US GEOTRACES Pacific Meridional Transect – GP15
Cruise Report

18 September – 24 November 2018

Seattle, Washington – Papeete, Tahiti (port stop in Hilo, Hawaii, 21-25 October 2018)

R/V Roger Revelle

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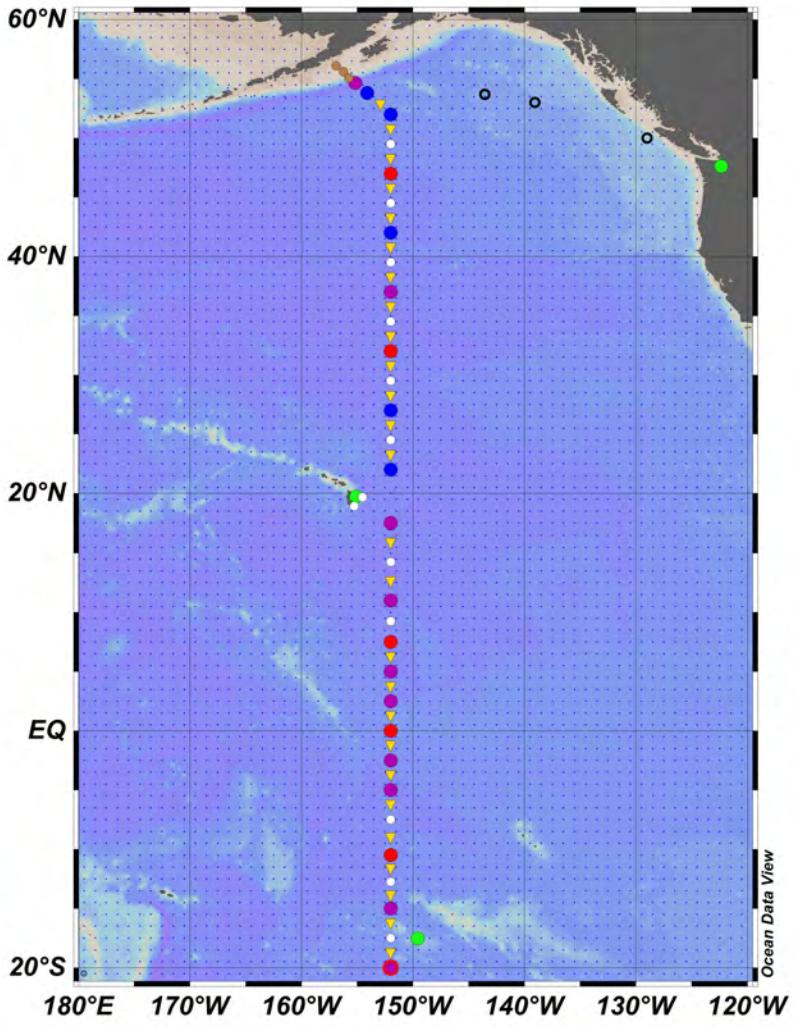

GP15 Cruise Track: Green circles: ports; open black circles: rinse stations; brown circles: shelf and slope stations; Purple circles: Full-36 stations; Blue circles: Full-24 stations; white circles: demi stations; yellow triangles: intermediate fish.

1. Introduction

The fact that many trace elements are bioactive and essential (e.g., Fe, Zn), or toxic (e.g., As, Hg), underlies interest in studying them, but their effects on primary production and oceanic carbon dioxide uptake are the primary drivers. In parallel, many radioactive and stable isotopic tracers allow trace element sources to be identified (e.g., ^{3}He, ^{56}Fe) and rates of transformation or fluxes determined (e.g., ^{230}Th, ^{228}Ra, ^{15}N and δ^{13}C). The use of multi-element, high-resolution sampling on GEOTRACES, coupled with various modeling approaches, allows the inputs/sources and internal cycling of TEIs to be revealed and quantified in an unprecedented fashion. The Pacific Meridional Transect in the central Pacific basin along 152°W from 56°N to 20°S (GEOTRACES GP15) allowed us to sample: strong margin fluxes, sub-Arctic HNLC waters, the oldest deep water in the world's oceans, the distal ends of hydrothermal plumes from the Juan de Fuca Ridge and East Pacific Rise, as well as the relatively recent inputs from Loihi Seamount. We also sampled the far-field oxygen minimum zones originating well to the east, equatorial upwelling, and some of the most oligotrophic waters in the world's oceans in the South Pacific gyre at 20°S. In total, we sampled 36 vertical profile stations over a 67 day period.

To address our overall goals of examining fluxes at ocean interfaces and studying the internal cycling of trace elements and isotopes (TEIs), we sampled at 36 vertical profile stations using 3 primary sampling systems: GTC (GEOTRACES Trace element Carousel) for contamination-prone, dissolved TEIs; ODF (Ocean Data Facility) conventional rosette for the rest of dissolved TEIs, and McLane in-situ pumps for particulate TEIs. Stations were divided into 3 major types: Full where samples were taken at 24 ("Full-24"; 2 GTC and 3 ODF casts, 2 pump casts) to 36 ("Full-36"; 3 GTC and 4 ODF casts, 2 pump casts) depths from surface to bottom; Demi where samples were taken at 12 depths in the upper 1000 m (1 GTC and 1 ODF casts), and Super where 36 depths were also sampled but additional hydrocasts were undertaken to acquire larger volumes and particle sampling resolution was increased (4 GTC and 4 ODF casts, 3 pump casts). In addition to these vertical profile stations, we also sampled surface waters while underway using a towed fish ("Geo-fish" from a 40' aluminum boom extending off the starboard side, forward of the squirt boom) and the ship's flow-through seawater system. These samples were taken within one hour of arriving at a vertical profile station ("arriving fish"), and at locations midway between the vertical profile station ("intermediate fish"). Finally, atmospheric aerosols and event-based rain sampling occurred throughout the entire cruise. More complete descriptions of the stations and sampling systems are found below. Specialized sampling for parameters such as ^{7}Be and Ra isotopes are discussed in their individual science reports. Appendix 1 is a list of the stations occupied with exact locations, dates, and observed bottom depths, while Appendix 2 is a list of science participants on the cruise. Appendix 3 contains the list of all parameters sampled and to be measured at sea or at land-based laboratories as part of the GP15 cruise.

2. Station Descriptions

Mobilization. R/V Revelle was loaded and all science systems set up in Seattle, Washington at Pier 91 from September 14-18, 2018. Four science lab "vans" (built within 20' cargo container) were loaded and secured: US GEOTRACES (ODU) Clean lab (main deck fantail, starboard), WHOI Café Thorium (main deck fantail, port), University of Hawaii Sampling and Analytical Lab (main deck, port quarter), and UNOLS General Purpose lab van (01 deck, aft, port). The

GEOTRACES winch and A-frame were installed on the main deck just aft of the hangar and overboarded on the starboard side. This required removal of one bulwark. On the spare winch (DESH5) the existing drum of .322" metal hydrowire was replaced with one containing 6200 m of 0.322" Vectran cable for the McLane pumps and lead through a composite sheave on the starboard hydroboom. For pump deployments to facilitate safety from boarding seas, one starboard bulwark under the hydroboom was moved 2' inboard and 2' forward (by one set of deck threaded openings in and forward); ratchet straps acted as lifelines between this inboard bulwark and existing ones fore and aft.

To move the ODF 36-place rosette from its storage in the hangar, a track and cart system driven by an air tugger was installed on the starboard quarter deck and the rosette deployed using the ship's automated CTD Launch and Recovery System (LARS) deployment/recovery device and Markey CAST-6 Winch. The tow-fish pedestal and boom were mounted on the main quarter deck, immediately aft of the 01 rescue boat storage location. The boom was swung from vertical storage to a horizontal deployed position using 3/8" Amsteel 12 strand line from the tip of the boom through a block on the 02 deck and down to an air tugger on the quarter deck. It was also guyed forward with a ¼" stainless cable and turnbuckle led to the 02 deck and a 5/8" line led to an aft cleat. Eight McLane pumps were kept in the hangar and secured to the deck using deck bolts through aluminum bars. The four spare McLane pumps were kept aft of the CafeTh van and accessed as needed for spare parts. Finally, a winch for the ^{7}Be pump system and 7 polyethylene tanks were installed under and near the ship's aft A-frame. Five high volume aerosol samplers, an automated rain sampler, and wind sensors where placed against the forward rail of the 03 deck (just forward of the Chief Scientist and Captain's staterooms).

Test Stations. After leaving Seattle for Leg 1 on 18 September 2018, three test stations were occupied (Appendix 1) to test the sampling systems and operations. At Test 1 only the GTC system was deployed to rinse and fill the GO-FLO sample bottles with clean seawater; this required two hydrocasts. Test 2 also filled the GTC bottles, and the water from these casts was analyzed on board for Al, Fe, Mn, and Zn to evaluate potential contamination. Test 2 also included a shallow cast of the ODF and McLane pump systems. Test 3 included two GTC casts and the waters again analyzed for contamination-prone trace metals. The ODF rosette was also deployed with the monocore at test station 3 to test the altimeter cloaking device.

Leg 1 stations. Although the transit ran from Stations 1-18 (Fig. 1, Appendix 1), we first occupied Station 5 (24-25 September) on our way north because it was a deep, offshore station that allowed us to practice our sampling routines without the exact timing required of a shallow shelf station (i.e., fast surface currents). Stations 1-3 on the Alaskan shelf and slope were occupied from 26 to 28 September in stormy conditions with large, 6 m seas and swell. Likely due to these conditions, the electrical termination on the GTC cable failed, necessitating us hoving to in the lee of Chirikof Island to allow repairs. The shelf-deep transit was completed at Station 6 on 1 October and thereafter the transit was directly south along 152° W. It should be noted that our GEOTRACES Intercalibration Crossover station with the 2017 Japanese GP2 cruise was at Station 8 on 4-5 October. In terms of sampling problems on Leg 1, the tow-fish had considerable problems with breaching in the high seas in the northern portion and required numerous adjustments of its fin angles to allow it to reliably stay underwater. Also, at Demi Station 11 the electric motor on the GTC A-frame seized and we could not perform a cast with

this system; the ODF cast was successfully conducted. The ship's electrician Harry Smith rebuilt the motor and it worked excellently for the rest of the cruise. More significantly, at Station 16 a winch operator error resulted in significant damage to the first 2247 m of the Hytrel plastic coating of the 0.322" Vectran pump cable such that it was questionable whether the cable could hold the pumps without failure. Temporary repairs (Scotch coat and electrical tape) were made to allow continued pump operations for the next 2 stations, but the cable would have to be properly repaired during the Hilo port stop. See further details in the McLane pump section.

Puna Ridge bonus station. By Station 16 we were 14 hours ahead of schedule and we decided to conduct a bonus station sampling of the Puna Ridge where the highest concentrations of ^{226}Ra have ever been measured in the ocean (Moore et al., 2008) and likely could be a unique source of TEIs to this region. We added Station 18.3 to our transit from Station 18 to our port stop in Hilo, HI. At this station (Appendix 1) we did one cast each to 2130 m (bottom depth was 2160 m) of the GTC, ODF, and McLane pump systems.

Port stop in Hilo, Hawaii. The Hilo port stop was from 21-24 October where we refueled the ship, added provisions, received some scientific gear, offloaded 9 pallet boxes of samples, 15-20 ice chests of frozen samples, plus two dry shippers, and samples for Po/Pb, $\Delta^{17}O$, and Ra groups. 13 scientists (including the two resident technicians) and more than half the crew were also exchanged in Hilo. As an important outreach event coordinated by Mariko Hatta, over 50 undergraduate and graduate students from the University of Hawaii, Hilo, toured the ship and learned about the GEOTRACES science we were conducting. Finally, and most importantly, the Vectran pump cable was repaired. The latter involved air shipping a spool of used Vectran cable from UC Santa Cruz, cutting out the damaged original Vectran, and splicing a 3849 m piece of Vectran onto the remaining 3245 m of cable on the winch drum. To do this, a technician from Cortland Cable, the manufacturer, flew in to perform the splicing. All of this forced a 12 hour later departure than planned.

Leg 2 stations. We left Hilo at 9 pm on 24 October and very soon thereafter occupied another bonus Station, 18.6, above the Loihi Seamount crater (1320 m depth) to serve as a bench mark/end-member for hydrothermal emissions from this source to the North Pacific. The station itself was only sampled with the GTC and ODF systems, in effect a demi station, but with the sampling focus on the deep, near-bottom waters. This only added 4 hours to our Leg 2 times. Thereafter, we sampled Station 19 on the original transect at 152° W (Appendix 1) that was originally placed to sample the Loihi plume for which we now had an end member for comparison. However, we still had to make up for the 12 hour "Vectran deficit" so we chose to eliminate Demi Stations 24, 26, 28, 30 and 32 near the equator, replacing them with a surface-only fish sampling. A benefit to this elimination, besides saving some time, was that closely-spaced stations around the equator were causing worker stress from lack of sleep and we all benefitted from the added rest times. Otherwise, the stations and sampling during Leg 2 occurred without interruptions.

In terms of any sampling problems during Leg 2, the major one was that the Vectran repair made the cable substantially wider for ca. 1 m and caused very poor level winding and cable crossings that slowed deployment and recoveries by ca. 2 hours. The problem turned out to be the poorly fitted shrink wrap coating the cable splice. After we removed it and replaced it with Scotch coat

and electrical tape, the level winding went perfectly and without delay. The second sampling issue was due to the tow-fish breaching. The cause this time was a missing steering fin and the ship engineers fabricated a replacement until this too broke off at Station 35. Thereafter, we deployed and recovered the fish between uses (arriving and intermediate fish) while only steaming at 8 knots during use.

Due to increased efficiency, we were able to conduct sampling at full-36 resolution at station 37, rather than the reduced full-24 resolution. Our final station, 39, at 20° S, was sampled on 21-23 October and was modified slightly from the original plan of being a Full-36 station. In view of its location in the ultra-oligotrophic South Pacific gyre and the probable location for the first station of the next (2021?) US GEOTRACES transect (GP17), we added an additional pump cast so that 24 rather than 16 depths were sampled for particles. This added 12 hours to our station time, but we completed it on time to get to Tahiti as scheduled and with a much more complete sampling for this future Crossover Station.

Demobilization in Papeete, Tahiti. We arrived in Papeete at 0710 on 24 November and immediately started demobilization. This was completed on 26 November with virtually of the scientific gear and samples removed from the ship and on their way for the United States by container and air.

Reference

Moore, W.S., Ussler III, W., Paull, C.K., 2008. Marine Chemistry. Short-lived radium isotopes in the Hawaiian margin: Evidence for large fluid fluxes through the Puna Ridge, 109: 421-430.

GP15 Leg 1 (RR1814) group photo.

GP15 Leg 2 (RR1815) group photo

3. Sampling systems

3.1 GTC

The Cutter (ODU) group provided the GEOTRACES Trace Element Carousel sampling system (GTC), including the Dynacon winch with 7300 m of Vectran cable with conductors, clean lab, and Seabird carousel/CTD with 24 12L GO-FLO bottles (and 11 spares). Laramie Jensen (TAMU) and Brent Summers (USF) were the "super technicians" in charge of the trace element sampling itself as well as deploying and recovering the GTC. Lisa Oswald (ODU) oversaw the logistics including maintaining the cruise Event Log for the entire cruise. Kyle McQuiggan and Greg Cutter ran the GTC sampling operations (data acquisition, winch operations) with assistance from ODU graduate student Sveinn Einarsson.
In total, 72 GTC hydrocasts were conducted and 2 GO-FLOs per depth were triggered (3 per depth for super stations to accommodate water requests), with subsequent filtration using Acropak capsules (0.2 □m). An average of 10 sample bottles were filled from each Acropak-filtered GO-FLO, but this number varied based on station type and depth. For the 35 stations occupied on Leg 1 and Leg 2, which includes shelf, slope, demi, full, super, and "bonus" stations between 56°N and 20°S, this represented the acquisition of upwards of 15,500 trace element samples. Shipboard analyses of Al, Mn, and Fe (UH), and Zn (ODU) indicated intermittent contamination for some GO-FLOs, and these were replaced with a backup bottle upon discovery of a consistent contamination pattern. Additionally, intermittent leakage or mistrips occurred in some GO-FLO bottles, and a "GO-FLO Leaker List" on an Excel Spreadsheet has been created and distributed.
Besides samples for ship-based analyses, most samples were taken from the GTC in support of shore-based analyses. Including these, the following groups received samples: Anderson (LDEO; colloidal Th); Boyle/Rember (MIT/UAF; Cr and Pb isotopes); Conway/John (USF/USC; TEI isotopes); Cutter (ODU; shipboard H_2S, Zn and nanonutrients); Fitzsimmons (TAMU; colloidal TEIs); Fitzsimmons/Till (Humboldt; dissolved metals); Hatta/Measures (UH; shipboard Al, Fe, Mn); Horner (WHOI; Ba); Mason (UConn; Hg); Moffett (USC; inert Cu); Repeta (WHOI; ligands); Saito (WHOI; Co); Shiller (USM; REEs). In addition to these parameters, samples of opportunity were taken at select stations for Lamborg (UCSC; total Hg); Dulaquais (UBO; DOM); Fitzsimmons/Buck/Bundy/Hurst (TAMU/USF/UW/Humboldt; Fe ligands) when water budgets allowed. It should also be noted that a malfunction with the A-frame motor did not allow us to use the GTC at Demi Station 11.

3.2 ODF Rosette

The 36-place Scripps Ocean Data Facility (ODF) rosette was used to sample water for less contamination-prone elements (Table 1). Casciotti (Stanford, co-cruise leader), along with Marty Fleisher (LDEO) and Colette Kelly (Stanford) were responsible for managing the water budget and overall sampling of the ODF rosette. The ODF group was responsible for maintenance and calibration of the rosette bottles and instrumentation. Costs associated with management of the rosette and sample collection on this cruise was covered by Casciotti's portion of the GP15 management grant (OCE-1657944), with subcontracts to Swift (SIO) and Anderson (LDEO).

Sampling order for unfiltered samples was: CFCs, He, ODF O2, Δ17O-O2 (where collected; see ODF sample log appendix), N2O (where collected), CH4, δ13C-DIC, salts and nuts, and δ18O-H2O. DOC and genomics samples were collected after the gas sampling was completed. When DOC and genomics samples were collected from 'gas' bottles, they were collected after Si and NO2-/NO3- isotope samples. For filtered samples, the order of collection was Si (where collected), NO2-/NO3-, DOS (where collected). Nutrients were sampled from every bottle. O2 and salts were collected from one (usually the first) bottle at every depth.

Gas samples, Si, and NO_2^-/NO_3^- samples were also collected from the first bottle at every depth. Large volume samples were collected from additional bottles tripped at a given depth: Th/Pa, Nd/REE, Po/Pb (where collected), artificial radionuclides (where collected), U series isotopes (where collected), and Th/Pa archive samples (where collected). Po/Pb, Th/Pa, Nd/REE and artificial radionuclides were generally sampled in that order. Cubitainers for Po/Pb samples were not acid washed, while those for Th/Pa and Nd/REE were. To save water, sample rinses went from acid washed into non-acid washed containers. Po/Pb cubitainers were processed by Mark Stephens immediately after collection. Th/Pa, Nd/REE, and artificial radionuclide samples were acidified with 6N HCl (20 mL in 5 L samples, 40 mL in 10 L samples, and 60 mL in 20 L samples). Cubitainers were sealed with parafilm and double bagged before transfer to pallet boxes on deck. Please see individual science reports for more details of onboard sample processing.

Table 3.2-1: PI, parameters, and samplers of ODF rosette.

Role (PI-param)	**Sampler (Leg 1)**	**Sampler (Leg 2)**
Lead/Bottle cop	Karen Casciotti	Karen Casciotti
Super tech	Marty Fleisher	Marty Fleisher
Super tech	Collette Kelly	Collette Kelly
ODF O_2	Erin Hunt	Susan Becker
	Melissa Miller	Andrew Barna
ODF salts and nuts	John Calderwood	Erin Hunt
	John Collins	Kelsey Vogel
Fine-CFCs	David Cooper	Jim Happell
German/Jenkins-^{3}He	Kevin Cahill	Zoe Sandwith
Casciotti—N_2O	Colette Kelly	Colette Kelly
Shiller-CH_4	Laura Whitmore	Virginie Sanial
Quay-δ^{13}C-DIC, Δ^{17}O-O_2	Chuck Stump	Chuck Stump
Sikes--δ^{18}O-H_2O	Kevin Cahill	Zoe Sandwith
Casciotti—δ^{15}N-NO_2^-/NO_3^-	Casciotti/Kelly/Fleisher	Casciotti/Kelly/Fleisher
Repeta-Ligands, DOC	Lydia Babcock-Adams	Jingxuan Li
Buesseler-^{234}Th, ^{129}I	Jennifer Kenyon	Jennifer Kenyon
Charette/Moore-Ra	Paul Henderson	Emilie LeRoy
Biogeotraces	Sveinn Einarsson	Sveinn Einarsson
Pigments	Alex Fox	Alex Fox
Brzezinski--Si isotopes	ODF super techs	ODF super techs
Anderson—Th/Pa	ODF super techs	ODF super techs

Kadko/Cochran-Po/Pb	ODF super techs	ODF super techs
Goldstein--Nd/REE	ODF super techs	ODF super techs
Kenna—Art. radionuclides	ODF super techs	ODF super techs
Cutter—DOS	ODF super techs	ODF super techs

Cast types included 'Demi' station casts to 1000 m, shallow casts to 400-1000m, intermediate casts from 400-2000 m, and deep casts to within 40 m of the bottom. At each full and super station, an additional cast of the ODF rosette was conducted to sample large volumes for pigments, Radium, and Thorium isotopes (PigRaTh). On the PigRaTh casts, eight depths were selected to match the shallowest eight pump depths. Another four depths were chosen for resolution of Th-234, and a surface bottle was tripped for a 13th sample depth. The surface bottle was used primarily to sample dissolved gases at the sea surface, rather than drawing from the towfish or the ship's underway system. Surface bottle sampling also occurred at demi stations (13 depths sampled instead of 12).

Pigments were sampled from the shallowest 6 depths on every PigRaTh cast (including the surface bottle). Pigments were collected into 2L amber bottles, triple rinsed with sample prior to filling. They were immediately filtered under vacuum through 47 mm GF/F filters. They were folded and placed inside cryovials, labeled with appropriate GEOTRACES numbers, and frozen at -80 °C.

Samples for $\Delta^{17}O\text{-}O_2$ were collected at the shallowest 7-8 depths on PigRaTh. On Leg 2, CH_4 was also sampled from the shallowest 8-10 depths on PigRaTh. At super stations, N_2O was sampled from PigRaTh instead of the shallow ODF cast. Cesium isotope samples were collected from the ODF rosette at Stations 7, 9, 11, 13, 15, 17, 20, and 22 (Table 2).

Additionally, 47 samples were collected for shipboard Al, Fe, and Mn from Station 18.3 (Puna Ridge), Station 18.6 (Loihi Seamount) and one superstation (station 35) for comparison to analyses from the GEOTRACES rosette. These samples were collected by M. Hatta and G. Weiss, filtered through the 0.8/0.45m μm Acropak 500 capsule filter prior to collection of the NO_2^-/NO_3^- isotope samples.

Filtered samples were collected through Acropak filters (nested 0.8, 0.45 um filter capsules). These filters were reused on similar casts (shallow, intermediate, or deep), drained, and kept refrigerated between uses. Tubing for filters was reused for every cast, rinsed with milliQ between casts. There were 36 filters in use at any one time, with 12 in use for shallow and demi cast depths, 12 in use for intermediate cast depths, and 12 in use for deep cast depths. All 36 filters were changed out between Leg 1 and Leg 2. One filter was used exclusively for all depths on the shelf stations, and then discarded.

For details on CTD instrumentation, data processing, nutrient, salts, and oxygen measurements at sea, please see ODF facility report.

Reported sampling issues:

Water budgets were prepared based on requested water amounts from each group. In some instances, the 'gas' bottle contained less than the expected amount of water. In such cases, water was sometimes borrowed from Th/Pa and Nd/REE bottles.

On occasion, when a 30-L niskin bottle deployed with the McLane pumps did not close properly, water was collected from the ODF niskin rosette at the appropriate depths.

$\delta^{18}O$-H_2O samples were filled as prescribed, though it was difficult to avoid bubbles with the shoulder on the scintillation vials. Tightly capped bottles were wrapped twice with electrical tape (mostly clockwise).

Teflon liners on the caps of Si isotope sample bottles were difficult to contend with, as they were not secured to the caps. Some were lost in rough seas.

3.3 McLane Pumps

The McLane pumping operations were part of Phoebe Lam's (UCSC) management proposal with subcontract to Steve Pike (WHOI). The McLane pumps were used to collect size-fractionated small (~1um-51um) and large (>51um) particles using "mini-MULVFS" filter holders and short-lived radionuclides (Ra quartet, Th-228, Ac-227) using 1-2 Mn-coated cartridge(s) attached downstream of the filter holders.

3.3.1 Equipment:

In-situ pumps, wire, 30 L Niskins

WHOI provided 12 dual-flow battery-operated McLane pumps with two cartridge holders (modified WTS-LV-upright) from the WHOI UNOLS pump pool, and 6200 m of 0.322" OD Hytrel-coated non-conducting Vectran wire, MBS=5700 lbs (property of Ken Buesseler at WHOI). Two titanium pressure cases rated to 6000 m depth were purchased on the management grant for the two deepest McLane pumps (normal upright McLane pump pressure cases are rated to 5000 m), and will become part of the WHOI UNOLS pump pool.

The Vectran was spooled onto a refurbished and newly powder coated SIO drum at MarFac prior to the cruise (summer 2018) and deployed from the DESH-5 winch and squirt boom on Revelle. Up to eight McLane pumps were deployed at a time on a cast. The remaining four pumps were used for parts and as spares. WHOI also supplied eight 30L Niskin bottles (plus two spares) that were mounted on the pump wire on intermediate and deep casts.

SBE 19-plus Seacat CTD with optical sensors

Lam provided a SBE 19-plus Seacat self-recording CTD that was shackled to the end of the non-conducting Vectran wire for each pump cast. The Seacat CTD was outfitted with the following optical sensors:

- Seapoint Turbidity Meter (S/N 15785 at stns 5,3; S/N 10595 at Stns 4-16; S/N 12809 at Stns 18-39) (V0)
- WetLab ECO-AFL/FL Fluorometer (S/N FLNTURTD-870) (V1)

- prototype WetLabs/UC Berkeley Particulate Inorganic Carbon Sensor (S/N PIC 011) from Dr. Bishop (V2)
- WetLabs C-Star Transmissometer (S/N CST 1450) on loan from Dr. Jim Bishop (UC Berkeley) (V3)

Three Seapoint Turbidity Meters were used:

- S/N 15785 (Lam—UCSC) was deployed at the first station 5, but sustained damage when the CTD hit bottom on Station 5d (see "Problems encountered" section). It was deployed again at Station 3 before damage was noticed.
- S/N 10595 (Bishop—UCB) was deployed from Station 4-16, but it had 10x lower sensitivity and so was changed out.
- S/N 12809 (Bishop—UCB) was deployed from Station 18-39.

Pingers

Four pingers were used on the cruise to determine proximity of the Seacat CTD to the bottom. The pingers were attached by hose clamps and shackles onto the Seacat CTD frame. The first pinger was supplied by WHOI (Oceanographic Instrument Systems, Hi-Power Pinger, Model 6000), and the other three belonged to SIO STS (Benthos).

WHOI Pinger:

- This was deployed on the test cast (Rinse Station 2).
- The signal was too faint and was lost as the package was lowered, and was not used again.

SIO STS Pinger 1 (#1291):

- This was deployed on all subsequent pump casts during leg 1. The signal strength was variable. The direct pinger signal was usually (but not always) visible for the whole cast, and the bottom reflection was visible on about half of the casts. The pinger stayed on the CTD for all casts, but was turned on only for deep casts to save batteries.
- At the port stop at the end of leg 1, mineral oil was purchased to fill the transducer head in an attempt to boost the signal strength, but the bolt broke when it was tightened to (apparent) specifications

SIO STS Pinger 2 (#1214):

- This was tested when the newly spliced Vectran wire was unspooled and respooled onto the drum (see "Problems encountered") at the beginning of leg 2 and had a strong signal.
- It was subsequently deployed at stations 19 and 21. The bottom reflection was only visible 100 m from the bottom (visible at 5040m) at station 19D; pinger reflection was never visible on station 21D. There was an oily film on the outside of the transducer end after the 21D recovery, indicating an oil leak from the transducer. The pinger stayed on the CTD for shallow and deep casts of these two stations, but was turned on only for deep casts to save batteries.

SIO STS Pinger 3 (#1074)

- This was deployed on Station 23D and a pinger reflection appeared at payout=3275m (bottom depth = 5210m).
- Deployed on Station 25D—pinger fainter, and reflection not visible. Oily film on outside after 25D recovery, indicating an oil leak.

No more pingers were deployed after station 25D. Vectran level-wind on the drum was good by this point, so wire payout was within 5 m of depth as sensed by the CTD.

3.3.2 McLane pump team:

The pump team consisted of the two McLane pump "supertechs", Steve Pike (WHOI) and Yang Xiang (UCSC), Vinicius Amaral (UCSC), Jennifer Kenyon (WHOI-short-lived thorium), Paul Henderson (WHOI-radium isotopes, leg 1), Emilie LeRoy (LEGOS-radium isotopes, leg 2), and Phoebe Lam (UCSC). Pike was responsible for pump programming and maintenance; Xiang led the particle processing and subsampling with help from Amaral; Lam oversaw pump operations and particle processing; Henderson/LeRoy were responsible for Ra sampling from Mn-coated cartridges attached to the pumps; Kenyon was responsible for sampling for Ra and Th from the 30L Niskin bottles. She also sampled all Niskins for nutrients and salts, which were analyzed by the ODF group. All helped with pump deployments and recoveries.

3.3.3. McLane pump operations:

McLane pumps were programmed with a trigger delay time that was determined based on our best estimate of the deployment time from start to finish (reaching of final target depth), plus a small (usually ~10 minute) cushion. The CTD was deployed first and was allowed to debubble for 1 minute just below the surface. Starting at Station 6S, a snap shackle was attached to the bottom frame of the CTD to lift the CTD to a horizontal position to let bubbles escape from the vertically-mounted PIC sensor. This was found to improve PIC sensor data quality. Just after the CTD was deployed, the pumps were triggered using a screwdriver to short the connection, setting the pumps to countdown to start pumping (see "Problems encountered" section for more).

A 30 L Niskin was mounted above each pump on all intermediate and deep casts to collect water for the radium and short-lived thorium groups. Niskins were not mounted above pumps on the shallow casts because water for these groups was collected on the ODF PigRaTh cast that followed each shallow McLane pump cast.

On shallow casts, the McLane pumps were mounted at wire out readings determined from target sampling depths. On intermediate and deep casts, the 30L Niskin was mounted first, then a pump was mounted 1-2m below the Niskin. A long lanyard with Teflon-coated messenger was attached to the Niskin and the messenger was clipped below the pump, thereby bypassing the Niskin and pump pair. On these deeper casts, a messenger was dropped halfway (2 hours) through pumping to trigger the Niskin bottles to close.

3.3.4. McLane pump cast statistics:

See Table 3.3-1 and bullet points below for a summary of how many and where McLane pumps were deployed.

- McLane pumps were deployed at a total of 23 stations: 12 stations on leg 1 and 11 stations on leg 2
- The number of McLane casts on each station was one at shelf and slope stations, two at full-24 and full-36 stations, and three at super and full-36-PLUS stations.
    - A total of 49 McLane casts were completed (not including the test cast at Rinse station 2): 23 casts on leg 1 and 26 casts on leg 2.
- The number of pumps deployed was 388: 180 on leg 1, and 208 on leg 2.

- Including dipped blank filters, we collected 437 of each of QMA pairs, Supor pairs, QP prefilters, and SP prefilters.
- The total volume filtered in-situ by pumps was about 491,891 L over the whole cruise.

