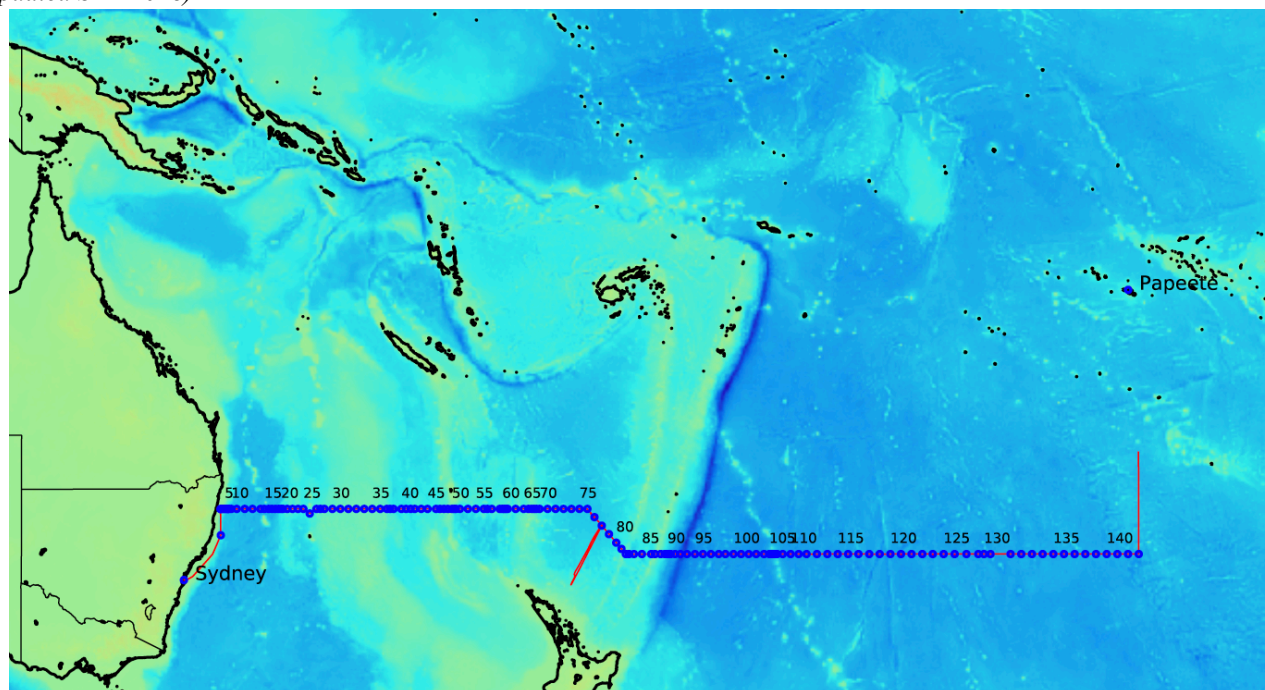


# CRUISE REPORT: P06W

(Updated SEP 2018)



## Highlights

### Cruise Summary Information

Section Designation	<b>P06W</b>		
Expedition designation (ExpoCodes)	<b>320620170703</b>		
Chief Scientist	<b>Sabine Mecking/UW-APL</b>		
Co-Chief Scientist	<b>Isabella Rosso/UCSD</b>		
Dates	2017 JUL 03 - 2017 AUG 17		
Ship	<i>Nathaniel B Palmer</i>		
Ports of call	Papeete, Tahiti - Valparaiso, Chile		
Geographic Boundaries	30° 4' 43" S		
	153° 28' 47.6" E	148° 54' 29.5" W	
	32° 30' 5.4" S		
Stations	143		
Floats and drifters deployed	4 Argo/O2 floats		
	2 SOCCOM floats		
	5 SIO floats (2 SOLO II, 3 Deep Solo)		
	14 drifters		
Moorings deployed or recovered	0		
Contact Information:			
Sabine Mecking University of Washington Applied Physics Laboratory Email: <a href="mailto:mecking@uw.edu">mecking@uw.edu</a> • Phone: 206-221-6570		Isabella Rosso University of California, San Diego Scripps Institution of Oceanography Email: <a href="mailto:irosso@ucsd.edu">irosso@ucsd.edu</a>	

## 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	<b>CTD Data:</b>
Geographic Boundaries	Acquisition
Cruise Track (Figure)	Processing
Description of Stations	Calibration
Description of Parameters Sampled	Temperature    Pressure
Bottle Depth Distributions (Figure)	Salinities        Oxygens
Floats and Drifters Deployed	<b>Bottle Data</b>
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	LADCP
Navigation        Bathymetry	
Acoustic Doppler Current Profiler (ADCP)	
Thermosalinograph	
XBT and/or XCTD	
Meteorological Observations	<b>Acknowledgments</b>
Atmospheric Chemistry Data	
Data Processing Notes	References





# **Cruise Report of the 2017 P06W US GO-SHIP Reoccupation**

*Release Draft 1*

**Sabine Mecking**

Sep 16, 2018



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## GO-SHIP P06W 2017 HYDROGRAPHIC PROGRAM

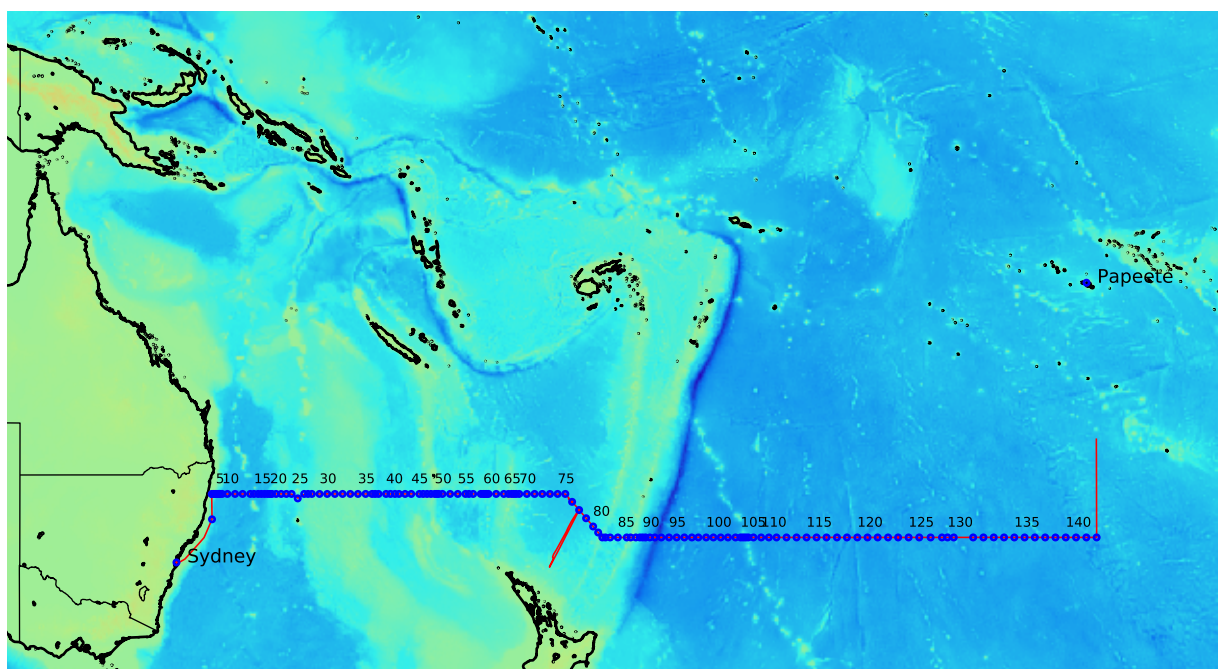


Fig. 1.1: Cruise track of P06W

The Pacific Ocean P06W repeat hydrographic line was reoccupied for the US Global Ocean Carbon and Repeat Hydrography Program. Reoccupation of the P06W transect occurred on the RVIB Nathaniel B Palmer from July 3, 2017 to August 17, 2017. The survey of P06W consisted of *CTDO*, rosette, *LADCP*, chipod, water samples and underway measurements. The ship departed from the port of Sydney, Australia and completed the cruise in the port of Papeete on the island of Tahiti, French Polynesia.

A total of 143 stations (plus one test station) were occupied with one CTDO/rosette/LADCP/chipod package. At these stations, a total of 150 CTDO/rosette/LADCP/chipod casts, including 2 test casts were performed. The stations were, for the most part, a reoccupation of P06W-2009, and they are detailed in the following sections. 4 UW Argo floats were deployed on P06W and are detailed in the UW Float section. 2 *SOCCOM* floats were deployed on P06W and are detailed in the SOCCOM section. 5 SIO floats, 2 SOLO II and 3 Deep Solo, were deployed on P06W and are detailed in the SIO float section. 14 drifters were deployed on P06W and are detailed in the drifter section of the cruise report.

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 Nitrate  $\delta^{15}\text{N}$  and  $\delta^{18}\text{O}$ , *DOC/IDN*,  $13\text{C}/14\text{C}$ , *POC*, *HPLC*, DOP and DON.

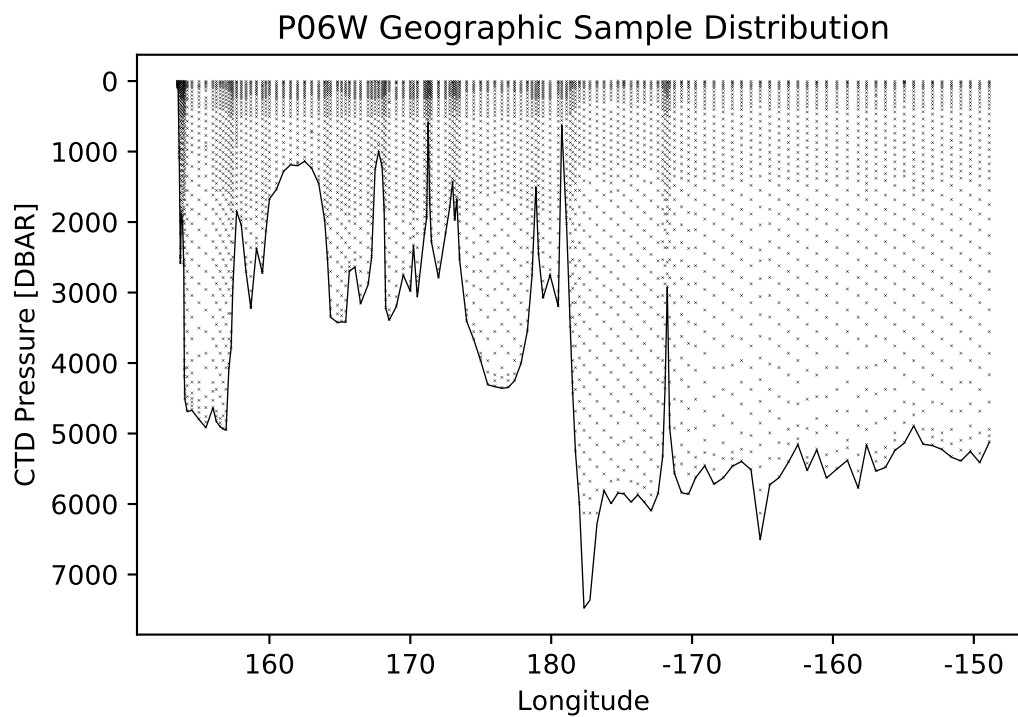


Fig. 1.2: Distrubtion of samples by longitude.

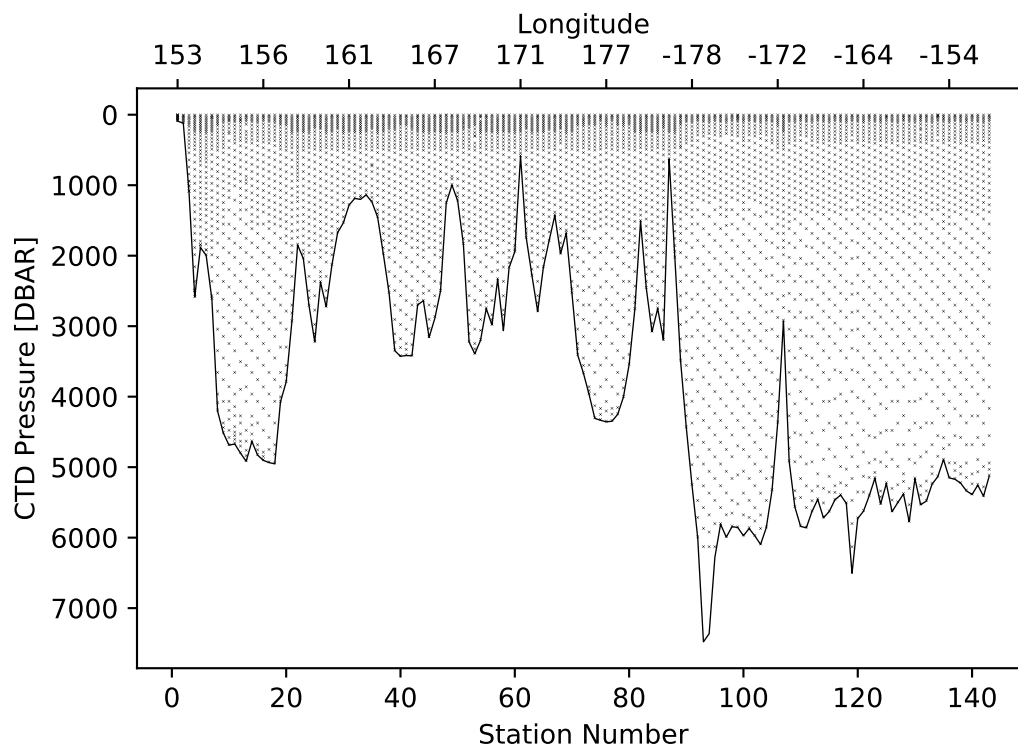


Fig. 1.3: Distribution of samples by station number.

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

## 1.1 Programs and Principal Investigators

Program	Affiliation	Principal Investigator	Email
<i>CTDO</i> Data, Salinity, Nutrients, Dissolved O <sub>2</sub>	<i>SIO-UCSD</i>	Susan Becker, Jim Swift	sbecker@ucsd.edu, jswift@ucsd.edu
Total CO <sub>2</sub> (DIC)	<i>PMEL-NOAA, AOML-NOAA</i>	Richard Feely, Rik Wanninkhof	Richard.A.Feely@noaa.gov, Rik.Wanninkhof@noaa.gov
Underway Temperature, Salinity, and pCO <sub>2</sub>	<i>AOML-NOAA, ASC</i>	Rik Wanninkhof, <i>ASC</i>	Rik.Wanninkhof@noaa.gov, admin@nbp.usap.gov
Total Alkalinity, pH	<i>SIO-UCSD</i>	Andrew Dickson	adickson@ucsd.edu
ADCP	<i>UH</i>	Eric Firing	efiring@soest.hawaii.edu
<i>LADCP</i>	<i>LDEO</i>	Andreas Thurnherr	ant@ldeo.columbia.edu
<i>CFCs, SF6</i>	<i>U Miami, UT</i>	Rana Fine, Dong-Ha Min	rfine@rsmas.miami.edu, dongha@mail.utexas.edu
<i>DOC, TDN</i>	<i>UCSB</i>	Craig Carlson	carlson@lifesci.ucsb.edu
C13 & C14	<i>WHOI, Princeton</i>	Ann McNichol, Robert Key	amcnichol@whoi.edu, key@princeton.edu
Transmissometry	<i>TAMU</i>	Wilf Gardner	wgardner@ocean.tamu.edu
Fluorescence and Backscatter ( <i>SOCOM</i> ), HPLC & POC	<i>U Maine</i>	Emmanuel Boss	emmanuel.boss@maine.edu
Chipod	<i>OSU</i>	Jonathan Nash	nash@coas.oregonstate.edu
Nitrate $\delta^{15}\text{N}$ and $\delta^{18}\text{O}$	<i>Princeton</i>	Daniel Sigman	sigman@princeton.edu
DON and DOP	<i>FSU</i>	Angela Knapp	anknapp@fsu.edu
Argo Floats	<i>UW, SIO-UCSD</i>	Steve Riser, Dean Roemmich, John Gilson	riser@ocean.washington.edu, droemmich@ucsd.edu, jegilson@gmail.com
<i>SOCOM</i> Floats	<i>UW, SIO-UCSD</i>	Steve Riser, Lynne Talley	riser@ocean.washington.edu, ltalley@ucsd.edu
Surface Drifters	<i>NOAA, AOML</i>	Shaun Dolk	Shaun.dolk@noaa.gov
Underway Bathymetry and Meteorological Data	<i>ASC</i>	<i>ASC</i>	admin@nbp.usap.gov

## 1.2 Science Team and Responsibilities

Duty	Name	Affiliation	Email Address
Chief Scientist	Sabine Mecking	<i>UW-APL</i>	mecking@uw.edu
Co-Chief Scientist, floats and drifters	Isabella Rosso	<i>UCSD</i>	irrosso@ucsd.edu
CTD Watchstander	Kimberly Gottschalk	<i>UW</i>	kgotts@uw.edu
CTD Watchstander	Maxime Duchet	<i>ENSTA</i>	maxime.duchet@ensta-paristech.fr
CTD Watchstander, Chipods	Ratnaksha Lele	<i>UCSD</i>	rlele@ucsd.edu
CTD Watchstander	Rebecca Beadling	<i>UA</i>	beadling@email.arizona.edu
CTD Watchstander, LADCP	Natalie Zielinski	<i>TAMU</i>	njzielinski@tamu.edu

Continued on next page

Table 1.1 – continued from previous page

Duty	Name	Affiliation	Email Address
Nutrients, <i>ODF</i> supervisor, <i>SOCCOM</i> floats	Susan Becker	<i>UCSD ODF</i>	sbecker@ucsd.edu
Nutrients	David Cervantes	<i>UCSD ODF</i>	d1cervantes@ucsd.edu
CTDO Processing, Database Management	Joseph Gum	<i>UCSD ODF</i>	jgum@ucsd.edu
Salts, ET	John Calderwood	<i>UCSD SEG</i>	jcalderwood@ucsd.edu
Salts	Kelsey Vogel	<i>UCSD STS</i>	kdvogel@ucsd.edu
Dissolved O <sub>2</sub> , Database Management	Andrew Barna	<i>UCSD ODF</i>	abarna@ucsd.edu
Dissolved O <sub>2</sub> , Database Support	Courtney Schatzman	<i>UCSD ODF</i>	cschatzman@ucsd.edu
SADCP, <i>LADCP</i>	Alma Carolina Castillo-Trujillo	<i>UH</i>	acast@hawaii.edu
<i>DIC</i> , underway pCO <sub>2</sub>	Charles Featherstone	<i>AOML</i>	charles.featherstone@noaa.gov
<i>DIC</i>	Andrew Collins	<i>PMEL</i>	andrew.collins@noaa.gov
<i>CFCs</i> , SF6	Jim Happell	<i>U Miami</i>	jhappell@miami.edu
<i>CFCs</i> , SF6	David Cooper		davidcooper59@gmail.com
<i>CFCs</i> , SF6 student	Kelly McCabe	<i>FSU</i>	kmm12c@my.fsu.edu
Total Alkalinity	Manuel Belmonte	<i>UCSD</i>	manbelmonte1@gmail.com
Total Alkalinity	Derek Smith	<i>UCSD</i>	dereksmith50@gmail.com
pH	Stephanie Mumma	<i>UCSD</i>	smumma@ucsd.edu
<i>DOC</i> , <i>TDN</i> , Radio Carbon	Chance English	<i>UCSB</i>	cje@umail.ucsb.edu
Marine Projects Coordinator	Eric Hutt	<i>ASC</i>	mpc@nbp.usap.gov
Marine Lab Technician	John Betz	<i>ASC</i>	mlt@nbp.usap.gov
Marine Technician	Jennie Mowatt	<i>ASC</i>	mt@nbp.usap.gov
Marine Technician	Michael Tepper-Rassmusen	<i>ASC</i>	mt@nbp.usap.gov
Marine Technician	Paul Savoy	<i>ASC</i>	mt@nbp.usap.gov
Electronic Technician	Barry Bjork	<i>ASC</i>	et@nbp.usap.gov
Electronic Technician	George Aukon	<i>ASC</i>	et@nbp.usap.gov
Network Administrator	Sean Drabant	<i>ASC</i>	admin@nbp.usap.gov
Network Administrator	Matt Pullen	<i>ASC</i>	admin@nbp.usap.gov

### 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 niskin bottles with an absolute volume of 10.6L. 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 backscatter meter, oxygen optode, and altimeter. LADCP and chipods instruments were deployed with the CTD/rosette package and their use is outlined in sections of this document specific to their titled analysis.

CTD and cage were vertically mounted at the bottom of the rosette frame, located below the carousel for all stations. The temperature, conductivity, dissolved oxygen, respective pumps and exhaust tubing was mounted to the CTD and cage 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 transmissometer was mounted horizontally. The fluorometer, oxygen optode, and altimeters were mounted vertically inside the bottom ring of the rosette frames. The 150 KHz bi-directional Broadband LADCP (RDI) unit was mounted vertically on the bottom side of the frame. The 300 KHz bi-directional Broadband LADCP (RDI) unit was mounted vertically on the top side of the frame. The LADCP battery pack was also mounted on the bottom of the frame.



Equipment	Model	S/N	Cal Date	Stations	Responsible Pa
Rosette	36-place	Yellow	–	1-143	<i>STS/ODF</i>
CTD	SBE9+	1281	–	1-143	<i>STS/ODF</i>
Pressure Sensor	Digiquartz	136428	Apr 10, 2017	1-143	<i>STS/ODF</i>
Primary Temperature	SBE3+	35844	Apr 11, 2017	1-143	<i>STS/ODF</i>
Primary Conductivity	SBE4C	42569	Sep 20, 2016	1-116	<i>STS/ODF</i>
Primary Conductivity	SBE4C	43399	Apr 7, 2017	117-143	<i>STS/ODF</i>
Primary Pump	SBE5	54890	–	1-7	<i>STS/ODF</i>
Primary Pump	SBE5	51646	–	8-143	<i>ASC</i>
Secondary Temperature	SBE3+	32309	Apr 18, 2017	1-143	<i>STS/ODF</i>
Secondary Conductivity	SBE4C	42819	Apr 11, 2017	1-143	<i>STS/ODF</i>
Secondary Pump	SBE5	54377	–	1-10	<i>STS/ODF</i>
Secondary Pump	SBE5	55644	–	10-143	<i>ASC</i>
Transmissometer	Cstar	CST-1803DR	Sep 16, 2016	1-143	<i>TAMU</i>
Fluorometer (Chl) and Backscatter	WetLabs	FLBBRTD-3698	Sep 23, 2014	1-143	<i>U Maine</i>
Primary Dissolved Oxygen	SBE43	430255	Apr 7, 2017	901-902, 105-143	<i>STS/ODF</i>
Primary Dissolved Oxygen	SBE43	431136	Apr 11, 2017	1-73	<i>STS/ODF</i>
Primary Dissolved Oxygen	SBE43	430275	Mar 30, 2017	74-76	<i>STS/ODF</i>
Primary Dissolved Oxygen	SBE43	430080	Feb 4, 2017	77-143	<i>ASC</i>
Oxygen Optode	RINKO	0251	Dec 21, 2015	1-143	<i>STS/ODF</i>
Reference Temperature	SBE35	0035	Apr 13, 2017	1-143	<i>STS/ODF</i>
Carousel	SBE32	0187	–	1-12	<i>STS/ODF</i>
Carousel	SBE32	1178	–	13-143	<i>STS/ODF</i>
Altimeter	Tritech LPA200	–	–	901, 4-5, 7	<i>STS/ODF</i>
Altimeter	Benthos PSA-916	–	–	901-3, 6	<i>ASC</i>
Altimeter	Valeport 500	–	–	8-143	<i>ASC</i>

The DUSH5 baltic room winch deployment system was successfully used for all stations. 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 P06W-2017. An electrical and mechanical termination was completed after station/cast 106/01 due to a small kink in the wire.

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 flushing fresh water through both plumbed sensor lines between casts. The rosette was routinely examined for valves and o-rings leaks, which were maintained as needed.

Some complications were overcome to complete CTDO/rosette/LADCP/chipod station casts for P06W. Mounting sea state due to storms caused two kinks in the wire on different stations shortly after retermination on station/cast 106/01. The kinks were inspected for severity, bent back into shape, and then redeployed without retermination. The storms caused casts to proceed slower than normal, limiting deployment speed to 20 meters per minute for the first 1000 meters on some stations during storms.



## CRUISE NARRATIVE

### 2.1 Summary

A hydrographic survey, P06, leg 1 (P06W) was conducted in the South Pacific Ocean from 3 July – 17 August 2017 aboard the RVIB Nathaniel B. Palmer. The icebreaker, owned by Edison Chouest Offshore (ECO), is operated by NSF's U.S. Antarctic Program (USAP) via a contract with the Antarctic Support Contractors (ASC). A total of 143 CTD rosette stations were occupied on a transect running along 32.50°S (30.08°S at the beginning off the Australian Coast) from 153.48°E to 148.91°W with port calls in Sydney, Australia and Papeete, French Polynesia at the beginning and the end of the cruise, respectively. CTD casts extended to within about 10 meters of the seafloor, and up to 36 water samples were collected in Niskin bottles (with Bullister modifications) throughout the water column on all casts. In addition to the CTD (conductivity, temperature, depth/pressure) sensors, two oxygen (O) sensors, upward and downward looking LADCPs (lowered acoustic Doppler current profilers), a transmissometer, a fluorometer (including backscatter sensor), and an altimeter were mounted onto the rosette frame. In addition, 4 UW Argo floats, 2 SIO SOLO floats, 3 SIO Deep SOLO floats, 2 SOCCOM floats, and 14 drifters were deployed on the 2017 P06, leg 1 occupation.

Salinity and dissolved oxygen samples, drawn from all Niskin bottles that were closed on each cast, were analyzed and used to calibrate the CTDO conductivity and oxygen sensors. Water samples were also analyzed onboard the ship for nutrients (nitrate, nitrite, phosphate, silicate), total CO<sub>2</sub>/TCO<sub>2</sub> (aka dissolved inorganic carbon/DIC), pH, total alkalinity, and transient tracers (chlorofluorocarbons/CFCs and sulfur hexafluoride/SF<sub>6</sub>).

Additional samples were collected for onshore analysis: radiocarbon ( $\delta^{13}\text{C}/\delta^{14}\text{C}$ ), dissolved organic carbon (DOC), dissolved organic phosphorus (DOP), nitrogen and oxygen isotopes of nitrate ( $\delta^{15}\text{N}$ ,  $\delta^{18}\text{O}$ ), phytoplankton pigment using high performance liquid chromatography (HPLC), and particulate organic carbon (POC).

Underway measurements included GPS navigation, multibeam and Knudsen bathymetry, ADCP, meteorological parameters, and sea surface measurements (including temperature, conductivity/salinity, dissolved oxygen, fluorescence, and pCO<sub>2</sub>) and gravity.

### 2.2 Cruise Narrative

The GO-SHIP 2017 P06 repeat hydrography cruise across the South Pacific subtropical gyre is a repeat of earlier section occupations that were conducted in 1992 as part of the U.S. WOCE program, in 2003 as part of the Japanese BEAGLE cruises, and in 2009/2010 as part of the U.S. CLIVAR/CO<sub>2</sub> Repeat Hydrography program. Goals of the repeat sections include the monitoring of oceanic inventories of CO<sub>2</sub>, heat, and freshwater, examination of changes in ocean transports and ventilation fluxes, and combining observations of a plethora of oceanic properties with global models, for a better prediction of the future state of the ocean and the atmosphere.

Mobilization for leg 1 of the P06 cruise began in Sydney on 28 June (all dates are local times/dates) when most of the science gear was loaded onto the RVIB Nathaniel B. Palmer (NBP), docked in the White Bay section (terminal 4) of Sydney Harbor. Only the ODF van and some missing sample bottles were left for loading on 29 June. All the

measurement groups started setting up in the labs, running tests, and trouble-shooting as soon as their items were on board. The NBP left Sydney on 3 July at 10:00am with 24 science party members from seven countries on board (plus the ASC and ECO crews), heading north toward the first station of leg 1. Along the way, on the morning of 4 July, a test station was conducted in Australian waters (as permitted by the clearance request) at ~31.5S, 153.5E, in about 3830m of water. In order to test the equipment and to give both watches practice with the CTD console procedures, two casts were performed. The first cast went to a depth of 100m without any bottles fired. On the second cast, the rosette was lowered to 2000m, and all 36 bottles were closed at this depth. Measurement groups could choose how many of these bottles to sample for their own test purposes.

Based on analysis of test station samples, the CFC group reported elevated SF<sub>6</sub> concentrations. Since the rosette was brand new, including the Niskin bottles, the suspicion was that there could be some contamination coming from the bottles. Thus, seven Niskin bottles (first seven odd ones) were exchanged against old ones from the back-up rosette. However, analysis of samples from double-fired bottles at subsequent stations indicated that the bottles were not the issue. Instead, adjustment of flushing times and trap temperatures on the CFC system could fix the SF<sub>6</sub> problem.

The first “real” station was occupied on the evening of 4 July at 30.09°S, 153.48°E, a few miles off the Australian Coast, in just 84m of water. From there on, the cruise track of P06, leg 1 followed an eastward path along 30.08°S across the northern part of the Tasman Basin, the Lord Howe Rise, the New Caledonia Trough and a couple of other ridges and troughs until the South Fiji Basin, with station depths ranging from 100-5100m.

At the beginning of the cruise, over the steeply declining continental slope, the altimeter on the rosette frame was exchanged several times because of inconsistent readings. At stations 3–7 (30.08S, 153.60–155.49E) the bottom approach of the CTD package was done by comparing the depth of the package (read from CTD console) to the Knudsen bathymetry display because the altimeter did not seem to turn on or report properly. With the CTD package likely not directly under the ship due to drift, it is possible that at these stations the turn-around point for the CTD package was more than the targeted 10–20m above the sea floor.

During the initial stations, as soon as water depths started becoming deeper, a few more hiccups had to be dealt with. At station 7 (30.08°S, 153.92°E; 2900m), the communication between the LADCP and its console became intermittent until it completely stopped at station 10 (30.08°S, 154.16°E; 4599m). Most cables had been exchanged by then, in order to solve the issue. However, only the removal of the magnetometer, which turned out to be flooded, finally fixed the problem after station 13 (30.08S, 155.49E), and the LADCP operated well for the rest the cruise. Readjustments of the downward facing LADCP unit (150 KHz), mounted on the bottom of the rosette, were necessary throughout the cruise because the unit kept slipping downward within its bracket, but the slipping did not compromise the LADCP operations.

First problems with Niskin bottles not closing and mistrips occurred at station 6 (30.08°S, 153.84°E; 1985m). By station 12 (30.08°S, 155.00°E; 4707m), seven bottles stayed open despite confirmation on the console that they had been fired. Even though there were no obvious signs of leaking or deterioration within the pylon’s solenoids, the carousel was exchanged against SIO’s new 36-place pylon (that was meant for the new rosette, but did not arrive in time for assembly) right after station 12. The new carousel functioned pretty much flawlessly for the remainder of the cruise.

On departure from station 12, the first float of leg 1, a UW Argo float was deployed, followed by several more floats and drifters throughout the cruise.

The cruise track diverted slightly to the south for station 26 (30.33°S, 158.08°S) to maintain sufficient distance to the Elizabeth Reef. After that, stations continued along 30.08°S.

Within the South Fiji Basin, after station 76 at 30.08°S, 176.50°E, the cruise track deflected to the southeast, until station 82 at 32.50°S, 178.91°E. From station 82 onward, the cruise track continued straight eastward again along the 32.50°S latitude band. This change in latitude from 30.08°S to 32.50°S occurs on all P06 occupations and is dictated by moored current meter arrays that were deployed during the time of WOCE, just poleward of 30°S within the East Australia Current (off Australia) and along 32.50°S within the deep western boundary current (DWBC) region, east of the Tonga Kermadec Ridge (TKR, ~179°W) (WOCE PCM9 array). One of the goals of the P06 WOCE occupation in 1992 was to perform hydrographic surveys along these arrays.

Within the South Fiji Basin, we also encountered the first seriously bad weather that interrupted operations on 20 July,

after station 76. Wind gusts of >50 knots meant that the NBP could not hold station. Station 77 (30.53°S, 176.94°E) could not be deployed until the next day (21 July) in the afternoon. After that, operations were stopped again through the night. By the morning of 22 July, waves were even higher. We were also informed that a medevac was necessary for one of the ECO crew members. What followed was a bumpy ride to New Zealand, with wave heights at 6–8m and some even bigger rollers, and evacuation of the ill seaman by helicopter, about 100nm north of New Zealand. By 10:00am on 23 July, we were back on our way to the South Fiji Basin. Station 78 at 30.98°S, 177.40°E was finally occupied at 6am on 24 July. A total of ~3.5 days of station time had been lost due to weather and medevac at this point.

With several days of delay, we crossed the Lau Basin on 25 July, including the International Dateline at ~11:30pm. The corresponding set-back of clocks by a day gave us the opportunity to enjoy a “full 48 hours of Tuesday, July 25” (the Captain’s words).

After the Lau Basin and the adjacent TKR (to the east), followed the crossing of the DWBC and its recirculation between the TKR and Louisville Seamount Chain at ~188.2°W. The eastern flank of the TKR descends into the Kermadec Trench where the deepest stations of P06, leg 1 were encountered. With a maximum depth of 10,047m, the Kermadec Trench is known as one of the deepest ocean trenches in the world. At stations 93 (32.50°S, 177.67°W) and 94 (32.50S, 176.75W), the trench stations, bottom depth readings from the Knudsen exceeded 7000m. The CTD rosette, however, was only lowered to 6000m depth, because of some of the sensor’s pressure ratings.

On the weekend of 20–30 July, just before and during the crossing of the Louisville Seamount Chain, the weather turned rougher again. Operations did not have to be stopped, but wire tension readings were pretty low (double digits) during the descent of the rosette on several stations, despite reduced wire speeds. A kink was noticed in the wire upon recovery at station 106 (32.50°S, 171.12°W). The wire (no loose strands) and the electronic transmissions were still intact. However, with more than 100 stations completed, it was about time to re-terminate anyway, and thus it was decided to perform a re-termination. It took about 4 hours, a little bit longer than usual, because new technicians, some staying on for leg 2, were being trained on the procedures. With the stations across the Louisville Seamount Chain pretty close together (8–17nm), the measurements groups were thankful for the little bit of extra time due to the re-termination to catch up on samples.

To the east of the Louisville Seamount Chain began the still very deep (5000-6000m), but flatter stretch of the Southwest Pacific Basin. A particular deep fracture zone was encountered at station 119 (32.50°S, 165.16°W; 6364m) where elevated CFC concentrations had been observed on past cruises and were also found on 2017 P06, leg 1. Because of the time lost earlier in the cruise, it was unfortunately not possible to reduce station spacing around this fracture zone, as originally planned.

Bad weather caught up with us again on the evening of 3 August, just after some smooth sailing, reminding us that it was the height of winter in the southern hemisphere after all. A particularly persistent low pressure system hovered to the east of us for pretty much the next four days. Wind speeds gusted >40 knots some of the time, but it was mostly the big and often confused swells that provided problems. Sea states were continuously examined by scientists and ASC staff, and whenever the waves looked reasonable, the CTD rosette was deployed. Two casts had to be aborted and retried later because of continuously low wire tensions and large spikes on the downcast (at station 121, 32.50°S, 163.83°W, and station 126, 32.50°S, 160.46°W). Two more small kinks appeared in the wire after stations 123 and 126, luckily at a safe distance from each other (more than 100 wire diameters). After thorough examination, neither kink was deemed serious enough to warrant another re-termination right away.

During the four days of the storm, only seven stations could be completed (121–127), resulting in about two more days of station time lost due to weather. The option of doing stations slowly, however, was still more efficient than trying to steam eastward past the (large) low pressure system and doing stations in reverse order, as sometimes it is done to escape storms.

On 8 August, operations were back to normal, although wire speeds on the down casts often still had to be kept very low (20m/min until 1000-1500m). During the last five days of station work on p06, leg 1, the last SOCCOM float and the last Deep SOLO float, as well as several drifters, were deployed. The last station, station #143 at 32.50°S, 148.91°W, was completed on 13 August early in the morning (5:15am), followed by the last float, a UW Argo float. A “drop dead” time of 5:00am had been given to us by the Captain. Thus, another station, as hoped for to put less burden of leg 1 stations onto leg 2 (4 instead of 5 stations from original station plan), was unfortunately not possible.



While there were a lot of delays on this cruise due to weather and the medevac, with a total of about 5.5 days of station time lost, we were happy that we could nevertheless make it just past the longitude of Tahiti ( $\sim 150^{\circ}\text{W}$ ), our port call between legs 1 and 2. Station spacing at the end of leg 2 was 33.9nm, only slightly up from the 30nm in the original plan.

There were also some things that went remarkably well and that helped make up time on P06W. The winch in the Baltic room performed pretty much flawlessly, even with 49 of the 143 stations at depths  $>5000\text{m}$ , allowing for fast station times when the weather was good. There were no communication/data transfer problems with the CTD package, and the new SIO 36-place carousel, once installed, also operated without any further bottle-closing issues. Station positioning, despite the large size of the ship, was pretty speedy most of the time and within the 0.1-minute accuracy (in lat/lon) we had asked from the bridge. The steam speed of the NBP was somewhat faster ( $>9$  knots) than planned for which also helped.

In general, station spacing on p06, leg 1 varied between 2.1nm and 38.8nm. 109 stations were at a distance of less than 30nm from the prior station because the cruise crossed a lot of “interesting topography” (a quote from the chief scientist, often repeated on the cruise) that required tight station spacing. For the remaining 34 stations, a spacing of 30nm, the typically desired distance between stations on GO-SHIP cruises, or more was used. To make up for time lost due to weather/medevac, station spacing was increased beyond 30nm over flat topography for a few stations in the South Fiji Basin ( $\sim 36\text{nm}$ ; stations 78–80) and in the Southwest Pacific Basin to the east of  $169^{\circ}\text{W}$  for all but one station (stations 114–129, 131–143). In the latter case, the typical spacing was around 34nm. A few stations (stations 127–129) had significantly larger spacing ( $\sim 38\text{nm}$ ), matching the location of three WOCE stations here. An attempt was generally made to match up the 2017 p06 stations with either WOCE or CLIVAR 2009 stations unless the spacing during those earlier programs seemed too large (e.g. east of  $158^{\circ}\text{W}$ ). Particular attention was given to the DWBC region between the TKR and Louisville Seamount Chain and a couple of degrees to the east of the seamounts (stations 88–112), where the WOCE PCM9 current meter array had been located. Station locations here were kept the same as during WOCE/CLIVAR 2009 except for one station that was added on the western flank of the Louisville Seamount chain (station 105,  $32.50^{\circ}\text{S}$ ,  $172.09^{\circ}\text{E}$ ) and two stations further to the west (station 101,  $32.50^{\circ}\text{S}$ ,  $173.86^{\circ}\text{E}$ , and station 102,  $32.50^{\circ}\text{S}$ ,  $173.38^{\circ}\text{E}$ ) that were rearranged to obtain more regular station spacing here.

Leg 1 ended in Papeete, Tahiti ( $\sim 17.5^{\circ}\text{S}$ ,  $149.6^{\circ}\text{E}$ ) after an about 960m steam from the last station on the  $32.50\text{S}$  transect. The ship arrived early on 17 August, 2017, meeting the pilot boat at about 5:00am and clearing customs by 8:00am. A meeting with the chief and co-chief scientists of leg 2, Kevin Speer and Lena Schulze, had been arranged for 10:00am to hand over all important leg 1 information. After 46 days at sea, we were then able to set foot on land again, to gather for a post-cruise party at the Three Brothers pub, and to explore Tahiti.

## 2.3 Preliminary results

We find that the preliminary salinity and oxygen data collected and processed by ODF show the typical signatures of Antarctic Bottom Water (AABW; low salinity, high oxygen) and Circumpolar Deep Water (CDW; higher salinity, lower oxygen), that have been observed in the DWBC and the adjacent basin on prior P06 occupations. There is a strong CFC signal associated with the DWBC, showing an increase in concentrations compared to 2009. We also observed the typical characteristics of the water masses of the upper ocean, in particular Subantarctic Mode Water (SAMW; low stratification) at about 750m and Antarctic Intermediate Water (AAIW; low salinity) at about 1000m depth. Changes in both bottom/deep water properties and thermocline/intermediate water properties were looked at on board during the cruise and will be the subject of future investigations.

## 2.4 Acknowledgments

There are many thanks to give for a successful completion of P06, leg 1. Jim Swift, Lynne Talley, and Alison Macdonald were essential in organizing the cruise. The GO-SHIP exec committee and PIs gave advice when needed. ODF, under the lead of Susan Becker, provided the brand new rosette and related equipment, and made sure everything was

working well on board. We are grateful for the funding provided by NSF and NOAA for the GO-SHIP program. Pre-cruise planning was done in collaboration with ASC (Adam Jenkins and Brad Fabling) who were enjoyable to work with. ASC was also responsible for marine operations while at sea, and we appreciate all the professional support we received from the ASC techs, in particular with the deployment and recovery of the rosette. ECO did a great job of keeping the ship running. Meetings with Captain Brandon Bell (ECO) and Marine Projects Coordinator Eric Hutt (ASC) every day at 12:30pm on the bridge to discuss weather and day-to-day operations were fun and productive. All scientists on board worked extremely hard, kept spirits high, and were great to be with. Much thanks to all!



## CTDO AND HYDROGRAPHIC ANALYSIS

### PIs

- Susan Becker
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### Technicians

- Joseph Gum

### 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. SBE SeaSave7 v.7.26.1.8 software was used for data acquisition and to close bottles on the rosette.

CTD deployments were initiated by the console watch operators (CWO) 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 sensor pumps were configured to start 10 seconds after the primary conductivity cell reports salt water in the cell. The CWO checked the CTD data for proper sensor operation, waited for sensors to stabilize, and instructed the winch operator to bring the package to the surface in good weather or no more than 5 meters 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 CWO 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 multi-beam depth were all monitored to determine the distance of the package from the bottom. The winch was directed to slow decent rate to 40m/min 100m from the bottom and 20m/min 30m from the bottom. The bottom of the CTD cast was usually to within 10-20 meters of the bottom determined by 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 CWO 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 averaged from 14 samples.

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

Additionally, the watch created a sample log for the deployment which would be later used to record the depths bottles were tripped and correspondence between rosette bottles and analytical samples drawn.

Normally the CTD sensors were rinsed after each station using a fresh water tap connected to Tygon tubing. The tubing was left on the CTD between casts, with the temperature and conductivity sensors immersed in fresh water.

Each bottle on the rosette had a unique serial number, independent of the bottle position on the rosette. Sampling for specific programs were 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 CTD Data Processing

Shipboard CTD data processing was performed after deployment using SIO/ODF python CTD processing software v. 0.1. CTD acquisition data were copied onto a OS X system, and then processed. 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 after corrections outlined in the following sections were applied.

A total of 144 CTD stations were occupied including one test station. A total of 150 CTDO/rosette/LADCP/chipod casts were completed. 144 standard CTDO/rosette/LADCP/chipod casts and one test cast completed with a single 36-place (CTD #1281) rosette was used for all station/casts.

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<sub>2</sub> 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 P06W-2017 that directly impacted CTD analysis. Issues that directly impacted bottle closures, such as slipping guide rings, were detailed in the Underwater Sampling Package section of this report. Temperature, conductivity and oxygen analytical sensor issues are detailed in the following respective sections.

## 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: 831-99677 was calibrated on November 17th, 2015 at the SIO Calibration Facility. The lab calibration coefficients provided on the calibration 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 converted pressures during each cast. These offsets were determined by the pre and post-cast on-deck pressure offsets. The pressure offsets were applied per configuration cast sets.

- CTD Serial 1281-99677; Station Set 1 - 143

	Start P (dbar)	End P (dbar)
Min	0.0	-0.1
Max	0.3	0.2
Average	0.2	0.1
Applied Offset		0.1081

An offset of 0.1081 was applied to every cast performed by CTD 1281. On-deck pressure reading for CTD 831 varied from 0.0 to 0.3 dbar before the casts, and -0.1 to 0.2 dbar after the casts. Before and after average difference was 0.2 and 0.1 dbar respectively. The overall average offset before and after cast was 0.1081 dbar.



### 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 ITS-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. The SBE35RT is triggered by the SBE32 carousel in response to a bottle closure. According to the manufacturer's specifications, the typical stability is 0.001°C/year. The SBE35RT was set to internally average over a 15 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 the following figures.

