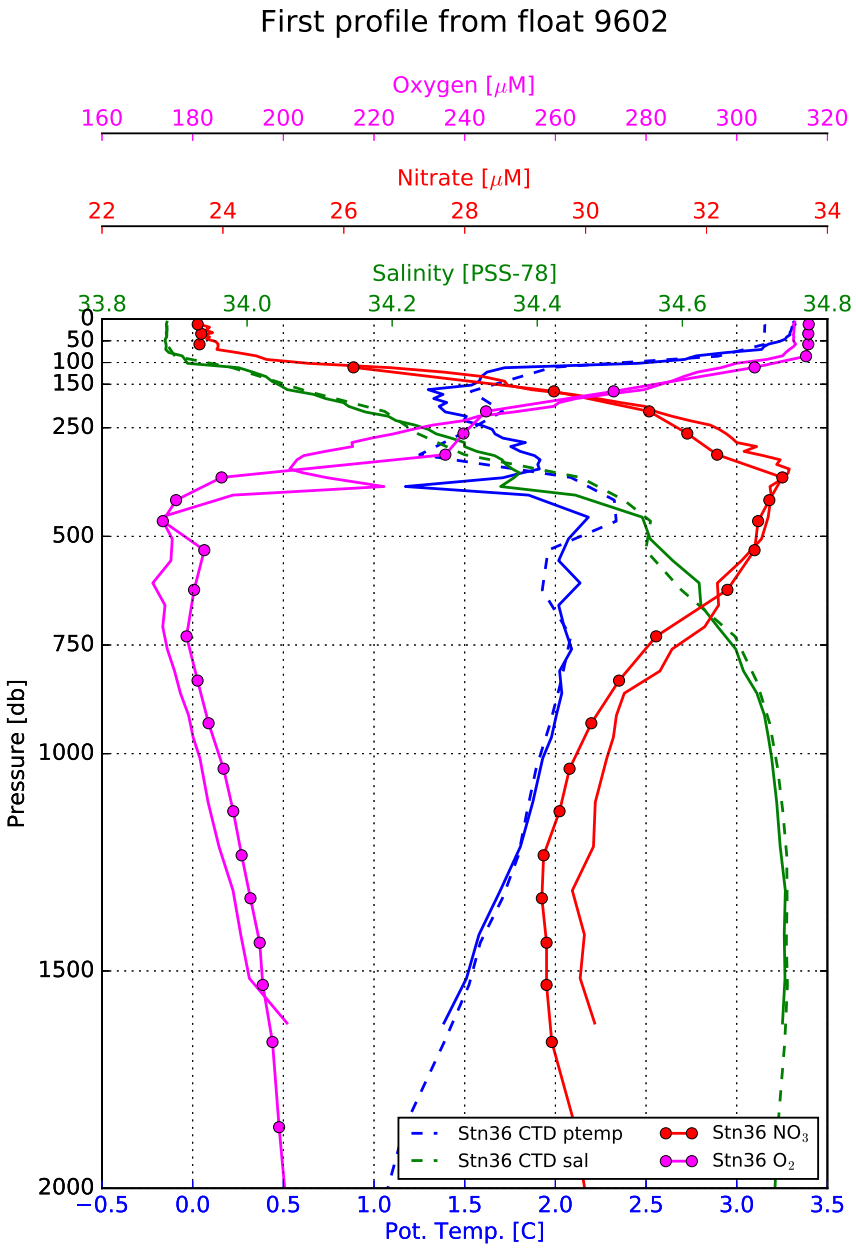



Fig. 19.1: Float 9602 Comparison

The above plot compares the first profile from the Argo float 9602 with preliminary data from station 36. The plain solid lines represent the float profiles. The broken blue and green lines show the temperature and salinity data from the station 36 CTD cast. The red and magenta lines with circular markers show nitrate and oxygen concentrations measured from station 36 bottle samples.

Table 19.1: This table summarizes the deployment time and location of each float.

| Nominal location (°S, °E) | Float UW ID | Sensors | I8S Sta. # Cast# | Deployment Date | Deployment Time | Lat. | Lon. | Name (deployer) |
|---|---|---|---|---|---|---|---|---|
| 63.525S, 82.00E | 0564 Navis | IONpF | 11/02 | Feb. 21, 2016 | 16:08 UTC | 63.535S | 82.000E | E. Wilson/J. Manger |
| 57.61S, 82.38E | 0510 Navis | IONpF | 25/02 | Feb. 24, 2016 | 20:31 UTC | 57.512S | 82.521E | E. Wilson/ J. Calderwood |
| 53.12S, 87.50E | 9602 Apex | IONpF | 36/02 | Feb. 28, 2016 | 07:16 UTC | 53.028S | 87.48E | E. Wilson/J. Manger |
| 50.57S, 90.03E | 9637 Apex | ONpF | 41/03 | Mar. 1, 2016 | 05:35 UTC | 50.48S | 89.84E | E. Wilson/J. Manger |
| 47.14S, 93.14E | 9650 Apex | ONpF | 48/02 | Mar. 3, 2016 | 01:52 UTC | 47.05S | 93.07E | E. Wilson/ J. Calderwood |
| 42.512S, 95.0E | 9600 Apex | ONpF | 56 | Mar. 5, 2016 | 3:33 UTC | 42.43S | 95.00E | E. Wilson/D. Webb |
| 35.0S, 95.0E | 9642 Apex | ONpF | N/A | N/A | N/A | N/A | N/A | N/A |

Table 19.2: Table of deployment comments

| Float UW ID | Comments |
|---|---|
| 0564 Navis | Line got snagged on first two attempts. Float was not harmed during recoveries. |
| 0510 Navis | Deployment was smooth. |
| 9602 Apex | Deployed at Station 36 instead of 37. Process was smooth. Several albatrosses flocked around the float while it was still at the surface. The float was likely OK. |
| 9637 Apex | Deployed at station 41 instead of 43. No issues with deployment. |
| 9650 Apex | Deployed at station 48 instead of 51. No issues with deployment. |
| 9600 Apex | Deployed at station 56 instead of 63. No issues with deployment. |
| 9642 Apex | Dead on arrival. Sent back to Seattle. |

CHAPTER

# TWENTY

# DRIFTER DEPLOYMENTS

**PI** Shaun Dolk (AOML)

Ten drifters were deployed on I08S for the Global Drifter Program. The deployment process was simple. All the plastic wrapping, and only the plastic wrapping, was removed from the drifter. After permission was obtained from the bridge for deployment, the drifter was then carried out to the stern. Carrying usually required two people, one of whom was the res-tech on duty, the other was a member of the CTD watch. A third person was usually in the lab, ready to take a snapshot of the tabulated GPS display as the drifter was dropped in. The time, position, and estimated height of the drop was then recorded on the log sheet. The log sheets were return to Shaun Dolk at AOML. At last word all 10 drifters had reported back. The table below indicates the particulars for each deployment.

Table 20.1: Table of deployments

| DRIFTER ID | STA# | DATE (UTC) | TIME (UTC) | LATITUDE (DEG MIN S) | LONGITUDE (DEG MIN E) | SHIP SPEED (knots) | SIDE OF STERN DEPLOYED FROM | HEIGHT ABOVE MEAN SEA LEVEL (m) |
|---|---|---|---|---|---|---|---|---|
| 139844 | 19 | 02/23/16 | 16:34 | 59 29.93 | 82 00.00 | 3.4 | Starboard | 5 |
| 139849 | 22 | 02/24/16 | 04:50 | 58 14.23 | 82 00.35 | 1 | Starboard | 6 |
| 139843 | 24 | 02/24/16 | 14:22 | 57 36.52 | 82 23.08 | 6.4 | Starboard | 4.5 |
| 139847 | 28 | 02/25/16 | 16:37 | 56 28.79 | 83 46.58 | 7.2 | Starboard | 4 to 4.5 |
| 139845 | 31 | 02/26/16 | 12:56 | 55 11.52 | 85 11.57 | 7.2 | Starboard | 7 |
| 132656 | 33 | 02/27/16 | 01:27 | 54 21.78 | 86 8.58 | 10 | Starboard | 8 |
| 115013 | 35 | 02/28/16 | 00:55 | 53 31.51 | 87 1.37 | 2 | Port | 8 |
| 114800 | 38 | 02/29/16 | 04:49 | 52 01.77 | 88 25.52 | 4.7 | Port | 6 |
| 115016 | 39 | 02/29/16 | 16:08 | 51 32.10 | 88 53.09 | 2 | Starboard | 4.5 |
| 115017 | 40 | 02/29/16 | 22.55 | 51 1.91 | 89 21.23 | 9.6 | Port | 5 to 6 |

Height above mean sea level was estimated as: 3 meter freeboard + 1 meter rail + estimated wave height

APPENDIX

A

# ABBREVIATIONS

**AOML** Atlantic Oceanographic and Meteorological Laboratory

**AP** Particulate Absorbtion Spectra

**CDOM** Chromophoric Dissolved Organic Matter

**CFCs** Chlorofluorocarbons

**CTDO** Conductivity Temperature Depth Oxygen

**DIC** Dissolved Inorganic Carbon

**DOC** Dissolved Organic Carbon

**ETHZ** Edgenössische Technische Hochschule Zürich

**HPLC** High-Performance Liquid Chromatography

**LDEO** Lamont-Doherty Earth Observatory - Columbia University

**LADCP** Lowered Accoustic Doppler Profiler

**NOAA** National Oceanographic Atmospheric Administration

**MBARI** Monterey Bay Aquarium Research Institute

**ODF** Ocean Data Facility

**OSU** Oregon State University

**PMEL** Pacific Marine Environmental Laboratory

**POC** Particulate Organic Carbon

**Princeton** Princeton University

**RSMAS** Rosenstiel School of Marine and Atmospheric Science - UM

**SF6** Sulfur Hexafluoride

**SIO** Scripps Institution of Oceanography

**SOCCOM** The Southern Ocean Carbon and Climate Observations and Modeling project. http://soccom.princeton.edu/

**STS** Shipboard Technical Support - SIO

**TAMU** Texas Agricultural and Mechanical Engineering University

**TDN** Total Dissolved Nitorgen

**U Colorado** University of Colorado

**UCSB** University of California Santa Barbara

**UCSD** University of California San Diego

**UH** University of Hawaii

**UM** University of Miami

**UNSW** University of New South Wales

**UW** University of Washington

**UWA** University of Western Australia

**VUB** Vrije Universiteit Brüssel

**WHOI** Woods Hole Oceanographic Institution

[Mill82] Millard, R. C., Jr., “CTD calibration and data processing techniques at WHOI using the practical salinity scale,” Proc. Int. STD Conference and Workshop, p. 19, Mar. Tech. Soc., La Jolla, Ca. (1982).

[Owen85] Owens, W. B. and Millard, R. C., Jr., “A new algorithm for CTD oxygen calibration,” Journ. of Am. Meteorological Soc., 15, p. 621 (1985).

[UNESCO1981] UNESCO 1981. Background papers and supporting data on the Practical Salinity Scale, 1978. UNESCO Technical Papers in Marine Science, No. 37 144.

[Armstrong1967] Armstrong, F.A.J., Stearns, C.A., and Strickland, J.D.H., “The measurement of upwelling and subsequent biological processes by means of the Technicon Autoanalyzer and associated equipment,” Deep-Sea Research, 14, pp.381-389 (1967).

[Atlas1971] Atlas, E.L., Hager, S.W., Gordon, L.I., and Park, P.K., “A Practical Manual for Use of the Technicon AutoAnalyzer in Seawater Nutrient Analyses Revised,” Technical Report 215, Reference 71-22, p.49, Oregon State University, Department of Oceanography (1971).

[Aoyama2006] Aoyama, M., 2006: 2003 Intercomparison Exercise for Reference Material for Nutrients in Seawater in a Seawater Matrix, Technical Reports of the Meteorological Research Institute No.50, 91pp, Tsukuba, Japan.

[Aoyama2007] Aoyama, M., Susan B., Minhan, D., Hideshi, D., Louis, I. G., Kasai, H., Roger, K., Nurit, K., Doug, M., Murata, A., Nagai, N., Ogawa, H., Ota, H., Saito, H., Saito, K., Shimizu, T., Takano, H., Tsuda, A., Yokouchi, K., and Agnes, Y. 2007. Recent Comparability of Oceanographic Nutrients Data: Results of a 2003 Intercomparison Exercise Using Reference Materials. Analytical Sciences, 23: 1151-1154.

[Aoyama2008] Aoyama M., J. Barwell-Clarke, S. Becker, M. Blum, Braga E. S., S. C. Coverly,E. Czobik, I. Dahllof, M. H. Dai, G. O. Donnell, C. Engelke, G. C. Gong, Gi-Hoon Hong, D. J. Hydes, M. M. Jin, H. Kasai, R. Kerouel, Y. Kiyomono, M. Knockaert, N. Kress, K. A. Krogslund, M. Kumagai, S. Leterme, Yarong Li, S. Masuda, T. Miyao, T. Moutin, A. Murata, N. Nagai, G.Nausch, M. K. Ngirchechol, A. Nybakk, H. Ogawa, J. van Ooijen, H. Ota, J. M. Pan, C. Payne, O. Pierre-Duplessix, M. Pujo-Pay, T. Raabe, K. Saito, K. Sato, C. Schmidt, M. Schuett, T. M. Shammon, J. Sun, T. Tanhua, L. White, E.M.S. Woodward, P. Worsfold, P. Yeats, T. Yoshimura, A.Youenou, J. Z. Zhang, 2008: 2006 Intercomparison Exercise for Reference Material for Nutrients in Seawater in a Seawater Matrix, Technical Reports of the Meteorological Research Institute No. 58, 104pp.

[Bernhardt1967] Bernhardt, H., and Wilhelms, A., “The continuous determination of low level iron, soluble phosphate and total phosphate with the AutoAnalyzer,” Technicon Symposia, I,pp.385-389 (1967).

[Gordon1992] Gordon, L.I., Jennings, J.C., Ross, A.A., Krest, J.M., “A suggested Protocol for Continuous Flow Automated Analysis of Seawater Nutrients in the WOCE Hydrographic Program and the Joint Global Ocean Fluxes Study,” Grp. Tech Rpt 92-1, OSU College of Oceanography Descr. Chem Oc. (1992).

[Hager1972] Hager, S.W., Atlas, E.L., Gordon L.I., Mantyla, A.W., and Park, P.K., ” A comparison at sea of manual and autoanalyzer analyses of phosphate, nitrate, and silicate ,” Limnology and Oceanography, 17,pp.931-937 (1972).

[Hydes2010] Hydes, D.J., Aoyama, M., Aminot, A., Bakker, K., Becker, S., Coverly, S., Daniel,A.,Dickson,A.G., Grosso, O., Kerouel, R., Ooijen, J. van, Sato, K., Tanhua, T., Woodward, E.M.S., Zhang, J.Z., 2010. Determination of Dissolved Nutrients (N, P, Si) in Seawater with High Precision and Inter-Comparability Using Gas-Segmented Continuous Flow Analysers, In: GO-SHIP Repeat Hydrography Manual: A Collection of Expert Reports and Guidelines. IOCCP Report No. 14, ICPO Publication Series No 134.

[Kerouel1997] Kerouel, R., Aminot, A., "Fluorometric determination of ammonia in sea and estuarine waters by direct segmented flow analysis." Marine Chemistry, vol 57, no. 3-4, pp. 265-275, July 1997.

[Sato2010] Sato, K., Aoyama, M., Becker, S., 2010. RMNS as Calibration Standard Solution to Keep Comparability for Several Cruises in the World Ocean in 2000s. In: Aoyama, M., Dickson, A.G., Hydes, D.J., Murata, A., Oh, J.R., Roose, P., Woodward, E.M.S., (Eds.), Comparability of nutrients in the world's ocean. Tsukuba, JAPAN: MOTHER TANK, pp 43-56.

[DOE1994] DOE (U.S. Department of Energy). (1994). *Handbook of Methods for the Analysis of the Various Parameters of the Carbon Dioxide System in Seawater*. Version 2.0. ORNL/CDIAC-74. Ed. A. G. Dickson and C. Goyet. Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, Oak Ridge, Tenn.

[Dickson2007] Dickson, A.G., Sabine, C.L. and Christian, J.R. (Eds.), (2007): *Guide to Best Practices for Ocean CO2 Measurements*. PICES Special Publication 3, 191 pp.

[Feely1998] 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 pCO2 measurements aboard research ships."* Anal. Chim. Acta, 377, 185-191.

[Johnson1985] Johnson, K.M., A.E. King, and J. McN. Sieburth (1985): *"Coulometric DIC analyses for marine studies: An introduction."* Mar. Chem., 16, 61-82.

[Johnson1987] Johnson, K.M., P.J. Williams, L. Brandstrom, and J. McN. Sieburth (1987): *"Coulometric total carbon analysis for marine studies: Automation and calibration."* Mar. Chem., 21, 117-133.

[Johnson1992] 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.

[Johnson1993] 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.

[Johnson1999] Johnson, K.M., Körtzinger, A.; Mintrop, L.; Duinker, J.C.; and Wallace, D.W.R. (1999). *Coulometric total carbon dioxide analysis for marine studies: Measurement and interna consistency of underway surface TCO2 concentrations.* Marine Chemistry 67:123–44.

[Lewis1998] Lewis, E. and D. W. R. Wallace (1998) Program developed for CO2 system calculations. Oak Ridge, Oak Ridge National Laboratory. http://cdiac.ornl.gov/oceans/co2rprt.html

[Wilke1993] 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

[Carter2013] 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.

[Liu2011] Liu, X., Patsavas, M.C., Byrne R.H., "Purification and Characterization of meta Cresol Purple for Spectrophotometric Seawater pH Measurements," Environmental Science and Technology, 2011.

[Lueker2000] Lueker, T.J., Dickson, A.G., Keeling, C.D. "Ocean pCO2 calculated from dissolved inorganic carbon, alkalinity, and equations for K1 and K2: validation based on laboratory measurements of CO2 in gas and seawater at equilibrium," Marine Chemistry, 2000.

[Patsavas2013] Patsavas, M.C., Byrne, R.H., and Liu X. "Purification of meta-cresol purple and cresol red by flash chromatography: Procedures for ensuring accurate spectrophotometric seawater pH measurements," Marine Chemistry, 2013.

[Pierrot2009] Pierrot, D.; Neill, C.; Sullivan, K.; Castle, R.; Wanninkhof, R.; Luger, H.; Johannessen, T.; Olsen, A.; Feely, R.A.; and Cosca, C.E. (2009). *Recommendations for autonomous underway pCO2 measuring systems and data-reduction routines.* Deep-Sea Res., II, v. 56, pp. 512-522.

[Wanninkhof1993] Wanninkhof, R., and Thoning, K. (1993). *Measurement of fugacity of CO2 in surface water using continuous and discrete sampling methods.* Mar. Chem., v. 44, no. 2-4, pp. 189-205.

[Mueller2003] Mueller, J.L., G.S Fargion, and C.R. McClain (eds), 2003. Ocean Optics Protocols For Satellite Ocean Color Sensor Validation, Revision 4. Greenbelt, MD, NASA Goddard Spaceflight Center, NASA/TM-2003-211621/Rev4.

[Nelson1998] Nelson, N.B., D.A. Siegel, and A.F. Michaels, 1998. Seasonal dynamics of colored dissolved organic matter in the Sargasso Sea. Deep-Sea Res. 45, 931-957.

[Nelson2007] Nelson, N.B., D.A. Siegel, C.A. Carlson, C. Swan, W.M. Smethie, Jr., and S. Khatiwala,. 2007. Hydrography of chromophoric dissolved organic matter in the North Atlantic. Deep-Sea Res. 54, 710-731.

[Nelson2009] Nelson, N.B., and P.G. Coble, 2009. Optical analysis of chromophoric dissolved organic matter. In: Practical Guidelines for the Analysis of Seawater, Wurl. O. (ed). San Diego: CRC Press.

[Nelson2016] Nelson, N.B., and J.M. Gauglitz, 2016. Optical signatures of dissolved organic matter transformation in the global ocean. Front. Mar. Sci. 2:118. doi: 10.3389/fmars.2015.00118.

[Slade2010] Slade, W.H., E. Boss, G. Dall'Omo, M.R. Langner, J. Loftin, M.J. Behrenfeld, C. Roesler, and T.K. Westberry, 2010. Underway and Moored Methods for Improving Accuracy in Measurement of Spectral Particulate Absorption and Attenuation. J. Atmos. Ocean. Tech. 27: 1733-1746.