Table 3.3-1: McLane pump cast statistics

Leg	Station #	station type	# pump casts	# pumps/cast	#pumps/ station	#QMA pairs/ station	#Supor pairs/ station	#51um over QMA/ station	#51um over Supor/ station
1	5	full	2	8	16	18	18	18	18
1	1	shelf	1	4	4	5	5	5	5
1	3	slope	1	8	8	9	9	9	9
1	4	full-36	2	8	16	18	18	18	18
1	6	full-24	2	8	16	18	18	18	18
1	8	Super	3	8	24	27	27	27	27
1	10	full-24	2	8	16	18	18	18	18
1	12	full-36	2	8	16	18	18	18	18
1	14	Super	3	8	24	27	27	27	27
1	16	full-24	2	8	16	18	18	18	18
1	18	full-24	2	8	16	18	18	18	18
1	18.3	shelf	1	8	8	9	9	9	9
2	19	full-36	2	8	16	18	18	18	18
2	21	full-36	2	8	16	18	18	18	18
2	23	Super	3	8	24	27	27	27	27
2	25	full-36	2	8	16	18	18	18	18
2	27	full-36	2	8	16	18	18	18	18
2	29	Super	3	8	24	27	27	27	27
2	31	full-36	2	8	16	18	18	18	18
2	33	full-36	2	8	16	18	18	18	18
2	35	Super	3	8	24	27	27	27	27
2	37	full-36	2	8	16	18	18	18	18
2	39	full-36-PLUS	3	8	24	27	27	27	27
Whole cruise total	23		49		388	437	437	437	437
Leg 1 total	12		23		180	203	203	203	203
Leg 2 total	11		26		208	234	234	234	234
Total volume filtered (L)					491,819				

leg 1 total					234,979				
leg 2 total					256,841				

3.3.5 Particle Sample collection:

Each pump contained two "mini-MULVFS" style filter holders (Bishop et al. 2012) plumbed into the pump head. One holder was loaded with a 51um polyester mesh prefilter (underlain by a 150um polyester mesh support filter) above paired 0.8um polyethersulfone Supor membrane filters on a separate stage (0.8-51um size fraction) for contamination prone TEIs; the second holder was loaded with a 51um polyester mesh prefilter (underlain by a 150um polyester mesh support filter) above paired Whatman QMA quartz fiber filters underlain by a 150um polyester mesh support filter on a separate stage (1-51um size fraction) for particulate organic carbon and TEIs requiring higher volumes (e.g. short-lived radionuclides). The 51um prefilters over the Supor and QMA filters are referred to with the suffixes "Sp" and "Qp", respectively. Typically the volumes filtered through the Supor and QMA sides were ~400 L and 1100 L, respectively. One of the pumps ("Pump 3") had a larger top plate that allowed the attachment of two additional filter holders loaded with a Supor set and a QMA set of filters, each filter set overlain by a 0.2 um Supor to act as a particle prefilter. These holders were not plumbed into the pump head, but were exposed to seawater for the duration of the cast and functioned as seawater/process blanks ("dipped blanks") for each filter type (i.e., Sp, Qp, Supor, QMA).

Please refer to the narrative from the Radium group for details and statistics about the Mn-coated cartridge sample collection.

3.3.6 Particle sample handling and subsampling:

Excess seawater in the headspace of filters holders was sucked down on deck using an aspirator pump before removing filter holders from the pump. Filter holders were brought into the main lab bubble and sample processing began within an hour (usually within half an hour) of recovery of all pumps.

In the bubble, filter holders were again connected to a vacuum pump to remove excess seawater before disassembling. Digital photographs were taken under constant lighting conditions of each of the four filters to come off a pump (Qp, Sp, Q, S for QMA prefilter, Supor prefilter, QMA, and Supor, respectively). Dipped blank samples were processed first, then filters were processed from shallow to deep.

Table 3.3-2 summarizes the recipients of particle subsamples, the TEIs measured, and processing requirements. A total of 16 groups will receive particle subsamples to analyze over 23 TEIs. Filter subsamples that needed to be frozen or rinsed were subsampled immediately. Remaining QMA filters were dried in a 55°C oven in a 150 mm petri dish. Qp and Supor samples that could be stored dry were first dried in a laminar flow hood on eggcrate grids for >12 hrs, and then subsampled and bagged for distribution.

Table 3.3-2: Particle subsamples

PI	**parameter**	**Which filter; processing notes**	**container**	**representative at sea**

Anderson/ Edwards	$^{230}Th/^{231}Pa$	Qp, Supor: laminar flow dry	6x8" cleanroom bag	Marty Fleisher
Basak/ Goldstein	eNd	Qp: proteins; supor: w/ Th/Pa	see proteins; Th/Pa	Marty Fleisher
Brzezinski	Si isotopes	Supor: laminar flow dry	6x8" cleanroom bag	none
Buesseler (CafeTh)	^{234}Th, ^{228}Th	Sp: CafeTh rinse then oven dry; QMA: oven dry	150mm petri (from CafeTh)	Jennifer Kenyon, Steve Pike
Casciotti	$\delta^{15}N$	QMA, Sp: post ^{234}Th	see ^{234}Th	Karen Casciotti
Charette/ Moore	^{226}Ra	QMA: oven dry	150mm petri (from CafeTh)	Paul Henderson, Emilie Le Roy
Cochran/ Kadko	^{210}Po-^{210}Pb	Qp,Sp,Supor: laminar flow dry	6x8" cleanroom bag	Mark Stephens
Cutter	AVS&CrRS	Supor, QMA: -80C	cryovials	Nicole Buckley, Greg Cutter
Horner	Ba isotopes	Qp,Sp,Supor: laminar flow dry	6x8" cleanroom bag	none
John	TM isotopes	Supor: laminar flow dry	3x5" cleanroom bag	none
Kadko	^{7}Be	QMA: oven dry	150mm petri (from CafeTh)	Mark Stephens
Kenna	Artificial R. (Pu/Np)	QMA: oven dry	150mm petri (from CafeTh)	none
Lam/Lee	pTM	Qp: rinse then laminar flow dry; Supor: laminar flow dry	Qp: leached petrislide; Supor: 3x5"	Phoebe Lam, Yang Xiang, Vinicius Amaral
	PIC	Qp: laminar flow dry; QMA: oven dry	Qp: 3x5" (w/bSi); QMA: 3x5"	Phoebe Lam, Yang Xiang, Vinicius Amaral
	bSi	Qp, Supor: laminar flow dry	Qp: 3x5" (w/PIC); Supor: 3x5"	Phoebe Lam, Yang Xiang, Vinicius Amaral
	C/N+isotopes	Sp,QMA: post ^{234}Th	see ^{234}Th	Phoebe Lam, Yang Xiang, Vinicius Amaral
Hammer-schmidt	pHg	QMA: laminar flow dry in vials	Hg vials	Yipeng He, Rob Mason

Repeta	ligands	QMA: frozen	teflon-lined ziplocs	Lydia Babcock-Adams, Jingxuan Li
Saito	proteins	Qp, QMA: RNALater, then -80 freezer	Cryovials; Ziploc bags to foil to -80C for "QMA rest of filter"	Rebecca Chmiel

3.3.7 Transmissometer Maintenance:

Transmissometer windows were cleaned before and after each deployment with a kimwipe wetted with dilute Dawn detergent, a liberal MQ water rinse, and wiped dry with a kimwipe. On-CTD readings of Vair (unblocked beam) and Vdark (blocked beam) were taken every few stations. Windows were cleaned until Vair was maximized.

Transmissometers from the three main systems (GTC, ODF, McLane pumps) were intercalibrated by taking readings of Vair and Vdark powered by a 12V power supply and read by a multimeter. Two of these intercalibrations were conducted on leg 1 (start of cruise, after station 8D), and one on leg 2 (before station 38).

3.3.8 Problems encountered:

Initial spooling onto the drum:

Poor initial level-winding onto the drum at MarFac prior to the cruise led to skipping on the metering wheel and therefore significant underestimate of the actual wire out by the metering wheel payout reading. On the first deep cast, we hit bottom with the self-recording CTD at the end of the wire even though the wire payout reading at the final depth was 4575m and the multibeam bottom depth was 4610m. Luckily, the sensitive optical sensors on the CTD were not permanently damaged and were restored to working condition after a thorough cleaning. On subsequent casts, we paid much closer attention to the pinger and were much more conservative in our approach to the seafloor. Careful respooling and level winding of the wire back onto the drum after a few deep casts fixed the problem of the inaccurate wire payout.

Wire damage incident (10/16/18)

Winch operator error during the deep McLane pump deployment at station 16 (27°N, 152°W) on 10/16/18 during leg 1 led to damage of the first 2247m of the Vectran wire: the wire had gotten caught in a hook of a stanchion between the winch and the block, and abraded against this hook at high tension, severely damaging the Hytrel jacket. The Vectran strength core did not appear damaged, but the core was exposed at many places along the first 2247m of wire. For the rest of this cast (recovery) and the remaining three casts of this leg (station 18s, 18d and station 18.3), deployments and recoveries were significantly delayed as we attempted to patch the jacket wherever the core was exposed using a combination of ScotchKote and electrical tape. This became unsustainable, and a decision was made to rush freight a spare spool of Vectran wire from UC Santa Cruz belonging to Lam to Hilo, HI. The original line was chopped at 2955m, which included the damaged 2247m as well as damage on the wire from a previous cruise at 2955m. A travelling rigger from Cortland Cable company, the manufacturers of the Vectran wire, was engaged to fly to Hilo to splice the old line to the spare line. A length of 3855m of spare line was spliced to and spooled on top of 3245m of the remaining old line, for a total of 7094 m of spliced line on the DESH-5 drum for leg 2. During the transit to the first station of

leg 2 (Station 19), a small pigweight and SIO Pinger #2 were shackled to the end of the Vectran wire and 4200 m of wire (to pass the 3855 m splice) was unspooled (~150 lbs tension) and respooled (~300 lb tension).
The jacket that was placed around the splice at 3855m by the Cortland rigger increased the OD of the wire in the spliced section by a factor of 2, causing major level wind issues. On the first deep McLane cast of leg 2 (Station 19D), the Cortland jacket (two layers of heat shrink tubing) was cut off, and the exposed Vectran splice was Scotchkoted and electrical taped to approximately match the OD of the rest of the Hytrel-jacketed Vectran wire. This fixed the level winding issues.

Pumping issues:
a) The sum of the QMA and Supor flowmeters should be within 5% or so of the reading of the final flowmeter. If the final flowmeter is significantly greater than the sum of the QMA and Supor flowmeters, this indicates a leak in the plumbing, often associated with a Mn cartridge holder that is not sealed. In these cases, the QMA and Supor volumes are generally lower than usual, but should be ok. However, the appropriate volume to be used for the Mn cartridges may not be easily recoverable.

b) the ratio of volume filtered through the Supor/QMA sides is typically 0.38. If the ratio deviates significantly from this, this may indicate a leak in the Supor or QMA flowmeters.

c) The triggers for Pumps 1, 2 (with updated CF-2 firmware) stopped functioning starting station 33D; the trigger for pump 8 (old TT8 firmware) stopped functioning starting station 35S; the trigger for pump 3 (old TT8 firmware) stopped functioning starting station 37D (failed pump); the trigger for pump 4 (old TT8 firmware) stopped functioning starting station 39S. Pumps with failed triggers were programmed on a schedule just after the CTD was deployed. The remaining pumps were programmed with a trigger delay as usual.

d) We had 12 failed pumps out of a total of 388 deployed (3% failure rate). Failed pumps were generally due to one of the following problems:
i) corrosion in the pins connecting the pressure case to the motor cable: the solution was to carefully clean the pins and make sure the plug was properly seated and sealed. The McLane pump error for this was either “sudden flow obstruction”, or “sudden pressure release”.
ii) corrosion in the communication pins on the pressure case: the McLane pump error message for this was “stopped by user”. The solution was to carefully clean the pins and make sure the plug was properly seated and sealed.
iii) failed trigger: despite carefully cleaning the trigger pins and using a variety of screwdrivers to short the connection, we could not get these to work. Our solution was to switch to “Schedule” mode when programming pumps with failed triggers.

30L Niskin issues:
Several bottles failed to trip, especially on leg 1, due to the messenger lanyard getting caught on various Niskin hardware parts. When this happened, water for the Ra and short-lived thorium groups was often obtained from the ODF rosette cast at the expense of water for unfunded parameters.

3.4 Tow-fish

The clean sampling system using for obtaining clean trace element surface samples during transits and arriving on stations has been called the "Geo-fish" due to its designer and builder, Geoffry Smith at UC Santa Cruise; for GP15 we simply called it the Tow-fish. This system was provided by Cutter (ODU) as a portion of this management grant. It consisted of a weighted torpedo with adjustable fins to control its depth and horizontal position relative to the ship's hull, and a vane that directed the ½" Teflon sample tubing into fresh water while travelling up to 12 kts. These were held away from the ship with a 40' aluminum boom mounted to a pedestal on the starboard, main quarter deck (see Mobilization section above). The Teflon tubing is lead to a compressed air-powered, Teflon bellows pump and another length of tubing leads to a filtration manifold kept in the main lab clean bubble. The manifold has Teflon valves that allow the water to be directly sampled unfiltered, or passed sequentially through a 0.45 μm, 10" filtration cartridge then a 0.2 μm, 10" cartridge. From these the water is directed into in a 60L, polyethylene tank for sampling non-contamination prone trace elements and isotopes (TEIs; in this case the ones sampled using the ODF system) or directly sampled for contamination-prone TEIs such as those sampled with the GTC sampling system. The flow rate through the systems averaged 4L per minute, and the filter cartridges were installed on 21 September 2018 before Station 1 and changed on 11 October and 11 November 2018.

Deployment, recovery and general system maintenance was done by Sveinn Einarsson and Kyle McQuiggan (both from ODU), with help from Greg Cutter (ODU). For Leg 1 Cliff Buck (SkIO) led the clean sampling efforts, while Chris Marsay (SkIO) did contamination-prone sampling on Leg 2. The non-contamination prone and BioGEOTRACES samplings were done by Karen Casciotti, Marty Fleisher, and Sveinn Einarsson. Tow-fish sampling occurred just before arrival at every station ("arriving fish", also called Cast 1, 0 m, on the master data sheet) to obtain surface water for all TEIs, and at stations located half-way between vertical profile Demi, Full and Super stations ("intermediate fish" with a #.5 station number). The primary tow-fish problem during GP15 was fish breaching where the vane and torpedo would leave the water, largely due to ship's roll in heavy, breaking seas, but also when fins came out of adjustment or were damaged/torn away. These problems led to no Tow-fish samples at Intermediate stations 6.5, 7.5, 9.5, 14.5, and 36.5, and Demi station 7. Otherwise, over the course of the GP15 transect, 1180 samples were collected from 54 stations. Table 3.4-1 lists the samples and labs to which they were distributed.

Table 3.4-1: PI and parameters of distributed fish samples

Parameter	PI	Filtered?	Station Type
Contamination-prone			
Cells	Twining	No	Stns.4,6,8,14
H2S	Cutter	Yes	Full & Super
pH	Cutter	Yes	Full & Super

Zn	Cutter	Yes	Full & Super
Nano nuts	Cutter	Yes	Full & Super
Pb/Cr	Boyle/Rember	Yes	Super
Fe	Fitzsimmons	Yes	All stations & intermediate fish
TMs	Fitzsimmons/Till	Yes	All stations & intermediate fish
Fe/Al/Zn	Hatta	Yes	All stations & intermediate fish
Ba	Horner	Yes	All stations & intermediate fish
TM isotopes	John	Yes	All stations & intermediate fish
TM isotopes	Conway	Yes	All stations & intermediate fish
Hg	Mason	Yes	All stations & intermediate fish
Siderophores	Repeta	Yes	All stations
Co	Saito	Yes	All stations
REE	Shiller	Yes	All stations & intermediate fish
Fe ligands	Jensen	Yes	Full & Super
TBD	Dulaquais	Yes	Demi & Super
Cu	Moffett	Yes	All stations & intermediate fish
Non-contamination prone			
Salt	ODF	No	All stations & intermediate fish
Nuts	ODF	No	All stations & intermediate fish
d18O-H2O	Sikes	No	All stations
DIC	Stump	No	All stations
I-129	Buesseler	No	Stns. 3,6,10,16
Th-234	Buesseler	No	Demi & int. fish
Po/Pb	Cochran	No	Stns. 1,3,8,14,18
Biogeotraces	Sven	No	All stations & intermediate fish
d15N-NO3	Casciotti	Yes	All stations & intermediate fish
d15N-NO2	Casciotti	Yes	All stations
DOS	Cutter	Yes	Stns. 4,6,8,10,12,14
Th/Pa/Nd/REE	Anderson	Yes	All stations & intermediate fish
Art. nukes	Kenna	Yes	Stns. 4,6,10,16

3.5 Aerosols and rain

Aerosol samples were collected over periods of two to three days using sector-controlled high-volume aerosol samplers (Tisch Environmental, model 5170V-BL). Four samplers were each loaded with twelve 47 mm filters, and a fifth was loaded with a five-stage Sierra-style slotted cascade impactor to collect size-fractionated aerosols (from >7 μm to <0.49 μm) over periods of four to six days. A breakdown of replicate filter distribution to collaborating PIs is given in Table 3.5-1.

In total, 23 aerosol filter deployments/collections were made, resulting in:

- 23 × 36 47mm Whatman-41 filters
- 23 × 12 47□m GFF filters
- 12 × size fractionated samples (six filters each)

Unused filters of each type were also set aside for blank analysis.

Table 3.5-1 – allocation of aerosol samples collected on W41 and GFF filters during GP15.

PI	Treatment/ analyte	Odd deployment allocation	Even deployment allocation
W41 filters			
Buck/Landing	Archive	3	3
Buck/Landing	Total digest	3	3
Buck/Landing	UPW leach	3	3
Buck/Landing	0.2□m seawater leach	3	3
Buck/Landing	0.02□m seawater leach	3	3
Buck/Landing	Berger leach	3	3
Buck/Landing	Sequential leach	3	3
Anderson/Edwards/Hayes	$^{232}Th/^{230}Th/^{231}Pa$	3	--
Boyle/Zurbrick/Rember	Pb isotopes	2	--
Fitzsimmons	Colloidal TEIs	--	3
Goldstein/Basak/Wu	Nd/REE	--	3
Ingall	Solid state speciation	--	3
John/Conway	TM isotopes	2	
Cochran/Kadko	^{7}Be, ^{210}Po-^{210}Pb	3	3
Till	Sc, Y, La	--	3
Horner	Ba isotopes	2	--
intercalibration reserve	---	3	--
	TOTAL	**36**	**36**
GFF filters			
Hastings	N isotopes	3	3
Mason	Hg speciation	3	3
spare/reserve		6	6
	TOTAL	**12**	**12**

Extractions of aerosol-laden W41 filters were carried out while at sea, using ultrapure water (UPW), filtered (0.2 □m) seawater from the towfish, and ultra-filtered seawater (filtered seawater from the towfish, with a 0.02 □m Anodisc filter loaded beneath the aerosol filter). Each extraction was carried out on three replicate filters from each deployment. These leaches included:

- UPW – 63 × 100ml sample leaches and 17 × 100ml blanks; subsamples also taken from one UPW leach per deployment for major anion analysis.
- 0.2 □m filtered seawater – 63 × 100ml sample leaches and 20 × 100ml blanks.
- 0.02 □m filtered seawater – 63 × 100ml sample leaches and 20 x 100ml blanks.

Additional extractions were carried out while at sea for collaborators Anderson, Conway, and Till.

In addition, an aethalometer and a condensation nuclei counter were installed to make autonomous measurements throughout the cruise.

Two automated rain samplers were used to collect rain (one dedicated to samples for analyses of multiple TEIs and the second designated for samples for Hg analysis). In practice, an electrical problem with one of samplers resulted in all samples coming from the remaining sampler. A total of 17 rain samples were collected. Priorities for rain samples were 0.2 □m filtered samples for major ions and trace element analyses, followed by unfiltered samples for total mercury. Where sufficient volume was collected, unfiltered or 0.02 □m filtered subsamples were also taken for trace element analyses.

4. Individual labs/PI Reports

4.1 ODF

Please see accompanying file "odf_report_gp15_2018.pdf" for full report on activities from the Ocean Data Facility group.

4.2 Mercury

PI: Robert Mason (at sea leg 2)
At sea leg 1: Yipeng He

Mason's research group was responsible for monitoring the concentrations of various forms of mercury (Hg) in surface waters and in the atmosphere (i.e. elemental Hg (Hg^0), monomethylmercury (MeHg) and dimethylmercury (DMeHg)) using both continuous measurement devices and batch collection approaches. They also obtained water column samples from the GEOTRACES (GTC) rosette for the measurement of total methylated Hg ($MeHg_T$ = MeHg + DMeHg), at all stations, as well as total dissolved Hg (HgT), and particulate Hg and MeHg samples (Hg_P and $MeHg_P$) from the *in situ* pumps at most stations besides the Demi stations. The continuous measurement of dissolved gaseous mercury (DGHg = Hg^0 + DMeHg) concentrations in surface seawater was achieved using a gas equilibrator system that sampled water from the ship's underway sampling system that also provides measurements of underway parameters (temperature, salinity, fluorescence) and was also used by other groups measuring dissolved gases (methane, O_2/Ar, and pCO_2). The analysis of DMeHg was done using batch collections of 1-2 days, allowing for the determination of the dissolved Hg^0 concentration (DHg^0) concentration by difference. For comparison of data across sampling systems, and for validation, DGHg and MeHgT surface water samples were collected at each station and at the intermediate stations from the underway "fish" sampler. Mostly, DMeHg was low (<2 fM) and was mostly <5% of the DGHg. Concentrations of DGHg were low in the North Pacific, and started increasing in the more tropical waters, with the highest levels in the Intertropical Convergence Zone and around the equator. Lower concentrations were found in the South Pacific. Overall, there was good agreement between measurements made using the underway system and samples collected from the over-the-side "fish" sampler.

For the atmospheric sampling, bulk aerosol samples will be obtained from the Buck/Marsay group for total Hg and MeHg analysis (Hg_{HV} and $MeHg_{HV}$) as well as splits from the rain samples they collected for measurement of Hg and MeHg in wet deposition (Hg_{TWD} and $MeHg_{TWD}$). For these measurements, the volume in the table below reflects the expected air

amount sampled by the filters to be analyzed and not the total air volume sampled. The Tekran air speciation unit continuously measures the Hg speciation in the air as three fractions: Hg^0, reactive (oxidized) gaseous Hg (RGHg) and particulate Hg (Hg_{LV}). For comparison with this system, RGHg is also being collected using ion exchange filters ($RGHg_{LV}$). Finally, DMeHg was measured in the air ($DMeHg_{LV}$).

A summary of the samples collected and the typical sample resolution, volume collected and some details about where the analysis was/will be done is given in Table 4.2.1, as well as an estimate of the expected total number of samples collected for later analysis or analyzed on board during the cruise.

Table 4.2-1: Mercury Sampling and Analysis

*Notes: 1) Acronyms are defined in the text; 2) Sample Type: a) Underway: the ship's underway surface water sampling system that was sampled in the Hydrolab. While surface water sampling was continuous, it was not always sampled while on station, and there were times when it was stopped for maintenance and cleaning, and for system calibration; b) Fish: the surface water "fish" sampler deployed off the side of the ship while steaming between stations; c) GTC: GEOTRACES trace metal clean rosette system; d) Tekran: the Tekran mercury air speciation sampler; e) High vol: the high volume air samplers of the Buck/Marsay group 4) Resolution: a) The automated Tekran speciation units were set to sample gaseous Hg at 5 minute resolution; b) Batch analysis time depended on expected concentrations and for air sampling, the wind direction and fraction of time sampling (systems were sector-controlled to prevent contamination); and c) Station indicates water samples that were collected using the GTC rosette, or the fish sampler; and 5) Analysis: a) From the results of on board analysis, DHg^0 is calculated by difference; and b) samples still to be analyzed are indicated as UConn if they will be analyzed by Mason's group or UCSC if to be analyzed by Lamborg and Hammerschmidt's groups; 6) Note that the * indicates this is a volume of air rather than water and represents the air collected from the equilibrator system. Volumes are in L unless indicated otherwise.*

Parameter	Mode	Resolution	Sample Type	Volume (L)	Analysis	# Samples, analyses[#]
Water						
DGHg	Cont. Batch	5 min Station	Underway Fish	5* 1-6	On board On board	Many 100
DMeHg	Batch Batch	1-3 days Station	Underway Fish	1-3 m^3 * 1-6	On board On board	30 100
DHg^0	Cont. Batch	5 min Station	Underway Fish	5* 1-6	Calculated Calculated	Many 100
$MeHg_T$	Batch	Station	Fish and GTC	0.125	UConn	1000
Hg_T	Batch	Station	GTC	0.25	UCSC	600
Hg_{SPT}	Batch	Station	*In situ* pumps	Various	UCSC	670
$MeHg_{SPT}$	Batch	Station	*In situ* pumps	Various	UCSC	210
Air						
Hg^0	Cont.	5 min	Tekran	5	On board	Many
RGHg	Cont.	2 hr	Tekran	600	On board	800
Hg_{LV}	Cont.	2 hr	Tekran	600	On board	800

Hg_{HV}	Batch	1-2 days	High vol	1-5 m^3	UConn	25
$MeHg_{HV}$	Batch	1-2 days	High vol	1-5 m^3	UConn	25
$DMeHg_{LV}$	Batch	1-2 days	Air sample	1-3 m^3	On board	25
$RGHg_{LV}$	Batch	1-2 days	Air sample	1-3 m^3	UConn	25
Hg_{TWD}	Batch	Intermittent	Rain sample	0.05-0.2	UConn	12
$MeHg_{TWD}$	Batch	Intermittent	Rain sample	0.05-0.2	UConn	12

4.3 Nitrogen Isotopes

Onboard:

Karen Casciotti (PI, Stanford University; seawater nitrate, nitrite, and nitrous oxide isotopes)

Colette Kelly (Graduate Student, Stanford University, seawater nitrate, nitrite, and nitrous oxide isotopes)

Co-PIs:

Daniel Sigman (co-PI, Princeton University; seawater nitrate, particulate ^{15}N),

Meredith Hastings (co-I, Brown University; subcontract to Stanford, aerosol nitrate)

4.3.1 Major overall goals

The objectives of our project are to collect and analyze samples for the stable isotope ratios of nitrate, nitrite, and nitrous oxide from the US GEOTRACES GP15 Pacific Meridional Transect to better understand the processes controlling the inventory of bioavailable N and its supply to surface waters across the Pacific. On this cruise, we sampled high nutrient waters in the Subarctic North Pacific and in the Equatorial upwelling, as well as some of the most oligotrophic ocean provinces in the north and south Pacific subtropical gyres. In addition, aerosol and rain samples were collected to constrain atmospheric inputs. Finally, suspended particle and sediment samples were collected to assess the N isotopic composition of sinking and suspended particles along the transect. Onboard, we also determined nitrite concentrations on all casts that sampled shallow waters ("ODF shallow" and 'ODF Demi' casts)[1], as well as underway surface samples, to determine which samples should be preserved for nitrite isotope analyses.

Samples for nitrous oxide isotope analyses were collected in duplicate from the ODF Niskin rosette at nearly every full and super station (we sampled Station 37 at lower resolution, and with single samples below 450 m, due to sample limitation). At all stations, a surface nitrous oxide isotope sample was collected from the surface bottle on the so-called PigRaTh[1] cast. At stations

[1] ODF rosette casts were one of five possible types: "shallow", "intermediate", and "deep ODF" casts, which included most of the ODF samplers/parameters, and a special "PigRaTh" cast to accommodate the large volume needs of pigments, radium, and thorium-234. Single ODF casts

4, 6, 8, 14, 16, 23, 29, and 35, shallow (upper 500 meters) nitrous oxide samples were collected from the PigRaTh cast; at all other stations, shallow nitrous oxide samples were collected from the shallow ODF cast. At some depths, these shallow nitrous oxide samples from the PigRaTh may not have associated nitrate and nitrite isotope samples, which were always collected from the shallow ODF cast. Nitrous oxide samples were collected only from niskin bottle casts, not from the fish or ship's underway system. Samples were filled through Tygon tubing into 160 mL glass serum bottles. The bottles were overflowed twice with water before withdrawing the tubing. A small (~ 1mL) headspace was introduced, and the bottles were capped with grey butyl septa immediately after sampling. After sampling the last bottle from each cast, N_2O samples were returned to the lab, then individually uncapped, poisoned with 100 uL of saturated mercuric chloride solution via pipette, and recapped and crimped with aluminum crimp seals. The bottles were then wrapped with bubble wrap and stored indoors at room temperature in the analytical lab, or inside the aft hold.

Samples for nitrate isotope analyses were collected in triplicate from every station and depth, including surface samples, either from the arriving fish (super and full stations) or the surface bottle (demi stations). On rare occasions, nitrate and nitrite isotope samples were also collected from the ODF PigRaTh cast to augment the resolution of the shallow ODF cast, if unique depths were being sampled on PigRaTh. Samples for nitrate and nitrite isotope analyses were collected through Acropak filters (nested 0.8, 0.45 um filter capsules). These filters were reused on similar casts, drained, and kept refrigerated between uses. There were 36 filters in use at any one time, with 12 in use for shallow and demi cast depths, 12 in use for intermediate cast depths, and 12 in use for deep cast depths. All 36 filters were changed out between Leg 1 and Leg 2. One filter was used exclusively for all depths on the shelf stations, and then discarded. The filters were rinsed prior to collection of NO_3^- and NO_2^- isotope samples by either sampling Si isotopes first (~2.5 L), or by allowing ~ 0.5 L to pass through the filters prior to rinsing and filling the NO_3^- and NO_2^- isotope bottles. No evidence of cross-contamination could be detected for nitrite concentration determination on samples tested with and without filtration. Nitrate isotope samples were collected in triplicate and frozen immediately.

Nitrite samples were collected into 50 mL square wide mouth HDPE bottles, numbered 1-13 (including the "13th" surface depth), which were reused throughout the cruise. Bottles were rinsed three times and filled with Acropak-filtered water, as for nitrate isotope samples. After sampling, nitrite concentrations were determined by spectrophotometry with SAN and NED, against a standard curve of 0-0.625 □M NO_2^-. Five (5) mL of each sample or standard was pipetted into 15 mL falcon tubes, and 0.2 mL of each SAN and NED were added. The samples were capped and shaken, then pipetted (2 mL each) into 1 cm path length plastic cuvettes. Absorbance at 543 nm was determined 5x for each sample and standard, and the readings were averaged. Samples with absorbance >0.004 (~ 0.1 □M NO_2^-) were subsampled for nitrite isotope analyses. 10 mL volumes were pipetted into 20 mL headspace vials. In parallel, 3 mL NO_2^--free seawater was pipetted into vials for 1 blank and 1-3 sets of six standards. A set of six standards

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to 1000 m at Demi stations included a subset of these parameters. See ODF section of the cruise report for further information.

included 1 of each standard at 50 uL (10 nanomole) and 25 uL (5 nanomole) amounts. Batches with 1 sample (2 vials) generally had 1 set of standards, batches with 2-4 samples had 2 sets of standards, and batches with 5-6 samples (10-12 vials) had 3 sets of standards.

After samples and NO_2^- free seawater were pipetted into the vials, the standards were added by pipette. Then all vials were sealed, crimped and purged with N_2 gas for 15 minutes. After sparging, azide solution was added: 0.1 mL to 3 mL blanks and standards, 0.2 mL to 5-6 mL samples, and 0.3 mL to 10 mL samples. The samples were mixed and reacted for 30 minutes, then 6 N NaOH was added to match the azide reagent (0.1 mL for 3 mL blank and standards, 0.3 mL for 10 mL samples). After NaOH addition, samples were stored at room temperature. Vials were numbered on their caps, with 1-7 always being the blank and the first set of standards, followed by the samples, and then the second set of standards. For larger runs, samples were numbered consecutively from one set of standards, half of the samples, another set of standards, and so forth.

NO_2^- isotope standards N-23, N-7373, and N-10219 in 200 □M concentrations were aliquoted in 1.5 mL volumes in cryovials at the beginning of the cruise. Five sets of standards were used, each for 1-2 weeks. Standards were stored frozen between uses. A set of standards was retired with 300-400 uL remaining and will be tested in parallel upon return to the lab.

Samples collected include approximately 916 unique samples (2,748 sample bottles) for nitrate isotope analyses, 150 unique samples (~600 vials) for nitrite isotope analyses, and 738 unique samples (1,440 serum bottles) for N_2O isotope analyses.

Education and Outreach

To further outreach goals for our project, styrofoam cups decorated (prior to the cruise) by elementary school (K-4) students from 8 classrooms were deployed on the deep casts at 7 stations (4, 12, 18, 23, 29, 37, and 39). The cups were extensively photographed before and after deployment. Representative photos were emailed to teachers and in some cases, posted to Twitter. Communication with the classrooms resulted in students submitting additional questions during the cruise, which were answered in a timely fashion.

4.3.2 Preliminary findings

In the Subarctic North Pacific, we encountered high nitrate (>10 μM) surface waters (Figure 4.3-1), with the highest fluorescence seen on the entirety of the cruise (Figure 4.3-2). These stations also showed a relatively shallow mixed layer, with low but detectable levels of nitrite present throughout the mixed layer (Figure 4.3-3). The chlorophyll fluorescence showed a subsurface maximum between 50-52 °N. We sampled these HNLC waters for nitrate, nitrite, and nitrous oxide isotopes and will be looking for isotopic signals associated with nitrate utilization, and nitrite and nitrous oxide production.

In the subtropical North Pacific, nitrate and nitrite were below detection in the surface waters. A primary nitrite maximum (PNM) was detectable in the nitracline below the deep chlorophyll

maximum. In past work, nitrate isotopes have been used at Station ALOHA to estimate the contributions of N_2 fixation in the North Pacific Subtropical Gyre. Our data from this cruise will allow us to evaluate the extent of this signal over a larger region of the subtropical north Pacific.

In the Equatorial region, nitrite concentrations reached 1-2 µM in the PNM. This large amount of NO_2^- occurred despite lower NO_3^- concentrations (~4 µM) than those found in the Subarctic North Pacific (Figure 4.3-1). We will use the isotopic composition of nitrate and nitrite together to better understand the effects of upwelling and iron limitation on nitrogen cycling in these HNLC waters.