The 95% confidence limits for the mean low-gradient (values  $-0.002^\circ\text{C} \leq T_1 - T_2 \leq 0.002^\circ\text{C}$ ) differences are  $\pm 0.0068^\circ\text{C}$  for SBE35RT-T1,  $\pm 0.0067^\circ\text{C}$  for SBE35RT-T2 and  $\pm 0.0042^\circ\text{C}$  for T1-T2. The 95% confidence limits for the deep temperature residuals (where pressure  $\geq 2000\text{dbar}$ ) are  $\pm 0.00086^\circ\text{C}$  for SBE35RT-T1,  $\pm 0.0010^\circ\text{C}$  for SBE35RT-T2 and  $\pm 0.0008^\circ\text{C}$  for T1-T2.

#### Minor complications impacted the temperature sensor data used for the P06W cruise.

- The SBE35RT was unconfigured at the beginning and set to average and record one sample (one second) per trip.
- This was noticed and fixed to average 14 samples (15 seconds) before station 19.
- The SBE35RT sensor data was not uploaded before cast for stations 7 and 8, with no data reported for those casts.
- The SBE35RT sensor memory was partially full, and there are partial data reported for casts on stations 6 and 12.
- Storms caused tripping on the fly in the upper 100 meters on many stations, leading to some surface SBE35RT averaging periods out of the water.

The resulting affected sections of data have been coded and documented in the quality code APPENDIX.

### 3.5 Conductivity Analysis

Laboratory calibrations of conductivity 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 SBE4C frequencies to mS/cm conductivity values. Additional ship-board calibrations were performed to correct sensor bias. Corrections for both pressure and

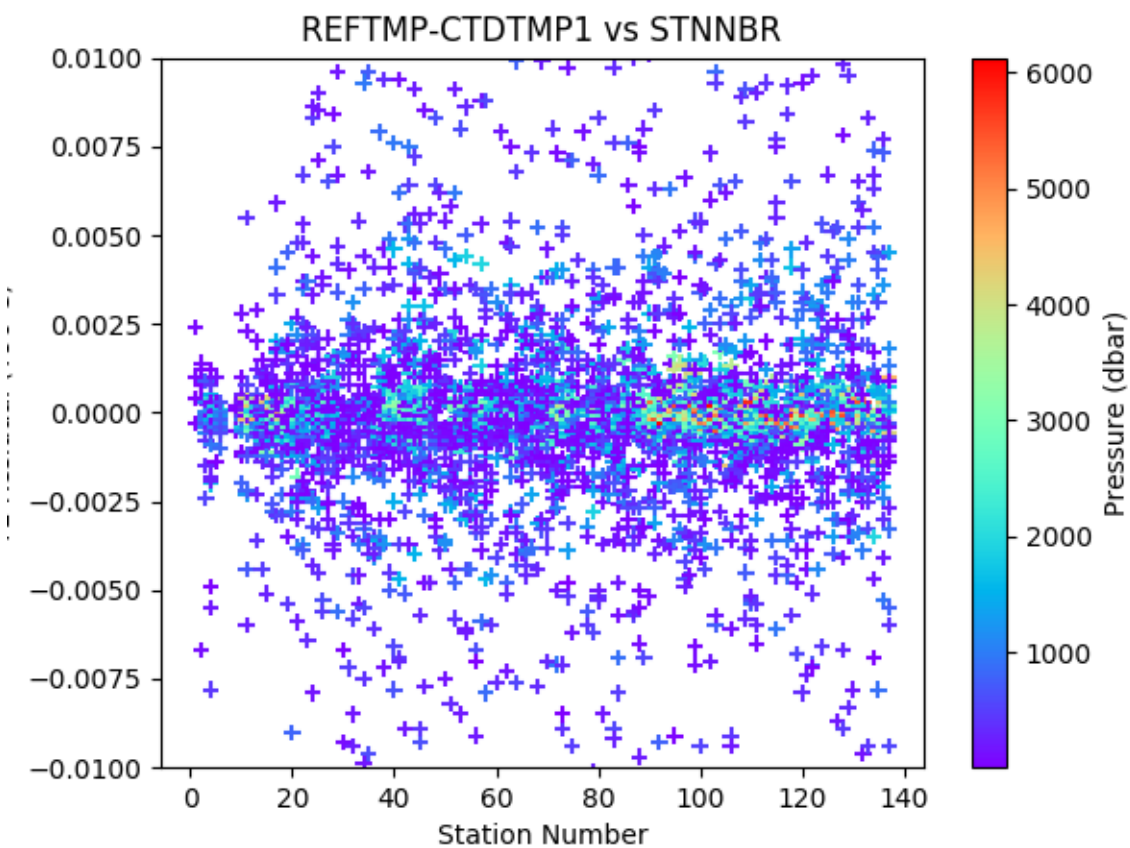


Fig. 3.1: SBE35RT-T1 by station ( $-0.002^{\circ}\text{C} \leq T1-T2 \leq 0.002^{\circ}\text{C}$ ).

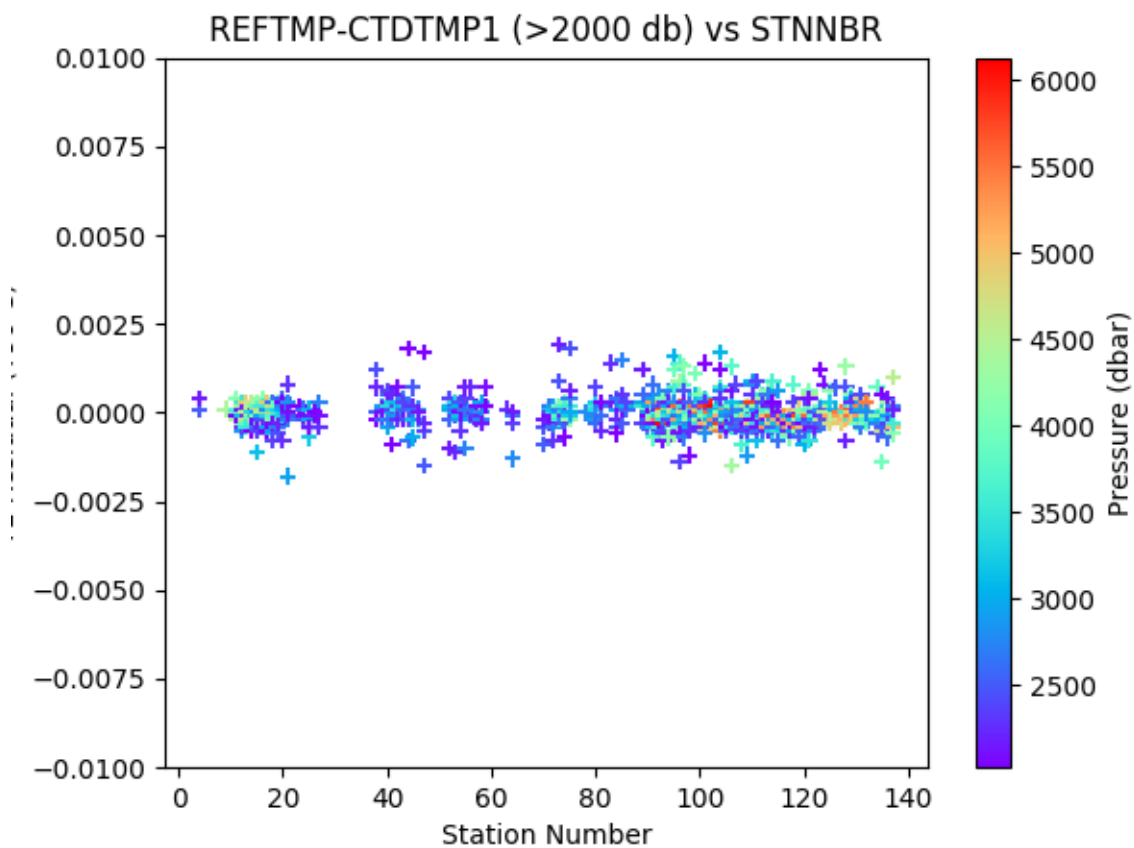


Fig. 3.2: Deep SBE35RT-T1 by station (Pressure  $\geq 2000$ dbar).

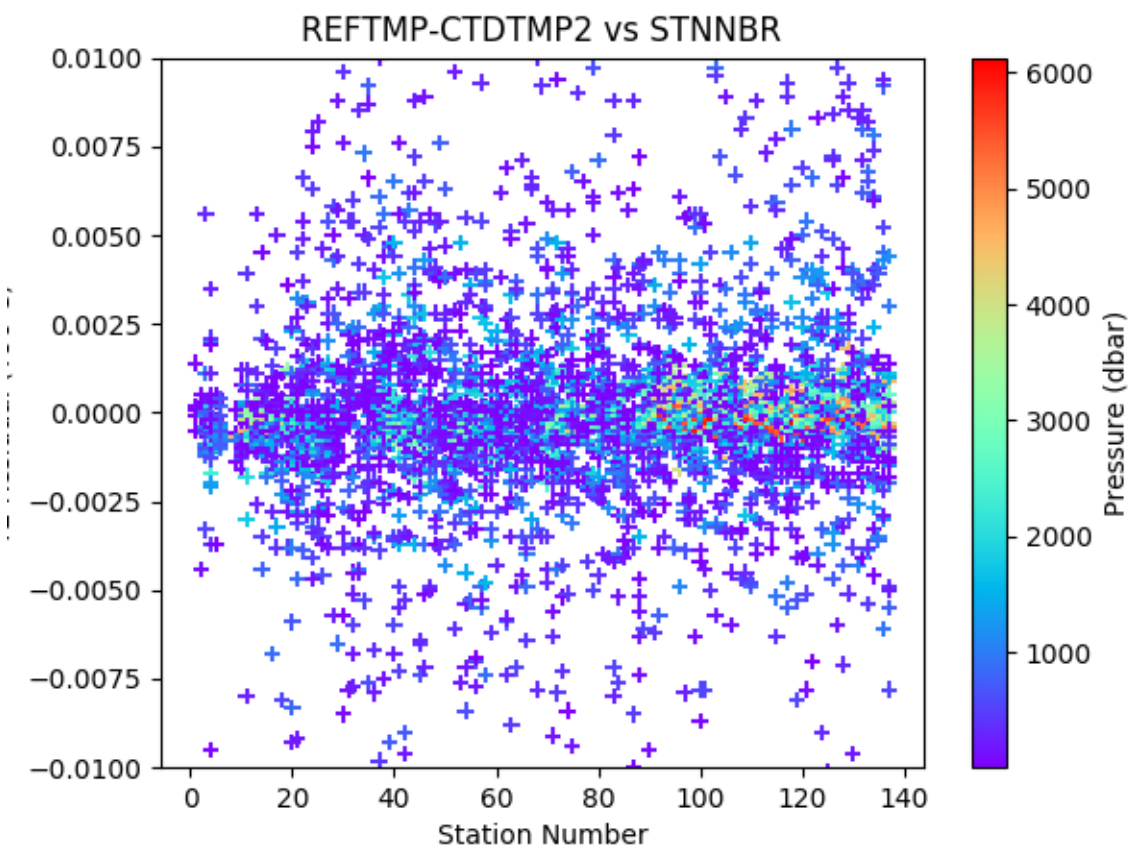


Fig. 3.3: SBE35RT-T2 by station ( $-0.002^{\circ}\text{C} \leq T1-T2 \leq 0.002^{\circ}\text{C}$ ).

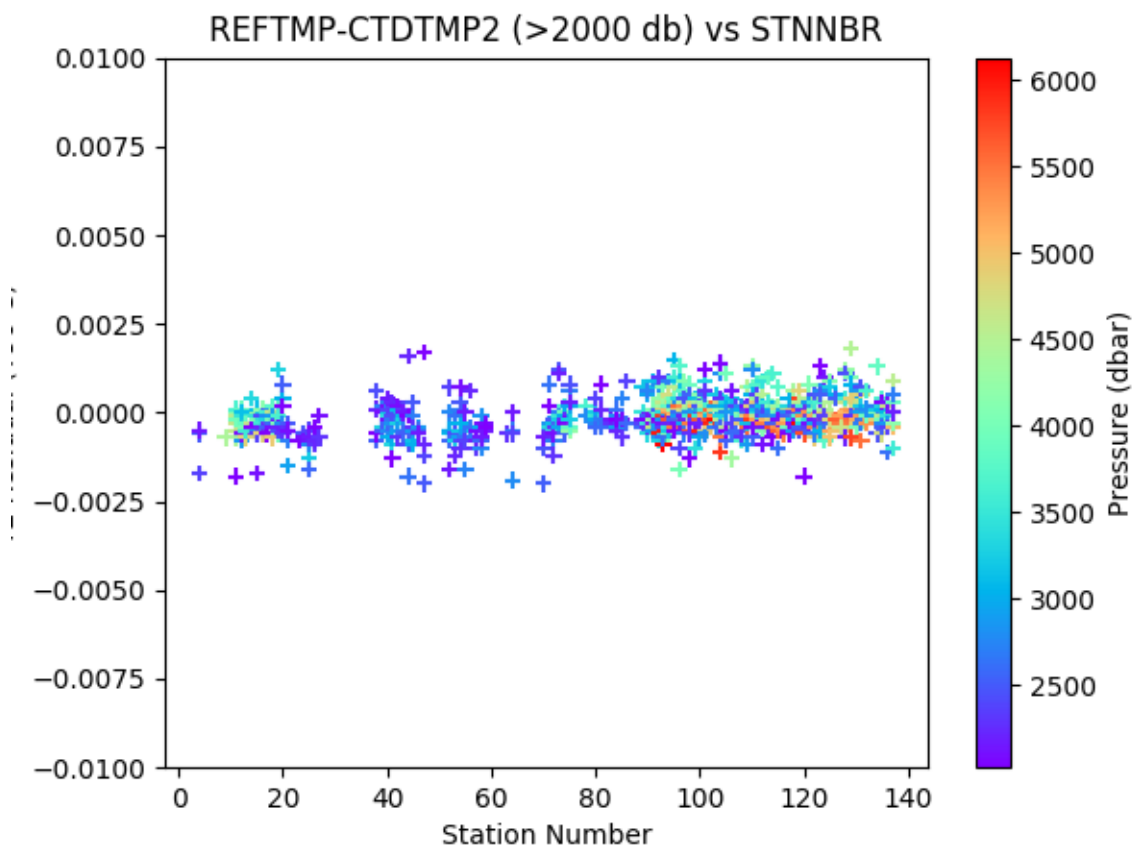


Fig. 3.4: Deep SBE35RT-T2 by station (Pressure  $\geq 2000$ dbar).

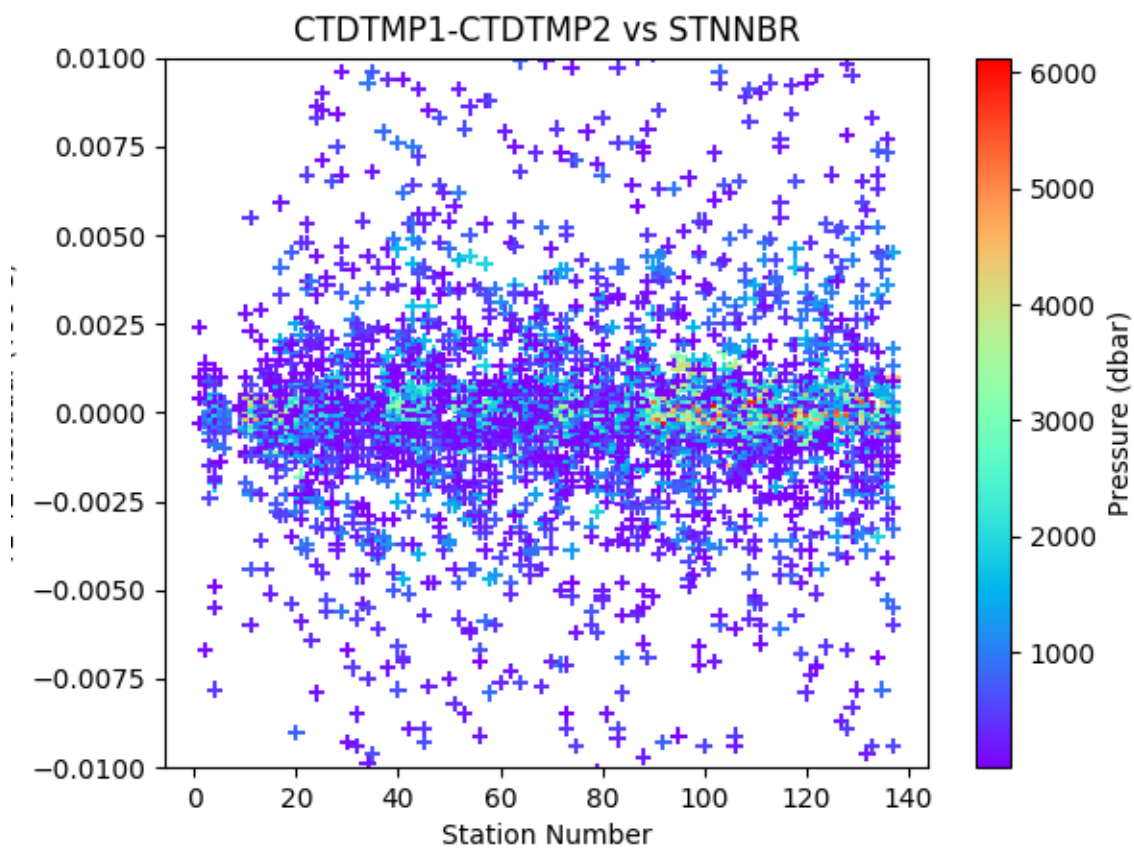


Fig. 3.5: T1-T2 by station ( $-0.002^{\circ}\text{C} \leq \text{T1-T2} \leq 0.002^{\circ}\text{C}$ ).

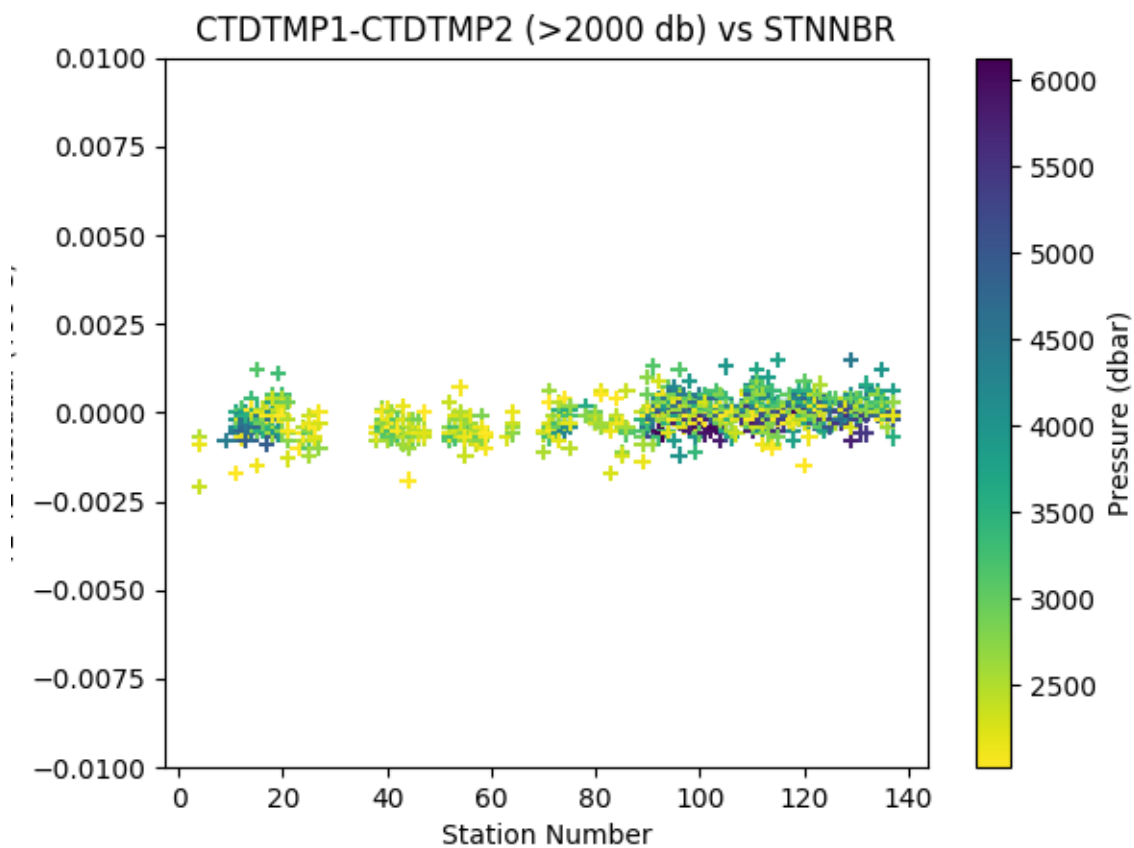


Fig. 3.6: Deep T1-T2 by station (Pressure  $\geq 2000$ dbar).

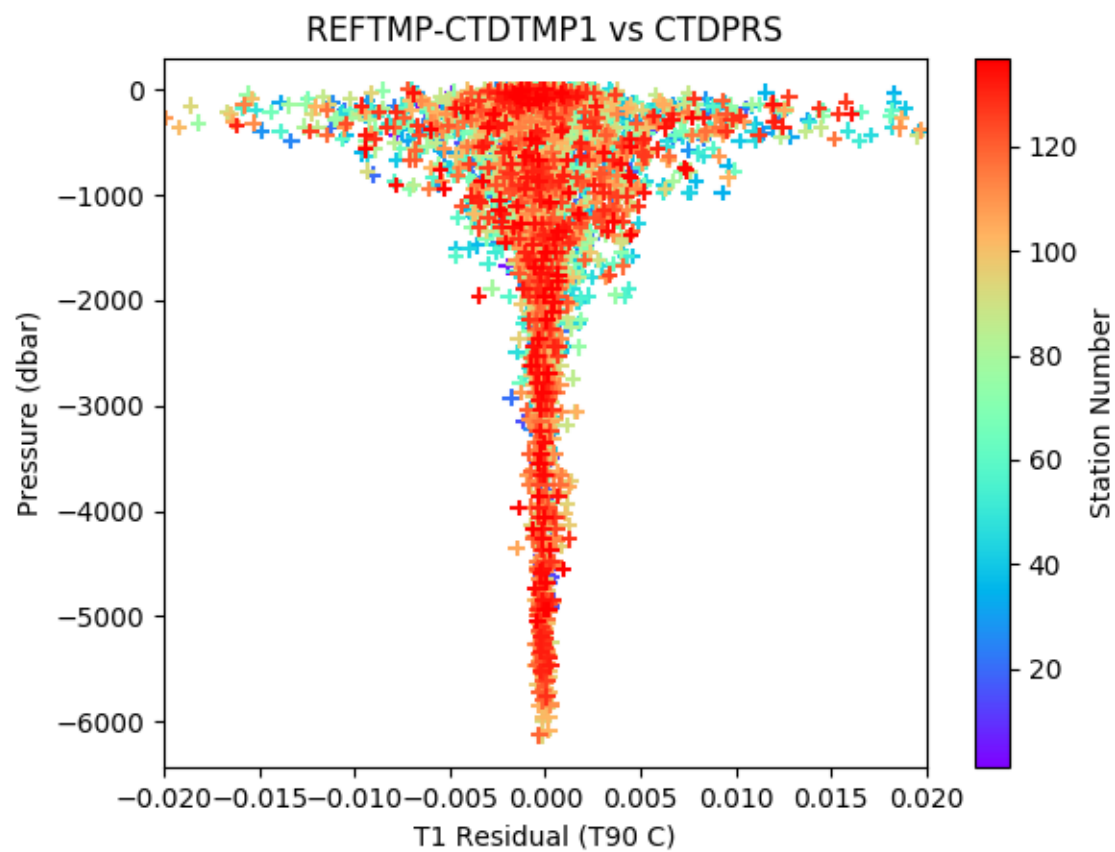


Fig. 3.7: SBE35RT-T1 by pressure ( $-0.002^{\circ}\text{C} \leq T1-T2 \leq 0.002^{\circ}\text{C}$ ).



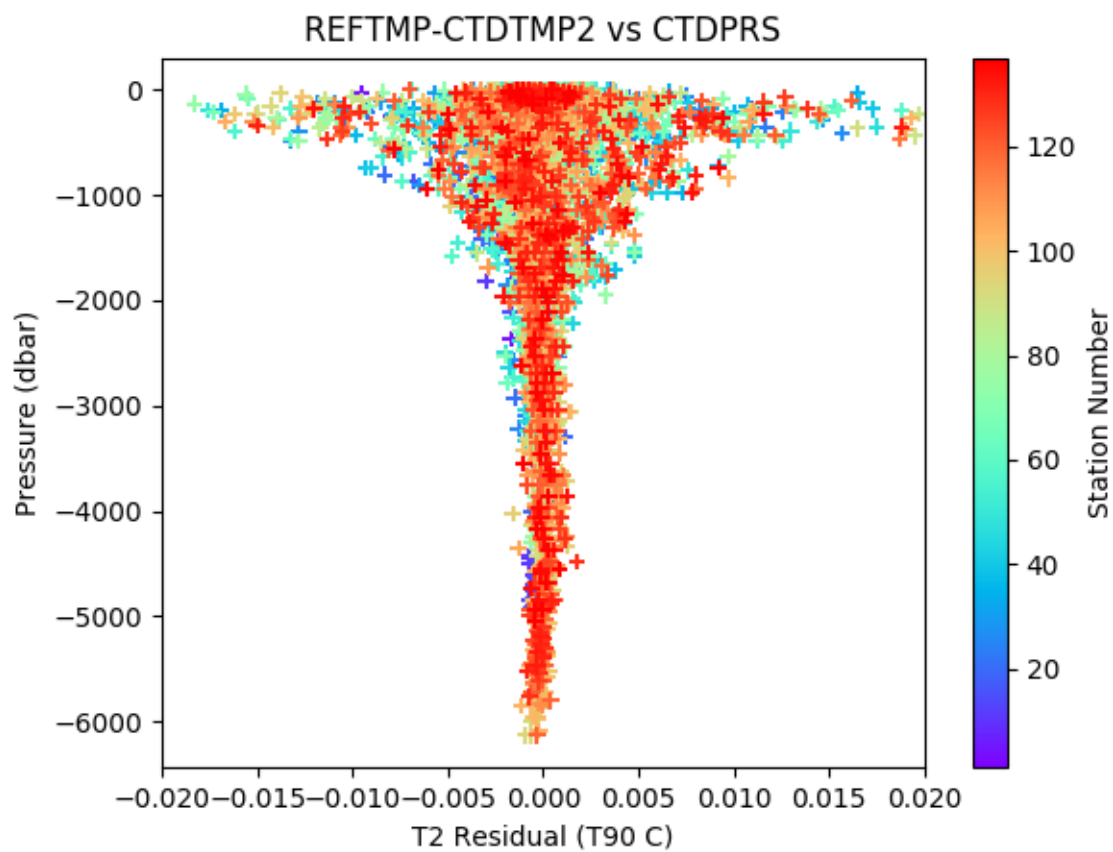


Fig. 3.8: SBE35RT-T2 by pressure ( $-0.002^{\circ}\text{C} \leq T1-T2 \leq 0.002^{\circ}\text{C}$ ).

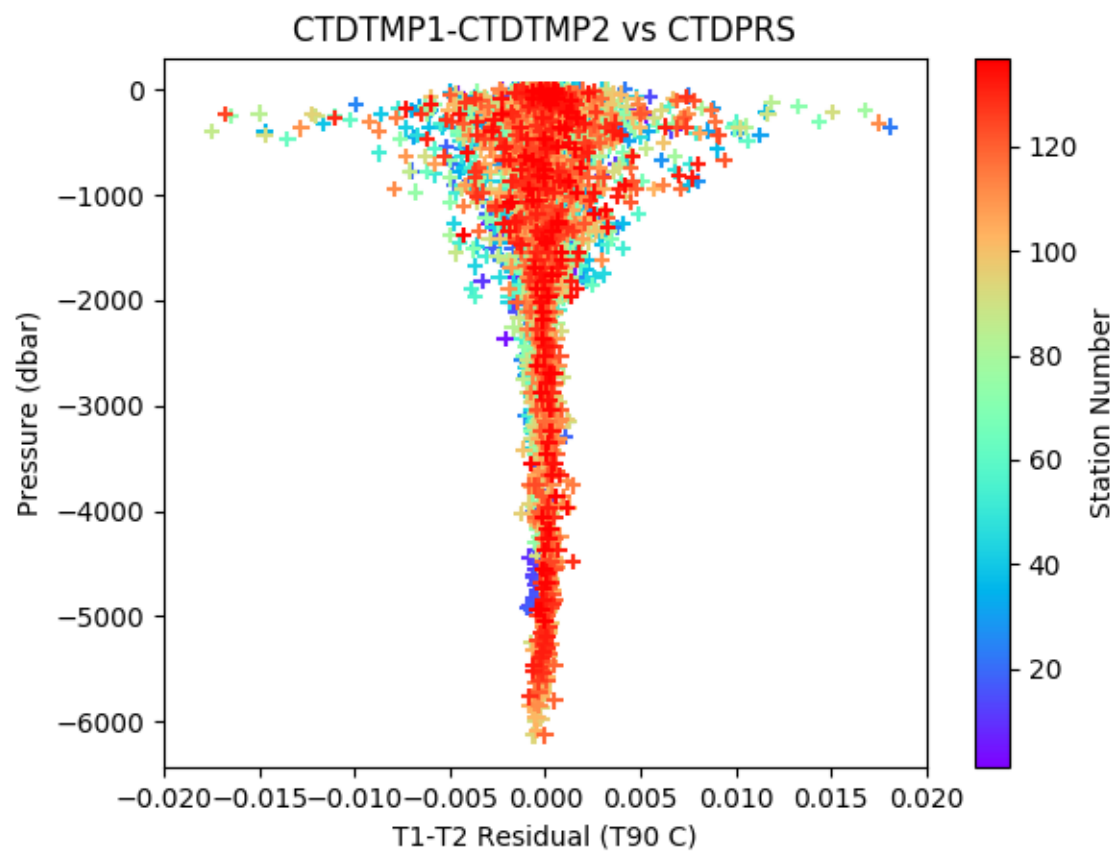


Fig. 3.9: T1-T2 by pressure ( $-0.002^{\circ}\text{C} \leq \text{T1-T2} \leq 0.002^{\circ}\text{C}$ ).

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.

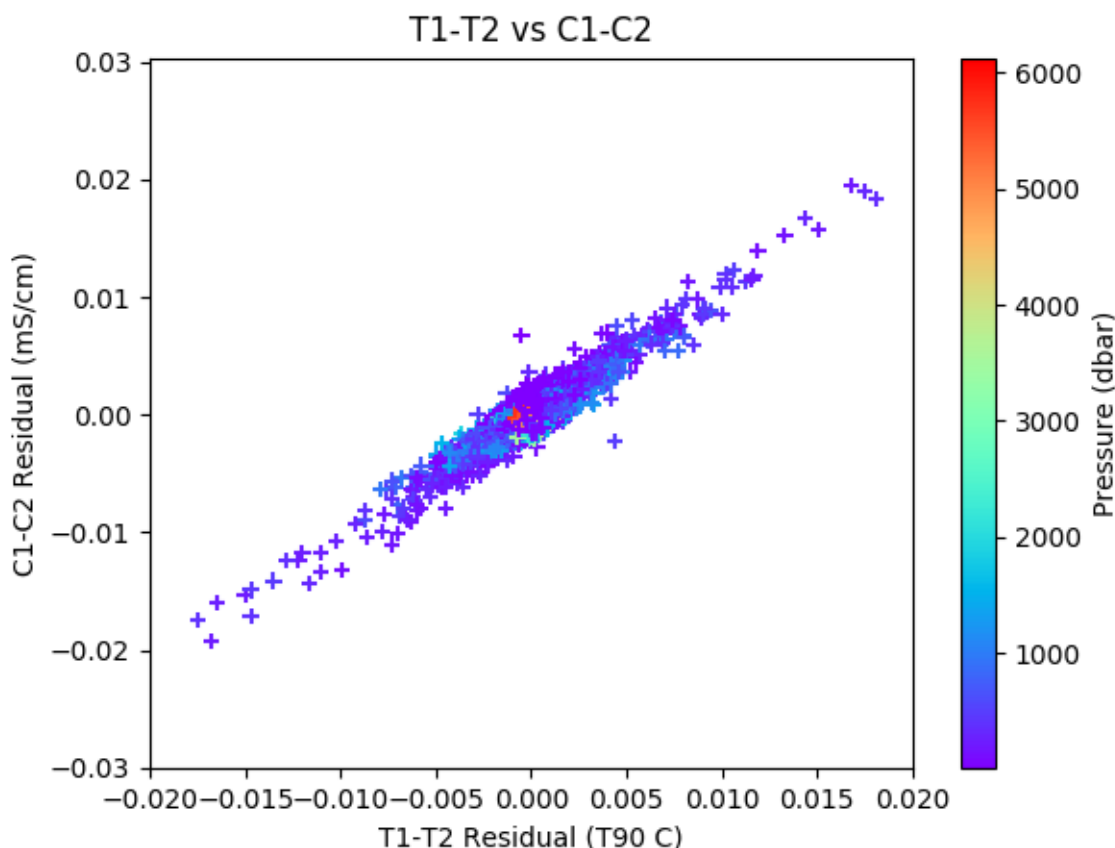


Fig. 3.10: Coherence of conductivity differences as a function of temperature differences.

Uncorrected conductivity comparisons are shown in figures *Uncorrected CBottle - C1 by station* ( $-0.002 \text{ mS/cm}$  *BTLCOND-C1*  $0.002 \text{ mS/cm}$ ), through *Uncorrected C1-C2 by station* ( $-0.002 \text{ mS/cm}$  *C1-C2*  $0.002 \text{ mS/cm}$ ).

The residual conductivity differences after correction are shown in figures *Corrected CBottle - C1 by station* ( $-0.002 \text{ mS/cm}$  *BTLCOND-C1*  $0.002 \text{ mS/cm}$ ), through *Corrected C1-C2 by conductivity* ( $-0.002 \text{ mS/cm}$  *C1-C2*  $0.002 \text{ mS/cm}$ ).

A functioning SBE4C sensor typically exhibit a predictable modeled response. Offsets for each C sensor were determined using  $C_{\text{Bottle}} - C_{\text{CTD}}$  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, second order with respect to temperature, second order with respect to conductivity and a first order with respect to time. The functions used to apply shipboard calibrations are as follows.

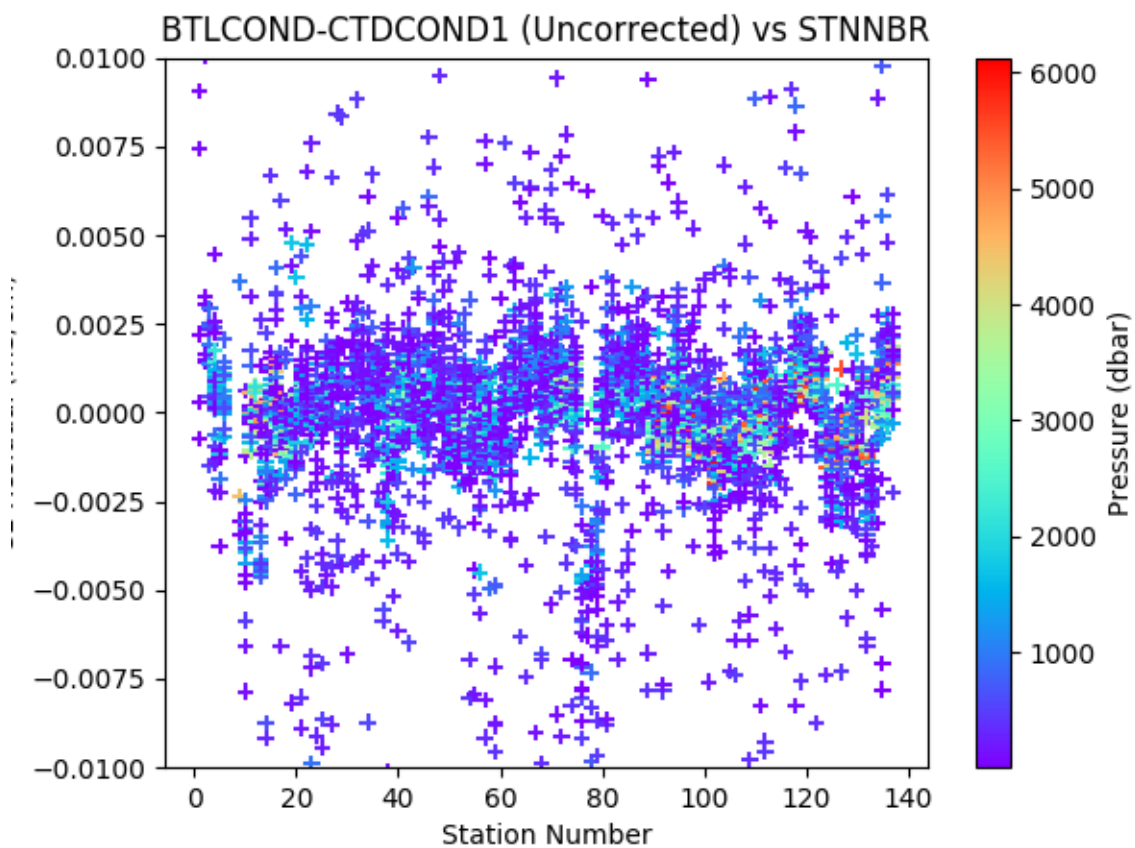


Fig. 3.11: Uncorrected  $C_{\text{Bottle}} - C_1$  by station ( $-0.002 \text{ mS/cm} \leq \text{BTLCOND}-C_1 \leq 0.002 \text{ mS/cm}$ ).

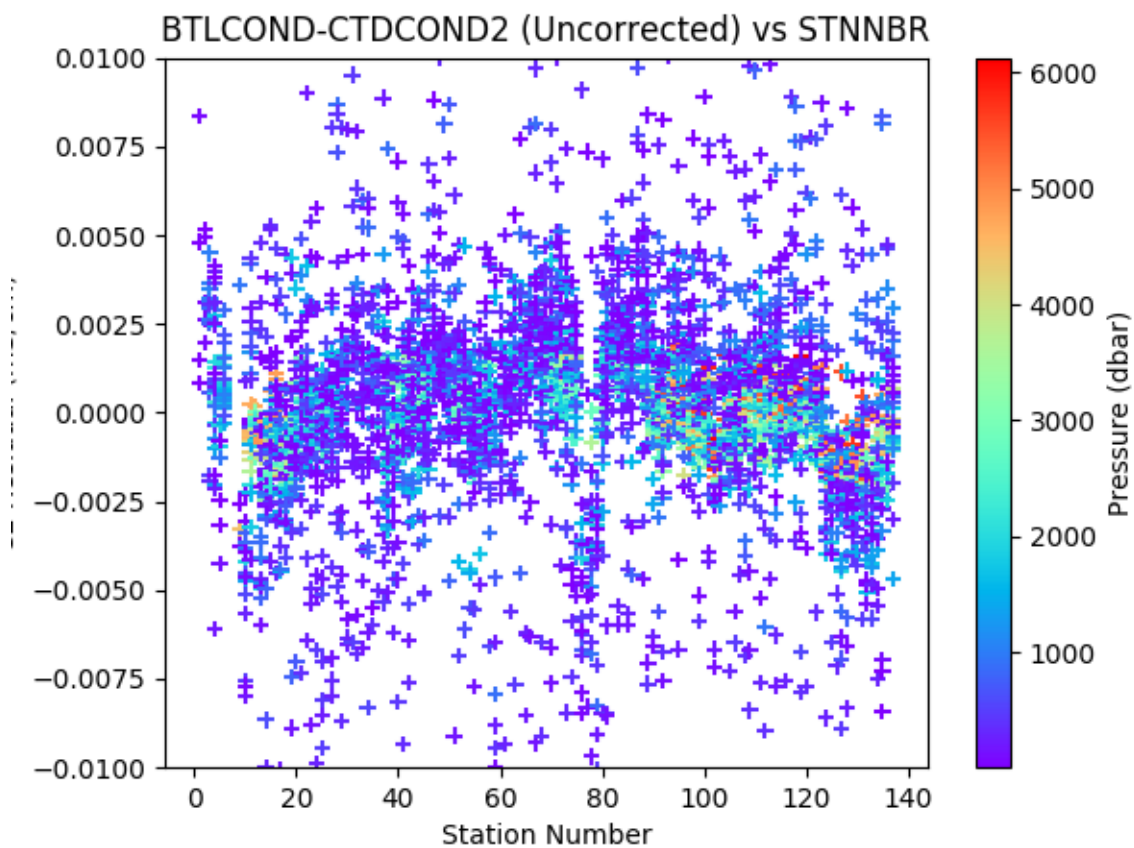


Fig. 3.12: Uncorrected  $C_{\text{Bottle}} - C_2$  by station ( $-0.002 \text{ mS/cm} \leq \text{BTLCOND}-C_2 \leq 0.002 \text{ mS/cm}$ ).

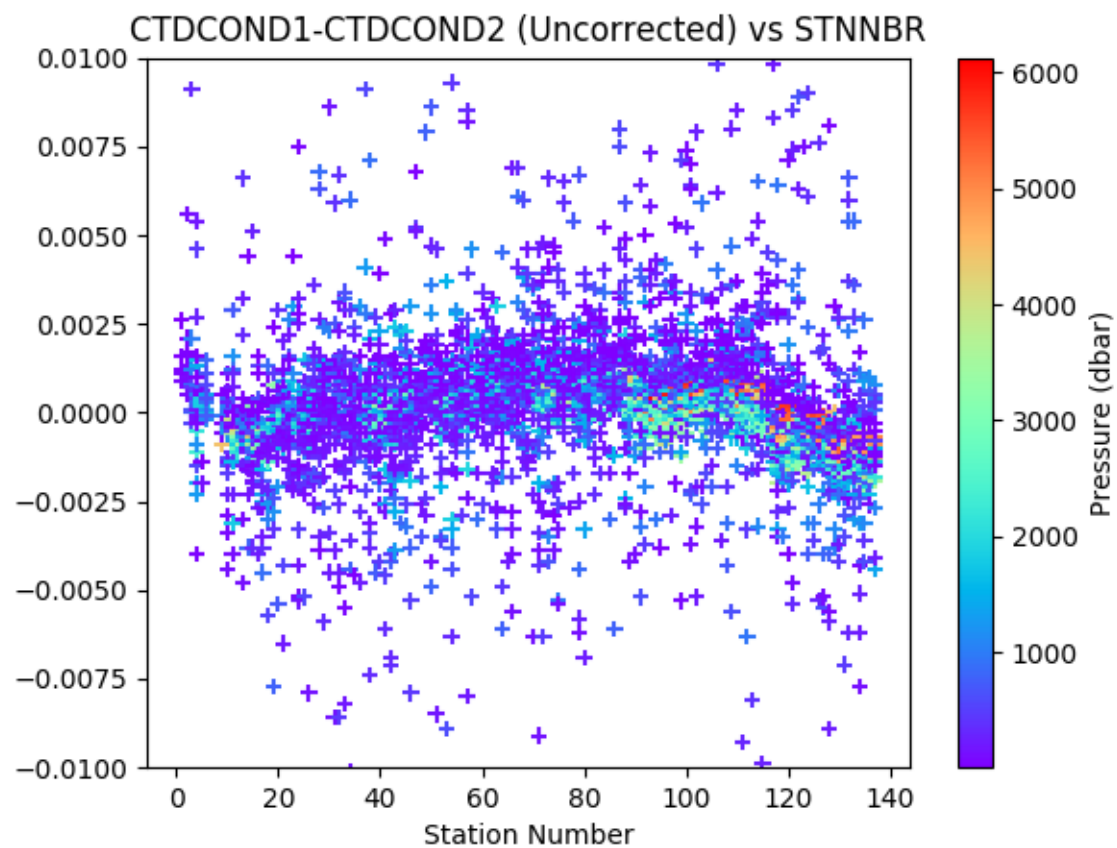


Fig. 3.13: Uncorrected C1-C2 by station ( $-0.002 \text{ mS/cm} \leq \text{C1-C2} \leq 0.002 \text{ mS/cm}$ ).