APPENDIX

# B

# BOTTLE QUALITY COMMENTS

Table B.1: Carbon, Oxygen, and Nutrient Quality Comments

| Station | Cast | Bottle | Param | Code | Comment |
|---|---|---|---|---|---|
| 2 | 3 | 6 | OXYGEN | 2 | Bottle value does not match downcast, does match upcast. Code good. |
| 2 | 3 | 10 | OXYGEN | 2 | Bottle value does not match downcast, does match upcast. Code good. |
| 2 | 3 | 11 | OXYGEN | 2 | Bottle value does not match downcast, does match upcast. Code good. |
| 3 | 1 | 2 | PH_TMP | 3 | High baseline absorbance (Ao=-0.009) |
| 3 | 1 | 2 | PH_TOT | 3 | High baseline absorbance (Ao=-0.009) |
| 3 | 1 | 14 | OXYGEN | 2 | Bottle value does not match downcast, does match upcast. Code good. |
| 3 | 1 | 24 | OXYGEN | 2 | Bottle value does not match downcast, does match upcast. Code good. |
| 3 | 1 | 26 | PH_TMP | 3 | Difference between replicates was 0.0013 |
| 3 | 1 | 26 | PH_TOT | 3 | Difference between replicates was 0.0013 |
| 5 | 1 | 17 | OXYGEN | 2 | Bottle value does not match downcast, does match upcast. Code good. |
| 5 | 1 | 33 | OXYGEN | 2 | Bottle value does not match downcast, does match upcast. Code good. |
| 6 | 1 | 1 | PH_TMP | 3 | High baseline absorbance (Ao=0.009) |
| 6 | 1 | 1 | PH_TOT | 3 | High baseline absorbance (Ao=0.009) |
| 6 | 1 | 17 | ALKALI | 3 | Operator thinks the sampling pipette might not have been properly filled. |
| 6 | 1 | 27 | OXYGEN | 2 | Bottle value does not match downcast, does match upcast. Code good. |
| 6 | 1 | 28 | OXYGEN | 2 | Bottle value does not match downcast, does match upcast. Code good. |
| 6 | 1 | 32 | OXYGEN | 3 | Bottle value is a little high compared with profile. No feature to support the divation on this trace. Code questionable. |
| 7 | 2 | 12 | ALKALI | 3 | No issues found with analyses but values for 12-15 jump back and forth. Irregular pattern. Sampled incorrectly? |
| 7 | 2 | 13 | ALKALI | 3 | No issues found with analyses but values for 12-15 jump back and forth. Irregular pattern. Sampled incorrectly? |

Continued on next page

Table B.1 – continued from previous page

| Station | Cast | Bottle | Param | Code | Comment |
|---|---|---|---|---|---|
| 7 | 2 | 14 | ALKALI | 3 | No issues found with analyses but values for 12-15 jump back and forth. Irregular pattern. Sampled incorrectly? |
| 7 | 2 | 15 | ALKALI | 3 | No issues found with analyses but values for 12-15 jump back and forth. Irregular pattern. Sampled incorrectly? |
| 7 | 2 | 21 | OXYGEN | 2 | Bottle value does not match downcast, does match upcast. Code good. |
| 7 | 2 | 24 | OXYGEN | 2 | Bottle value does not match downcast, does match upcast. Code good. |
| 7 | 2 | 25 | OXYGEN | 2 | Bottle value does not match downcast, does match upcast. Code good. |
| 7 | 2 | 26 | ALKALI | 2 | Values for 26 and 27 appear to be switched. Will tell samplers to double check bottle and niskin numbers when sampling. |
| 7 | 2 | 26 | OXYGEN | 2 | Bottle value does not match downcast, does match upcast. Code good. |
| 7 | 2 | 27 | ALKALI | 3 | Values appears high |
| 7 | 2 | 31 | OXYGEN | 2 | Bottle value does not match downcast, does match upcast. Code good. |
| 8 | 1 | 16 | ALKALI | 3 | Value appears low |
| 8 | 1 | 18 | ALKALI | 2 | Values for 16 and 18 appear to be switched. Will tell samplers to double check bottle and niskin numbers when sampling. |
| 8 | 1 | 22 | OXYGEN | 4 | Bottle value does not match profile. Code bad. |
| 8 | 1 | 28 | OXYGEN | 2 | Bottle value does not match downcast, does match upcast. Code good. |
| 8 | 1 | 30 | OXYGEN | 3 | Bottle value between downcast and upcast. Code questionable. |
| 8 | 1 | 32 | OXYGEN | 2 | Bottle value does not match downcast, does match upcast. Code good. |
| 8 | 1 | 33 | OXYGEN | 2 | Bottle value does not match downcast, does match upcast. Code good. |
| 8 | 1 | 35 | OXYGEN | 3 | Bottle value between downcast and upcast. Code questionable. |
| 9 | 1 | 9 | ALKALI | 3 | Value appears a couple units low. |
| 9 | 1 | 11 | ALKALI | 3 | Value appears a couple units low. |
| 9 | 1 | 14 | ALKALI | 3 | Value appears a couple units low. |
| 9 | 1 | 20 | ALKALI | 3 | Value appears a couple units high |
| 9 | 1 | 21 | ALKALI | 3 | Value appears a couple units low. |
| 9 | 1 | 24 | OXYGEN | 2 | Bottle value does not match downcast, does match upcast. Code good. |
| 9 | 1 | 27 | OXYGEN | 2 | Bottle value does not match downcast, does match upcast. Code good. |
| 9 | 1 | 28 | ALKALI | 2 | A litle unusual 28 is so close to 29. |
| 9 | 1 | 29 | ALKALI | 2 | A litle unusual 28 is so close to 29. |
| 9 | 1 | 30 | ALKALI | 2 | A little unusual that 30 is so close to 31. Don't think 31 could have been sampled three times though. |
| 9 | 1 | 31 | ALKALI | 6 | Duplicate average great. |

Continued on next page

Table B.1 – continued from previous page

| Station | Cast | Bottle | Param | Code | Comment |
|---|---|---|---|---|---|
| 9 | 1 | 31 | OXYGEN | 2 | Bottle value does not match downcast, does match upcast. Code good. |
| 9 | 1 | 34 | OXYGEN | 3 | Bottle value is a little high compared with profile. No feature to support the divation on this trace. Code questionable. |
| 10 | 1 | 23 | OXYGEN | 2 | Bottle value does not match downcast, does match upcast. Code good. |
| 10 | 1 | 26 | OXYGEN | 2 | Bottle value does not match downcast, does match upcast. Code good. |
| 10 | 1 | 27 | OXYGEN | 2 | Bottle value does not match downcast, does match upcast. Code good. |
| 10 | 1 | 31 | OXYGEN | 2 | Bottle value does not match downcast, does match upcast. Code good. |
| 10 | 1 | 34 | OXYGEN | 2 | Bottle value does not match downcast, does match upcast. Code good. |
| 12 | 1 | 25 | PHSPHT | 4 | bad_peak |
| 13 | 1 | 22 | OXYGEN | 2 | Bottle value does not match downcast, does match upcast. Code good. |
| 13 | 1 | 22 | PH_TMP | 3 | Baseline absorbance (Ao) = 0.03 |
| 13 | 1 | 22 | PH_TOT | 3 | Baseline absorbance (Ao) = 0.03 |
| 14 | 3 | 1 | PH_TMP | 3 | High baseline absorbance (Ao=0.01) due to bubble. |
| 14 | 3 | 1 | PH_TOT | 3 | High baseline absorbance (Ao=0.01) due to bubble. |
| 15 | 1 | 27 | OXYGEN | 3 | Bottle value between downcast and upcast. Code questionable. |
| 15 | 1 | 28 | OXYGEN | 3 | Bottle value between downcast and upcast. Code questionable. |
| 15 | 1 | 32 | ALKALI | 2 | Second duplicate thrown out. |
| 16 | 1 | 7 | OXYGEN | 2 | Bottle value does not match downcast, does match upcast. Code good. |
| 16 | 1 | 21 | OXYGEN | 2 | Bottle value does not match downcast, does match upcast. Code good. |
| 18 | 1 | 17 | OXYGEN | 2 | Bottle value does not match downcast, does match upcast. Code good. |
| 21 | 1 | 20 | ALKALI | 5 | Operator lost sample due to system error. |
| 23 | 2 | 21 | OXYGEN | 3 | Bottle value is a little high compared with profile. No feature to support the divation on this trace. Code questionable. |
| 24 | 1 | 22 | OXYGEN | 2 | Bottle value does not match downcast, does match upcast. Code good. |
| 24 | 1 | 25 | OXYGEN | 3 | Bottle value is a little high compared with profile. No feature to support the divation on this trace. Code questionable. |
| 25 | 1 | 26 | OXYGEN | 4 | Bottle value does not match profile. Code bad. |
| 26 | 1 | 27 | OXYGEN | 2 | Bottle value does not match downcast, does match upcast. Code good. |
| 26 | 1 | 28 | OXYGEN | 2 | Bottle value does not match downcast, does match upcast. Code good. |

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Table B.1 – continued from previous page

| Station | Cast | Bottle | Param | Code | Comment |
|---|---|---|---|---|---|
| 26 | 1 | 30 | OXYGEN | 2 | Bottle value does not match downcast, does match upcast. Code good. |
| 27 | 1 | 20 | ALKALI | 3 | Could be a couple units low? Samples were dumped after being ran to keep up with incoming sampling. This sample could have been reran but the salinity values were not up to check the data after the initial run. |
| 27 | 1 | 22 | ALKALI | 3 | Could be a couple units low? Samples were dumped after being ran to keep up with incoming sampling. This sample could have been reran but the salinity values were not up to check the data after the initial run. |
| 27 | 1 | 28 | OXYGEN | 2 | Bottle value does not match downcast, does match upcast. Code good. |
| 27 | 1 | 29 | OXYGEN | 2 | Bottle value does not match downcast, does match upcast. Code good. |
| 27 | 1 | 30 | OXYGEN | 2 | Bottle value does not match downcast, does match upcast. Code good. |
| 27 | 1 | 31 | OXYGEN | 2 | Bottle value does not match downcast, does match upcast. High gradient region. Code good. |
| 27 | 1 | 35 | ALKALI | 3 | Value looks reasonable but electrode plot was off and the sample should have been reran. |
| 27 | 1 | 36 | OXYGEN | 2 | CTD O2 trace does not match bottle value, CTD value seems to be from pre-10m wait. Code good. |
| 28 | 1 | 18 | PHSPHT | 3 | bad_peak |
| 28 | 1 | 24 | OXYGEN | 2 | Bottle value does not match downcast, does match upcast. Code good. |
| 28 | 1 | 26 | OXYGEN | 2 | Bottle value does not match downcast, does match upcast. Code good. |
| 28 | 1 | 29 | OXYGEN | 2 | Bottle value does not match downcast, does match upcast. High gradient region. Code good. |
| 29 | 1 | 25 | OXYGEN | 3 | Bottle value is a little high compared with profile. No feature to support the divation on this trace. Code questionable. |
| 29 | 1 | 28 | OXYGEN | 3 | Bottle value is a little high compared with profile. No feature to support the divation on this trace. Code questionable. |
| 30 | 1 | 20 | NH4 | 2 | all nutrients high_o2 low_good |
| 30 | 1 | 20 | NITRAT | 2 | all nutrients high_o2 low_good |
| 30 | 1 | 20 | NITRIT | 2 | all nutrients high_o2 low_good |
| 30 | 1 | 20 | OXYGEN | 3 | Bottle value is a little high compared with profile. No feature to support the divation on this trace. Code questionable. |
| 30 | 1 | 20 | PHSPHT | 2 | all nutrients high_o2 low_good |
| 30 | 1 | 20 | PH_TMP | 3 | Possible misfire? Value deviates from profile. |
| 30 | 1 | 20 | PH_TOT | 3 | Possible misfire? Value deviates from profile. |
| 30 | 1 | 20 | SILCAT | 2 | all nutrients high_o2 low_good |
| 30 | 1 | 28 | OXYGEN | 3 | Bottle value is a little low compared with profile. No feature to support the divation on this trace. Code questionable. |

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Table B.1 – continued from previous page

| Station | Cast | Bottle | Param | Code | Comment |
|---|---|---|---|---|---|
| 30 | 1 | 29 | OXYGEN | 2 | Bottle value does not match downcast, does match upcast. Code good. |
| 30 | 1 | 31 | OXYGEN | 2 | Bottle value does not match downcast, does match upcast. Code good. |
| 30 | 1 | 32 | OXYGEN | 2 | Bottle value does not match downcast, does match upcast. Code good. |
| 31 | 3 | 25 | OXYGEN | 2 | Bottle value does not match downcast, does match upcast. Code good. |
| 31 | 3 | 26 | OXYGEN | 2 | Bottle value does not match downcast, does match upcast. Code good. |
| 32 | 1 | 21 | ALKALI | 3 | mis-trip |
| 32 | 1 | 21 | PH_TMP | 4 | Niskin misfire |
| 32 | 1 | 21 | PH_TOT | 4 | Niskin misfire |
| 32 | 1 | 29 | OXYGEN | 2 | Bottle value does not match downcast, does match upcast. Code good. |
| 32 | 1 | 30 | OXYGEN | 2 | Bottle value does not match downcast, does match upcast. Code good. |
| 32 | 1 | 33 | OXYGEN | 2 | Bottle value does not match downcast, does match upcast. Code good. |
| 32 | 1 | 34 | OXYGEN | 3 | Bottle value is a little low compared with profile. No feature to support the divation on this trace. Code questionable. |
| 33 | 1 | 28 | OXYGEN | 2 | Bottle value does not match downcast, does match upcast. Code good. |
| 33 | 1 | 32 | OXYGEN | 2 | Bottle value does not match downcast, does match upcast. Code good. |
| 33 | 1 | 33 | OXYGEN | 3 | Bottle value does not match downcast or upcast. High gradient region. Code questionable. |
| 34 | 1 | 21 | ALKALI | 3 | mis-trip |
| 34 | 1 | 21 | PH_TMP | 4 | Niskin misfire |
| 34 | 1 | 21 | PH_TOT | 4 | Niskin misfire |
| 34 | 1 | 25 | OXYGEN | 3 | Bottle value does not match downcast or upcast. High gradient region. Code questionable. |
| 34 | 1 | 27 | ALKALI | 3 | mis-trip |
| 34 | 1 | 27 | PH_TMP | 4 | Niskin misfire |
| 34 | 1 | 27 | PH_TOT | 4 | Niskin misfire |
| 36 | 1 | 22 | OXYGEN | 3 | Bottle value is a little high compared with profile. Code questionable. |
| 36 | 1 | 24 | OXYGEN | 3 | Bottle value is a little high compared with profile. Code questionable. |
| 36 | 1 | 27 | OXYGEN | 4 | Bottle value does not match profile. Code bad. |
| 36 | 1 | 29 | OXYGEN | 3 | Bottle value between downcast and upcast. Code questionable. |
| 37 | 1 | 1 | ALKALI | 3 | Value appears ~2 units high |
| 37 | 1 | 20 | OXYGEN | 3 | Bottle value between downcast and upcast. Code questionable. |
| 38 | 1 | 23 | OXYGEN | 3 | Bottle value between downcast and upcast. Code questionable. |
| 39 | 1 | 2 | OXYGEN | 2 | Bottle value does not match downcast, does match upcast. Code good. |

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Table B.1 – continued from previous page

| Station | Cast | Bottle | Param | Code | Comment |
|---|---|---|---|---|---|
| 39 | 1 | 15 | OXYGEN | 2 | Bottle value does not match downcast, does match upcast. Code good. |
| 39 | 1 | 22 | OXYGEN | 2 | Bottle value does not match downcast, does match upcast. Code good. |
| 39 | 1 | 23 | OXYGEN | 2 | Bottle value does not match downcast, does match upcast. Code good. |
| 39 | 1 | 25 | OXYGEN | 2 | Bottle value does not match downcast, does match upcast. Code good. |
| 39 | 1 | 26 | OXYGEN | 2 | Bottle value does not match downcast, does match upcast. Code good. |
| 39 | 1 | 27 | OXYGEN | 2 | Bottle value does not match downcast, does match upcast. Code good. |
| 40 | 1 | 21 | OXYGEN | 2 | Bottle value does not match downcast, does match upcast. Code good. |
| 40 | 1 | 22 | OXYGEN | 2 | Bottle value does not match downcast, does match upcast. Code good. |
| 40 | 1 | 29 | OXYGEN | 3 | Bottle value does not match downcast or upcast. High gradient region. Code questionable. |
| 40 | 1 | 30 | OXYGEN | 3 | Bottle value does not match downcast or upcast. High gradient region. Code questionable. |
| 42 | 2 | 28 | OXYGEN | 2 | Bottle value does not match downcast, does match upcast. Code good. |
| 43 | 1 | 2 | PH_TMP | 3 | Difference between duplicates was 0.0017. |
| 43 | 1 | 2 | PH_TOT | 3 | Difference between duplicates was 0.0017. |
| 43 | 1 | 19 | OXYGEN | 2 | Bottle value does not match downcast, does match upcast. Code good. |
| 43 | 1 | 21 | OXYGEN | 2 | Bottle value does not match downcast, does match upcast. Code good. |
| 43 | 1 | 24 | OXYGEN | 2 | Bottle value does not match downcast, does match upcast. Code good. |
| 44 | 1 | 19 | OXYGEN | 2 | Bottle value does not match downcast, does match upcast. Code good. |
| 44 | 1 | 33 | ALKALI | 2 | Seems a like it could be a little high but the rerun was spot on. |
| 45 | 1 | 19 | OXYGEN | 2 | Bottle value does not match downcast, does match upcast. Code good. |
| 45 | 1 | 22 | OXYGEN | 2 | Bottle value does not match downcast, does match upcast. Code good. |
| 46 | 1 | 30 | PH_TMP | 3 | Difference between replicates was 0.0010. |
| 46 | 1 | 30 | PH_TOT | 3 | Difference between replicates was 0.0010. |
| 48 | 1 | 24 | OXYGEN | 2 | Bottle value does not match downcast, does match upcast. Code good. |
| 49 | 1 | 26 | OXYGEN | 2 | Bottle value does not match downcast, does match upcast. Code good. |
| 50 | 1 | 22 | OXYGEN | 2 | Bottle value does not match downcast, does match upcast. Code good. |
| 51 | 1 | 17 | OXYGEN | 2 | Bottle value does not match downcast, does match upcast. Code good. |
| 51 | 1 | 27 | OXYGEN | 2 | Bottle value does not match downcast, does match upcast. Code good. |

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Table B.1 – continued from previous page

| Station | Cast | Bottle | Param | Code | Comment |
|---|---|---|---|---|---|
| 52 | 1 | 24 | OXYGEN | 3 | Bottle value between downcast and upcast. Code questionable. |
| 52 | 1 | 26 | OXYGEN | 3 | Bottle value between downcast and upcast. Code questionable. |
| 52 | 1 | 27 | OXYGEN | 3 | Bottle value between downcast and upcast. Code questionable. |
| 53 | 1 | 26 | OXYGEN | 2 | Bottle value does not match downcast, does match upcast. Code good. |
| 53 | 1 | 27 | OXYGEN | 2 | Bottle value does not match downcast, does match upcast. Code good. |
| 54 | 1 | 23 | OXYGEN | 2 | Bottle value does not match downcast, does match upcast. Code good. |
| 54 | 1 | 31 | OXYGEN | 2 | Bottle value does not match downcast, does match upcast. Code good. |
| 55 | 1 | 17 | OXYGEN | 2 | Bottle value does not match downcast, does match upcast. Code good. |
| 55 | 1 | 34 | OXYGEN | 2 | Trace does not match bottle value at surface/mixed layer. Code good. |
| 56 | 1 | 23 | OXYGEN | 2 | Bottle value does not match downcast, does match upcast. Code good. |
| 57 | 1 | 24 | OXYGEN | 2 | Bottle value does not match downcast, does match upcast. Code good. |
| 59 | 1 | 28 | PH_TMP | 5 | LabView program crashed during measurement. Lost data. |
| 59 | 1 | 28 | PH_TOT | 5 | LabView program crashed during measurement. Lost data. |
| 61 | 1 | 27 | OXYGEN | 3 | Bottle value between downcast and upcast. Code questionable. |
| 62 | 1 | 17 | OXYGEN | 2 | Bottle value does not match downcast, does match upcast. Code good. |
| 62 | 1 | 34 | OXYGEN | 2 | Bottle value does not match downcast, does match upcast. Code good. |
| 62 | 1 | 36 | PH_TMP | 3 | Difference between replicates was 0.001. |
| 62 | 1 | 36 | PH_TOT | 3 | Difference between replicates was 0.001. |
| 63 | 1 | 24 | OXYGEN | 2 | Bottle value does not match downcast, does match upcast. Code good. |
| 63 | 1 | 25 | OXYGEN | 2 | Bottle value does not match downcast, does match upcast. Code good. |
| 64 | 1 | 24 | OXYGEN | 2 | Bottle value follows nutrient samples, CTD temp, salinity data, o2 trace looks bad. Code good. |
| 64 | 1 | 25 | OXYGEN | 2 | Bottle value follows nutrient samples, CTD temp, salinity data, o2 trace looks bad. Code good. |
| 64 | 1 | 26 | OXYGEN | 2 | Bottle value follows nutrient samples, CTD temp, salinity data, o2 trace looks bad. Code good. |
| 64 | 1 | 36 | OXYGEN | 2 | Bottle value follows nutrient samples, CTD temp, salinity data, o2 trace looks bad. Code good. |
| 65 | 2 | 8 | OXYGEN | 2 | Bottle value does not match downcast, does match upcast. Code good. |
| 65 | 2 | 35 | OXYGEN | 2 | Bottle value does not match downcast, does match upcast. Code good. |