The primary NO_2^- maximum was found just below the fluorescence maximum (Figure 4.3-2) at every station. In the subarctic Pacific and equatorial upwelling, where NO_3^- was present in surface waters, NO_2^- also extended into surface. There was generally enough nitrite to preserve at least one sample per station for nitrite isotopic analysis at the PNM.

In the subtropical South Pacific, nitrate and nitrite were below detection in the surface waters. For example, at station 38 the nutricline started at 135 meters (Figure 4.3-1), with a deep chlorophyll maximum at 120-150 m (Figure 4.3-2). At these south Pacific gyre stations, there was barely enough NO_2^- for isotopic measurements at the PNM, but we did preserve the samples with the highest NO_2^- concentrations (~ 0.1 µM).

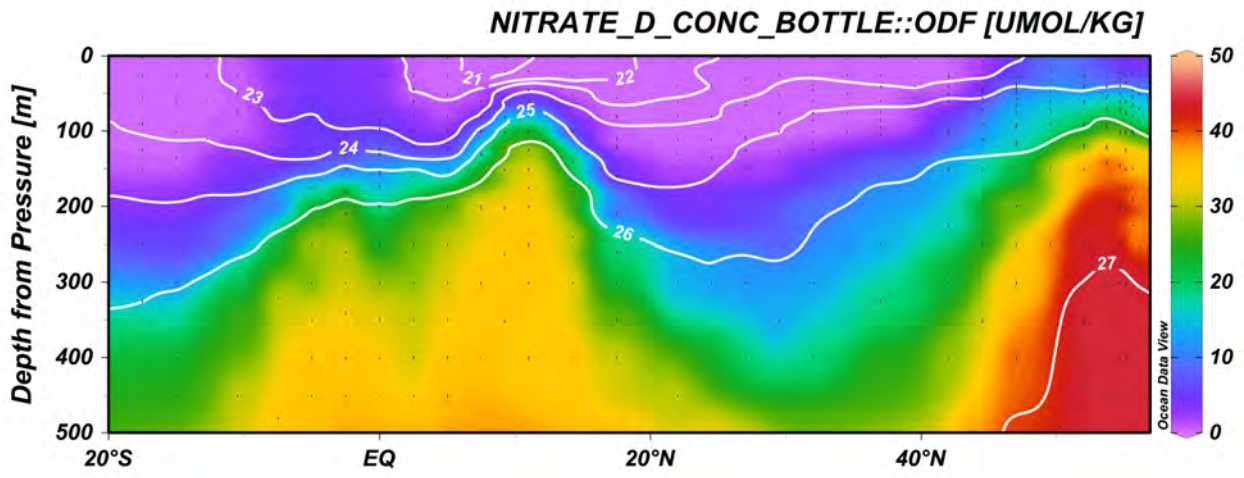

Figure 4.3-1. Preliminary nitrate concentrations from GP15 in the upper 500 m with contours of potential density (sigma-theta), courtesy of Scripps Ocean Data Facility (ODF).

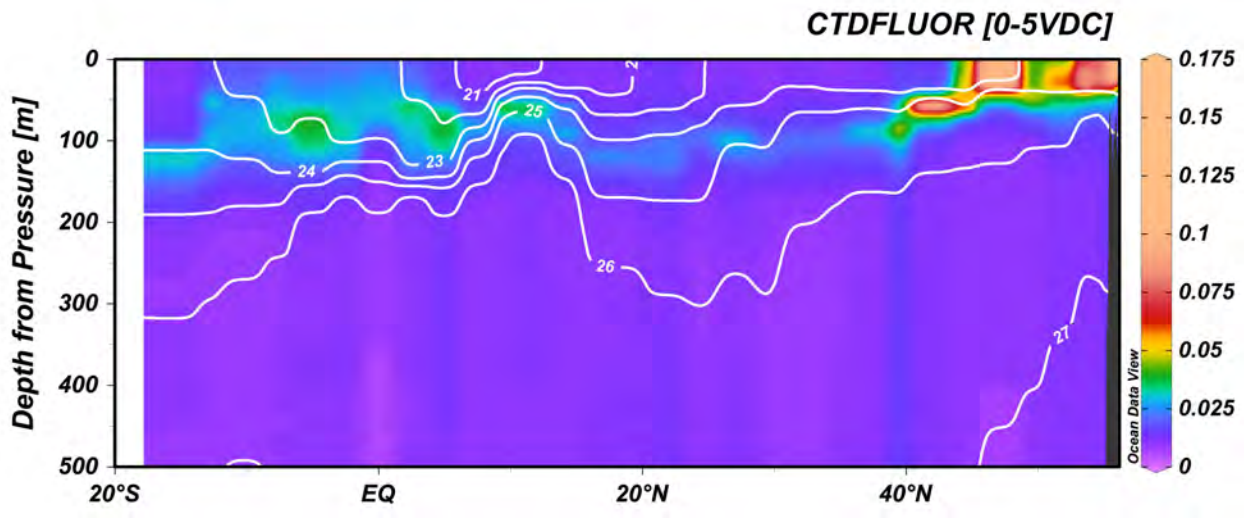

Figure 4.3-2. CTD fluorescence in the upper water column of GP15, with contours of potential density (sigma-theta), courtesy of Scripps Ocean Data Facility (ODF).

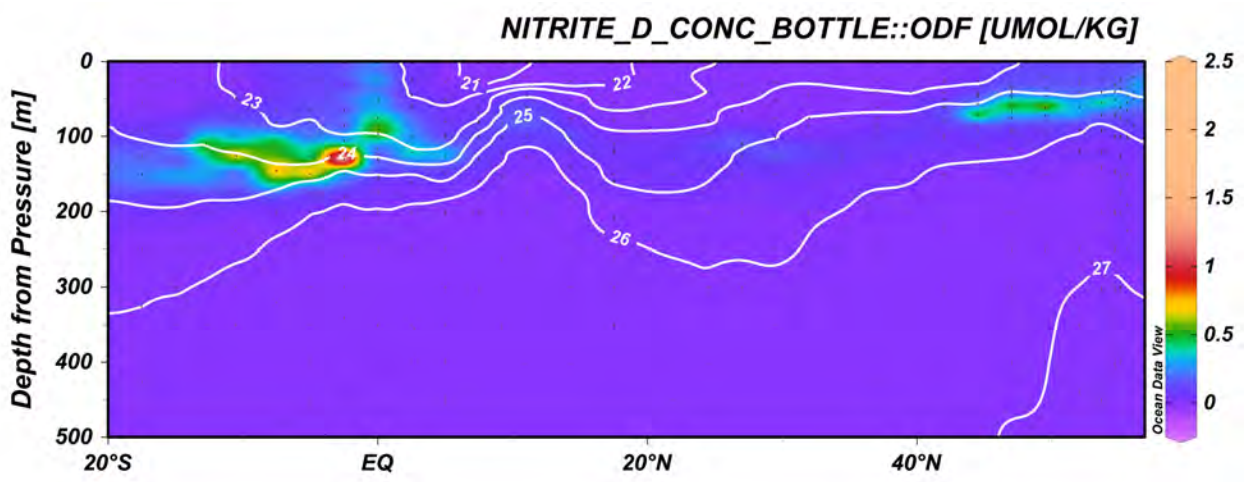

Figure 4.3-3. Preliminary nitrite concentrations from GP15 in the upper 500 m with contours of potential density (sigma-theta), courtesy of Scripps Ocean Data Facility (ODF).

Preliminary Equatorial ADCP readings

A strong eastward flowing equatorial undercurrent (EUC) was found centered on the equator around 150 m depth. This water is believed to be an important source of nitrate to equatorial surface waters (Rafter and Sigman, 2016) and helps ventilate the eastern topical Pacific. A strong westward flowing south equatorial current (SEC) was sampled at 2.5 °N in the surface waters, and a weaker westward SEC was sampled at 5 °S. A strong eastward north equatorial counter current (NECC) was also sampled between at 9.25 and 7.5 °N, increasing in depth to the south. Finally, a weak westward north equatorial current (NEC) was sampled between 10-15 °N (Figure 4.3.4). These observations closely match those of earlier studies of equatorial circulation

between 150-160 °W (Wyrtki and Kilonsky, 1984). We will use these samples to analyze nutrient and isotope transport by these strong equatorial currents.

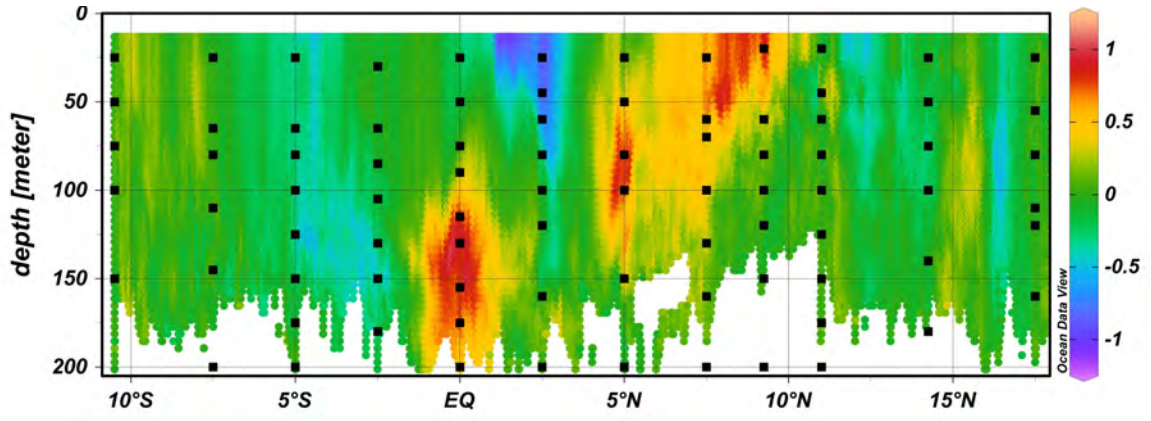

Figure 4.3-4. Eastward velocity on GP15 between 17.5 °N and 10 °S, with water sample depths marked with black squares.

4.4 CFC-11, CFC-12, and SF6

PI: Rana Fine

At sea: Jim Happell (leg 2) and David Cooper (leg 1)

4.4.1 Sample Collection

All water samples were collected from the 10.4 liter Niskin bottles on the ODF rosette

A water sample was collected from the Niskin bottle petcock using silcone tubing to fill a 300 ml BOD bottle. The 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 tubing came out and the bottle was stoppered under water while still in the overflow container. Additional surface water samples were also collected from the ships underway system. Air samples, pumped into the system using an Air Cadet pump from a Dekoron air intake hose mounted high on the foremast were also run Air measurements are used as a check on accuracy.

4.4.2 Equipment and technique

Chlorofluorocarbons CFC-11, CFC-12, and SF_6 were measured on 39 stations for a total of ~ 900 samples. Analyses were performed on a custom built purge and trap gas chromatograph (GC) equipped with an electron capture detector (ECD). The samples were stored at room temperature and analyzed within 12 hours of collection. Every 12 samples were followed by a

instrument 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.

4.4.3 Calibration

Two gas phase standards, 33780 and 426505, were used for calibration. The concentrations of the compounds in this standard are reported on the SIO 1998 absolute calibration scale. 6 calibration curves were run over the course of the cruise. Estimated accuracy is +/- 2%. Precision for CFC-12, CFC-11, and SF_6 was less than 1%. Estimated limit of detection is 1 fmol/kg for CFC-11, 3 fmol/kg for CFC-12 and 0.05 fmol/kg for SF_6

4.5 ^{232}Th, ^{230}Th, ^{231}Pa , and Nd isotopes/Rare Earth Elements and monocore sediment samples

PIs: Robert Anderson, Lawrence Edwards, Steve Goldstein, Chandranath Basak, Brian Haley

At sea: Martin Fleisher

Thanks to ODF personnel (Leg1-Melissa Miller, Joseph Gum, Erin Hunt, John Calderwood, John Collins. Leg 2-Susan Becker, Erin Hunt, Kelsey Vogel, Kenneth Jackson, Andrew Barna) and the ResTechs (Leg 1-Brendon Mendenhall, Keith Shadle. Leg 2-Josh Manger, Drew Cole) for their help with maintaining and deploying the ODF rosette.

4.5.1 ODF Rosette Filtered water

Sampling was carried by Karen Casciotti, Colette Kelly (both from Stanford University) and Marty Fleisher (Lamont Doherty Earth Observatory). Water from the ODF 36 place rosette, equipped with modified Bullister Bottles (10.3 liters), was passsed through

Teflon-lined Tygon™ tubing connected to Pall Acropak500™ capsule filters (0.8µm/0.45µm filter pair). A single 10-liter cubitainer™ was used to collect water from surface casts. Two 5-liter cubitainers were used to collect samples on Intermediate and Deep casts. Samples were acidified to pH~2 (20ml 6M HCl for 5-liter samples and 40 ml for 10-liter samples), caps were parafilmed, and the cubitainers were double bagged prior to storage.

We collected 10-liter samples from the McLane pump depths at 10 stations for on-board processing by Mark Stephens of the Po/Pb group. Two liter samples were collected and stored for Si isotopes (M. Brzezinski at UCSB) at almost every Full/Super station.

In addition, 5-liter water samples were collected at Super Stations (~10 samples/station) for high precision Uranium isotope measurements by Larry Edwards group at the University of Minnesota. Twenty-liter samples were collected at 8 stations for Tim Kenna (LDEO) to make artificial radionuclide measurements (Pu isotopes and ^{237}Np).

4.5.2 Intermediate and Arriving Fish water samples

Filtered water (details from Cutter on filters, 0.45 and 0.2µm?) was collected in a 60 liter tank from the surface fish. Ten-liter samples were collected at intermediate stations, and upon arrival

at Full/Super/Demi stations for Th isotopes, ^{231}Pa and Nd/REE. Twenty-liter samples were collected at arriving stations where Tim Kenna was getting samples for artificial radionuclides.

4.5.3 Cross-Flow Filtration and Anapore Filter Colloid samples

At Super Stations, Janelle Steffen processed samples at 12 depths from the GTC system for colloidal Th isotopes and Pa. We received 60 ml samples filtered through a 0.02µm Anapore filter, and a pair of 1 liter samples (permeate and retentate) from the Texas A&M Cross-Flow Filtration system. Samples were acidified with 6M HCl (250µl/sample for 60 ml samples and 4ml/sample for each 1 liter sample.

4.5.4 Summary of water collected

	Leg 1	Leg 2	Total
5 liter (Rosette)	387	580	967
10 liter (Rosette, Fish)	186	174	360
20 liter (Rosette, Fish)	57	65	122
1 liter Colloids (CFF Permeate/Retentate)	50	72	122
60 ml Anapore Colloids	24	36	60

4.5.5 Monocore sediment samples

We were very successful coring on this cruise. Seventeen of 20 deployments (before Station 39) were successful. Core lengths ranged from 7cm to 25 cm. On Leg 1, John Calderwood was very helpful with making modifications to the cloaking device that made the corer virtually invisible to the altimeter mounted on the rosette. On two occasions, the line that attached the corer to the rosette was in disarray n recovery; once preventing two bottles from closing properly. Mistakenly, the new 25 meter line for attaching the corer to the rosette was made with a "floaty" rope, Amsteel Blue. To keep this from happening multiple shackles were tiewrapped to the line along it's length to ensure that the line sank during the coring process at the seafloor.

Clear changes in lithology and sediment sources are visible in the suite of cores collected.

4.6 Total ^{234}Th (Particulate and Dissolved) Collection and Analyses

PI: Ken Buesseler, Woods Hole Oceanographic Institution

Shipboard collection and analyses: Jennifer Kenyon and Steven Pike, Woods Hole Oceanographic Institution

Total ^{234}Th samples were collected at all stations. For shallow depths, typically less than 1000 m, total ^{234}Th samples were collected from the PigRaTh (pigments, radium, and thorium) cast and the Demi ODF cast where applicable. For deeper depths, seawater was collected from 30 L Niskins incorporated into the McLane pump casts at depths that coincided with pump depths. In the event where 30 L Niskins on the pump casts miss-tripped, samples were collected from the corresponding depths during the appropriate intermediate and/or deep ODF casts. Typically, 13 water depths were collected during shallow ODF casts and 8 water depths collected per pump cast. Shallow cast seawater samples were collected at depths that coincided with the 8 shallow pump depths, as well as 4 additional depths selected on the basis of interesting features observed on the station's CTD data. Intermediate fish seawater samples were also collected for total ^{234}Th analyses.

Seawater samples were collected into approximately 2 L FLPE Nalgene bottles from each Niskin. Each sample was spiked with 1 mL of a 50.03 dpm/g ^{230}Th standard for future recovery calculations. Total ^{234}Th was precipitated via additions of $KMnO_4$ and $MnCl_2$ onto QMA filters. Precipitate samples were counted onboard using RISØ Laboratory anti-coincidence beta counters for preliminary first and second counts, with third counts to be completed onshore. Total ^{234}Th samples will be coupled with particulate ^{234}Th data (as well as other particulate trace metal and isotope data) in order to produce flux calculations. In summary, 701 total ^{234}Th, 392 small-size fraction (<51um) particulate ^{234}Th, and 392 large-size fraction (>51um) particulate ^{234}Th samples were collected and processed onboard. See section on pump operations for more detail on particulate analyses.

4.7 Ra Isotopes

PIs: Matt Charette and Willard Moore

At Sea: Paul Henderson (leg 1) and Emilie Le Roy (leg 2)

4.7.1 Surface sampling for Ra isotopes

At all GEOTRACES and Repeat Hydrography stations, ~1500 L of surface water was collected and filtered through Mn-oxide coated acrylic cartridges to collect Ra isotopes. In total, 36 samples were collected. Water was collected using a Surface pump with tubing deployed over the port side of the R/Vf Roger Revelle to ~3 m depth. At sea, these surface samples were processed in a similar manner to the MnO_2 pump cartridge samples. They were analyzed for short-lived Ra isotopes on the ship-board RaDeCC systems by Paul Henderson and Emilie LeRoy.

4.7.2 Large Volume Ra/Th/Ac Sample Processing and At-Sea Radium Counting

MnO_2-impregnated sample cartridges for Ra/Th/Ac radionuclide collection were removed from the pumps after cast recovery and rinsed with radium-free freshwater to remove salt. Cartridges were dried to dampness prior to shipboard measurement of short-lived radium isotopes. ^{224}Ra ($t_{1/2}$ = 3.7 d) and ^{223}Ra ($t_{1/2}$ = 11.4 d) were measured on the Radium Delayed Coincidence

Counter (RaDeCC) system and typically counted within 24 h of sample collection. All cartridge filter processing and counting for radium was conducted by Paul Henderson and Emilie LeRoy. Scavenging efficiencies of the cartridge filters for Ra and Th is validated by a discrete seawater sample taken in parallel with every pump depth sampled. For shallow pump cast depths, this calibration sample was collected by the ODF Niskin rosette; for mid-water and deep pump casts, a 30 L Niskin bottle was hung next to each pump and bottles were triggered by messenger at mid-cast. For ^{226}Ra, 20-25 L seawater was passed over a column of MnO_2 impregnated acrylic fiber on deck, which removes radium at 100% efficiency. These filter samples were bagged and will be analyzed for ^{226}Ra through it daughter, ^{222}Rn back in land-based laboratories. Efficiency filter samples were collected by Jennifer Kenyon and processed by Paul Henderson and Emilie LeRoy.

4.8 Dissolved Cobalt and Underway Proteomics

PI: Mak Saito

At sea: Rebecca Chmiel

Shipboard analysis of dissolved total cobalt (samples were UV irradiated prior to analysis) and dissolved labile cobalt (samples were not UV irradiated) was performed by Rebecca Chmiel. Duplicate 60 mL samples were collected in acid-washed LDPE bottles using the GEOTRACES trace-element rosette and the trace-element clean towfish. Samples were filtered using a 0.2 µM Acropack filter. One duplicate was run within 3 days of collection for shipboard dissolved cobalt analysis, and the other duplicate was kept in an oxygen depleted sealed container for future verification and analysis. Dissolved cobalt was measured using a hanging mercury drop electrode following the cathotic stripping voltammetry method outlined in Saito et al. 2001. In total, 1042 dissolved cobalt samples were analyzed during the cruise: 719 dissolved total cobalt samples from 36 stations and 323 dissolved labile cobalt samples from 22 stations. At least one intra-laboratory seawater standard was run once per day and at least one D1 and GSC 2 GEOTRACES intercalibration standard was run once per week during shipboard analysis. Triplicate technical replicates were run on every sample to determine the precision of the method, and duplicate depths from different rosette casts were run when available. Blank analysis was completed with each new batch of reagents, and the blanks were found to be within acceptable limits of <10 pM.

Filtered particulate samples for proteomic and genomic analysis by the Saito lab were collected from the underway seawater system by Rebecca Chmiel. Particulate samples were first filtered through a 51 µm Nitex filter (not collected). Samples were collected first onto a 3 µm Versapore filter and then onto a 0.2 µm Supor filter. The volume of seawater filtered varied between 15 L and 58 L, depending on the oligotrophy of the seawater. Both size fractions of filter were sub-sampled into proteomics samples and DNA samples, with 1/8 of the filter collected for DNA analysis and 7/8 of the filter collected for proteomic analysis. Samples were stored at -80^{0}C. 100 particulate samples were taken in total from 25 stations, including all full and super stations.

4.9 Ultrafiltration/Colloids

PI: Jessica Fitzsimmons

At sea: Janelle Steffen

Two ultrafiltration methods were used to separate the truly dissolved, "soluble," metal fraction from the colloidal fraction in various samples: 1) a cross flow filtration system (Pellicon XL) and 2) a membrane filtration system (Anodisc). All membrane filters had a pore size of 20 nm, while two separately sized cross flow filters had pore sizes of 3 nm (10 kDa) and 9 nm (300 kDa), respectively. Ultrafiltered samples from all three systems, along with the <0.2 μm dissolved samples collected using the GTC rosette, will be analyzed in the Fitzsimmons laboratory at Texas A&M University using ICP-MS techniques for Fe, Mn, Cu, Cd, Zn, Ni, Pb, and Sc concentrations. The four size fractions will then be analyzed together from a single depth to reveal the relative contributions of small (3-9 nm), medium (9-20 nm), and large (20-200 nm) colloids to the dissolved metal fraction. In addition to the analysis at Texas A&M, the total dissolved concentrations (<0.2 μm) from super stations will be measured by Claire Till (Humboldt State University) using a separate, non-isotope dilution, multi-element method for intercalibration.

858 total dissolved (<0.2 μm) 250 mL samples were collected from the GTC rosette. Additionally, 702 x 60 mL samples were collected through the Anopore membrane system (<20 nm). 594 x 60 mL samples were collected through the 10 kDa cross-flow filtration system (3 nm) - one permeate 60mL bottle and one retentate 60mL bottle from each of 297 sampling depths. 342 x 60 mL samples were collected through the 300 kDa cross-flow filtration system (9 nm)—again, one permeate 60 mL bottle and one retentate 60 mL bottle from each of 171 sampling depths.

In addition, ultrafiltered samples were provided collaboratively to several other groups. 206 x 500 mL total dissolved (<0.2 um) samples were collected from the GTC rosette for Claire Till for the intercalibration of total dissolved concentrations for Fe, Mn, Cu, Cd, Zn, Ni, Pb, and Sc mentioned above. 52 x 60 mL Anodisc filtered (<20 nm) seawater samples and 102 x 1 L cross flow filtered (<3 nm) samples from the super stations were provided to Marty Fleischer and Bob Anderson (Lamont-Doherty Earth Observatory) to calculate the partitioning of Th isotopes into soluble and colloidal fractions. 48 x 1 L cross flow filtered (<3 nm) samples were provided to Seth John (University of Southern California) for measurement of Ni and Cu isotopes. 122 x 1L cross flow filtered (<3 nm) samples were provided to Tim Conway (University of South Florida) to determine whether soluble and colloidal Fe have variable Fe isotope ratios in seawater, which would suggest different sources or different controlling processes for soluble and colloidal Fe.

Lastly, 168 x 500 mL dissolved (<0.2 μm) samples were provided to Laramie Jensen (Fitzsimmons lab, Texas A&M), 122 x 500 mL dissolved (<0.2 um) samples were provided to Randie Bundy (University of Washington) and Kristen Buck (University of South Florida), and

57 x 500 mL dissolved (<0.2 um) samples were provided to Matt Hurst (Humboldt University) for measurement of organic Fe-binding ligand concentration and strength by electrochemistry.

4.10 Trace element organic speciation ("Ligands")

PI: Daniel Repeta, WHOI

At sea: Lydia Babcock-Adams (Leg 1), Jingxuan Li (Leg 2)

We processed water and particulate matter along the GEOTRACES meridional transect for molecular analyses of trace element organic matter. Water from the GEOTRACES trace metal clean rosette and underway "fish" system was filtered, and the filtrate pumped through extraction cartridges. 4 L of filtered (Acropak 0.2 um for rosette) seawater is collected into PC bottles (acid-cleaned but re-used). Dissolved ligands are concentrated from seawater using solid phase extraction onto hydrophobic and hydrophilic resins. Twelve samples from a cast are processed at the same time. The samples are pumped through the ENV (polystyrene based, for moderately nonpolar and nonpolar ligands) cartridge to a second set of bottles. For some casts, these samples are acidified to pH 2 and pumped back through the ENVI-Carb column (graphitized non-porous carbon packing, for very polar ligands) into the original sample bottles to be discarded. Approximately 1000 ENV column, and 300 ENVI-Carb column are loaded with samples. These cartridges were frozen and returned to our laboratory for mass spectral analyses.

In addition, we collected particulate matter from the ODF Niskin rosette that will be used for companion genomic analyses. We also collected samples for ligands in the particulate phase, in collaboration with the pump team. Finally, we collected large volume particulate and dissolved organic matter from the ship's underway seawater system to collect material for targeted organic matter analyses. Once the samples are returned to our laboratory, we will extract the organic matter, recover the organic compounds by washing the cartridges with methanol, and measure the distribution of iron, copper, and other trace elements using inductively coupled mass spectrometry. Samples will then be screened by high resolution electrospray ionization mass spectrometry and the two datasets merged to identify each iron, copper, or other trace metal compounds. The distribution of trace metal organic complexes will be assessed in relation to the physical and biological features that characterize the sampling region.

On Leg 1, approximately 351 GTC samples, 162 ODF samples, and 16 Fish samples were collected (see table). In addition, 4 incubations were conducted. On Leg 2, 440 GTC samples, 246 ODF samples, and 20 Fish samples for ligands were processed on board. 3 incubations (water taking from unfiltered fish) were also conducted, and 117 Pump filters (provided by pump team) were collected.

Table of organic ligand samples collected from towfish on GP15

Fish samples Station	4L Ligands (filtered)	4L Genomics (unfiltered)	20L Ligands (filtered)	Incubation (unfiltered)	20L for culture work at WHOI
1	y				
2	y				
3	y	y			
4	y	y			
5	y			y	
6	y	y		y	
7					
8	y	y		y	
9	y				
10	y	y	y		Y
11	y		y		
12		y	y		
13	y		y		
14	y	y		y	
15	y		y		
16	y	y	y		
17	y		y		
18	y	y	y		

Fish samples Station	4L Ligands (filtered)	4L Genomics (unfiltered)	20L Ligands (filtered)	Incubation (unfiltered)
Loihi				
19	Y	Y	Y	
20	Y	Y	Y	
21	Y	Y	Y	
22	Y	Y	Y	
23	Y	Y	Y	
24				
25	Y	Y	Y	
26				
27	Y	Y	Y	
28	Y		Y	
29	Y	Y	Y	Y
30	Y		Y	
31	Y	Y	Y	
32	Y		Y	
33	Y	Y	Y	Y
34	Y		Y	
35	Y	Y	Y	
36	Y		Y	
37	Y	Y	Y	Y
38	Y		Y	
39	Y			

4.11 Helium isotopes

PI: William Jenkins

At sea: Kevin Cahill (Leg 1), Zoe Sandwith (Leg 2)

Helium samples were collected from every station and every depth from the ODF Shallow, Intermediate, and Deep casts. A sample was also collected at every surface niskin of the ODF PigRaTh casts. There were a total of 891 discreet samples collected. Almost all were collected in duplicate, save for 6 samples where 1 of the 2 duplicates was compromised during sealing.

Sampling method:

Samples were collected using the copper tube method. In this method 2 ~45” sections of tygon tubing is attached to a 29.5” section of 5/8” soft copper refrigeration tubing (Cambridge-Lee Industries, LLC) that has been straightened, sectioned, deburred, and marked into 2x12” sections with 2.75” spare length at each end. Both sections of tygon tubing have a clamp placed ~18” from the copper tube. While flushing with sample water, the copper tube is thumped with a bat to remove bubbles from the walls of the tube. After flushing roughly 1 liter of water through them, the clamps are closed. The sample filled copper tube is then cut into the 2 predefined 12” lengths using pneumatic jaws. This means that each sample is collected in duplicate. The samples are then rinsed and cleaned thoroughly with fresh water to inhibit corrosion on the copper surface during storage.

Samples will be analyzed at the Helium Isotope Lab at Woods Hole Oceanographic Institution.

4.12 ^{7}Be

PI: David Kadko

At sea: Mark Stephens

Samples of seawater, aerosols and particles were collected for ^{7}Be analyses. Seawater was sampled at all full stations and superstations (20 Be-7 casts, 118 seawater samples total). Water for ^{7}Be was pumped into vertical tanks on deck (600-700L) with a centrifugal pump and 1.5 inch pvc hose. Typically six depths were sampled per station, up to a maximum depth of 130m. A profiling CTD (Seabird 19plus) was attached to the hose inlet to determine exact depths. The water was then pumped out of the barrels through Fe-coated acrylic fibers. Aerosols will be provided by C. Buck, and particulate samples on filters by P. Lam. All samples will be counted by high resolution, low background gamma spectrometry at FIU. In order to expedite analysis of Be-7 (half life 53 days), samples from leg 1 (RR1814) were shipped to Miami from Hawaii at the midpoint of the cruise.

4.13 ^{210}Pb—^{210}Po

PIs: J. Kirk Cochran and David Kadko

At sea: Mark Stephens

We are measuring the activities of the natural radionuclides ^{210}Po and ^{210}Pb in water and particulate samples. Water samples of ~10L were taken, filtered through Acropak filters and acidified to pH ~2. Further processing was completed on board as follows: ^{209}Po, stable Pb and Fe were added, and Po and Pb were co-precipitated with Fe(OH)3 by raising the pH to ~8 with NH_4OH. The precipitates were filtered and subsequently dissolved in HCl. Po isotopes were plated onto silver disks for return to the laboratory and determination of the alpha activity of ^{210}Po. In addition, particulate samples were taken by P. Lam and Y. Xiang using in situ pumps deployed at the same depths as the water samples. Aliquots of the filters were returned to Cochran's laboratory for analysis on shore. The following stations were sampled by us:

Leg	Station	Number of Depths
1	1	5
"	3	9
"	8	25
"	14	25
"	18	17
"	18.3 (Puna Ridge)	8
2	18.6 (Loihi)	4 (8 samples, filtered & unfiltered)

“	21	17
“	23	25
“	29	25
“	35	25
“	39	25

4.14 Methane

PI: Alan Shiller – University of Southern Mississippi
At sea: Laura Whitmore (leg 1), Virginie Sanial (leg 2)

4.14.1 Continuous surface seawater methane analysis

Dissolved methane concentration was continuously measured at the surface (~ 5m) using the ship’s seawater intake. A Weiss-type equilibrator was used to generate an equilibrated headspace that was measured every 13 seconds on a Picarro methane analyzer (G2301). Bow air methane concentration was also measured regularly. Typically, equilibrated air was measured for 120 minutes, then bow air measured for 10 minutes. The exception to this pattern was when we were on station, only equilibrator air was measured as contamination from the ship is more likely for the bow air. These measurements, combined with ship windspeed data, were used to make flux estimates for the section (Fig. 4.14-1).

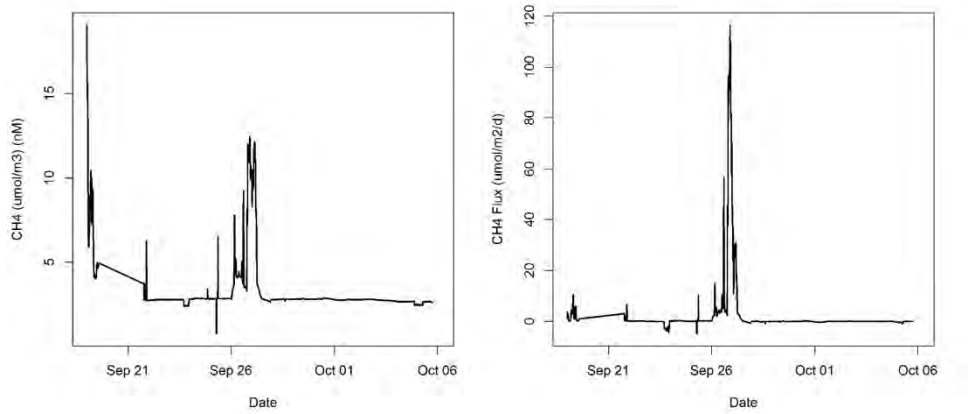

Figure 4.14-1. Methane concentrations of surface waters from September 16th to October 6th (Panel A). Concentration data are paired with atmospheric measurements and ship MET data to calculate flux (Panel B). Note that the data are preliminary and have not been QA/QC'd.