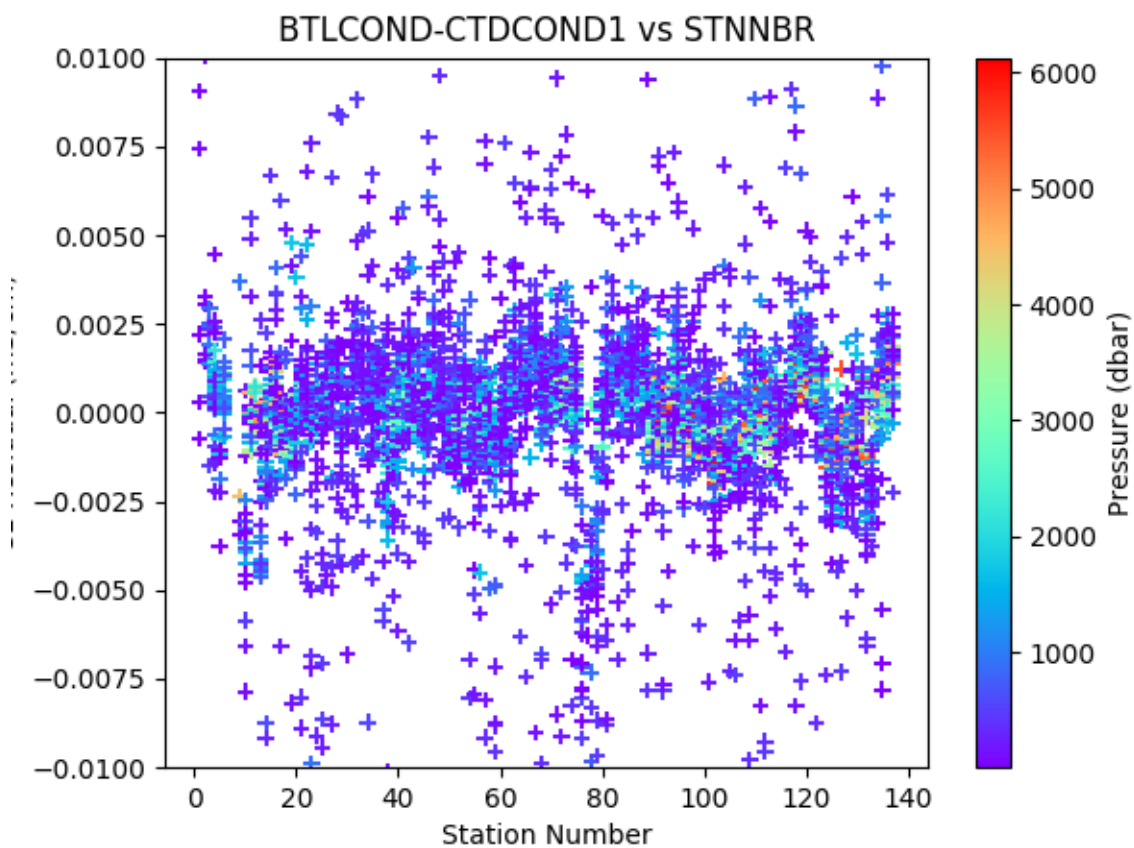


Fig. 3.14: Corrected  $C_{\text{Bottle}} - C_1$  by station ( $-0.002 \text{ mS/cm} \leq \text{BTLCOND}-C_1 \leq 0.002 \text{ mS/cm}$ ).

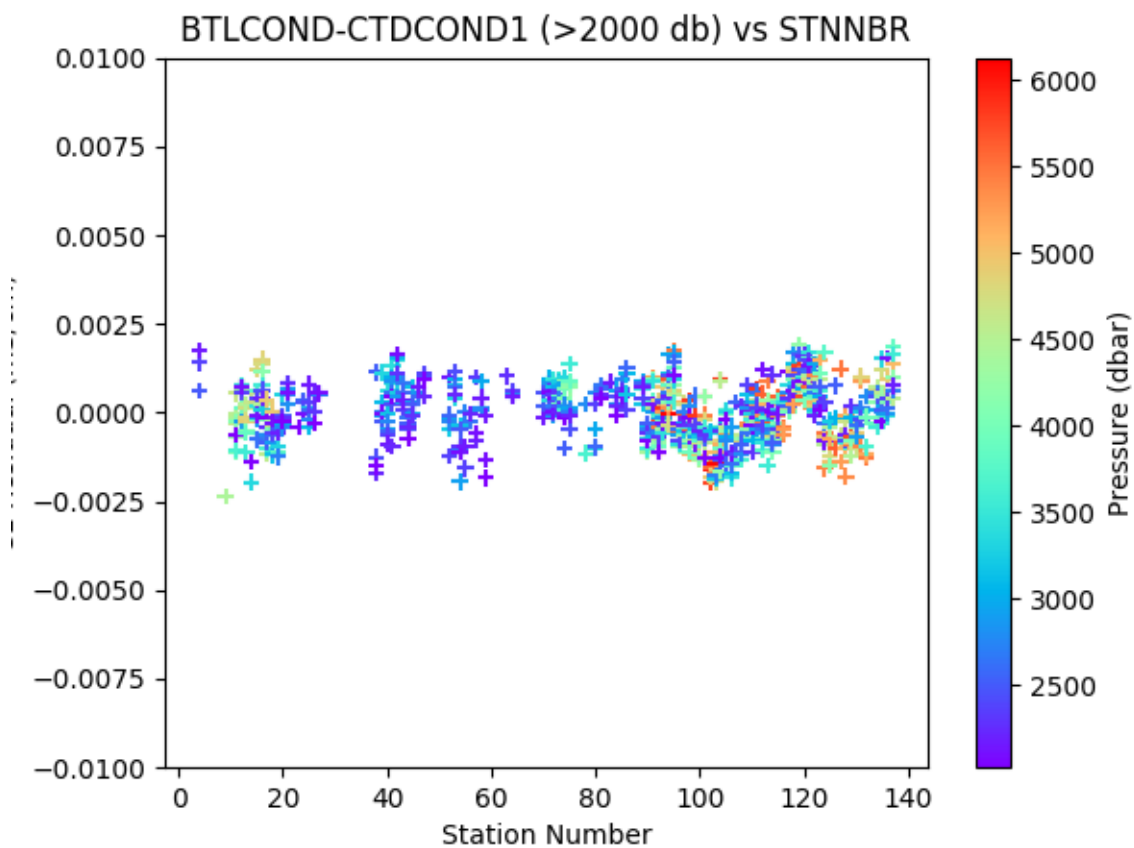


Fig. 3.15: Deep Corrected  $C_{\text{Bottle}} - C1$  by station (Pressure  $\geq 2000$ dbar).



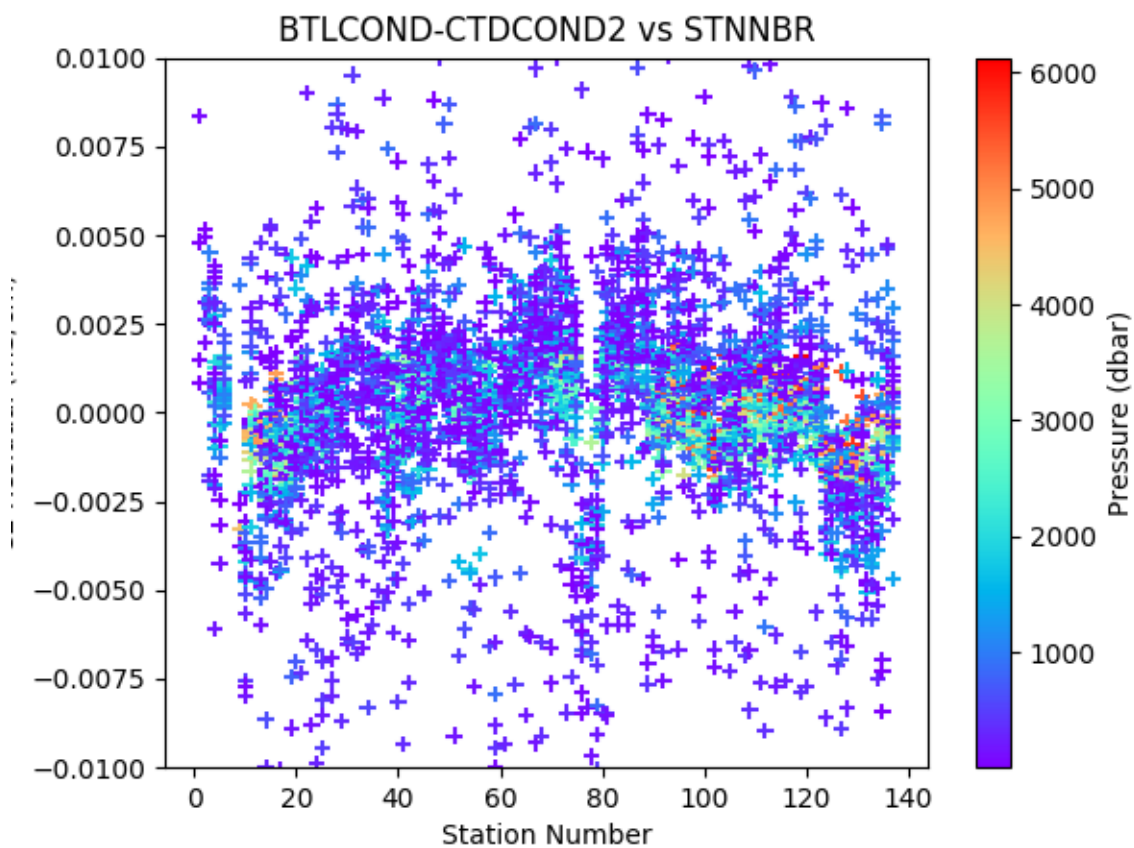


Fig. 3.16: Corrected  $C_{\text{Bottle}} - C_2$  by station ( $-0.002 \text{ mS/cm} \leq \text{BTLCOND}-C_2 \leq 0.002 \text{ mS/cm}$ ).

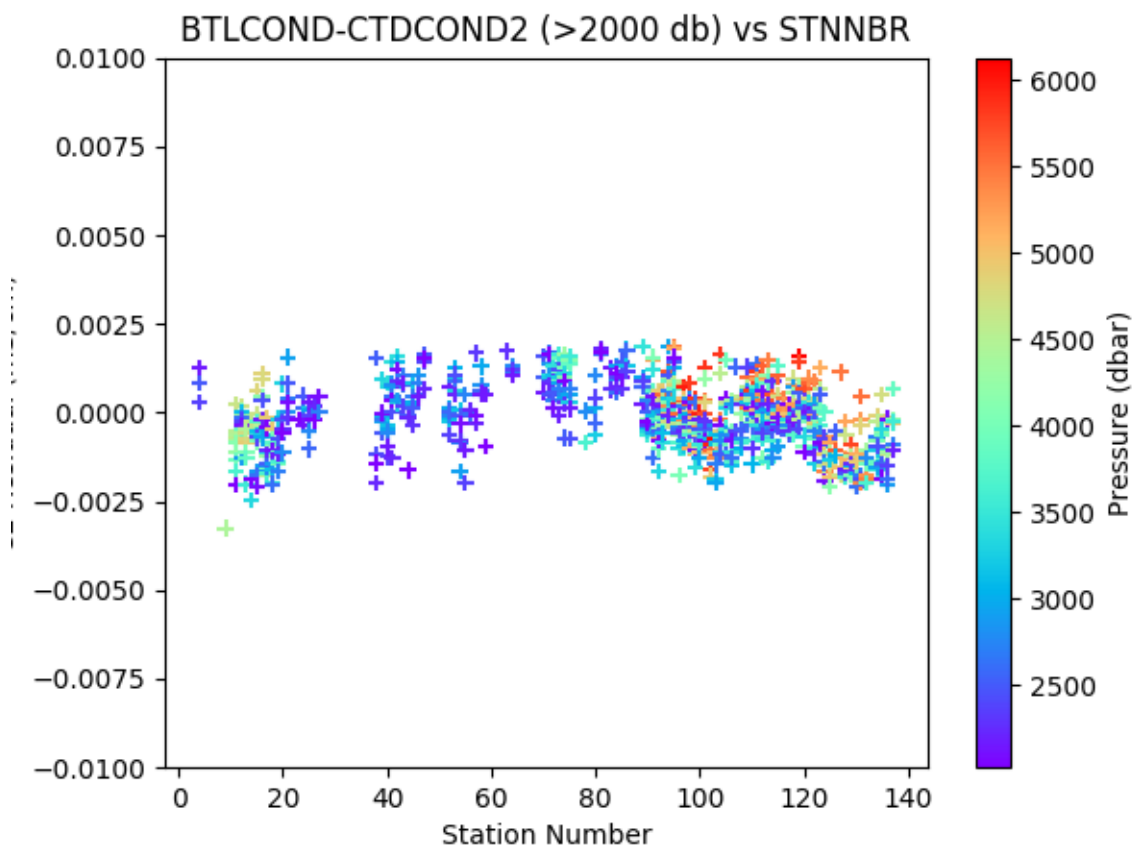


Fig. 3.17: Deep Corrected  $C_{\text{Bottle}} - C_2$  by station (Pressure  $\geq 2000$ dbar).

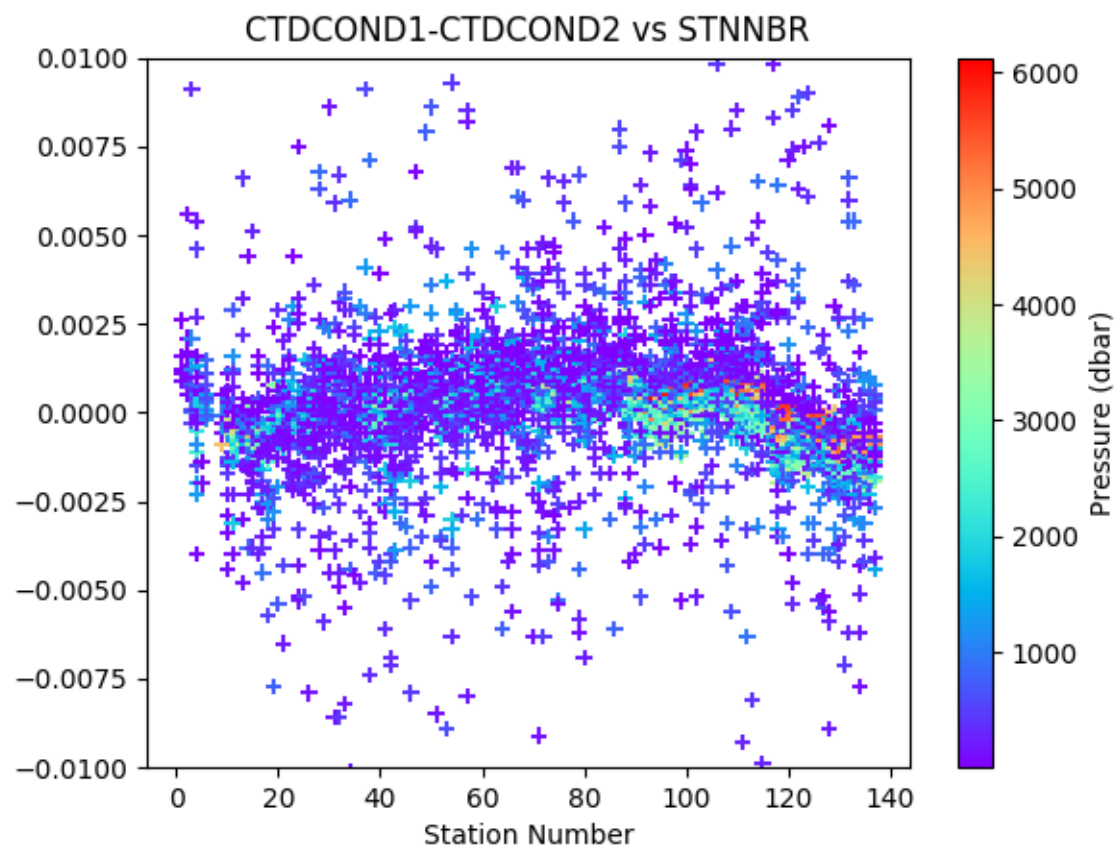


Fig. 3.18: Corrected C1-C2 by station ( $-0.002 \text{ mS/cm} \leq \text{C1-C2} \leq 0.002 \text{ mS/cm}$ ).

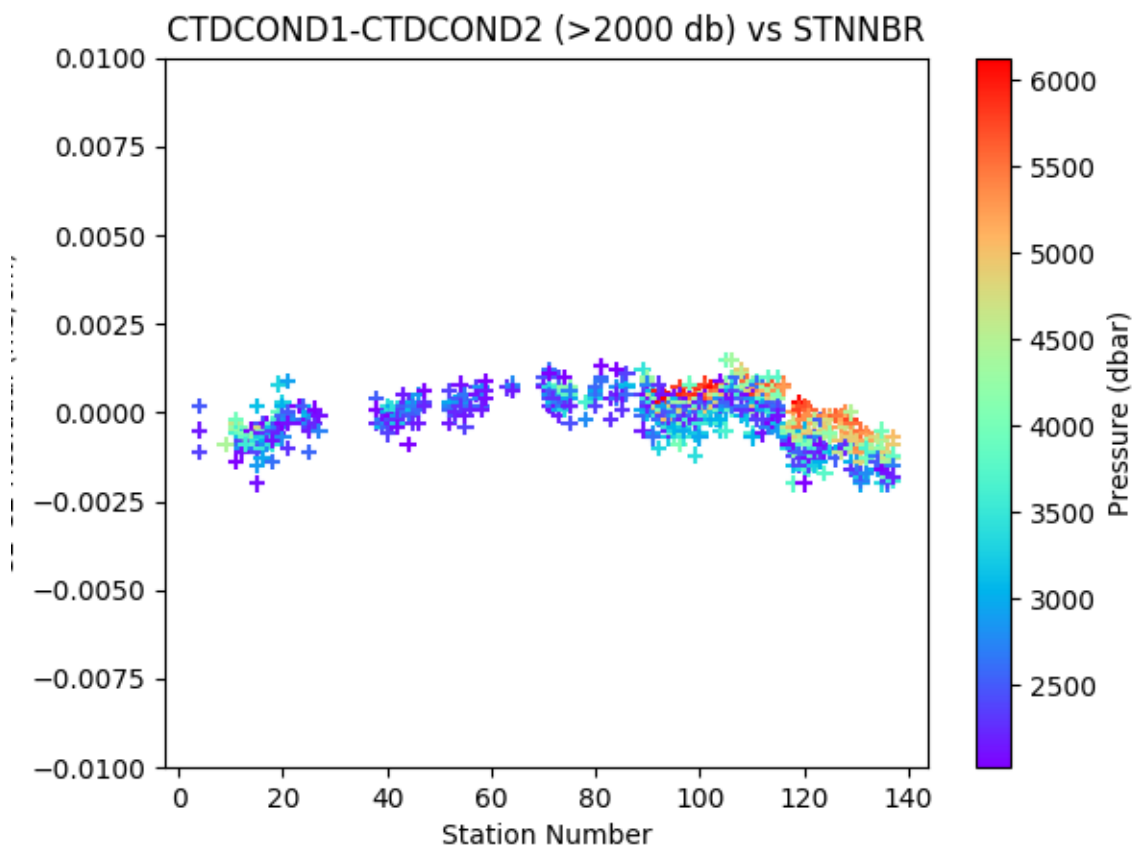


Fig. 3.19: Deep Corrected C1-C2 by station (Pressure  $\geq 2000$ dbar).

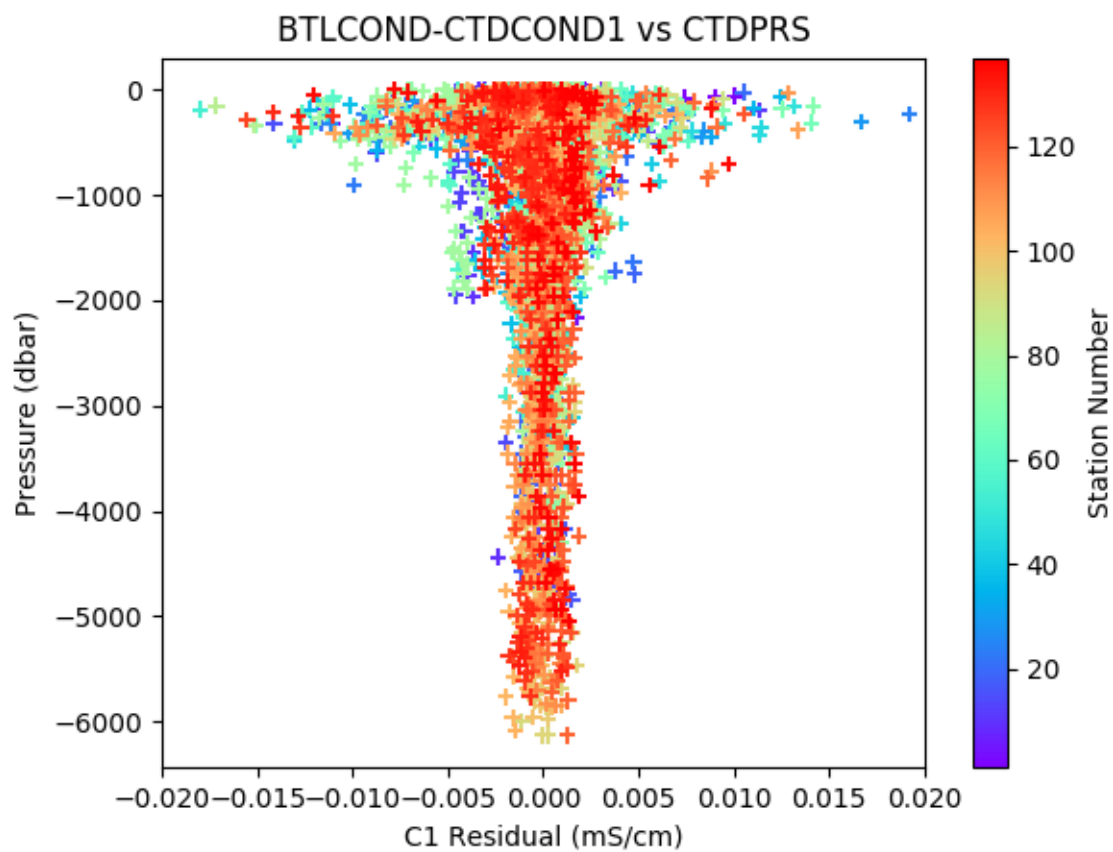


Fig. 3.20: Corrected  $C_{\text{Bottle}} - C1$  by pressure ( $-0.002 \text{ mS/cm} \leq \text{BTLCOND}-C1 \leq 0.002 \text{ mS/cm}$ ).

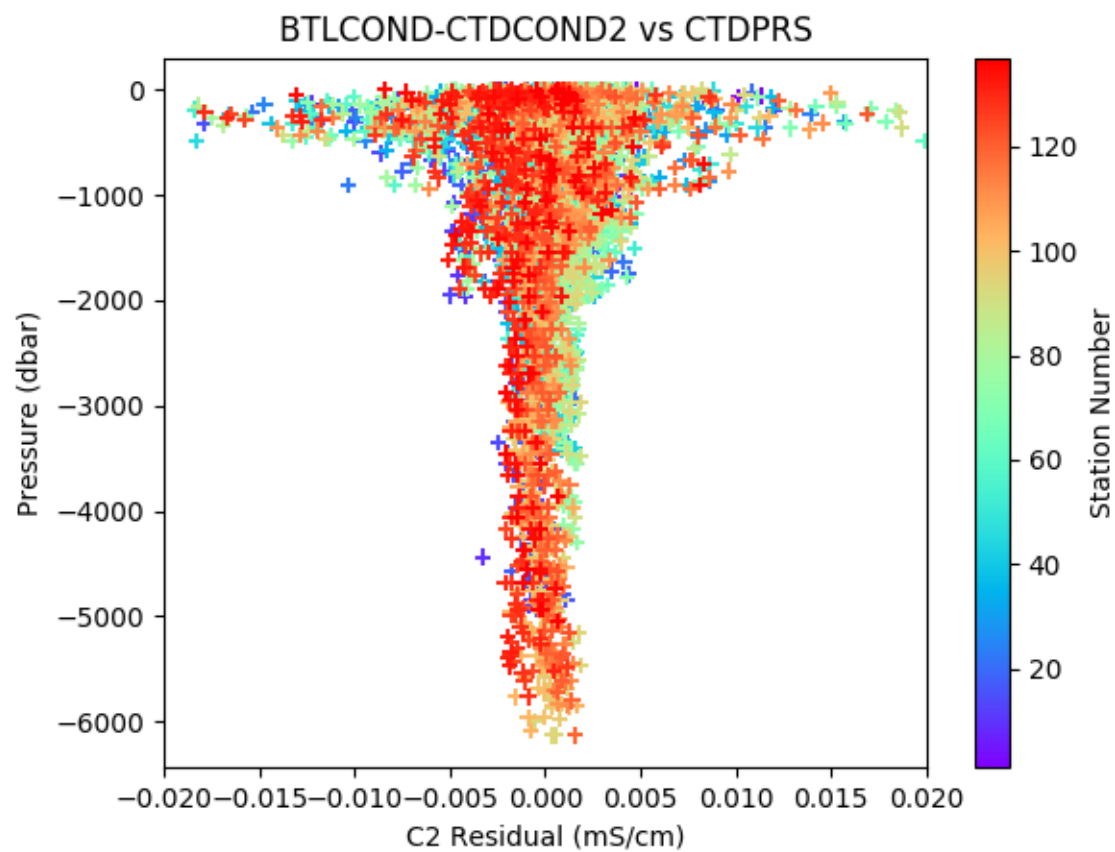


Fig. 3.21: Corrected  $C_{\text{Bottle}} - C_2$  by pressure ( $-0.002 \text{ mS/cm} \leq \text{BTLCOND}-C_2 \leq 0.002 \text{ mS/cm}$ ).

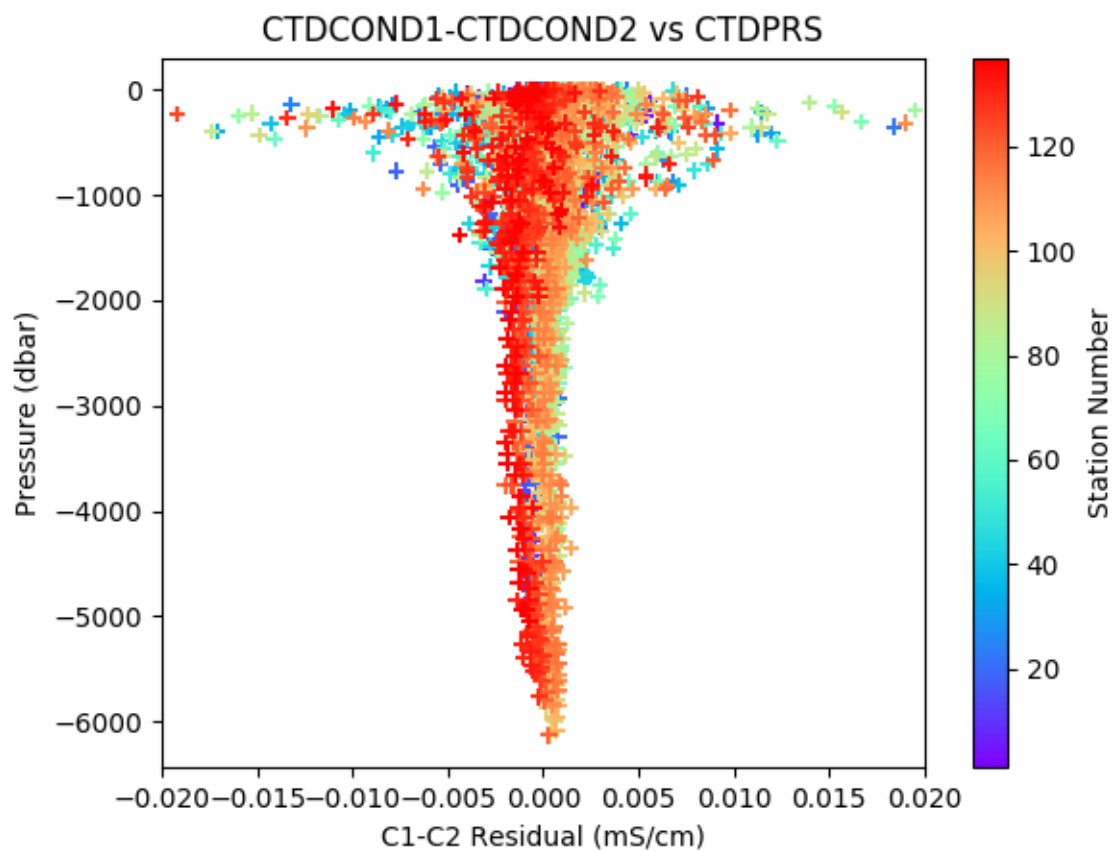


Fig. 3.22: Corrected C1-C2 by pressure ( $-0.002 \text{ mS/cm} \leq \text{C1-C2} \leq 0.002 \text{ mS/cm}$ ).

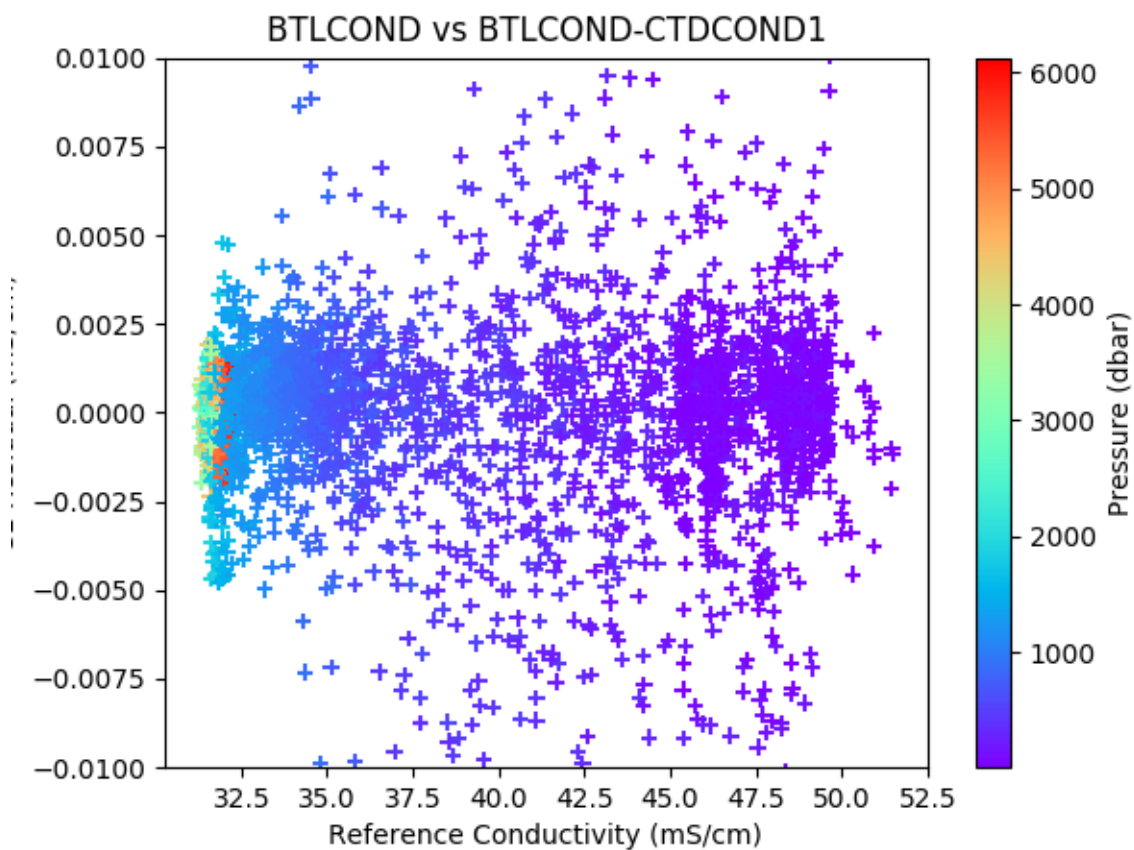


Fig. 3.23: Corrected  $C_{\text{Bottle}} - C_1$  by conductivity ( $-0.002 \text{ mS/cm} \leq \text{BTLCOND}-C_1 \leq 0.002 \text{ mS/cm}$ ).



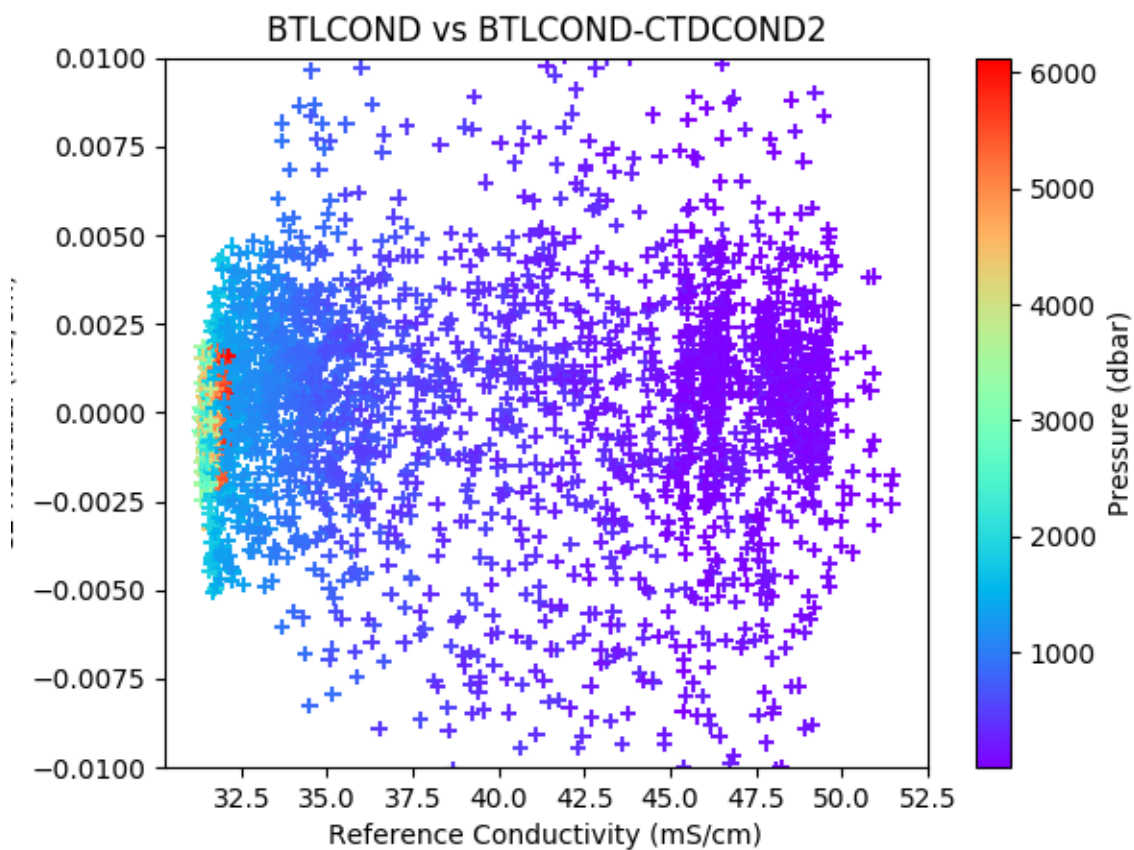


Fig. 3.24: Corrected  $C_{\text{Bottle}} - C_2$  by conductivity ( $-0.002 \text{ mS/cm} \leq \text{BTLCOND}-C_2 \leq 0.002 \text{ mS/cm}$ ).

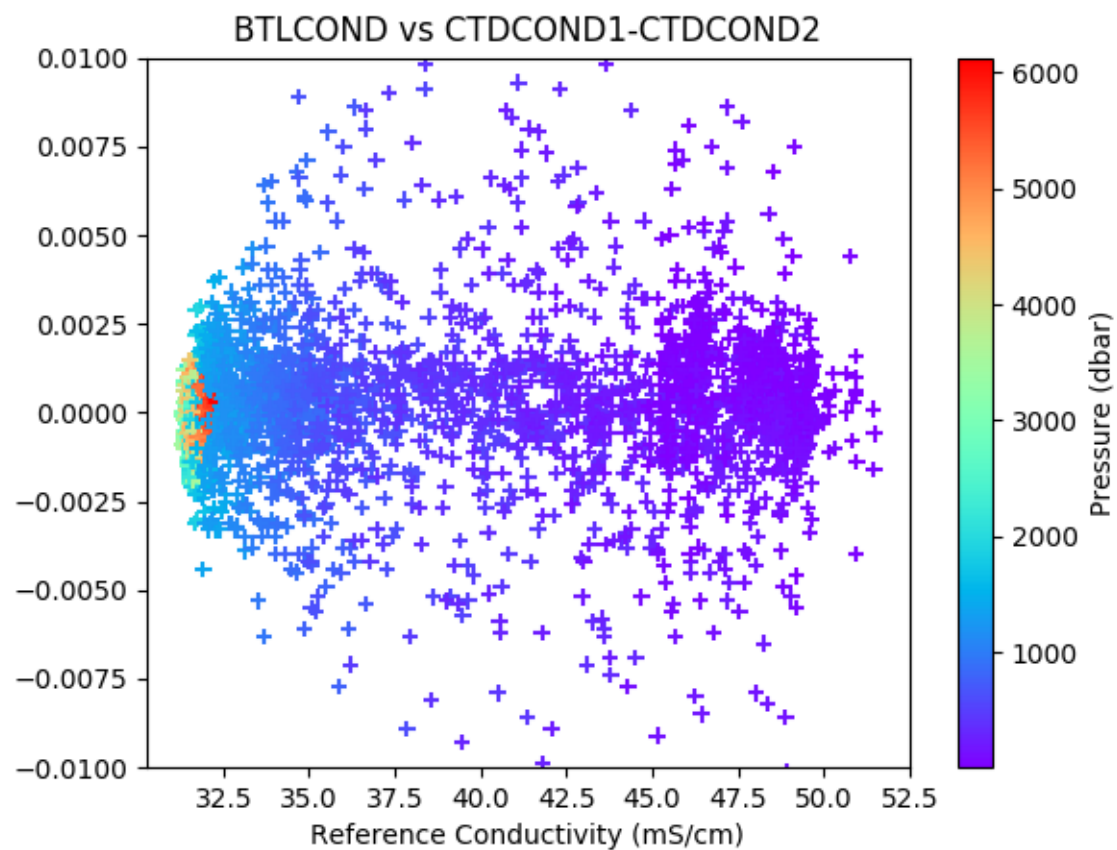


Fig. 3.25: Corrected C1-C2 by conductivity ( $-0.002 \text{ mS/cm} \leq \text{C1-C2} \leq 0.002 \text{ mS/cm}$ ).

Corrections made to all conductivity sensors are of the form:

$$C_{cor} = C + cp_2P^2 + cp_1P + ct_2T^2 + ct_1T + cc_2C^2 + cc_1C + \text{Offset}$$

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 published in the APPENDIX of this report.

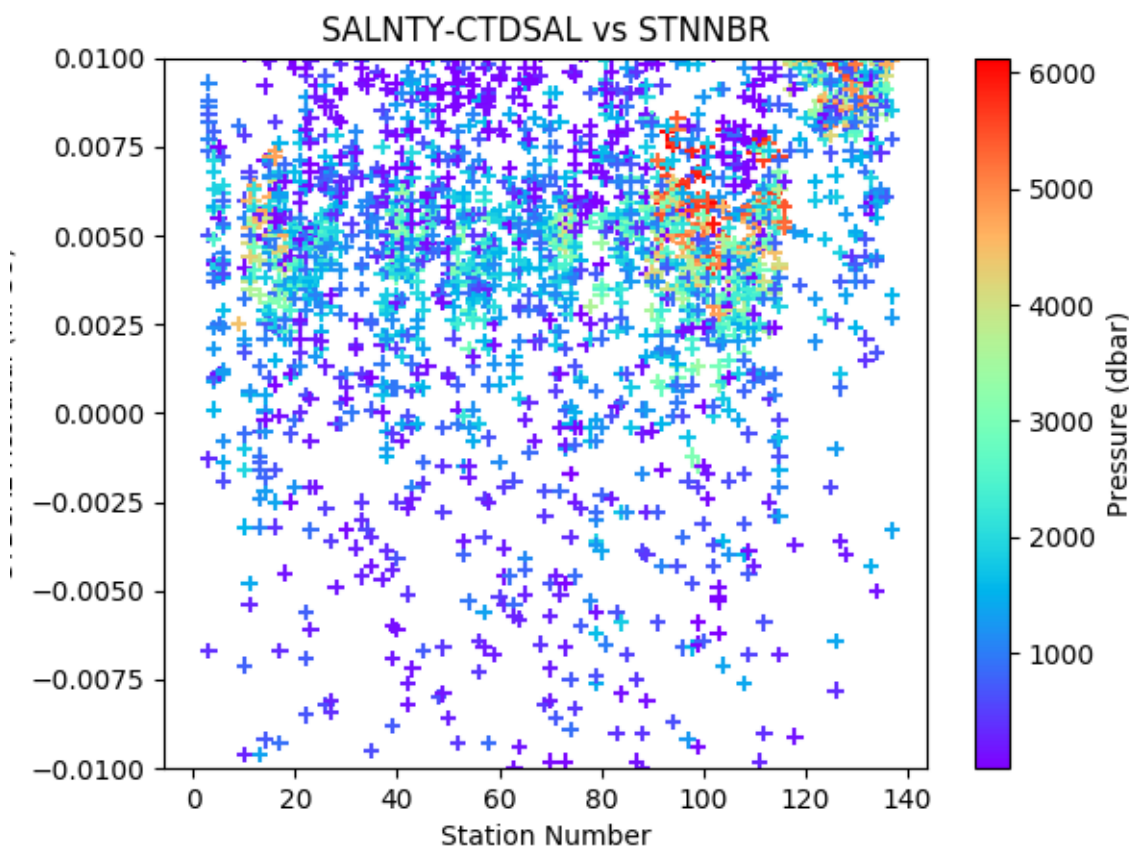


Fig. 3.26: Salinity residuals by station ( $-0.002 \text{ mPSU} \leq \text{SALNTY-C1SAL} \leq 0.002 \text{ mPSU}$ ).

The 95% confidence limits for the mean low-gradient (values  $-0.002 \text{ mPSU} \leq T1-T2 \leq 0.002 \text{ mPSU}$ ) differences are  $\pm 0.0429 \text{ mPSU}$  for salinity-C1SAL. The 95% confidence limits for the deep salinity residuals (where pressure  $\geq 2000 \text{ dbar}$ ) are  $\pm 0.0209 \text{ mPSU}$  for salinity-C1SAL.

#### A number of issues affected conductivity and calculated CTD salinities during this cruise.

- Primary conductivity sensor (S/N: 2569) failed shortly after the bottom of cast 116/01. Inspection after recovery showed goo inside the cell.
- Bottle salinity analysis was complicated due to problems with the two Autosals, leading to knock-on problems when attempting to calibrate conductivity against bottle salinity.
- Salinity lab temperatures were unstable during the time of analysis for stations 134-142. Further details on lab temperature complications are outlined in the Salinity section of this report.

The resulting affected sections of data have been coded and documented in the quality code APPENDIX.

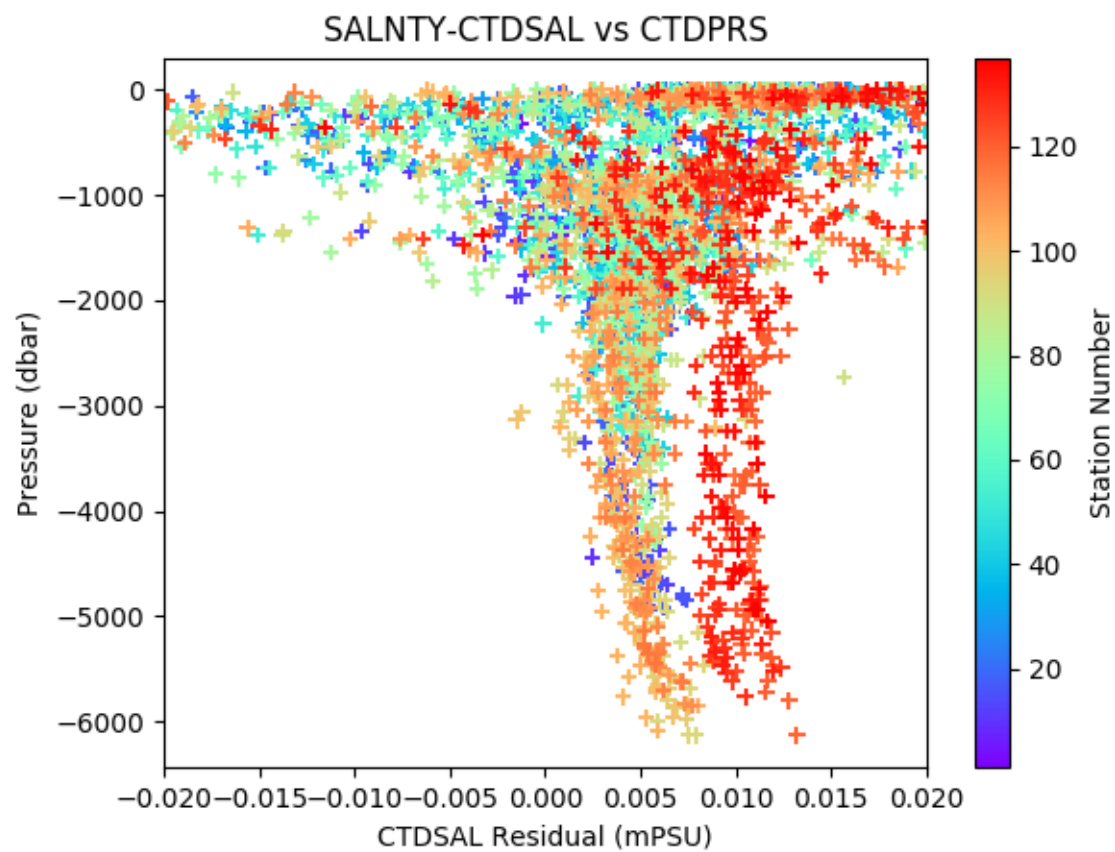


Fig. 3.27: Salinity residuals by pressure ( $-0.002 \text{ mPSU} \leq \text{SALNTY-CTDSAL} \leq 0.002 \text{ mPSU}$ ).