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Table B.1 – continued from previous page

| Station | Cast | Bottle | Param | Code | Comment |
|---|---|---|---|---|---|
| 67 | 1 | 12 | OXYGEN | 2 | Bottle value does not match downcast, does match upcast. Code good. |
| 68 | 1 | 2 | PH_TMP | 3 | A large bubble formed in the water bath tubing and stopped circulation. Measurement temperature is questionable. |
| 68 | 1 | 2 | PH_TOT | 3 | A large bubble formed in the water bath tubing and stopped circulation. Measurement temperature is questionable. |
| 68 | 1 | 30 | OXYGEN | 2 | Bottle value does not match downcast, does match upcast. Code good. |
| 69 | 1 | 17 | OXYGEN | 2 | Bottle value does not match downcast, does match upcast. Code good. |
| 69 | 1 | 21 | OXYGEN | 2 | Bottle value does not match downcast, does match upcast. Code good. |
| 69 | 1 | 28 | OXYGEN | 2 | Bottle value does not match downcast, does match upcast. Code good. |
| 71 | 1 | 17 | OXYGEN | 2 | Bottle value does not match downcast, does match upcast. Code good. |
| 72 | 2 | 34 | OXYGEN | 4 | Bottle value does not match profile. O2 detector problem while running analysis. Code bad. |
| 73 | 1 | 32 | OXYGEN | 4 | Bottle value does not match profile. Code bad. |
| 74 | 1 | 24 | OXYGEN | 2 | Bottle value does not match downcast, does match upcast. Code good. |
| 75 | 1 | 20 | OXYGEN | 2 | Bottle value does not match downcast, does match upcast. Code good. |
| 75 | 1 | 24 | PH_TMP | 3 | Difference between replicates was 0.001. |
| 75 | 1 | 24 | PH_TOT | 3 | Difference between replicates was 0.001. |
| 76 | 2 | 29 | OXYGEN | 2 | Bottle value does not match downcast, does match upcast. Code good. |
| 76 | 2 | 30 | OXYGEN | 2 | Bottle value does not match downcast, does match upcast. Code good. |
| 76 | 2 | 32 | OXYGEN | 2 | Bottle value does not match downcast, does match upcast. Code good. |
| 76 | 2 | 33 | OXYGEN | 2 | Bottle value does not match downcast, does match upcast. Code good. |
| 78 | 1 | 15 | OXYGEN | 2 | Bottle value does not match downcast, does match upcast. Code good. |
| 79 | 1 | 21 | OXYGEN | 2 | Bottle value does not match downcast, does match upcast. Code good. |
| 80 | 1 | 6 | OXYGEN | 3 | Bottle value between downcast and upcast. Code questionable. |
| 80 | 1 | 7 | OXYGEN | 3 | Bottle value does not match downcast, does match upcast. Code good. |
| 82 | 1 | 26 | PH_TMP | 3 | Difference between duplicates was 0.0013. |
| 82 | 1 | 26 | PH_TOT | 3 | Difference between duplicates was 0.0013. |

Table B.2: Bottle, CTD, and Salintiy Quality Comments

| Station | Bottle | Param | Code | Source | Comment |
|---|---|---|---|---|---|
| 001/01 | 101 | Bottle | 3 | cms | Leaking. |
| 011/01 | 101 | Reference T | 3 | cms | SBE35 value does not match profile or adjacent casts. Code questionable. |
| 011/01 | 133 | Reference T | 3 | cms | Unstable temperature in all 3 sensors. Code questionable. |
| 011/01 | 133 | CTD T1 Temperature | 3 | cms | Unstable temperature in all 3 sensors. Code questionable. |
| 011/01 | 133 | CTD T2 Temperature | 3 | cms | Unstable temperature in all 3 sensors. Code questionable. |
| 011/01 | 134 | Reference T | 3 | cms | Unstable temperature in all 3 sensors. Code questionable. |
| 011/01 | 134 | CTD T1 Temperature | 3 | cms | Unstable temperature in all 3 sensors. Code questionable. |
| 011/01 | 134 | CTD T2 Temperature | 3 | cms | Unstable temperature in all 3 sensors. Code questionable. |
| 012/01 | 102 | Salinity | 4 | cms | Salinity value high vs DCTC1/CTDC2 for this part of profile. Value better matches level 3. Possible mis-sample. code bad. |
| 012/01 | 128 | CTD T2 Temperature | 4 | cms | CTDT2 high vs CTDT1/SBE35. Code bad. |
| 012/01 | 129 | Salinity | 2 | cms | Salinity value high vs CTDC1/CTDC2. High gradient. Matches upcast. Code good. |
| 013/01 | 122 | Salinity | 2 | cms | Salinity value high vs CTDC1/CTDC2. High gradient. Matches upcast. Code good. |
| 014/03 | 303 | Bottle | 3 | slog | Bottle leaking. Bad. |
| 014/03 | 305 | Bottle | 3 | slog | Bottle slow flow. Possible blocked spigot. |
| 014/03 | 306 | Bottle | 3 | slog | Bottle leaking. Top air vent left open. |
| 014/03 | 318 | Bottle | 3 | slog | Bottle leaking. Bad. |
| 014/03 | 331 | Bottle | 3 | slog | Bottle leaking. Bad. |
| 015/01 | 104 | Bottle | 2 | slog | Grease on spigot. |
| 015/01 | 105 | Bottle | 3 | slog | Bottle slow flow. Possible blocked air vent. |
| 015/01 | 118 | Bottle | 3 | slog | Bottle leaking. Possible top end cap. Replaced top end cap after cast. |
| 016/01 | 108 | Bottle | 3 | slog | Bottle leaking. Top o-ring not seated correctly. |
| 016/01 | 118 | Bottle | 3 | slog | Bottle leaking. Replaced Bottletle after cast. |
| 016/01 | 122 | Reference T | 4 | cms | SBE35 value high vs CTDT1/CTDT2. High gradient. Sensor needed more time to equilibrate. Code bad. |
| 016/01 | 122 | Salinity | 2 | cms | Salinity value high vs CTDC1/CTDC2. High gradient. Matches upcast. Code good. |
| 017/01 | 110 | Bottle | 3 | slog | Leaking from Bottletom end cap. |
| 017/01 | 122 | Bottle | 3 | slog | Leaker |
| 018/01 | 118 | CTD T1 Temperature | 3 | cms | CTDT1 low vs CTDC2/SBE35. Code questionable. |
| 018/01 | 119 | Salinity | 2 | cms | CTDT1 low vs CTDC2/SBE35. Salinity valuie matches upcast. |
| 018/01 | 122 | Salinity | 4 | cms | Salinity value anomalously high. Code bad. |
| 019/02 | 221 | Reference T | 3 | cms | Unstable temperature in all 3 sensors. Code questionable. |

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Table B.2 – continued from previous page

| Station | Bottle | Param | Code | Source | Comment |
|---|---|---|---|---|---|
| 019/02 | 221 | CTD T1 Temperature | 3 | cms | Unstable temperature in all 3 sensors. Code questionable. |
| 019/02 | 221 | CTD T2 Temperature | 3 | cms | Unstable temperature in all 3 sensors. Code questionable. |
| 019/02 | 222 | Reference T | 3 | cms | Unstable temperature in all 3 sensors. Code questionable. |
| 019/02 | 222 | CTD T1 Temperature | 3 | cms | Unstable temperature in all 3 sensors. Code questionable. |
| 019/02 | 222 | CTD T2 Temperature | 3 | cms | Unstable temperature in all 3 sensors. Code questionable. |
| 002/03 | 321 | Salinity | 2 | cms | Salinity value low vs CTDC1/CTDC2. Matches upcast data. Code good. |
| 022/01 | 103 | Bottle | 3 | slog | Bottle had slight leak before vent opened. |
| 022/01 | 106 | Bottle | 2 | slog | Lanyard broken then replaced after sampling. |
| 023/02 | 222 | Reference T | 4 | cms | SBE35 value low vs CTDT1/CTDT2. Sensor did not equilibrate. |
| 023/02 | 222 | Salinity | 2 | cms | Salinity value low vs CTDC1/CTDC2. High gradient. Matches up-cast. Code good. |
| 024/01 | 127 | Reference T | 4 | cms | SBE35 value low vs CTDT1/CTDT2. High gradient. Sensor likely not equilibrated. |
| 024/01 | 127-129 | Bottle | 2 | slog | Nutrient sampler skipped ahead of CFCS sampling. |
| 025/01 | 103 | Bottle | 3 | slog | Bottle had slight leak before vent opened. |
| 025/01 | 134 | Bottle | 2 | slog | Bottle ran out of water prior to HPLC, nutrient and Salinity sample draw. |
| 026/01 | 113 | Bottle | 2 | slog | 13 has a lot of grease on the cap. |
| 026/01 | 131 | Bottle | 2 | slog | 31 clip on lanyard does not close properly. |
| 026/01 | 135 | Salinity | 2 | cms | Salinity value high vs CTDT1/CTDT2. High gradient.Salinity matches up-cast. Code good. |
| 029/01 | 103 | Bottle | 3 | slog | Leak. |
| 030/01 | 103 | Bottle | 3 | slog | Leaking. Vent not closed tight. |
| 030/01 | 107 | Bottle | 2 | slog | Bottle is loose. |
| 030/01 | 125 | Bottle | 3 | slog | Leaking. Vent not closed tight. |
| 031/03 | 307 | CTD T2 Temperature | 4 | cms | CTDT2 lower vs CTD1/SBE35. Anomalous. Code bad |
| 032/01 | 110 | Salinity | 4 | cms | Salinity value high vs CTDC1/CTDC2. Low gradient. Code bad. |
| 032/01 | 115 | Bottle | 2 | slog | Lanyard caught on 15 during recovery. Not sure if opened. |
| 032/01 | 121 | Bottle | 4 | cms | Mis-trip. |
| 032/01 | 121 | Salinity | 3 | cms | Mis-trip. |
| 032/01 | 129 | CTD T1 Temperature | 4 | cms | CTDT1 lower vs CTD2/SBE35. Anomalous. Code bad |
| 033/01 | 101 | Salinity | 4 | cms | Salinity value does not match Bottletom of profile. Value matches Bottletle 35. May have been mis-sampled. |
| 033/01 | 102 | Salinity | 4 | cms | Salinity value does not match Bottletom of profile. Code bad. |
| 033/01 | 111 | Reference T | 4 | cms | Tripped on the fly due to weather. SBE35 did not equilibrate. |

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Table B.2 – continued from previous page

| Station | Bottle | Param | Code | Source | Comment |
|---|---|---|---|---|---|
| 033/01 | 116 | Reference T | 4 | cms | Tripped on the fly due to weather. SBE35 did not equilibrate. |
| 033/01 | 121 | Bottle | 4 | cms | Mis-trip |
| 033/01 | 121 | Salinity | 3 | cms | Mis-trip |
| 033/01 | 130-134 | Reference T | 4 | cms | Tripped on the fly due to weather. SBE35 did not equilibrate. 40 dbar change in pressure depth of thermocline from beginning of cast to end of cast. |
| 034/01 | 103 | Bottle | 3 | slog | Leaker. Vent was not closed. |
| 034/01 | 117 | Bottle | 3 | slog | Leaker. Vent was not closed. |
| 034/01 | 125 | Bottle | 3 | slog | Leaker. Vent was not closed. |
| 034/01 | 131 | Reference T | 4 | cms | Tripped on the fly due to weather. SBE35 did not equilibrate. |
| 034/01 | 121 | Bottle | 4 | cms | Mis-trip |
| 034/01 | 121 | Salinity | 3 | cms | Mis-trip |
| 034/01 | 127 | Bottle | 4 | cms | Mis-trip |
| 034/01 | 127 | Salinity | 3 | cms | Mis-trip |
| 035/01 | 108 | Reference T | 4 | cms | Tripped on the fly due to weather. SBE35 did not equilibrate. |
| 035/01 | 123 | CTD T1 Temperature | 4 | cms | CTDT1 high vs CTDT2/SBE35. Code bad. |
| 035/01 | 124-125 | Reference T | 4 | cms | Tripped on the fly due to weather. SBE35 did not equilibrate. |
| 035/01 | 128 | CTD T2 Temperature | 4 | cms | CTDT2 high vs CTDT1/SBE35. Code bad. |
| 035/01 | 133 | CTD T1 Temperature | 4 | cms | CTDT1 low vs CTDT2/SBE35. Code bad. |
| 035/01 | 130-131 | Reference T | 4 | cms | Tripped on the fly due to weather. SBE35 did not equilibrate. |
| 036/01 | 126 | Reference T | 4 | cms | Tripped on the fly due to weather. SBE35 did not equilibrate. |
| 036/01 | 128 | Reference T | 4 | cms | Tripped on the fly due to weather. SBE35 did not equilibrate. |
| 036/01 | 130 | Reference T | 4 | cms | Tripped on the fly due to weather. SBE35 did not equilibrate. |
| 036/01 | 131 | CTD T1 Temperature | 4 | cms | CTDT1 low vs CTDT2/SBE35. Code bad. |
| 037/01 | 104 | Reference T | 4 | cms | SBE35 value does not fit profile. Bottle tripped on the fly. Sensor did not equilibrate. Code bad. |
| 037/01 | 123 | CTD T1 Temperature | 4 | cms | CTDT1 high vs CTDT2/SBE35. Code bad. |
| 037/01 | 124 | Reference T | 4 | cms | SBE35 value does not fit profile. Bottle tripped on the fly in high gradient. Sensor did not equilibrate. Code bad. |
| 038/01 | 103 | Bottle | 3 | cms | Leaker. |
| 038/01 | 103 | Salinity | 4 | cms | Salinity value high vs CTDC1/CTDC2 for this depth. Code bad. |
| 038/01 | 132 | CTD T2 Temperature | 3 | cms | CTDT2 value high vs SBE35/CTDT1. Code questionable. |
| 039/01 | 134 | Bottle | 3 | slog | Almost all water lost on btl 34. O-ring not seated correctly. Enough water was left to collect nutrients. |
| 039/01 | 103 | Bottle | 3 | slog | Leaker. Air vent not seated correctly. |
| 004/01 | 130 | Salinity | 2 | cms | Salinity value high vs CTDC1/CTDC2. Matches upcast data. Code good. |
| 004/01 | 129 | Salinity | 4 | cms | Salinity value high vs CTDC1/CTDC2. |

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Table B.2 – continued from previous page

| Station | Bottle | Param | Code | Source | Comment |
|---|---|---|---|---|---|
| 040/01 | 107 | Salinity | 4 | cms | Salinity value does not match this part of the profile. Possibly mis-sampled or run out of order. |
| 040/01 | 112 | Bottle | 2 | slog | Lanyard snapped on recovery. |
| 040/01 | 112 | Salinity | 4 | cms | Salinity value does not match this part of the profile. Possibly mis-sampled or run out of order. |
| 040/01 | 136 | Bottle | 2 | slog | Bottle might have been fired out of the water due to winch display problems. |
| 041/02 | 211 | Bottle | 3 | slog | Leaking. Vent was not closed tightly. |
| 041/02 | 227 | Reference T | 4 | cms | SBE35 low vs CTDT1/CTDT2. Sensor did not equilibrate. Code bad. |
| 041/02 | 231 | Reference T | 4 | cms | SBE35 low vs CTDT1/CTDT2. Sensor did not equilibrate. Code bad. |
| 042/02 | 211 | Bottle | 3 | slog | Leaking. Top vent was cracked replaced after cast. |
| 042/02 | 219 | Reference T | 4 | cms | SBE35 value low vs CTDT1/CTDT2. Some interleaving. Sensor likely not equilibrated. Code bad. |
| 042/02 | 223 | Reference T | 3 | cms | Unstable temperatures in all three sensors. Code questionable. |
| 042/02 | 223 | CTD T1 Temperature | 3 | cms | Unstable temperatures in all three sensors. Code questionable. |
| 042/02 | 223 | CTD T2 Temperature | 3 | cms | Unstable temperatures in all three sensors. Code questionable. |
| 043/01 | 105 | Bottle | 3 | slog | Leaking from Bottletom end cap. Lanyard adjusted after sampling. |
| 043/01 | 107 | CTD T2 Temperature | 3 | cms | CTDT2 value low vs SBE35/CTDT1. Code questionable. |
| 043/01 | 130 | Reference T | 3 | cms | Unstable temperature values in all three sensors. Code questionable. |
| 043/01 | 130 | CTD T1 Temperature | 3 | cms | Unstable temperature values in all three sensors. Code questionable. |
| 043/01 | 130 | CTD T2 Temperature | 3 | cms | Unstable temperature values in all three sensors. Code questionable. |
| 044/01 | 117 | CTD T1 Temperature | 3 | cms | CTDT1 reads low vs SBE35/CTDT2. Variation around feature. code questionable. |
| 044/01 | 131 | Salinity | 4 | cms | Bottle value is too high vs CTDC1/CTDC2. Value better matches sample at level ~127 dbar. This salinity sample appears to have been sampled from Bottletle number 30. |
| 045/01 | 130 | Salinity | 5 | cms | Bottle was skipped during sampling. Not reported. |
| 045/01 | 117 | CTD T1 Temperature | 3 | cms | CTDT1 reads low vs SBE35/CTDT2. Variation around feature. code questionable. |
| 046/01 | 104 | Reference T | 4 | cms | SBE35 value high vs CTDT1/CTDT2 for this part of profile. Low gradient. Wait time probably not observed for sensor to equilibrate. Code bad. |
| 046/01 | 108 | Salinity | 4 | cms | Salinity value high for this part if profile. Matches trip level 7. Possible mis-sample. Code bad. |
| 047/01 | 106 | Salinity | 4 | cms | Sample value does not match this part of profile. Appears to have been mis-sampled or run out of order. |

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Table B.2 – continued from previous page

| Station | Bottle | Param | Code | Source | Comment |
|---|---|---|---|---|---|
| 047/01 | 115 | Salinity | 4 | cms | Salinity value high vs CTDT1/CTDT2. Code bad. |
| 047/01 | 122 | CTD T2 Temperature | 3 | cms | CTDT2 value low vs CTDT1/SBE35. Code questionable. |
| 047/01 | 124 | CTD T2 Temperature | 3 | cms | CTDT2 value low vs CTDT1/SBE35. Code questionable. |
| 047/01 | 132 | CTD T2 Temperature | 3 | cms | CTDT2 value low vs CTDT1/SBE35. Code questionable. |
| 047/01 | 134 | Bottle | 3 | cms | Broken o-ring. No water coming out of petcock. |
| 048/01 | 102-123 | Salinity | 4 | cms | Unstable lab temperatures. |
| 048/01 | 132 | CTD T2 Temperature | 3 | cms | CTDT2 low vs SBE35/CTDT1. Code questionable. |
| 048/01 | 134 | Bottle | 4 | cms | Bottle did not fire. |
| 049/01 | 101-129 | Salinity | 4 | cms | Unstable lab temperatures. |
| 049/01 | 121 | Reference T | 4 | cms | SBE35 low vs CTDT1/CTDT2. Code bad. |
| 049/01 | 125 | CTD T1 Temperature | 3 | cms | CTDT1 low vs SBE35/CTDT2. Code questionable. |
| 049/01 | 126 | Reference T | 4 | cms | SBE35 high vs CTDT1/CTDT2. High gradient, sensor not equilibrated. Code bad. |
| 049/01 | 127 | CTD T1 Temperature | 4 | cms | CTDT1 low vs SBE35/CTDT2. Code questionable. |
| 005/01 | 119 | Reference T | 4 | cms | SBE35 value high vs CTDT1/CTDT2. Some interleaving. Sensor likely not equilibrated. Code bad. |
| 005/01 | 133 | Salinity | 2 | cms | Salinity value low vs CTDC1/CTDC2. Matches up cast. Code good. |
| 050/01 | 133 | CTD T2 Temperature | 4 | cms | CTDT2 high vs SBE35/CTDT1. Code bad. |
| 050/01 | 135 | CTD T2 Temperature | 4 | cms | CTDT2 low vs SBE35/CTDT1. Code bad. |
| 050/01 | 115 | CTD T1 Temperature | 4 | cms | CTDT1 low vs SBE35/CTDT2. Code bad. |
| 051/01 | 104 | CTD T1 Temperature | 3 | cms | CTDT1 high vs CTDT2/SBE35. Code bad. |
| 051/01 | 133 | CTD T2 Temperature | 3 | cms | CTDT2 high vs CTDT1/SBE35. Code questionable. |
| 052/01 | 119 | CTD T1 Temperature | 3 | cms | CTDT2 low vs SBE35/CTDT1. Code questionable. |
| 052/01 | 118 | Salinity | 4 | cms | Salinity value does not match this part of profile. Value better matches btl 19. Possibly missampled. |
| 053/01 | 129 | CTD T2 Temperature | 3 | cms | CTDT2 low vs SBE35/CTDT1. Code questionable. |
| 053/01 | 130 | Reference T | 3 | cms | Unstable temperatures in all 3 sensors. Code questionable. |
| 053/01 | 130 | CTD T1 Temperature | 3 | cms | Unstable temperatures in all 3 sensors. Code questionable. |
| 053/01 | 130 | CTD T2 Temperature | 3 | cms | Unstable temperatures in all 3 sensors. Code questionable. |
| 054/01 | 103 | Bottle | 3 | slog | Leaking. Vent not tight. |
| 054/01 | 115 | Bottle | 4 | cms | Bottle mis-trip. |
| 054/01 | 115 | Salinity | 3 | cms | Bottle mis-trip. |
| 054/01 | 129 | CTD T2 Temperature | 3 | cms | CTDT2 low vs SBE35/CTDT1. Code questionable. |