The continuous system was calibrated by regularly measuring air standards with different methane concentrations. Additionally, several discrete seawater samples were collected from the ship’s flow-through and run separately following the discrete analysis method (see below) to validate the methane concentration from the continuous system. Discrete samples from surface Niskin bottle (5 m) were also compared to the continuous system (Fig. 4.14-2).

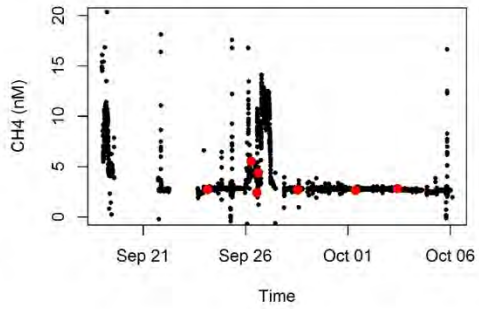

Figure 4.14-2. Comparison of discretely collected surface samples from the <5 m Niskin bottle (red dots) to underway system measurements.

4.14.2 Water column discrete methane analysis

Seawater samples were collected from the ODF rosette to determine dissolved methane concentration throughout the water column. This method involves seventy-milliliter samples collected into 140-mL syringes with 3-way gas-tight Luer-Lock valves. Samples were prepared for head-space equilibration by adding 70 mL methane-free gas to the sample syringe. Samples were equilibrated for approximately 30 minutes. The equilibrated headspace was then measured on a Picarro methane analyzer (G2301).

The Picarro methane analyzer for measuring the discrete samples was calibrated the same way as the continuous system, i.e. by frequently measuring air standards of different methane concentration. In addition, ship intake underway samples were collected in triplicate to check the reproducibility. Three samples were collected in duplicate from the Niskin bottles (at stations 21, 33, and 39) as well.

Partial (demi stations) or full (full and super stations) depth profiles were collected at stations 1 to 39 from the ODF rosette. Samples were also collected from the underway seawater sinks in conjunction with the intermediate fish (surface samples) at 42 stations. During leg 2, additional samples were collected from the ODF PigRaTh cast and compared to the ODF shallow cast to provide information on temporal variability of methane concentration in surface and subsurface waters (Fig. 4.14-3). In total, 1234 discrete seawater samples were collected and processed aboard ship (including replicates).

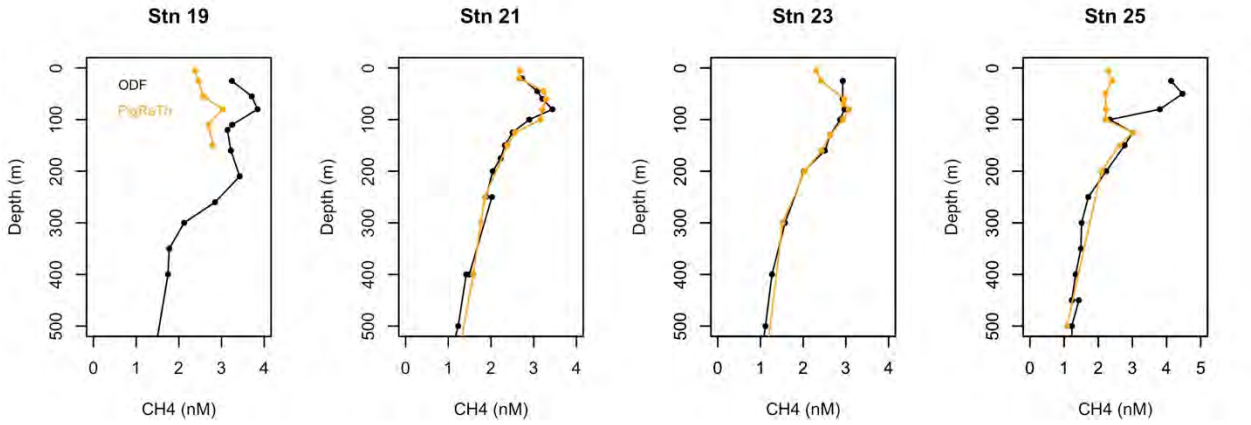

Figure 4.14-3. Example of vertical profiles of dissolved methane concentrations measured on samples collected from ODF shallow cast and PigRaTh cast.

Preliminary results show that methane concentrations and shape of the vertical profiles agree well with other published oceanic methane data. There is a broad methane enrichment in the first 300 m of the water column associated to productivity. Then, the methane concentration decreased with increasing depth (Fig. 4.14-4). Lower methane concentrations are observed south of the Equator. High methane concentrations (up to 27 nM) were measured over the Alaska shelf (Fig. 4.14-4), as well as at the bottom of station 18.6 (Loihi station) showing a potential hydrothermal methane signal.

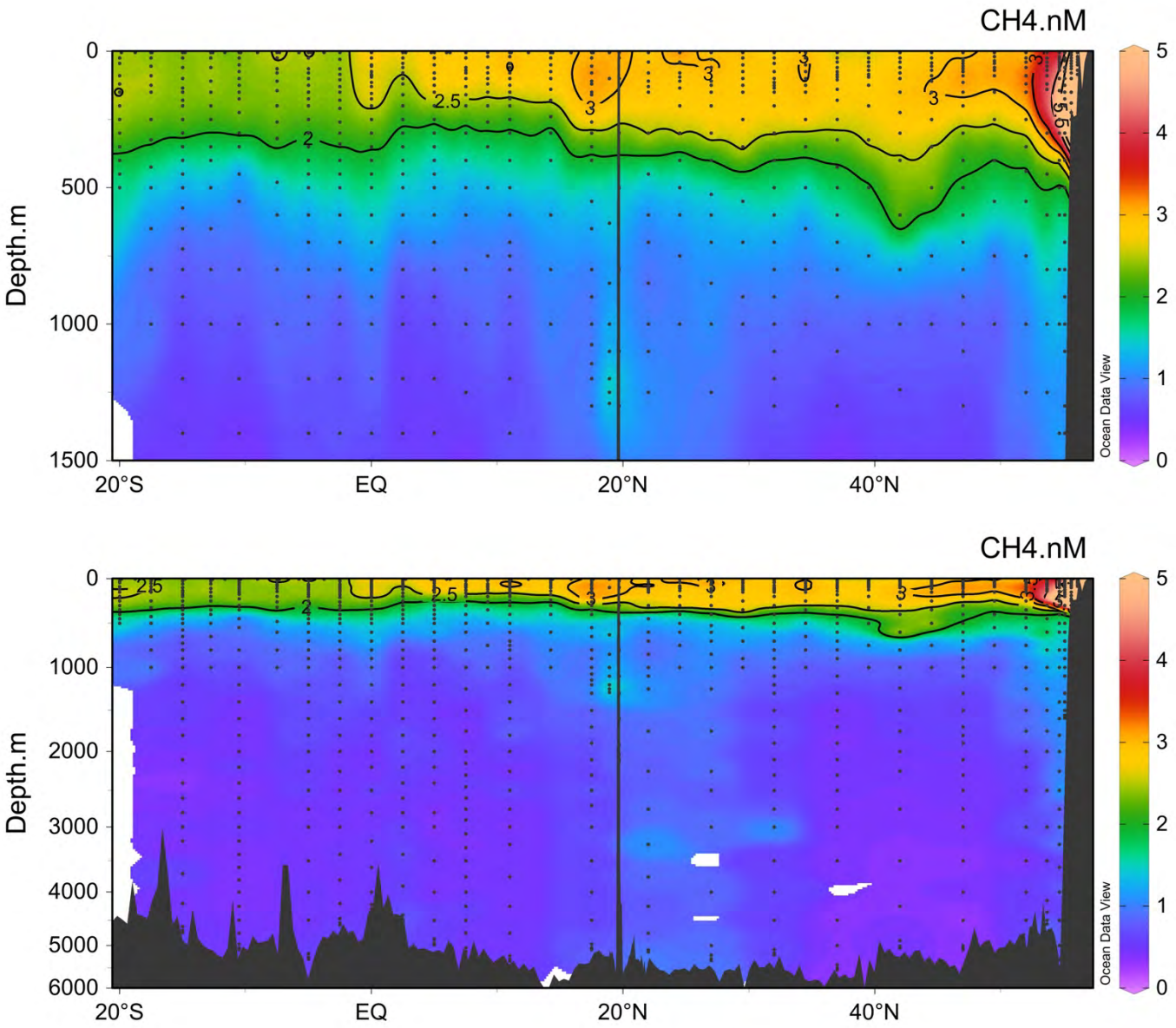

Figure 4.14-4. GP15 section of methane concentration from Alaska to Tahiti. Note, that the data need to be QA/QC'd

4.15 DIC and dissolved gases

4.15.1 Dissolved Inorganic Carbon Isotopes (C. Stump)

Dissolved Inorganic Carbon (13C/12C, 14C) samples (for Quay lab) were collected at 34 stations (Repeat Hydrography and Geotraces stations). There were 91 total ODF casts sampled and a total of 988 DIC samples were taken from those ODF casts. Station 1 and 2 and the two test stations were not sampled. In addition 32 DIC samples were collected from the underway seawater line as a comparison with surface seawater from the ODF Pigrath (pigment, radium, thorium) cast.

All samples were 250 mL total volume and were poisoned with 100 µL HgCl2. A total of 1010 DIC-isotope samples were collected throughout the duration of the cruise. Samples will be processed at University of Washington and other institutes.

4.15.2 Dissolved Gases (N2/Ar) (C. Stump)

250 ml dissolved gas samples were collected for Paul Quay at 32 stations from either the ODF Pigrath (pigment, radium, thorium) cast or from a surface seawater Niskin on demi stations. A 6 – 8 sample profile was done on the 20 Pigrath casts comprising depths from the surface to 200 meters. In addition 30 N2/Ar samples were taken from the underway seawater line as a comparison with surface seawater from the ODF Pigrath (pigment, radium, thorium) cast. In addition 35 duplicate O2 samples were collected at the same time from the underway seawater line, also as a comparison to the surface seawater from the ODF Pigrath cast.

All samples were 250 mL total volume and were poisoned with 100 µL HgCl2. A total of 193 N2/Ar samples and 70 O2 samples were collected throughout the duration of the cruise. Samples will be processed at University of Washington and other institutes.

4.15.3 Underway Gas and Nutrient Sampling (C. Stump)

During the length of the cruise, both a MIMS Prisma Plus(membrane inlet mass spectrometer) quadrapole mass spectrometer and a Picarro G2131-i cavity-ring-down laser system were continually run using the underway seawater line and a Weiss-type equilibrator was used to generate an equilibrated headspace to sample the water. A reverse flow column of N2 gas was used to dry the sampled headspace before entering the two analyzers. A script allowed for seven hours of sampling. After each seven hours, a Valco valve switched to either deck air collected from the bow of the ship or an air standard. Each was analyzed for one hour. The MIMS mass spectrometer read the ion currents of oxygen, nitrogen, argon and the real-time O2/Ar data. The Picarro G2131-i read the concentrations of pCO2 , del 13CO2 of dissolved CO2 and CH4. In addition an Aanderaa Optode was placed in a container being overflowed with the underway seawater. Once a day the Optode was air calibrated for one hour. A fluorometer was also in line with the underway seawater as well as a SUNA nitrate analyzer. The SUNA nitrate analyzer was only employed from 56N to 35N and from 5N to 5S.

4.16 Shipboard analysis of Dissolved Al, Fe, and Mn

Dissolved Al, Fe, and Mn (dAl, dFe, and dMn) samples were obtained from the GEOTRACES trace metal rosette equipped with 24 Teflon-coated, 12L General Oceanic GO-FLO bottles. The University of Hawaii group (Hatta and Weiss) performed shipboard determinations on 0.2µm Acropak filtered subsamples from these bottles taken by the subsampling team. Subsamples were collected into 125mL acid washed PMP bottles and acidified to 0.006M HCl and microwaved for 58 seconds/125mL of sample. These samples were subsequently analyzed shipboard for dissolved Al, Fe, and Mn using flow injection analyses (Resing and Measures, 1994; Measures et al., 1995; Resing and Mottl, 1992 respectively). A total of 846 trace metal samples were collected at 41 GEOTRACES water column stations (including two test stations). This total includes the surface samples collected by the GEO Tow Fish, which collected surface seawater at a nominal depth of 5m. The surface samples collected by tow fish were also filtered through a 0.2 µm Acropak filtered and acidified and microwaved as described above. Additionally, 47 samples were obtained from the ODF rosette at the Puna (station 18.3), Loihi (station 18.6) and one superstation (station 35) and were also filtered through a 0.8/0.45m µm Acropak 500 capsule filter. The precision of each of the methods was determined by replicate determination of the same sample at the beginning of the day's run, with typical values of 1.5% for Al at 2.8nM; 1.8% for Fe at 1.4nM, and 0.9% for Mn at 1.3nM.

Dissolved Al, Fe, and Mn concentrations were determined from samples obtained from both the GEOTRACES and ODF rosettes at the Puna and Loihi stations for comparison. The preliminary concentrations of dAl and dMn were comparable between the two rosettes; however, dFe concentrations were slightly higher for the samples from the ODF rosette compared to the ones from the GEOTRACES rosette. We did see the differences between the cast, which could be temporally variable between the two casts. Elevated dFe and dMn value were seen in the vicinity of the shelf stations (stations 1 &2) and in the vicinity of hydrothermal activity at 1100-1300 m at the Puna (station 18.3) and at Loihi (station 18.6). Elevated dAl value was seen in the EUC (station 29) and in the mixed layer between 27°N to 2,5°N. Also, elevated dAl were seen in the deep-water value (below 4000m depth) from 27°N to the south.

4.17 Hydrogen Sulfide

PI: Gregory Cutter, ODU

At Sea: Nicole Buckley (ODU graduate Student)

Samples of 0.2 µm-filtered water from the GTC system and tow-fish pump, and particles from the McLane pumps were collected for sulfide analyses. ODU graduate student, Nicole Buckley, made shipboard measurements on sulfide speciation and pH at 34 stations. In total, she analyzed over 1,000 samples for total dissolved sulfide (TDS), free (uncomplexed) sulfide, particulate acid volatile sulfide (pAVS), and pH.

Approximately 425 total dissolved sulfide samples were collected and measured in duplicate or triplicate analyses. Concentrations of TDS were higher on the shelf and slope stations, typically between 75-150 pM through station 5, with station 2 having greater concentrations between 150-

250 pM. The water column TDS concentrations decreased as we transited south. Most stations had concentrations that did not exceed 50 pM.

Approximately 250 pAVS samples were measured in single analyses of Supor filters supplied by the Pump/Lam group. Particulate acid volatile sulfide concentrations were greatest near the shelf and decreased as we proceeded southward. In the open ocean water column the greatest pAVS concentration rarely exceeded 3 pM. Approximately 250 samples of QMA filters from the McLane pumps were placed in heat-sealed Tedlar bags with oxygen scrubbers and stored at -80C. These will be returned to the ODU lab via a LN2 dry shipper for subsequent determinations of particulate chromium-reducible sulfur (pCRS, typically FeS_2 + CuS).

Approximately 350 pH samples were collected and were typically measured in single analyses using the spectrometric method of Carter et al. (2013). Based on preliminary calculations, the pH values tabulated from Leg 1 are close to the values that were collected along 152°W in the North Pacific in 2006 and reported by Byrne et al. (2009).

References

Carter, B. R., Radich, J. A., Doyle, H. L., and A.G. Dickson. 2013. An automated system for spectrophotometric seawater pH measurements. *Limnol. Oceanogr.: Methods*, 11: 16-27.

Byrne, R. H., Mecking, S., Feely, R. A., and Xuewu Liu. 2009. Direct observations of basin-wide acidification of the North Pacific Ocean. *Geophys. Res*., 37, L02601, doi: 10.1029/2009GL040999, 2010.

4.18 Biogeotraces

PIs: Dreux Chappell, Paul Berube, Sophie Clayton, Ginger Armburst, Benjamin Twining

At sea: Sveinn Einarsson

Single cell preservation samples and DNA samples were collected at all tow-fish sampling points, arriving and intermediate points, and from the DCM at full and super stations. DCM samples were collected from the ODF CTD. Single cell preservation samples were preserved and frozen (-80) and DNA samples were collected by filtering seawater through sterivex filters (6 liters/per filter for tow-fish sample, ~4.5 liters/filter for DCM samples). DNA preservation solution was added to sterivex filters and frozen (-80). 313 total single cell preservation samples were collected and 158 total stervex filters were collected. Samples will be analyzed at Old Dominion University (Chappell and Clayton), Massachusetts Institute of Techonology (Berube), and the University of Washington (Armbrust).

SeaFlow flowcytometer was sampling at all times when the ship flow through system was turned on. Data generated will be analyzed at UW (Armbrust).

Samples for Synchrotron X-ray Fluorescence (SXRF) and were collected at 8 vertical profile stations. Unfiltered water samples were taken for SXRF analysis from tow-fish. Samples were preserved with 0.25% trace metal clean buffered glutaraldehyde and centrifuged onto C/formvar-coated Au TEM grids. Stations 4,6,8 and all super stations were sampled for SXRF, and samples will be analyzed at Bigelow (Twining). Total of 32 SXRF samples were collected.

4.19 Shipboard determinations of dissolved Zinc (dZn)

PI: Gregory Cutter, ODU (management grant)

At Sea: Lisa Oswald, ODU

Samples were collected from the trace metal clean rosette at stations 1, 2, 5, 6, 10, & 12 for shipboard zinc determinations. All samples were filtered (0.2 μm AcroPak Supor), acidified (0.024 M q-HCl) and then analyzed shipboard for dZn using analysis using a Lab-on-Valve, GlobalFIA MiniSIA-2 analyzer and FloZF software, as described in Grand *et al.* (2016). Data generated onboard served primarily to validate the sample collection methods by highlighting any potential contamination sources in near real-time. Samples were collected from all bottles in a given cast to access bottle replicates. While the MiniSIA-2 provides excellent precision (generally better than 1% RSD), the accuracy was in question. The preconcentration column necessary to quantify sub-nanomolar dZn measurements suffered from breakthrough at higher concentrations, making it difficult to quantify a profile of samples without multiple calibration curves. Ultimately, the precision of the system made it a good tool for assessing GO-FLO bottle contamination, but the method will need some revision to be useful for accurate sample quantitation in a timely manner.

References:

Grand, M.M., Chocholous P., Ruzicka J., Solich P., and Measures, C.I. 2016. Determination of trace zinc in seawater by coupling solid phase extraction and fluorescence detection in the Lab-On-Valve format. Anal Chim Acta, 923: 45-54

4.20 Nanomolar-level nutrient analyses

PI: Gregory Cutter, ODU (management grant)

At Sea: Lisa Oswald, ODU

Samples were collected from the uppermost 4 depths of the trace metal clean rosette and from the trace metal clean fish beginning at Station 25. Samples were held until ODF analyses determined whether the nutrient concentrations were below their detection limit of 0.02 nM. All samples were filtered (0.2 μm AcroPak Supor) into acid-cleaned 25 mL scintillation vials then refrigerated until analysis. Samples were to be analyzed on an Astoria-Pacific Segmented Flow Analyzer using World Precision Instruments Waveguides as detector cells with three channels: PO_4, NO_2, and NO_3+NO_2. Instrument issues were ongoing, including the x-y autosampler, the waveguides, and the peristaltic pump and Lisa was unable to complete the analyses.

4.21 Outreach

PI: Phoebe Lam, UCSC (management grant)

At Sea: Alex Fox

As part of the management grant, we hired a professional freelance science writer, Alex Fox, to be in charge of outreach for the cruise. Fox assisted in the creation of the GP15 website and social media accounts (Twitter, Facebook, and Instagram) in collaboration with the management team.

Per the statement of work, Fox created daily social media posts, weekly in depth blog posts, and conducted outreach to gain media coverage for the expedition. Fox created multimedia content (photos and video) to furnish social media accounts and to provide collateral materials for the cruise and its researchers.

Social media:

1. Instagram: 85 posts, 251 followers
2. Twitter: 331 followers
3. Facebook: 269 page likes

Blog:

10,382 page views; 2,523 visitors; 15 posts

1. The journey begins…almost! - By Karen Casciotti
2. Packing time! - By Karen Casciotti
3. Loading up and shoving off
4. What is GEOTRACES?
5. What's up with GP15?
6. Paperclips and duct tape
7. Not that kind of cruise: a GEOTRACES glossary
8. The North Pacific's "shadow zone" traps the oldest water in the ocean
9. 3 photo galleries from leg 1
10. Deep sea mining appears on GP15's radar
11. Super Station, Super Techs – part 1
12. Super Station, Super Techs – part 2
13. GUEST POST - Teamwork makes the dream work: the Scripps technicians of GP15 - By Melissa Miller edited by Alex Fox
14. Women in Oceanography
15. GP15 by the numbers

Coverage:

News stories from UC Santa Cruz, Stanford University and University of Hawaii.

GP15 Cruise Report Appendix 1: Station lat, long

GP15 Pacific Meridional Cruise

Cruise	Stn #	Station type	UTC date	UTC time	Lat (°N)	Long (°E)	Bottom Depth (m)
RR1814	Rinse/Tes	Rinse	09/19/18	22:44	50.000	-129.0014	
RR1814	Rinse/Tes	Rinse/test	09/21/18	15:01	53.014	-138.9516	
RR1814	Rinse/Tes	Rinse/test	09/22/18	15:22	53.01248	-144.2497	
RR1814	**1**	shelf w/pump	09/26/18	11:45	56.094	-156.961	96
RR1814	**2**	shelf no pump	9/26/18	20:21	55.59477	-156.3461	260
RR1814	**3**	Slope	09/27/18	19:00	55.08013	-155.7201	1605
RR1814	**4**	Full-36	09/28/18	18:56	54.65985	-155.1706	5603
RR1814	**5**	Full-24	09/24/18	8:56	53.67681	-153.7969	4616
RR1814	**5.5**	intermediate fish	10/01/18	4:02	53.1492	-153.3448	
RR1814	**6**	Full-24	10/01/18	14:35	51.99993	-152	5120
RR1814	**6.5**	intermediate fish	cancelled		50.75	-152.00	
RR1814	**7**	Demi	10/03/18	15:50	49.49992	-152	4900
RR1814	**7.5**	intermediate fish	cancelled		48.25	-152.00	
RR1814	**8**	**Super**	10/04/18	11:02	46.99996	-152	5132
RR1814	**8.5**	intermediate fish	10/06/18	17:44	45.769	-152	
RR1814	**9**	Demi	10/07/18	1:47	44.50005	-151.9998	5059
RR1814	**9.5**	intermediate fish	cancelled		43.25	-152.00	
RR1814	**10**	Full-24	10/07/18	22:58	41.99993	-152.0001	5103
RR1814	**10.5**	intermediate fish	10/09/18	13:21	40.45	-152	
RR1814	**11**	Demi	10/09/18	20:30	39.50007	-152.0001	5233
RR1814	**11.5**	intermediate fish	10/10/18	20:00	38.28123	-152	
RR1814	**12**	Full-36	10/10/18	13:17	37.00008	-152.0001	5590
RR1814	**12.5**	intermediate fish	10/12/18	11:15	35.75	-152	
RR1814	**13**	Demi	10/12/18	18:22	34.49892	-152.0014	5590
RR1814	**13.5**	intermediate fish	10/13/18	3:55	33.25007	-152	
RR1814	**14**	**Super**	10/13/18	10:54	31.99997	-151.9999	5255
RR1814	**14.5**	intermediate fish	cancelled		30.75	-152.00	
RR1814	**15**	Demi	10/16/18	0:40	29.50003	-152	5455

RR1814	**15.5**	intermediate fish	10/16/18	5:41	29.02612	-152	
RR1814	**16**	Full-24	10/16/18	16:02	26.99995	-152.0001	5381
RR1814	**16.5**	intermediate fish	10/18/18	1:44	26.95257	-152	
RR1814	**17**	Demi	10/18/18	14:37	24.50007	-152.0001	5339
RR1814	**17.5**	intermediate fish	10/18/18	18:45	24.41558	-152	
RR1814	**18**	Full-24	10/19/18	7:38	22.00036	-152.0002	5205
RR1814	**18.3**	Demi+pumps	10/21/18	14:16	19.68122	-154.5128	2165
RR1815	**18.6**	Demi (8 depths)	10/25/18	14:10	18.90652	-155.2578	1320
RR1815	**19**	Full-36	10/26/18	19:30	17.50003	-152.0001	5144
RR1815	**19.5**	intermediate fish	10/28/18	21:33	15.8621	-152.0002	
RR1815	**20**	Demi	10/29/18	6:37	14.25156	-152	5886
RR1815	**20.5**	intermediate fish	10/29/18	18:03	12.625	-152	
RR1815	**21**	Full-36	10/30/18	2:55	11.00004	-152.0002	5392
RR1815	**22**	Demi	11/01/18	1:22	9.249285	-151.9979	5176
RR1815	**23**	**Super**	11/01/18	13:49	7.500213	-151.9999	5228
RR1815	**24**	Demi fish	11/03/18	20:59	6.2558	-152	
RR1815	**25**	Full-36	11/04/18	5:23	5.000008	-151.9954	5037
RR1815	**26**	Demi fish	11/06/18	2:30	4.75685	-152	
RR1815	**27**	Full-36	11/06/18	9:35	2.501157	-152.0133	4579
RR1815	**28**	Demi fish	11/08/18	5:45	1.265767	-152.0002	
RR1815	**29**	**Super**	11/08/18	17:03	0.000002	-151.9986	4382
RR1815	**30**	Demi fish	11/10/18	12:24	-0.184167	-151.9999	
RR1815	**31**	Full-36	11/11/18	2:07	-2.500367	-151.9999	4634
RR1815	**32**	Demi fish	11/12/18	19:50	-3.75	-152	
RR1815	**33**	Full-36	11/13/13	2:20	-5.000433	-152.0003	5342
RR1815	**33.5**	intermediate fish	11/14/18	20:15	-6.25	-152	
RR1815	**34**	Demi	11/15/18	2:51	-7.500017	-152	5040
RR1815	**34.5**	intermediate fish	11/15/18	12:48	-9	-152	
RR1815	**35**	**Super**	11/15/18	20:19	-10.5	-152.0001	5142
RR1815	**35.5**	intermediate fish	11/18/18	0:40	-11.625	-152	
RR1815	**36**	Demi	11/18/18	6:24	-12.75001	-152	5056

RR1815	**36.5**	intermediate fish	cancelled		-13.875	-152.00	
RR1815	**37**	Full-36	11/18/18	21:20	-14.99997	-152.0001	4795
RR1815	**37.5**	intermediate fish	11/20/18	15:06	-16.25	-152	
RR1815	**38**	Demi	11/20/18	23:24	-17.50019	-152.0006	4168
RR1815	**38.5**	intermediate fish	11/21/18	8:11	-18.76025	-152	
RR1815	**39**	Full-36+pumps	11/21/18	16:08	-19.99996	-152	4277
	Papeete				-17.53	149.57	

#	Role (PI-param)	RR1814--leg1-name	RR1815--leg2
1	chief sci	Greg Cutter	Greg Cutter
2	co-leader	Karen Casciotti	Karen Casciotti
3	co-leader	Phoebe Lam	Phoebe Lam
4	GTC super1	Laramie Jensen	Laramie Jensen
5	GTC super2	Brent Summers	Brent Summers
6	ODF super1	Marty Fleisher	Marty Fleisher
7	ODF super2	Collette Kelly	Collette Kelly
8	Pump super1	Steve Pike	Steve Pike
9	Pump super2	Yang Xiang	Yang Xiang
10	Journalist	Alex Fox	Alex Fox
11	GTC person (Cutter)	Kyle McQuiggan	Kyle McQuiggan
12	GTC person (Cutter-Zn,nan	Lisa Oswald	Lisa Oswald
13	ODF1 data	Joseph Gum	(Kenneth) Jackson
14	ODF2 CTD/salts/O2	John Calderwood	Andrew Barna
15	ODF3 O2/salts	Erin Hunt	Erin Hunt
16	ODF4 nuts	Melissa Miller	Susan Becker
17	ODF5 CTD/salts	John Collins	Kelsey Vogel
18	SIO STS computer tech	Kenneth Olsen	Brent De Vries
19	SIO ResTech	Keith Shadle	Josh Manger
20	SIO ResTech	Brendon Mendenhall	Drew Cole
21	Buesseler-234Th	Jennifer Kenyon	Jennifer Kenyon
22	Shiller-CH4	Laura Whitmore	Virginie Sanial
23	Fitzsimmons-colloids	Janelle Steffen	Janelle Steffen
24	Buck/Landing-aerosols	Cliff Buck	Chris Marsay
25	Saito-Co/proteins	Rebecca Chmiel	Rebecca Chmiel
26	Lam-particles	Vinicius Amaral	Vinicius Amaral
27	Charette/Moore-Ra	Paul Henderson	Emilie LeRoy
28	Cutter - H2S and pH	Nicole Buckley	Nicole Buckley
29	German/Jenkins-3He	Kevin Cahill	Zoe Sandwith
30	Kadko/Cochran-Po/Pb/Be	Mark Stephens	Mark Stephens
31	Hatta/Measures-FIA	Mariko Hatta	Mariko Hatta
32	Hatta/Measures-FIA	Gabrielle Weiss	Gabrielle Weiss
33	Repeta-ms ligands	Lydia Babcock-Adams	Jingxuan Li
34	Fine-CFCs	David Cooper	Jim Happell
35	Mason-Hg	Yipeng He	Rob Mason
36	Quay-d13C, O2/Ar, pCO2	Chuck Stump	Chuck Stump
37	Fish/biogeotraces	Sveinn Einarsson	Sveinn Einarsson