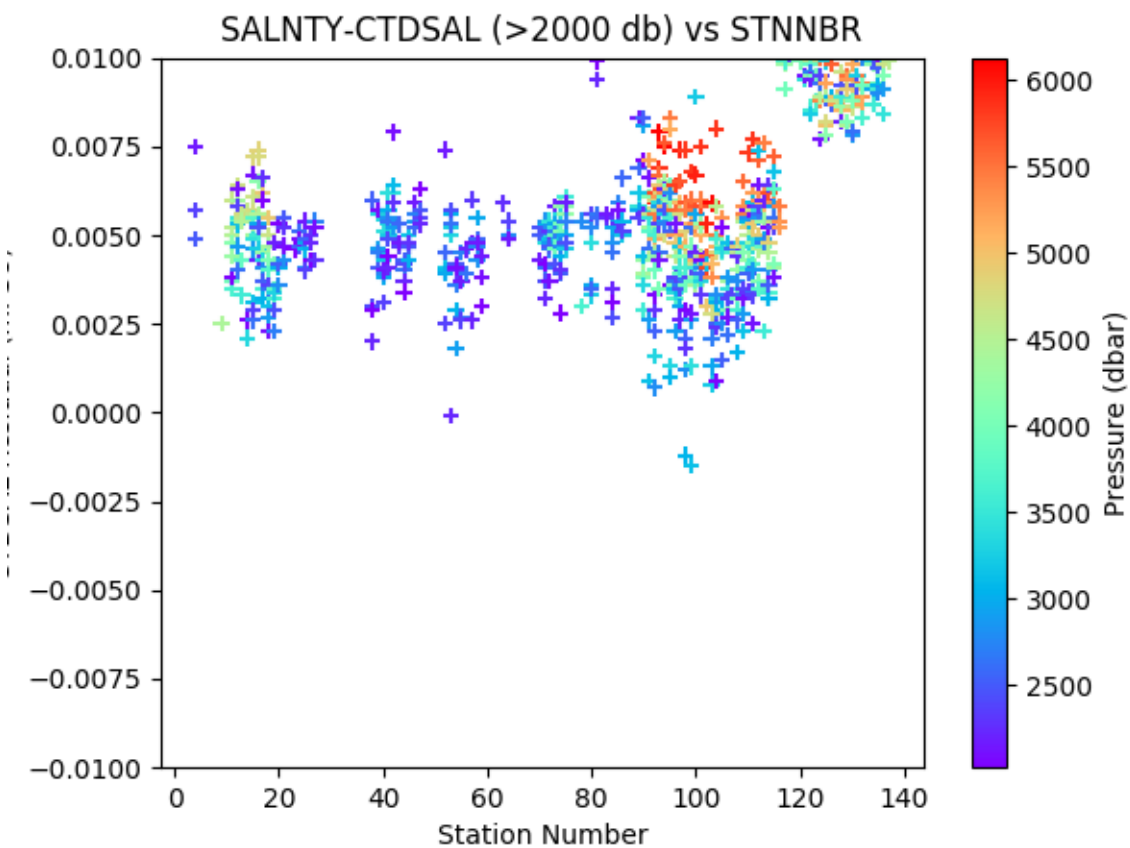


Fig. 3.28: Deep Salinity residuals by station (Pressure  $\geq 2000$ dbar).

### 3.6 CTD Dissolved Oxygen

Laboratory calibrations of the dissolved oxygen sensors were performed prior to the cruise at the SBE 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  $\mu\text{mol/kg}$  oxygen values for acquisition only. Additional shipboard fitting 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  $\text{O}_2$  check samples taken at bottle stops by matching the down cast CTD data to the up cast trip locations along isopycnal surfaces. CTD dissolved  $\text{O}_2$  was then calculated using Clark Cell MPOD  $\text{O}_2$  sensor response model for Beckman/SensorMedics and SBE43 dissolved  $\text{O}_2$  sensors. The residual differences of bottle check value versus CTD dissolved  $\text{O}_2$  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-linearity in sensor response introduced by inappropriate analog thermal compensation. Package velocity is approximated by low-pass filtering 1st-order pressure differences, and is intended to correct flow-dependent response. Dissolved  $\text{O}_2$  concentration is then calculated:

$$\text{O}_2 \text{ ml/l} = \left[ C_1 \cdot V_{\text{DO}} \cdot e^{C_2 \frac{P_h}{5000}} + C_3 \right] \cdot f_{\text{sat}}(T, P) \cdot e^{(C_4 t_l + C_5 t_s + C_7 P_l + C_6 \frac{dO_c}{dT} + C_8 \frac{dP}{dT} + C_9 dT)}$$

Where:

- $\text{O}_2$  ml/l Dissolved  $\text{O}_2$  concentration in ml/l
- $V_{\text{DO}}$  Raw sensor output
- $C_1$  Sensor slope
- $C_2$  Hysteresis ronse coefficient
- $C_3$  Sensor offset
- $f_{\text{sat}}(T, P)$   $|\text{O}_2|$  saturation at T,P (ml/l)
- $T$  In-situ temperature ( $^{\circ}\text{C}$ )
- $P$  In-situ pressure (decibars)
- $P_h$  Low-pass filtered hysteresis pressure (decibars)
- $T_l$  Long-ronse low-pass filtered temperature ( $^{\circ}\text{C}$ )
- $T_s$  Short-ronse low-pass filtered temperature ( $^{\circ}\text{C}$ )
- $P_l$  Low-pass filtered pressure (decibars)
- $dO_c / dt$  Sensor current gradient ( $\mu\text{amps/sec}$ )
- $dP/dt$  Filtered package velocity (db/sec)
- $dT$  Low-pass filtered thermal diffusion estimate ( $T_s - T_l$ )
- $C_4 - C_9$  Ronse coefficients

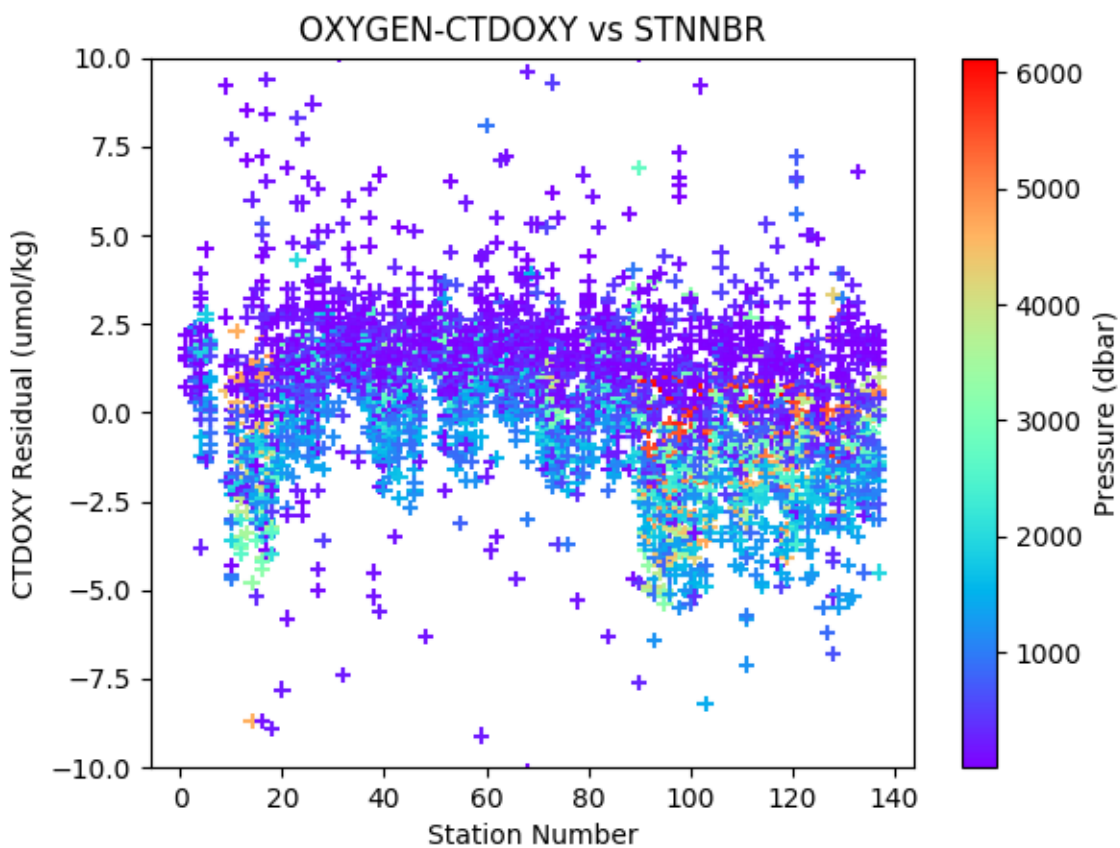


Fig. 3.29: O<sub>2</sub> residuals by station ( $-0.01 \mu\text{mol/kg} \leq \text{OXYGEN-BTLOXY} \leq 0.01 \mu\text{mol/kg}$ ).

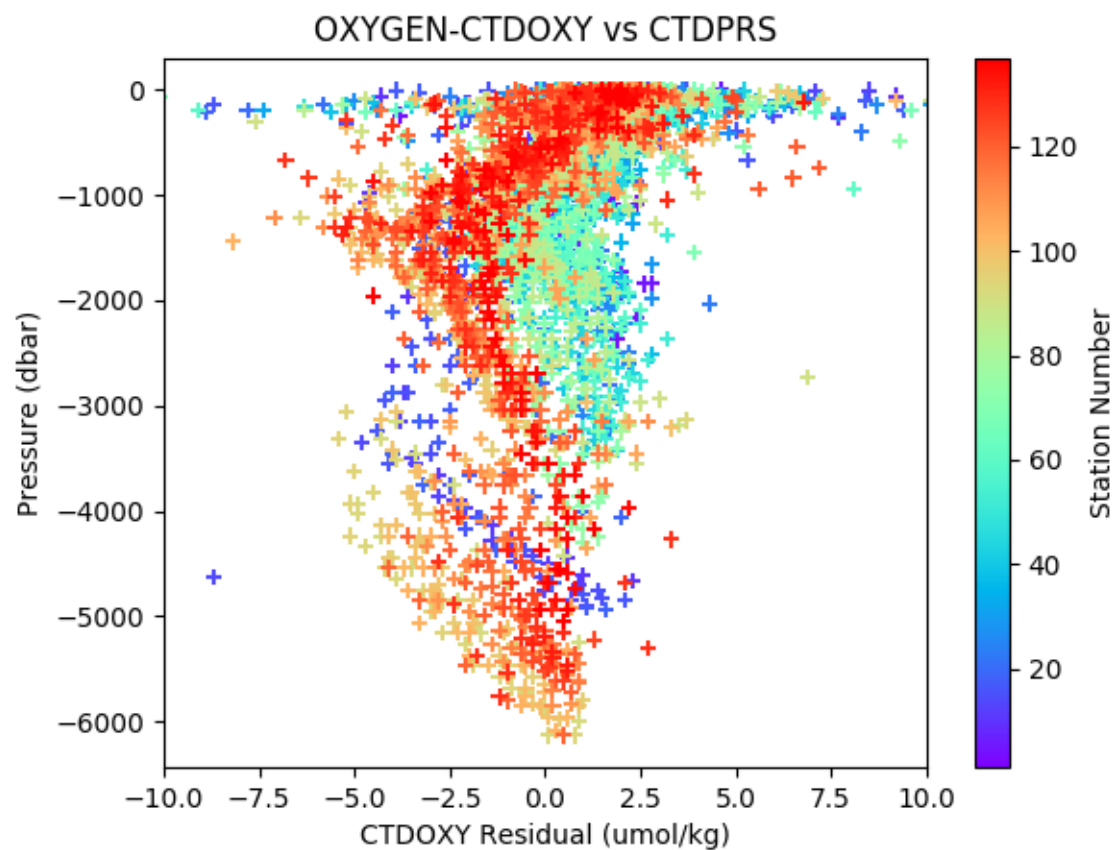


Fig. 3.30: O<sub>2</sub> residuals by pressure ( $-0.01 \mu\text{mol/kg} \leq \text{OXYGEN-BTLOXY} \leq 0.01 \mu\text{mol/kg}$ ).



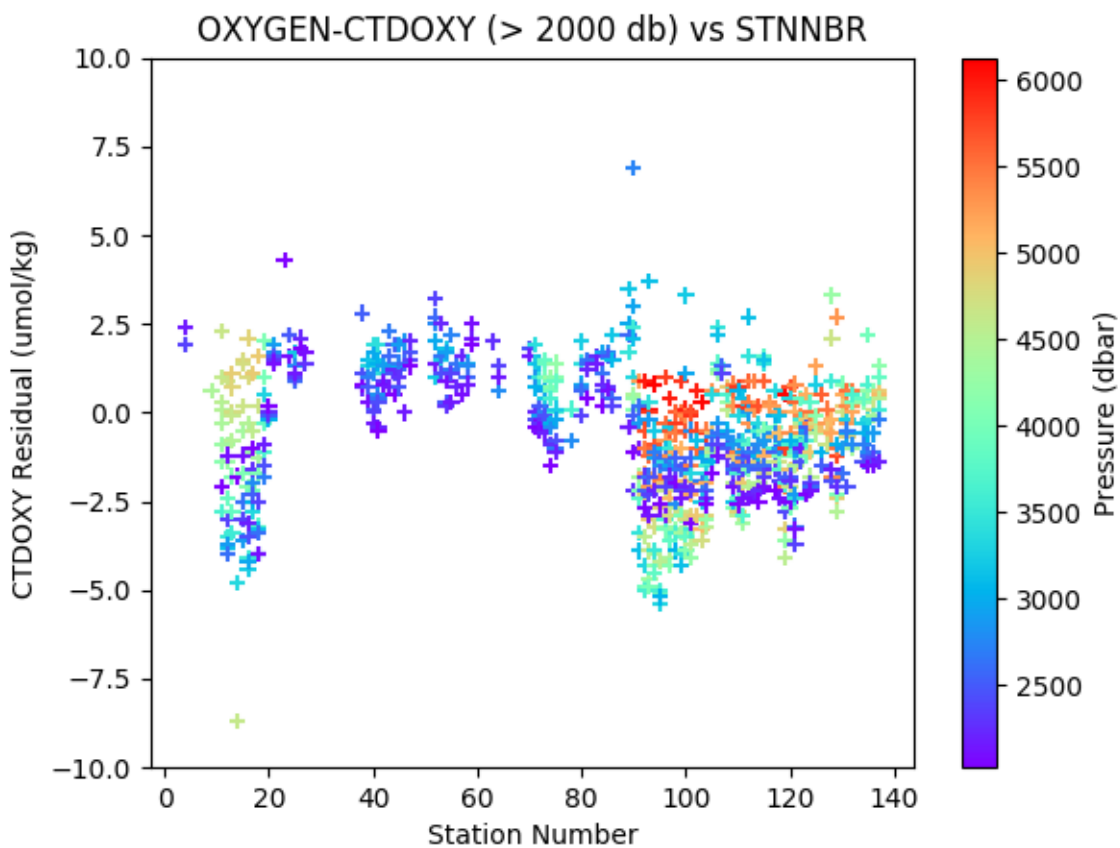


Fig. 3.31: Deep O<sub>2</sub> residuals by station (Pressure >= 2000dbar).

CTD dissolved O<sub>2</sub> residuals are shown in the following figures *O2 residuals by station* (-0.01  $\mu\text{mol/kg}$  OXYGEN-BTLOXY 0.01  $\mu\text{mol/kg}$ ). through *Deep O2 residuals by station* (Pressure  $\geq 2000\text{dbar}$ )..

The standard deviations of 5.21 ( $\mu\text{mol/kg}$ ) for all dissolved oxygen bottle data values and 3.52 ( $\mu\text{mol/kg}$ ) for deep dissolved oxygen values are only presented as general indicators of the goodness of fit. CLIVAR GO-SHIP standards for CTD dissolved oxygen data are  $< 1\%$  accuracy against on board Winkler titrated dissolved O<sub>2</sub> lab measurements.

**A number of complications arose with the acquisition and processing of CTD dissolved oxygen data.**

- New software used to fit the data is not working as intended, and the data will be re-fit post cruise after a thorough checking of the code.
- SBE43 (S/N: 430255) failed on the test station, spiking and subsequently reporting negative values at 200 db.
- SBE43 (S/N: 431136) was placed on the CTD before station 1 and replaced at station 73 due to growing noise in the signal.
- SBE43 (S/N: 430275) was placed on the CTD before station 74 until station 76 and was noted to have a similarly noisy signal.
- SBE43 (S/N: 430080) was borrowed from ASC and put on the CTD before station 77 until the end of the cruise.
- Technicians rerouted the exhaust lines from the primary sensors for a straighter fit before station 72.

All compromised data signals were recorded and coded in the data files. The bottle trip levels affected by the signals were coded and are included in the bottle data comments section of the APPENDIX.

**SALINITY****PIs**

- Susan Becker
- James Swift

**Technicians**

- John Calderwood
- Kelsey Vogel

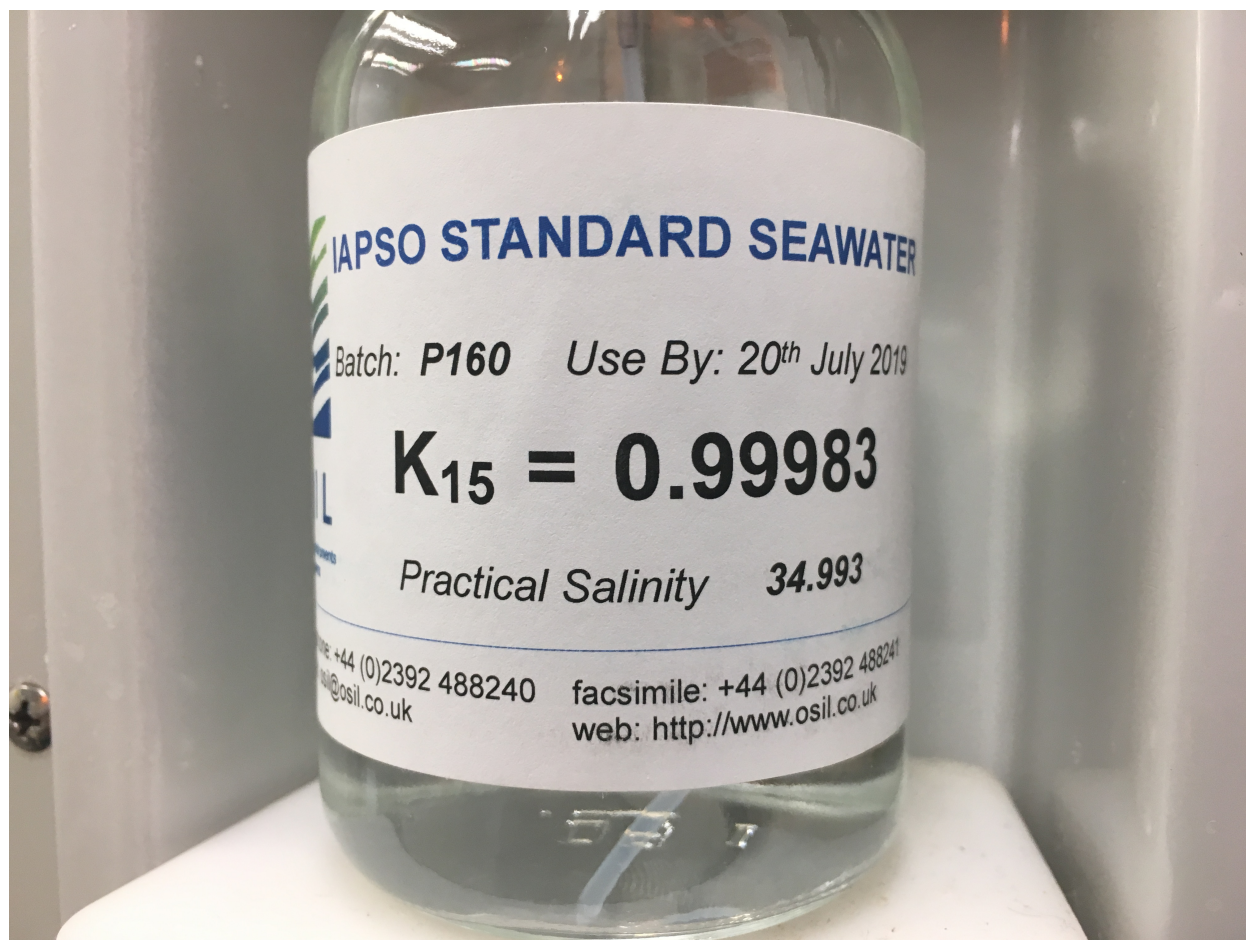
## 4.1 Equipment and Techniques

Two Guildline Autosals, model 8400B salinometer (S/N 69-180) and model 8400A salinometer (S/N 57-526) located in salinity analysis room, were used for all salinity measurements. Autosal model 8400B was serviced prior to NBP1701 and remained on ship. Autosal model 8400A was serviced prior to P06W and sent with other equipment in June. The salinometer readings were logged on a computer using in house LabView program developed by Carl Mattson. The Autosal water bath temperature was set to 24°C. The laboratory's temperature was also set and maintained to 22°C. This is to ensure stabilize reading values and improve accuracy. Salinity analyses were performed after samples had equilibrated to laboratory temperature range of 22-25°C, usually 6 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 2 times before a set of conductivity ratio reading was taken. For each sample, the salinometer cell was initially flushed at least 2 times before a set of conductivity ratio readings were taken.

IAPSO Standard Seawater Batch P-160 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.

### 4.3 Narrative

Autosal 69-180 was left on the ship in good working condition, however upon return for P06W the autosal was not circulating water. The stir motor drive was blown and pumps were not pulling water. The stir motor drive was fixed with a replaced rubber band on the motor. The pumps not pulling water was fixed by cleaning the air filter, straightening kinks in tubing, and reattaching sampling tubing to tubing to sample chamber. Autosal 57-526 was then used from station 1 to 65, when water was noticed in the manifold. Analysis then returned to Autosal 69-180 from stations 66 to 75, when higher than normal readings were reported and lack of drawing water from sample bottle. Autosal 57-526 was then used from stations 76 to 80 until suppression switch stopped working on Autosal 57-526. The problem on Autosal 69-180 was hypothesized to be oxidation accumulating on the connectors, which was fixed by disconnecting and reconnecting connectors multiple times. Autosal 69-180 was then used from stations 81 to 123, when Autosal 57-526 appeared to be working again. Autosal 57-526 was then used from stations 124 to 135, when readings were unstable, possibly related to earlier switch issues, and subsequently not used. Autosal 69-180 was used from stations 136-143, and ended the cruise in good working order. Autosal 57-526 has been deemed to need servicing before further samples can be run on it.

Autosal 69-180	Autosal 57-526	UTC Time Date Swapped
Stations Run	Stations Run	-
-	1-65	2017-07-05
66-75	-	2017-07-18
-	76-80	2017-07-21
81-123	-	2017-07-25
-	124-135	2017-08-08
136-143	-	2017-08-11
<b>Total: 58</b>	<b>Total: 85</b>	-



## NUTRIENTS

**PIs**

- Susan Becker
- James Swift

**Technicians**

- Susan Becker
- David Cervantes

## 5.1 Summary of Analysis

- 4816 samples from 144 CTD stations, including the test station
- The cruise started with new pump tubes and they were changed 3 times, before stations 031, 081, and 122.
- 7 sets of Primary/Secondary standards were made up over the course of the cruise.
- The cadmium column efficiency was checked periodically and ranged between 93%-100%. The column was replaced in/when the efficiency dropped below 96%.

## 5.2 Equipment and Techniques

Nutrient analyses (phosphate, silicate, nitrate+nitrite, and nitrite) 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 sulfanilamide in 1.2N HCl and bring to 1 liter volume. Add 2 drops of 40% surfynol 465/485 surfactant. Store at room temperature in a dark poly bottle.

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

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

**Imidazole Buffer** Dissolve 13.6g imidazole in ~3.8 liters DIW. Stir for at least 30 minutes to completely dissolve. Add 60 ml of CuSO<sub>4</sub> + NH<sub>4</sub>Cl 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.

**NH<sub>4</sub>Cl + CuSO<sub>4</sub> mix** Dissolve 2g cupric sulfate in DIW, bring to 100 ml volume (2%). Dissolve 250g ammonium chloride in DIW, bring to 1 liter volume. Add 5ml of 2% CuSO<sub>4</sub> solution to this NH<sub>4</sub>Cl 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 H<sub>2</sub>SO<sub>4</sub> sol'n** Pour 420 ml of DIW into a 2 liter Erlenmeyer flask or beaker, place this flask or beaker into an ice bath. SLOWLY add 330 ml of conc H<sub>2</sub>SO<sub>4</sub>. 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 dihydrazine 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 H<sub>2</sub>SO<sub>4</sub>. (Dilute H<sub>2</sub>SO<sub>4</sub> = 2.8ml conc H<sub>2</sub>SO<sub>4</sub> or 6.4ml of H<sub>2</sub>SO<sub>4</sub> diluted for PO<sub>4</sub> moly per liter DW) (dissolve powder, then add H<sub>2</sub>SO<sub>4</sub>) 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 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.

## 5.7 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.

## 5.8 Standards and Glassware Calibration

Primary standards for silicate ( $\text{Na}_2\text{SiF}_6$ ), nitrate ( $\text{KNO}_3$ ), nitrite ( $\text{NaNO}_2$ ), and phosphate ( $\text{KH}_2\text{PO}_4$ ) were obtained from Johnson Matthey Chemical Co. and/or Fisher Scientific. The supplier reports purities of >98%, 99.999%, 97%, and 99.999 respectively.

All glass volumetric flasks and pipettes were gravimetrically calibrated prior to the cruise. The primary standards were dried and weighed out to 0.1mg 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 every 10-12 hours from a secondary. Working standards were made up in low nutrient seawater (LNSW). two different batches of LNSW were used on the cruise. LNSW, 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 concentrations in micro-moles per liter of the working standards used were:

-	N+N (uM)	PO <sub>4</sub> (uM)	SIL (uM)	NO <sub>2</sub> (uM)	NH <sub>4</sub> (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

## 5.9 Quality Control

All final data was reported in micro-moles/kg.  $\text{NO}_3$ ,  $\text{PO}_4$ , and  $\text{NO}_2$  were reported to two decimals places and SIL to one. Accuracy is based on the quality of the standards the levels are:

$\text{NO}_3$	0.05 $\mu\text{M}$ (micro moles/Liter)
$\text{PO}_4$	0.004 $\mu\text{M}$
SIL	2-4 $\mu\text{M}$
$\text{NO}_2$	0.05 $\mu\text{M}$

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.

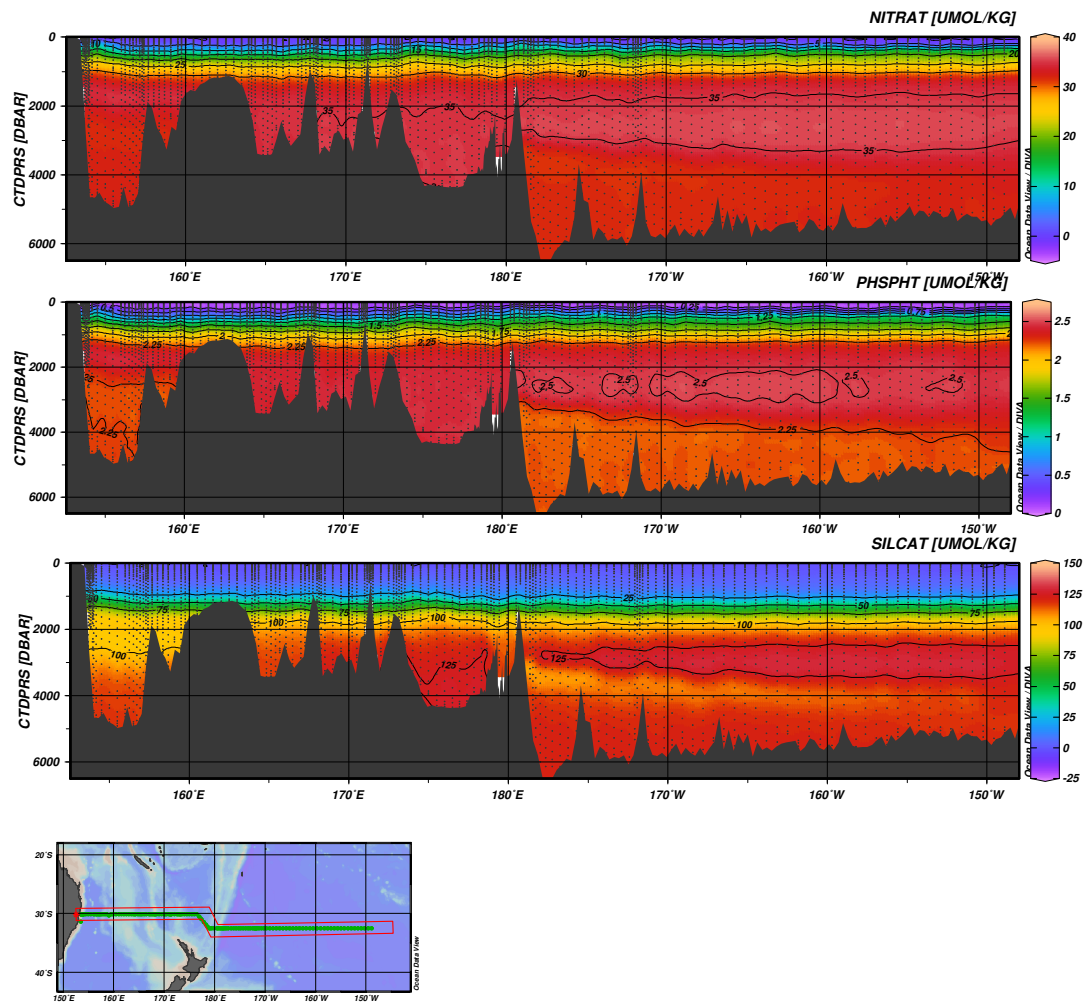
Parameter	Concentration ( $\mu\text{M}$ )	stddev
$\text{NO}_3$	34.14	0.18
$\text{PO}_4$	2.40	0.01
SIL	96.7	0.4

Reference materials for nutrients in seawater (RMNS) were also used as a check sample run once a day. The RMNS preparation, verification, and suggested protocol for use of the material are described by [\[Aoyama2006\]](#) [\[Aoyama2007\]](#), [\[Aoyama2008\]](#) and Sato [\[Sato2010\]](#). RMNS batch BV was used on this cruise, with each bottle being used once or twice before being discarded and a new one opened. Data are tabulated below.

Parameter	Concentration	stddev	assigned conc
-	( $\mu\text{mol/kg}$ )	-	( $\mu\text{mol/kg}$ )
$\text{NO}_3$	36.1	0.12	36.19
$\text{PO}_4$	2.54	0.02	2.56
Sil	105.1	0.4	104.6
$\text{NO}_2$	0.06	0.00	0.05

## 5.10 Analytical Problems

No major analytical problems.





## OXYGEN ANALYSIS

### PIs

- Susan Becker
- James Swift

### Technicians

- Andrew Barna
- Courtney Schatzman

## 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 [Carpenter1965] with modifications by [Culberson1991] 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

4790 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  $\mu\text{mol/kg}$  concentrations, and as a diagnostic check of bottle integrity. Reagents ( $\text{MnCl}_2$  then  $\text{NaI/NaOH}$ ) 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°C. The 20°C normalities and the blanks were plotted versus time and were reviewed for possible problems. The blanks and thiosulfate normalities for each batch of thiosulfate were 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

Setup occurred in Sydney, Australia starting June 29th, 2017. The equipment was already on board the RV Palmer from NBP1701 in January. During setup it was discovered that the 4 large reagent jugs (~4L each) were not present. This had the effect of limiting the amount of reagents which could be made in advance. The primary consequence of this is that each batch of Thiosulfate would be independent. Setup otherwise went smoothly and the analysis rig was running, secured, and standardizing before leaving port on July 3rd.

Scientific stations occurred within 24 hours of leaving port. Issues were minor, occasional communication issues occurred between the analytical computer and the 1ml burette, resulting in the restart of the computer. The communication problems did not result in any lost sample analysis. On station 14, deep samples (bottles 2-7) showed significant discrepancies from the CTD O2 profile and from adjacent bottles, the cause was not identified.

Around station 112 a KIO3 standard (2017B.2) change resulted in an out of spec jump in the Thiosulfate normality. The existing thiosulfate was subsequently standardized with both an OSIL Oxygen standard (0.1N) and a second ODF oxygen standard. It was determined that the 2017B.2 standard which had been swapped in was the source of the jump. This batch was reported to the shore calibration facility which observed a similar thiosulfate normality discrepancy when some of standard 2017B.2 was rerun.

An OSIL oxygen standard was run against the usual ODF oxygen standard in the process of troubleshooting. The OSIL standardization resulted in a thiosulfate normality within specifications of the last accepted good standardization using the ODF oxygen standard. The OSIL standardization followed the same procedures as normal with the exception of using an Eppendorf pipette to dispense the standard.

A standardization run after station 134 resulted in constantly increasing thiosulfate titration values, with detectable increases even in the minutes between each titration. The likely cause of which was a decreasing concentration of thiosulfate from an infection. The existing thiosulfate was subsequently discarded and all glassware, burettes, and tubing was acid washed. A new batch of thiosulfate was made and used for the remaining stations for the cruise. While the normal rest period for a new batch of thiosulfate could not be done, the normality as reported by each standardization run (approx. every 24 hours) showed excellent stability.

The necessity of smoothing the normality of each batch of thiosulfate was considered separately for each batch. There was no drift or trend observed in any of the batches, so no smoothing procedure was performed. A total of 5 batches were made and used throughout the cruise.

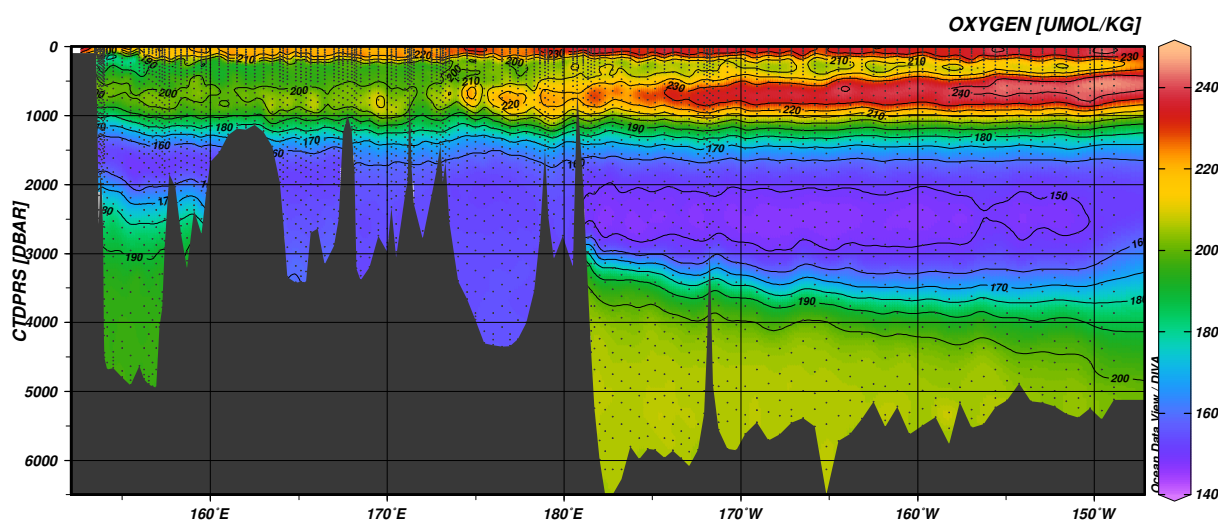


Fig. 6.1: Preliminary dissolved oxygen section of P06W





## TOTAL ALKALINITY

### PI

- Andrew G. Dickson – Scripps Institution of Oceanography

### Technicians

- Manuel Belmonte
- Derek Smith

## 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 P06W Stations (1-143) except for stations 16, 20, 56, 60, 69 and 72. Two Niskin bottles at each station were sampled twice for duplicate measurements except for stations where 24 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 0.12 mL of saturated mercuric chloride solution was added to each sample for preservation. After sampling was completed, each sample's temperature was equilibrated to approximately 20°C using a Thermo Scientific RTE water bath.

## 7.4 Problems and Troubleshooting

The RVIB Nathaniel B. Palmer is a fantastic research vessel. However, our electrodes appeared to continually pick up larger than expected interference from the lab's neighboring instruments or the ship itself. Electrode plots could show increased electrode sensitivity over time. Luckily, enough electrodes were brought on P06W and replacing them minimized bad measurements. Any unusual measurements (poor electrode plot / profile outlier) were reran when possible.

Normally after samples are collected, they are placed into a water bath to equilibrate the sample temperature near 20°C, the temperature at which the sample is measured. This is normally fine when the lab temperature is within 2°C of 20°C. The lab temperature for P06W ranged from 19°C to 25°C due to some air conditioning issues. At the beginning of the cruise, before the air conditioning was fixed, lab temperatures ranged from 20°C to 25°C. Once the air conditioning was fixed, the temperature ranged from 19°C to 22°C. This constantly delayed the titration start times. To remedy the situation, we equilibrated the sample temperatures to about 22.5°C at the start of the cruise and 20°C after the lab temperatures were more stable. This strategy enabled most of the sample temperatures to not exceed a 0.2°C range while being titrated.

Throughout the cruise, varying issues resulted from the Sample Delivery System. At the start of the cruise (during station 5), Sample Delivery System B would not fill the pipette completely so it was replaced with Sample Delivery System A. About a third of the way into the cruise (before station 55), a shift in Sample Delivery System A's delivery volume was noticed causing smaller samples sizes to be dispensed: A calibration using a manual pipette resolved this issues. Once again, towards the end of the cruise (during station 140) Sample Delivery Station A's dispensed volume shifted and another calibration was performed. Lastly, throughout the cruise, the Sample Delivery System's program would freeze in Deliver Sample mode or Prepare Pipette mode and caused a few sample bottles to be emptied. This resulted in lost samples due to the novice operators. Despite these issues, a minimal amount of samples were lost, and the amount of samples that were suspected of being low in volume were reran or flagged if a rerun was not possible.

## 7.5 Quality Control

Dickson laboratory Certified Reference Material (CRM) Batch 165 was used to determine the accuracy of the total alkalinity analyses. The total alkalinity certified value for this batch is:

- Batch 165  $2214.09 \pm 0.41 \mu\text{mol/kg}$  (32;16)

The cited uncertainties represent the standard deviation. Figures in parentheses are the number of analyses made (total number of analyses; number of separate bottles analyzed).

At least one reference material was analyzed at every I09N stations resulting in 110 reference material analyses. On I09N, the measured total alkalinity value for each batch is:

- Batch 165  $2213.37 \pm 3.94 \mu\text{mol kg}^{-1}$  (179) [mean  $\pm$  std. dev. (n)]

If greater than 24 Niskin bottles were sampled at a station, two Niskin bottles on that station were sampled twice to conduct duplicate analyses. If 24 or less Niskin bottles were sampled at a station, only one Niskin on that station was sampled twice for duplicate analyses. The standard deviation for the duplicates measured on P06W is:

Duplicate Standard Deviation  $\pm 3.52 \mu\text{mol kg}^{-1}$  (196) [ $\pm$  std. dev. (n)]

The total alkalinity measurements for each P06W stations have not been compared to measurements taken from the neighboring P06W 2017 stations and the P06W 2009 stations of similar if not identical coordinates.

3136 total alkalinity values were submitted for P06W. The total alkalinity of the entire transect is shown as a section in *P06W Alkalinity Section*. Although most corrections have been applied and it is unlikely that any additional corrections will need to be performed, this data should be considered preliminary until a more thorough analysis of the data can take place on shore, especially during the stations where the SDS Pipette Boards were having problems.

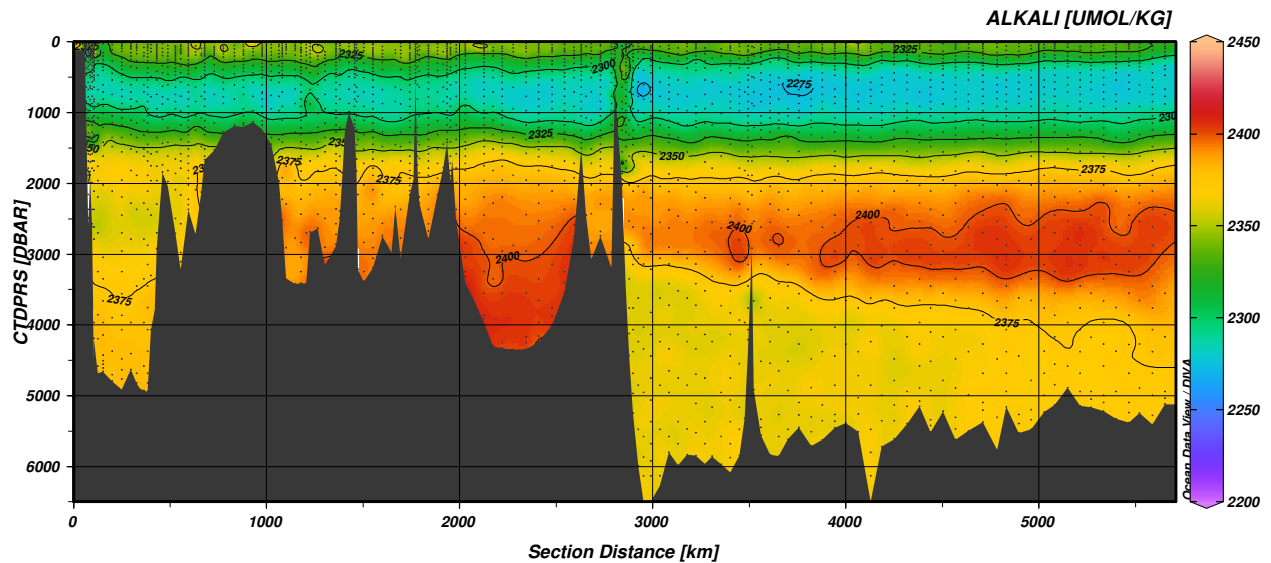


Fig. 7.1: P06W Alkalinity Section  
Section of total alkalinity along P06W (Stations 1 to 143).



## DISSOLVED INORGANIC CARBON (DIC)

### PI's

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

### Technicians

- Andrew Collins (NOAA/PMEL)
- Charles Featherstone (NOAA/AOML)

## 8.1 Sample collection

Samples for DIC measurements were drawn (according to procedures outlined in the PICES Publication, *Guide to Best Practices for Ocean CO<sub>2</sub> 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<sub>2</sub> 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.

## 8.2 Equipment

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 (PMEL 1 and PMEL 2) were set up in a seagoing container modified for use as a shipboard laboratory on the aft main working deck of the RVIB Nathaniel B. Palmer.

## 8.3 DIC Analysis

In coulometric analysis of DIC, all carbonate species are converted to CO<sub>2</sub> (gas) by addition of excess hydrogen ion (acid) to the seawater sample, and the evolved CO<sub>2</sub> 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  $\text{OH}^-$  ions at the anode. The  $\text{OH}^-$  ions react with the  $\text{H}^+$  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  $\text{CO}_2$  that enters the cell is determined by integrating the total change during the titration.