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Table B.2 – continued from previous page

| Station | Bottle | Param | Code | Source | Comment |
|---|---|---|---|---|---|
| 054/01 | 130 | CTD T2 Temperature | 3 | cms | CTDT2 low vs SBE35/CTDT1. Code questionable. |
| 055/01 | 131 | Reference T | 4 | cms | SBE35 value low vs CTDT1/CTDT2. High gradient, sensor not equilibrated. Code bad. |
| 056/01 | 112 | Reference T | 4 | cms | SBE35 value low vs CTDT1/CTDT2. Slight gradient and feature. Sensor likely not equilibrated. Code questionable. |
| 056/01 | 131 | Reference T | 3 | cms | Unstable temperatures in all three sensors. High gradient. Code questionable. |
| 056/01 | 131 | CTD T1 Temperature | 3 | cms | Unstable temperatures in all three sensors. High gradient. Code questionable. |
| 056/01 | 131 | CTD T2 Temperature | 3 | cms | Unstable temperatures in all three sensors. High gradient. Code questionable. |
| 057/01 | 103 | Bottle | 3 | slog | Leaking. Top vent not tight enough. |
| 057/01 | 111 | Salinity | 4 | cms | Bottle value does not match this part of cast. Value resembles level 13. Probably mis-sampled. |
| 057/01 | 116 | CTD T2 Temperature | 4 | cms | CTDT2 value high vs CTDT1/SBE35. Code unusable. |
| 057/01 | 119 | CTD T2 Temperature | 4 | cms | CTDT2 value high vs CTDT1/SBE35. Code unusable. |
| 057/01 | 132 | Reference T | 4 | cms | SBE35 value low vs CTDT1/CTDT2. High gradient. Sensor not equilibrated. Code unusable. |
| 058/01 | 117 | CTD T2 Temperature | 3 | cms | CTDT2 value low vs SBE35/CTDT1. Some gradient. Code questionable. |
| 058/01 | 119 | Reference T | 3 | cms | Unstable temperatures in all three sensors. High gradient. Code questionable. |
| 058/01 | 119 | CTD T1 Temperature | 3 | cms | Unstable temperatures in all three sensors. High gradient. Code questionable. |
| 058/01 | 119 | CTD T2 Temperature | 3 | cms | Unstable temperatures in all three sensors. High gradient. Code questionable. |
| 059/01 | 115 | Reference T | 4 | cms | SBE35 high vs CTDT1/CTDT2. Some gradient. Sensor likely did not equilibrate. Code bad. |
| 059/01 | 118 | Reference T | 4 | cms | SBE35 high vs CTDT1/CTDT2. High gradient. Sensor did not equilibrate. Code bad. |
| 006/01 | 115 | CTD T1 Temperature | 3 | cms | CTDT1 reads low vs SBE35/CTDT2. Variation around slight feature. code questionable. |
| 006/01 | 135 | Bottle | 3 | cms | Leaking due to chipod cable. Cable moved. |
| 060/01 | 106 | CTD T2 Temperature | 3 | cms | CTDT2 value low vs SBE35/CTDT1. Code questionable. |
| 060/01 | 114 | CTD T2 Temperature | 3 | cms | CTDT2 value high vs SBE35/CTDT1. Code questionable. |
| 060/01 | 120 | CTD T1 Temperature | 3 | cms | CTDT1 high vs SBE35/CTDT2. High gradient. Code unusable. |
| 060/01 | 121 | Reference T | 3 | cms | SBE35 did not equilibrate. Code questionable. |
| 060/01 | 121 | Salinity | 4 | cms | Salinity value |
| 060/01 | 133 | CTD T2 Temperature | 3 | cms | CTDT2 high vs SBE35/CTDT1. High gradient. Code unusable. |
| 061/01 | 119 | Reference T | 4 | cms | High gradient. SBE35 did not equilibrate. Code unusable. |

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Table B.2 – continued from previous page

| Station | Bottle | Param | Code | Source | Comment |
|---|---|---|---|---|---|
| 061/01 | 122 | CTD T2 Temperature | 3 | cms | CTDT2 high vs SBE35/CTDT1. High gradient. Code unusable. |
| 061/01 | 133 | CTD T1 Temperature | 3 | cms | CTDT1 high vs SBE35/CTDT2. High gradient. Code unusable. |
| 062/01 | 118 | CTD T1 Temperature | 3 | cms | CTDT1 low vs SBE35/CTDT2. High gradient. Code questionable. |
| 062/01 | 119 | CTD T2 Temperature | 3 | cms | CTDT2 high vs SBE35/CTDT1. High gradient. Code questionable. |
| 062/01 | 120 | CTD T1 Temperature | 3 | cms | CTDT1 low vs SBE35/CTDT2. High gradient. Code questionable. |
| 062/01 | 132 | CTD T2 Temperature | 3 | cms | CTDT2 high vs SBE35/CTDT1. High gradient. Code questionable. |
| 062/01 | 133 | CTD T2 Temperature | 3 | cms | CTDT2 low vs SBE35/CTDT1. High gradient. Code questionable. |
| 062/01 | 134 | Reference T | 3 | cms | High gradient. Unstable temperatures in all three sensors. Code unusable. |
| 062/01 | 134 | Reference T | 3 | cms | High gradient. Unstable temperatures in all three sensors. Code unusable. |
| 062/01 | 134 | CTD T1 Temperature | 3 | cms | High gradient. Unstable temperatures in all three sensors. Code unusable. |
| 062/01 | 134 | CTD T2 Temperature | 3 | cms | High gradient. Unstable temperatures in all three sensors. Code unusable. |
| 063/01 | 117 | CTD T2 Temperature | 3 | cms | CTDT2 value high vs SBE35/CTDT1. Gradient. Code questionable. |
| 063/01 | 118 | CTD T1 Temperature | 4 | cms | CTDT1 low vs SBE35/CTDT2. Gradient. Code unusable. |
| 063/01 | 120 | CTD T2 Temperature | 4 | cms | CTDT2 low vs SBE35/CTDT1. Gradient. Code unusable. |
| 063/01 | 134 | CTD T1 Temperature | 3 | cms | CTDT2 high vs SBE35/CTDT1. High gradient. Code questionable. |
| 064/01 | 133 | Reference T | 3 | cms | High gradient. Unstable temperatures in all three sensors. Code questionable. |
| 064/01 | 133 | CTD T1 Temperature | 3 | cms | High gradient. Unstable temperatures in all three sensors. Code questionable. |
| 064/01 | 133 | CTD T2 Temperature | 3 | cms | High gradient. Unstable temperatures in all three sensors. Code questionable. |
| 065/02 | 215 | CTD T2 Temperature | 3 | cms | CTDT2 value high vs CTDT1/SBE35. Code questionable. |
| 065/02 | 216 | CTD T2 Temperature | 3 | cms | CTDT2 value high vs CTDT1/SBE35. Code questionable. |
| 065/02 | 218 | Reference T | 4 | cms | SBE35 high vs CTDT1/CTDT2. High gradient. Sensor did not equilibrate. Code bad. |
| 065/02 | 231 | CTD T2 Temperature | 3 | cms | CTDT2 value high vs CTDT1/SBE35. Code unusable. |
| 065/02 | 234 | Reference T | 4 | cms | SBE35 value high vs CTDT1/CTDT2. High gradient, sensor did not equilibrate. Code unusable. |
| 066/01 | 121 | CTD T2 Temperature | 3 | cms | CTDT2 value low vs SBE35/CTDT1. High gradient. Code questionable. |
| 067/01 | 133 | CTD T2 Temperature | 4 | cms | CTDT2 value high vs SBE35/CTDT1. Code unusable. |

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Table B.2 – continued from previous page

| Station | Bottle | Param | Code | Source | Comment |
|---|---|---|---|---|---|
| 067/01 | 135 | CTD T1 Temperature | 3 | cms | CTDT1 value high vs SBE35/CTDT2. Code questionable. |
| 068/01 | 115 | CTD T2 Temperature | 3 | cms | CTDT2 value high vs SBE35/CTDT1. Code questionable. |
| 068/01 | 118 | CTD T2 Temperature | 3 | cms | CTDT2 value high vs SBE35/CTDT1. Code questionable. |
| 068/01 | 130 | CTD T1 Temperature | 3 | cms | CTDT1 value high vs SBE35/CTDT2. Code questionable. |
| 068/01 | 132 | CTD T2 Temperature | 3 | cms | CTDT2 value high vs SBE35/CTDT1. Code questionable. |
| 068/01 | 134 | CTD T2 Temperature | 3 | cms | CTDT2 value high vs SBE35/CTDT1. Code questionable. |
| 068/01 | 134 | ctdc1 | 3 | cms | CTDC1 value high vs SALT/CTDC2. Code questionable. |
| 068/01 | 134 | ctdc2 | 3 | cms | CTDC2 value high vs SALT/CTDC1. Code questionable. |
| 069/01 | 117 | Salinity | 4 | cms | Salinity value low vs CTDC1/CTDC2. Value batter matches trip level 19. Likely mis-sampled. Code bad. |
| 069/01 | 136 | CTD T1 Temperature | 3 | cms | CTDT1 value high vs SBE35/CTDT2. Code questionable. |
| 007/02 | 206 | Salinity | 4 | cms | Salinity value low vs CTDC1/CTDC2 and better matches trip level 8. Possibly mis-sampled. Code bad. |
| 007/02 | 228 | Bottle | 3 | cms | Small leak. |
| 007/02 | 228 | Salinity | 4 | cms | Salinity value high vs CTDC1/CTDC2. Leak noted on Bottletle. Code bad. |
| 007/02 | 235 | Salinity | 4 | cms | Salinity value low vs CTDC1/CTDC2. Surface value. Code bad. |
| 070/01 | 108 | Reference T | 4 | cms | SBE35 high vs CTDT1/CTDT2. Sensor likely not equilibrated. Code unusable. |
| 070/01 | 133 | Reference T | 3 | cms | High gradient. Unstable temperatures in all three sensors. Code questionable. |
| 070/01 | 133 | CTD T1 Temperature | 3 | cms | High gradient. Unstable temperatures in all three sensors. Code questionable. |
| 070/01 | 133 | CTD T2 Temperature | 3 | cms | High gradient. Unstable temperatures in all three sensors. Code questionable. |
| 070/01 | 134 | Salinity | 2 | cms | Salinity value high vs CTDC1/CTDC2. Value matches up-cast not down-cast. Code good. |
| 071/01 | 121 | Reference T | 4 | cms | SBE35 value high vs CTDT1/CTDT2. Gradient; sensor likely not equilibrated. Code unusable. |
| 071/01 | 131 | CTD T2 Temperature | 3 | cms | CTDT2 value high vs SBE35/CTDT2. Code questionable. |
| 071/01 | 133 | Reference T | 3 | cms | High gradient. Unstable temperatures in all three sensors. Code questionable. |
| 071/01 | 133 | CTD T1 Temperature | 3 | cms | High gradient. Unstable temperatures in all three sensors. Code questionable. |
| 071/01 | 133 | CTD T2 Temperature | 3 | cms | High gradient. Unstable temperatures in all three sensors. Code questionable. |

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Table B.2 – continued from previous page

| Station | Bottle | Param | Code | Source | Comment |
|---|---|---|---|---|---|
| 071/01 | 134 | Reference T | 3 | cms | High gradient. Unstable temperatures in all three sensors. Code questionable. |
| 071/01 | 134 | CTD T1 Temperature | 3 | cms | High gradient. Unstable temperatures in all three sensors. Code questionable. |
| 071/01 | 134 | CTD T2 Temperature | 3 | cms | High gradient. Unstable temperatures in all three sensors. Code questionable. |
| 071/01 | 136 | Salinity | 2 | cms | Salinity value high vs CTDC1/CTDC2. Value matches up-cast not down-cast. Code good. |
| 072/02 | 201 | Salinity | 4 | cms | Salinity value high vs CTDC1/CTDC2. Value better matches trip level 3. Possibly mis-sampled. Code bad. |
| 072/02 | 219 | Reference T | 4 | cms | SBE35 value high vs CTDT1/CTDT2. Gradient; sensor likely not equilibrated. Code unusable. |
| 072/02 | 234 | CTD T2 Temperature | 3 | cms | CTDT2 value high vs SBE35/CTDT1. Code questionable. |
| 073/01 | 105 | Salinity | 4 | cms | Salinity value low vs CTDC1/CTDC2. Code bad. |
| 073/01 | 106 | CTD T2 Temperature | 3 | cms | CTDT2 value high vs SBE35/CTDT1. Code questionable. |
| 073/01 | 117 | CTD T1 Temperature | 3 | cms | CTDT1 value high vs SBE35/CTDT2. Code unusable. |
| 074/01 | 101 | Salinity | 4 | cms | Salinity value high vs CTDC1/CTDC2 and low for Bottletom part of profile. AutoSal cell likely not flushed well for first initial sample. Code bad. |
| 075/01 | 136 | Reference T | 5 | cms | Not reported. Data over written. |
| 076/02 | 201-236 | Reference T | 5 | cms | Not reported. Data over written. |
| 077/01 | 101-132 | Reference T | 5 | cms | Not reported. Data over written. |
| 078/01 | 101-121 | Reference T | 5 | cms | Not reported. Data over written. |
| 079/01 | 103 | Salinity | 4 | cms | Salinity value low vs CTDC1/CTDC2 and low for Bottletom part of profile. Code bad. |
| 079/01 | 105 | Salinity | 4 | cms | Salinity value low vs CTDC1/CTDC2 and low for Bottletom part of profile. Code bad. |
| 079/01 | 110 | Reference T | 4 | cms | SBE35 value high vs CTDT1/CTDT2. Sensor not equilibrated. Code bad. |
| 079/01 | 121 | Reference T | 4 | cms | SBE35 value high vs CTDT1/CTDT2. Sensor not equilibrated. Code bad. |
| 008/01 | 103 | Salinity | 4 | cms | Salinity value low cs CTDC1/CTDC2 and better matches trip level 1. Possibly mis-sampled. Code bad. |
| 008/01 | 104 | Salinity | 3 | cms | Salinity value low vs CTDC1/CTDC2. Code questionable. |
| 008/01 | 109 | Salinity | 4 | cms | Salinity value low vs CTDC1/CTDC2 and better matches trip level 8. Possibly mis-sampled. Code bad. |
| 008/01 | 110 | Salinity | 4 | cms | Salinity value low vs CTDC1/CTDC2 and better matches trip level 9. Possibly mis-sampled. Code bad. |
| 008/01 | 133 | Reference T | 3 | cms | High gradient. Sensor not equilibrated. Code bad. |
| 008/01 | 133 | Salinity | 2 | cms | Salinity high vs CTDC1/CTDC2. High gradient. Matches up-cast feature. Code good. |

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Table B.2 – continued from previous page

| Station | Bottle | Param | Code | Source | Comment |
|---|---|---|---|---|---|
| 080/01 | 110 | Reference T | 4 | cms | SBE35 value high vs CTDT1/CTDT2. Sensor likely not equilibrated. Code bad. |
| 080/01 | 116 | CTD T1 Temperature | 3 | cms | CTDT1 value high vs SBE35/CTDT2. Code questionable. |
| 081/02 | 201 | Salinity | 4 | cms | Salinity value high CTDC1/CTDC2 at Bottletom of water column. Code bad. |
| 081/02 | 205 | CTD T2 Temperature | 3 | cms | CTDT2 value high vs CTDT1/SBE35. Code questionable. |
| 081/02 | 218 | Reference T | 4 | cms | SBE35 value high vs CTDT1/CTDT2. Sensor likely not equilibrated. Code bad. |
| 082/01 | 118 | Reference T | 4 | cms | SBE35 value high vs CTDT1/CTDT2. Sensor likely not equilibrated. Code bad. |
| 082/01 | 126 | Reference T | 3 | cms | High gradient. Unstable temperatures in all three sensors. Code unusable. |
| 082/01 | 126 | CTD T1 Temperature | 3 | cms | High gradient. Unstable temperatures in all three sensors. Code unusable. |
| 082/01 | 126 | CTD T2 Temperature | 3 | cms | High gradient. Unstable temperatures in all three sensors. Code unusable. |
| 083/01 | 114 | Salinity | 4 | cms | Salinity value high vs CTDC1/CTDC2. Code bad. |
| 083/01 | 118 | CTD T1 Temperature | 3 | cms | CTDT1 value high vs SBE35/CTDT2. Code questionable. |
| 083/01 | 131 | CTD T1 Temperature | 3 | cms | CTDT1 value low vs SBE35/CTDT2. Code questionable. |
| 083/01 | 132 | Reference T | 4 | cms | SBE35 value high vs CTDT1/CTDT2. Sensor likely not equilibrated. Code bad. |
| 083/01 | 133 | Reference T | 4 | cms | SBE35 value low vs CTDT1/CTDT2. Sensor likely not equilibrated. Code bad. |
| 083/01 | 134 | Reference T | 4 | cms | SBE35 value low vs CTDT1/CTDT2. Sensor likely not equilibrated. Code bad. |
| 083/01 | 135 | Reference T | 4 | cms | SBE35 value low vs CTDT1/CTDT2. Sensor likely not equilibrated. Code bad. |
| 009/01 | 135 | Reference T | 3 | cms | Unstable temperature in all 3 sensors. Code questionable. |
| 009/01 | 135 | CTD T1 Temperature | 3 | cms | Unstable temperature in all 3 sensors. Code questionable. |
| 009/01 | 135 | CTD T2 Temperature | 3 | cms | Unstable temperature in all 3 sensors. Code questionable. |

APPENDIX

C

# CALIBRATION DOCUMENTS

# Pressure Calibration Report
# STS/ODF Calibration Facility

**SENSOR SERIAL NUMBER: 0401**
**CALIBRATION DATE: 17-NOV-2015**
**Mfg: SEABIRD  Model: 09P  CTD Prs s/n: 59916**

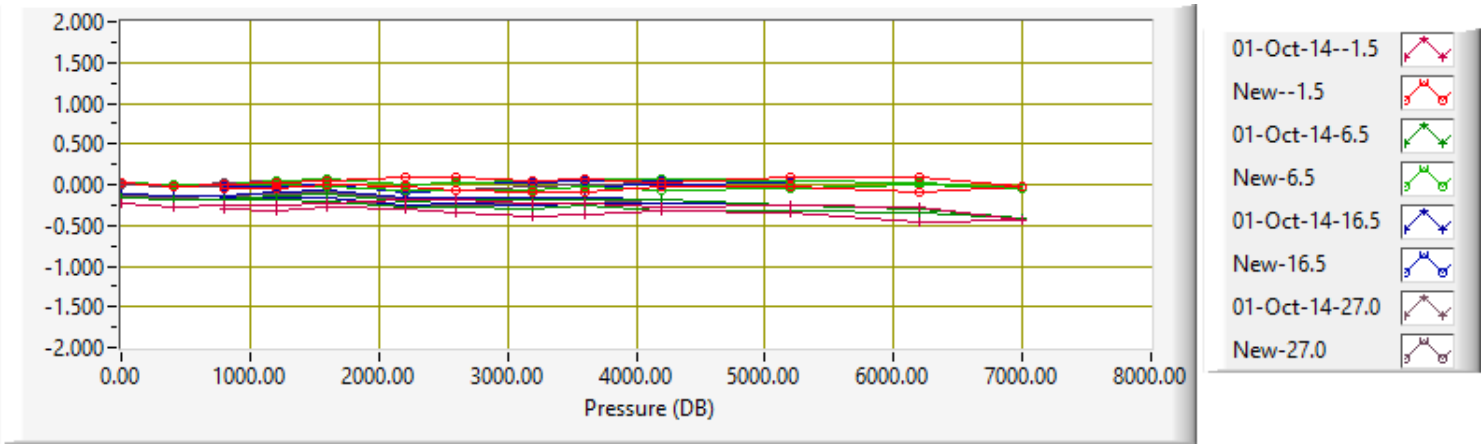
**C1= -4.587369E+4**
**C2= 3.118823E-1**
**C3= 1.172430E-2**
**D1= 3.986591E-2**
**D2= 0.000000E+0**
**T1= 2.998619E+1**
**T2= -2.458697E-4**
**T3= 3.889329E-6**
**T4= 2.882252E-9**
**T5= 0.000000E+0**
**AD590M= 1.11700E-2**
**AD590B= -8.66832E+0**
**Slope = 1.00000000E+0**
**Offset = 0.00000000E+0**