Principal Investigator	Organization	PIEmailAddress	NSF Proposal Title
Ken Buesseler	Woods Hole Oceanographic Institution	kbuesseler@whoi.edu	Quantifying Upper Ocean Export and Remineralization of Bioactive and Particle Reactive Trace Elements along the US GEOTRACES Tahiti to Alaska Transect
David Kadko	Florida International University	dkadko@fiu.edu	GEOTRACES Pacific Meridional Transect: Measurement of Beryllium-7 as a Tracer of Upper Ocean Processes
Rana Fine	University of Miami Rosenstiel School of Marir	rfine@rsmas.miami.edu	GEOTRACES Pacific Meridional Transect: Measurement of chlorofluorocarbons and sulfur hexafluoride
Brian Haley	Oregon State University	bhaley@coas.oregonstate.edu	Collaborative Research: US GEOTRACES Pacific Meridional Transect: Sources and Sinks of Neodymium Isotopes and Rare Earth Elements
J. Kirk Cochran	SUNY at Stony Brook	kirk.cochran@stonybrook.edu	Collaborative Research: Lead-210 and Polonium-210 as tracers for scavenging and export: GEOTRACES Pacific Meridional Section
David Kadko	Florida International University	dkadko@fiu.edu	Collaborative Research: Lead-210 and Polonium-210 as tracers for scavenging and export: GEOTRACES Pacific Meridional Section
Jessica Fitzsimmons	Texas A&M University Main Campus	jessfitz@tamu.edu	Collaborative Research: U.S. GEOTRACES PMT: Dissolved trace metal distributions and size partitioning
Robert Mason	University of Connecticut	robert.mason@uconn.edu	US GEOTRACES Pacific Meridional Transect: Determination of the air-sea exchange of inorganic and methylated mercury in the anthropogenically-impacted and remote Pacific Ocean
Mariko Hatta	University of Hawaii	mhatta@hawaii.edu	US GEOTRACES PMT: Shipboard determination of key dissolved trace elements
Claire Till	Humboldt State University Foundation	Claire.Till@humboldt.edu	Collaborative Research: U.S. GEOTRACES PMT: Dissolved trace metal distributions and size partitioning
Seth John	University of Southern California	sethjohn@usc.edu	Collaborative research: US GEOTRACES PMT: Trace-metal concentrations and stable isotopes in the North Pacific
Christopher Hayes	University of Southern Mississippi	christopher.t.hayes@usm.edu	Collaborative Research: U.S. GEOTRACES Pacific Meridional Transect: Thorium-232, Thorium-231 and Protactinium-231 as tracers of trace element supply and removal
James Moffett	University of Southern California	jmoffett@usc.edu	U.S. GEOTRACES PMT: Measurement of the organic complexation and chemical lability of dissolved copper using multiple techniques
Willard Moore	University of South Carolina at Columbia	moore@geol.sc.edu	Collaborative Research: US GEOTRACES PMT: Sources and Rates of Trace Element and Isotope Cycling Derived from the Radium Quartet
Matthew Charette	Woods Hole Oceanographic Institution	mcharette@whoi.edu	Collaborative Research: US GEOTRACES PMT: Sources and Rates of Trace Element and Isotope Cycling Derived from the Radium Quartet
Mak Saito	Woods Hole Oceanographic Institution	msaito@whoi.edu	US GEOTRACES PMT: Cobalt Biogeochemical Cycling and Connections to Metalloenzymes in the Pacific Ocean
Alan Shiller	University of Southern Mississippi	alan.shiller@usm.edu	US GEOTRACES PMT: Rare earth elements, gallium, barium, and methane as indicators of internal cycling and input processes
Steven Goldstein	Columbia University	steveg@ldeo.columbia.edu	Collaborative Research: US GEOTRACES Pacific Meridional Transect: Sources and Sinks of Neodymium Isotopes and Rare Earth Elements
Chris German	Woods Hole Oceanographic Institution	cgerman@whoi.edu	Measurement of Helium Isotopes on the U.S. GEOTRACES Alaska-Tahiti Section (GP15)
Clifton Buck	University of Georgia Research Foundation Inc	Clifton.Buck@skio.uga.edu	Collaborative Research: US GEOTRACES PMT: Quantification of Atmospheric Deposition and Trace Element Fractional Solubility
William Landing	Florida State University	wlanding@fsu.edu	Collaborative Research: US GEOTRACES PMT: Quantification of Atmospheric Deposition and Trace Element Fractional Solubility
Daniel Sigman	Princeton University	sigman@princeton.edu	Collaborative Research: US GEOTRACES PMT: Investigating geochemical tracers of the Pacific nitrogen cycle and budget
Karen Casciotti	Stanford University	kcasciotti@stanford.edu	Collaborative Research: US GEOTRACES PMT: Investigating geochemical tracers of the Pacific nitrogen cycle and budget
Phoebe Lam	University of California-Santa Cruz	pjlam@ucsc.edu	US GEOTRACES PMT: the geochemistry of size-fractionated suspended particles collected by in-situ filtration
Tristan Horner	Woods Hole Oceanographic Institution	Tristan.Horner@whoi.edu	U.S. GEOTRACES Pacific Meridional Transect: Tracing Basin-scale Nutrient Cycling and Carbon Export with Dissolved and Particulate Barium-isotopic Distributions
Timothy Conway	University of South Florida	tmconway@usf.edu	Collaborative research: US GEOTRACES PMT: Trace-metal concentrations and stable isotopes in the North Pacific
Paul Quay	University of Washington	pdquay@uw.edu	Collaborative research: US GEOTRACES PMT: Measuring the d13C-DIC distribution and estimating organic matter export rates
R. Lawrence Edwards	University of Minnesota-Twin Cities	edwar001@umn.edu	Collaborative Research: U.S. GEOTRACES Pacific Meridional Transect: Thorium-232, Thorium-231 and Protactinium-231 as tracers of trace element supply and removal
Robert Anderson	Columbia University	boba@ldeo.columbia.edu	Collaborative Research: U.S. GEOTRACES Pacific Meridional Transect: Thorium-232, Thorium-231 and Protactinium-231 as tracers of trace element supply and removal
Gregory Cutter	Old Dominion University Research Foundation	gcutter@odu.edu	US GEOTRACES PMT: hydrogen sulfide as a strong ligand affecting trace metal cycling
Mark Brzezinski	University of California-Santa Barbara	mark.brzezinski@lifesci.ucsb.edu	US GEOTRACES Pacific Meridional Transect (GP-15): Resolving Silicon Isotope Anomalies in the Northeast Pacific
Daniel Repeta	Woods Hole Oceanographic Institution	drepeta@whoi.edu	Trace Element Organic Speciation along the US GEOTRACES Pacific Meridional Transect
Robert Rember	University of Alaska Fairbanks Campus	rrember@iarc.uaf.edu	Collaborative Research: US GEOTRACES PMT: Pb and Cr isotopes
Edward Boyle	Massachusetts Institute of Technology	eaboyle@mit.edu	Collaborative Research: US GEOTRACES PMT: Pb and Cr isotopes
Douglas Hammond	University of Southern California	dhammond@usc.edu	U.S. GEOTRACES Pacific Meridional Transect: Measurements of Actinium-227 to Trace Solute Transport

Samples also collected for:		Parameters
Gabriel Dulaquais	Gabriel.Dulaquais@univ-brest.fr	chromatographic analysis of DOC; electrochemical analysis of humics
Elisabeth Sykes	sikes@marine.rutgers.edu	d18O of seawater
Jessica Fitzsimmons	jessfitz@tamu.edu	Fe ligands by CSV
Randelle Bundy	rbundy@uw.edu	Fe ligands by CSV
Kristen Buck	kristenbuck@usf.edu	Fe ligands by CSV
Matthew Hurst	matthew.hurst@humboldt.edu	Fe ligands by CSV
Rob Mason	robert.mason@uconn.edu	Water column mercury
Carl Lamborg	clamborg@ucsc.edu	Water column mercury
Chad Hammerschmidt	chad.hammerschmidt@wright.ed	Water column mercury and particles
Benjamin Twining	btwining@bigelow.org	SXRF at superstations only
Timothy Kenna	tkenna@ldeo.columbia.edu	Artifical radionuclides (subset)
Ken Buesseler/Alison Macdonald	amacdonald@whoi.edu	Cs isotopes (demi stations)
Nuria Casacuberta	ncasacuberta@phys.ethz.ch	129I
Dreux Chappell	pdchappe@odu.edu	various targetted and meta 'omics
Penny Chisholm/Paul Berube	pmberube@mit.edu	various targetted and meta 'omics
Ginger Armburst	armbrust@u.washington.edu	various targetted and meta 'omics

whp_name
Pu_240_D_CONC_BOTTLE::KENNA
Pu_239_Pu_240_D_CONC_BOTTLE::KENNA
Sr_90_D_CONC_BOTTLE::KENNA
Cs_134_D_CONC_BOTTLE::KENNA
Cs_137_D_CONC_BOTTLE::KENNA
Np_237_D_CONC_BOTTLE::KENNA
U_238_D_CONC_BOTTLE::KENNA
Pu_239_D_CONC_BOTTLE::KENNA
U_234_238_D_RATIO_BOTTLE::KENNA
Pu_240_239_D_RATIO_BOTTLE::KENNA
Pu_240_STP_CONC_PUMP::KENNA
Cs_134_SPT_CONC_PUMP::KENNA
Cs_137_SPT_CONC_PUMP::KENNA
Np_237_SPT_CONC_PUMP::KENNA
Pu_239_SPT_CONC_PUMP::KENNA
Pu_240_239_SPT_RATIO_PUMP::KENNA
Fe_D_CONC_BOTTLE::HATTA
Al_D_CONC_BOTTLE::HATTA
Mn_D_CONC_BOTTLE::HATTA
Fe_D_CONC_FISH::HATTA
Al_D_CONC_FISH::HATTA
Mn_D_CONC_FISH::HATTA
Cd_114_110_D_DELTA_BOTTLE
Cu_65_63_D_DELTA_BOTTLE
Fe_56_54_D_DELTA_BOTTLE
Zn_66_64_D_DELTA_BOTTLE
Ni_60_58_D_DELTA_BOTTLE
TEI_SPE_ENV_LIGANDS_D_CONC_BOTTLE
TEI_SPE_ENV_LIGANDS_TD_CONC_BOTTLE
TEI_LIGANDNAMES_TD_CONC_BOTTLE
Chlide a_HPLC_P_CONC_BOTTLE
Zea_HPLC_P_CONC_BOTTLE
Chl a_HPLC_P_CONC_BOTTLE
DV chl a_HPLC_P_CONC_BOTTLE
Viola_HPLC_P_CONC_BOTTLE
Chl b_HPLC_P_CONC_BOTTLE
Perid_HPLC_P_CONC_BOTTLE
Fuco_HPLC_P_CONC_BOTTLE
But fuco_HPLC_P_CONC_BOTTLE
Hex fuco_HPLC_P_CONC_BOTTLE
Allo_HPLC_P_CONC_BOTTLE
Diadino_HPLC_P_CONC_BOTTLE

Diato_HPLC_P_CONC_BOTTLE
Alpha Car_HPLC_P_CONC_BOTTLE
Beta Car_HPLC_P_CONC_BOTTLE
Chl c TOT_HPLC_P_CONC_BOTTLE
Lut_HPLC_P_CONC_BOTTLE
TEI_LIGANDNAME_D_ENVCONC_BOTTLE
METAGENOME_P_BOTTLE
Cr_53_52_D_DELTA_BOTTLE::BOYLE
Pb_206_204_D_RATIO_BOTTLE::BOYLE
Pb_207_204_D_RATIO_BOTTLE::BOYLE
Pb_208_204_D_RATIO_BOTTLE::BOYLE
Pb_206_207_D_RATIO_BOTTLE::BOYLE
Pb_208_207_D_RATIO_BOTTLE::BOYLE
Cr_53_52_D_DELTA_FISH::BOYLE
Pb_206_204_D_RATIO_FISH::BOYLE
Pb_207_204_D_RATIO_FISH::BOYLE
Pb_208_204_D_RATIO_FISH::BOYLE
Pb_206_207_D_RATIO_FISH::BOYLE
Pb_208_207_D_RATIO_FISH::BOYLE
BTL_TIME
CFC-11_D_CONC_BOTTLE::FINE
CFC-12_D_CONC_BOTTLE::FINE
SF6_D_CONC_BOTTLE::FINE
Ra_226_D_CONC_BOTTLE::CHARETTE_MOORE
Ra_223_D_CONC_PUMP::CHARETTE_MOORE
Ra_224_D_CONC_PUMP::CHARETTE_MOORE
Ra_226_D_CONC_PUMP::CHARETTE_MOORE
Ra_228_D_CONC_PUMP::CHARETTE_MOORE
BTL_DATE
SILICATE_D_CONC_BOTTLE::ODF
PHOSPHATE_D_CONC_BOTTLE::ODF
NITRATE_D_CONC_BOTTLE::ODF
NITRITE_D_CONC_BOTTLE::ODF
OXYGEN_D_CONC_BOTTLE::ODF
SALINITY_D_CONC_BOTTLE::ODF
SILICATE_D_CONC_FISH::ODF
PHOSPHATE_D_CONC_FISH::ODF
NITRATE_D_CONC_FISH::ODF
NITRITE_D_CONC_FISH::ODF
SALINITY_D_CONC_FISH::ODF
SILICATE_D_CONC_PUMP::ODF
PHOSPHATE_D_CONC_PUMP::ODF
NITRATE_D_CONC_PUMP::ODF

NITRITE_D_CONC_PUMP::ODF
OXYGEN_D_CONC_PUMP::ODF
SALINITY_D_CONC_PUMP::ODF
SILICATE_D_CONC_UWAY::ODF
PHOSPHATE_D_CONC_UWAY::ODF
NITRATE_D_CONC_UWAY::ODF
NITRITE_D_CONC_UWAY::ODF
OXYGEN_D_CONC_UWAY::ODF
SALINITY_D_CONC_UWAY::ODF
C_CELL_CONC_BOTTLE::TWINING
Fe_CELL_CONC_BOTTLE::TWINING
Ni_CELL_CONC_BOTTLE::TWINING
Si_CELL_CONC_BOTTLE::TWINING
Mn_CELL_CONC_BOTTLE::TWINING
Zn_CELL_CONC_BOTTLE::TWINING
Co_CELL_CONC_BOTTLE::TWINING
P_CELL_CONC_BOTTLE::TWINING
S_CELL_CONC_BOTTLE::TWINING
Cu_CELL_CONC_BOTTLE::TWINING
CELL_VOLUME_BOTTLE::TWINING
CELL_TYPE_BOTTLE::TWINING
Cd_114_110_D_DELTA_FISH
Cu_65_63_D_DELTA_FISH
Fe_56_54_D_DELTA_FISH
Zn_66_64_D_DELTA_FISH
NITRATE_18_16_D_DELTA_FISH
Ni_60_58_D_DELTA_FISH
TEI_SPE_ENG_LIGANDS_D_CONC_FISH
TEI_SPE_ENV_LIGANDS_TD_CONC_FISH
TEI_LIGANDNAME_D_ENVCONC_FISH
TEI_LIGANDNAME_TD_FISH
DEPTH
SILICATE_30_28_D_DELTA_BOTTLE::BRZEZENSKI
SILICATE_D_CONC_BOTTLE::BRZEZINSKI
NITRITE_15_14_D_DELTA_BOTTLE::CASCOTTI
N2O_ALPHA_15_14_D_DELTA_BOTTLE::CASCIOTTI
NITRATE_15_14_D_DELTA_BOTTLE::CASCIOTTI
N2O_15_14_D_DELTA_BOTTLE::CASCIOTTI
NITRATE_18_16_D_DELTA_BOTTLE::CASCIOTTI
NITRITE_18_16_D_DELTA_BOTTLE::CASCIOTTI
N2O_18_16_D_DELTA_BOTTLE::CASCIOTTI
N2O_BETA_15_14_EXT_D_DELTA_BOTTLE::CASCIOTTI
NITRITE_D_CONC_BOTTLE::CASCIOTTI

N2O_D_CONC_BOTTLE::CASCIOTTI
NITRATE_15_14_D_DELTA_FISH::CASCIOTTI
NITRITE_15_14_D_DELTA_FISH::CASCIOTTI
NITRITE_18_16_D_DELTA_FISH::CASCIOTTI
NITRITE_D_CONC_FISH::CASCIOTTI
CTDSAL
Pb_C_CONC_BOTTLE::TILL
Sc_C_CONC_BOTTLE::TILL
Cd_C_CONC_BOTTLE::TILL
Fe_C_CONC_BOTTLE::TILL
Ni_C_CONC_BOTTLE::TILL
Mn_C_CONC_BOTTLE::TILL
Zn_C_CONC_BOTTLE::TILL
Cu_C_CONC_BOTTLE::TILL
Pb_D_CONC_BOTTLE::TILL
Sc_D_CONC_BOTTLE::TILL
Cd_D_CONC_BOTTLE::TILL
Fe_D_CONC_BOTTLE::TILL
Ni_D_CONC_BOTTLE::TILL
Mn_D_CONC_BOTTLE::TILL
Zn_D_CONC_BOTTLE::TILL
Cu_D_CONC_BOTTLE::TILL
Pb_S_CONC_BOTTLE::TILL
Sc_S_CONC_BOTTLE::TILL
Cd_S_CONC_BOTTLE::TILL
Fe_S_CONC_BOTTLE::TILL
Ni_S_CONC_BOTTLE::TILL
Mn_S_CONC_BOTTLE::TILL
Cu_S_CONC_BOTTLE::TILL
Pb_C_CONC_FISH::TILL
Sc_C_CONC_FISH::TILL
Cd_C_CONC_FISH::TILL
Fe_C_CONC_FISH::TILL
Ni_C_CONC_FISH::TILL
Mn_C_CONC_FISH::TILL
Zn_C_CONC_FISH::TILL
Cu_C_CONC_FISH::TILL
Pb_D_CONC_FISH::TILL
Sc_D_CONC_FISH::TILL
Cd_D_CONC_FISH::TILL
Fe_D_CONC_FISH::TILL
Ni_D_CONC_FISH::TILL
Mn_D_CONC_FISH::TILL

Zn_D_CONC_FISH::TILL
Cu_D_CONC_FISH::TILL
Pb_S_CONC_FISH::TILL
Sc_S_CONC_FISH::TILL
Cd_S_CONC_FISH::TILL
Fe_S_CONC_FISH::TILL
Ni_S_CONC_FISH::TILL
Mn_S_CONC_FISH::TILL
Zn_S_CONC_FISH::TILL
Cu_S_CONC_FISH::TILL
POC_13_12_LPT_DELTA_PUMP:LAM
PN_15_14_LPT_DELTA_PUMP:LAM
POC_13_12_SPT_DELTA_PUMP::LAM
PN_15_14_SPT_DELTA_PUMP::LAM
Ba_LPT_CONC_PUMP::LAM
La_LPT_CONC_PUMP::LAM
Pb_LPT_CONC_PUMP::LAM
Tb_LPT_CONC_PUMP::LAM
Yb_LPT_CONC_PUMP::LAM
PIC_LPT_CONC_PUMP::LAM
POC_LPT_CONC_PUMP::LAM
Sc_LPT_CONC_PUMP::LAM
Cd_LPT_CONC_PUMP::LAM
Gd_LPT_CONC_PUMP::LAM
Nd_LPT_CONC_PUMP::LAM
Ce_LPT_CONC_PUMP::LAM
Fe_LPT_CONC_PUMP::LAM
Th_LPT_CONC_PUMP::LAM
Ni_LPT_CONC_PUMP::LAM
bSi_LPT_CONC_PUMP::LAM
Ti_LPT_CONC_PUMP::LAM
Al_LPT_CONC_PUMP::LAM
Sm_LPT_CONC_PUMP::LAM
Tm_LPT_CONC_PUMP::LAM
Mn_LPT_CONC_PUMP::LAM
PN_LPT_CONC_PUMP:LAM
Zn_LPT_CONC_PUMP::LAM
Co_LPT_CONC_PUMP::LAM
Ho_LPT_CONC_PUMP::LAM
P_LPT_CONC_PUMP::LAM
PP_LPT_CONC_PUMP::LAM
Cr_LPT_CONC_PUMP::LAM
Er_LPT_CONC_PUMP::LAM

Pr_LPT_CONC_PUMP::LAM
PARTICLEMASS_LPT_CONC_PUMP::LAM
Cu_LPT_CONC_PUMP::LAM
Eu_LPT_CONC_PUMP::LAM
Lu_LPT_CONC_PUMP::LAM
V_LPT_CONC_PUMP::LAM
Y_LPT_CONC_PUMP::LAM
Dy_LPT_CONC_PUMP::LAM
Ba_SPT_CONC_PUMP::LAM
La_SPT_CONC_PUMP::LAM
Pb_SPT_CONC_PUMP::LAM
Tb_SPT_CONC_PUMP::LAM
Yb_SPT_CONC_PUMP::LAM
PIC_SPT_CONC_PUMP::LAM
POC_SPT_CONC_PUMP::LAM
Sc_SPT_CONC_PUMP:LAM
Cd_SPT_CONC_PUMP::LAM
Gd_SPT_CONC_PUMP::LAM
Nd_SPT_CONC_PUMP::LAM
Ce_SPT_CONC_PUMP::LAM
Fe_SPT_CONC_PUMP::LAM
Th_SPT_CONC_PUMP::LAM
Ni_SPT_CONC_PUMP::LAM
bSi_SPT_CONC_PUMP::LAM
Ti_SPT_CONC_PUMP::LAM
Al_SPT_CONC_PUMP::LAM
Sm_SPT_CONC_PUMP::LAM
Tm_SPT_CONC_PUMP::LAM
Mn_SPT_CONC_PUMP::LAM
PN_SPT_CONC_PUMP::LAM
Zn_SPT_CONC_PUMP::LAM
Co_SPT_CONC_PUMP::LAM
Ho_SPT_CONC_PUMP::LAM
P_SPT_CONC_PUMP::LAM
PP_SPT_CONC_PUMP::LAM
Cr_SPT_CONC_PUMP::LAM
Er_SPT_CONC_PUMP::LAM
Pr_SPT_CONC_PUMP::LAM
PARTICLEMASS_SPT_CONC_PUMP::LAM
Cu_SPT_CONC_PUMP::LAM
Eu_SPT_CONC_PUMP::LAM
Lu_SPT_CONC_PUMP::LAM
V_SPT_CONC_PUMP::LAM

Y_SPT_CONC_PUMP::LAM
Dy_SPT_CONC_PUMP::LAM
NITRATE_15_14_D_DELTA_BOTTLE::SIGMAN
NITRATE_18_16_D_DELTA_BOTTLE::SIGMAN
NITRATE_15_14_D_DELTA_FISH::SIGMAN
NITRATE_18_16_D_DELTA_FISH::SIGMAN
Pb_210_D_CONC_BOTTLE::COCHRAN
Po_210_D_CONC_BOTTLE::COCHRAN
Pb_210_D_CONC_FISH::COCHRAN
Po_210_D_CONC_FISH::COCHRAN
Pb_210_LPT_CONC_PUMP::COCHRAN
Po_210_LPT_CONC_PUMP::COCHRAN
Pb_210_SPT_CONC_PUMP::COCHRAN
Po_210_SPT_CONC_PUMP::COCHRAN
L1_Fe_D_CONC_BOTTLE::JENSEN
La_D_CONC_BOTTLE::GOLDSTEIN
Nd_D_CONC_BOTTLE::GOLDSTEIN
Ce_D_CONC_BOTTLE::GOLDSTEIN
Sm_D_CONC_BOTTLE::GOLDSTEIN
Pr_D_CONC_BOTTLE::GOLDSTEIN
Nd_143_144_D_EPSILON_BOTTLE::GOLDSTEIN
Nd_143_144_D_RATIO_BOTTLE::GOLDSTEIN
BTL_LON
Hg_0_D_CONC_BOTTLE::MASON
Hg_Me_D_CONC_BOTTLE::MASON
Hg_D_CONC_BOTTLE::MASON
Hg_0_DM_D_CONC_BOTTLE::MASON
Hg_DM_D_CONC_BOTTLE::MASON
Hg_MM_D_CONC_BOTTLE::MASON
Hg_TD_CONC_BOTTLE::MASON
Hg_T_CONC_BOTTLE::MASON
Hg_0_D_CONC_FISH::MASON
Hg_Me_D_CONC_FISH::MASON
Hg_D_CONC_FISH::MASON
Hg_0_DM_D_CONC_FISH::MASON
Hg_DM_D_CONC_FISH::MASON
Hg_MM_D_CONC_FISH::MASON
Hg_TD_CONC_FISH::MASON
Hg_T_CONC_FISH::MASON
Hg_SPT_CONC_PUMP::MASON
Hg_MM_SPT_CONC_PUMP::MASON
Hg_0_D_CONC_UWAY::MASON
Th_230_C_CONC_BOTTLE::ANDERSON

Pa_231_C_CONC_BOTTLE::ANDERSON
Th_232_C_CONC_BOTTLE::ANDERSON
Th_230_D_CONC_BOTTLE::ANDERSON
Pa_231_D_CONC_BOTTLE_ANDERSON
Th_232_D_CONC_BOTTLE::ANDERSON
U_238_D_CONC_BOTTLE::ANDERSON
Th_230_S_CONC_BOTTLE_ANDERSON
Pa_231_S_CONC_BOTTLE::ANDERSON
Th_232_S_CONC_BOTTLE::ANDERSON
U_234_238_D_RATIO_BOTTLE::ANDERSON
Th_230_SPT_CONC_PUMP::ANDERSON
Pa_231_SPT_CONC_PUMP_ANDERSON
Th_232_SPT_CONC_PUMP::ANDERSON
Pb_210_D_CONC_BOTTLE::KADKO
Po_210_D_CONC_BOTTLE::KADKO
Pb_210_D_CONC_FISH::KADKO
Po_210_D_CONC_FISH::KADKO
Be_7_T_CONC_PUMP::KADKO
Pb_210_LPT_CONC_PUMP::KADKO
Po_210_LPT_CONC_PUMP::KADKO
Pb_210_SPT_CONC_PUMP::KADKO
Po_210_SPT_CONC_PUMP::KADKO
Be_7_SPT_CONC_PUMP::KADKO
CTDRINKO
GEOTRC_SAMPNO
GEOTRC_EVENTNO
Ni_D_CONC_BOTTLE::SAITO
Co_D_CONC_BOTTLE::SAITO
Ni_DL_CONC_BOTTLE::SAITO
Co_DL_CONC_BOTTLE::SAITO
Ni_D_CONC_FISH::SAITO
Co_D_CONC_FISH::SAITO
Ni_DL_CONC_FISH::SAITO
Co_DL_CONC_FISH::SAITO
PROTEINS_LP_PUMP::SAITO
PROTEINS_SP_PUMP::SAITO
PROTEINS_LP_UWAY::SAITO
PROTEINS_SP_UWAY::SAITO
CTDTMP
REFTMP
Fe_56_54_SPL_DELTA_PUMP
Cd_114_110_SPT_DELTA_PUMP
Ba_138_134_SPT_DELTA_PUMP

Fe_56_54_SPT_DELTA_PUMP
Zn_66_64_SPT_DELTA_PUMP
TEI_LIGANDNAME_TP_CONC_PUMP
BTLNBR
TH_234_T_CONC_BOTTLE::BUESSELER
C_137_T_CONC_BOTTLE::BUESSELER
I_129_T_CONC_BOTTLE::BUESSELER
TH_234_T_CONC_FISH::BUESSELER
TH_234_LPT_CONC_PUMP::BUESSELER
TH_234_SPT_CONC_PUMP::BUESSELER
TH_228_SPT_CONC_PUMP::BUESSELER
I_129_T_CONC_UWAY::BUESSELER
CH4_D_CONC_BOTTLE::SHILLER
Ba_D_CONC_BOTTLE::SHILLER
Ga_D_CONC_BOTTLE::SHILLER
La_D_CONC_BOTTLE::SHILLER
Tb_D_CONC_BOTTLE::SHILLER
Yb_D_CONC_BOTTLE::SHILLER
Sc_D_CONC_BOTTLE::SHILLER
Gd_D_CONC_BOTTLE::SHILLER
Nd_D_CONC_BOTTLE::SHILLER
Ce_D_CONC_BOTTLE::SHILLER
Ni_D_CONC_BOTTLE::SHILLER
Sm_D_CONC_BOTTLE::SHILLER
Tm_D_CONC_BOTTLE::SHILLER
Mn_D_CONC_BOTTLE::SHILLER
Ho_D_CONC_BOTTLE::SHILLER
Mo_D_CONC_BOTTLE::SHILLER
Er_D_CONC_BOTTLE::SHILLER
Pr_D_CONC_BOTTLE::SHILLER
Cu_D_CONC_BOTTLE::SHILLER
Eu_D_CONC_BOTTLE::SHILLER
Lu_D_CONC_BOTTLE::SHILLER
V_D_CONC_BOTTLE::SHILLER
Y_D_CONC_BOTTLE::SHILLER
Dy_D_CONC_BOTTLE::SHILLER
Ba_D_CONC_FISH::SHILLER
Ga_D_CONC_FISH::SHILLER
La_D_CONC_FISH::SHILLER
Tb_D_CONC_FISH::SHILLER
Yb_D_CONC_FISH::SHILLER
Sc_D_CONC_FISH::SHILLER
Gd_D_CONC_FISH::SHILLER

Nd_D_CONC_FISH::SHILLER
Ce_D_CONC_FISH::SHILLER
Ni_D_CONC_FISH::SHILLER
Sm_D_CONC_FISH::SHILLER
Tm_D_CONC_FISH::SHILLER
Mn_D_CONC_FISH::SHILLER
Ho_D_CONC_FISH::SHILLER
Mo_D_CONC_FISH::SHILLER
Er_D_CONC_FISH::SHILLER
Pr_D_CONC_FISH::SHILLER
Cu_D_CONC_FISH::SHILLER
Eu_D_CONC_FISH::SHILLER
Lu_D_CONC_FISH::SHILLER
V_D_CONC_FISH::SHILLER
Y_D_CONC_FISH::SHILLER
Dy_D_CONC_FISH::SHILLER
CH4_D_CONC_UWAY::SHILLER
Ba_138_134_D_DELTA_BOTTLE::HORNER
Ba_D_CONC_BOTTLE::HORNER
Ba_138_134_D_DELTA_FISH::HORNER
Ba_D_CONC_FISH::HORNER
Ba_138_134_LPT_DELTA_PUMP::HORNER
TDS_D_CONC_BOTTLE::CUTTER
DFS_D_CONC_BOTTLE::CUTTER
PH_SWS_BOTTLE::CUTTER
PH_TOT_BOTTLE::CUTTER
PH_TMP::CUTTER
CRS_SPT_CONC_PUMP::CUTTER
AVS_SPT_CONC_PUMP::CUTTER
CTDFLUOR
U_234_238_D_DELTA_BOTTLE::EDWARDS
Th_230_D_CONC_BOTTLE::EDWARDS
Pa_231_D_CONC_BOTTLE::EDWARDS
Th_232_D_CONC_BOTTLE::EDWARDS
Th_230_LPT_CONC_PUMP::EDWARDS
Pa_231_LPT_CONC_PUMP::EDWARDS
Th_232_LPT_CONC_PUMP::EDWARDS
Th_230_SPT_CONC_PUMP::EDWARDS
Pa_231_SPT_CONC_PUMP::EDWARDS
Th_232_SPT_CONC_PUMP::EDWARDS
H2O_18_16_D_DELTA_BOTTLE::SIKES
Th_230_D_CONC_BOTTLE::HAYES
Pa_231_D_CONC_BOTTLE::HAYES

Th_232_D_CONC_BOTTLE::HAYES
Th_230_SPT_CONC_PUMP::HAYES
Pa_231_SPT_CONC_PUMP::HAYES
Th_232_SPT_CONC_PUMP::HAYES
DOC_D_CONC_BOTTLE::DULAQUAIS
He_D_CONC_BOTTLE::JENKINS
Ne_D_CONC_BOTTLE::JENKINS
He_D_CONC_UWAY::JENKINS
Ne_D_CONC_UWAY::JENKINS
Pb_C_CONC_BOTTLE::FITZSIMMONS
Sc_C_CONC_BOTTLE::FITZSIMMONS
Cd_C_CONC_BOTTLE::FITZSIMMONS
Fe_C_CONC_BOTTLE::FITZSIMMONS
Ni_C_CONC_BOTTLE::FITZSIMMONS
Mn_C_CONC_BOTTLE::FITZSIMMONS
Zn_C_CONC_BOTTLE::FITZSIMMONS
Cu_C_CONC_BOTTLE::FITZSIMMONS
Pb_D_CONC_BOTTLE::FITZSIMMONS
Sc_D_CONC_BOTTLE::FITZSIMMONS
Cd_D_CONC_BOTTLE::FITZSIMMONS
Fe_D_CONC_BOTTLE::FITZSIMMONS
Ni_D_CONC_BOTTLE::FITZSIMMONS
Mn_D_CONC_BOTTLE::FITZSIMMONS
Zn_D_CONC_BOTTLE::FITZSIMMONS
Cu_D_CONC_BOTTLE::FITZSIMMONS
Pb_S_CONC_BOTTLE::FITZSIMMONS
Sc_S_CONC_BOTTLE::FITZSIMMONS
Cd_S_CONC_BOTTLE::FITZSIMMONS
Fe_S_CONC_BOTTLE::FITZSIMMONS
Ni_S_CONC_BOTTLE::FITZSIMMONS
Mn_S_CONC_BOTTLE::FITZSIMMONS
Zn_S_CONC_BOTTLE::FITZSIMMONS
Cu_S_CONC_BOTTLE::FITZSIMMONS
Pb_C_CONC_FISH::FITZSIMMONS
Sc_C_CONC_FISH::FITZSIMMONS
Cd_C_CONC_FISH::FITZSIMMONS
Fe_C_CONC_FISH::FITZSIMMONS
Ni_C_CONC_FISH::FITZSIMMONS
Mn_C_CONC_FISH::FITZSIMMONS
Zn_C_CONC_FISH::FITZSIMMONS
Cu_C_CONC_FISH::FITZSIMMONS
Pb_D_CONC_FISH::FITZSIMMONS
Sc_D_CONC_FISH::FITZSIMMONS

Cd_D_CONC_FISH::FITZSIMMONS
Fe_D_CONC_FISH::FITZSIMMONS
Ni_D_CONC_FISH::FITZSIMMONS
Mn_D_CONC_FISH::FITZSIMMONS
Zn_D_CONC_FISH::FITZSIMMONS
Cu_D_CONC_FISH::FITZSIMMONS
Pb_S_CONC_FISH::FITZSIMMONS
Sc_S_CONC_FISH::FITZSIMMONS
Cd_S_CONC_FISH::FITZSIMMONS
Fe_S_CONC_FISH::FITZSIMMONS
Ni_S_CONC_FISH::FITZSIMMONS
Mn_S_CONC_FISH::FITZSIMMONS
Cu_S_CONC_FISH::FITZSIMMONS
CTDPRS
CTDXMISS
BTL_LAT
DNA_P_CONC_BOTTLE::DREUX
nifH_Het-1_DNA_P_CONC_BOTTLE::DREUX
nifH_Het-2_DNA_P_CONC_BOTTLE::DREUX
nifH_Gamma A_DNA_P_CONC_BOTTLE::DREUX
nifH_UCYN-A_DNA_P_CONC_BOTTLE::DREUX
nifH_UCYN-B_DNA_P_CONC_BOTTLE::DREUX
nifH_UCYN-C_DNA_P_CONC_BOTTLE::DREUX
nifH_CIII_DNA_P_CONC_BOTTLE::DREUX
nifH_Fil_DNA_P_CONC_BOTTLE::DREUX
nifH_sum_DNA_P_CONC_BOTTLE::DREUX
DIC_13_12_D_DELTA_BOTTLE::QUAY
DIC_14_12_D_DELTA_BOTTLE::QUAY
DIC_D_CONC_BOTTLE::QUAY
TALK_D_CONC_BOTTLE::QUAY
DIC_13_12_D_DELTA_UWAY::QUAY
DIC_D_CONC_UWAY::QUAY
Tb_D_CONC_BOTTLE::GOLDSTEIN_BASAK_HALEY
Yb_D_CONC_BOTTLE::GOLDSTEIN_BASAK_HALEY
Gd_D_CONC_BOTTLE::GOLDSTEIN_BASAK_HALEY
Tm_D_CONC_BOTTLE::GOLDSTEIN_BASAK_HALEY
Ho_D_CONC_BOTTLE::GOLDSTEIN_BASAK_HALEY
Er_D_CONC_BOTTLE::GOLDSTEIN_BASAK_HALEY
Eu_D_CONC_BOTTLE::GOLDSTEIN_BASAK_HALEY
Lu_D_CONC_BOTTLE::GOLDSTEIN_BASAK_HALEY
Dy_D_CONC_BOTTLE::GOLDSTEIN_BASAK_HALEY
La_D_CONC_FISH::GOLDSTEIN_BASAK_HALEY
Tb_D_CONC_FISH::GOLDSTEIN_BASAK_HALEY

Yb_D_CONC_FISH::GOLDSTEIN_BASAK_HALEY
Gd_D_CONC_FISH::GOLDSTEIN_BASAK_HALEY
Nd_D_CONC_FISH::GOLDSTEIN_BASAK_HALEY
Ce_D_CONC_FISH::GOLDSTEIN_BASAK_HALEY
Sm_D_CONC_FISH::GOLDSTEIN_BASAK_HALEY
Tm_D_CONC_FISH::GOLDSTEIN_BASAK_HALEY
Ho_D_CONC_FISH::GOLDSTEIN_BASAK_HALEY
Er_D_CONC_FISH::GOLDSTEIN_BASAK_HALEY
Pr_D_CONC_FISH::GOLDSTEIN_BASAK_HALEY
Eu_D_CONC_FISH::GOLDSTEIN_BASAK_HALEY
Lu_D_CONC_FISH::GOLDSTEIN_BASAK_HALEY
Dy_D_CONC_FISH::GOLDSTEIN_BASAK_HALEY
Nd_143_144_D_EPSILON_FISH::GOLDSTEIN_BASAK_HALEY
Nd_143_144_D_RATIO_FISH::GOLDSTEIN_BASAK_HALEY
Nd_143_144_SPL_EPSILON_PUMP::GOLDSTEIN_BASAK_HALEY
Nd_143_144_SPT_EPSILON_PUMP::GOLDSTEIN_BASAK_HALEY
Nd_143_144_SPL_RATIO_PUMP::GOLDSTEIN_BASAK_HALEY
Nd_143_144_SPT_RATIO_PUMP::GOLDSTEIN_BASAK_HALEY
CTDOXY

ODF report for GEOTRACES Pacific 2018

Release Draft 1

ODF

Nov 23, 2018

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CHAPTER

ONE

CTD AND ROSETTE SETUP

1.1 Underwater Sampling Package

CTDO/rosette 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 housing unit with Paroscientific pressure sensor with dual plumbed lines where each line has a pump, temperature sensor, conductivity sensor, and exhaust line. A SeaBird Electronics membrane oxygen sensor was mounted on the "primary" line. A reference thermometer, transmissometer, chlorophyll-a fluorometer and backscatter meter, oxygen optode, altimeter and for some casts, a monocore were also mounted on the rosette.