## 8.4 DIC Calculation

Calculation of the amount of  $\text{CO}_2$  injected was according to the  $\text{CO}_2$  handbook [DOE1994]. The concentration of  $\text{CO}_2$  ( $[\text{CO}_2]$ ) in the samples was determined according to:

$$[\text{CO}_2] = \text{Cal. Factor} * \frac{(\text{Counts} - \text{Blank} * \text{Run Time}) * K \mu\text{mol/count}}{\text{pipette volume} * \text{density of sample}}$$

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 ( $\mu\text{mol/kg}$ ) using density obtained from the CTD's salinity. The DIC values were corrected for dilution due to the addition of 0.12 ml of saturated  $\text{HgCl}_2$  used for sample preservation. The total water volume of the sample bottles was 305.55 ml (calibrated by Dana Greeley, AOML). The correction factor used for dilution was 1.0004. 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 ( $\pm$  SD) correction was  $0.97 \pm 1.22 \mu\text{mol/kg}$  for PMEL 1 and  $1.00 \pm 1.00 \mu\text{mol/kg}$  for PMEL 2.

The coulometer cell solution was replaced after 25 – 28 mg of carbon was titrated, typically after 9 – 12 hours of continuous use. The average ( $\pm$  SD) blanks for PMEL 1 and PMEL 2 were  $17.8 \pm 5.8$  and  $18.3 \pm 5.8$  counts, respectively.

## 8.5 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  $\text{CO}_2$  (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 165 CRM value. The CRM certified value for this batch is  $2064.33 \mu\text{mol/kg}$ .

The precision of the two DICE systems can be demonstrated via the replicate samples. Approximately 11.5% of the niskins sampled were duplicates taken as a check of our precision. These replicate samples were interspersed throughout the station analysis for quality assurance and integrity of the coulometer cell solutions. The average absolute difference from the mean of these replicates is  $0.6 \mu\text{mol/kg}$  - 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 Dev	Dupes
PMEL 1	1.002533	1.006530	27.5812 ml	2064.13, N= 82	1.22	1.56
PMEL 2	1.004927	1.002611	26.3417 ml	2065.25, N= 68	1.24	1.45

## 8.6 Underway DIC Samples

Underway samples were collected from the flow thru system in the Hydro 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  $\mu\text{mol/kg}$  and the average standard deviation was 0.88.

## 8.7 Summary

The overall performance of the analytical equipment was good during the cruise. Several small leaks were fixed in the HSG during the cruise.

Including the duplicates, 3,889 samples were analyzed from 143 CTD casts for dissolved inorganic carbon (DIC) which means that there is a DIC value for approximately 81% of the niskins tripped. The distribution of DIC with depth along the 2017 cruise track can be seen in Figure 1, while differences in DIC distributions observed between 2009 and 2017 can be seen in Figure 2. 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.

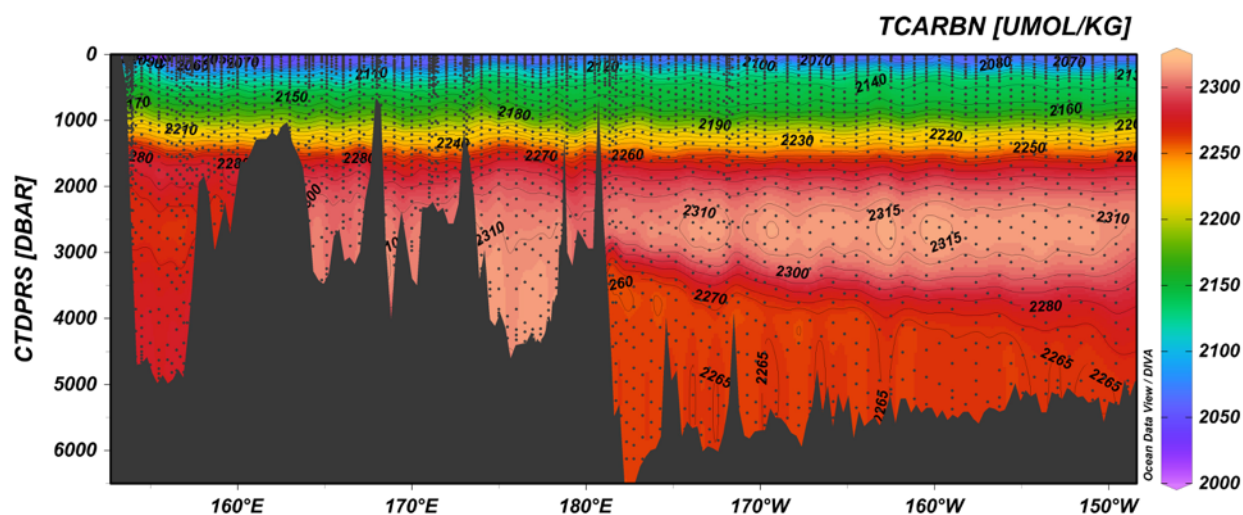


Fig. 8.1: Distribution of dissolved inorganic carbon measured during the 2017 GO-SHIP P06 research expedition.



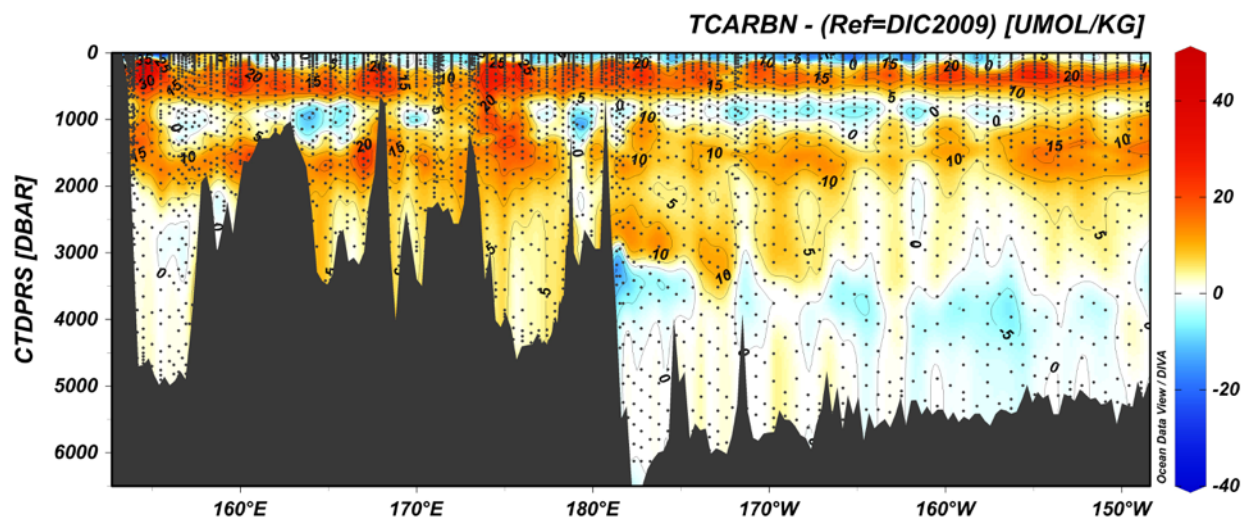


Fig. 8.2: Changes observed in the distributions of dissolved inorganic carbon measured during the 2017 P06 occupation compared to those measured during the 2009 P06 occupation.



## DISCRETE PH ANALYSES (TOTAL SCALE)

### PI

- Dr. Andrew Dickson

### Technicians

- Stephanie Mumma
- Manuel Belmonte

## 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 ( $\text{HgCl}_2$ ). 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, duplicate samples were collected from 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 Kloeohn 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.

## 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 four batches were used during P06, Leg 1. The pHs of these batches were adjusted with 0.1 mol kg<sup>-1</sup> solutions of HCl and NaOH (in 0.6 mol kg<sup>-1</sup> NaCl background) to approximately 7.75, measured with a pH meter calibrated

with NBS buffers. The indicator was obtained from Dr. Robert Byrne at the University of 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 Problems and Troubleshooting

Many of the samples had a 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 from each station. Efforts were made to reduce bubble formation by verifying all pump fittings were tight, slowing down the speed of the syringe pump, and holding samples below 25°C. When bubbles formed during station analysis, they were cleared by the aforementioned methods between samples. Bubbles were also cleared from the syringe by flushing with ethanol, followed by DI water. This method of flushing with ethanol and DI water proved to be effective and removed bubbles when accumulated. These bubbles appeared to have no affect on the samples' pH values. On two occasions near the beginning of the P06, Leg 1, the valve on the Kloehn syringe pump appeared to be "sticking" in between ports, resulting in cross-port contamination of the measured sample. The spare Kloehn pump was installed and this issue was not encountered again. The two affected Niskin samples were measured again from the original sample bottles with good results.

The Labview software that controls the automated pH system crashed once during P06, Leg 1, resulting in the loss of data for one measurement. The uncorrected pH values were documented in the pH lab notebook. This sample was run again and the resulting pH value for the second analysis was used for data submission.

## 9.6 Standardization/Results

The precision of the data was assessed from measurements of duplicate analyses, replicate analyses (two successive measurements on one bottle), and certified reference material (CRM) Batch 165 (provided by Dr. Andrew Dickson, UCSD). Two duplicate and two replicate measurements were performed on every station when at least twenty-three Niskins were sampled. If less than twenty-three Niskins were sampled, only one duplicate and one replicate measurement were performed. CRMs were measured at the beginning and ending of each day.

The precision statistics for P06, Leg 1 are:

Duplicate precision	$\pm 0.00057$ (n=206)
Replicate precision	$\pm 0.00039$ (n=244)
B165	$7.7598 \pm 0.00104$ (n=78)
B165 within-bottle SD	$\pm 0.00026$ (n=78)

3478 pH values were submitted for P06, Leg 1. Additional corrections will need to be performed and these data should be considered preliminary until a more thorough analysis of the data can take place on shore. The preliminary pH of the entire transect is shown as a section in *pH Section*.

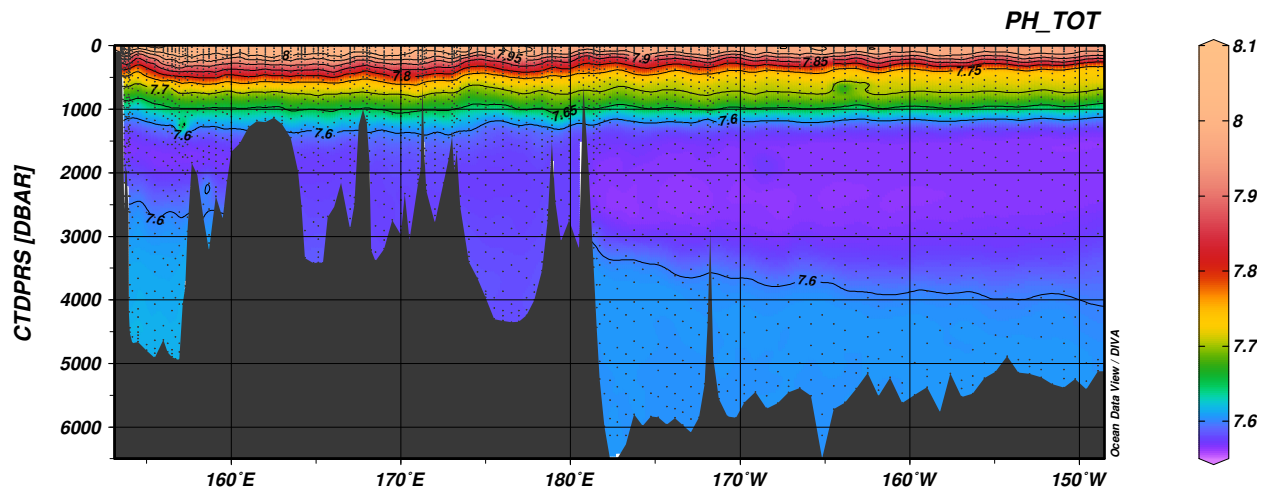


Fig. 9.1: pH Section

Section of preliminary pH measurements on the total scale along P06 cruise track (Stations 1 to 143).



## CFC-11, CFC-12, CFC-113, AND SF<sub>6</sub>

### Analysts

- Jim Happell
- David Cooper
- Kelly McCabe

## 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, and SF<sub>6</sub> were measured on 129 of 143 stations for a total of 3500 samples. Salt water flooded the analytical system just after analyzing station 48, which was the cause of most of the missed stations, although some of the added stations with very short station spacing were also skipped. 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 Porapak 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 180°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 N<sub>2</sub>O and keep it from entering the main column. The second pre-column 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, and SF<sub>6</sub> was 1.2%, 1.6% and 2.5% respectively. Estimated limit of detection is 1 fmol/kg for CFC-11, 3 fmol/kg for CFC-12, and 0.1 fmol/kg for SF<sub>6</sub>

## DISSOLVED ORGANIC PHOSPHORUS

### PIs

- Angela Knapp (FSU)

### Technician

- Kelly McCabe

Marine dissolved organic matter (DOM) is considered a primary substrate for heterotrophic microbes, but can also be used by some nutrient-limited phytoplankton that especially consume dissolved organic phosphorus (DOP) when phosphate ( $\text{PO}_4$ ) is scarce. However, very few measurements of surface ocean DOP concentration have been made, which limits our understanding the extent to which DOP is utilized by phytoplankton. The goal of this data collection is to increase the spatial coverage of DOP measurements to constrain the use of DOP as a nutrient source supporting export production and di-nitrogen fixation in the global marine environment.

DOP samples were collected from the upper 400 meters at stations with two-degree longitude spacing. A total of 375 samples from 29 stations were collected. All samples were hand filtered through Whatman 25mm Puradisc 0.2 $\mu\text{m}$  PES filters. The syringe and filter were rinsed with 40mL of seawater before each 60mL HDPE bottle was rinsed once with 40mL of filtered seawater. All samples were stored onboard at  $-20^\circ\text{C}$  to preserve for land based analysis.

Analysis: All samples will be analyzed for total dissolved P (TDP) using the high temperature combustion magnesium sulfate oxidation techniques modified according to Monaghan and Ruttenberg [*Monaghan1999*]. DOP concentration will be reported as the difference between the TDP concentration and the  $\text{PO}_4$  concentration determined onboard by ODF.





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

### PIs

- Angela Knapp (FSU)

### Technician

- Kelly McCabe

Nitrate ( $\text{NO}_3^-$ ) is the dominant dissolved inorganic form of nitrogen in the oceans. As a macro-nutrient, nitrate is depleted in the surface due to biological consumption and abundant in the ocean interior due to remineralization. The dual isotopes of  $\text{NO}_3^-$  ( $\delta^{15}\text{N}$  and  $\delta^{18}\text{O}$ ) allow us to constrain the utilization and consumption processes controlling the nitrogen cycle within the South Pacific Subtropical Gyre.

Nitrate  $\delta^{15}\text{N}$  samples were collected from all depths at every two degrees of longitude. Two 60mL samples were collected from each niskin bottle fired in the shallowest six depths. One 30mL sample was taken from all other depths. All samples collected above 400 meters were hand filtered with a BD 60mL Luer-Lok tip syringe and a 25mm Puradisc 0.2 $\mu\text{m}$  PES filter. The syringe and filter were rinsed with 40mL of seawater before each HDPE (both 60mL and 30mL) bottles were rinsed once with half their full volume of filtered seawater. The samples were stored onboard at  $-20^\circ\text{C}$  to preserve for land based analysis.

Analysis: The denitrifier method [*Casciotti2002*] [*Sigman2001*] will be used to analyze  $\text{NO}_3^-$   $\delta^{15}\text{N}$  and  $\delta^{18}\text{O}$ . Briefly, this method converts all  $\text{NO}_3^-$  to nitrous oxide ( $\text{N}_2\text{O}$ ) via denitrifying bacteria before the sample is analyzed by an IRMS.



## DISSOLVED ORGANIC CARBON AND TOTAL DISSOLVED NITROGEN

### PI

- Craig Carlson (UCSB)

### Technician

- Chance English

### Analysts

- Keri Opalk
- Elisa Halewood

**Support** NSF

## 13.1 Project Goals

The goal of the DOM project is to evaluate dissolved organic carbon (DOC) and total dissolved nitrogen (TDN) concentrations along the P06 zonal transect (30 to 32.5°S & 153°E to 72°W). During the P06 cruise Leg 1 (July – Aug 2017), casts were specifically targeted in order to overlap with the TCO<sub>2</sub> sampling program.

## 13.2 Sampling

DOC profiles were taken at approximately every other station from 26 of 36 niskin bottles ranging the full depth of the water column (68 stations; ~1800 DOC and 600 TDN samples). DOC samples were passed through an inline filter holding a combusted GF/F filter attached directly to the Niskin for samples in the top 500 m of each cast. This was done to eliminate particles larger than 0.7 µm from the sample. Samples from deeper depths were not filtered. Previous work has demonstrated that there is no resolvable difference between filtered and unfiltered samples in waters below the upper 500 m at the µmol kg<sup>-1</sup> resolution. All samples were rinsed 3 times with about 5 mL of seawater and collected into combusted 40 mL glass EPA vials. Samples were fixed with 50 µL of 4N Hydrochloric acid and stored at 4°C on board. Samples were shipped back to UCSB for analysis via high temperature combustion on Shimadzu TOC-V or TOC L analyzers.

Sample Vials were prepared for this cruise by soaking in 10% Hydrochloric acid, followed by a 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 with DI water and left out to dry.

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

### 13.3 Standard Operating Procedure for DOC Analyses- Carlson Lab UCSB

DOC samples will be analyzed via high temperature combustion using a Shimadzu TOC-V or Shimadzu TOC-L at an in shore based laboratory at the University of California, Santa Barbara. The operating conditions of the Shimadzu TOC-V have been slightly modified from the manufacturer's model system. The condensation coil has been removed and the headspace of an internal water trap was reduced to minimize the system's dead space. The combustion tube contains 0.5 cm Pt pillows placed on top of Pt alumina beads to improve peak shape and to reduce alteration of combustion matrix throughout the run. CO<sub>2</sub> free carrier gas is produced with a Whatman® gas generator [Carlson2010]. Samples are drawn into a 5 ml injection syringe and acidified with 2M HCL (1.5%) and sparged for 1.5 minutes with CO<sub>2</sub> free gas. Three to five replicate 100 µl of sample are injected into a combustion tube heated to 680°C. The resulting gas stream is passed through several water and halide traps, including an added magnesium perchlorate trap. The CO<sub>2</sub> in the carrier gas is analyzed with a non-dispersive infrared detector and the resulting peak area is integrated with Shimadzu chromatographic software. Injections continue until the at least three injections meet the specified range of a SD of 0.1 area counts, CV ≤ 2% or best 3 of 5 injections.

Extensive conditioning of the combustion tube with repeated injections of low carbon water (LCW) and deep seawater is essential to minimize the machine blanks. After conditioning, the system blank is assessed with UV oxidized low carbon water. The system response is standardized daily with a four-point calibration curve of potassium hydrogen phthalate solution in LCW. All samples are systematically referenced against low carbon water and deep Sargasso Sea (2600 m) or Santa Barbara Channel (400 m) reference waters and surface Sargasso Sea or Santa Barbara Channel sea water every 6 – 8 analyses [Hansell1998]. The standard deviation of the deep and surface references analyzed throughout a run generally have a coefficient of variation ranging between 1-3% over the 3-7 independent analyses (number of references depends on size of the run). Daily reference waters were calibrated with DOC CRM provided by D. Hansell (University of Miami; [Hansell2005]).

### 13.4 DOC calculation

$$\mu\text{MC} = \frac{\text{average sample area} - \text{average machine blank area}}{\text{slope of std curve}}$$

### 13.5 Standard Operating Procedure for TDN analyses- Carlson Lab UCSB

TDN samples were analyzed via high temperature combustion using a Shimadzu TOC-V with attached Shimadzu TNM1 unit at an in-shore based laboratory at the University of California, Santa Barbara. The operating conditions of the Shimadzu TOC-V were slightly modified from the manufacturer's model system. The condensation coil was removed and the headspace of an internal water trap was reduced to minimize the system's dead space. The combustion tube contained 0.5 cm Pt pillows placed on top of Pt alumina beads to improve peak shape and to reduce alteration of combustion matrix throughout the run. Carrier gas was produced with a Whatman® gas generator [Carlson2010] and ozone was generated by the TNM1 unit at 0.5L/min flow rate. Three to five replicate 100 µl of sample were injected at 130mL/min flow rate into the combustion tube heated to 680°C, where the TN in the sample was converted to nitric oxide (NO). The resulting gas stream was passed through an electronic dehumidifier. The dried NO gas then reacted with ozone producing an excited chemiluminescence NO<sub>2</sub> species [Walsh1989] and the fluorescence signal was detected with a Shimadzu TNMI chemiluminescence detector. The resulting peak area was integrated with Shimadzu chromatographic software. Injections continue until at least three injections meet the specified range of a SD of 0.1 area counts, CV ≤ 2% or best 3 of 5 injections.

Extensive conditioning of the combustion tube with repeated injections of low nitrogen water and deep seawater was essential to minimize the machine blanks. After conditioning, the system blank was assessed with UV oxidized low

nitrogen water. The system response was standardized daily with a four-point calibration curve of potassium nitrate solution in blank water. All samples were systematically referenced against low nitrogen water and deep Sargasso Sea reference waters (2600 m) and surface Sargasso Sea water every 6 – 8 analyses [Hansell1998]. Daily reference waters were calibrated with deep CRM provided by D. Hansell (University of Miami; [Hansell2005]).

Dissolved organic nitrogen (DON) concentrations are calculated as the difference between TDN and DIN. Samples with less than 10  $\mu\text{mol/kg}$  DIN are most reliable estimates of DON.

## 13.6 TDN calculation

$$\mu\text{MN} = \frac{\text{average sample area} - \text{average machine blank area}}{\text{slope of std curve}}$$



## CARBON ISOTOPES IN SEAWATER ( $^{14}\text{C}/^{13}\text{C}$ )

### PI

- Ann McNichol (WHOI)

### Technician

- Chance English

A total of 27 samples were collected from 24 stations along Leg 1 of the P06 zonal transect (30-32.5°S & 153°E to 72°W). Samples were taken from only the surface bottle (~ 5m) at each station with approximately 2.5 degrees of spacing between each station. Duplicates were made at three separate stations. Samples were collected in 500 mL airtight glass bottles. Using silicone tubing, the flasks were rinsed 2 times with seawater from the surface niskin. While keeping the tubing at the bottom of the flask, the flask was filled and flushed by allowing it to overflow 1.5 times its volume. Once the sample was taken, about 10 mL of water was removed to create a headspace and 120  $\mu\text{L}$  of 50% saturated mercuric chloride solution was added to the sample. To avoid contamination, gloves were used when handling all sampling equipment and plastic bags were used to cover any surface where sampling or processing occurred.

After each sample was taken, the glass stoppers and ground glass joint were dried and Apiezon-M grease was applied to ensure an airtight seal. Stoppers were secured with a large rubber band wrapped around the entire bottle. Samples were stored in AMS crates in the ship's dry laboratory. Samples were shipped to WHOI for analysis.

The radiocarbon/DIC content of the seawater ( $\text{DI}^{14}\text{C}$ ) is measured by extracting the inorganic carbon as  $\text{CO}_2$  gas, converting the gas to graphite and then counting the number of  $^{14}\text{C}$  atoms in the sample directly using an accelerated mass spectrometer (AMS).

Radiocarbon values will be reported as  $^{14}\text{C}$  using established procedures modified for AMS applications. The  $^{13}\text{C}/^{12}\text{C}$  of the  $\text{CO}_2$  extracted from seawater is measured relative to the  $^{13}\text{C}/^{12}\text{C}$  of a  $\text{CO}_2$  gas standard calibrated to the PDB standard using an isotope ratio mass spectrometer (IRMS) at NOSAMS.





## LADCP

### PI

- Dr. Andreas Thurnherr

### Cruise Participant

- Alma Carolina Castillo-Trujillo

LADCP was collected during full depth CTD casts at all stations by Alma Carolina Castillo-Trujillo and Natalie Zielinski. Preliminary processing and QC was made on board by Alma Carolina Castillo-Trujillo. Approximately every 5 casts or when data was questionable post-processed data was sent to Andreas Thurnherr for further QC.

## 15.1 LADCP system configuration

An upward-looking (UL) and a downward-looking (DL) ADCPs and a rechargeable battery were affixed to the rosette using custom brackets ([Figure 1](#) and [2](#)). The UL instrument was positioned ~5 inches over the top rosette ring while the DL instrument was positioned between Niskin bottles 4 and 6 and affixed through the brackets to the rosette bottom center bar.

An external magnetometer/accelerometer package (independent measurement package; IMP) was installed on the rosette to collect additional pitch, roll and heading data. The instrument was removed from the rosette after station 13 after a leak was found in the pressure case. A star cable was used to connect both UL and DL LADCPs to the battery and deck/connection cables.

While on deck, two communications and one power cable ran from the aft dry lab to the baltic room where the ctd package rested while on transit between stations. One of the power cables connected the battery to a battery charger while the second power cable connected the ADCPs through the star cable to a power supply. The communications cable connected the ADCPS to a MAC computer via a USB serial adapter which was used for communications to the instrument and data download. The LADCP acquisitions computer clock was synced to the master clock via the ship network system.

Two different ADCP instruments were used during the cruise. The Teledyne RDI WHM150 (S/N:24544) as DL and the Teledyne RDI WHM300 (S/N:24997) as the UL. The battery package was a Deepsea Power and Light SB 48 V/16 A (S/N: 02126). All instruments were set up to record velocity data with 8 m bins and zero blanking distance. Staggered pinging was used to avoid previous ping interference.

## 15.2 Problems/Setup changes

For stations 5 to 13 problems were due to a leak in the IMP pressure case. IMP was removed and replaced with a star cable after station 13.

- Station 5: Unable to connect to LADCPs. Data was lost.

- Station 6: Unable to connect to LADCPs. Data was lost.
- Station 7: Unable to connect to UL instrument. Data for UL ADCP data was lost.
- Station 8: Unable to connect to UL instrument. Data for UL ADCP data was lost.
- Station 9: Unable to connect to UL instrument. Data for UL ADCP data was lost.
- Station 10 to 13: Unable to connect to LADCPs. Data was lost.
- Station 31: 2 UL files were created.
- Station 37: 2 UL files were created.

For stations 60, 63, 65, 77, 89 and 90 problems were due to a communication error in the Acquire software. After restarting computer and replacing the Keyspan serial-to-usb port, problem was resolved.

- Station 60: Manually downloaded data.
- Station 63: Manually downloaded data.
- Station 65: Manually downloaded data, USB serial adapter was replaced.
- Station 77: Manually downloaded data. 2 casts were made. Cast 1 was canceled at the surface due to bad weather.
- Station 89: Manually downloaded data.
- Station 90: Manually downloaded data.
- Station 97: Broken beam 3.
- Station 121: 2 casts were made. Cast 1 was canceled at ~600 m due to bad weather.
- Station 126: 2 casts were made. Cast 1 was canceled at the surface due to bad weather.
- Station 130: Due to a CTD altimetry problem, two casts were made and saved into one file. First cast was canceled after ~50m. Data was not downloaded between casts.

DCP programming and data acquisition were carried out by Alma Carolina Castillo-Trujillo and Natalie Zielinski using the LDEO Acquire software running on a MAC computer. Prior to each cast, the corresponding command files were sent to both the UL and DL ADCPs, communications were then terminated, deck cables disconnected and all connections were secured and sealed with dummy plugs. After the rosette was brought back up on deck following a cast, the communication and power cables were connected to the MAC computer. Data acquisition were terminated and files were downloaded with the corresponding command using the Acquire software. The battery was disconnected from the star cable and connected to a charger via a deck cable running from the the baltic room to the dry aft lab. The battery remained connected to the charger between stations. The battery pack was periodically vented manually to prevent pressure build up. Log files were kept for each cast with LADCP and CTD information to ensure all steps were made properly.

## 15.3 Data Processing and Quality Control

The ADCP data was processed daily by AC. Castillo using the Matlab-based LDEO LADCP processing software version IX (1). Processing warnings and figures created through the software were reviewed for signs of anomalies such as rosette rotation and tilt, biased shear, agreement between LADCP and SADCPC velocities, beam strength and range and ADCP distance to the sea bottom. Data was sent to Andreas Thurnherr every 5 stations or when questionable profiles were observed.

Figure 3 and 4 show the preliminary results of zonal and meridional velocities for all the available stations. Maximum values reach up ~40 cm/s in the upper ~200 m. There is a relatively strong northward current (~15 cm/s) on the west side of the Kermadec Trench at -178 W. Vertical velocity were also computed for the first 53 stations using the LADCP\_w software V1.3 (1). Figure 5 shows a contour plot of vertical velocities on available stations. Typical values

range at ~3 cm/s. Vertical propagating signals are seen throughout the transect. Further QC and post-processing of horizontal and vertical velocities at all available stations will be done by Andreas Thurnherr at LDEO post-cruise.

Available for download at <http://www.ldeo.columbia.edu/LADCP>

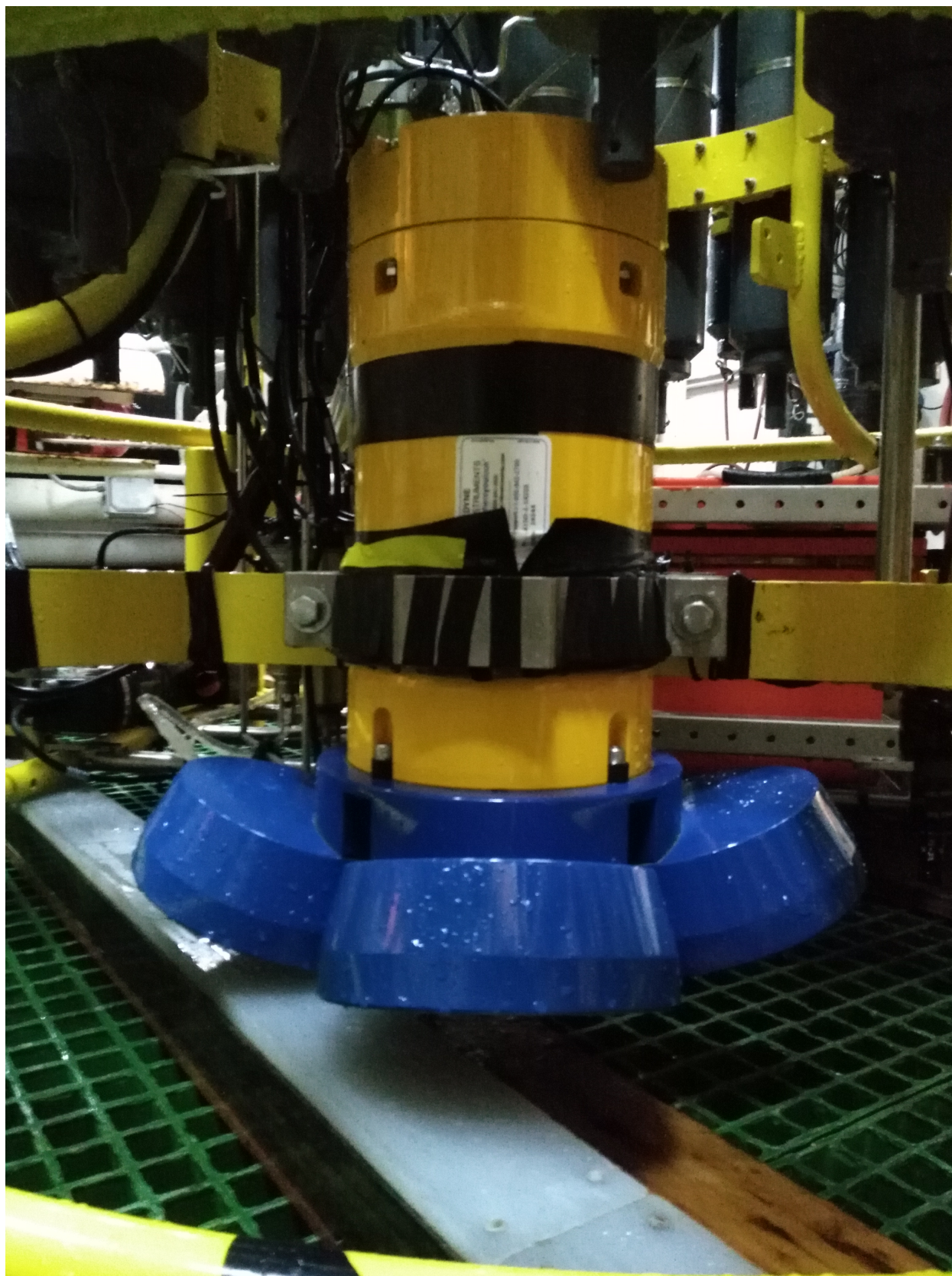


Fig. 15.1: Downward looking ADCP





Fig. 15.2: Upward looking ADCP

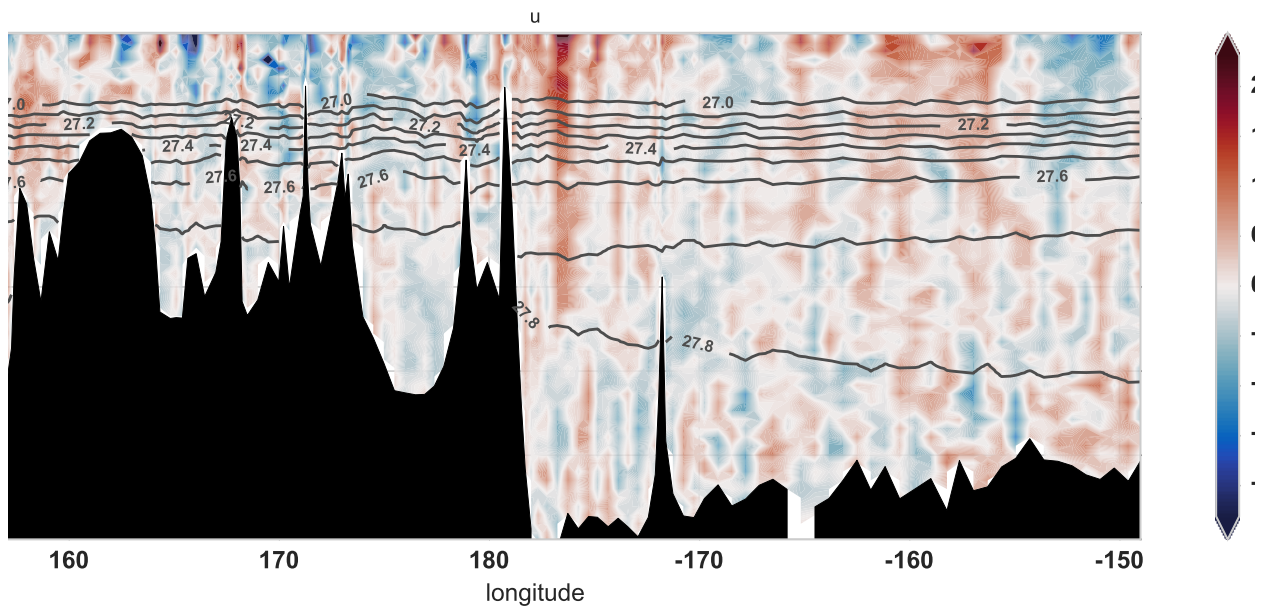


Fig. 15.3: LADCP derived zonal velocities observed from available stations during P06-leg1. Grey lines indicate density contours calculated from CTD observations.

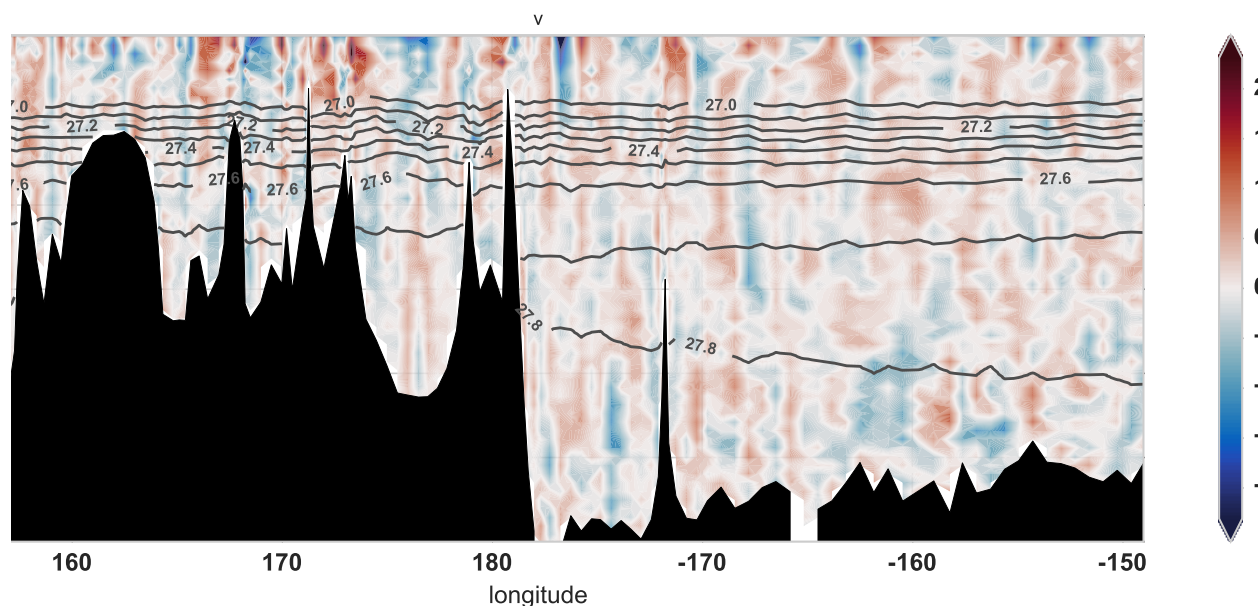


Fig. 15.4: LADCP derived meridional velocities observed from available stations during P06-leg1. Grey lines indicate density contours calculated from CTD observations.

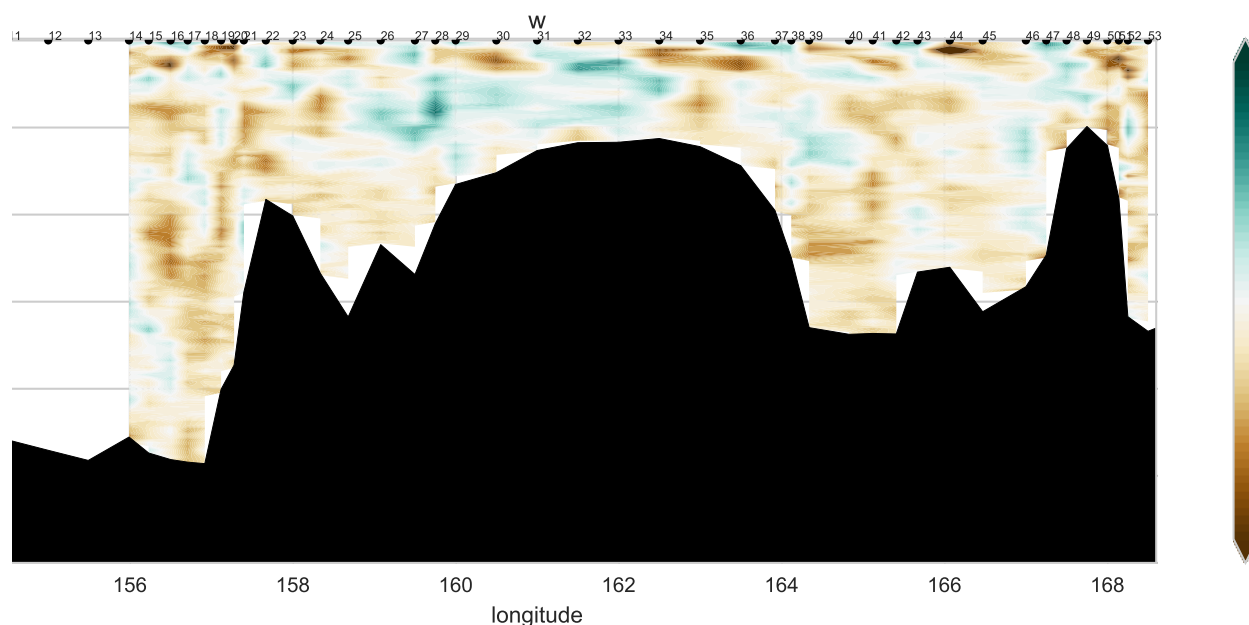


Fig. 15.5: Vertical velocities for stations 1 to 53 during P06-leg1 calculated with the LADCP\_w software V1.3 using LADCP and CTD observations.

## CHIPODS

### PI

- Jonathan Nash

### Cruise Participant

- Ratnaksha Lele

## 16.1 Overview

Chipods are instrument packages that measure turbulence and mixing in the ocean. Specifically, they are used to compute turbulent diffusivity of heat ( $K$ ) which is inferred from measuring dissipation rate of temperature variance ( $\chi$ ) from a shipboard CTD. Chipods are self-contained, robust and record temperature and derivative signals from FP07 thermistors at 100 Hz; they also record sensor motion at the same sampling rate. Details of the measurement and our methods for processing chi can be found in Moum and Nash [2009] (Moum, J., and J. Nash, Mixing Measurements on an Equatorial Ocean Mooring, *Journal of Atmospheric and Oceanic Technology*, 26(2), 317–336, 2009). In an effort to expand our global coverage of deep ocean turbulence measurements, the ocean mixing group at Oregon State University has supported chipod measurements on all of the major global repeat hydrography cruises since Dec 2013.

## 16.2 System Configuration and Sampling

Three 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 100 Hz. Two chipods were oriented such that their sensors pointed upward. The third one was pointed downward.

The up-looking sensors were positioned higher than the Niskin bottles on the rosette in order to avoid measuring turbulence generated by flow around the rosette and/or its wake while its profiling speed oscillates as a result of swell-induced ship-heave. The down-looking sensors were positioned as far from the frame as possible and as close to the leading edge of the rosette during descent as possible to avoid measuring turbulence generated by the rosette frame and lowered ADCP.

Logger Board SN	Pressure Case SN	Up/Down Looker	Cast Used
2025	Ti 44-7	Up	1-143
2030	Ti 44-11	Up	1-107
2032	Ti 44-11	Down	1-143
2027	Ti 44-11	Up	112-143





Fig. 16.1: Chipod pressure case attached on the rosette

## 16.3 Data

The chipods were turned on by connecting the sensors to the pressure case at the beginning of the cruise. They continuously recorded data until the end of the leg. Data was uploaded onto the computer once every day to ensure proper functioning and data collection. SN2030 was replaced by SN2027 before cast 112 due to problems with file acquisition and communicating with the device possibly due to a memory card issue. SN2030 memory card and batteries were replaced soon after.



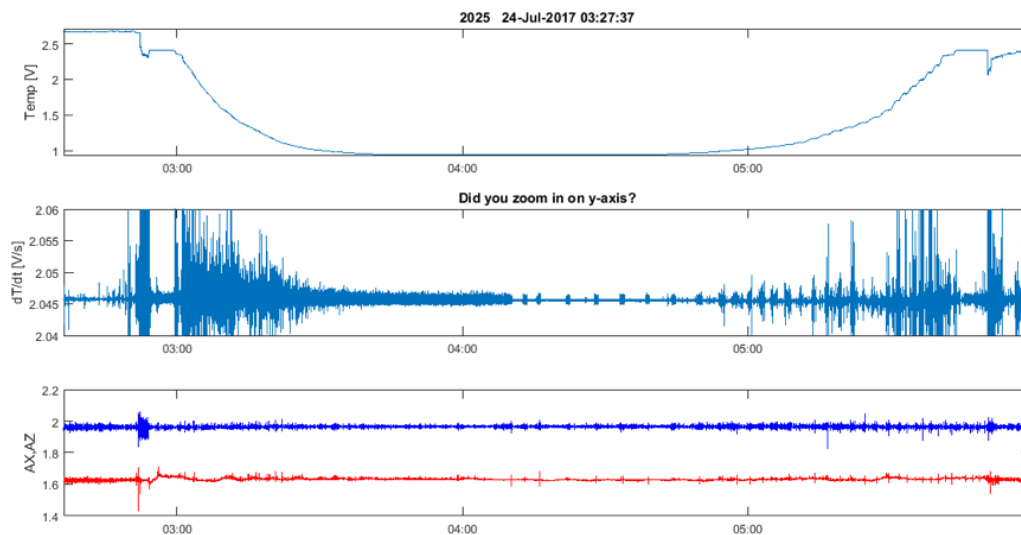


Fig. 16.2: A typical plot of chipod raw data



## FLOAT DEPLOYMENTS

During leg 1 of the GO-SHIP P06 cruise (P06W), a total of 11 profiling floats were deployed, which were part of several programs: 4 UW Argo, 2 SIO SOLO II, 3 SIO Deep SOLO and 2 biogeochemical SOCCOM floats. Co-chief scientist Isa Rosso (postdoc at SIO and SOCCOM personnel) was responsible for all deployments, recording and communicating their deployment details to the various PIs of the programs. The assistance from the ASC marine technicians was necessary for all deployments, first because it was required for any operation on the back deck, and second in order to reduce any possible difficulties with the floats' deployment. Each deployment occurred with the use of line strung to the float, with one end of the line tied to a cleat and the other held by the technician. Deployments were always done on departure from a CTD station while the ship was steaming at 1 knot. Before the deployment, the marine technician communicated with the bridge to disengage the propeller on the side of the deployment, in order to avoid any risk of having the float going through the propeller. The three students working on the opposite shift to Isa Rosso also assisted with the deployments.