**Calibration Standard:  Mfg: FLUKE  Model: P3125  s/n: 70856**
**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 |
|---|---|---|---|---|---|---|
| 33354.207 | 0.16 | 0.14 | -0.23 | 0.03 | 0.38 | -1.521 |
| 33564.319 | 400.20 | 400.22 | -0.28 | -0.02 | 0.38 | -1.521 |
| 33772.871 | 800.22 | 800.22 | -0.25 | 0.01 | 0.38 | -1.520 |
| 33979.937 | 1200.23 | 1200.22 | -0.25 | 0.01 | 0.38 | -1.521 |
| 34185.538 | 1600.25 | 1600.21 | -0.22 | 0.04 | 0.38 | -1.521 |
| 34491.267 | 2200.29 | 2200.20 | -0.19 | 0.08 | 0.38 | -1.521 |
| 34693.350 | 2600.32 | 2600.23 | -0.19 | 0.09 | 0.38 | -1.521 |
| 34993.926 | 3200.34 | 3200.28 | -0.23 | 0.05 | 0.38 | -1.521 |
| 35192.614 | 3600.33 | 3600.27 | -0.24 | 0.06 | 0.38 | -1.520 |
| 35488.212 | 4200.32 | 4200.28 | -0.28 | 0.03 | 0.39 | -1.521 |
| 35974.494 | 5200.33 | 5200.25 | -0.25 | 0.08 | 0.39 | -1.521 |
| 36453.137 | 6200.33 | 6200.25 | -0.29 | 0.08 | 0.39 | -1.521 |
| 36830.777 | 7000.29 | 7000.32 | -0.43 | -0.03 | 0.39 | -1.520 |
| 36453.200 | 6200.29 | 6200.39 | -0.47 | -0.10 | 0.38 | -1.520 |
| 35974.541 | 5200.34 | 5200.36 | -0.35 | -0.01 | 0.38 | -1.521 |
| 35488.247 | 4200.35 | 4200.36 | -0.32 | -0.01 | 0.38 | -1.521 |
| 35192.684 | 3600.33 | 3600.41 | -0.37 | -0.08 | 0.38 | -1.521 |

| Sensor Output | Standard | Sensor New_Coefs | Standard-Sensor Prev_Coefs | Standard-Sensor NEW_Coefs | Sensor_Temp | Bath_Temp |
|---|---|---|---|---|---|---|
| 34993.990 | 3200.32 | 3200.41 | -0.38 | -0.09 | 0.38 | -1.520 |
| 34693.425 | 2600.30 | 2600.38 | -0.35 | -0.08 | 0.38 | -1.521 |
| 34491.326 | 2200.29 | 2200.32 | -0.30 | -0.03 | 0.38 | -1.520 |
| 34185.569 | 1600.27 | 1600.28 | -0.27 | -0.01 | 0.37 | -1.520 |
| 33979.971 | 1200.24 | 1200.29 | -0.31 | -0.05 | 0.37 | -1.520 |
| 33772.890 | 800.22 | 800.26 | -0.29 | -0.04 | 0.37 | -1.521 |
| 33564.311 | 400.20 | 400.21 | -0.27 | -0.01 | 0.37 | -1.521 |
| 33356.094 | 0.16 | 0.15 | -0.16 | 0.01 | 8.37 | 6.487 |
| 33566.223 | 400.20 | 400.21 | -0.18 | -0.01 | 8.38 | 6.487 |
| 33774.810 | 800.22 | 800.22 | -0.18 | 0.00 | 8.38 | 6.487 |
| 33981.887 | 1200.23 | 1200.19 | -0.14 | 0.04 | 8.38 | 6.487 |
| 34187.518 | 1600.25 | 1600.18 | -0.12 | 0.07 | 8.39 | 6.487 |
| 34493.339 | 2200.29 | 2200.29 | -0.20 | 0.00 | 8.39 | 6.487 |
| 34695.437 | 2600.31 | 2600.29 | -0.19 | 0.02 | 8.39 | 6.487 |
| 34996.028 | 3200.35 | 3200.30 | -0.18 | 0.05 | 8.40 | 6.487 |
| 35194.749 | 3600.36 | 3600.30 | -0.18 | 0.06 | 8.40 | 6.487 |
| 35490.378 | 4200.37 | 4200.31 | -0.19 | 0.06 | 8.40 | 6.487 |
| 35976.752 | 5200.39 | 5200.34 | -0.25 | 0.05 | 8.40 | 6.488 |
| 36455.456 | 6200.37 | 6200.34 | -0.31 | 0.03 | 8.41 | 6.488 |
| 36833.126 | 7000.34 | 7000.38 | -0.42 | -0.04 | 8.41 | 6.488 |
| 36455.465 | 6200.36 | 6200.36 | -0.35 | -0.01 | 8.41 | 6.488 |
| 35976.781 | 5200.36 | 5200.40 | -0.33 | -0.04 | 8.41 | 6.487 |
| 35490.425 | 4200.35 | 4200.40 | -0.32 | -0.06 | 8.40 | 6.487 |
| 35194.776 | 3600.34 | 3600.36 | -0.25 | -0.01 | 8.40 | 6.487 |
| 34996.075 | 3200.33 | 3200.39 | -0.29 | -0.06 | 8.40 | 6.487 |
| 34695.482 | 2600.30 | 2600.37 | -0.29 | -0.07 | 8.40 | 6.487 |
| 34493.381 | 2200.28 | 2200.36 | -0.28 | -0.08 | 8.40 | 6.487 |
| 34187.563 | 1600.25 | 1600.27 | -0.21 | -0.01 | 8.40 | 6.487 |
| 33981.914 | 1200.24 | 1200.23 | -0.18 | 0.00 | 8.40 | 6.487 |
| 33774.825 | 800.23 | 800.24 | -0.19 | -0.01 | 8.40 | 6.487 |
| 33566.227 | 400.20 | 400.20 | -0.18 | -0.00 | 8.41 | 6.488 |
| 33357.671 | 0.16 | 0.14 | -0.11 | 0.02 | 18.53 | 16.495 |
| 33567.835 | 400.20 | 400.20 | -0.13 | 0.00 | 18.53 | 16.495 |
| 33776.469 | 800.23 | 800.23 | -0.13 | 0.01 | 18.54 | 16.495 |
| 33983.590 | 1200.25 | 1200.21 | -0.10 | 0.04 | 18.54 | 16.495 |
| 34189.259 | 1600.28 | 1600.21 | -0.08 | 0.07 | 18.54 | 16.495 |
| 34495.142 | 2200.33 | 2200.32 | -0.16 | 0.00 | 18.54 | 16.496 |
| 34697.281 | 2600.35 | 2600.33 | -0.16 | 0.02 | 18.54 | 16.496 |
| 34997.934 | 3200.39 | 3200.36 | -0.17 | 0.02 | 18.54 | 16.496 |
| 35196.682 | 3600.40 | 3600.35 | -0.16 | 0.05 | 18.54 | 16.496 |
| 35492.360 | 4200.40 | 4200.35 | -0.19 | 0.04 | 18.54 | 16.495 |
| 35978.815 | 5200.40 | 5200.38 | -0.24 | 0.02 | 18.54 | 16.496 |
| 35492.377 | 4200.38 | 4200.39 | -0.24 | -0.01 | 18.54 | 16.495 |
| 35196.701 | 3600.36 | 3600.39 | -0.23 | -0.03 | 18.54 | 16.495 |
| 34997.954 | 3200.35 | 3200.41 | -0.25 | -0.06 | 18.53 | 16.495 |

| Sensor Output | Standard | Sensor New_Coefs | Standard-Sensor Prev_Coefs | Standard-Sensor NEW_Coefs | Sensor_Temp | Bath_Temp |
|---|---|---|---|---|---|---|
| 34697.301 | 2600.31 | 2600.38 | -0.24 | -0.06 | 18.53 | 16.495 |
| 34495.176 | 2200.30 | 2200.39 | -0.26 | -0.09 | 18.53 | 16.495 |
| 34189.291 | 1600.27 | 1600.27 | -0.15 | -0.00 | 18.53 | 16.495 |
| 33983.617 | 1200.25 | 1200.26 | -0.16 | -0.01 | 18.53 | 16.496 |
| 33776.486 | 800.24 | 800.26 | -0.16 | -0.03 | 18.53 | 16.495 |
| 33567.850 | 400.20 | 400.23 | -0.15 | -0.02 | 18.53 | 16.495 |
| 33358.332 | 0.16 | 0.16 | -0.15 | 0.01 | 29.07 | 27.002 |
| 33568.545 | 400.20 | 400.22 | -0.17 | -0.01 | 29.07 | 27.002 |
| 33777.211 | 800.24 | 800.22 | -0.15 | 0.01 | 29.08 | 27.002 |
| 33984.380 | 1200.25 | 1200.21 | -0.12 | 0.04 | 29.09 | 27.002 |
| 34190.090 | 1600.28 | 1600.20 | -0.09 | 0.08 | 29.09 | 27.002 |
| 34496.046 | 2200.32 | 2200.33 | -0.19 | -0.01 | 29.10 | 27.001 |
| 34698.220 | 2600.34 | 2600.33 | -0.18 | 0.01 | 29.10 | 27.002 |
| 34998.934 | 3200.37 | 3200.35 | -0.18 | 0.02 | 29.10 | 27.002 |
| 35197.725 | 3600.38 | 3600.34 | -0.18 | 0.04 | 29.11 | 27.001 |
| 35493.476 | 4200.38 | 4200.36 | -0.22 | 0.02 | 29.11 | 27.002 |
| 35197.738 | 3600.37 | 3600.37 | -0.22 | -0.00 | 29.11 | 27.001 |
| 34998.951 | 3200.35 | 3200.38 | -0.24 | -0.03 | 29.11 | 27.002 |
| 34698.245 | 2600.32 | 2600.38 | -0.25 | -0.06 | 29.11 | 27.001 |
| 34496.076 | 2200.30 | 2200.39 | -0.28 | -0.09 | 29.11 | 27.001 |
| 34190.122 | 1600.26 | 1600.26 | -0.17 | 0.00 | 29.11 | 27.001 |
| 33984.397 | 1200.24 | 1200.24 | -0.17 | 0.00 | 29.11 | 27.001 |
| 33777.228 | 800.23 | 800.25 | -0.18 | -0.02 | 29.11 | 27.001 |
| 33568.555 | 400.20 | 400.23 | -0.19 | -0.03 | 29.11 | 27.001 |
| 33358.325 | 0.16 | 0.14 | -0.13 | 0.02 | 29.11 | 27.002 |



# Pressure Calibration Report
# STS/ODF Calibration Facility

**SENSOR SERIAL NUMBER: 0831**
**CALIBRATION DATE: 17-NOV-2015**
**Mfg: SEABIRD  Model: 09P  CTD Prs s/n: 99677**

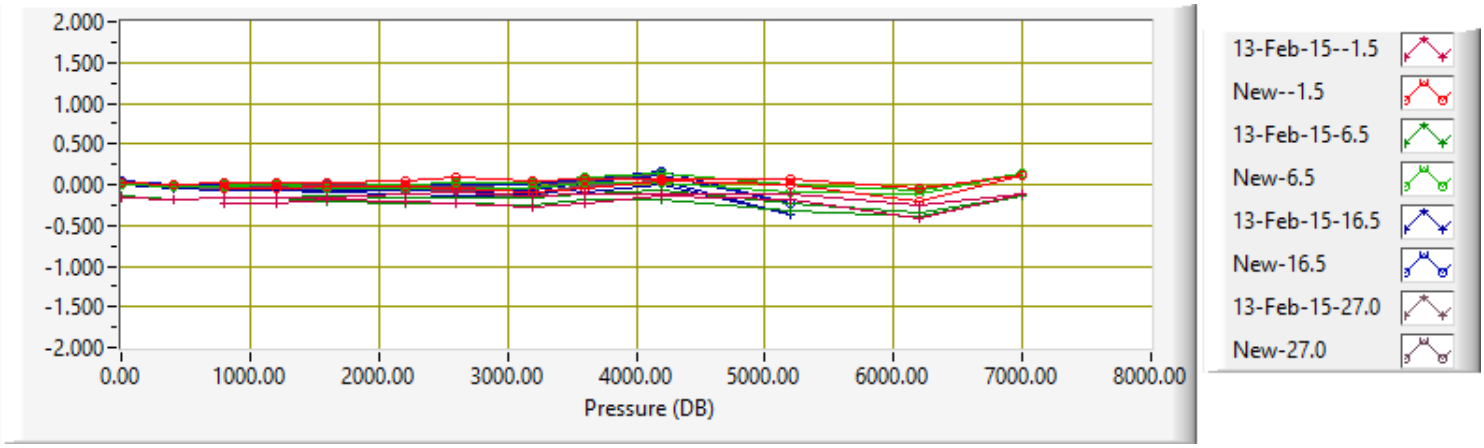
**C1= -4.345638E+4**
**C2= -2.285116E-1**
**C3= 9.849962E-3**
**D1= 3.362284E-2**
**D2= 0.000000E+0**
**T1= 3.004593E+1**
**T2= -4.406140E-4**
**T3= 3.956775E-6**
**T4= 4.712297E-9**
**T5= 0.000000E+0**
**AD590M= 1.28916E-2**
**AD590B= -8.23481E+0**
**Slope = 1.00000000E+0**
**Offset = 0.00000000E+0**

**Calibration Standard:  Mfg: FLUKE  Model: P3125  s/n: 70856**
**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 |
|---|---|---|---|---|---|---|
| 33288.082 | 0.16 | 0.13 | -0.16 | 0.03 | 0.01 | -1.521 |
| 33509.413 | 400.20 | 400.20 | -0.19 | -0.00 | 0.03 | -1.521 |
| 33729.050 | 800.22 | 800.21 | -0.17 | 0.02 | 0.02 | -1.520 |
| 33947.078 | 1200.23 | 1200.22 | -0.17 | 0.01 | 0.03 | -1.521 |
| 34163.522 | 1600.25 | 1600.23 | -0.16 | 0.02 | 0.03 | -1.521 |
| 34485.276 | 2200.29 | 2200.23 | -0.13 | 0.06 | 0.03 | -1.521 |
| 34697.885 | 2600.32 | 2600.23 | -0.10 | 0.08 | 0.03 | -1.521 |
| 35014.062 | 3200.34 | 3200.30 | -0.14 | 0.04 | 0.03 | -1.521 |
| 35222.998 | 3600.33 | 3600.27 | -0.12 | 0.06 | 0.03 | -1.520 |
| 35533.779 | 4200.32 | 4200.26 | -0.12 | 0.06 | 0.03 | -1.521 |
| 36044.903 | 5200.33 | 5200.25 | -0.11 | 0.08 | 0.03 | -1.521 |
| 36547.856 | 6200.33 | 6200.39 | -0.26 | -0.06 | 0.03 | -1.521 |
| 36944.357 | 7000.29 | 7000.18 | -0.11 | 0.11 | 0.03 | -1.520 |
| 36547.916 | 6200.29 | 6200.51 | -0.42 | -0.22 | 0.03 | -1.520 |
| 36044.950 | 5200.34 | 5200.34 | -0.19 | -0.00 | 0.03 | -1.521 |
| 35533.806 | 4200.35 | 4200.31 | -0.15 | 0.04 | 0.03 | -1.521 |
| 35223.051 | 3600.33 | 3600.37 | -0.22 | -0.04 | 0.02 | -1.521 |

| Sensor Output | Standard | Sensor New_Coefs | Standard-Sensor Prev_Coefs | Standard-Sensor NEW_Coefs | Sensor_Temp | Bath_Temp |
|---|---|---|---|---|---|---|
| 35014.112 | 3200.32 | 3200.40 | -0.26 | -0.08 | 0.02 | -1.520 |
| 34697.938 | 2600.30 | 2600.34 | -0.22 | -0.04 | 0.02 | -1.521 |
| 34485.317 | 2200.29 | 2200.32 | -0.21 | -0.03 | 0.01 | -1.520 |
| 34163.541 | 1600.27 | 1600.28 | -0.19 | -0.01 | 0.01 | -1.520 |
| 33947.110 | 1200.24 | 1200.29 | -0.24 | -0.05 | 0.01 | -1.520 |
| 33729.072 | 800.22 | 800.26 | -0.22 | -0.04 | 0.01 | -1.521 |
| 33509.416 | 400.20 | 400.23 | -0.22 | -0.03 | 0.00 | -1.521 |
| 33291.672 | 0.16 | 0.16 | -0.14 | 0.01 | 7.90 | 6.487 |
| 33513.010 | 400.20 | 400.22 | -0.18 | -0.02 | 7.91 | 6.487 |
| 33732.673 | 800.22 | 800.24 | -0.17 | -0.01 | 7.91 | 6.487 |
| 33950.707 | 1200.23 | 1200.22 | -0.15 | 0.01 | 7.91 | 6.487 |
| 34167.172 | 1600.25 | 1600.23 | -0.14 | 0.02 | 7.93 | 6.487 |
| 34488.980 | 2200.29 | 2200.29 | -0.17 | 0.00 | 7.93 | 6.487 |
| 34701.612 | 2600.31 | 2600.30 | -0.17 | 0.01 | 7.93 | 6.487 |
| 35017.792 | 3200.35 | 3200.32 | -0.16 | 0.03 | 7.93 | 6.487 |
| 35226.747 | 3600.36 | 3600.28 | -0.11 | 0.08 | 7.94 | 6.487 |
| 35537.531 | 4200.37 | 4200.23 | -0.06 | 0.15 | 7.94 | 6.487 |
| 36048.783 | 5200.39 | 5200.38 | -0.22 | 0.01 | 7.95 | 6.488 |
| 36551.745 | 6200.37 | 6200.45 | -0.34 | -0.08 | 7.96 | 6.488 |
| 36948.251 | 7000.34 | 7000.19 | -0.14 | 0.15 | 7.96 | 6.488 |
| 36551.759 | 6200.36 | 6200.48 | -0.38 | -0.12 | 7.96 | 6.488 |
| 36048.817 | 5200.36 | 5200.44 | -0.31 | -0.08 | 7.96 | 6.487 |
| 35537.586 | 4200.35 | 4200.32 | -0.18 | 0.03 | 7.96 | 6.487 |
| 35226.779 | 3600.34 | 3600.32 | -0.18 | 0.02 | 7.96 | 6.487 |
| 35017.842 | 3200.33 | 3200.38 | -0.24 | -0.05 | 7.97 | 6.487 |
| 34701.658 | 2600.30 | 2600.35 | -0.23 | -0.05 | 7.97 | 6.487 |
| 34489.025 | 2200.28 | 2200.33 | -0.22 | -0.05 | 7.98 | 6.487 |
| 34167.225 | 1600.25 | 1600.29 | -0.20 | -0.04 | 7.98 | 6.487 |
| 33950.743 | 1200.24 | 1200.24 | -0.16 | 0.00 | 7.98 | 6.487 |
| 33732.706 | 800.23 | 800.24 | -0.16 | -0.01 | 7.98 | 6.487 |
| 33513.038 | 400.20 | 400.21 | -0.16 | -0.01 | 7.98 | 6.488 |
| 33295.454 | 0.16 | 0.12 | -0.01 | 0.04 | 18.14 | 16.495 |
| 33516.821 | 400.20 | 400.19 | -0.05 | 0.01 | 18.14 | 16.495 |
| 33736.523 | 800.23 | 800.23 | -0.06 | 0.00 | 18.14 | 16.495 |
| 33954.594 | 1200.25 | 1200.24 | -0.05 | 0.01 | 18.14 | 16.495 |
| 34171.091 | 1600.28 | 1600.27 | -0.06 | 0.01 | 18.14 | 16.495 |
| 34492.935 | 2200.33 | 2200.32 | -0.08 | 0.00 | 18.14 | 16.496 |
| 34705.598 | 2600.35 | 2600.35 | -0.08 | 0.00 | 18.14 | 16.496 |
| 35021.828 | 3200.39 | 3200.39 | -0.11 | -0.01 | 18.14 | 16.496 |
| 35230.791 | 3600.40 | 3600.33 | -0.04 | 0.07 | 18.14 | 16.496 |
| 35541.590 | 4200.40 | 4200.24 | 0.04 | 0.16 | 18.14 | 16.495 |
| 36053.018 | 5200.40 | 5200.62 | -0.37 | -0.22 | 18.14 | 16.496 |
| 35541.603 | 4200.38 | 4200.26 | -0.01 | 0.12 | 18.14 | 16.495 |
| 35230.800 | 3600.36 | 3600.35 | -0.09 | 0.02 | 18.14 | 16.495 |
| 35021.836 | 3200.35 | 3200.41 | -0.16 | -0.06 | 18.14 | 16.495 |