CTD and cage were horizontally 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 on the lower LADCP brace with hose clamps around both of its ends, avoiding shiny metal or black tape inside that would introduce noise in the signal. The fluorometer and backscatter meter, oxygen optode, and altimeters were mounted vertically inside the bottom ring of the rosette frames, with nothing obstructing their line of sight.

Equipment	Model	S/N	Cal Date	Stations	Responsible
Rosette	36-place	Yellow	_	1-39	*STS/ODF*
CTD	SBE9+	1281	8/16/18	1-39	*STS/ODF*
Pressure Sensor	Digiquartz	1282	8/16/18	1-39	*STS/ODF*
Primary Temperature	SBE3+	2309	1/30/18	1-39	*STS/ODF*
Primary Conductivity	SBE4C	4546	2/8/18	1-6	*STS/ODF*
Primary Conductivity	SBE4C	2319	4/26/18	8-Aug	*STS/ODF*
Primary Conductivity	SBE4C	4650	2/22/18	9-39	*STS/ODF*
Primary Pump	SBE5	5124	_	1-3	*STS/ODF*
Primary Pump	SBE5	4160	_	12-Apr	*STS/ODF*
Primary Pump	SBE5	1871	_	12-39	*STS/ODF*
Secondary Temperature	SBE3+	5820	1/30/18	1-39	*STS/ODF*
Secondary Conductivity	SBE4C	1880	2/2/18	1-39	*STS/ODF*
Secondary Pump	SBE5	1892	_	1-12	*STS/ODF*
Secondary Pump	SBE5	1781	_	12-39	*STS/ODF*
Transmissometer	Cstar	CST-1873DR	9/16/16	1-39	*STS/ODF*
Fluorometer Chlorophyll and Backscatter	WetLabs	FLBBRTD-4333	4/6/16	1-39	*STS/ODF*
Primary Dissolved Oxygen	SBE43	1138	8/25/18	1-39	*STS/ODF*
RINKO	JFE Advantech RINKO-III	296	4/7/17	1-39	*STS/ODF*
Reference Temperature	SBE35	35	2/1/18	1-39	*STS/ODF*
Carousel	SBE32	1178	3/31/17	1-12	*STS/ODF*
Carousel	SBE32	187	12/12/17	12-39	*STS/ODF*
Altimeter	Valeport 500	59116	_	1-39	*STS/ODF*

1.2 Winch and Deployment

The CAST6 aft 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 GP15 ODF, and no further terminations were necessary afterwards.

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. Any biofouling noted was cleaned off the outsides of the rosette before the next cast, and the insides of the bottles were checked for biofouling and sprayed down. 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 the reverse of launching.

1.3 Maintenance and Calibrations

During GP15 ODF routine maintenance was done to the rosette to ensure quality of the science done. Actions taken included rinsing all electrical instruments on the rosette down with fresh water after each cast. Care was taken not to rinse the spigots and other parts of the bottle that might be touched by samplers in order to not contaminate the samples. After each cast fresh water filled syringes were connected to the plumbed lines to rinse the sensors between casts. The rosette was routinely examined for valves and o-ring leaks, which were maintained as needed. SBE35RT temperature data was routinely downloaded each day.

Throughout the cruise, the transmissometer windows were cleaned and an on deck blocked and un-blocked voltage readings were recorded prior to the cast. The transmissometer was also calibrated before and after the start and end science operations.

1.4 Problems

Some complications were overcome to complete CTDO/rosette station casts for GP15 ODF.

We encountered several problems with the SBE 5P pumps.Prior to station 4, cast 3, the primary pump was replaced due to fouling of the instrument. Before station 12 cast 9 the deck box was not turned off and the pumps were left on for an excess of 4 hours in air. The pump was subsequently switched out due to its questionable status. During station 21 cast 11 the pumps turned on early as the CTD was being deployed, after that both pumps were rinsed out 3 times with fresh water before syringes were attached.

We had several problems with sensors throughout the cruise. After station 6 cast 9, the primary conductivity sensor was switched out due to questionable data. The primary conductivity sensor was replaced again after station 8 cast 3. After station 16 cast 5, the transmissometer had strange artifacts in the top 100m during both the upcast and the downcast due to bad cables that were replaced. During station 25 cast 11, the altimeter readings were noisy after it had locked onto the sea floor, it was determined that the noise was due to monocore cabling wrapping around the rosette.

We were required to switch Niskin bottles on the rosette due to leaking. Due to multiple mistrips, after station 8 cast 5, the bottle positions were offset one to the left of the SBE32 carousel number (eg. bottle 34 is not 33) in order to prevent future mistrips. On station 12 cast 9, bottle 33 failed to close. This had happened previously in the cruise on station 6 cast 2 and as a result the carousel was replaced. Prior to station 23 cast 6, bottle 7 was replaced due to leaking.

There were several failed bottle closures due to bottle caps getting caught or jammed on equipment. Prior to station 4 cast 8, the bottom of bottle 12 did not close due to it hooking on the hose clamp/lanyard of bottle 11. On station 13 cast 12, bottle 36 was leaking upon opening. Sea cable zip tied to a post interfered with the bottle closing. On station 31 cast 11, the top caps of bottles 27 and 29 did not close due to monocore cable getting caught between the top caps and the bottle. On station 34 cast 3, the bottom of bottle 30 did not close. On station 34 cast 3, the top of bottle 32 did not close due to the top cap being blocked by a bolt on the cross frame of the rosette.

On station 17 bottle 22 was observed to be leaking from the bottom collar seam, prompting the replacement with a new bottle. On stations 77 and 78 bottle 26 was observed to be leaking. Prior to station 79 the bottle was inspected and a scratch was noticed across the surface of the bottom collar. A bottle swap was attempted before station 79, but during leak testing the replacement bottle was also found to be leaking. The previous bottle was put back on with minor sanding in order to keep to schedule for station 79. When the bottle came up for sampling after station 79 and was still leaking, another spare bottle that passed leak testing was found and placed on the rosette. On station 80 bottle 26 did not leak. On station 111 bottle 9 was observed to leak from the bottom, and upon inspection scratches were noticed. The bottom of bottle 9 was resurfaced and on station 112 the bottle 9 did not leak. When bottle 9 leaked on station 115, the bottom end cap was replaced, and for the remainder of the cruise the bottle did not leak.

During cocking and uncocking the rosette we had inner cap lanyards snap at multiple times during the cruise. The lanyards were thought to develop excessive wear due to the force required to cock the bottle, where the lanyard would rub against the inner lower collar of the bottle.

Below is a table of all leaks, mistrips, etc. documented in sample logs.

station	cast	bottle	comment
1	3	35	leaked from bottom
2	3	3	leaked from spigots
3	4	7	leaked from bottom
4	5	12	bottle 12 bottom did not close
4	11	21	leaked from bottom
4	11	33	failed to close
6	3	33	failed to close
6	5	22	leaked from bottom
8	3	3	vent was not closed

Continued on next page

Table 1.1 – continued from previous page

station	cast	bottle	comment
8	3	19	vent was not closed
8	5	28	failed to close
8	13	33	failed to close
11	2	27	mistrip
12	9	33	failed to close
12	12	12	failed to close
13	3	36	leaked from bottom
13	12	36	leaked from bottom
18	3	8	vent was not closed
18	5	18	failed to close
21	3	17	spigot was open
21	11	35	failed to close
23	6	4	questionable nutrients
23	9	7	leaked from bottom
23	13	7	leaked from bottom
27	8	15	questionable nutrients
29	3	2	leaked from spigot
29	5	6	leaked from spigot
29	9	2	leaked from bottom
29	9	21	leaked form spigot
29	13	32	failed to close
31	11	2	leaked from spigot
31	11	10	questionable nutrients
31	11	27	monocore red line caught in bottom top causing a failure to close
31	11	29	monocore red line caught in bottom top causing a failure to close
31	11	35	leaked from spigot
34	3	30	bottom was open
35	5	1	questionable nutrients
35	5	32	bottom top caught in crossframe and failed to close
35	13	32	failed to close
36	3	30	bottle was empty
38	3	30	failed to close
39	3	1	questionable nutrients

CHAPTER

TWO

CTDO AND HYDROGRAPHIC ANALYSIS

PIs

- Susan Becker
- James Swift

Technicians

- Joseph Gum (Leg 1)
- Kenneth Jackson (Leg 2)

2.1 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 a console watch operator (CWO) after the ship had stopped on station. The CWO maintained CTD cast logs for each attempted cast containing a description of each deployment event. This cast log included the bottle bottle, any phenomena, and any possible problems.

Once the deck watch had deployed the rosette, the winch operator would lower it to 10 meters in good weather. 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. The Resident Technician would signal to the winch operator what was acceptable for rising to the surface. The winch was then instructed to lower the package to the initial target wire-out at 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 would monitor altimeter readings, taking notice 100m from the bottom and slowing quickly to a final stop 10m from the bottom. The bottom of the CTD cast was usually to within 10-20 meters of the bottom determined by altimeter data.

On deep casts where the monocore was mounted, the package was lowered to 45m off of the bottom and then slowed to to 20m/min until the package was 10-15m from the bottom. The monocore was allowed to take a sample and then the package was raised up at 10m/min to a depth of 40m off of the bottom where the first bottle was fired.

For each up-cast, the winch operator was directed to stop the winch at up to 14 predetermined sampling pressures. These depth were mirrored from the GEOTRACES rosette and chosen to collect samples from features such as the mixed layer, surface, chlorophyll maximum, oxygen minimum, nutricline, and important depths determined by examining profiles from P16N and P16S GO-SHIP occupations. A maximum of 35 unique depths were taken throughout multiple casts during a single station.

The CTD CWO waited 30 seconds prior to tripping sample bottles, to ensure package shed wake had dissipated. When multiple bottles were fired at a depth, the CWO waited 5 seconds between each bottle trip. 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 13 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 CWO 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.

The CTD sensors were then rinsed after each station using a fresh water tap connected to Tygon tubing.

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.

2.2 CTDO Data Processing

Shipboard CTD data processing was performed after deployment using SIO/ODF python CTD processing software v. 0.3. 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 122 CTD stations were occupied including one test station. A total of 125 CTDO/rosette casts were completed. 122 standard CTDO/rosette 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_2 comparisons were made between down and up casts as well as between groups of adjacent deployments. Vertical sections of measured and derived properties from sensor data were checked for consistency.

A number of issues were encountered during GP15 ODF 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.

2.3 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 December 12th, 2017 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 - 39

	Start P (dbar)	End P (dbar)
Min	-1.8	-0.4
Max	7.2	0.2
Average	0.0	-0.1
Applied Offset		-0.0622

An offset of -0.0539 was applied to every cast performed by CTD 1281. On-deck pressure reading for CTD 1281 varied from -0.6 to -0.0 dbar before the casts, and -0.5 to 0.8 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 -0.0539 dbar.

2.4 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 depth, 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.

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

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

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

Corrected temperature differences are shown in the following figures.

The 95% confidence limits for the whole water column differences are ±0.0011°C for SBE35RT-T1, ±0.0010°C for SBE35RT-T2, and ±0.0008°C for T1-T2. The 95% confidence limits for the deep temperature residuals (where pressure ≥ 2000dbar) are ±0.00044°C for SBE35RT-T1, ±0.00037°C for SBE35RT-T2, and ±0.0003°C for T1-T2.

All compromised data signals were recorded and coded in the data files.

2.5 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 temperature sensors were finalized before analyzing conductivity differences. Two independent metrics of calibration

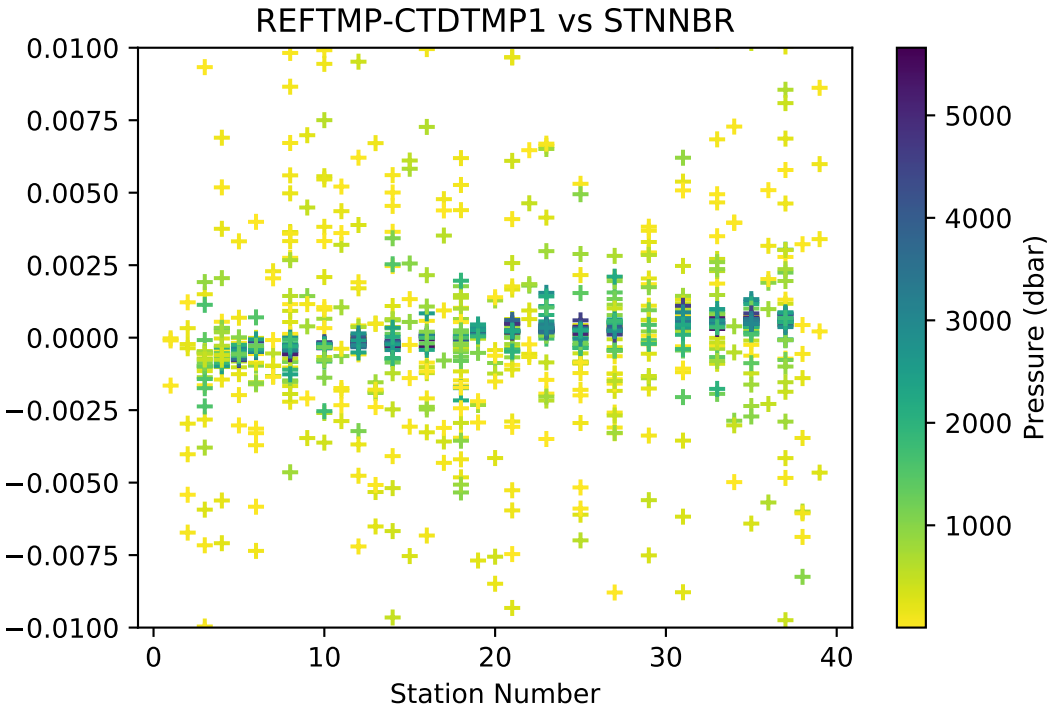

Fig. 2.1: SBE35RT-T1 by station (-0.002°C $\leq$ T1-T2 $\leq$ 0.002°C).

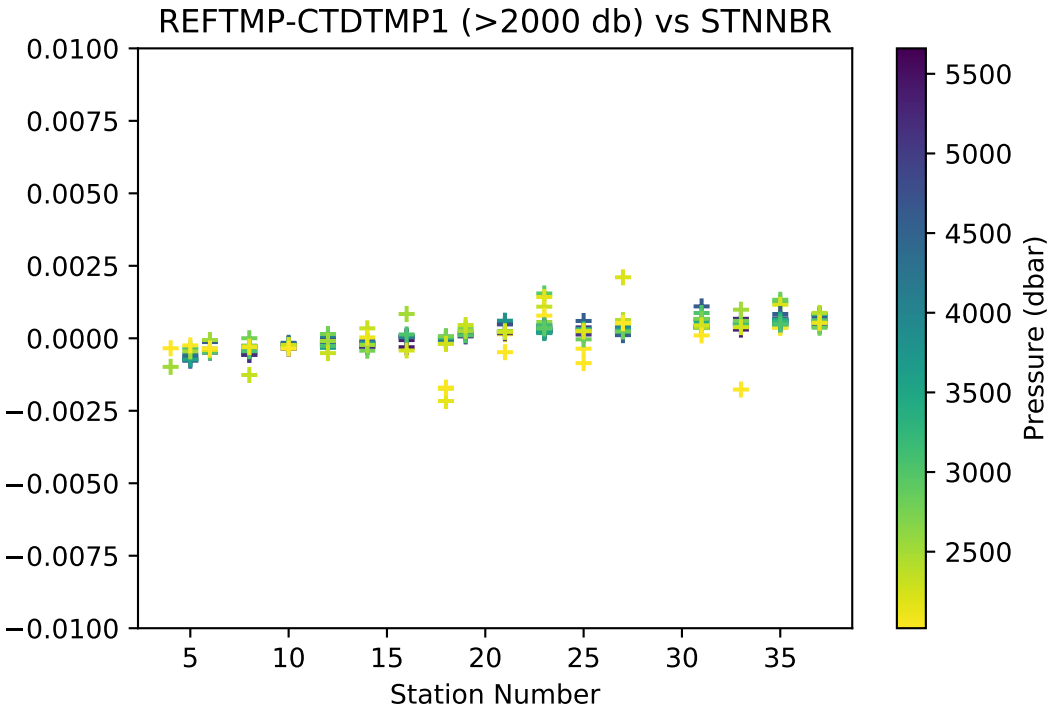

Fig. 2.2: Deep SBE35RT-T1 by station (Pressure $\geq$ 2000dbar).

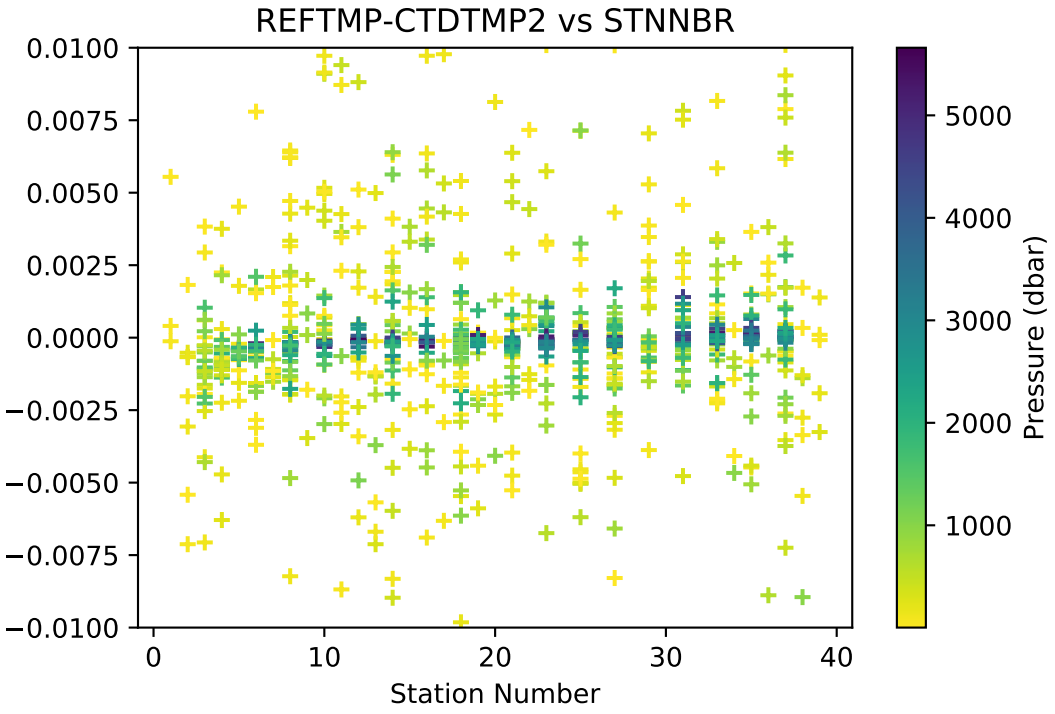

Fig. 2.3: SBE35RT-T2 by station (-0.002°C $\leq$ T1-T2 $\leq$ 0.002°C).

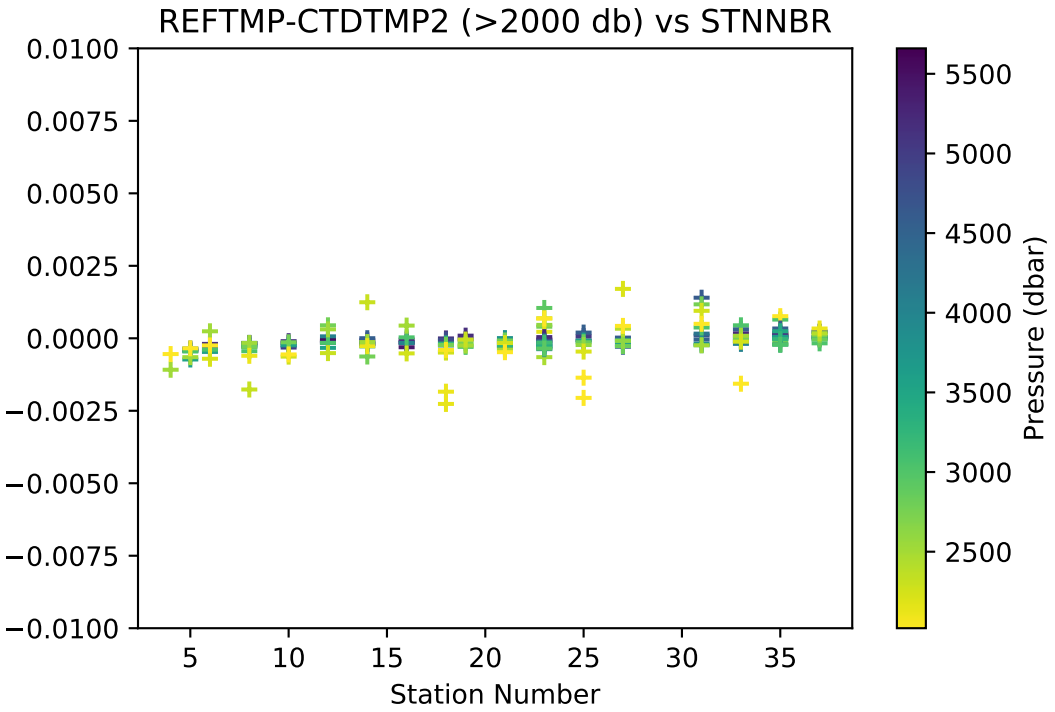

Fig. 2.4: Deep SBE35RT-T2 by station (Pressure $\geq$ 2000dbar).

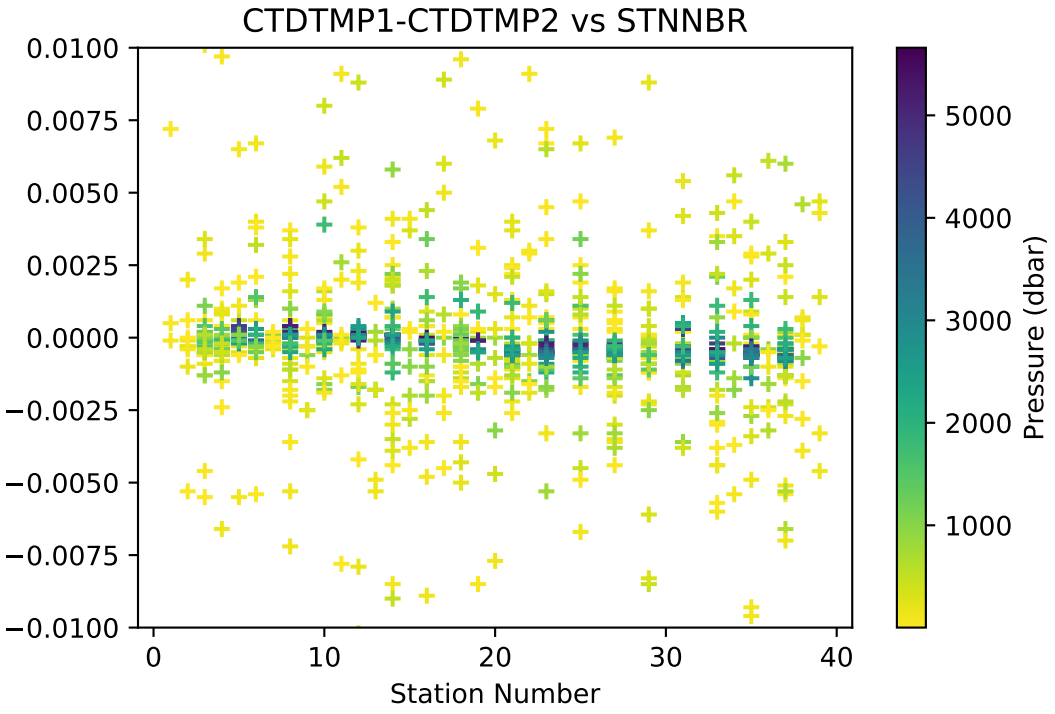

Fig. 2.5: T1-T2 by station (-0.002°C $\leq$ T1-T2 $\leq$ 0.002°C).

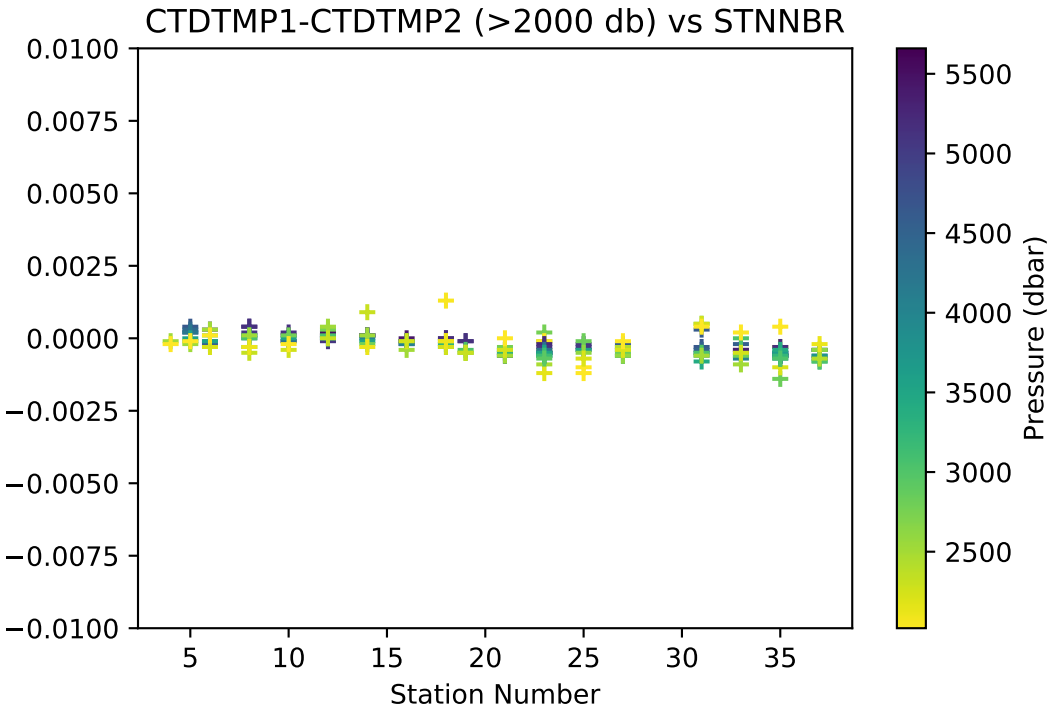

Fig. 2.6: Deep T1-T2 by station (Pressure $\geq$ 2000dbar).

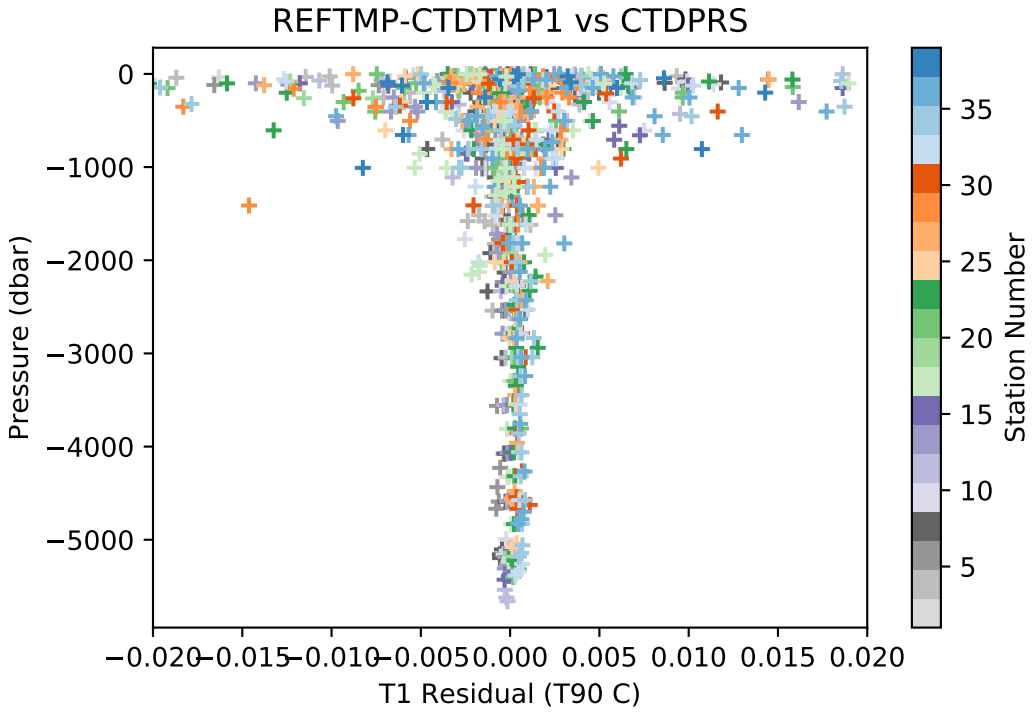

Fig. 2.7: SBE35RT-T1 by pressure (-0.002°C ≤ T1-T2 ≤ 0.002°C).

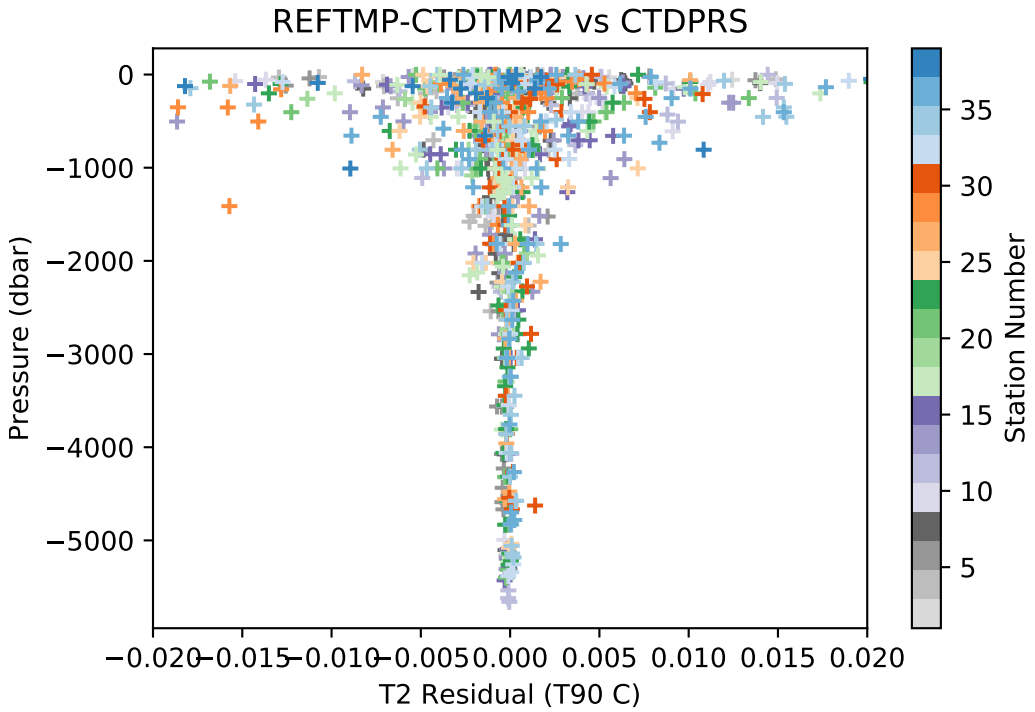

Fig. 2.8: SBE35RT-T2 by pressure (-0.002°C ≤ T1-T2 ≤ 0.002°C).