A 10-day cycle is set for the UW Argo, SOLO II, and SOCCOM floats: after an initial dive to a parking depth of 1000m, the floats drift for 10 days with the ocean currents at this depth; after a subsequent dive to 2000m, the floats then ascend to the surface, during which data are collected. The 2000m-surface data profiles are then sent to shore via satellite, using an antenna located at the top of the float. Measurements comprehend temperature, salinity, pressure and additional biogeochemical measurements for the SOCCOM type.

The SIO Deep SOLO profiling floats have a different cycle: they dive down to the full ocean depth and drift at 5000 dbar, or 500 dbar shallower than the bottom, with a cycle of approximately 15 days, in order to balance data collection with battery life.

Each of these floats was self-activating, so no initial operations were required before their deployment to activate them, except for the case of Deep SOLO floats for which John Gilson sent some commands few hours before their deployment.

In the following, each float program is discussed.

### 17.1 SOCCOM floats

#### PIs

- Steve Riser
- Ken Johnson
- Lynne Talley

Two biogeochemical floats have been deployed, as part of the “Southern Ocean Carbon and Climate Observations and Modeling” project (SOCCOM). SOCCOM is a U.S. project sponsored by NSF that focuses on carbon and climate in the Southern Ocean. Its goal is to deepen our knowledge of the processes that regulate the carbon export in the Southern Ocean. So far, SOCCOM has 82 active floats, and the data are available to the public at <http://socc.com.princeton.edu/content/float-data>. The floats are equipped with CTD, oxygen (Anderaa optode 4330), nitrate (MBARI/ISUS),

FLBB bio-optical (Wetlabs) and pH (Deep-Sea DuraFET) sensors. Data acquisition is made available through Iridium Satellite communication and GPS.

Rick Rupan and Andrew Meyer (UW) tested each float (for both leg 1 and leg 2 of the P06 occupation) at the beginning of the voyage during the port call in Sydney, Australia. They found a malfunction on one of the floats assigned to leg 2, and this float has been sent back to UW for investigation and repair.

Before the deployment of each float, the fluorometer/backscatter and the pH sensors were carefully cleaned using lens paper, 99% isopropyl alcohol and DI water. Co-chief scientist Isa Rosso, SOCCOM personnel responsible for the floats during this voyage, together with the ASC marine technician Jennie Mowatt, were in charge of all SOCCOM float deployments. Additional assistance was received by ASC marine technician Paul Savoy. The procedure required the use of a line strung through the deployment collar of the float. Each deployment occurred on the starboard side, mid-ship, while the ship was steaming at no more than 1 kn. No issues were encountered during the deployments. However, during the last of the SOCCOM float releases (#12372), a swell brought the float back up to ~1m out of the water, but fortunately no sensors hit the ship.

The deployments occurred after the completion of the CTD station that was chosen to be the closest to the planned deployment location and had a bottom depth greater than 2500m. Samples for HPLC and POC analyses were taken from the Niskin bottles, tripped as duplicates, at the surface and at the chlorophyll maxima depths. These samples will be sent to the U.S., where NASA (HPLC) and UCSB (POC) groups will perform the analyses. On board, only the filtration of the samples was required. Full-depth samples of other ocean properties (salts, pH, nitrate, oxygen) were collected and analysed by the different groups on board, in order to calibrate the floats' sensors. In particular, pH samples were collected and analysed by personnel from SIO, Dickson lab; dissolved inorganic carbon samples by personnel from AOML and PMEL; oxygen, nitrate and salinity samples by the ODF group at SIO.

After the deployment, Isa Rosso recorded the details and sent them to the SOCCOM PIs. The location and date of the float deployments are indicated in the table below, with hull and serial numbers, list of parameters measured by the floats and the CTD cast at the location of deployment. Both floats have reported their first profiles and their sensors are working well. The figure below shows an example of profiles for the [float #12380](#).

Table 17.1: summary of the deployment details of the SOCCOM floats

Hull #	Lon	Lat	Date and Time (UTC)	Parameters	P06 station	Deployers
Apex 12380	174° 50.45'W	32° 30.08'S	2017-07-28 23:43	CTD, oxygen, nitrate, pH, fluorescence and backscattering	99	Isa Rosso and Jennie Mowatt
Apex 12372	154° 56.01'W	32° 29.97'S	2017-08-10 17:05	CTD, oxygen, nitrate, pH, fluorescence and backscattering	134	Isa Rosso and Jennie Mowatt

## 17.2 SIO floats

### PIs

- Dean Roemmich
- John Gilson

2 SIO SOLO II floats and 3 SIO Deep SOLO were deployed during the cruise. The SIO SOLO II are part of a global 3°x3° array, while the Deep SOLO are part of the deep array, whose target is to have a float every 5°x5°. Both types of floats are programmed to do a first dive, and to come back to the surface after only hour. The data of this first dive are used by the SIO team to check that the float is working correctly. We have received confirmation that all the floats have reported correctly after 1 hour, and their data look good (the Figure below shows an example for the float [SIO SOLO II #8527](#)).

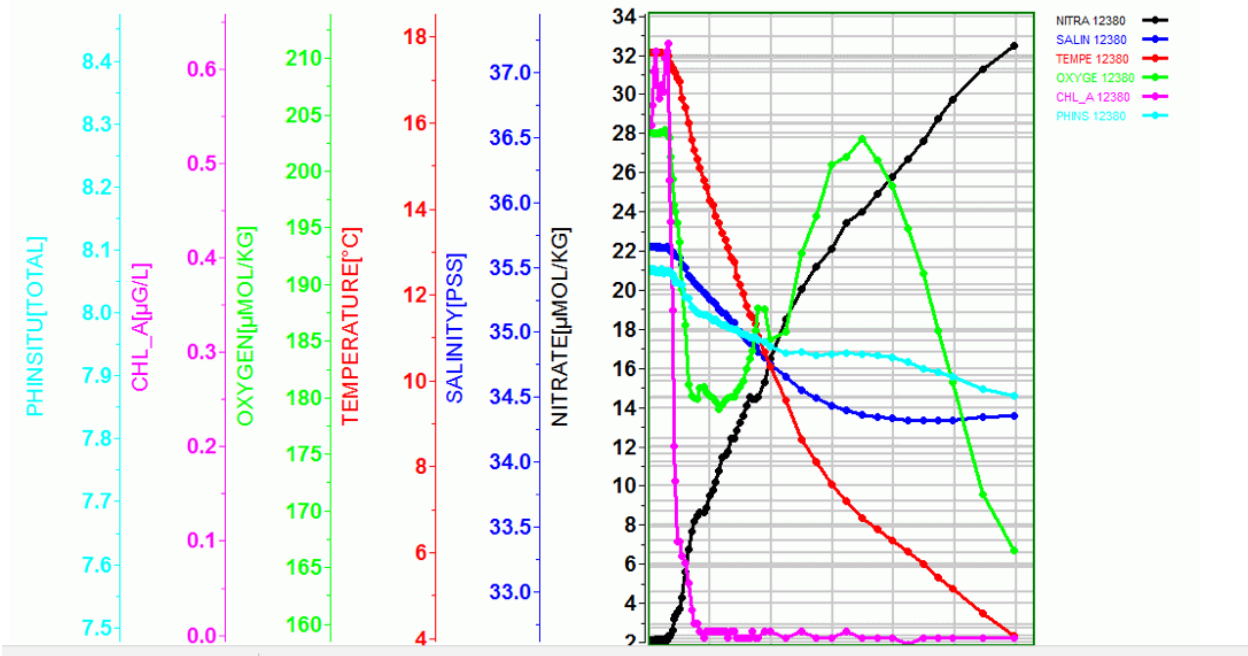
Float/VIZ Plot Page Station(s) 12380SOOCN.TXT; Y Var(s). NITRATE[ $\mu\text{MOL/KG}$ ];SALINITY[PSS];TEMPERATURE[ $^{\circ}\text{C}$ ];OXYGEN[ $\mu\text{MOL/KG}$ ];CHL\_A[ $\mu\text{G/L}$ ];PHINSITU[TOTAL]

Fig. 17.1: pH, oxygen, temperature and nitrate depth profiles for float Apex 12380

These floats were deployed in their original bio-degradable cardboard boxes, as requested, in order to prevent any damage. Two bands of soluble PVA tape were placed around the box, in order to hold it together. Four straps were attached around the box, connected to a water release mechanism (a metal cylinder) at the bottom and with four trailing loops on the top. The deployment line was slipped through the trailing loops at the top, and then secured on the other end to a cleat.

The deployments went all perfectly, except for the float Deep SOLO #6032: during its deployment, when still being lowered to the water, the release opened unexpectedly and the package dropped down from about 50cm above the ocean surface. The float did not, fortunately, report any damage, as we have received confirmation from John Gilson (SIO) that the float activated and sent good data after its first test cast.

After each deployment, the details were recorded by the scientist responsible for the deployment (either Isa Rosso or a CTD watchstander) and sent to John Gilson by co-chief scientist Isa Rosso. The location and date of the SIO float deployments are indicated in the [table](#) below, with serial numbers, CTD cast at the location of deployment and name of the personnel who deployed the floats.

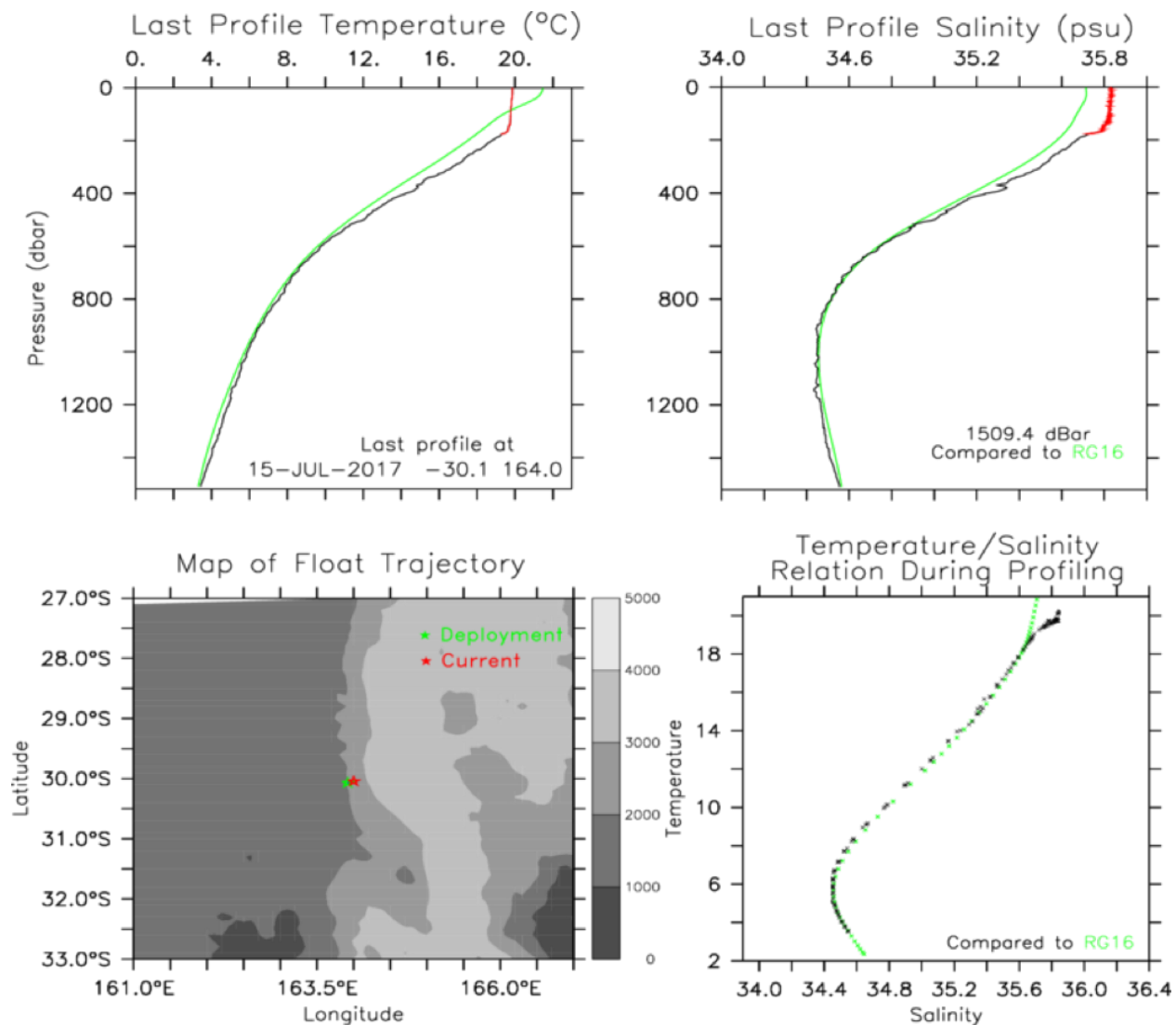


Fig. 17.2: SIO #8527 SOLO II profiles after 1 hour from the deployment

Table 17.2: summary of the deployment details of the 2 SIO SOLO II and 3 Deep SOLO floats

Hull #	Lon	Lat	Date and Time (UTC)	P06 station	Deployers
SIO SOLO II 8527	163° 55.196'E	30° 04.88'S	2017-07-12 01:25	37	Isa Rosso and Jennie Mowatt
SIO SOLO II 8555	178° 18.421'E	32° 53.84'S	2017-07-24 12:51	80	Kimberly Gottschalk and Michael Tepperrassmussen
SIO Deep SOLO 6030	167° 47.336'W	32° 29.99'S	2017-08-02 15:18	115	Isa Rosso and Jennie Mowatt
SIO Deep SOLO 6031	159° 43.06'W	32° 30.15'S	2017-08-08 08:33	127	Maxime Duchet and Michael Tepperrassmussen
SIO Deep SOLO 6032	152° 15.50'W	32° 30.00'S	2017-08-11 23:55	138	Ratnaksha Lele and Paul Savoy

## 17.3 UW floats

### PI Steve Riser

4 UW floats have been deployed during P06 leg 1, as part of the global Argo array. Rick Rupan and Andrew Meyer had tested the floats, during the port call in Sydney, Australia. The floats were all successfully deployed, with no issues. After the deployment, the details were recorded by the scientist responsible for the deployment and sent to Steve Riser, Dana Swift and Rick Rupan by co-chief scientist Isa Rosso. Date, time, location of the deployment, CTD cast associated with the deployments and the name of the deployers are reported in the Table below.

Table 17.3: summary of the deployment details of the 4 UW floats

Hull #	Lon	Lat	Date and Time (UTC)	P06 station	Deployers
UW #12471	155° 00.15'E	30° 04.91'S	2017-07-06 22:26	12	Isa Rosso and Jennie Mowatt
UW #12645	158° 40.66'E	30° 04.99'S	2017-07-09 20:21	25	Rebecca Beadling and Jennie Mowatt
UW #12638	175° 00.04'E	30° 04.78'S	2017-07-10 04:03	73	Kimberly Gottschalk and Michael Tepperrassmussen
UW #12447	148° 54.40'W	32° 29.94'S	2017-08-13 15:24	143	Isa Rosso and Jennie Mowatt





## DRIFTER DEPLOYMENTS

### PI

- Shaun Dolk ([AOML](#))

Fourteen drifters were deployed on P06W for the Global Drifter Program. The deployers were split between the night and the day shifts: Isa Rosso (co-chief scientist), Sabine Mecking (chief scientist) and the CTD watchstanders of each shift helped with the deployment. Secondary assistance was provided by ASC Marine Technicians Jennie Mowatt (night shift), Michael Tepperrassmussen (day shift) and Paul Savoy (day/night shift).

The simple deployment process involved: (1) removing the plastic wrapping from the drifter; (2) carrying the drifter to the back deck; (3) deployment of the drifter, after received confirmation from the bridge; (4) recoding of the deployment details. In case two deployments were required at the same location, the drifter release occurred with 30 seconds of distance between each other, in order to avoid any entanglement amongst the drifters' drogues. After the deployment, the scientist responsible for the operation recorded the details from the monitor in the wet lab, wrote them in the log sheet and Isa Rosso (co-chief scientist) or Sabine Mecking (chief scientist) sent the details to Shaun Dolk at AOML. The [Table](#) below reports the details for each deployment.

Table 18.1: Table of deployments

Drifter #	Date (UTC)	Lat	Lon	Deployers
64829450	2017-07-11 20:42	30°04.91'S	163°29.98'E	Isa Rosso and Jennie Mowatt
64828550	2017-07-29 16:45	32°30.02'S	173°29.86'W	Isa Rosso and Jennie Mowatt
64829010	2017-07-29 16:45	32°30.02'S	173°29.86'W	Isa Rosso and Jennie Mowatt
64829500	2017-08-01 10:23	32°29.95'S	170°00.31'W	Sabine Mecking and Michael Tepperrassmussen
64828540	2017-08-02 23:13	32°29.96'S	167°07.09'W	Isa Rosso and Jennie Mowatt
64829170	2017-08-02 23:13	32°29.96'S	167°07.09'W	Isa Rosso and Jennie Mowatt
64829460	2017-08-04 09:02	32°29.74'S	164°00.17'W	Kimberly Gottschalk and Michael Tepperrassmussen
64828510	2017-08-07 09:21	32°29.68'S	160°59.91'W	Sabine Mecking and Maxime Duchet
64828530	2017-08-07 09:21	32°29.68'S	160°59.91'W	Kimberly Gottschalk and Michael Tepperrassmussen
64828470	2017-08-09 03:04	32°30.23'S	158°00.00'W	Ratnaksha Lele and Paul Savoy
64829030	2017-08-10 12:36	32°29.98'S	155°01.14'W	Rebecca Beadling and Jennie Mowatt
64829510	2017-08-10 12:36	32°29.98'S	155°01.14'W	Natalie Zielinski and Jennie Mowatt
64829540	2017-08-12 01:18	32°30.04'S	152°00.00'W	Maxime Duchet and Michael Tepperrassmussen
64829400	2017-08-13 01:00	32°30.00'S	150°00.50'W	Kimberly Gottschalk and Michael Tepperrassmussen

## STUDENT STATEMENTS

### 19.1 Rebecca L. Beadling

I applied to participate on leg 1 of the U.S. GO-SHIP P06 cruise to gain experience in observational oceanography, to participate in the data collection myself and to learn about the techniques used including CTD deployment and measurements, deployment of floats and drifters, and the collection of water samples for analysis. I also participated in this cruise as a member of the Southern Ocean Carbon and Climate Observations and Modelling (SOCCOM) team, and was able to participate in the deployment of the SOCCOM floats along with my CTD watchstander responsibilities. My work at the University of Arizona has focused on carrying out modeling experiments and analyzing model output to gain a deeper understanding of ocean circulation in the North Atlantic Ocean. Specifically my research as focused on the Northern Hemisphere Atlantic Meridional Overturning Circulation, and how this large scale circulation is projected to change into the future.

Analyzing the results from modeling experiments requires a comprehensive understanding of geophysical fluid dynamics, knowledge of the framework of models, knowledge of both the atmospheric and oceanic circulation at the global scale, and an understanding of how these systems are observed in reality. It is this last piece that I felt was completely lacking from my understanding of oceanography, and the most critical to being able to make successful model to observation comparisons. After participation as a CTD watchstander on this cruise and through in-depth conversations with other scientists on board, I am walking away with a detailed knowledge of observational techniques and better strategies to bridge the gap from models to observations. In addition to my role as a CTD watchstander I also served as the primary alkalinity sampler on my shift, collecting alkalinity samples to be processed following each CTD recovery.

Furthermore, on this cruise spent time learning the Python programming language and plotted the underway Acoustic Doppler Current Profiler data from the cruise to look at the currents in the top 1000 meters as we transited. I also contributed multiple times to the cruise blog ([usgoship-p062017.blogspot.com](http://usgoship-p062017.blogspot.com)) and my own personal blog focused on science communication to a broader audience ([beadlingatsea.wordpress.com](http://beadlingatsea.wordpress.com)). My experiences and knowledge gained on this cruise will prove to be invaluable to advancing in my field, and I plan to remain in contact with those on board for future research collaborations.

### 19.2 Maxime Duchet

Pour changer, en voici un ecrit en francais clavier qwerty, vous excuserez les accents. Le travail est finalement assez simple et repetitif. Chaque jour, on effectue en moyenne 2 a 3 “cast”, en fonction de la profondeur de la station. Le deroulement est chaque fois le meme:

1. On met le CTD (plus communement appele rosetta) dans l’eau. On se trouve alors derriere plusieurs ecrans : un ordinateur qui enregistre les mesures effectues par la CTD (capteurs de temperature, salinite..), un qui nous indique la profondeur et la tension du fil retenant la structure de 36 bouteilles, et enfin un ecran pour voir le winch tourner. On passe des appels radio a la “Baltic room” ou se trouvent les winch operators pour indiquer la vitesse de descente, stopper la rosette a 10m du fond, et indiquer les differentes profondeurs auxquelles

s'arreter lors de la remontee. On ferme les bouteilles et note quelques informations. A surveiller: tension ne dois pas faire de sauts ni etre negative, bottom approach ne pas crasher la rosette, ne pas oublier de fermer une bouteille.

2. Une fois la rosette sur le deck, on effectue des prelevements selon divers procedes en fonction des parametres mesures. En gros, on remplit des bouteilles d'eau.
3. On prepare la rosette: on ouvre les bouteilles, on les vide, on tend les fils de nylon, on nettoie les capteurs.
4. Si on a de la chance, la prochaine station est dans 2h et on a le temps de chiller au ping pong ou dans la lounge.

Le plus important : prendre du plaisir en mer et profiter de l'experience humaine.

PS : si vous prevoyez de participer aux 4 repas journaliers, n'oubliez pas la gym, votre ventre appreciera.

## **19.3 Kimberly Gottschalk**

My first experience at sea, aboard the RVIB Palmer, was a fantastic voyage across the South Pacific. Serving as a CTD Watchstander for the P06W provided me with invaluable insight and working knowledge of how data is collected and processed at sea. Over the course of the past six weeks I have developed a greater appreciation of the work of the science party and an understanding of why gaps in data may occur on open ocean lines. The work of a CTD student required a keen eye for detail and communication for successful operation. In my off time I have had the pleasure of attending science talks, speaking with others about their work, helping with sampling, and plot creation. Between monitoring the rosette during casts the watchstanders had the opportunity to hold a journal club focusing on processes and water masses along our line - a wonderful learning experience!

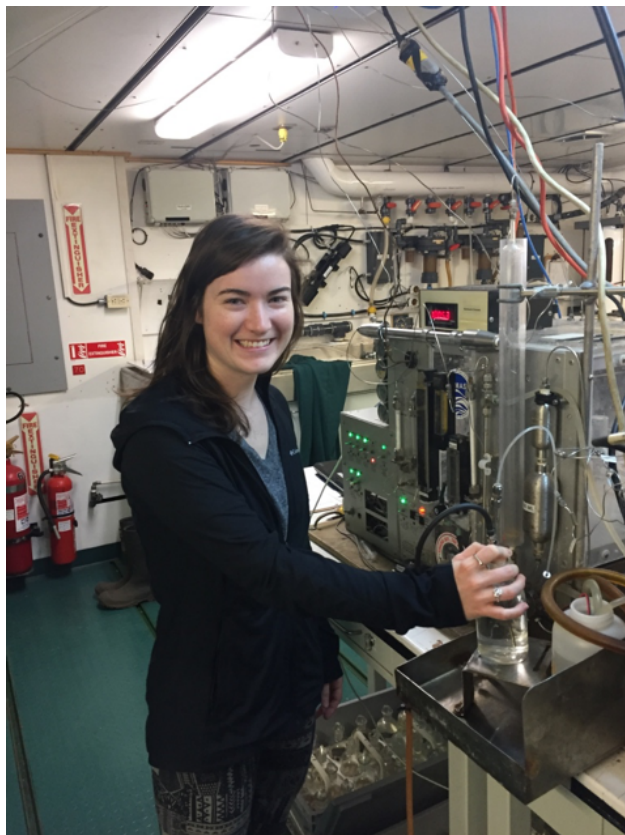
As the cruise comes to a wrap, I'll miss being at sea. The view of a sunset over the ocean, watching an Orca swim under our bow while on station, even the gentle rolling of the ship - are all things I will not soon forget. This may have been my first time at sea, but it will not be my last.

## **19.4 Ratnaksha Lele**

Being on board the RVIB Nathaniel B. Palmer for GO-SHIP P06 has been an experience that I will cherish for the rest of my life! This was my first time on a multi-week research cruise, and I was rather excited to leave the worries of the world behind as we set our sights to the horizon to our east in Sydney. My job as CTD-watchstander was primarily to prepare the rosette for each deployment and monitor the cast in the computer lab to ensure that the cast went smoothly, keeping an eye on instrument displays and firing the bottles at the assigned depths. It was exciting to see the CTD profiles on the computer in real time and be able to identify (debate) different water masses in the South Pacific which I very recently studied for my first year exams at SIO.

Once the rosette was back on deck after the cast, I thoroughly enjoyed my duties as Sample Cop, bringing necessary order to the chaos of sampling. I was also involved in downloading data from Chi-pods (instruments that measure turbulent mixing) and troubleshooting through glitches if and when they occurred. The cruise has helped me appreciate the behind the scenes effort put into every CTD cast by the science team, and the painstaking effort required to collect and measure samples for the consumption of researchers worldwide.

I hope to use the data collected on this cruise and previous P06 cruises to quantify changes in abyssal water masses in the South Pacific basin as part of my PhD research at SIO. I'm grateful to the GO-SHIP program for providing me with this wonderful opportunity and hope to continue to participate and contribute to future cruises as well.



## 19.5 Kelly McCabe

I want to thank GO-SHIP for providing me with this opportunity to assist the chlorofluorocarbon (CFC) team—Jim Happell and David Cooper—with sampling the CTD and onboard sample processing. As transient tracers, CFCs are a standard measurement on GO-SHIP cruises. Measuring CFC concentrations as well as sulfur hexafluoride (SF<sub>6</sub>), another tracer, allows physical and chemical oceanographers alike to understand ocean circulation and the distinct chemical characteristics of water masses. This is extremely valuable for understanding the global oceans and their role in mitigating climate. I am now able to collect CFC samples, successfully run them on a gas chromatograph, and interpret their gas chromatograms. Additionally, I created and analyzed CFC depth profiles in ODV. I can now identify distinct water masses based on a specific CFC signature such as Antarctic Bottom Water found in the Kermadec trench. In an attempt to objectively map CFC depth profiles, I also began coding in python and strengthened my MATLAB coding abilities.

I owe an additional thanks to GO-SHIP for helping support my PhD studies. In addition to my CFC responsibilities, I collected 375 samples for dissolved organic phosphorus analysis. All samples were filtered and stored frozen to preserve for land based analyses. These samples will greatly increase the special coverage of DOP data within the western Pacific, a previously under-sampled region. I am grateful to have had the opportunity to assist the GO-SHIP CFC team as well as contribute a new measurement. I hope to continue to work with the GO-SHIP program in the future.

## 19.6 Natalie Zielinski

The ability to sail as a student aboard the GO-SHIP NPB1706 cruise from Sydney to Papeete has granted me the invaluable opportunity for hands-on learning and networking with leading scientists in oceanography. Originally

hired on as a Conductivity Temperature Depth (CTD) Watch Stander, I also took on the responsibility of running the Lowered Acoustic Current Doppler Profiler (LADCP) during the night shift. Having prior experience at sea aboard the NBP, I felt right at home with the 12 on – 12 off shift schedule and adjusted well to having breakfast for lunch everyday. The need for additional personnel during water sampling also allowed me to learn how to sample alkalinity, nutrients and salts from the Niskin bottles, a task that I was happy to be a part of since it provided time to chat with my fellow scientists and to take part in unrestricted singing to the various songs we listened to.

As the sole LADCP contact for the night shift, I was responsible for turning the instrument on and off, recharging the battery, and ensuring that the data were downloaded and backed up to the computer. This meant revisiting my Unix coding skills as the ADCP software is strictly run with Unix. During each descent, I join my fellow student colleague, Rebecca Beadling from the University of Arizona, at the CTD monitor station to oversee the deployment and trigger Niskin bottles on the way up. Forced to sit together for 4 to 5 hours, we took advantage of the time by starting a Python Club instructed by wonderful, Co-Chief Scientist Dr. Isabella Rosso where we learned to code, expanded our capabilities with the guitar, read different papers and novels, and shared our life experiences for personal growth. I could not have asked for a better team to be a part of, with the addition of all the nightshift personnel including Technician Kelsey Volgel from Scripps who was another assiduous member of our Python Club.

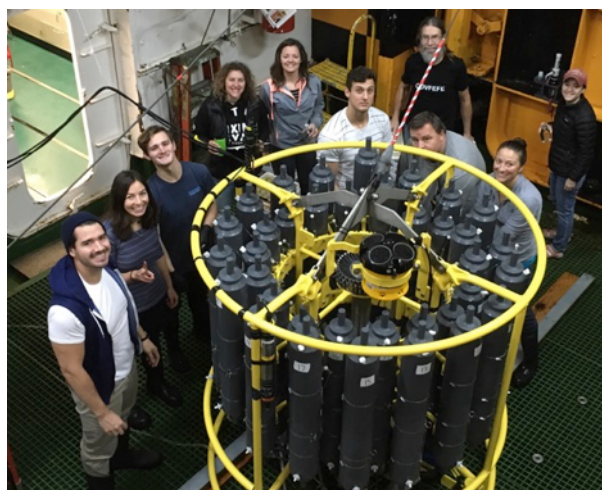


Fig. 19.1: The hardworking and also fun night shift science party. Long live Chuck's Boots

I also took part in some preliminary analysis for the cruise by drafting cross-sections of potential temperature, salinity, density, and calculated geostrophic velocity to be compared to those generated by Chief Scientist Dr. Sabine Mecking. The geostrophic velocities I generated were also compared to measured LADCP circulation for initial insight into the general circulation, particularly in the bathymetrically constrained areas closer to Australia. Later in the cruise while we were experiencing some rather unruly weather that prevented deployment of the CTD, Dr. Mecking asked me to give a science talk. Thrilled at the opportunity to practice my scientific speaking skills and discuss results from my Master's degree, I happily accepted. I also wrote a post for the official NBP1706 Blog run by Co-Chief Scientist Dr. Isabella Rosso about my responsibilities with the ADCP on the night shift that can be found at <http://usgoship-p062017.blogspot.com>.

I can't begin to describe how thankful I am for US GO-SHIP and the opportunity to sail as a student. I have been able to advance my observing, descriptive, and analytical skills as an aspiring young professional in oceanography, as well as to engage with outstanding professional scientist and technicians. I have grown professionally and personally from this experience, making memories and initiating relationships that will help drive my career. I'm particularly grateful for Dr. Sabine Mecking who took the time to get to know each student, encouraged our participation in all aspects of data collection, and was a rigorous ping-pong competitor, for Dr. Isabella Rosso and her ability to reignite my passion for scientific research, her motivation to believe in myself, and professional counsel as I transition from being a student to a career in oceanography and ocean engineering, for Mr. John Calderwood whose skills as a technician extended to the 3D printer, and for Mr. Barry Bjork whom with I spent a countless number of hours tackling cross-word puzzles

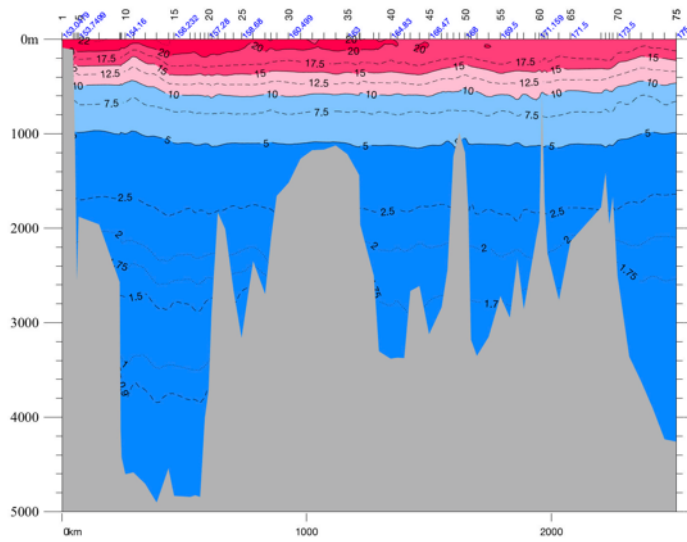


Fig. 19.2: Cross-section of potential temperature for stations 01 to 75.

and inventing new words. I will forever be grateful for this experience and hope to remain affiliated to the program through consideration for additional ocean-going positions in the future.





## ABBREVIATIONS

<b>ADCP</b>	Acoustic Doppler Current Profiler
<b>AOML</b>	Atlantic Oceanographic and Meteorological Laboratory
<b>AP</b>	Particulate Absorbance Spectra
<b>APL</b>	Applied Physics Laboratory
<b>ASC</b>	Antarctic Support Contract
<b>Bigelow</b>	Bigelow Laboratory for Ocean Sciences
<b>CDOM</b>	Chromophoric Dissolved Organic Matter
<b>CFCs</b>	Chlorofluorocarbons
<b>CTDO</b>	Conductivity Temperature Depth Oxygen
<b>DIC</b>	Dissolved Inorganic Carbon
<b>DOC</b>	Dissolved Organic Carbon
<b>ECO</b>	Edison Chouest Offshore
<b>ENSTA</b>	ENSTA ParisTech
<b>ETHZ</b>	Edgenössische Technische Hochschule Zürich
<b>FSU</b>	Florida State University
<b>HPLC</b>	High-Performance Liquid Chromatography
<b>LDEO</b>	Lamont-Doherty Earth Observatory - Columbia University
<b>LADCP</b>	Lowered Acoustic Doppler Profiler
<b>MBARI</b>	Monterey Bay Aquarium Research Institute
<b>NOAA</b>	National Oceanographic Atmospheric Administration
<b>NBP</b>	RVIB Nathaniel B Palmer
<b>NSF</b>	National Science Foundation
<b>ODF</b>	Ocean Data Facility - <i>SIO</i>
<b>OSU</b>	Oregon State University
<b>PMEL</b>	Pacific Marine Environmental Laboratory
<b>POC</b>	Particulate Organic Carbon
<b>POM</b>	Particulate Organic Matter

**Princeton** Princeton University

**RSMAS** Rosenstiel School of Marine and Atmospheric Science - *U Miami*

**SEG** Shipboard Electronics Group

**SF<sub>6</sub>** Sulfur Hexafluoride

**SIO** Scripps Institution of Oceanography

**SOCOM** The Southern Ocean Carbon and Climate Observations and Modeling project. <http://socom.princeton.edu/>

**STS** Shipboard Technical Support - *SIO*

**TAMU** Texas A&M University

**TDN** Total Dissolved Nitrogen

**UA** University of Arizona

**UCI** University of California Irvine

**U Colorado** University of Colorado

**UCSB** University of California Santa Barbara

**UCSD** University of California San Diego

**UH** University of Hawaii

**U Maine** University of Maine

**U Miami** University of Miami

**UNSW** University of New South Wales

**U Puerto Rico** University of Puerto Rico

**USAP** United States Antarctic Program

**USCG** United States Coast Guard

**UT** University of Texas

**UW** University of Washington

**UWA** University of Western Australia

**U. Wisconsin** University of Wisconsin

**VUB** Vrije Universiteit Brussel

**WHOI** Woods Hole Oceanographic Institution

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## BOTTLE QUALITY COMMENTS

Station	Cast	Bottle	Param	Code	Comment
4	1	2	OXYGEN	3	Flask 692 suspected bad; code 3 to be conservative
4	1	32	PH_TMP	5	MISTRIP
4	1	32	PH_TOT	5	MISTRIP
6	1	24	OXYGEN	4	Bad O2 Flask
7	1	6	NITRAT	4	mis trip? Oxy high nuts low
7	1	6	PHSPHT	4	mis trip? Oxy high nuts low
7	1	6	SILCAT	4	mis trip? Oxy high nuts low
7	1	6	NITRIT	4	mis trip? Oxy high nuts low
8	1	34	PH_TOT	4	mis trip
8	1	34	PH_TMP	4	mis trip
10	1	11	NITRAT	4	all nut values low
10	1	11	SILCAT	4	all nut values low
10	1	11	PHSPHT	4	all nut values low
10	1	11	NITRIT	4	all nut values low
10	1	26	OXYGEN	3	Flask 692 suspected bad; code 3 to be conservative
11	2	8	PH_TOT	5	LEAKY NISK
11	2	8	PH_TMP	5	LEAKY NISK
12	1	24	OXYGEN	4	Bad O2 Flask
14	1	26	OXYGEN	3	Flask 692 suspected bad; code 3 to be conservative
15	1	26	OXYGEN	3	Flask 692 suspected bad; code 3 to be conservative
16	1	17	NITRAT	4	high nuts low oxy
16	1	17	NITRIT	4	high nuts low oxy
Continued on next page					

Table B.1 – continued from previous page

Station	Cast	Bottle	Param	Code	Comment
16	1	17	SILCAT	4	high nuts low oxy
16	1	17	PHSPHT	4	high nuts low oxy
16	1	22	NITRAT	4	all nuts high, oxy low, mistrip? Check bottle salts
16	1	22	SILCAT	4	all nuts high, oxy low, mistrip? Check bottle salts
16	1	22	PHSPHT	4	all nuts high, oxy low, mistrip? Check bottle salts
16	1	22	NITRIT	4	all nuts high, oxy low, mistrip? Check bottle salts
16	1	24	PHSPHT	4	all nuts high, oxy low, mistrip? Check bottle salts
16	1	24	OXYGEN	4	Bad O2 Flask
16	1	24	SILCAT	4	all nuts high, oxy low, mistrip? Check bottle salts
16	1	24	NITRAT	4	all nuts high, oxy low, mistrip? Check bottle salts
16	1	24	NITRIT	4	all nuts high, oxy low, mistrip? Check bottle salts
18	1	2	OXYGEN	3	Flask 692 suspected bad; code 3 to be conservative
18	1	28	NITRIT	4	all nuts high, oxy low, mistrip? Check bottle salts
18	1	28	SILCAT	4	all nuts high, oxy low, mistrip? Check bottle salts
18	1	28	PHSPHT	4	all nuts high, oxy low, mistrip? Check bottle salts
18	1	28	NITRAT	4	all nuts high, oxy low, mistrip? Check bottle salts
19	1	15	SILCAT	3	high sil?
22	1	26	OXYGEN	3	Flask 692 suspected bad; code 3 to be conservative
23	1	10	NITRIT	4	all nuts high
23	1	10	NITRAT	4	all nuts high
23	1	10	PHSPHT	4	all nuts high
23	1	10	SILCAT	4	all nuts high
25	1	26	OXYGEN	3	Flask 692 suspected bad; code 3 to be conservative
27	1	2	OXYGEN	3	Flask 692 suspected bad; code 3 to be conservative
28	1	27	OXYGEN	4	Bad O2 Flask
29	1	3	PHSPHT	4	all nuts low, mis-sampled
29	1	3	SILCAT	4	all nuts low, mis-sampled
29	1	3	NITRAT	4	all nuts low, mis-sampled
29	1	3	NITRIT	4	all nuts low, mis-sampled
29	1	14	PHSPHT	4	po4 value high
30	1	2	OXYGEN	3	Flask 692 suspected bad; code 3 to be conservative

Continued on next page



Table B.1 – continued from previous page

Station	Cast	Bottle	Param	Code	Comment
31	1	2	OXYGEN	3	Flask 692 suspected bad; code 3 to be conservative
33	1	11	NITRIT	4	all nuts high mis-sampled
33	1	11	SILCAT	4	all nuts high mis-sampled
33	1	11	PHSPHT	4	all nuts high mis-sampled
33	1	11	NITRAT	4	all nuts high mis-sampled
36	1	2	OXYGEN	3	Flask 692 suspected bad; code 3 to be conservative
37	1	27	OXYGEN	4	Bad O2 Flask
39	1	2	OXYGEN	3	Flask 692 suspected bad; code 3 to be conservative
40	1	2	OXYGEN	3	Flask 692 suspected bad; code 3 to be conservative
42	1	27	OXYGEN	4	Bad O2 Flask
43	1	2	OXYGEN	3	Flask 692 suspected bad; code 3 to be conservative
46	1	27	OXYGEN	4	Bad O2 Flask
49	1	15	OXYGEN	4	Bad O2 Flask
52	1	30	OXYGEN	3	Bottle Oxygen is a little high on this one
53	1	27	OXYGEN	4	Bad O2 Flask
55	1	26	OXYGEN	3	Flask 692 suspected bad; code 3 to be conservative
Continued on next page					

Table B.1 – continued from previous page

Station	Cast	Bottle	Param	Code	Comment
57	1	26	OXYGEN	3	Flask 692 suspected bad; code 3 to be conservative
58	1	27	OXYGEN	4	Bad O2 Flask
59	1	26	OXYGEN	3	Flask 692 suspected bad; code 3 to be conservative
59	1	28	NITRAT	4	mis trip code bottle and all other parameters
59	1	28	PHSPHT	4	mis trip code bottle and all other parameters
59	1	28	NITRIT	4	mis trip code bottle and all other parameters
59	1	28	SILCAT	4	mis trip code bottle and all other parameters
60	1	27	OXYGEN	4	Bad O2 Flask
63	1	26	OXYGEN	3	Flask 692 suspected bad; code 3 to be conservative
64	1	3	OXYGEN	4	O2 value very high; does not fit profile
64	1	26	OXYGEN	3	Flask 692 suspected bad; code 3 to be conservative
65	1	2	OXYGEN	3	Flask 692 suspected bad; code 3 to be conservative
68	1	2	NITRIT	3	all nut values low
68	1	2	SILCAT	3	all nut values low
68	1	2	PHSPHT	3	all nut values low
68	1	2	NITRAT	3	all nut values low
69	1	26	OXYGEN	3	Flask 692 suspected bad; code 3 to be conservative
71	1	2	OXYGEN	3	Flask 692 suspected bad; code 3 to be conservative
75	1	26	OXYGEN	3	Flask 692 suspected bad; code 3 to be conservative
Continued on next page					

Table B.1 – continued from previous page

Station	Cast	Bottle	Param	Code	Comment
76	1	2	OXYGEN	3	Flask 692 suspected bad; code 3 to be conservative
78	1	2	OXYGEN	3	Flask 692 suspected bad; code 3 to be conservative
79	1	2	OXYGEN	3	Flask 692 suspected bad; code 3 to be conservative
85	1	2	OXYGEN	3	Flask 692 suspected bad; code 3 to be conservative
89	1	2	OXYGEN	3	Flask 692 suspected bad; code 3 to be conservative
90	1	31	OXYGEN	3	Bottle Oxygen is a little high on this one
90	1	36	OXYGEN	3	Bottle Oxygen is a little low on this one
91	1	2	OXYGEN	3	Flask 692 suspected bad; code 3 to be conservative
94	1	2	OXYGEN	3	Flask 692 suspected bad; code 3 to be conservative
95	1	2	OXYGEN	3	Flask 692 suspected bad; code 3 to be conservative
95	1	35	PH_TOT	4	mis trip
95	1	35	PH_TMP	4	mis trip
98	1	36	OXYGEN	3	Bottle Oxygen is a little low on this one
100	1	26	OXYGEN	3	Flask 692 suspected bad; code 3 to be conservative
Continued on next page					

Table B.1 – continued from previous page

Station	Cast	Bottle	Param	Code	Comment
101	1	8	PH_TMP	3	3 bottle cracked
101	1	8	PH_TOT	3	3 bottle cracked
101	1	24	OXYGEN	5	sample lost
104	1	26	OXYGEN	3	Flask 692 suspected bad; code 3 to be conservative
105	1	2	OXYGEN	3	Flask 692 suspected bad; code 3 to be conservative
108	1	2	OXYGEN	3	Flask 692 suspected bad; code 3 to be conservative
111	1	2	OXYGEN	3	Flask 692 suspected bad; code 3 to be conservative
114	1	2	OXYGEN	3	Flask 692 suspected bad; code 3 to be conservative
117	1	2	OXYGEN	3	Flask 692 suspected bad; code 3 to be conservative
118	1	11	PH_TOT	5	BOTTLE BROKE
118	1	11	PH_TMP	5	BOTTLE BROKE
120	1	26	OXYGEN	3	Flask 692 suspected bad; code 3 to be conservative
121	2	24	PH_TMP	4	mistrip
121	2	24	PH_TOT	4	mistrip
122	1	26	OXYGEN	3	Flask 692 suspected bad; code 3 to be conservative
123	1	2	OXYGEN	3	Flask 692 suspected bad; code 3 to be conservative
123	1	24	PH_TMP	4	MISTRIP?
123	1	24	PH_TOT	4	MISTRIP?
123	1	31	PH_TMP	4	mistrip
123	1	31	PH_TOT	4	mistrip
128	1	24	OXYGEN	5	sample lost
Continued on next page					