| Sensor Output | Standard | Sensor New_Coefs | Standard-Sensor Prev_Coefs | Standard-Sensor NEW_Coefs | Sensor_Temp | Bath_Temp |
|---|---|---|---|---|---|---|
| 34705.601 | 2600.31 | 2600.35 | -0.13 | -0.04 | 18.14 | 16.495 |
| 34492.946 | 2200.30 | 2200.34 | -0.12 | -0.04 | 18.14 | 16.495 |
| 34171.103 | 1600.27 | 1600.30 | -0.10 | -0.02 | 18.14 | 16.495 |
| 33954.603 | 1200.25 | 1200.26 | -0.08 | -0.01 | 18.14 | 16.496 |
| 33736.529 | 800.24 | 800.25 | -0.07 | -0.01 | 18.13 | 16.495 |
| 33516.830 | 400.20 | 400.21 | -0.07 | -0.01 | 18.12 | 16.495 |
| 33298.301 | 0.16 | 0.11 | 0.00 | 0.06 | 28.52 | 27.002 |
| 33519.713 | 400.20 | 400.20 | -0.04 | 0.01 | 28.53 | 27.002 |
| 33739.446 | 800.24 | 800.23 | -0.05 | 0.00 | 28.53 | 27.002 |
| 33957.557 | 1200.25 | 1200.26 | -0.06 | -0.01 | 28.53 | 27.002 |
| 34174.078 | 1600.28 | 1600.28 | -0.05 | 0.01 | 28.54 | 27.002 |
| 34495.975 | 2200.32 | 2200.34 | -0.08 | -0.02 | 28.55 | 27.001 |
| 34708.671 | 2600.34 | 2600.37 | -0.09 | -0.03 | 28.55 | 27.002 |
| 35024.945 | 3200.37 | 3200.42 | -0.11 | -0.04 | 28.56 | 27.002 |
| 35233.917 | 3600.38 | 3600.31 | -0.00 | 0.07 | 28.57 | 27.001 |
| 35544.777 | 4200.38 | 4200.25 | 0.06 | 0.13 | 28.57 | 27.002 |
| 35233.928 | 3600.37 | 3600.32 | -0.02 | 0.04 | 28.58 | 27.001 |
| 35024.954 | 3200.35 | 3200.42 | -0.13 | -0.07 | 28.58 | 27.002 |
| 34708.687 | 2600.32 | 2600.39 | -0.13 | -0.07 | 28.58 | 27.001 |
| 34495.996 | 2200.30 | 2200.36 | -0.12 | -0.07 | 28.58 | 27.001 |
| 34174.100 | 1600.26 | 1600.30 | -0.09 | -0.04 | 28.58 | 27.001 |
| 33957.567 | 1200.24 | 1200.26 | -0.07 | -0.02 | 28.59 | 27.001 |
| 33739.465 | 800.23 | 800.25 | -0.07 | -0.01 | 28.59 | 27.001 |
| 33519.731 | 400.20 | 400.20 | -0.05 | -0.00 | 28.59 | 27.001 |
| 33298.315 | 0.16 | 0.10 | 0.01 | 0.06 | 28.60 | 27.002 |



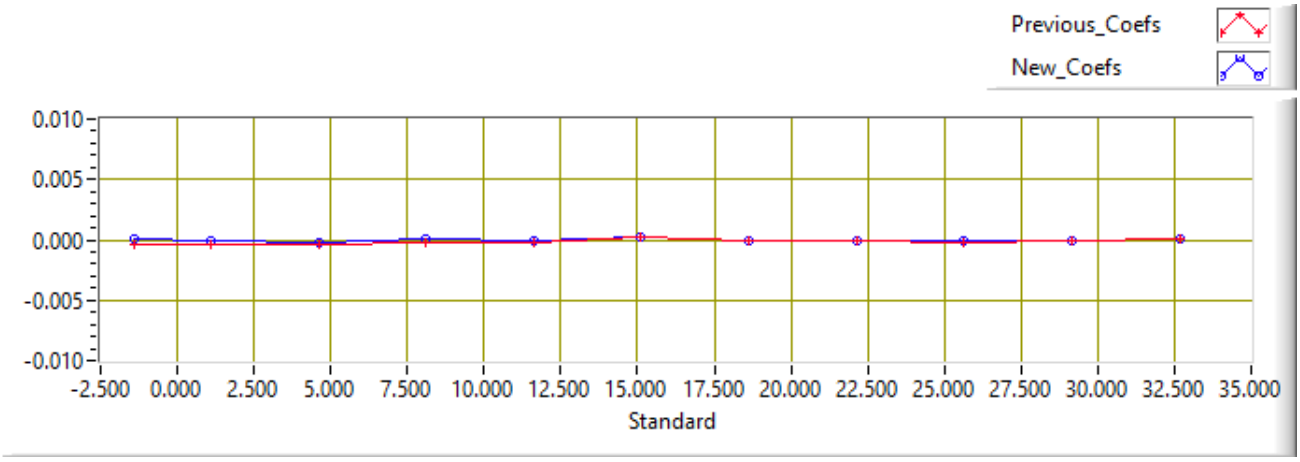
# Temperature Calibration Report
# STS/ODF Calibration Facility

**SENSOR SERIAL NUMBER: 4213**
**CALIBRATION DATE: 17-Nov-2015**
**Mfg: SEABIRD  Model: 03**
**Previous cal: 12-May-15**
**Calibration Tech: CAL**

| ITS-90_COEFFICIENTS | IPTS-68_COEFFICIENTS ITS-T90 | |
|---|---|---|
| g = 4.32200868E-3 | a = 4.32219547E-3 | |
| h = 6.26264462E-4 | b = 6.26467567E-4 | |
| i = 1.99506049E-5 | c = 1.99812061E-5 | |
| j = 1.56392489E-6 | d = 1.56527342E-6 | |
| f0 = 1000.0 | Slope = 1.0 | Offset = 0.0 |

**Calibration Standard:  Mfg: Isotech  Model: MicroK100  s/n: 291088-2**
**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 |
|---|---|---|---|---|
| 2880.2269 | -1.4091 | -1.4092 | -0.00032 | 0.00012 |
| 3049.5187 | 1.0954 | 1.0955 | -0.00044 | -0.00008 |
| 3298.6208 | 4.6030 | 4.6032 | -0.00044 | -0.00016 |
| 3562.0565 | 8.1099 | 8.1099 | -0.00018 | 0.00003 |
| 3840.3953 | 11.6176 | 11.6177 | -0.00019 | -0.00004 |
| 4133.3459 | 15.1184 | 15.1182 | 0.00017 | 0.00028 |
| 4442.7826 | 18.6288 | 18.6288 | -0.00009 | -0.00001 |
| 4768.0275 | 22.1367 | 22.1368 | -0.00008 | -0.00003 |
| 5109.8626 | 25.6464 | 25.6466 | -0.00017 | -0.00015 |
| 5467.8726 | 29.1504 | 29.1504 | -0.00001 | -0.00001 |
| 5843.7731 | 32.6615 | 32.6615 | 0.00009 | 0.00007 |



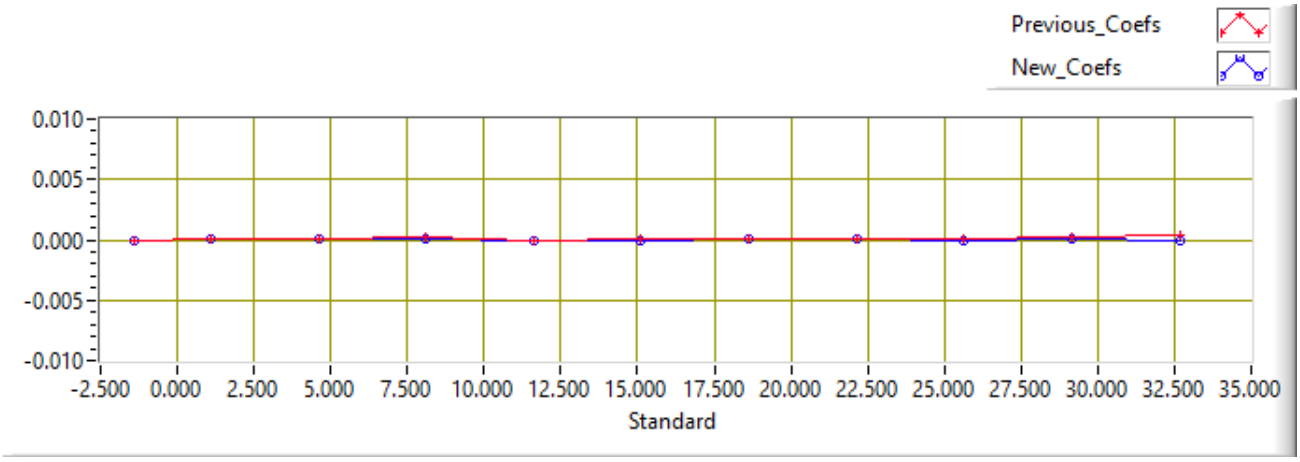
# Temperature Calibration Report
# STS/ODF Calibration Facility

**SENSOR SERIAL NUMBER: 2166**
**CALIBRATION DATE: 17-Nov-2015**
**Mfg: SEABIRD  Model: 03**
**Previous cal: 21-May-15**
**Calibration Tech: CAL**

| ITS-90_COEFFICIENTS | IPTS-68_COEFFICIENTS ITS-T90 | |
|---|---|---|
| g = 4.34268728E-3 | a = 4.34288064E-3 | |
| h = 6.45929292E-4 | b = 6.46139969E-4 | |
| i = 2.32633976E-5 | c = 2.32961239E-5 | |
| j = 2.17044750E-6 | d = 2.17200665E-6 | |
| f0 = 1000.0 | Slope = 1.0 | Offset = 0.0 |

**Calibration Standard:  Mfg: Isotech  Model: MicroK100  s/n: 291088-2**
**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 |
|---|---|---|---|---|
| 2893.9333 | -1.4091 | -1.4091 | -0.00013 | -0.00004 |
| 3059.8115 | 1.0954 | 1.0953 | 0.00007 | 0.00004 |
| 3303.5425 | 4.6030 | 4.6030 | 0.00012 | 0.00001 |
| 3560.8636 | 8.1099 | 8.1099 | 0.00018 | 0.00006 |
| 3832.2692 | 11.6176 | 11.6177 | -0.00001 | -0.00011 |
| 4117.4450 | 15.1184 | 15.1185 | 0.00004 | -0.00002 |
| 4418.1060 | 18.6288 | 18.6287 | 0.00010 | 0.00007 |
| 4733.6286 | 22.1367 | 22.1367 | 0.00006 | 0.00003 |
| 5064.6867 | 25.6464 | 25.6465 | 0.00001 | -0.00007 |
| 5410.8338 | 29.1504 | 29.1503 | 0.00028 | 0.00005 |
| 5773.6901 | 32.6615 | 32.6615 | 0.00046 | -0.00002 |



# 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: 3176
CALIBRATION DATE: 10-Nov-15

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

COEFFICIENTS:

```
g =  -1.04797365e+001
h =   1.47936580e+000
i =  -2.97450174e-003
j =   2.83006003e-004

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

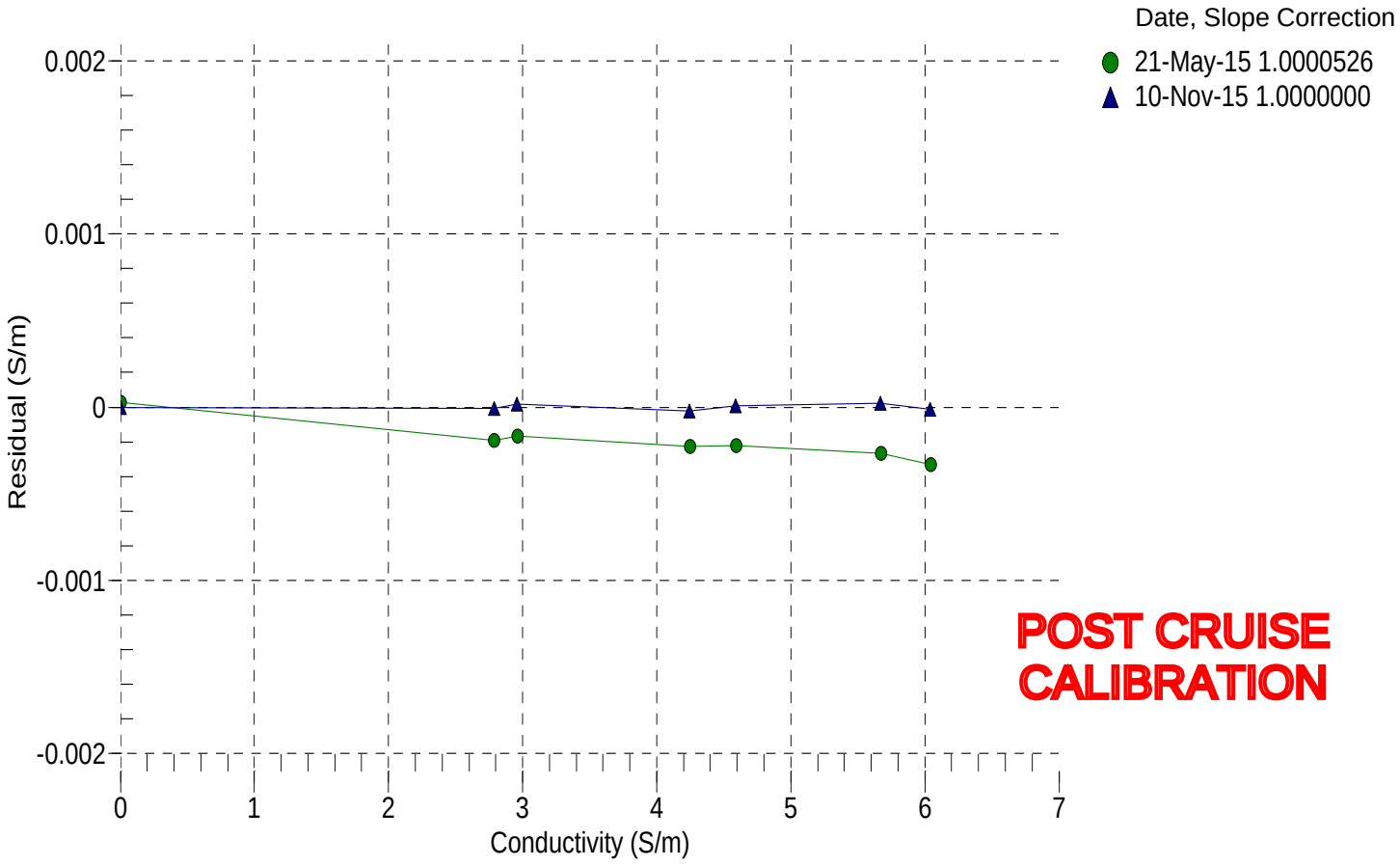
| BATH TEMP (° C) | BATH SAL (PSU) | BATH COND (S/m) | INSTRUMENT OUTPUT (kHz) | INSTRUMENT COND (S/m) | RESIDUAL (S/m) |
|---|---|---|---|---|---|
| 0.0000 | 0.0000 | 0.00000 | 2.66691 | 0.00000 | 0.00000 |
| -1.0001 | 34.5758 | 2.78699 | 5.10495 | 2.78698 | -0.00001 |
| 0.9999 | 34.5759 | 2.95736 | 5.21715 | 2.95737 | 0.00002 |
| 14.9999 | 34.5765 | 4.24529 | 5.99734 | 4.24527 | -0.00002 |
| 18.4999 | 34.5762 | 4.58993 | 6.18936 | 4.58994 | 0.00001 |
| 28.9999 | 34.5750 | 5.66722 | 6.75407 | 5.66724 | 0.00002 |
| 32.4999 | 34.5684 | 6.03762 | 6.93748 | 6.03761 | -0.00001 |

f = Instrument Output (kHz)

t = temperature (°C); p = pressure (decibars); $\delta$ = CTcor; $\varepsilon$ = CPcor;

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

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



# 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: 3057
CALIBRATION DATE: 10-Nov-15

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

COEFFICIENTS:

```
g =  -1.02119262e+001
h =   1.28788324e+000
i =  -2.64539680e-004
j =   7.44547952e-005

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

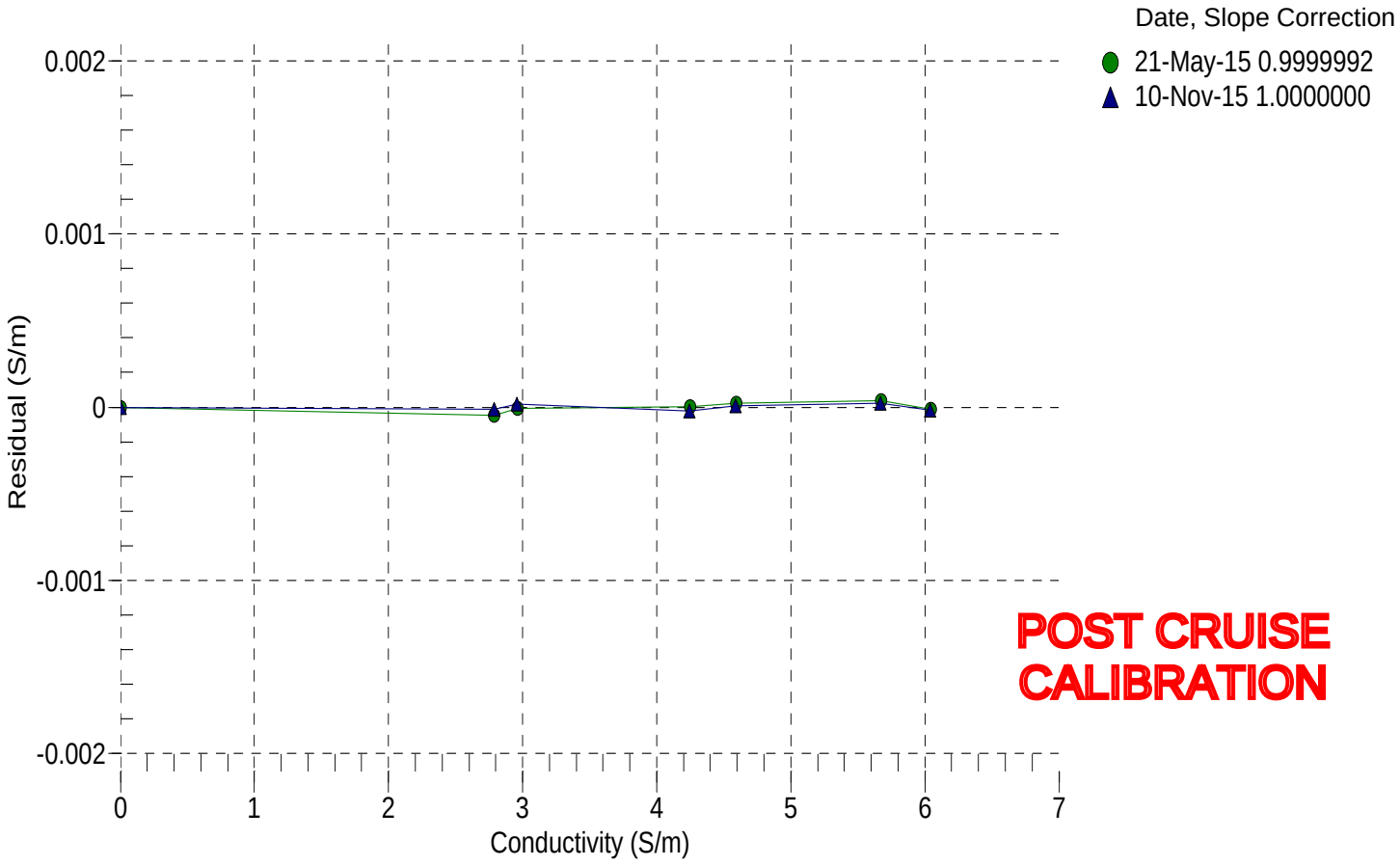
| BATH TEMP (° C) | BATH SAL (PSU) | BATH COND (S/m) | INSTRUMENT OUTPUT (kHz) | INSTRUMENT COND (S/m) | RESIDUAL (S/m) |
|---|---|---|---|---|---|
| 0.0000 | 0.0000 | 0.00000 | 2.81606 | 0.00000 | 0.00000 |
| -1.0001 | 34.5758 | 2.78699 | 5.43615 | 2.78698 | -0.00001 |
| 0.9999 | 34.5759 | 2.95736 | 5.55631 | 2.95738 | 0.00002 |
| 14.9999 | 34.5765 | 4.24529 | 6.39149 | 4.24527 | -0.00002 |
| 18.4999 | 34.5762 | 4.58993 | 6.59699 | 4.58994 | 0.00001 |
| 28.9999 | 34.5750 | 5.66722 | 7.20131 | 5.66724 | 0.00002 |
| 32.4999 | 34.5684 | 6.03762 | 7.39759 | 6.03760 | -0.00002 |

f = Instrument Output (kHz)

t = temperature (°C); p = pressure (decibars); $\delta$ = CTcor; $\varepsilon$ = CPcor;