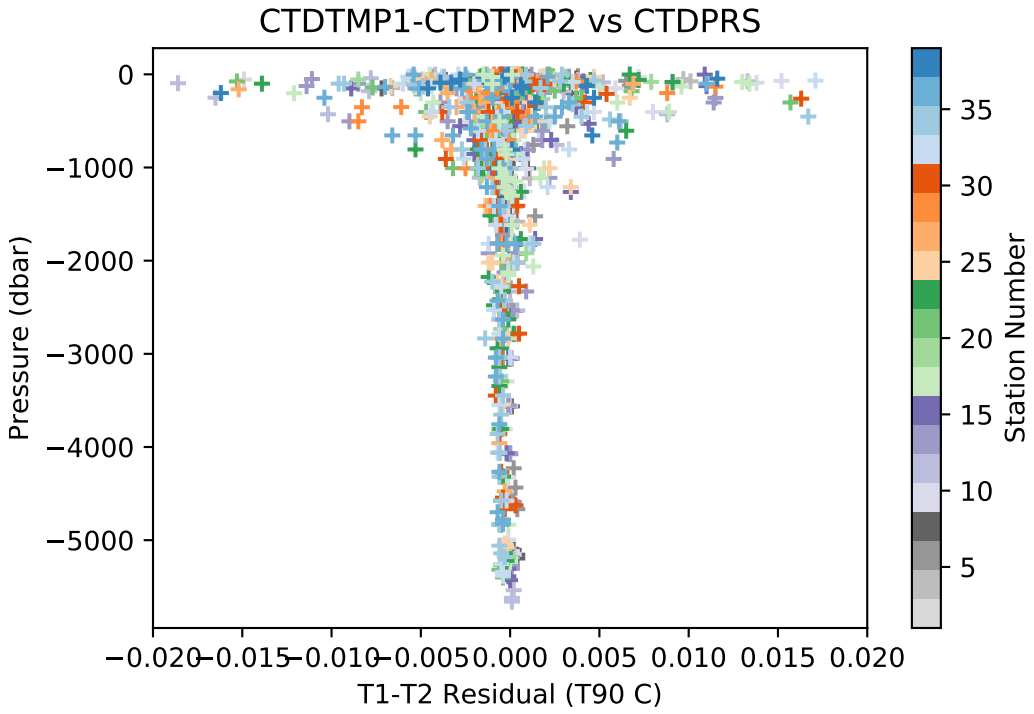

Fig. 2.9: T1-T2 by pressure (-0.002°C $\leq$ T1-T2 $\leq$ 0.002°C).

accuracy were examined. At each bottle closure, the primary and secondary conductivity were compared with each other. Each sensor was also compared to conductivity calculated from check sample salinities using CTD pressure and temperature.

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

Uncorrected conductivity comparisons are shown in figures *Uncorrected CBottle - C1 by station (-0.002 mS/cm BTLCOND-C1 0.002 mS/cm).* through *Uncorrected C1-C2 by station (-0.002 mS/cm C1-C2 0.002 mS/cm).*.

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

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

Corrections made to all conductivity sensors are of the form:

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

The 95% confidence limits for the whole water column differences are ±0.0041 mS/cm for BTLCOND-C1, ±0.0034 mS/cm for BTLCOND-C2, and ±0.0030 mS/cm for C1-C2. The 95% confidence limits for the deep temperature residuals (where pressure $\geq$ 2000dbar) are ±0.00172 mS/cm for BTLCOND-C1, ±0.00153 mS/cm for BTLCOND-C2, and ±0.00102 mS/cm for C1-C2.

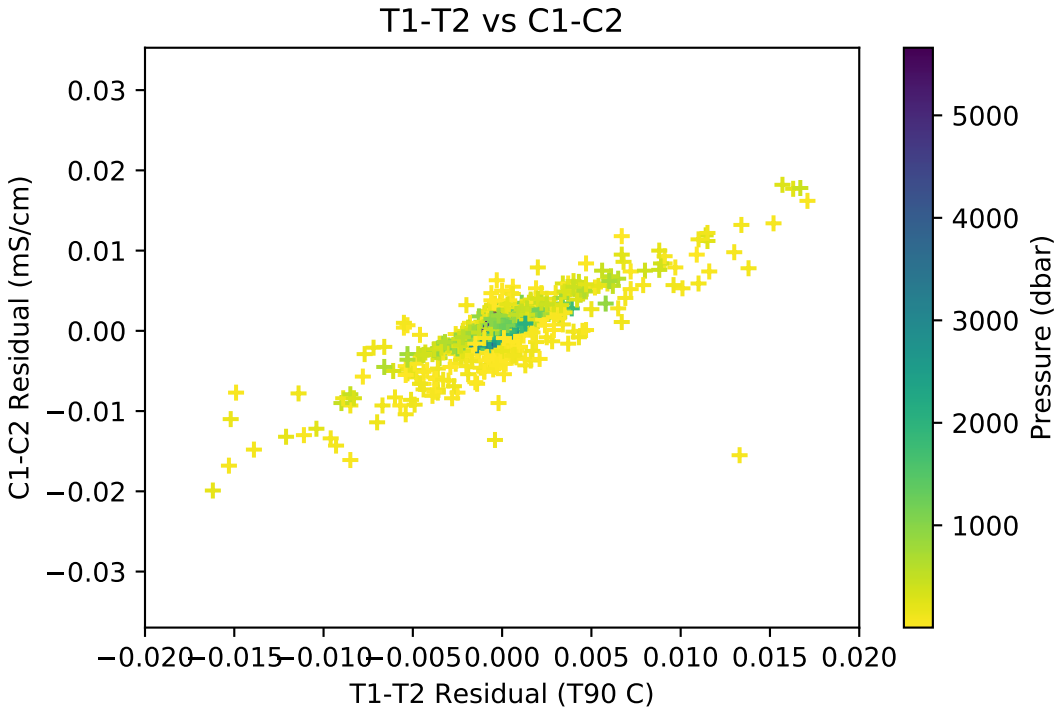

Fig. 2.10: Coherence of conductivity differences as a function of temperature differences.

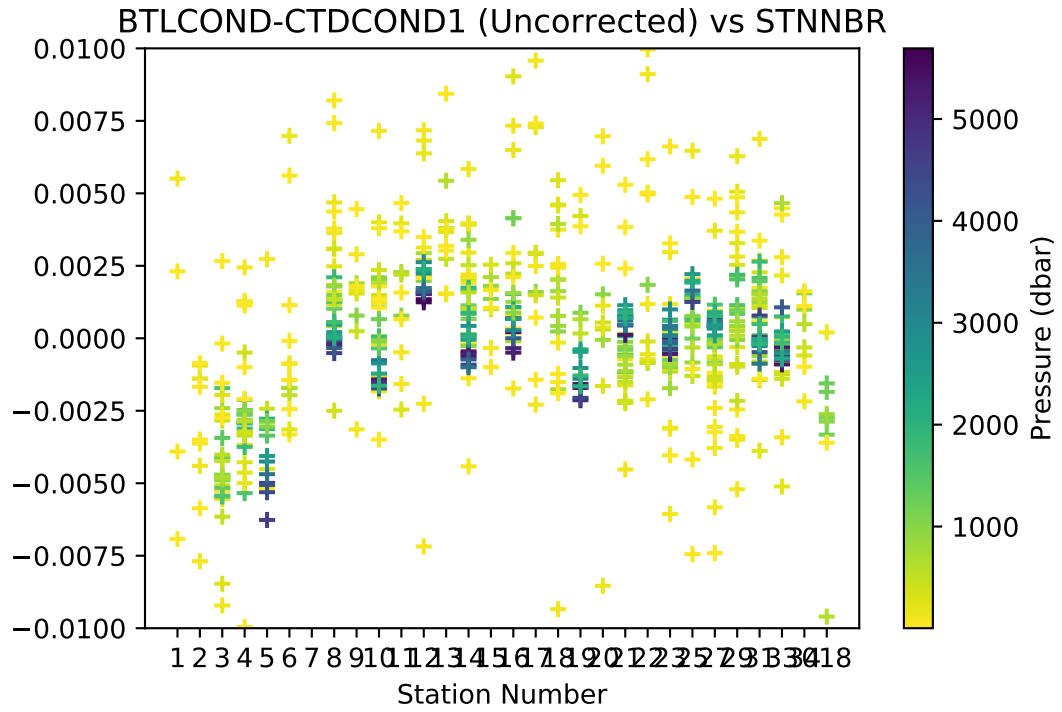

Fig. 2.11: Uncorrected C_{Bottle} - C1 by station (-0.002 mS/cm $\leq$ BTLCOND-C1 $\leq$ 0.002 mS/cm).

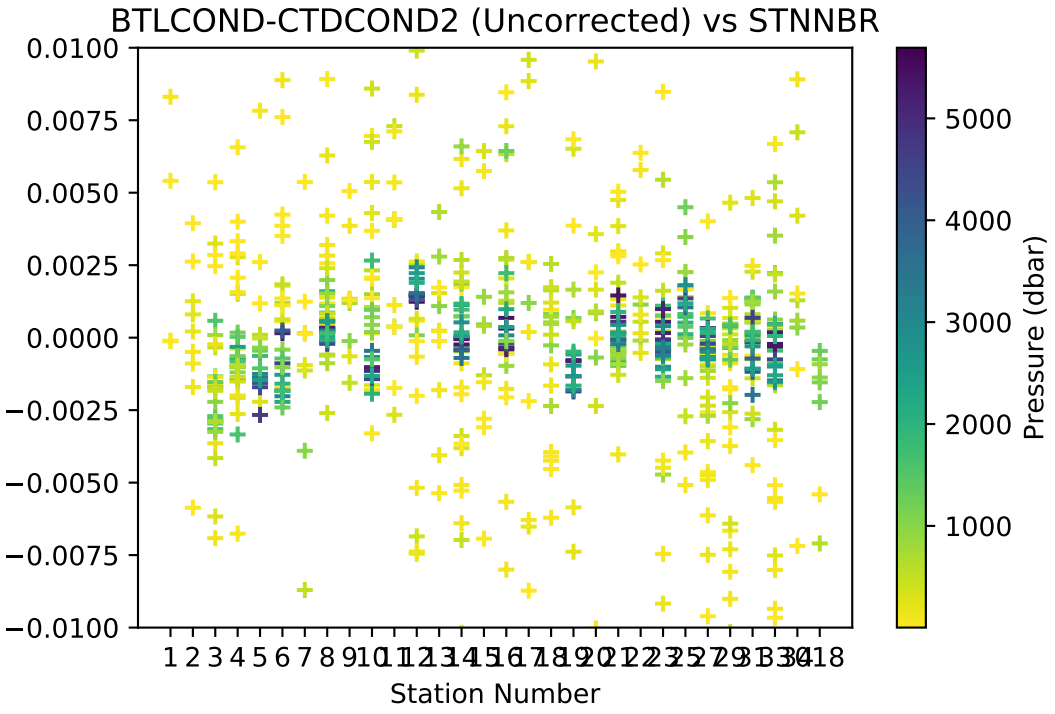

Fig. 2.12: Uncorrected C_{Bottle} - C2 by station (-0.002 mS/cm $\leq$ BTLCOND-C2 $\leq$ 0.002 mS/cm).

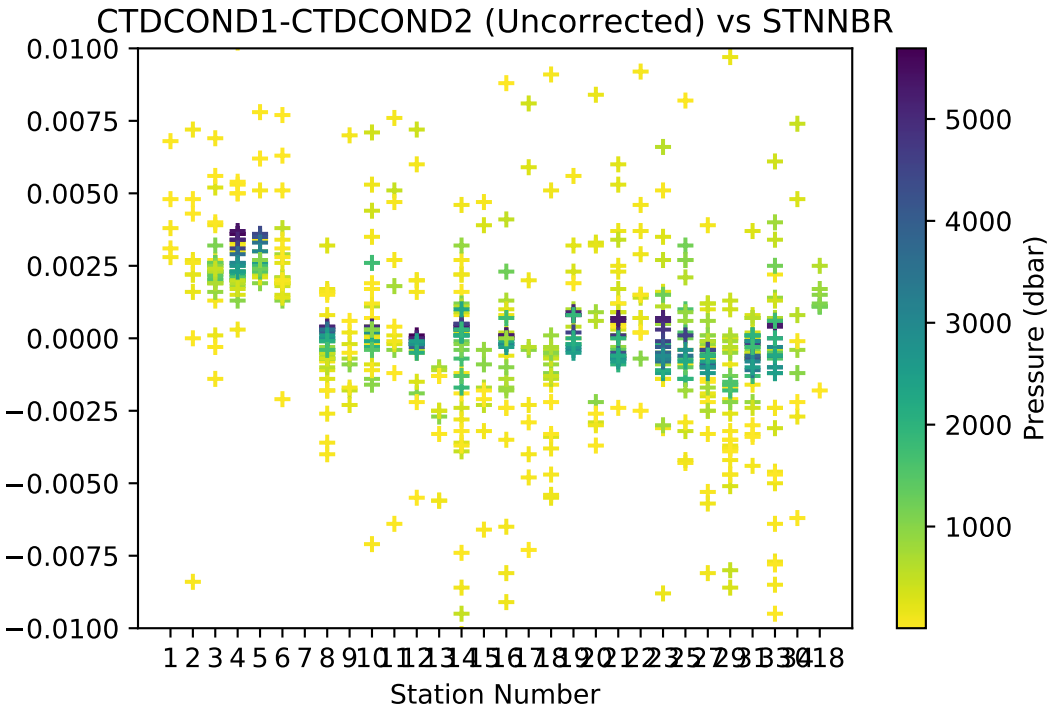

Fig. 2.13: Uncorrected C1-C2 by station (-0.002 mS/cm $\leq$ C1-C2 $\leq$ 0.002 mS/cm).

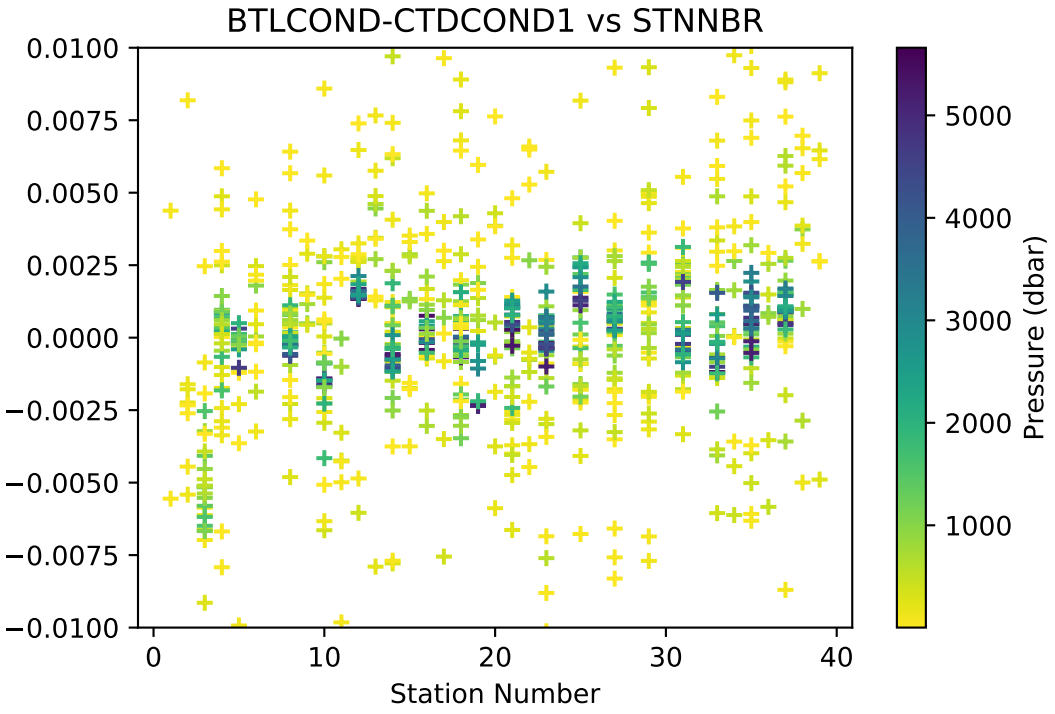

Fig. 2.14: Corrected C_{Bottle} - C1 by station (-0.002 mS/cm $\leq$ BTLCOND-C1 $\leq$ 0.002 mS/cm).

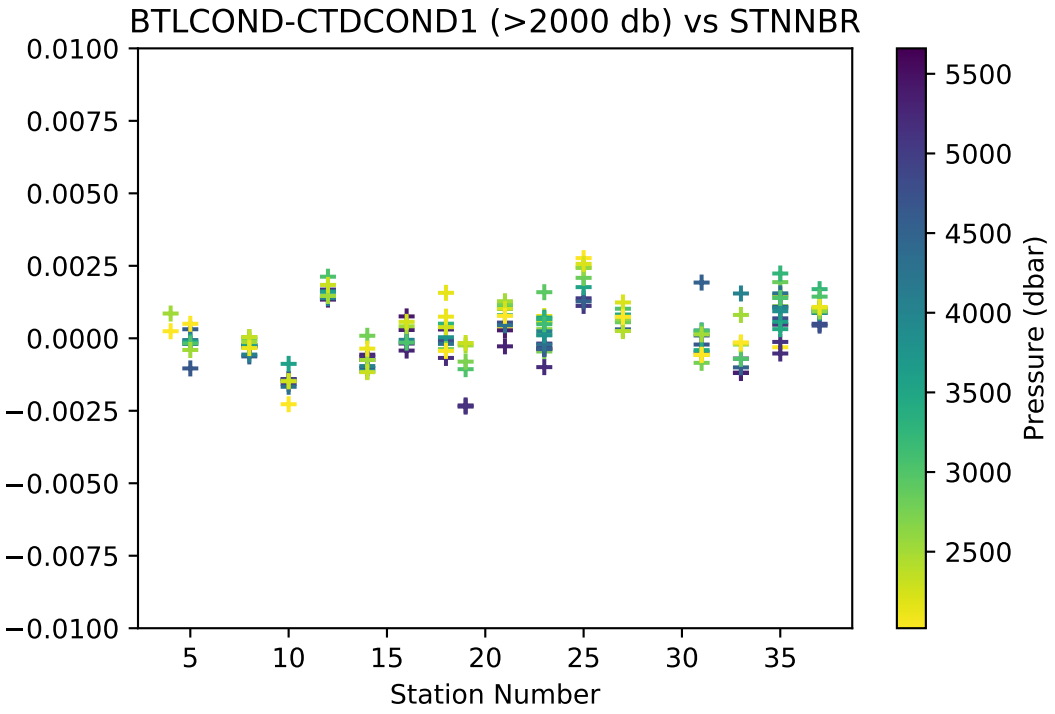

Fig. 2.15: Deep Corrected C_{Bottle} - C1 by station (Pressure >= 2000dbar).

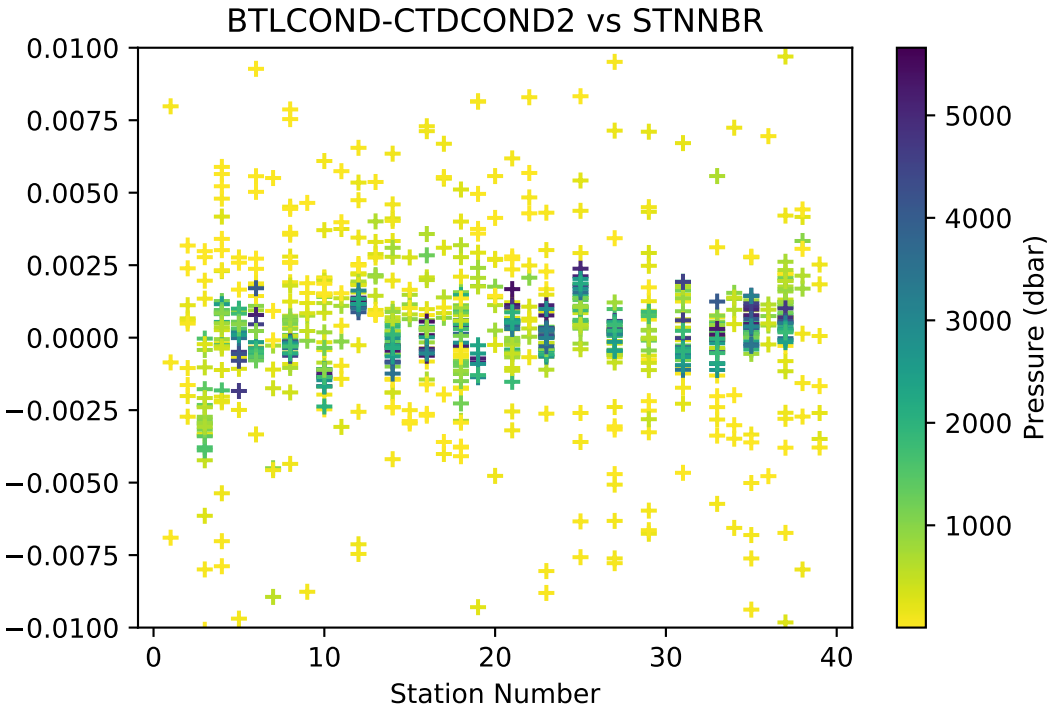

Fig. 2.16: Corrected C_{Bottle} - C2 by station (-0.002 mS/cm $\leq$ BTLCOND-C2 $\leq$ 0.002 mS/cm).

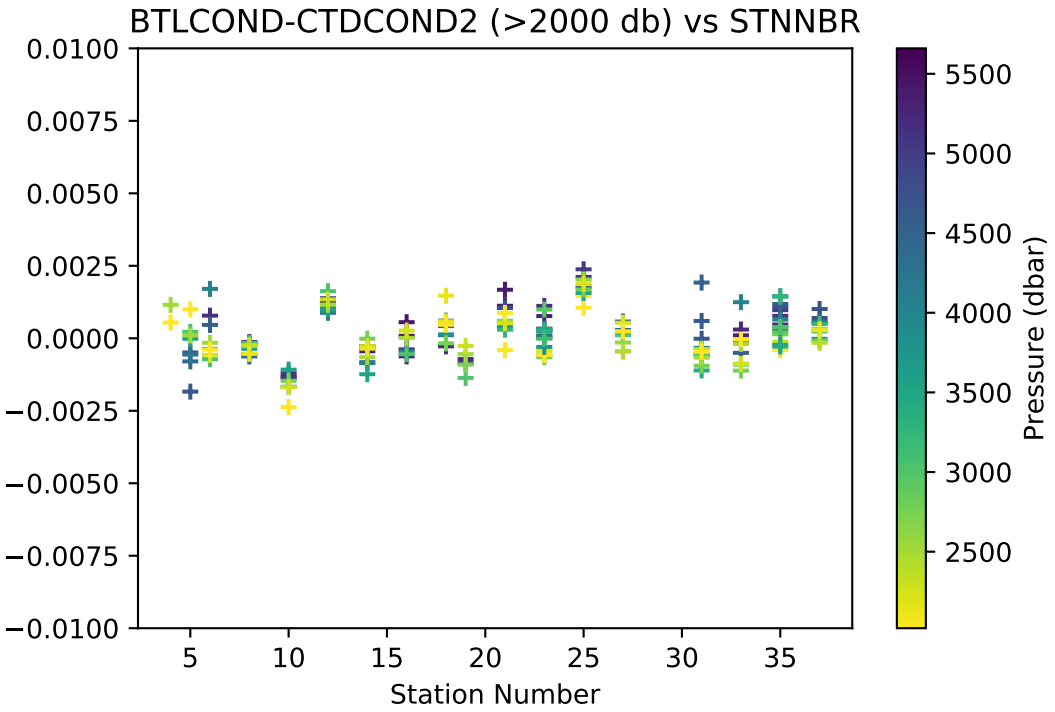

Fig. 2.17: Deep Corrected C_{Bottle} - C2 by station (Pressure >= 2000dbar).

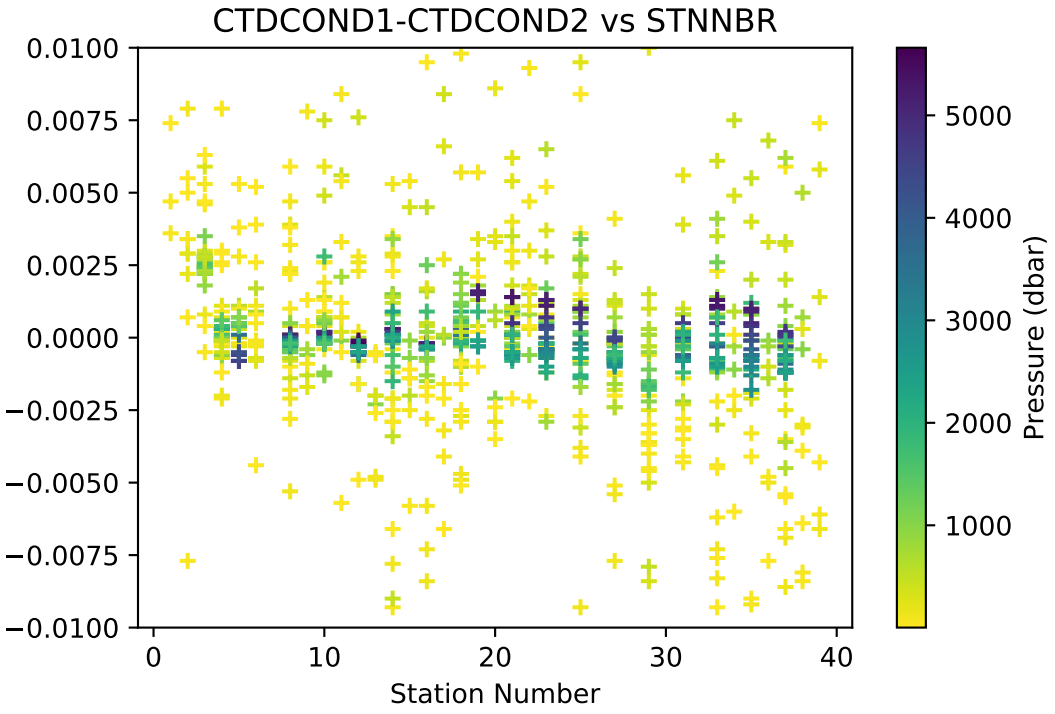

Fig. 2.18: Corrected C1-C2 by station (-0.002 mS/cm $\leq$ C1-C2 $\leq$ 0.002 mS/cm).

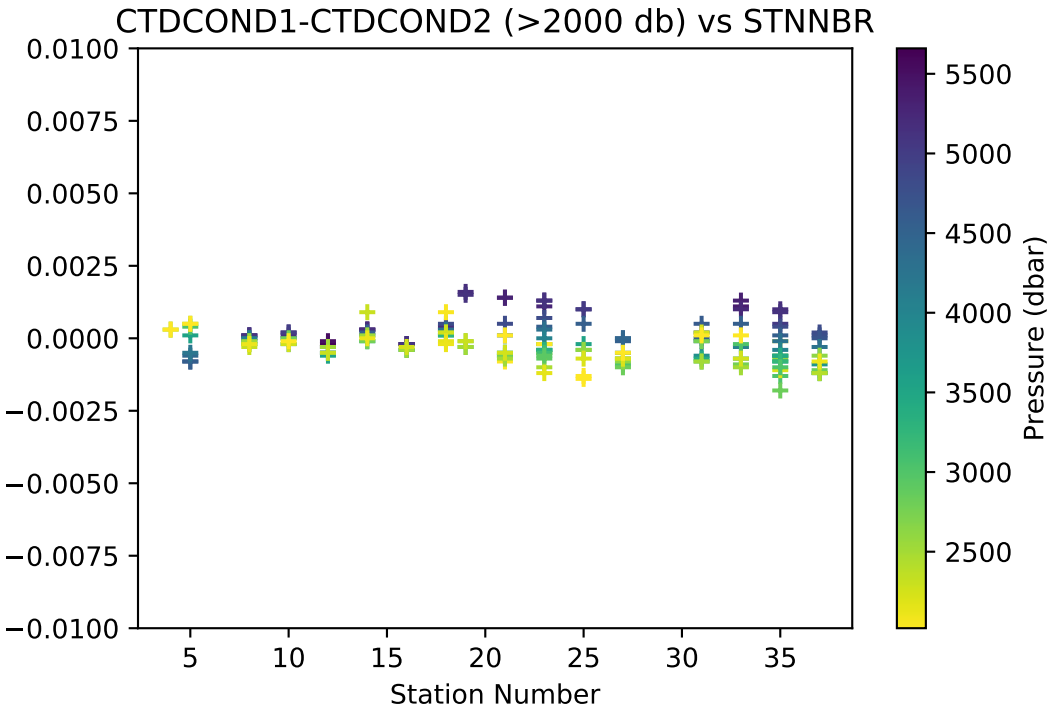

Fig. 2.19: Deep Corrected C1-C2 by station (Pressure >= 2000dbar).

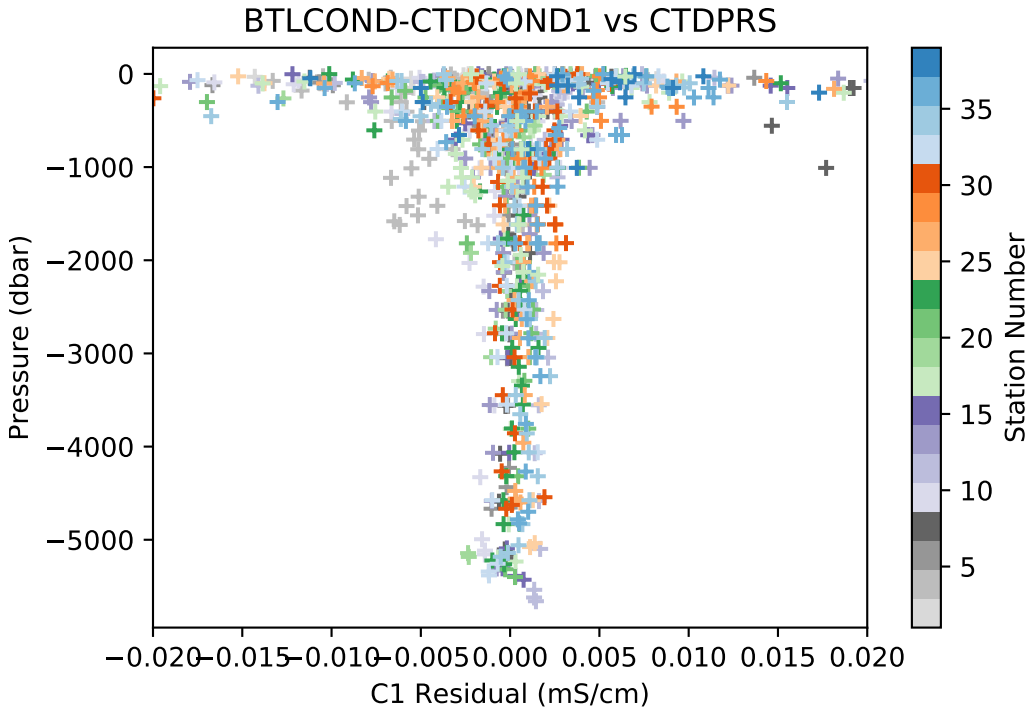

Fig. 2.20: Corrected C_{Bottle} - C1 by pressure (-0.002 mS/cm $\leq$ BTLCOND-C1 $\leq$ 0.002 mS/cm).