Table B.1 – continued from previous page

Station	Cast	Bottle	Param	Code	Comment
128	1	26	OXYGEN	3	O2 Value very high; does not fit profile



## CALIBRATION DOCUMENTS

# 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: 2569

CALIBRATION DATE: 20-Sep-16

SBE 4 CONDUCTIVITY CALIBRATION DATA

PSS 1978: C(35,15,0) = 4.2914 Siemens/meter

## COEFFICIENTS:

g = -1.04785719e+001

h = 1.58738716e+000

i = 9.17747073e-005

j = 9.25102032e-005

CPcor = -9.5700e-008 (nominal)

CTcor = 3.2500e-006 (nominal)

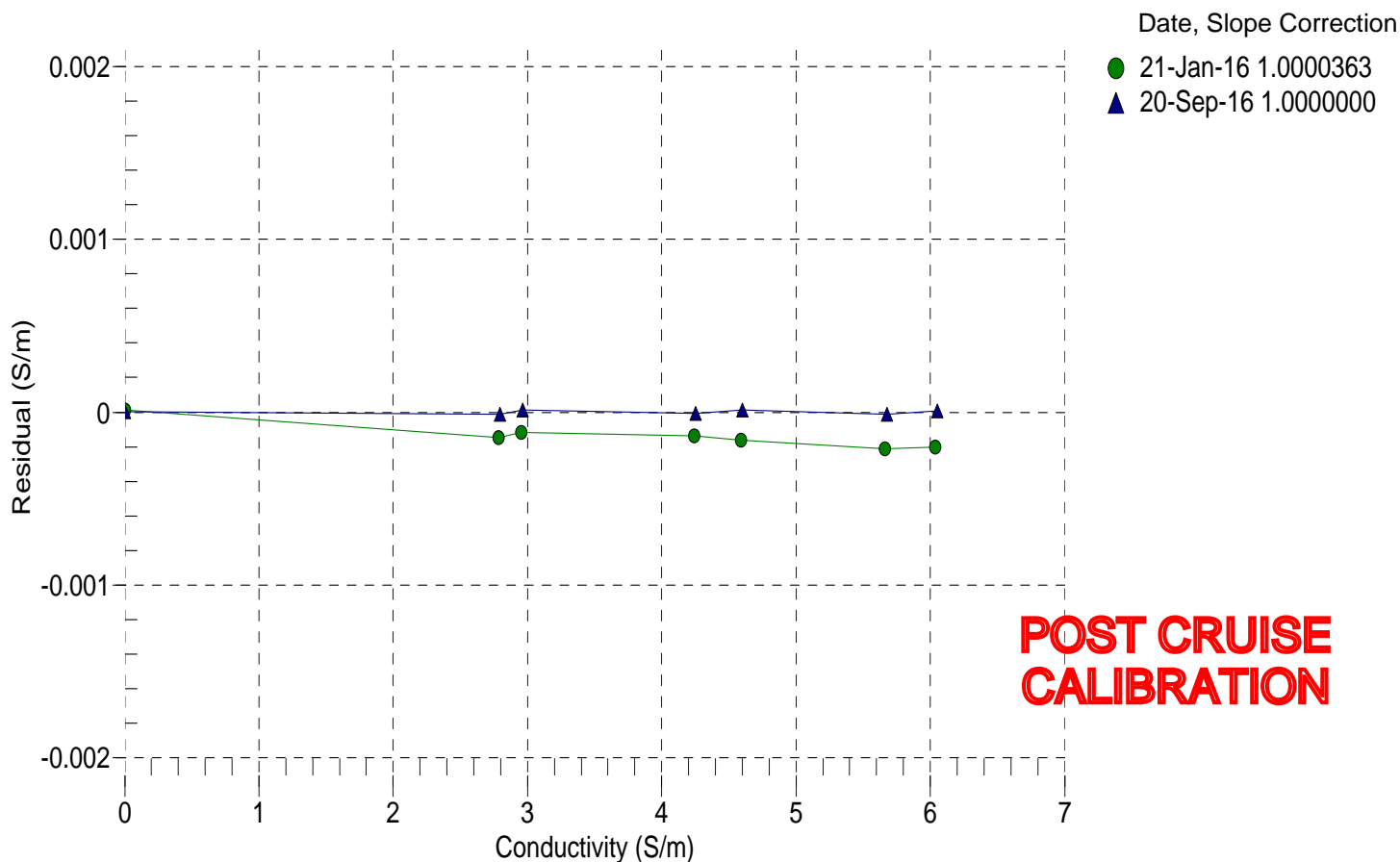
BATH TEMP (° C)	BATH SAL (PSU)	BATH COND (S/m)	INSTRUMENT OUTPUT (kHz)	INSTRUMENT COND (S/m)	RESIDUAL (S/m)
0.0000	0.0000	0.00000	2.56859	0.00000	0.00000
-1.0000	34.6548	2.79278	4.91464	2.79277	-0.00001
1.0000	34.6551	2.96350	5.02254	2.96351	0.00001
15.0000	34.6566	4.25409	5.77286	4.25408	-0.00001
18.5000	34.6563	4.59943	5.95753	4.59944	0.00001
29.0001	34.6543	5.67877	6.50068	5.67876	-0.00001
32.5001	34.6476	6.04990	6.67716	6.04991	0.00001

f = Instrument Output (kHz)

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

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

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: 2819

CALIBRATION DATE: 11-Apr-17

SBE 4 CONDUCTIVITY CALIBRATION DATA

PSS 1978: C(35,15,0) = 4.2914 Siemens/meter

## COEFFICIENTS:

g = -9.85851217e+000

h = 1.38071290e+000

i = 3.34284591e-004

j = 4.61675746e-005

CPcor = -9.5700e-008 (nominal)

CTcor = 3.2500e-006 (nominal)

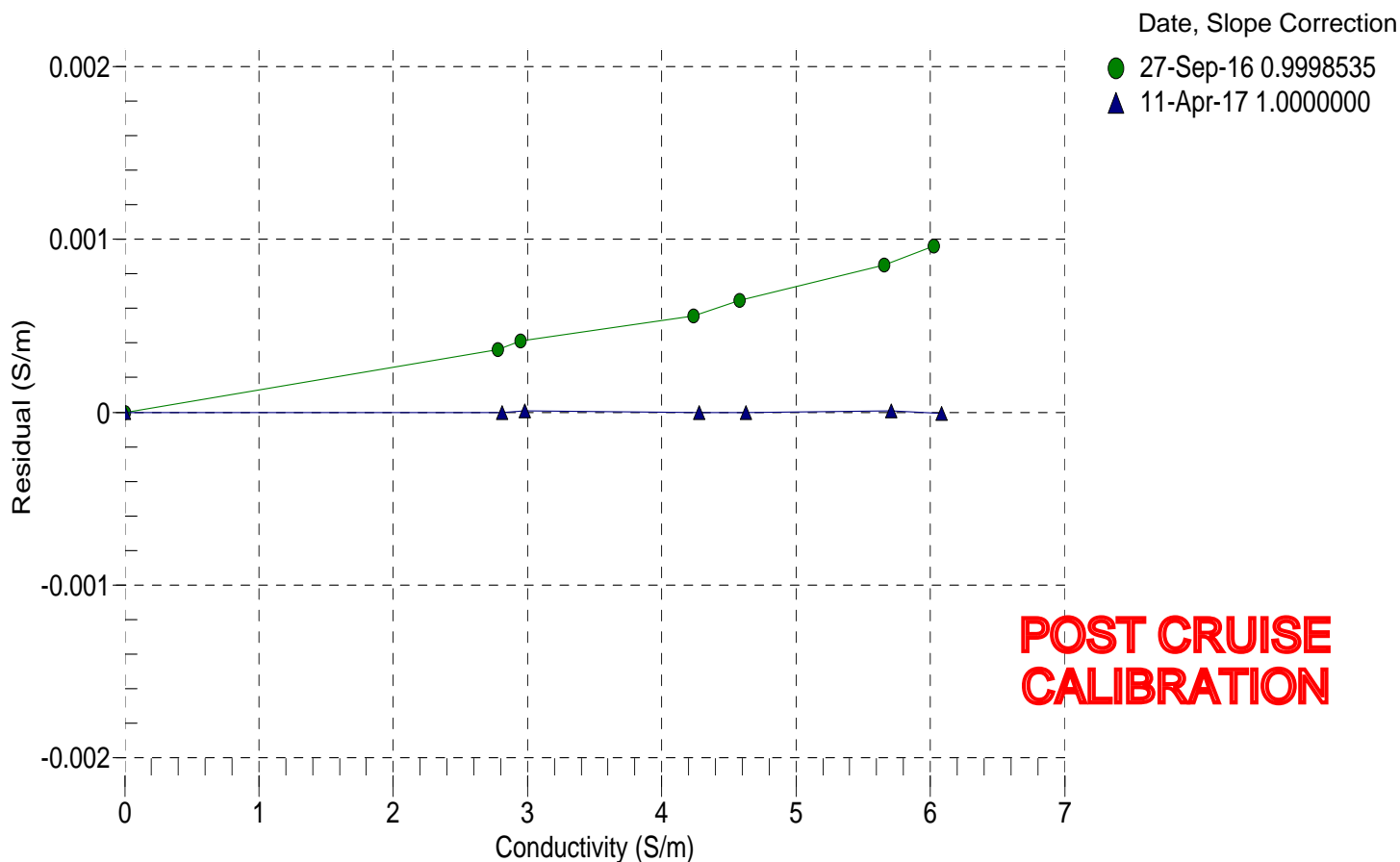
BATH TEMP (° C)	BATH SAL (PSU)	BATH COND (S/m)	INSTRUMENT OUTPUT (kHz)	INSTRUMENT COND (S/m)	RESIDUAL (S/m)
0.0000	0.0000	0.00000	2.67093	0.00000	0.00000
-1.0000	34.8911	2.81004	5.23758	2.81003	-0.00000
1.0000	34.8911	2.98175	5.35456	2.98175	0.00001
15.0000	34.8899	4.27968	6.16707	4.27968	-0.00000
18.5000	34.8883	4.62689	6.36676	4.62689	-0.00000
29.0000	34.8798	5.71155	6.95350	5.71155	0.00001
32.5000	34.8640	6.08337	7.14346	6.08336	-0.00001

f = Instrument Output (kHz)

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

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

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: 3399

CALIBRATION DATE: 07-Apr-17

SBE 4 CONDUCTIVITY CALIBRATION DATA

PSS 1978: C(35,15,0) = 4.2914 Siemens/meter

## COEFFICIENTS:

g = -9.89936522e+000

h = 1.49747858e+000

i = -2.33267274e-003

j = 2.62671888e-004

CPcor = -9.5700e-008 (nominal)

CTcor = 3.2500e-006 (nominal)

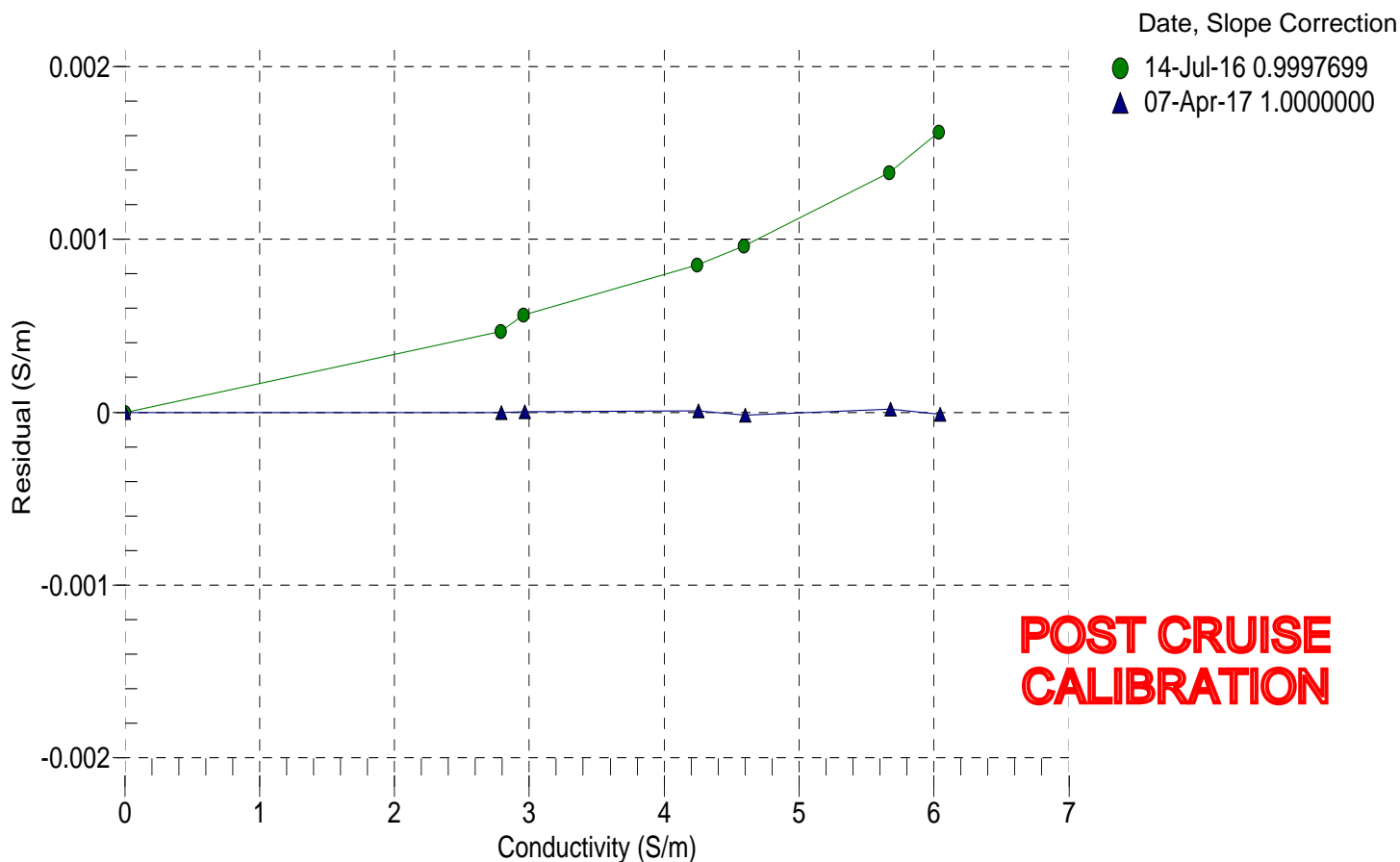
BATH TEMP (° C)	BATH SAL (PSU)	BATH COND (S/m)	INSTRUMENT OUTPUT (kHz)	INSTRUMENT COND (S/m)	RESIDUAL (S/m)
0.0000	0.0000	0.00000	2.57479	0.00000	0.00000
-1.0000	34.6606	2.79320	5.03482	2.79320	-0.00000
1.0000	34.6613	2.96398	5.14715	2.96398	0.00000
15.0001	34.6616	4.25465	5.92723	4.25466	0.00001
18.5000	34.6605	4.59993	6.11892	4.59991	-0.00002
29.0000	34.6522	5.67846	6.68203	5.67848	0.00002
32.5001	34.6389	6.04856	6.86446	6.04854	-0.00001

f = Instrument Output (kHz)

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

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

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



## Scattering Meter Calibration Sheet

9/23/2014

Wavelength: 700

S/N

FLBBRTD-3698

Use the following equation to obtain either digital or analog "scaled" output values:

$$\beta(\theta_c) \text{ m}^{-1} \text{ sr}^{-1} = \text{Scale Factor} \times (\text{Output} - \text{Dark Counts})$$

• <b>Scale Factor for 700 nm</b>	=	1.662E-06 (m <sup>-1</sup> sr <sup>-1</sup> )/counts	1.362E-03 (m <sup>-1</sup> sr <sup>-1</sup> )/volts
• <b>Output</b>	=	meter output counts	meter output volts
• <b>Dark Counts</b>	=	43 counts	0.0708 volts
Instrument Resolution	=	1.0 counts	1.66E-06 (m <sup>-1</sup> sr <sup>-1</sup> )
			1.0651 mV

Definitions:

- **Scale Factor:** Calibration scale factor,  $\beta(\theta_c)/\text{counts}$ . Refer to User's Guide for derivation.
- **Output:** Measured signal output of the scattering meter.
- **Dark Counts:** Signal obtained by covering detector with black tape and submersing sensor in water.

Instrument Resolution: Standard deviation of 1 minute of collected data.

## ECO Chlorophyll Fluorometer Characterization Sheet

Date: 9/23/2014

S/N: FLBBRTD-3698

Chlorophyll concentration expressed in  $\mu\text{g/l}$  can be derived using the equation:

$$\text{CHL } (\mu\text{g/l}) = \text{Scale Factor} * (\text{Output} - \text{Dark counts})$$

	Analog		Digital
Dark counts	0.057	V	40 counts
Scale Factor (SF)	6	$\mu\text{g/l/V}$	0.0072 $\mu\text{g/l/count}$
Maximum Output	4.99	V	4130 counts
Resolution	0.7	mV	1.0 counts
Ambient temperature during characterization			21.5 °C

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

**SF:** Determined using the following equation:  $\text{SF} = x \div (\text{output} - \text{dark counts})$ , where x is the concentration of the solution used during instrument characterization. SF is used to derive instrument output concentration from the raw signal output of the fluorometer.

**Maximum Output:** Maximum signal output the fluorometer is capable of.

**Resolution:** Standard deviation of 1 minute of collected data.

The relationship between fluorescence and chlorophyll-a concentrations in-situ is highly variable. The scale factor listed on this document was determined using a mono-culture of phytoplankton (*Thalassiosira weissflogii*). The population was assumed to be reasonably healthy and the concentration was determined by using the absorption method. To accurately determine chlorophyll concentration using a fluorometer, you must perform secondary measurements on the populations of interest. This is typically done using extraction-based measurement techniques on discrete samples. For additional information on determining chlorophyll concentration see "Standard Methods for the Examination of Water and Wastewater", part 10200 H, published jointly by the American Public Health Association, American Water Works Association, and the Water Environment Federation.

# Temperature Calibration Certificate

Model : ARO-CAV  
Serial No. : 0251  
Date : December 21, 2015  
Location : Production Section  
Method : Calibration equation is determined from third order regression of samples of the reference temperature against instrument voltages. Samples are taken at approximately 3, 10, 17, 24, and 31 °C.

1. Equation Instrument temperature[°C] =  $A+B \times V+C \times V^2+D \times V^3$  V: Instrument voltage[V]

2. Coefficients  
A = -5.275295e+00  
B = +1.670109e+01  
C = -2.172049e+00  
D = +4.643500e-01

### 3. Calibration results

Reference temperature [°C]	Instrument voltage [V]	Instrument temperature [°C]	Residual error [°C]	Acceptance [°C]	OK/NG
3.176	0.53955	3.176	0.000	±0.020	OK
9.842	1.00891	9.841	-0.001	±0.020	OK
16.630	1.51318	16.632	0.002	±0.020	OK
24.180	2.07520	24.179	-0.001	±0.020	OK
31.348	2.58124	31.348	0.000	±0.020	OK

### 4. Verification

Criteria of judgement : Residual error of the instrument temperature at arbitrary point is within the acceptance value.

Reference temperature [°C]	Instrument temperature [°C]	Residual error [°C]	Acceptance [°C]	Judgement
19.921	19.923	0.002	±0.020	Passed

Examined

*H. Shimotsu*

Approved

*A. Fukuoaka*

# Dissolved Oxygen Calibration Certificate

Model : ARO-CAV  
 Serial No. : 0251  
 Date : December 21, 2015  
 Location : Production Section  
 Method : Calibration is performed with the nitrogen gas (zero) and the oxygen saturated water (span) kept by air bubbling.  
 Film No. : 151502B

## 1. Equation

$$DO[\%] = G + H \times P'$$

Here,  $P'[\%]$  consists of the coefficients A-F determined by the initial calibration.

## 2. Coefficients

A = -3.893493e+01      E = +4.000000e-03  
 B = +1.192391e+02      F = +4.760000e-05  
 C = -3.509264e-01      G = +0.000000e+00  
 D = +1.006600e-02      H = +1.000000e+00

## 3. Verification

Criteria of judgement : Residual error of the instrument DO at arbitrary point is within the acceptance value. The test is performed 3 times.

Acceptance:  $\pm 0.5\%$  of full scale

Test for DO 0 %

	Test condition		Instrument DO [%]	Residual error [%]	Acceptance [%]	Judgement
	Atm. pressure [hPa]	Reference DO [%]				
1st	1023.7	0.00	-0.04	-0.04	$\pm 1.00$	Passed
2nd	1023.7	0.00	0.04	0.04	$\pm 1.00$	Passed
3rd	1023.8	0.00	0.04	0.04	$\pm 1.00$	Passed

Test for DO 100 %

	Test condition			Instrument DO [%]	Residual error [%]	Acceptance [%]	Judgement
	Water T. [°C]	Atm. pressure [hPa]	Reference DO [%]				
1st	25.1	1023.9	101.09	100.75	-0.34	$\pm 1.00$	Passed
2nd	25.1	1023.9	101.09	100.54	-0.55	$\pm 1.00$	Passed
3rd	25.1	1024.0	101.10	100.59	-0.51	$\pm 1.00$	Passed

Examined

*R. Kashida*

Approved

*A. Fukuoaka*

# 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: 0255

SBE 43 OXYGEN CALIBRATION DATA

CALIBRATION DATE: 07-Apr-17

## COEFFICIENTS:

Soc = 0.4872

Voffset = -0.5143

Tau20 = 1.19

A = -3.9824e-003

B = 2.2613e-004

C = -3.7106e-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

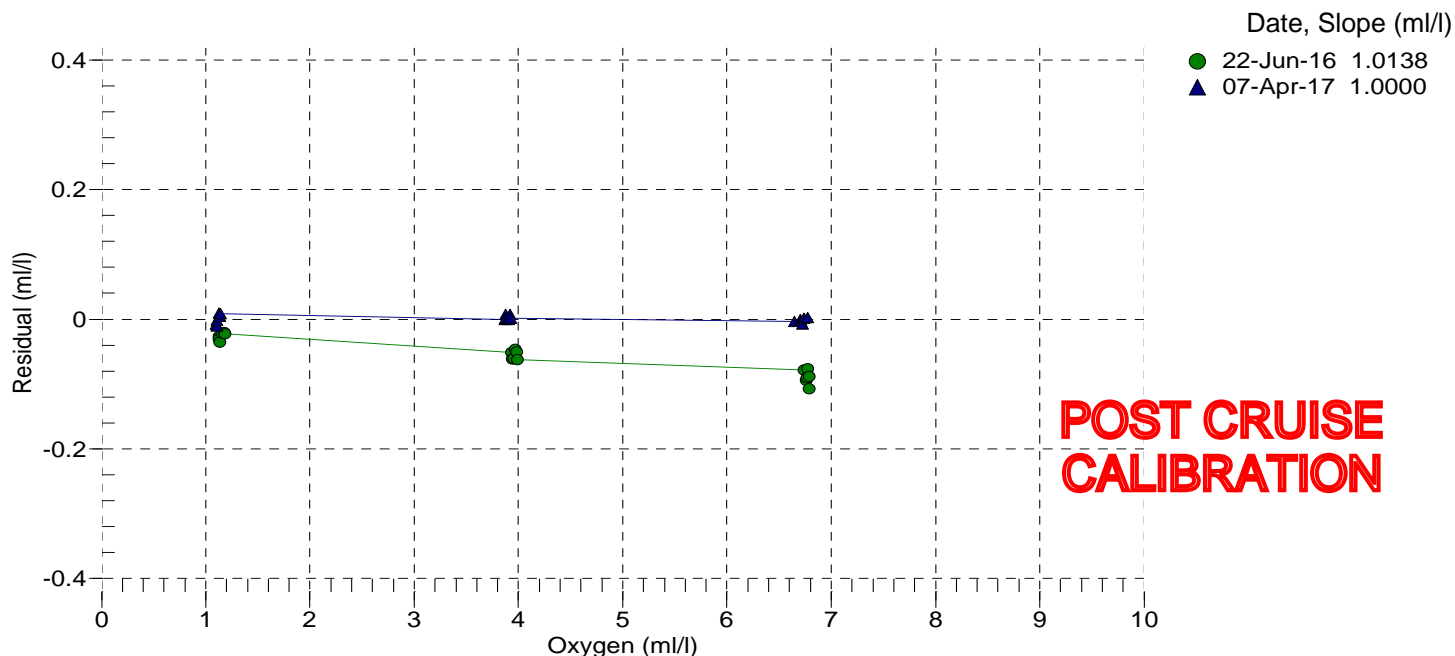
BATH OXYGEN (ml/l)	BATH TEMPERATURE (° C)	BATH SALINITY (PSU)	INSTRUMENT OUTPUT (volts)	INSTRUMENT OXYGEN (ml/l)	RESIDUAL (ml/l)
1.10	6.00	0.00	0.777	1.09	-0.01
1.10	2.00	0.00	0.748	1.09	-0.01
1.10	12.00	0.00	0.821	1.10	-0.00
1.13	26.00	0.00	0.932	1.14	0.01
1.13	20.00	0.00	0.888	1.14	0.00
1.14	30.00	0.00	0.969	1.15	0.01
3.87	6.00	0.00	1.442	3.87	-0.00
3.87	20.00	0.00	1.791	3.88	0.01
3.88	12.00	0.00	1.593	3.88	0.00
3.90	2.00	0.00	1.348	3.90	-0.00
3.92	26.00	0.00	1.957	3.93	0.01
3.93	30.00	0.00	2.063	3.93	0.00
6.65	30.00	0.00	3.135	6.64	-0.00
6.70	12.00	0.00	2.378	6.70	-0.00
6.71	26.00	0.00	2.978	6.70	-0.00
6.72	20.00	0.00	2.723	6.72	-0.01
6.74	2.00	0.00	1.955	6.74	0.00
6.77	6.00	0.00	2.138	6.78	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)

Oxygen (ml/l) = Soc \* (V + Voffset) \* (1.0 + A \* T + B \* T<sup>2</sup> + C \* T<sup>3</sup>) \* 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: 0275  
CALIBRATION DATE: 30-Mar-17

SBE 43 OXYGEN CALIBRATION DATA

## COEFFICIENTS:

Soc = 0.5402  
Voffset = -0.4998  
Tau20 = 1.21

A = -3.6705e-003  
B = 1.9061e-004  
C = -2.9805e-006  
E nominal = 0.036

## NOMINAL DYNAMIC COEFFICIENTS

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

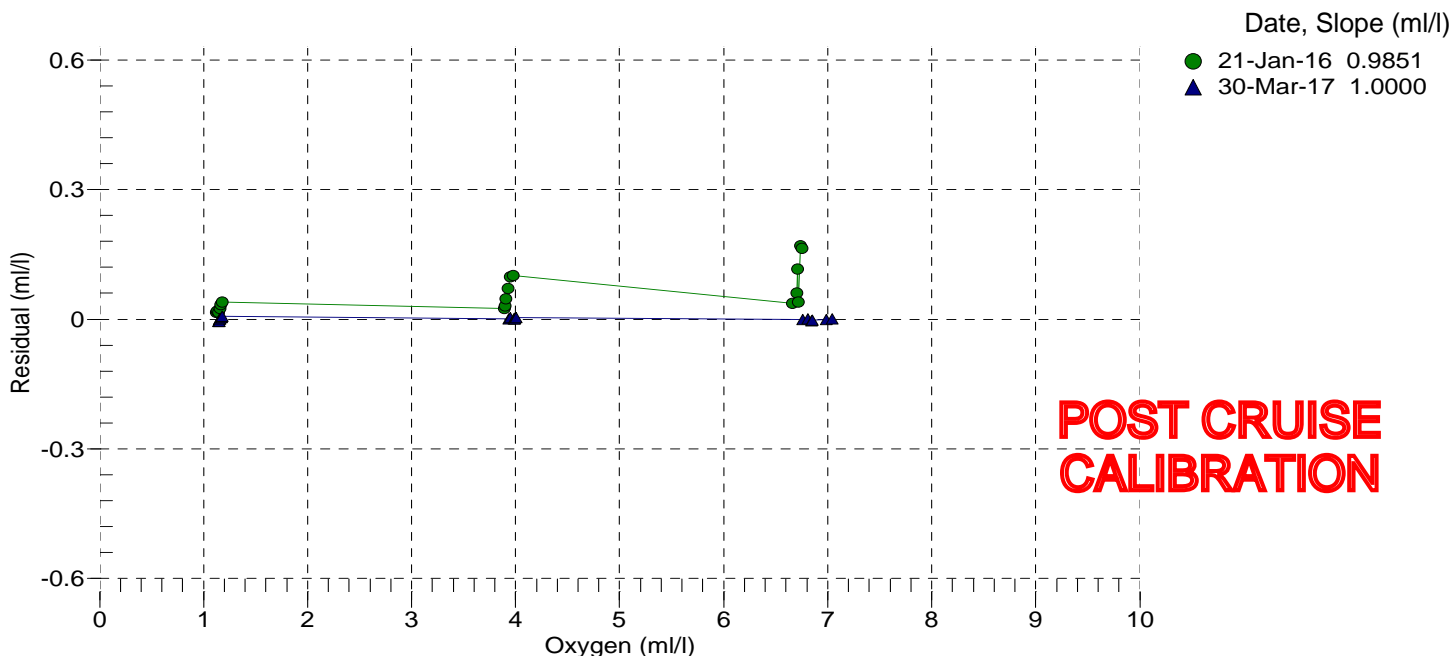
BATH OXYGEN (ml/l)	BATH TEMPERATURE (° C)	BATH SALINITY (PSU)	INSTRUMENT OUTPUT (volts)	INSTRUMENT OXYGEN (ml/l)	RESIDUAL (ml/l)
1.14	2.00	0.00	0.719	1.14	-0.00
1.15	12.00	0.00	0.788	1.15	-0.00
1.15	6.00	0.00	0.747	1.15	-0.00
1.16	20.00	0.00	0.844	1.16	0.00
1.17	26.00	0.00	0.889	1.17	0.00
1.18	30.00	0.00	0.922	1.18	0.01
3.93	2.00	0.00	1.258	3.94	0.00
3.95	6.00	0.00	1.353	3.95	0.00
3.98	20.00	0.00	1.684	3.98	0.00
3.99	26.00	0.00	1.826	3.99	0.00
3.99	12.00	0.00	1.501	3.99	0.00
4.01	30.00	0.00	1.931	4.01	0.00
6.76	2.00	0.00	1.801	6.76	-0.00
6.81	6.00	0.00	1.971	6.81	0.00
6.85	30.00	0.00	2.941	6.84	-0.00
6.85	12.00	0.00	2.219	6.85	-0.00
6.99	20.00	0.00	2.576	6.99	-0.00
7.04	26.00	0.00	2.840	7.04	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)

Oxygen (ml/l) = Soc \* (V + Voffset) \* (1.0 + A \* T + B \* T<sup>2</sup> + C \* T<sup>3</sup>) \* 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: 1136

SBE 43 OXYGEN CALIBRATION DATA

CALIBRATION DATE: 11-Apr-17

## COEFFICIENTS:

Soc = 0.4514

Voffset = -0.5352

Tau20 = 2.29

A = -3.2659e-003

B = 2.0102e-004

C = -3.4120e-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

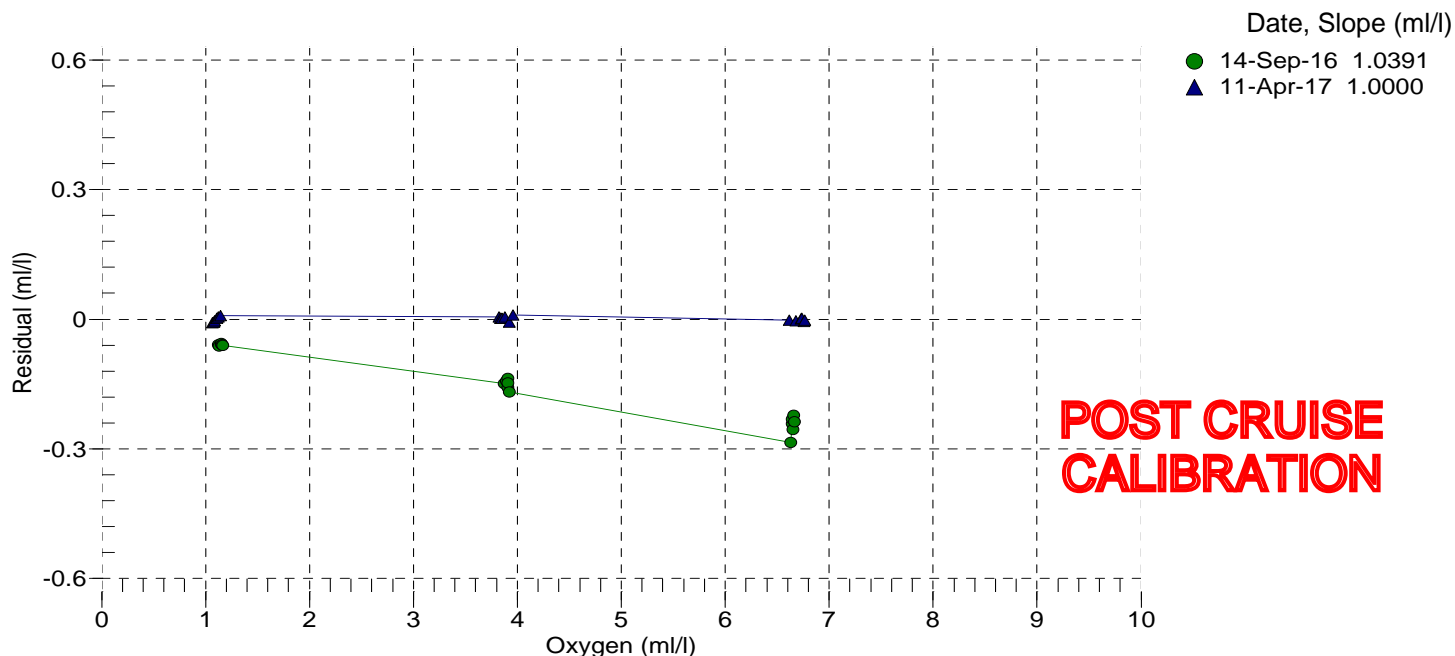
BATH OXYGEN (ml/l)	BATH TEMPERATURE (° C)	BATH SALINITY (PSU)	INSTRUMENT OUTPUT (volts)	INSTRUMENT OXYGEN (ml/l)	RESIDUAL (ml/l)
1.07	2.00	0.00	0.779	1.06	-0.01
1.08	6.00	0.00	0.811	1.07	-0.01
1.08	12.00	0.00	0.858	1.08	-0.00
1.11	20.00	0.00	0.926	1.11	0.00
1.13	26.00	0.00	0.980	1.13	0.01
1.14	30.00	0.00	1.022	1.15	0.01
3.83	2.00	0.00	1.418	3.83	0.01
3.84	6.00	0.00	1.525	3.84	0.00
3.85	12.00	0.00	1.685	3.85	0.00
3.88	20.00	0.00	1.904	3.88	0.00
3.92	26.00	0.00	2.078	3.92	-0.01
3.96	30.00	0.00	2.214	3.97	0.01
6.61	2.00	0.00	2.057	6.61	-0.00
6.68	12.00	0.00	2.528	6.67	-0.00
6.73	6.00	0.00	2.269	6.73	0.00
6.74	20.00	0.00	2.910	6.74	0.00
6.76	30.00	0.00	3.390	6.75	-0.01
6.76	26.00	0.00	3.197	6.76	-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)

Oxygen (ml/l) = Soc \* (V + Voffset) \* (1.0 + A \* T + B \* T<sup>2</sup> + C \* T<sup>3</sup>) \* 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: 0080  
CALIBRATION DATE: 04-Feb-17

SBE 43 OXYGEN CALIBRATION DATA

## COEFFICIENTS:

Soc = 0.5761

Voffset = -0.5113

Tau20 = 1.48

A = -4.1846e-003

B = 1.6396e-004

C = -2.5621e-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

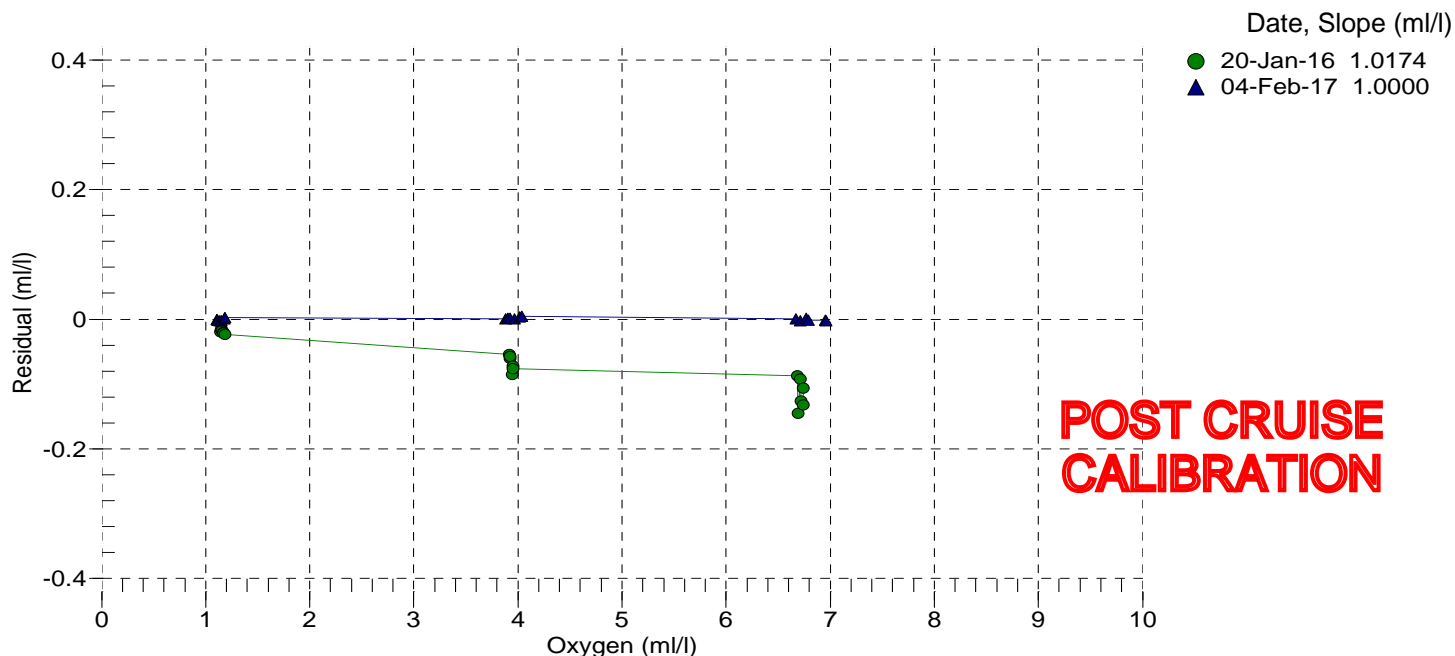
BATH OXYGEN (ml/l)	BATH TEMPERATURE (° C)	BATH SALINITY (PSU)	INSTRUMENT OUTPUT (volts)	INSTRUMENT OXYGEN (ml/l)	RESIDUAL (ml/l)
1.11	2.00	0.00	0.712	1.11	-0.00
1.12	12.00	0.00	0.777	1.12	-0.00
1.13	6.00	0.00	0.741	1.13	-0.00
1.15	20.00	0.00	0.838	1.15	-0.00
1.18	26.00	0.00	0.888	1.18	0.00
1.18	30.00	0.00	0.920	1.19	0.00
3.89	2.00	0.00	1.214	3.89	0.00
3.90	6.00	0.00	1.305	3.91	0.00
3.92	12.00	0.00	1.443	3.92	0.00
3.97	20.00	0.00	1.637	3.97	0.00
4.02	26.00	0.00	1.795	4.02	0.00
4.04	30.00	0.00	1.903	4.04	0.00
6.67	2.00	0.00	1.718	6.67	0.00
6.71	6.00	0.00	1.875	6.71	-0.00
6.77	12.00	0.00	2.119	6.77	0.00
6.79	20.00	0.00	2.437	6.79	-0.00
6.95	26.00	0.00	2.732	6.95	-0.00
6.96	30.00	0.00	2.908	6.96	-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)

Oxygen (ml/l) = Soc \* (V + Voffset) \* (1.0 + A \* T + B \* T<sup>2</sup> + C \* T<sup>3</sup>) \* Oxsol(T,S) \* exp(E \* P / K)

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



# Pressure Calibration Report

## STS/ODF Calibration Facility

SENSOR SERIAL NUMBER: 1281

CALIBRATION DATE: 10-APR-2017

Mfg: SEABIRD Model: 09P CTD Prs s/n: 136428

C1= -4.160528E+4

C2= -4.007210E-1

C3= 1.424636E-2

D1= 3.538591E-2

D2= 0.000000E+0

T1= 3.014002E+1

T2= -3.931397E-4

T3= 3.774435E-6

T4= 1.842545E-8

T5= 0.000000E+0

AD590M= 1.27846E-2

AD590B= -9.25586E+0

Slope = 1.00000000E+0

Offset = 0.00000000E+0

Calibration Standard: Mfg: FLUKE Model: P3125 s/n: 70856

$t0 = t1 + t2 * td + t3 * td * td + t4 * td * td * td$

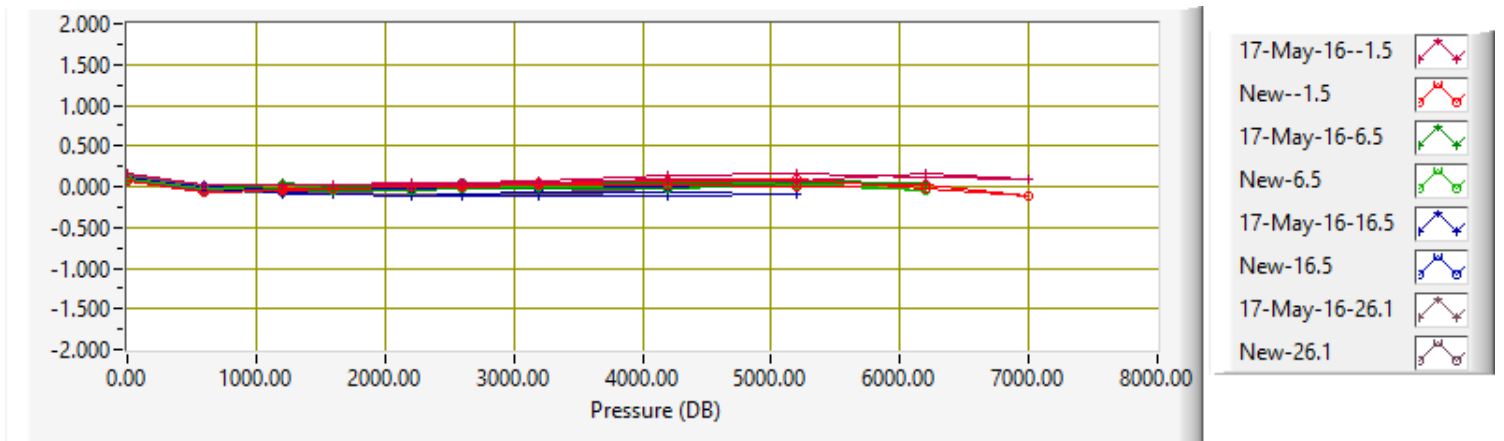
$w = 1 - t0 * t0 * f * f$

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
33184.184	0.26	0.19	0.17	0.06	-0.62	-1.530
33529.145	600.32	600.38	0.02	-0.06	-0.64	-1.530
33870.005	1200.36	1200.39	0.02	-0.04	-0.64	-1.530
34095.080	1600.39	1600.41	0.02	-0.03	-0.64	-1.530
34429.524	2200.43	2200.44	0.03	-0.01	-0.65	-1.530
34650.420	2600.45	2600.46	0.03	-0.01	-0.66	-1.530
34978.750	3200.49	3200.48	0.05	0.01	-0.68	-1.530
35518.180	4200.52	4200.49	0.08	0.03	-0.68	-1.530
36048.293	5200.54	5200.55	0.08	-0.01	-0.68	-1.530
36569.432	6200.54	6200.52	0.16	0.02	-0.68	-1.530
36980.245	7000.53	7000.64	0.08	-0.12	-0.68	-1.530
36569.450	6200.54	6200.56	0.12	-0.02	-0.68	-1.530
36048.243	5200.54	5200.46	0.17	0.08	-0.68	-1.530
35518.149	4200.52	4200.44	0.13	0.08	-0.69	-1.530
34978.728	3200.49	3200.45	0.07	0.04	-0.69	-1.530
34650.397	2600.45	2600.44	0.05	0.01	-0.69	-1.530
34429.496	2200.43	2200.42	0.04	0.01	-0.69	-1.530