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

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



# 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: 3399
CALIBRATION DATE: 10-Nov-15

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

COEFFICIENTS:

```
g =  -1.01577650e+001
h =   1.53709781e+000
i =  -2.63336443e-003
j =   2.84699598e-004

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

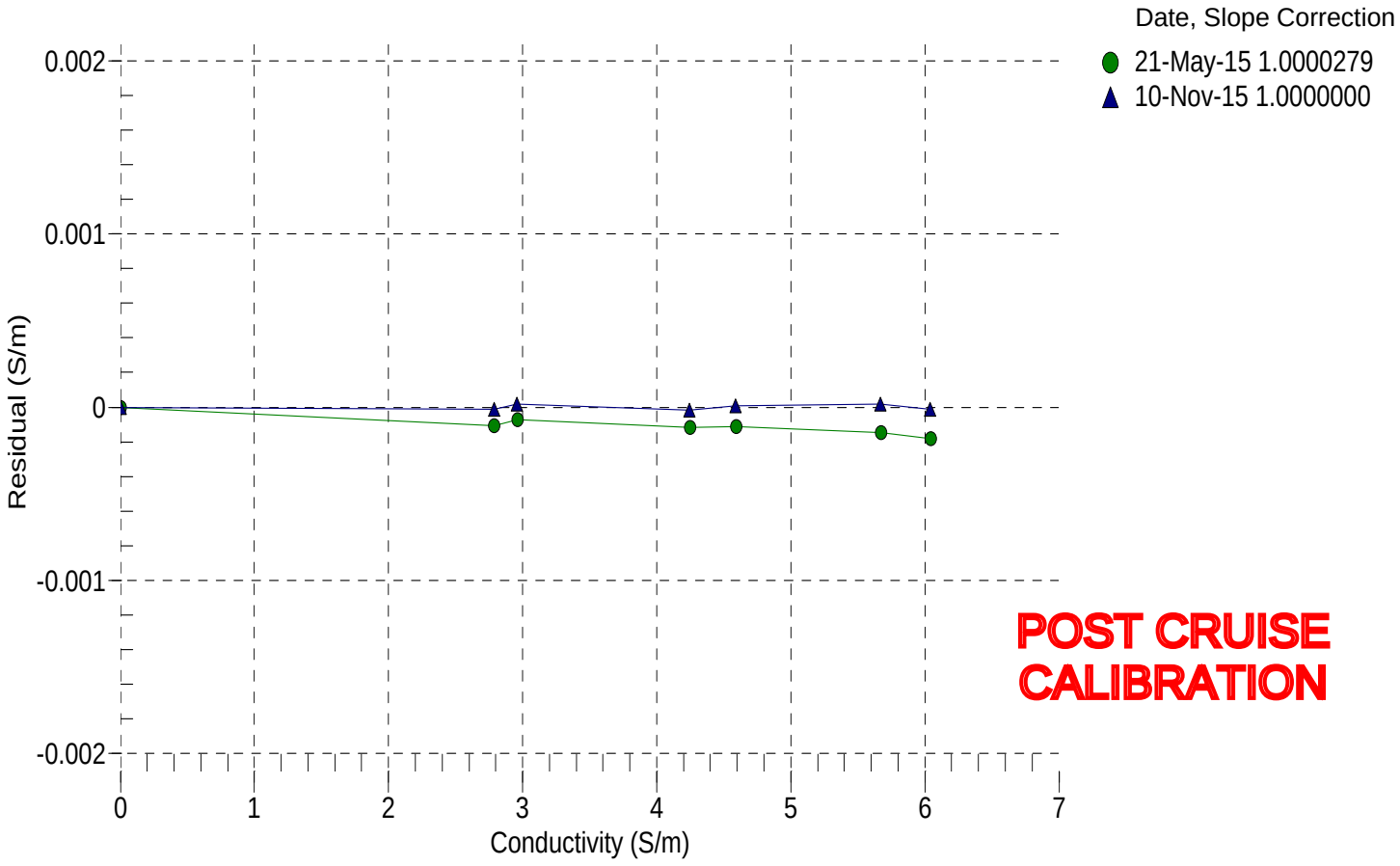
| BATH TEMP (° C) | BATH SAL (PSU) | BATH COND (S/m) | INSTRUMENT OUTPUT (kHz) | INSTRUMENT COND (S/m) | RESIDUAL (S/m) |
|---|---|---|---|---|---|
| 0.0000 | 0.0000 | 0.00000 | 2.57478 | 0.00000 | 0.00000 |
| -1.0001 | 34.5758 | 2.78699 | 4.98373 | 2.78698 | -0.00001 |
| 0.9999 | 34.5759 | 2.95736 | 5.09414 | 2.95738 | 0.00002 |
| 14.9999 | 34.5765 | 4.24529 | 5.86130 | 4.24527 | -0.00002 |
| 18.4999 | 34.5762 | 4.58993 | 6.05000 | 4.58994 | 0.00001 |
| 28.9999 | 34.5750 | 5.66722 | 6.60475 | 5.66723 | 0.00002 |
| 32.4999 | 34.5684 | 6.03762 | 6.78487 | 6.03761 | -0.00001 |

f = Instrument Output (kHz)

t = temperature (°C); p = pressure (decibars); $\delta$ = CTcor; $\varepsilon$ = CPcor;

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

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



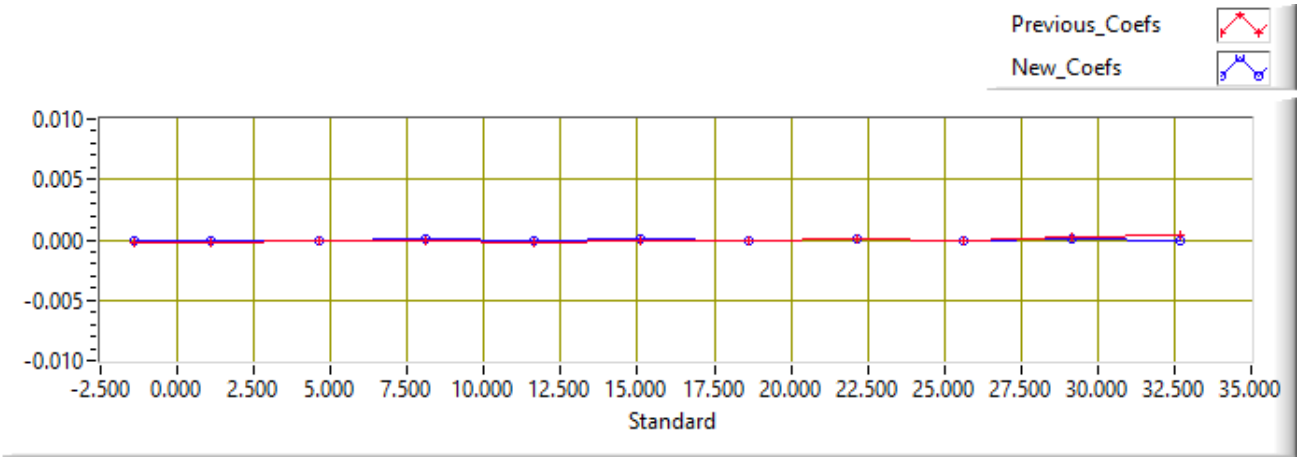
# Temperature Calibration Report
# STS/ODF Calibration Facility

**SENSOR SERIAL NUMBER: 2165**
**CALIBRATION DATE: 17-Nov-2015**
**Mfg: SEABIRD  Model: 03**
**Previous cal: 14-May-15**
**Calibration Tech: CAL**

| ITS-90_COEFFICIENTS | IPTS-68_COEFFICIENTS ITS-T90 | |
|---|---|---|
| g = 4.32792051E-3 | a = 4.32810905E-3 | |
| h = 6.42743492E-4 | b = 6.42951909E-4 | |
| i = 2.33776278E-5 | c = 2.34100810E-5 | |
| j = 2.24455310E-6 | d = 2.24611838E-6 | |
| f0 = 1000.0 | Slope = 1.0 | Offset = 0.0 |

**Calibration Standard:  Mfg: Isotech  Model: MicroK100  s/n: 291088-2**
**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 |
|---|---|---|---|---|
| 2839.8302 | -1.4091 | -1.4091 | -0.00028 | -0.00001 |
| 3003.3267 | 1.0954 | 1.0954 | -0.00019 | 0.00000 |
| 3243.6258 | 4.6030 | 4.6030 | -0.00014 | 0.00000 |
| 3497.4129 | 8.1099 | 8.1098 | -0.00003 | 0.00008 |
| 3765.1895 | 11.6176 | 11.6178 | -0.00023 | -0.00013 |
| 4046.6336 | 15.1184 | 15.1184 | -0.00003 | 0.00005 |
| 4343.4769 | 18.6288 | 18.6288 | -0.00008 | -0.00002 |
| 4655.0648 | 22.1367 | 22.1367 | 0.00005 | 0.00006 |
| 4982.1090 | 25.6464 | 25.6465 | -0.00004 | -0.00011 |
| 5324.1424 | 29.1504 | 29.1503 | 0.00030 | 0.00010 |
| 5682.8013 | 32.6615 | 32.6616 | 0.00035 | -0.00004 |



# 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: 2036
CALIBRATION DATE: 10-Nov-15

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

COEFFICIENTS:

```
g =  -1.06625241e+001
h =   1.45228125e+000
i =  -5.99256421e-003
j =   6.33276429e-004

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

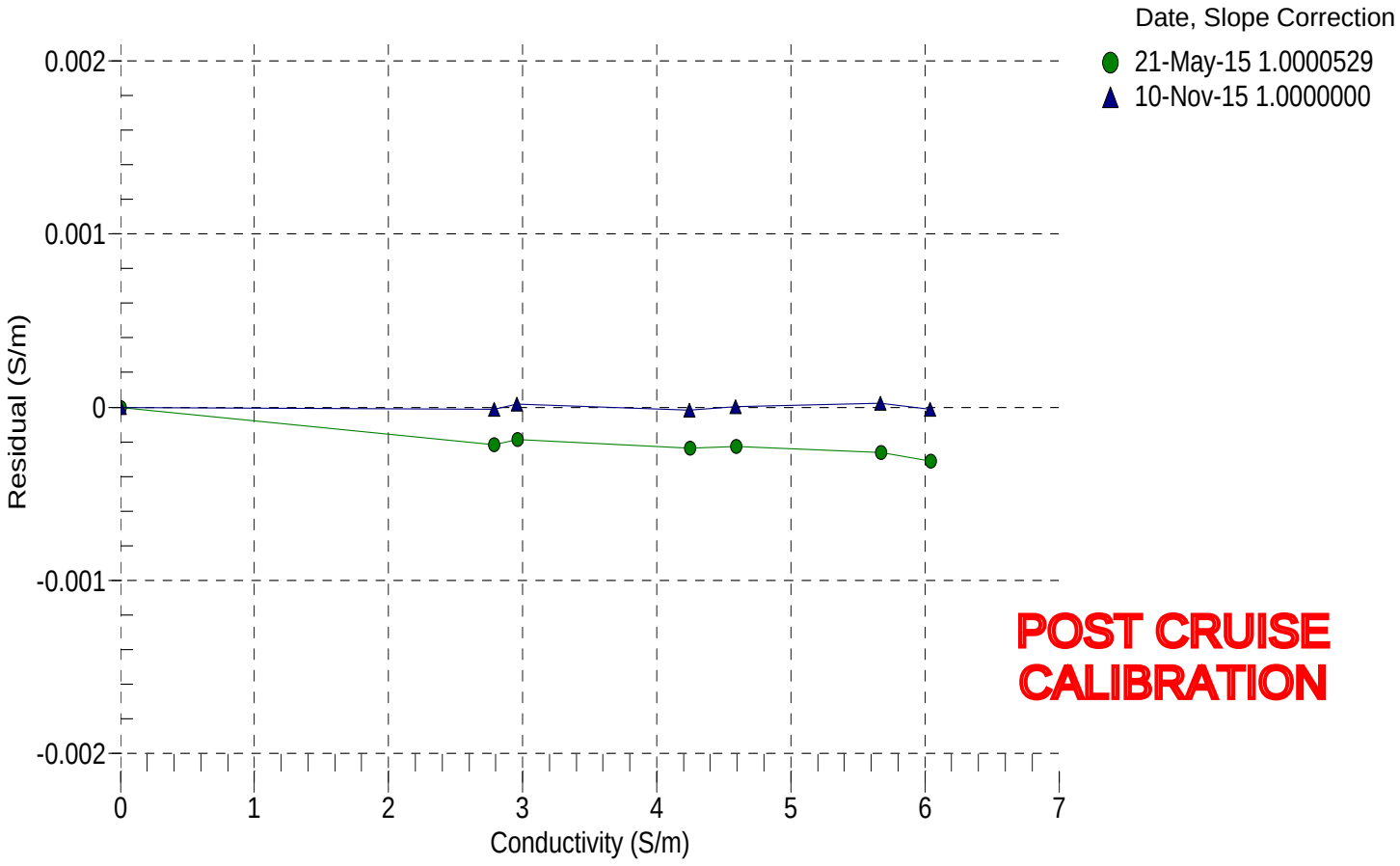
| BATH TEMP (° C) | BATH SAL (PSU) | BATH COND (S/m) | INSTRUMENT OUTPUT (kHz) | INSTRUMENT COND (S/m) | RESIDUAL (S/m) |
|---|---|---|---|---|---|
| 0.0000 | 0.0000 | 0.00000 | 2.72050 | 0.00000 | 0.00000 |
| -1.0001 | 34.5758 | 2.78699 | 5.17604 | 2.78698 | -0.00001 |
| 0.9999 | 34.5759 | 2.95736 | 5.28913 | 2.95738 | 0.00002 |
| 14.9999 | 34.5765 | 4.24529 | 6.07505 | 4.24527 | -0.00002 |
| 18.4999 | 34.5762 | 4.58993 | 6.26832 | 4.58994 | 0.00000 |
| 28.9999 | 34.5750 | 5.66722 | 6.83627 | 5.66724 | 0.00002 |
| 32.4999 | 34.5684 | 6.03762 | 7.02055 | 6.03761 | -0.00001 |

f = Instrument Output (kHz)

t = temperature (°C); p = pressure (decibars); $\delta$ = CTcor; $\varepsilon$ = CPcor;

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

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



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13431 NE 20th Street, Bellevue, WA 98005-2010 USA

Phone: (+1) 425-643-9866 Fax (+1) 425-643-9954 Email: seabird@seabird.com


SENSOR SERIAL NUMBER: 3023
CALIBRATION DATE: 01-Dec-15

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

COEFFICIENTS:

```
g =  -9.88423243e+000
h =   1.42709744e+000
i =   1.53440913e-004
j =   6.70552381e-005

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

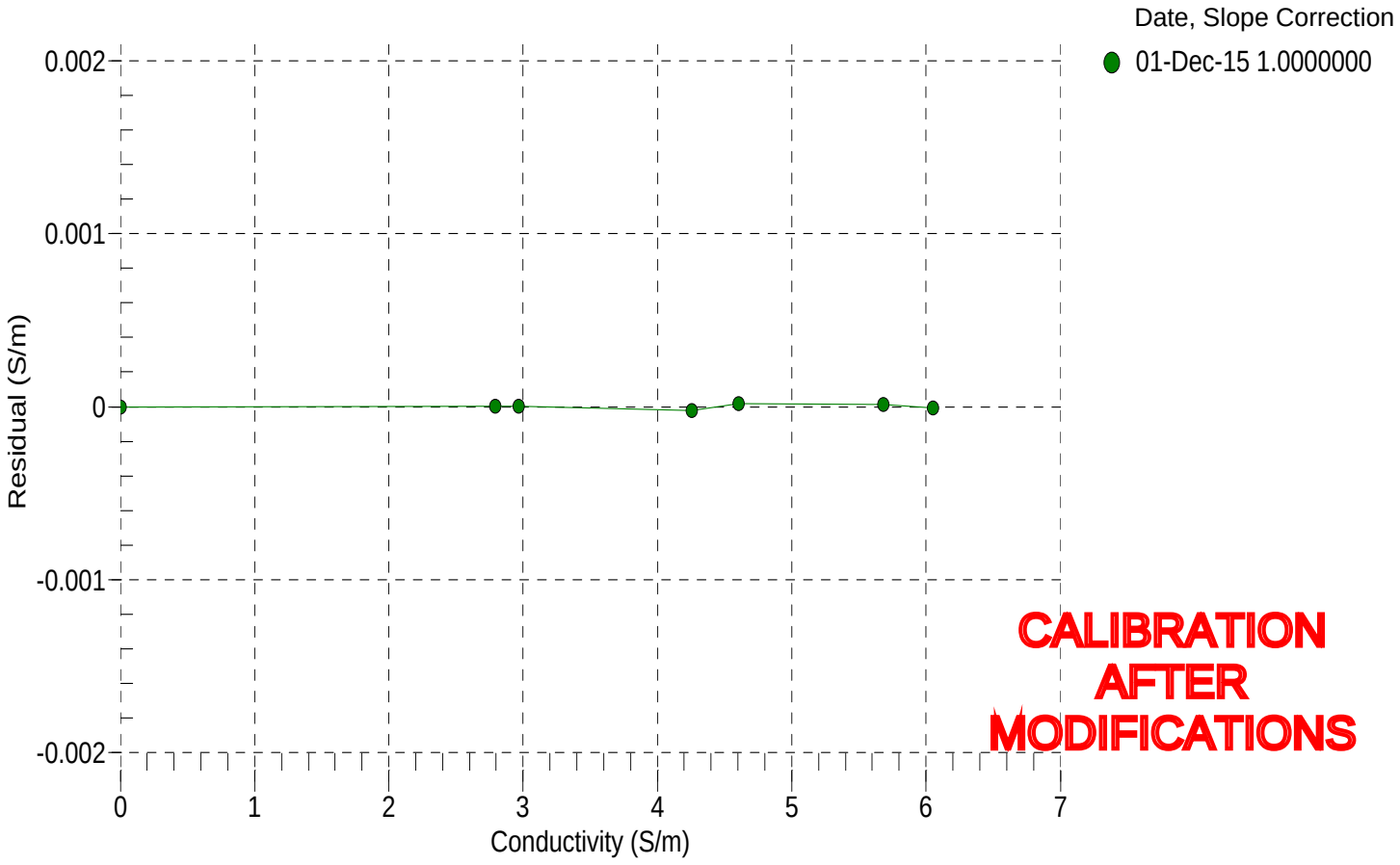
| BATH TEMP (° C) | BATH SAL (PSU) | BATH COND (S/m) | INSTRUMENT OUTPUT (kHz) | INSTRUMENT COND (S/m) | RESIDUAL (S/m) |
|---|---|---|---|---|---|
| 0.0000 | 0.0000 | 0.00000 | 2.63095 | 0.00000 | 0.00000 |
| -1.0001 | 34.6787 | 2.79451 | 5.14396 | 2.79452 | 0.00000 |
| 0.9999 | 34.6791 | 2.96534 | 5.25866 | 2.96534 | 0.00000 |
| 14.9999 | 34.6793 | 4.25657 | 6.05534 | 4.25655 | -0.00002 |
| 18.4999 | 34.6789 | 4.60209 | 6.25125 | 4.60211 | 0.00002 |
| 28.9999 | 34.6761 | 5.68192 | 6.82702 | 5.68193 | 0.00001 |
| 32.4999 | 34.6658 | 6.05270 | 7.01373 | 6.05269 | -0.00001 |

f = Instrument Output (kHz)

t = temperature (°C); p = pressure (decibars); $\delta$ = CTcor; $\varepsilon$ = CPcor;

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

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



# 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: 1919
CALIBRATION DATE: 10-Nov-15

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

COEFFICIENTS:

```
g =  -3.99264698e+000
h =   5.25774535e-001
i =  -1.02610382e-003
j =   8.04692089e-005

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

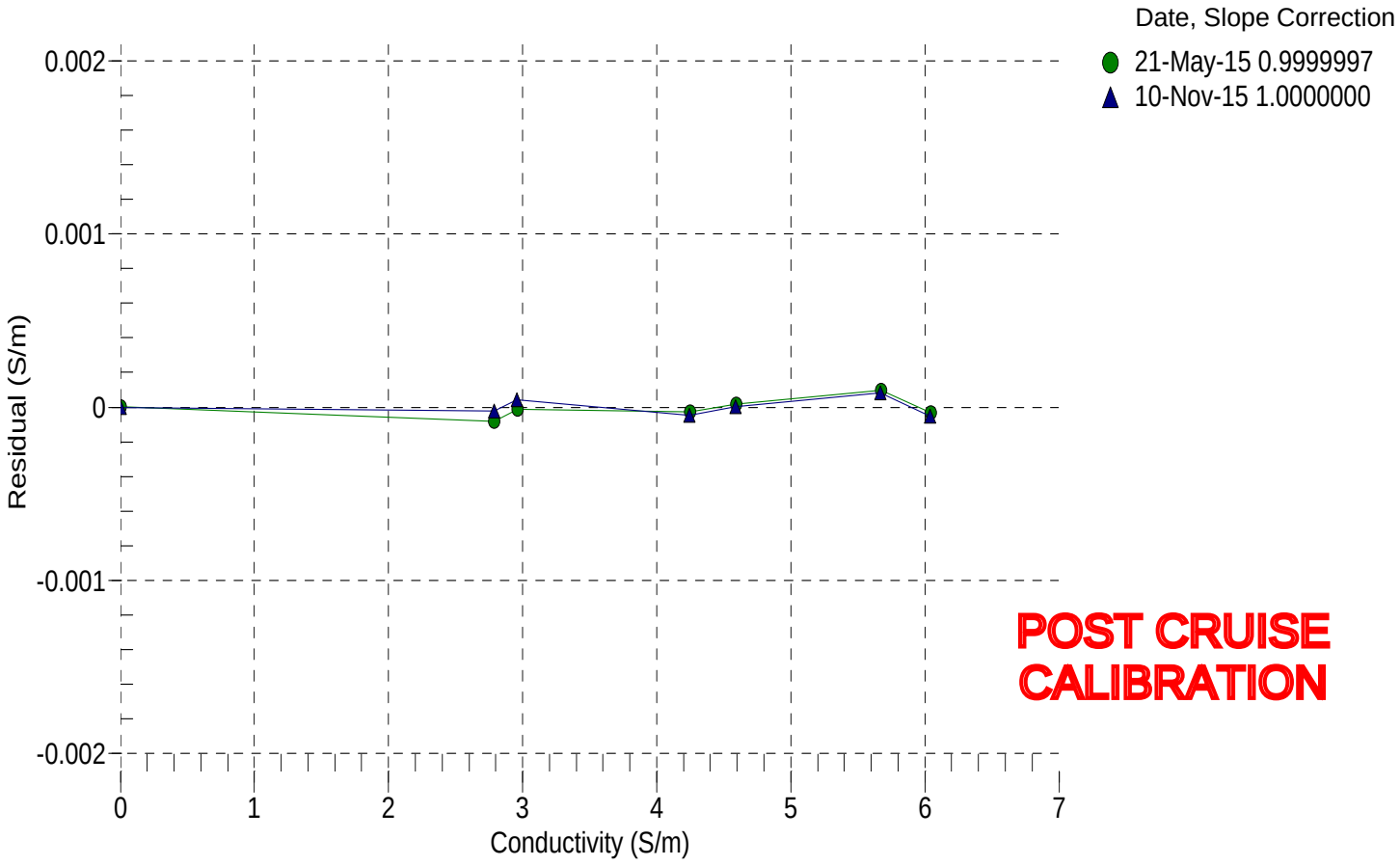
| BATH TEMP (° C) | BATH SAL (PSU) | BATH COND (S/m) | INSTRUMENT OUTPUT (kHz) | INSTRUMENT COND (S/m) | RESIDUAL (S/m) |
|---|---|---|---|---|---|
| 0.0000 | 0.0000 | 0.00000 | 2.76153 | 0.00000 | 0.00000 |
| -1.0001 | 34.5758 | 2.78699 | 7.80774 | 2.78697 | -0.00002 |
| 0.9999 | 34.5759 | 2.95736 | 8.01347 | 2.95740 | 0.00004 |
| 14.9999 | 34.5765 | 4.24529 | 9.42160 | 4.24524 | -0.00005 |
| 18.4999 | 34.5762 | 4.58993 | 9.76336 | 4.58993 | 0.00000 |
| 28.9999 | 34.5750 | 5.66722 | 10.75980 | 5.66730 | 0.00008 |
| 32.4999 | 34.5684 | 6.03762 | 11.08087 | 6.03757 | -0.00005 |

f = Instrument Output (kHz)

t = temperature (°C); p = pressure (decibars); $\delta$ = CTcor; $\varepsilon$ = CPcor;

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

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



PO Box 518
620 Applegate St.
Philomath, OR 97370

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

# C-Star Calibration

Date 6.3.15 S/N# CST-327DR Pathlength 25cm

| | Analog output |
|---|---|
| $V_d$ | 0.058 V |
| $V_{air}$ | 4.770 V |
| $V_{ref}$ | 4.658 V |

| | |
|---|---|
| Temperature of calibration water | 22.5 ℃ |
| Ambient temperature during calibration | 22.4 ℃ |

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: $\mathbf{c = -1/x * ln\ (Tr)}$

$\mathbf{V_d}$ Meter output with the beam blocked. This is the offset.
$\mathbf{V_{air}}$ Meter output in air with a clear beam path.
$\mathbf{V_{ref}}$ 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.
$\mathbf{V_{sig}}$ Measured signal output of meter.

PO Box 518
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Philomath, OR 97370

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

# C-Star Calibration

Date 11.11.14 S/N# CST-492DR Pathlength 25cm

| | Analog output |
|---|---|
| $V_d$ | 0.058 V |
| $V_{air}$ | 4.796 V |
| $V_{ref}$ | 4.683 V |

| | |
|---|---|
| Temperature of calibration water | 19.4 ℃ |
| Ambient temperature during calibration | 21.4 ℃ |

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: $\mathbf{c = -1/x * ln\ (Tr)}$

$\mathbf{V_d}$ Meter output with the beam blocked. This is the offset.
$\mathbf{V_{air}}$ Meter output in air with a clear beam path.
$\mathbf{V_{ref}}$ 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.
$\mathbf{V_{sig}}$ Measured signal output of meter.

# Sea-Bird Electronics, Inc.

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SENSOR SERIAL NUMBER: 1129
CALIBRATION DATE: 08-Dec-15

SBE 43 OXYGEN CALIBRATION DATA

COEFFICIENTS:
Soc = 0.5432
Voffset = -0.5210
Tau20 = 1.34

A = -4.3521e-003
B = 1.4933e-004
C = -2.7145e-006
E nominal = 0.036

NOMINAL DYNAMIC COEFFICIENTS
D1 = 1.92634e-4
D2 = -4.64803e-2

H1 = -3.300000e-2
H2 = 5.00000e+3
H3 = 1.45000e+3

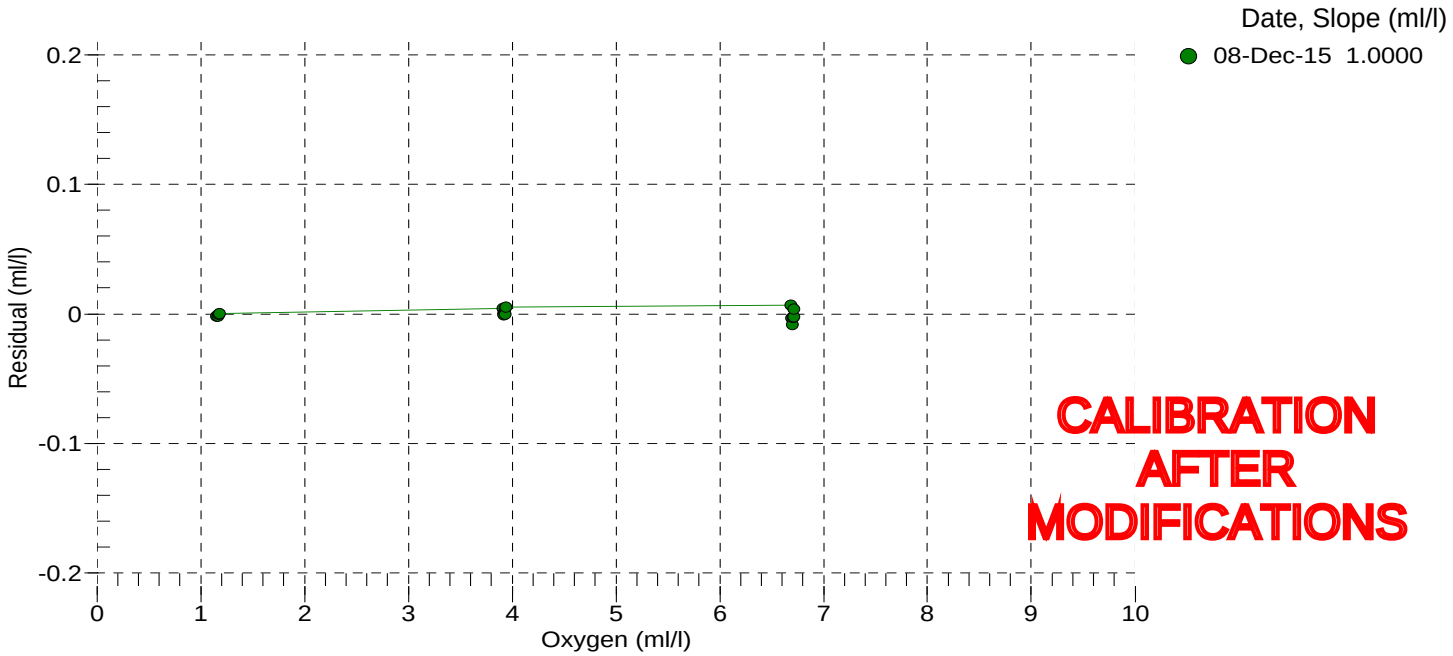
| BATH OXYGEN (ml/l) | BATH TEMPERATURE (° C) | BATH SALINITY (PSU) | INSTRUMENT OUTPUT (volts) | INSTRUMENT OXYGEN (ml/l) | RESIDUAL (ml/l) |
|---|---|---|---|---|---|
| 1.15 | 2.00 | 0.00 | 0.742 | 1.15 | -0.00 |
| 1.16 | 6.00 | 0.00 | 0.770 | 1.15 | -0.00 |
| 1.17 | 30.00 | 0.00 | 0.957 | 1.17 | -0.00 |
| 1.17 | 20.00 | 0.00 | 0.877 | 1.17 | -0.00 |
| 1.17 | 26.00 | 0.00 | 0.925 | 1.17 | -0.00 |
| 1.18 | 12.00 | 0.00 | 0.820 | 1.18 | 0.00 |
| 3.91 | 20.00 | 0.00 | 1.711 | 3.91 | 0.00 |
| 3.92 | 2.00 | 0.00 | 1.272 | 3.92 | 0.00 |
| 3.92 | 30.00 | 0.00 | 1.987 | 3.92 | -0.00 |
| 3.93 | 26.00 | 0.00 | 1.879 | 3.94 | 0.00 |
| 3.93 | 12.00 | 0.00 | 1.517 | 3.93 | -0.00 |
| 3.94 | 6.00 | 0.00 | 1.373 | 3.95 | 0.01 |
| 6.69 | 26.00 | 0.00 | 2.829 | 6.69 | 0.01 |
| 6.69 | 30.00 | 0.00 | 3.022 | 6.69 | -0.00 |
| 6.70 | 20.00 | 0.00 | 2.557 | 6.69 | -0.01 |
| 6.71 | 2.00 | 0.00 | 1.807 | 6.71 | -0.00 |
| 6.71 | 12.00 | 0.00 | 2.220 | 6.71 | -0.00 |
| 6.71 | 6.00 | 0.00 | 1.972 | 6.72 | 0.00 |

V = instrument output (volts); T = temperature (°C); S = salinity (PSU); K = temperature (°K)

Oxsol(T,S) = oxygen saturation (ml/l); P = pressure (dbar)

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

Residual (ml/l) = instrument oxygen - bath oxygen



# Sea-Bird Electronics, Inc.

13431 NE 20th Street, Bellevue, WA 98005-2010 USA

Phone: (+1) 425-643-9866 Fax (+1) 425-643-9954 Email: seabird@seabird.com


SENSOR SERIAL NUMBER: 1138
CALIBRATION DATE: 19-Nov-15

SBE 43 OXYGEN CALIBRATION DATA

COEFFICIENTS:
Soc = 0.4348
Voffset = -0.5124
Tau20 = 1.41

A = -2.3647e-003
B = 1.1539e-004
C = -2.0257e-006
E nominal = 0.036

NOMINAL DYNAMIC COEFFICIENTS
D1 = 1.92634e-4
D2 = -4.64803e-2
H1 = -3.300000e-2
H2 = 5.00000e+3
H3 = 1.45000e+3

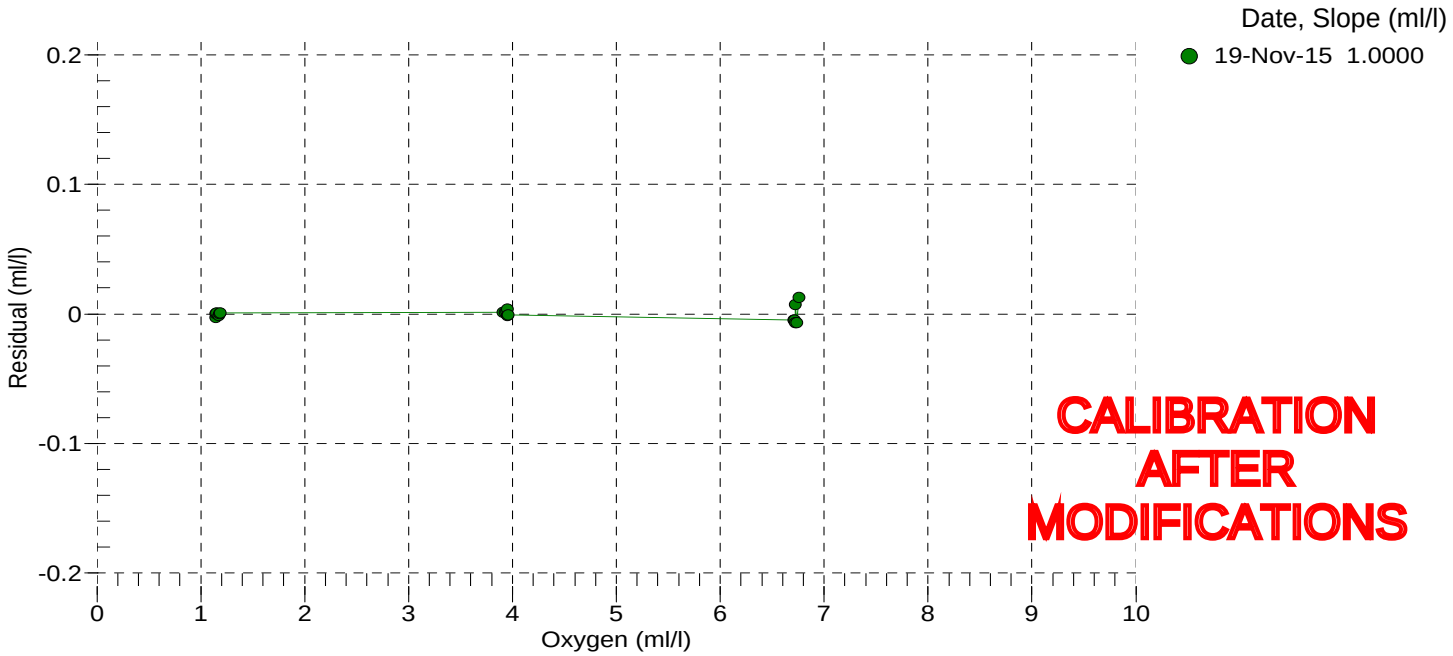
| BATH OXYGEN (ml/l) | BATH TEMPERATURE (° C) | BATH SALINITY (PSU) | INSTRUMENT OUTPUT (volts) | INSTRUMENT OXYGEN (ml/l) | RESIDUAL (ml/l) |
|---|---|---|---|---|---|
| 1.15 | 2.00 | 0.00 | 0.786 | 1.14 | -0.00 |
| 1.15 | 12.00 | 0.00 | 0.868 | 1.15 | 0.00 |
| 1.15 | 6.00 | 0.00 | 0.819 | 1.15 | 0.00 |
| 1.17 | 20.00 | 0.00 | 0.944 | 1.17 | -0.00 |
| 1.18 | 26.00 | 0.00 | 1.000 | 1.18 | 0.00 |
| 1.19 | 30.00 | 0.00 | 1.041 | 1.19 | 0.00 |
| 3.91 | 12.00 | 0.00 | 1.724 | 3.91 | 0.00 |
| 3.93 | 2.00 | 0.00 | 1.451 | 3.93 | 0.00 |
| 3.94 | 30.00 | 0.00 | 2.266 | 3.95 | 0.00 |
| 3.95 | 26.00 | 0.00 | 2.142 | 3.95 | -0.00 |
| 3.95 | 6.00 | 0.00 | 1.568 | 3.96 | 0.00 |
| 3.96 | 20.00 | 0.00 | 1.967 | 3.95 | -0.00 |
| 6.71 | 12.00 | 0.00 | 2.588 | 6.70 | -0.00 |
| 6.71 | 2.00 | 0.00 | 2.113 | 6.71 | -0.00 |
| 6.72 | 30.00 | 0.00 | 3.496 | 6.71 | -0.01 |
| 6.72 | 6.00 | 0.00 | 2.308 | 6.73 | 0.01 |
| 6.74 | 20.00 | 0.00 | 2.989 | 6.73 | -0.01 |
| 6.76 | 26.00 | 0.00 | 3.308 | 6.77 | 0.01 |

V = instrument output (volts); T = temperature (°C); S = salinity (PSU); K = temperature (°K)

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

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

Residual (ml/l) = instrument oxygen - bath oxygen



**CCHDO Data Processing Notes**

- **File Merge SEE**

33RR20160208_ct1.zip (download) #fc18a
**Date:** 2016-04-26
**Current Status:** merged

- **CTD exchange and netcdf formats online SEE**

**Date:** 2016-04-26
**Data Type:** CTD
**Action:** Website Update
**Note:**

```
I08 2016 33RR20160208 processing - CTD/merge -
CTDPRS,CTDTMP,CTDSAL,CTDOXY,CTDNOBS,XMISS,FLUOR,CDOMF,TRBDTY,RINKO,CTDETIME

2016-04-26

SEE


Submission

filename             submitted by  date       id
-------------------- ------------  ---------- -----
33RR20160208_ct1.zip Andrew Barna  2016-04-12 12194

Changes
-------

33RR20160208_ct1.zip
    - added UNITS comments
    - renamed ct1.csv files to CCHDO filename format.
    - renamed FLUORC to FLUOR
    - renamed CDOM to CDOMF
    - renamed TRANS to XMISS
    - included RINKO and TRBTY,  which are not yet defined as Exchange parameters.


Conversion
----------

file                     converted from       software
------------------------ -------------------- ------------------------
33RR20160208_nc_ctd.zip 33RR20160208_ct1.zip hydro 0.8.2-47-g3c55cd3
```

```
Updated Files Manifest
----------------------

file                     stamp
------------------------ -----------------
33RR20160208_ct1.zip     20160426CCHSIOSEE
33RR20160208_nc_ctd.zip  20160426CCHSIOSEE

:Updated parameters:
CTDPRS,CTDTMP,CTDSAL,CTDOXY,XMISS,FLUOR,CDOMF,CTDETIME,CTDNOBS,RINKO,TRBDTY

opened in JOA with no apparent problems:
     33RR20160208_ct1.zip
     33RR20160208_nc_ctd.zip

opened in ODV with no apparent problems:
     33RR20160208_ct1.zip
```

- **File Online Carolina Berys**

33RR20160208_do.pdf (download) #9638d
**Date:** 2016-04-12
**Current Status:** unprocessed

- **File Online Carolina Berys**

33RR20160208_do.txt (download) #787f7
**Date:** 2016-04-12
**Current Status:** unprocessed

- **File Online Carolina Berys**

33RR20160208_ct1.zip (download) #fc18a
**Date:** 2016-04-12
**Current Status:** merged

- **File Online Carolina Berys**

33RR20160208_hy1.csv (download) #45ed7
**Date:** 2016-04-12
**Current Status:** unprocessed

- **File Submission** **Andrew Barna**

33RR20160208_do.pdf (download) #9638d
**Date:** 2016-04-12
**Current Status:** unprocessed

- **File Submission** **Andrew Barna**

33RR20160208_do.txt (download) #787f7
**Date:** 2016-04-12
**Current Status:** unprocessed

- **File Submission** **Andrew Barna**

33RR20160208_ct1.zip (download) #fc18a
**Date:** 2016-04-12
**Current Status:** merged

- **File Submission** **Andrew Barna**

33RR20160208_hy1.csv (download) #45ed7
**Date:** 2016-04-12
**Current Status:** unprocessed