Sensor Output	Standard	Sensor New_Coefs	Standard-Sensor Prev Coefs	Standard-Sensor NEW Coefs	Sensor_Temp	Bath_Temp
34095.056	1600.39	1600.41	0.02	-0.02	-0.69	-1.530
33869.978	1200.36	1200.39	0.03	-0.03	-0.69	-1.529
33529.090	600.32	600.33	0.07	-0.01	-0.70	-1.530
33187.363	0.26	0.17	0.17	0.08	7.28	6.479
33532.336	600.32	600.34	0.03	-0.02	7.28	6.479
33873.234	1200.36	1200.40	-0.02	-0.04	7.28	6.480
34098.329	1600.39	1600.44	-0.04	-0.05	7.28	6.480
34432.800	2200.43	2200.48	-0.05	-0.05	7.28	6.479
34653.693	2600.45	2600.47	-0.02	-0.01	7.28	6.479
34982.050	3200.49	3200.50	-0.02	-0.01	7.28	6.479
35521.518	4200.52	4200.53	-0.01	-0.02	7.28	6.479
36051.617	5200.54	5200.52	0.05	0.01	7.28	6.480
36572.822	6200.54	6200.58	0.04	-0.04	7.29	6.479
36051.601	5200.54	5200.50	0.08	0.04	7.28	6.480
35521.479	4200.52	4200.47	0.06	0.05	7.28	6.479
34982.024	3200.49	3200.45	0.03	0.04	7.28	6.479
34653.681	2600.45	2600.45	-0.00	0.01	7.28	6.479
34432.769	2200.43	2200.43	0.00	0.00	7.28	6.479
34098.310	1600.39	1600.40	-0.00	-0.02	7.28	6.480
33873.193	1200.36	1200.33	0.06	0.03	7.28	6.479
33532.319	600.32	600.31	0.06	0.01	7.27	6.479
33190.565	0.26	0.16	0.13	0.10	17.28	16.489
33535.570	600.32	600.33	-0.02	-0.01	17.28	16.489
33876.498	1200.36	1200.38	-0.08	-0.03	17.29	16.489
34101.601	1600.39	1600.40	-0.08	-0.02	17.28	16.489
34436.101	2200.43	2200.45	-0.11	-0.02	17.28	16.489
34657.028	2600.45	2600.46	-0.11	-0.01	17.29	16.489
34985.419	3200.49	3200.50	-0.13	-0.01	17.28	16.490
35524.921	4200.52	4200.52	-0.11	-0.00	17.29	16.489
36055.082	5200.54	5200.54	-0.10	-0.00	17.29	16.489
35524.892	4200.52	4200.46	-0.06	0.05	17.28	16.489
34985.391	3200.49	3200.45	-0.07	0.04	17.29	16.489
34657.021	2600.45	2600.45	-0.10	0.00	17.28	16.489
34436.101	2200.43	2200.45	-0.11	-0.02	17.28	16.489
34101.601	1600.39	1600.40	-0.09	-0.02	17.27	16.489
33876.501	1200.36	1200.39	-0.09	-0.04	17.27	16.490
33535.571	600.32	600.33	-0.03	-0.01	17.27	16.489
33192.637	0.26	0.20	0.15	0.06	26.53	26.092
33537.680	600.32	600.36	-0.00	-0.04	26.55	26.093
33878.643	1200.36	1200.41	-0.06	-0.06	26.57	26.093
34103.774	1600.39	1600.43	-0.07	-0.04	26.59	26.093
34438.308	2200.43	2200.47	-0.09	-0.04	26.59	26.093
34659.257	2600.45	2600.47	-0.09	-0.02	26.61	26.093
34987.677	3200.49	3200.50	-0.09	-0.01	26.62	26.093
35527.229	4200.52	4200.49	-0.07	0.03	26.64	26.093

Sensor Output	Standard	Sensor New_Coefs	Standard-Sensor Prev Coefs	Standard-Sensor NEW Coefs	Sensor_Temp	Bath_Temp
34987.649	3200.49	3200.44	-0.03	0.05	26.64	26.093
34659.234	2600.45	2600.41	-0.03	0.04	26.66	26.093
34438.300	2200.43	2200.43	-0.05	-0.00	26.67	26.093
34103.776	1600.39	1600.40	-0.04	-0.02	26.68	26.093
33878.645	1200.36	1200.38	-0.02	-0.02	26.69	26.093
33537.688	600.32	600.33	0.03	-0.01	26.69	26.093
33192.651	0.26	0.17	0.17	0.08	26.69	26.093



# Temperature Calibration Report

## STS/ODF Calibration Facility

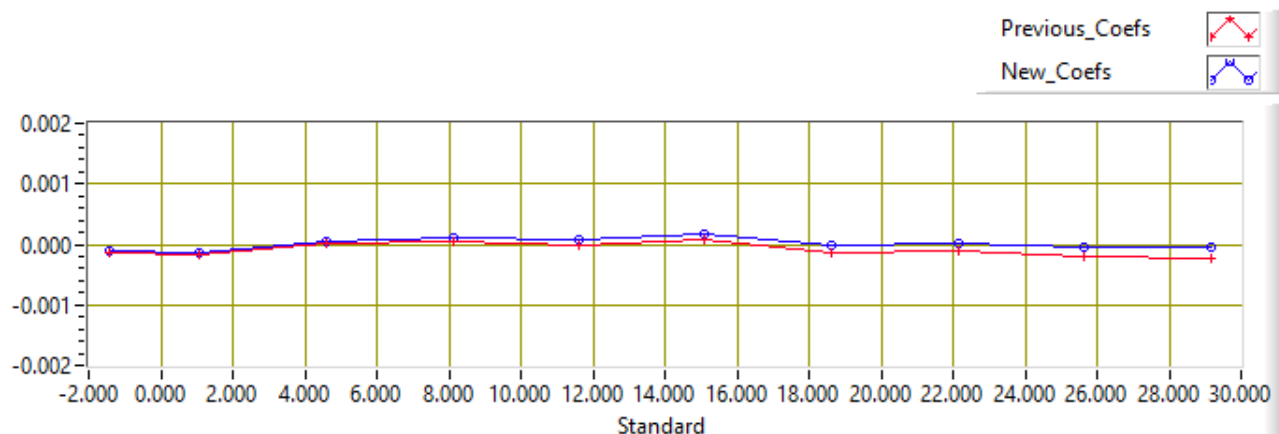
SENSOR SERIAL NUMBER: 0035  
 CALIBRATION DATE: 13-Apr-2017  
 Mfg: SEABIRD Model: 35  
 Previous cal: 29-Aug-16  
 Calibration Tech: CAL

### ITS-90\_COEFFICIENTS

a0 = 4.208496100E-3  
 a1 = -1.124111980E-3  
 a2 = 1.735065310E-4  
 a3 = -9.702815440E-6  
 a4 = 2.086576170E-7  
 Slope = 0.999995  
 Offset = -0.000024

Calibration Standard: Mfg: Isotech Model: MicroK100 s/n: 291088-2  
 Temperature ITS-90 =  $1/[a_0 + a_1[\ln(f)] + a_2[\ln^2(f)] + a_3[\ln^3(f)] + a_4[\ln^4(f)]] - 273.15$  (°C)

SBE35 Count	SPRT ITS-T90	SBE35 ITS-T90	SPRT-SBE35 OLD Coefs	SPRT-SBE35 NEW Coefs
-1.4135	-1.4136	-1.4135	-0.00013	-0.00011
1.0905	1.0903	1.0904	-0.00017	-0.00014
4.5965	4.5965	4.5964	0.00002	0.00006
8.1039	8.1040	8.1039	0.00005	0.00011
11.6134	11.6134	11.6133	-0.00001	0.00007
15.1146	15.1146	15.1145	0.00008	0.00017
18.6277	18.6275	18.6276	-0.00014	-0.00003
22.1350	22.1349	22.1349	-0.00012	0.00002
25.6458	25.6456	25.6456	-0.00019	-0.00004
29.1546	29.1544	29.1544	-0.00023	-0.00006
29.1546	29.1544	29.1544	-0.00023	-0.00006



# Temperature Calibration Report

## STS/ODF Calibration Facility

**SENSOR SERIAL NUMBER:** 2309  
**CALIBRATION DATE:** 18-Apr-2017  
**Mfg:** SEABIRD    **Model:** 03  
**Previous cal:** 10-Mar-17  
**Calibration Tech:** CM

### ITS-90\_COEFFICIENTS IPTS-68\_COEFFICIENTS

**g** = 4.35795296E-3    **a** = 4.35815123E-3  
**h** = 6.45303354E-4    **b** = 6.45514766E-4  
**i** = 2.44482718E-5    **c** = 2.44810575E-5  
**j** = 2.39242392E-6    **d** = 2.39402502E-6  
**f0** = 1000.0    **Slope** = 1.0    **Offset** = 0.0

**Calibration Standard:** Mfg: Isotech    Model: MicroK100    s/n: 291088-2

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

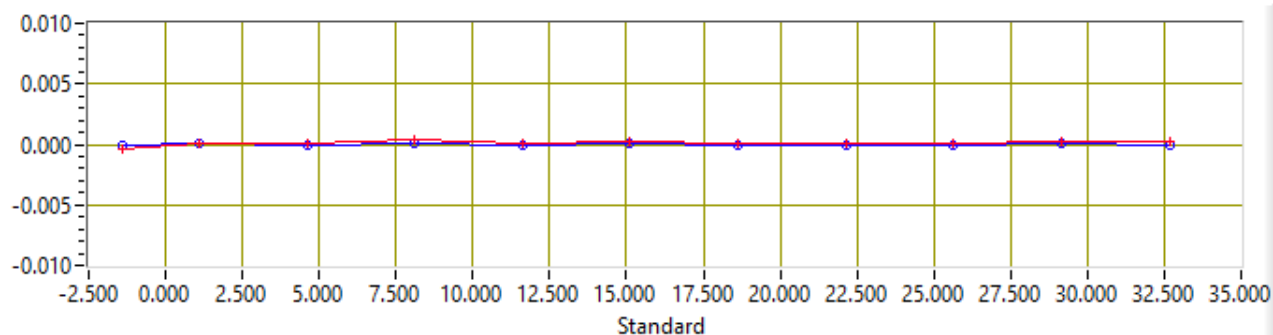
**Temperature IPTS-68** =  $1 / \{a + b[\ln(f_0/f)] + c[\ln^2(f_0/f)] + d[\ln^3(f_0/f)]\} - 273.15$  (°C)

**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
2976.6396	-1.4141	-1.4141	-0.00035	-0.00004
3148.2115	1.0899	1.0898	0.00004	0.00010
3400.3783	4.5960	4.5962	0.00004	-0.00013
3666.9010	8.1039	8.1038	0.00038	0.00013
3948.1828	11.6126	11.6127	0.00015	-0.00010
4243.8071	15.1136	15.1135	0.00031	0.00011
4555.7929	18.6256	18.6256	0.00009	-0.00005
4883.2295	22.1342	22.1342	0.00002	-0.00006
5226.9845	25.6450	25.6450	0.00003	-0.00004
5586.7653	29.1520	29.1518	0.00029	0.00015
5963.8548	32.6640	32.6640	0.00025	-0.00007

Previous\_Coefs

New\_Coefs



# Temperature Calibration Report

## STS/ODF Calibration Facility

SENSOR SERIAL NUMBER: 5844  
 CALIBRATION DATE: 11-Apr-2017  
 Mfg: SEABIRD Model: 03  
 Previous cal: 12-Sep-16  
 Calibration Tech: CAL

ITS-90_COEFFICIENTS	IPTS-68_COEFFICIENTS ITS-T90	
g = 4.36572108E-3	a = 4.36592217E-3	
h = 6.30346756E-4	b = 6.30554579E-4	
i = 2.02981226E-5	c = 2.03291260E-5	
j = 1.55658300E-6	d = 1.55793676E-6	
f0 = 1000.0	Slope = 1.0	Offset = 0.0

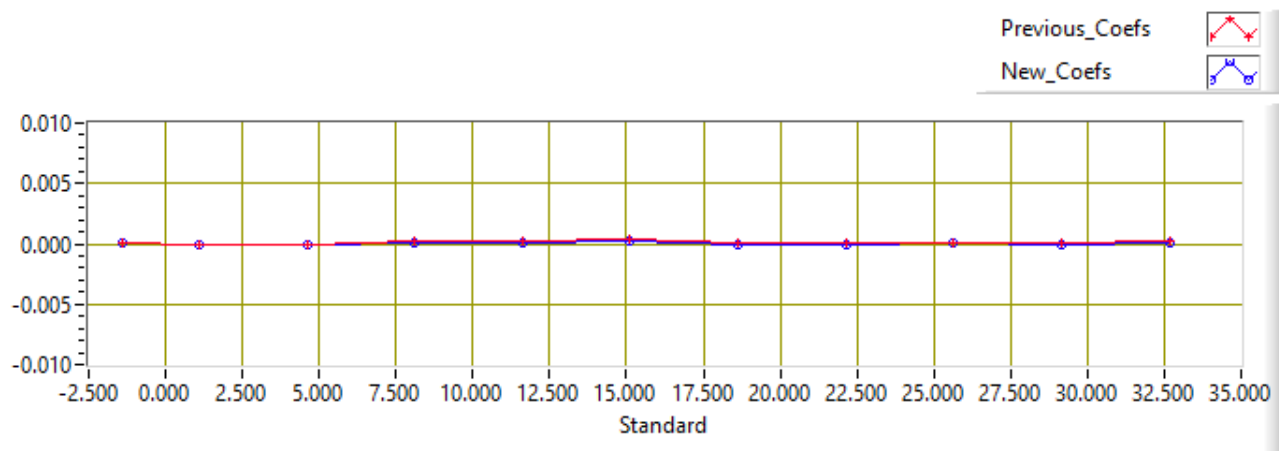
Calibration Standard: Mfg: Isotech Model: MicroK100 s/n: 291088-2

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

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

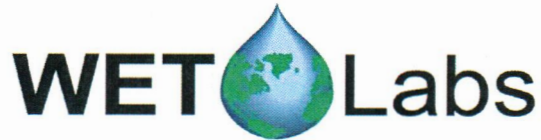
T68 = 1.00024 \* T90 (-2 to -35 Deg C)

SBE3 Freq	SPRT ITS-T90	SBE3 ITS-T90	SPRT-SBE3 OLD Coefs	SPRT-SBE3 NEW Coefs
3080.3281	-1.4132	-1.4133	0.00004	0.00012
3260.9407	1.0907	1.0908	-0.00010	-0.00012
3526.5836	4.5966	4.5967	0.00000	-0.00010
3807.6759	8.1044	8.1044	0.00019	0.00003
4104.6790	11.6137	11.6136	0.00020	0.00003
4417.1410	15.1148	15.1146	0.00036	0.00019
4747.1574	18.6258	18.6259	0.00006	-0.00010
5093.9888	22.1346	22.1347	0.00009	-0.00005
5458.5531	25.6460	25.6460	0.00014	0.00001
5840.6669	29.1545	29.1545	0.00011	-0.00005
6241.4164	32.6667	32.6666	0.00024	0.00004





PO Box 518  
620 Applegate St.  
Philomath, OR 97370



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

## C-Star Calibration

Date **9.16.16** S/N# **CST-1803DR** Pathlength **25 cm**

	Analog output	Digital output	
$V_d$	<b>0.008 V</b>	<b>0 counts</b>	
$V_{air}$	<b>4.813 V</b>	<b>15801 counts</b>	
$V_{ref}$	<b>4.699 V</b>	<b>15426 counts</b>	
Temperature of calibration water			<b>21.4 °C</b>
Ambient temperature during calibration			<b>21.6 °C</b>

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

To determine beam transmittance:  $Tr = (V_{sig} - V_{dark}) / (V_{ref} - V_{dark})$

To determine beam attenuation coefficient:  $c = -1/x * \ln(Tr)$

$V_d$  Meter output with the beam blocked. This is the offset.

$V_{air}$  Meter output in air with a clear beam path.

$V_{ref}$  Meter output with clean water in the path.

Temperature of calibration water: temperature of clean water used to obtain  $V_{ref}$ .

Ambient temperature: meter temperature in air during the calibration.

$V_{sig}$  Measured signal output of meter.



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# 2017 P6 GO\_SHIP Repeat Hydrography Section LADCP Post-Cruise QC Report

A.M. Thurnherr

December 15, 2017

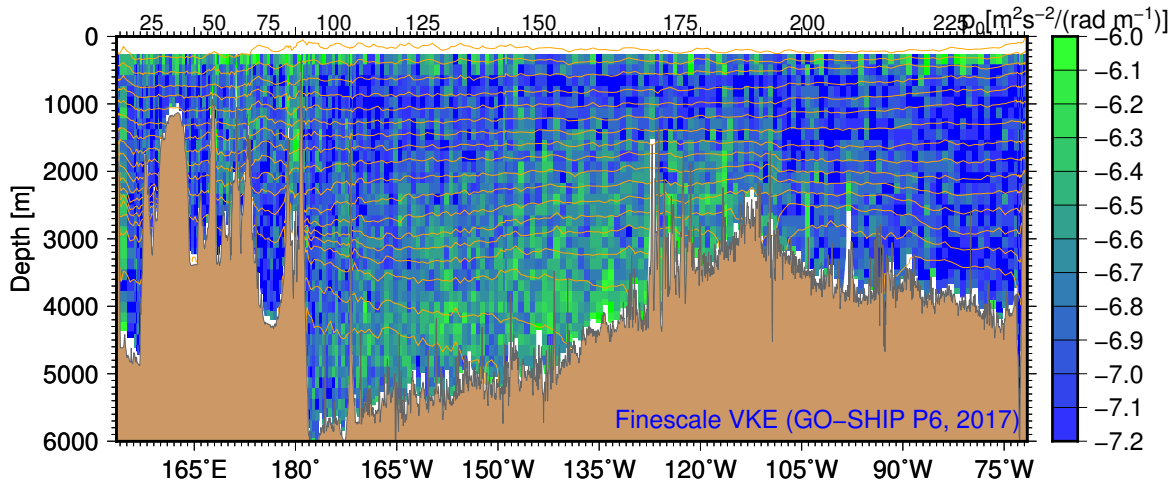


Figure 1: Cross-Pacific zonal section of  $p_0$ , a measure of finescale (100–320 m vertical wavelength) Vertical Kinetic Energy (VKE), along 32°S derived from the vertical LADCP velocities collected during the 2017 occupation of the GO-SHIP P6 section; the orange contours show neutral density from uncalibrated CTD data.

## 1 Summary

This report describes the results from the post-cruise quality control of the LADCP data collected during the two legs of the 2017 P6 GO-SHIP (CLIVAR repeat hydrography) cruise on the UNOLS *R/V Nathaniel B. Palmer*. Using two ADCPs installed on the hydrographic rosette (Section 2), one looking downward (DL) and the other upward (UL), full-depth profiles of all three components of the oceanic velocity field were collected at most stations. Entirely different methods are used for processing LADCP/CTD data for horizontal and vertical velocity, requiring separate QC (Sections 3 and 4, respectively).

*Main Findings:* 1) There is good overall agreement ( $\langle \Delta u_{\text{rms}} \rangle \approx 4 \text{ cm} \cdot \text{s}^{-1}$ ) between the independent upper-ocean horizontal velocity measurements from the LADCP and SADC systems, indicating that the LADCP-derived horizontal velocities from the 2017 re-occupation of the P6 repeat-hydrography line are of excellent quality. 2) Based on correlations between the independent vertical velocity measurements provided by the two ADCPs, the LADCP-derived  $w_{\text{ocean}}$  profiles are of high quality as well.

## 2 Instruments and Data Acquisition

During the first (profiles<sup>1</sup> 1–143) and second (144–250) cruise legs, Alma Castillo Trujillo and Elizabeth Simons, respectively, were responsible for LADCP data acquisition and shipboard QC. Additionally, the processing figures from every 5th profile and from profiles with suspected problems were sent to Thurnherr for additional checks.

Two different ADCP instruments were used during this cruise: the WHM150 #24544 as downlooker (DL) and the WHM300 #24497 as uplooker (UL). Initially (stations 1–13) the ADCPs were mounted on the rosette together with the “IMP” magnetometer/accelerometer package that also serves as connection between the instruments and the battery. Almost immediately there were intermittent but frequent communications problems that were eventually traced to a leak in the IMP pressure case. As a result there are insufficient LADCP data for processing the profiles of stations 6 and 10–13. On station 14 the IMP was replaced with a TRDI star cable and there are processable LADCP data from all remaining stations. However, intermittent communications problems continued during the entire cruise. The resulting profiles with multiple data files were processed with the largest files only. Five out of the final profiles (9, 60, 183, 200 and 221) were processed without any valid UL data.

During profile 97 beam #3 of the DL ADCP failed. Because the performance of the instrument remained otherwise good, because no spare WHM150 was available, and because the range of the WH300 uplooker was marginal in that region of relatively weak acoustic backscatter it was decided to continue data acquisition without replacing the ADCP with the bad beam with a 300 kHz instrument. The UL performed well throughout the entire cruise. Both ADCPs were set up to record velocity data with 8 m pulses/bins and zero blanking. Staggered pinging was used to avoid previous ping interference, which is particularly important for 150 kHz instruments. See cruise report for additional information.

The left panel of [Figure 2](#) shows the maximum profile depths. The topography of the first part of the cruise (the first 100 stations or so) is characterized by significant roughness in the Coral Sea and across a backarc basin just north of New Zealand. After crossing the deep Kermadec Trench around station 100 the seafloor becomes much smoother and rises gradually toward the EPR crest near station 188 before descending into the Chile Basin and, finally, rising again at the South American continental slope. Except for the three profiles from stations 93, 94 and 119, which were located in water deeper than 6000 m, bottom-track information is available for all profiles.

The right panel of [Figure 2](#) shows the number of rotations experienced by the rosette. The fact that the instrument rotated primarily counterclockwise during the downcasts and clockwise during the upcasts with approximately equal number of rotations suggests that there was comparatively little stress on the wire during this cruise.

LADCP data quality is sensitively dependent on instrument range ([Figure 3](#), left panel), which depends on the acoustic scattering environment. During the second half of the P6 cruise, acoustic backscatter was quite weak, with WH300 ranges below 65 m (an empirical limit for good horizontal-velocity profiles collected with single-ADCP systems) in most profiles after station 90 or so. The problem was compounded by a DL beam going bad on station 97, causing a significant reduction in instrument range, but the range of the 3-beam 150 kHz ADCP nevertheless remained above the 4-beam range of the 300 kHz UL for the remainder of the cruise, and the combined range of the two ADCPs was greater than 80 m in all dual-head profiles. Since the DL-only profiles (9, 60, 183, 200

<sup>1</sup>LADCP profile numbers, which are equal to the CTD station numbers of this cruise, are used throughout in this report. The LADCP data distribution contains the file `STATIONNUMBERS.nc`, which associates LADCP profile numbers with CTD station and cast numbers. The CTD station and cast numbers are also printed in the titles of all diagnostic figures produced by the LDEO [IX](#) software.

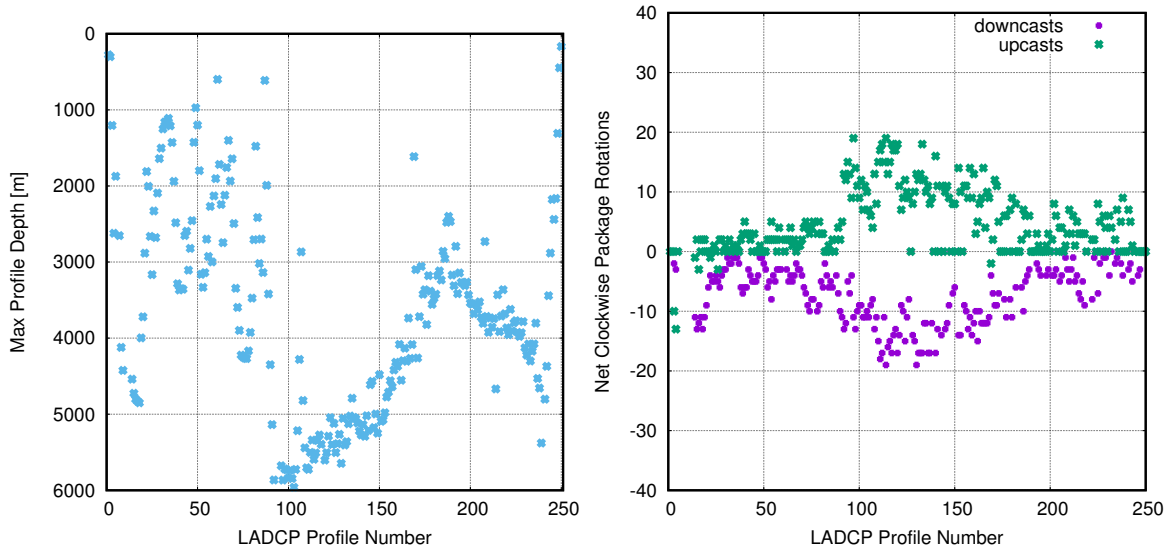


Figure 2: Profiling parameters. Left panel: Maximum depth. Right panel: Net package rotations.

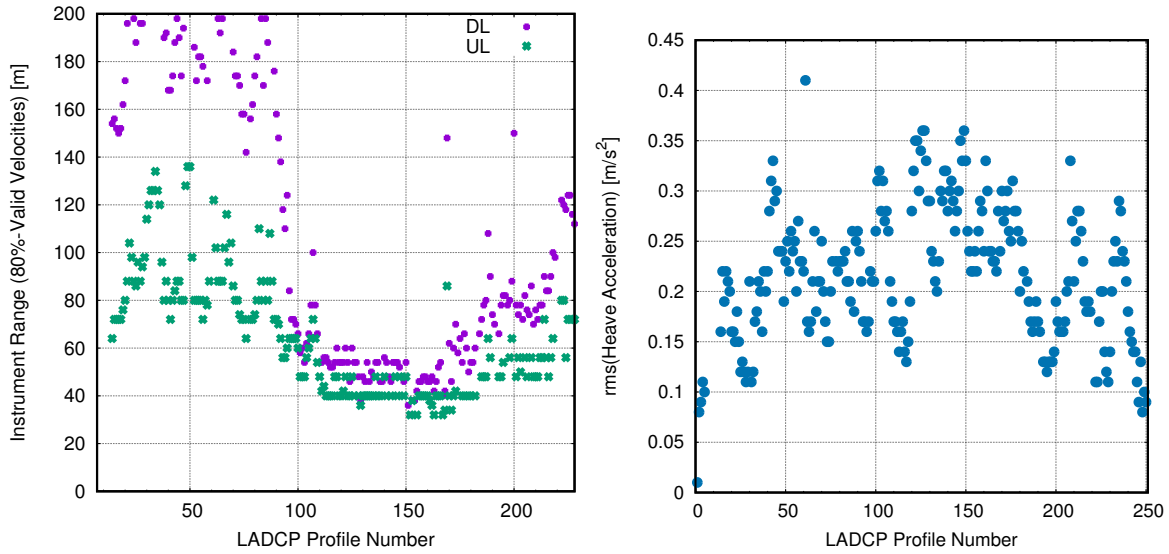


Figure 3: Left panel: Instrument range. Right panel: *rms* acceleration due to vessel heave (sea state).

and 221) all have ranges greater than 65 m, too, all P6 LADCP profiles are expected to yield good horizontal velocities.

Package motion due to surface waves (sea state) is also known to affect LADCP data quality; in the right panel of Figure 3 sea state is quantified as the *rms* vertical package acceleration. Calm seas are typically associated with accelerations below  $0.2 \text{ m}\cdot\text{s}^{-2}$  or so, implying significant wave-related package motion roughly in the middle third of the cruise. For context, the peak values around  $0.35 \text{ m}\cdot\text{s}^{-2}$  are small compared to values from the Southern Ocean, which frequently exceed  $0.4 \text{ m}\cdot\text{s}^{-2}$ ,

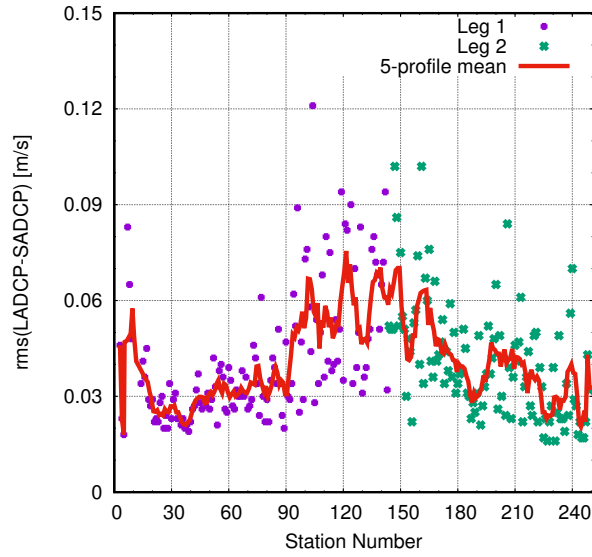


Figure 4: *rms* LADCP-SADCP horizontal velocity differences; low values indicate good agreement.

indicating that sea state is not expected to have a strong detrimental effect on the quality of the P6 LADCP profiles.

### 3 Horizontal Velocity

The overall quality of the horizontal LADCP velocities is assessed by processing all profiles with the velocity-inversion method (LDEO IX 13 software), using the bottom-track (BT) and ship-drift (GPS) constraints and comparing the resulting LADCP velocities near the sea surface to the corresponding SADC velocities. Based on data from other cruises, high-quality LADCP and SADC velocities typically agree within  $3\text{--}6\text{ cm}\cdot\text{s}^{-1}$  when averaged over a few profiles. The data from the 2017 P6 occupation clearly fit this criterion (Figure 4). Only in the middle of the section, roughly between profiles 90 and 170, are there velocity discrepancies around  $6\text{ cm}\cdot\text{s}^{-1}$ , and the number of profiles with significantly higher discrepancies is small. Both low acoustic backscatter and sea state likely contributed to this pattern (Figure 3). Diagnostic plots were inspected from all profiles with velocity discrepancies exceeding  $6\text{ cm}\cdot\text{s}^{-1}$ , but no data anomalies were found.

For final horizontal-velocity processing, the LADCP data were re-processed with all available referencing constraints, including the SADC velocities. As a result, the final velocity uncertainties are smaller than the discrepancies shown in Figure 4, at least for the profiles with errors above  $3\text{ cm}\cdot\text{s}^{-1}$ , which is the nominal accuracy of horizontal velocity from high-quality LADCP profiles. In summary, the quality of the final processed horizontal velocities derived from the 2017 P18 LADCP data is excellent. (Possible exceptions are profiles 1 and 2, both short and shallow casts where the seabed was not detected correctly and for which no good SADC data are available. There are no indications that the resulting horizontal velocity profiles, referenced with GPS data alone, are bad, however, and they are included in the archive.)



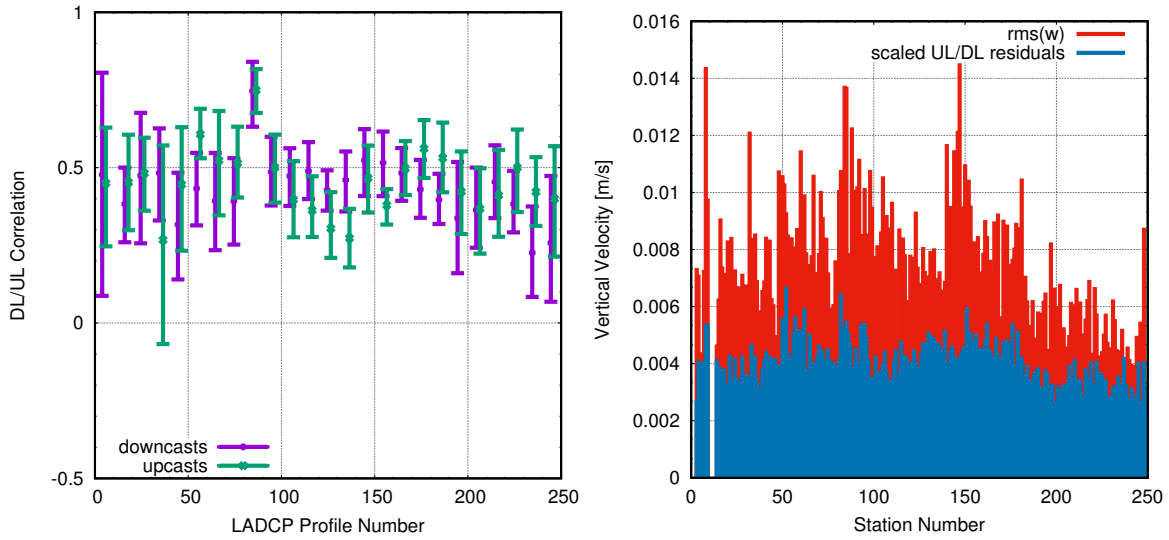


Figure 5: Left panel: Correlation coefficient of DL/UL vertical velocity correlation vs. profile number, averaged in groups of 10 profiles with error bars from bootstrapping. Right Panel: Vertical-velocity signal (red;  $rms(w)$ ) and noise (blue;  $rms$  DL/UL regression residuals scaled by  $2^{-0.5}$ ) vs. profile number. Data from the uppermost 300 m are excluded.

## 4 Vertical Velocity

In order to process the LADCP data for vertical ocean velocity the `LADCP_w` software, version 1.4, was used. In addition to high-quality velocity data from the ADCPs, vertical-velocity processing also requires 24 Hz CTD time series with very few or no missing scans. In contrast to other recent GO-SHIP cruises, there are no indication for CTD data transmission problems during P6, attesting to the high quality of the CTD winch system on the Palmer.

There are vertical-velocity profiles from all P6 stations with valid LADCP data. Dissipation estimates from a finestructure parameterization method (*Thurnherr et al.*, GRL 2015) are available from all stations except those without valid LADCP data (6 & 10–13) and two stations at both ends of the section (1, 2, 249, 250), which are not deep enough for the spectral method to be applied.

In contrast to LADCP-derived horizontal velocity, the two  $w$  measurements at a given depth (from the DL and UL ADCP) are largely<sup>2</sup> independent. Diagnostics based on linear regressions between UL vs. DL-derived  $w$  are therefore useful measures of profile quality. The left panel of Figure 5 shows the resulting correlation coefficients for the P6 LADCP data below 300 m, calculated from  $w_{ocean}$  profiles processed at the default 40 m vertical resolution. Based on experience with other data sets, high-quality LADCP profiles typically have DL-UL correlation coefficients above 0.3 when averaged over a few profiles. The P6 LADCP profiles clearly fit this criterion — the apparent outlier group with correlation coefficients consistently above 0.5 are profiles 81–89 crossing the Havre Trough, where the highest VKE levels were observed on this cruise.

The right panel of Figure 5 shows the vertical velocity signal and noise levels for all dual-head profiles. The red bars show profile-averaged  $w_{ocean}$  below 300 m. (LADCP vertical velocity measurements near the surface are often contaminated by biological effects.) The blue bars show the

<sup>2</sup>Only errors in the CTD package-velocity time series that persist over time scales of minutes can give rise to vertical-velocity errors that are correlated between the two ADCPs.

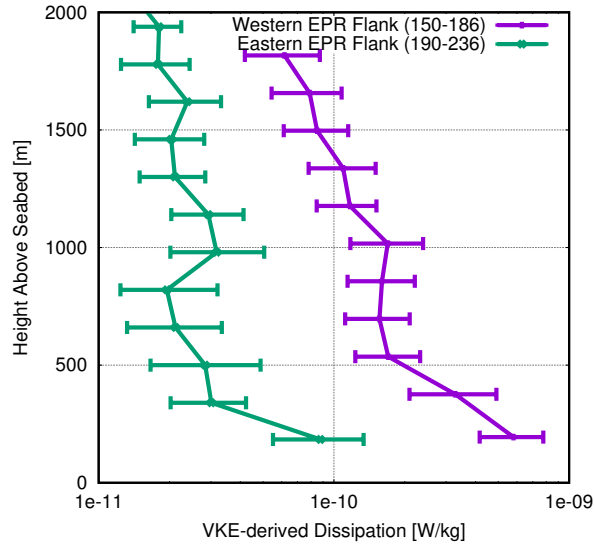


Figure 6: Average height-above-bottom profiles of finescale VKE from the eastern and western flanks of the EPR. VKE is rescaled as dissipation using an empirical scaling (*Thurnherr et al.*, GRL 2015). Error bars indicate 95% confidence from bootstrapping.

corresponding *rms* noise estimates, defined here as the DL-UL regression residuals scaled by  $1/\sqrt{2}$ . Based on experience with other data sets, high-quality LADCP  $w$  profiles typically have residual noise levels in the range  $0.003\text{--}0.006\text{ m}\cdot\text{s}^{-1}$ . The P6 LADCP profiles clearly fit this criterion, too. The profile-averaged Vertical Kinetic Energy (VKE) levels observed during P6 ranged between  $0.004\text{ m}\cdot\text{s}^{-1}$  and  $0.015\text{ m}\cdot\text{s}^{-1}$ , with the  $w$  signal exceeding the noise level in all profiles. East of the EPR crest (station 188) profile-averaged VKE levels are generally lower than west of the EPR crest. A section plot of finescale VKE reveals, among other patterns, that the cross-EPR difference is due to a thick layer of elevated finescale VKE over the entire western EPR flank (Figure 1). Average EPR-flank profiles of finescale VKE, rescaled as dissipation using an empirical scaling (*Thurnherr et al.*, GRL 2015), indicate that the differences are significant (Figure 6).

## CCHDO Data Processing Notes

### Data History

- **File Online Carolina Berys**

[p06\\_leg1.pdf \(download\)](#) #27406

**Date:** 2018-09-27

**Current Status:** unprocessed

- **File Submission Joseph Gum**

[p06\\_leg1.pdf \(download\)](#) #27406

**Date:** 2018-09-17

**Current Status:** unprocessed

**Notes**

Updated cruise report

- **File Merge Carolina Berys**

[320620170703\\_hy1.csv \(download\)](#) #24c69

**Date:** 2018-08-13

**Current Status:** merged

- **File Merge Carolina Berys**

[320620170703.exc.csv \(download\)](#) #6addd

**Date:** 2018-08-13

**Current Status:** merged

- **Bottle data online including TCARBN update Carolina Berys**

**Date:** 2018-08-13

**Data Type:** Bottle

**Action:** Website Update

**Note:**

P06 2017 320620170703 processing - BTL/merge - processing, TCARBN

2018-08-14

C Berys

Submission

filename	submitted by	date	id
320620170820_hy1.csv	Andrew Barna	2017-11-20	13769
320620170703.exc.csv	Bob Key	2016-01-28	12077

#### Changes

(samples are station-cast-sample)

\* 19-1-15 PH\_TOT flag from 5 to 3, pending final data update

\* value changed to fill value for nan or flag 5 at:

\* 112-1-24 PH\_TOT

\* 73-1-12 CFC-11, CFC-12

\* 73-1-14 CFC-11

\* 78-1-1 SF6

\* 78-1-2 CFC-11, CFC-12, SF6

\* removed decimal from DEPTH

#### Merge

320620170703.exc.csv merged into 320620170703\_hy1.csv using hydro 0.8.2-48-g594e1cb.

:Updated Parameters: TCARBON, TCARBON\_FLAG\_W

320620170703\_hy1.csv opened in JOA with no apparent problems.

#### Conversion

file	converted from	software
320620170703_nc_hyd.zip	320620170703_hy1.csv	hydro 0.8.2-48-g594e1cb
320620170703hy.txt	320620170703_hy1.csv	hydro 0.8.2-48-g594e1cb

#### Updated Files Manifest

file	stamp
320620170703_hy1.csv	20180814CCHSIOCBG
320620170703_nc_hyd.zip	20180814CCHSIOCBG
320620170703hy.txt	

- **File Online Carolina Berys**

[320620170703.exc.csv \(download\)](#) #6addd

**Date:** 2018-04-17

**Current Status:** merged

- **File Submission R.M. Key**

[320620170703.exc.csv \(download\)](#) #6addd

**Date:** 2018-04-17

**Current Status:** merged

**Notes**

Started with file posted at CCHDO  
Created header (still needs edits)  
Added final DIC from Dana Greeley

- **File Merge Carolina Berys**

[320620170703\\_do.txt \(download\)](#) #4df50

**Date:** 2018-04-03

**Current Status:** merged

- **File Merge Jerry Kappa**

[320620170703\\_do.txt \(download\)](#) #242e5

**Date:** 2018-04-03

**Current Status:** dataset

- **File Submission Jerry Kappa**

[320620170703\\_do.txt \(download\)](#) #242e5

**Date:** 2018-03-29

**Current Status:** dataset

**Notes**

The text version of the P06W\_2017 cruise report is ready to go online. It includes all of the PI-provided data reports as well as an LADCP QC report and CCHDO data processing notes.

- **File Merge Carolina Berys**

[320620170703\\_do.pdf \(download\)](#) #5f9b9

**Date:** 2018-03-16

**Current Status:** merged

- **File Merge Jerry Kappa**

[320620170703\\_do.pdf \(download\)](#) #0812e

**Date:** 2018-03-16

**Current Status:** dataset

- **File Submission Jerry Kappa**

[320620170703\\_do.pdf \(download\)](#) #0812e

**Date:** 2018-03-14

**Current Status:** dataset

**Notes**

An updated pdf version of the cruise report is ready to be added to the "merged" data area. It includes all PI-provided data reports as well as an LADCP QC report.

- **File Merge CCHSIO**

[320620170703\\_ct1.zip \(download\)](#) #342aa

**Date:** 2018-03-05

**Current Status:** merged

- **Update file in As Received to Dataset CCHSIO**

**Date:** 2018-03-05

**Data Type:** CTD

**Action:** Website Update

**Note:**

2017 320620170703 processing - CTD/merge -  
CTDPRS,CTDTMP,CTDSAL,CTDOXY,CTDFLUOR,CTDXMISS,CTDBBP700RAW,CTDRINKO

2018-03-05

CCHSIO

Submission

filename	submitted by	date	id
320620170703_ct1.zip	Joseph Gum	2017-11-18	13767

Changes

-----

320620170703\_ct1.zip

- This is a GO-SHIP Cruise: CTDOXY flags are all uncalibrated
- added cruise comments
- removed DEPTH from header, as all values are -999
- removed space before DATA header
- changed SECT\_ID description from nbp1706 to P06W

- changed parameter name from CTDBACKSCATTER to CTDBBP700RAW (and flag)  
- renamed files to match CCHDO format  
- RINKO: only 4 stations have RINKO data: Other stations were submitted as "0.0000,1"

#### Conversion -----

file	converted from	software
320620170703_nc_ctd.zip	320620170703_ct1.zip	hydro 0.8.2-48-g594e1cb

#### Updated Files Manifest -----

file	stamp
320620170703_ct1.zip	20170305CCHSIO
320620170703_nc_ctd.zip	20170305CCHSIO

:Updated parameters:  
CTDPRS,CTDTMP,CTDSAL,CTDOXY,CTDFLUOR,CTDBBP700RAW,CTDXMISS,CTDRINKO

opened in JOA with no apparent problems:  
320620170703\_ct1.zip  
320620170703\_nc\_ctd.zip

opened in ODV with no apparent problems:  
320620170703\_ct1.zip

- **File Online Carolina Berys**

[320620170703\\_do.txt \(download\)](#) #4df50

**Date:** 2017-11-20

**Current Status:** merged

- **File Online Carolina Berys**

[320620170703\\_do.pdf \(download\)](#) #5f9b9

**Date:** 2017-11-20

**Current Status:** merged

- **File Submission Joseph Gum**

[320620170703\\_do.pdf \(download\)](#) #5f9b9

**Date:** 2017-11-20

**Current Status:** merged

- **File Submission Joseph Gum**

[320620170703\\_do.txt \(download\)](#) #4df50

**Date:** 2017-11-20

**Current Status:** merged

- **File Online Carolina Berys**

[320620170703\\_ct1.zip \(download\)](#) #342aa

**Date:** 2017-11-20

**Current Status:** merged

- **File Online Carolina Berys**

[320620170703\\_hy1.csv \(download\)](#) #24c69

**Date:** 2017-11-20

**Current Status:** merged

- **File Submission Andrew Barna**

[320620170703\\_hy1.csv \(download\)](#) #24c69

**Date:** 2017-11-20

**Current Status:** merged

**Notes**

These data can go online in the dataset, the cruise report will be submitted as soon the CTD/Bottle residual plots are updated.



- **File Submission Joseph Gum**

[320620170703\\_ct1.zip \(download\)](#) #342aa

**Date:** 2017-11-18

**Current Status:** merged