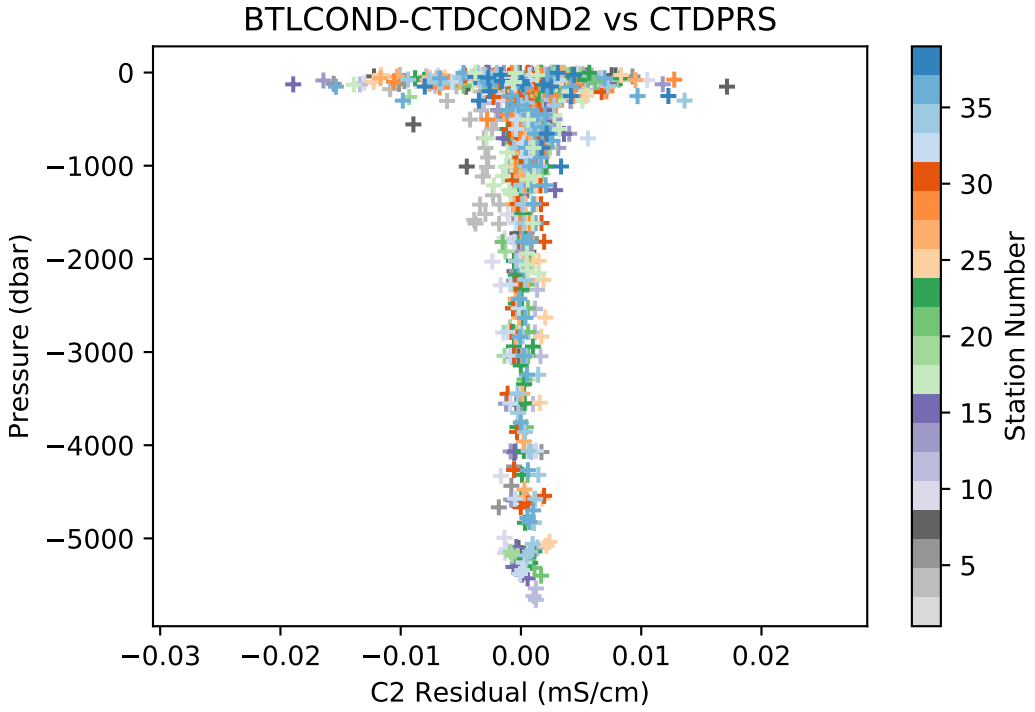

Fig. 2.21: Corrected C_{Bottle} - C2 by pressure (-0.002 mS/cm $\leq$ BTLCOND-C2 $\leq$ 0.002 mS/cm).

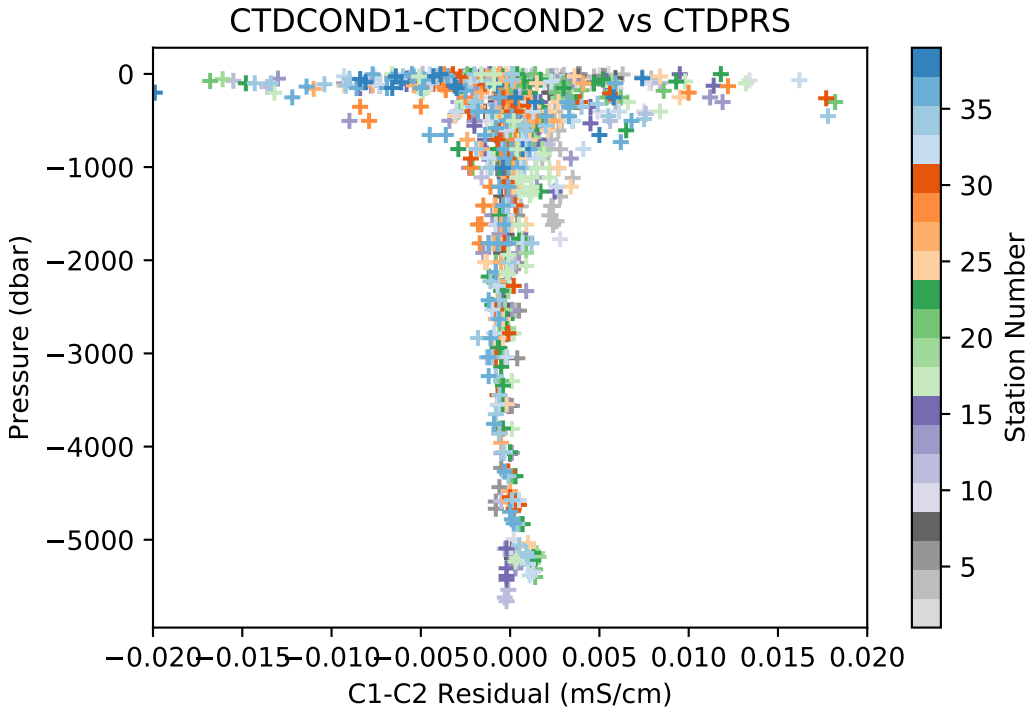

Fig. 2.22: Corrected C1-C2 by pressure (-0.002 mS/cm $\leq$ C1-C2 $\leq$ 0.002 mS/cm).

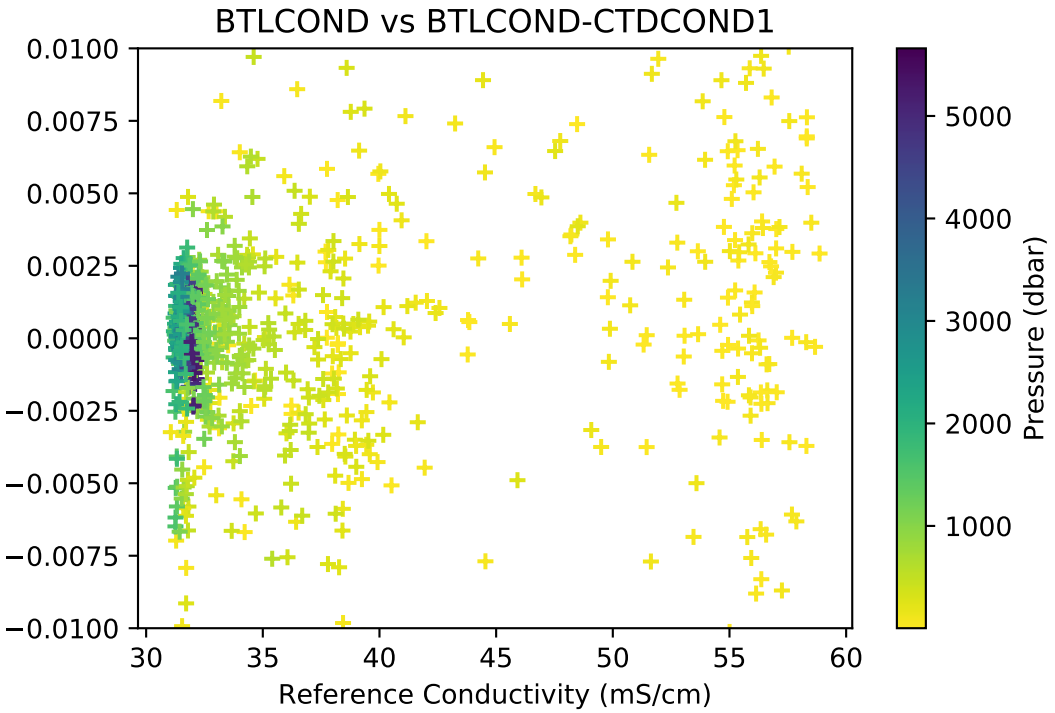

Fig. 2.23: Corrected C_{Bottle} - C1 by conductivity (-0.002 mS/cm $\leq$ BTLCOND-C1 $\leq$ 0.002 mS/cm).

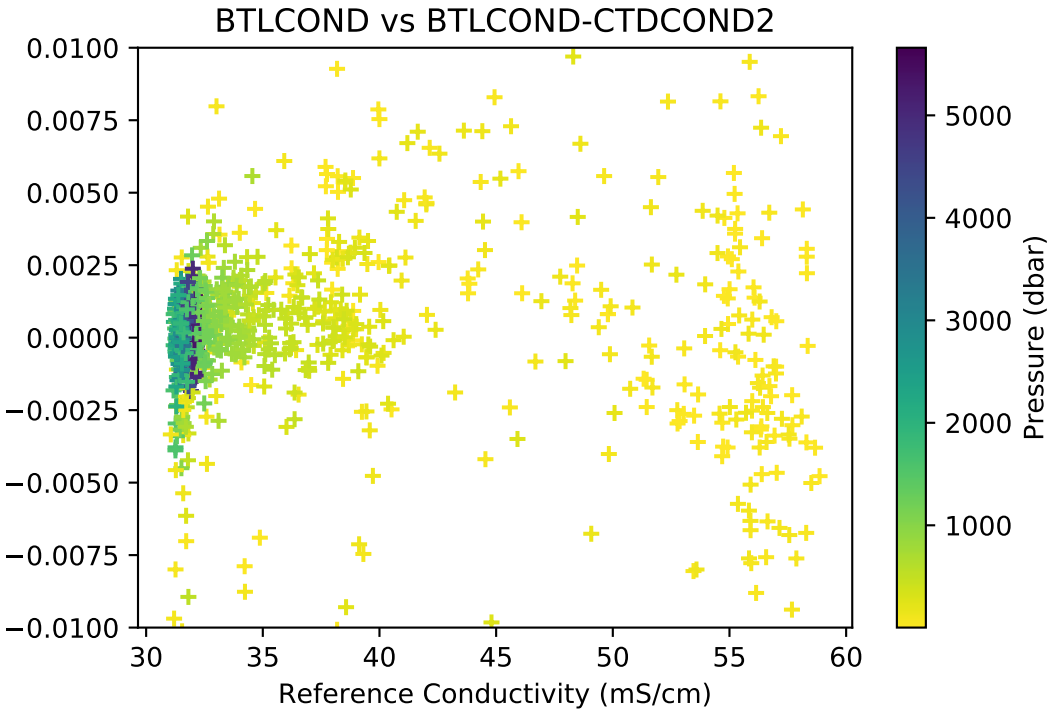

Fig. 2.24: Corrected C_{Bottle} - C2 by conductivity (-0.002 mS/cm $\leq$ BTLCOND-C2 $\leq$ 0.002 mS/cm).

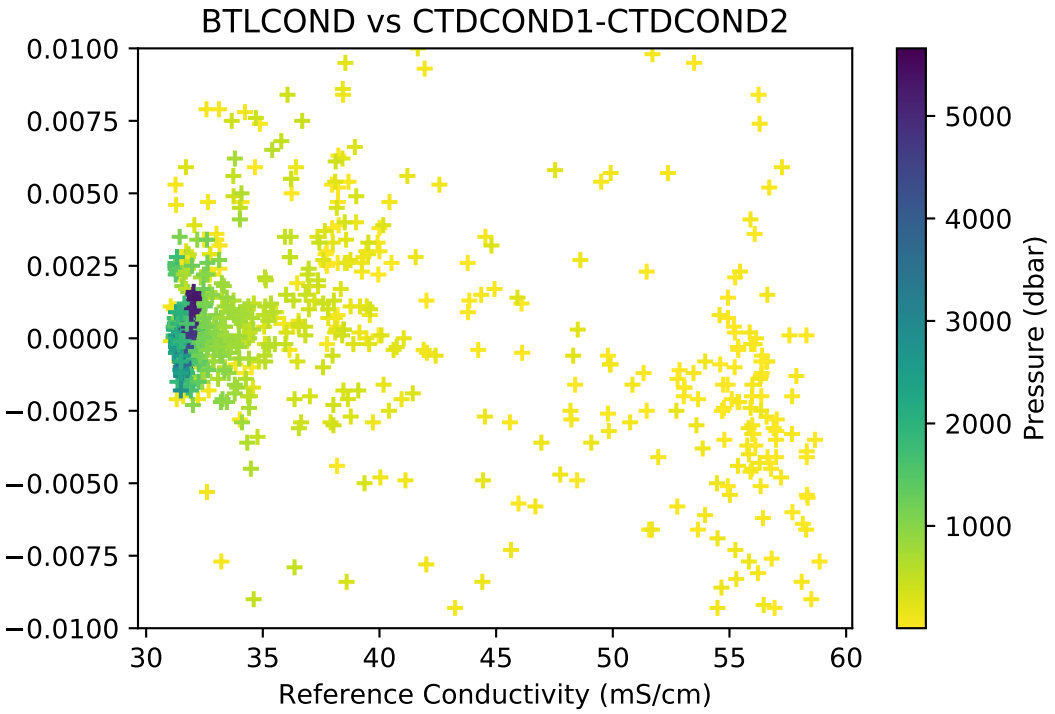

Fig. 2.25: Corrected C1-C2 by conductivity (-0.002 mS/cm $\leq$ C1-C2 $\leq$ 0.002 mS/cm).

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.

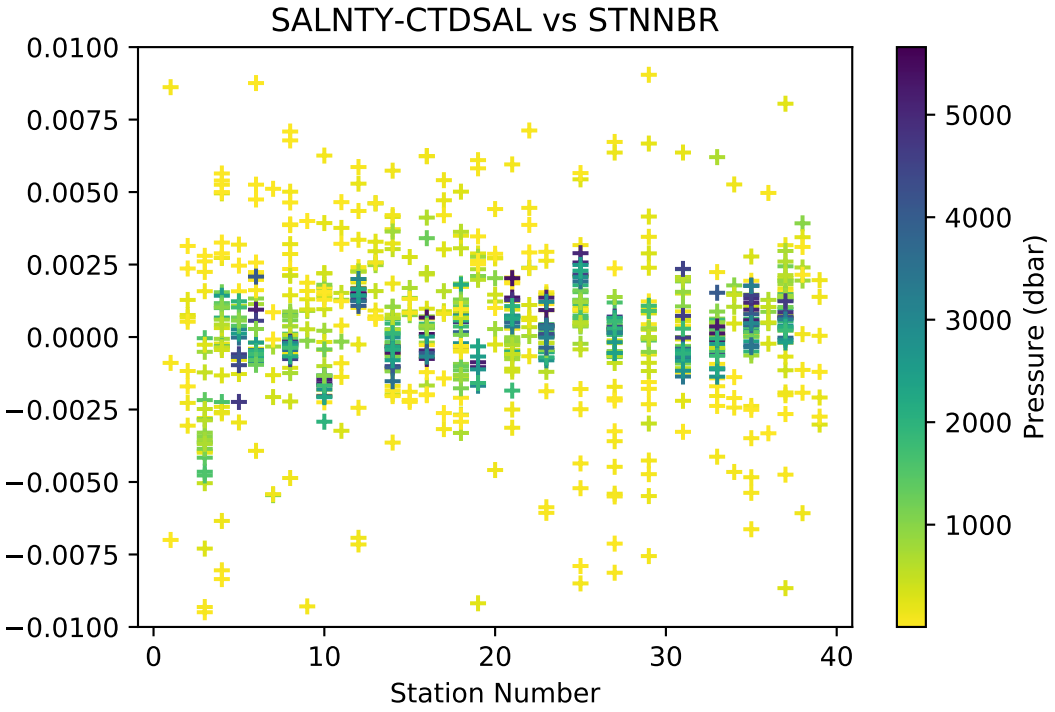

Fig. 2.26: Salinity residuals by station (-0.002 mPSU $\leq$ SALNTY-C1SAL $\leq$ 0.002 mPSU).

The 95% confidence limits for the whole water column differences are $\pm$0.0052 PSU for salinity-C2SAL. The 95% confidence limits for the deep salinity residuals (where pressure $\geq$ 2000dbar) are $\pm$0.00281 PSU for salinity-C2SAL.

All compromised data signals were recorded and coded in the data files.

2.6 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 µmol/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 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 O_2 was then calculated using Clark Cell MPOD O_2 sensor response model for Beckman/SensorMedics and SBE43 dissolved O_2 sensors. The residual differences of bottle check value versus CTD dissolved O_2 values are minimized by optimizing the SIO DO sensor response model coefficients with a Levenberg-Marquardt non-linear least-squares fitting procedure.

The general form of the SIO DO sensor response model equation for Clark cells follows Brown and Morrison *[Millard82]* and Owens *[Owens85]* 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 (τ_p), a slow

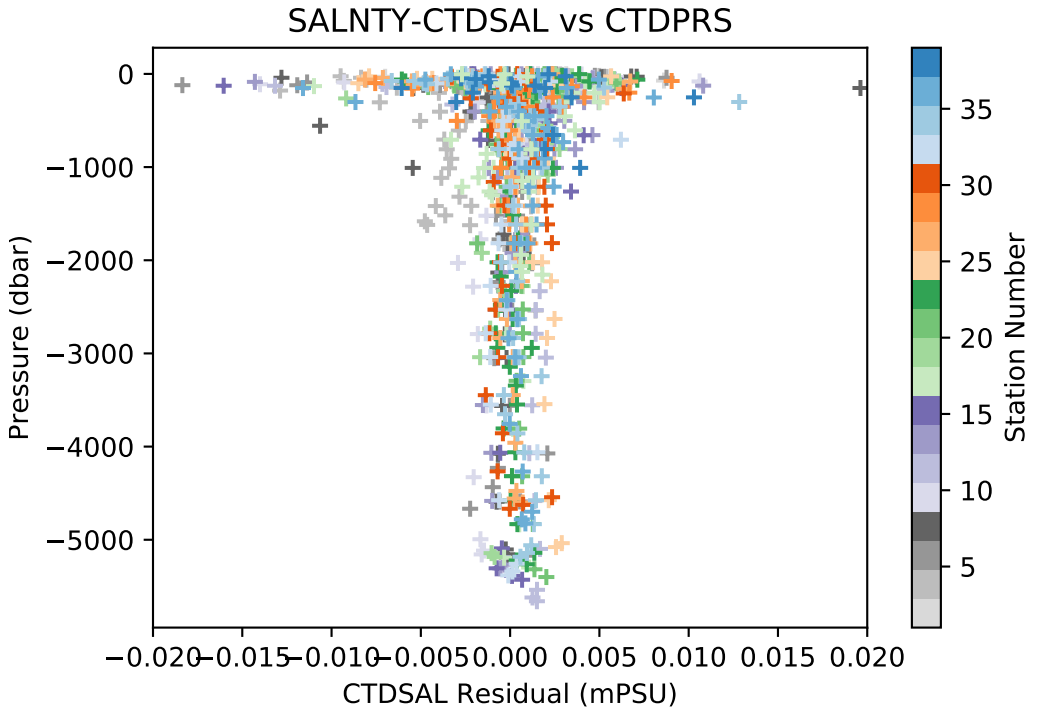

Fig. 2.27: Salinity residuals by pressure (-0.002 mPSU $\leq$ SALNTY-C1SAL $\leq$ 0.002 mPSU).

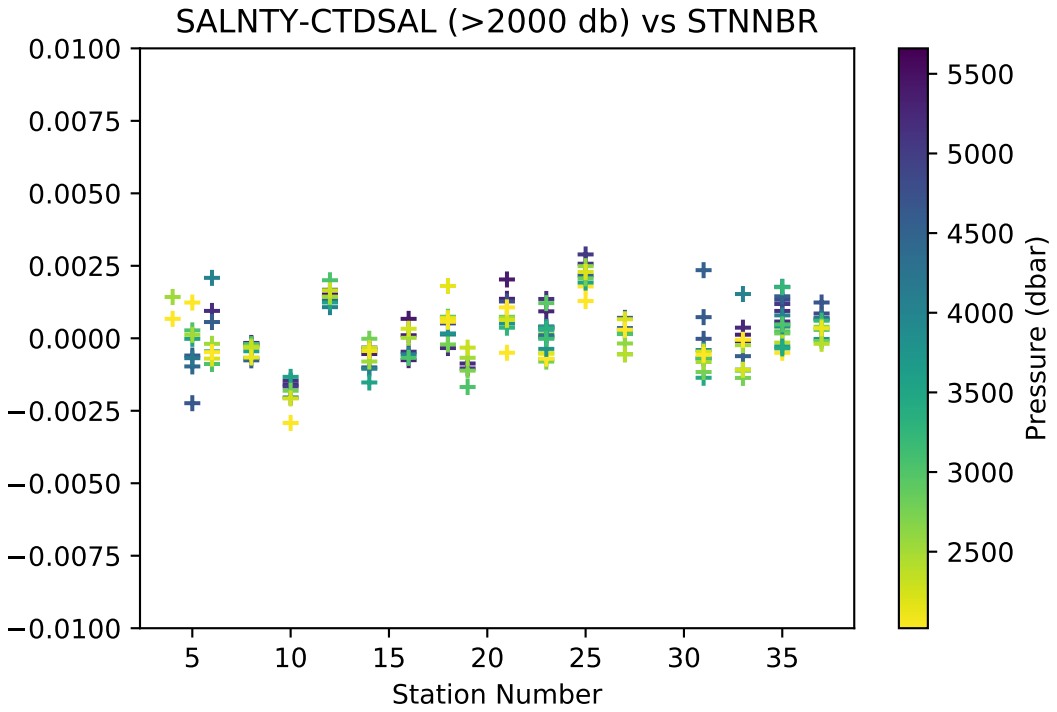

Fig. 2.28: Deep Salinity residuals by station (Pressure >= 2000dbar).

τ_{Tf} and fast τ_{Ts} thermal response, package velocity τ_{dP}, thermal diffusion τ_{dT} and pressure hysteresis τ_h are fitting parameters. Once determined for a given sensor, these time constants typically remain constant for a cruise. The thermal diffusion term is derived by low-pass filtering the difference between the 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 O_2 concentration is then calculated:

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

Where:

- O_2 ml/l Dissolved O_2 concentration in ml/l
- V_{DO} Raw sensor output
- C_1 Sensor slope
- C_2 Hysteresis response coefficient
- C_3 Sensor offset
- f_{sat} (T , P)|O2| saturation at T,P (ml/l)
- T In-situ temperature (°C)
- P In-situ pressure (decibars)
- P_h Low-pass filtered hysteresis pressure (decibars)
- T_l Long-response low-pass filtered temperature (°C)
- T_s Short-response low-pass filtered temperature (°C)
- P_l Low-pass filtered pressure (decibars)
- dO_c / dt Sensor current gradient (µamps/sec)
- dP/dt Filtered package velocity (db/sec)
- dT Low-pass filtered thermal diffusion estimate (T_s - T_l)
- C_4 - C_9 response coefficients

CTD dissolved O_2 residuals are shown in the following figures *O2 residuals by station (-0.01 µmol/kg OXYGEN-BTLOXY 0.01 µmol/kg).* through *Deep O2 residuals by station (Pressure >= 2000dbar).*.

The second standard deviations of 3.76 (µmol/kg) for all dissolved oxygen bottle data values and 0.82 (µmol/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_2 lab measurements.

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

- Multiple stations had impacted SBE 43 oxygen data due to the pump not working leading to errant values. Values presented for those casts should all be considered as questionable.
- RINKO oxygen optode data has been nominally calibrated and presented in the bottle data file and ctd data files. See RINKO section for more detail.

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.

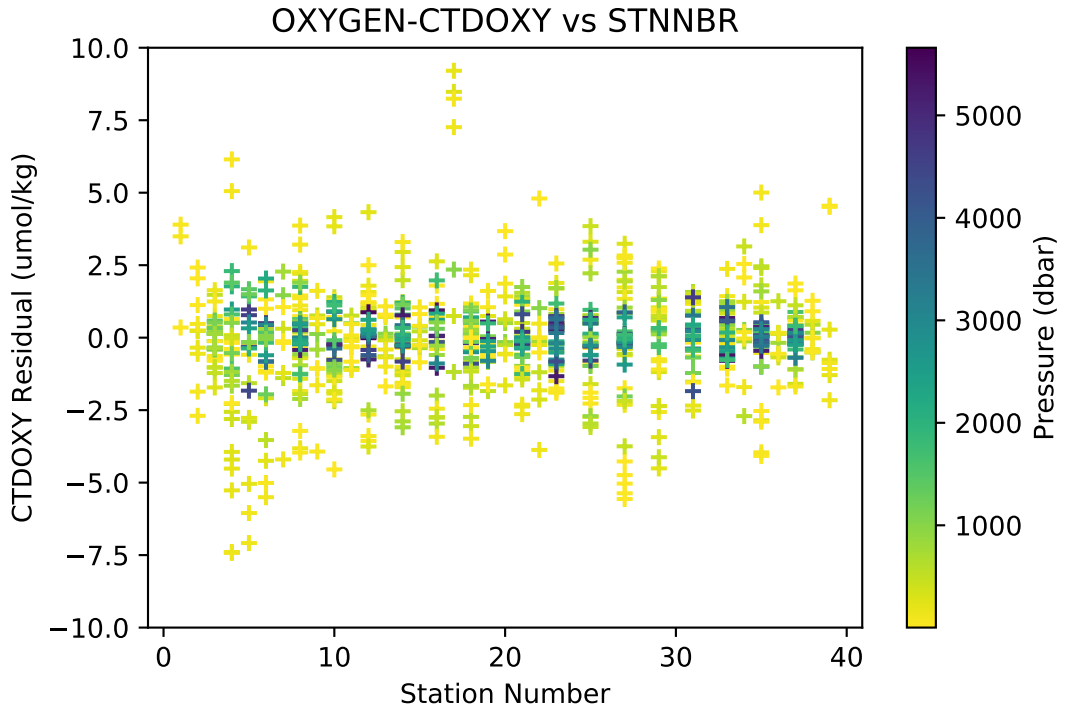

Fig. 2.29: O_2 residuals by station (-0.01 µmol/kg $\leq$ OXYGEN-BTLOXY $\leq$ 0.01 µmol/kg).

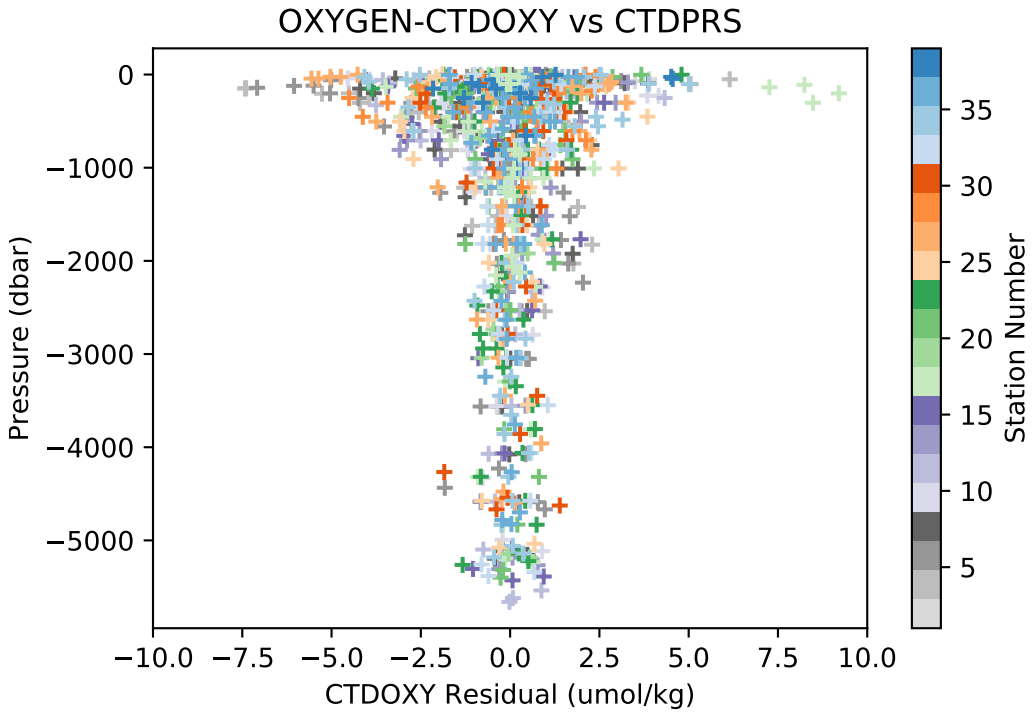

Fig. 2.30: O_2 residuals by pressure (-0.01 µmol/kg $\leq$ OXYGEN-BTLOXY $\leq$ 0.01 µmol/kg).

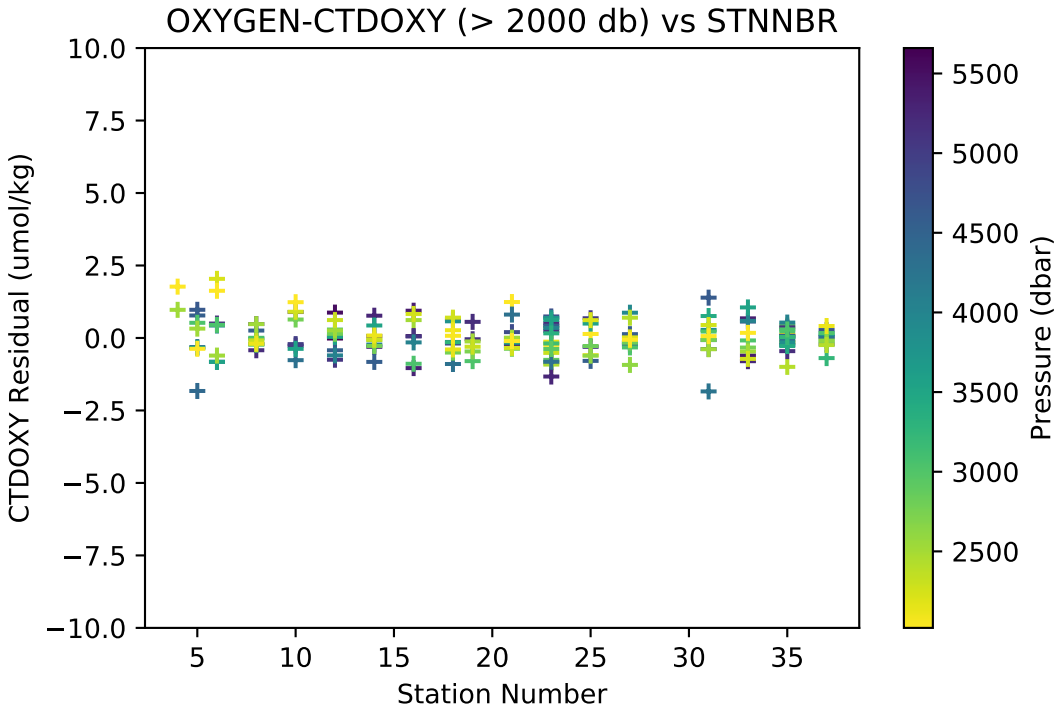

Fig. 2.31: Deep O_2 residuals by station (Pressure >= 2000dbar).

CHAPTER

THREE

CTDO AND HYDROGRAPHIC ANALYSIS OF THE GTC SYSTEM

PIs

- Greg Cutter

Technicians

- Kyle McQuiggan (Acquisition)
- Karen Casciotti (Acquisition)
- Kenneth Jackson (Processing)
- Joseph Gum (processing)

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 a console watch operator (CWO) after the ship had stopped on station. The CWO maintained CTD cast logs for each attempted cast containing a description of each deployment event. This cast log included the bottle bottle, any phenomena, and any possible problems.

Once the deck watch had deployed the rosette, the winch operator would lower it to depth without stopping. The CTD sensor pumps were configured to start 10 seconds after the primary conductivity cell reports salt water in the cell. The winch was then instructed to lower the package to the initial target wire-out at 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 target depth. The winch would monitor altimeter readings, taking notice 100m from the bottom and slowing quickly to a final stop 10m from the target depth. The bottom of the CTD cast was usually to within 10-20 meters of the target depth determined by altimeter data, CTD pressure, and wire-out.

For each up-cast, the winch operator was directed to stop the winch at up to 14 predetermined sampling pressures. These depth were and chosen to collect samples from features such as the mixed layer, surface, chlorophyll maximum, oxygen minimum, nutricline, and important depths determined by examining profiles from P16N and P16S GO-SHIP occupations. A maximum of 24 unique depths were taken throughout multiple casts during a single station.

All bottles on the GTC rosette were tripped without stopping the rosette as to avoid contamination to trace metal samples. The package was raised at a rate of 60m/min until it was within 20m of the target depth, where it was then slowed down to 20m/min. Once the package was within 10m of the target depth, it was slowed down to 10m/min. Finally, when the package was within 5m of the target depth it was slowed down to 3m/min or 5m/min if the weather was bad and a bottle was tripped at the target depth.

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. One the rosette was secured, shower caps were placed on each bottle to further prevent any contamination of samples. Each bottle was then removed from the rosette and hand-carried to a clean van where sampling took place.

Additionally, the CWO 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.

The CTD sensors were then rinsed after each station using a fresh water tap connected to Tygon tubing.

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 CTDO Data Processing

Shipboard CTD data processing was performed after deployment using SIO/ODF python CTD processing software v. 0.3. 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 122 CTD stations were occupied including one test station. A total of 125 CTDO/rosette casts were completed. 122 standard CTDO/rosette casts and one test cast completed with a single 24-place 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_2 comparisons were made between down and up casts as well as between groups of adjacent deployments. Vertical sections of measured and derived properties from sensor data were checked for consistency.

A number of issues were encountered during GP15 ODF 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 July 20th, 2018 at the SeaBird Calibration Facility. The lab calibration coefficients provided on the calibration report were used to convert frequencies to pressure. Initially SeaBird 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 - 39

	Start P (dbar)	End P (dbar)
Min	-2.5	-2.5
Max	-1.4	-1.5
Average	-1.8	-1.6
Applied Offset		-0.0617

An offset of -0.0617 was applied to every cast performed by CTD 1281. On-deck pressure reading for CTD 1281 varied from -2.5 to -1.4 dbar before the casts, and -2.5 to -1.5 dbar after the casts. The overall average offset before and after cast was -0.0617 dbar.

3.4 Temperature Analysis

Laboratory calibrations of temperature 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 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 depth, the primary and secondary temperature were compared with each other.

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.

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

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

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

Corrected temperature differences are shown in the following figures.

The 95% confidence limit for the whole water column differences is $\pm$0.0011°C for T1-T2. The 95% confidence limit for the deep temperature residuals (where pressure $\geq$ 2000dbar) is $\pm$0.000042°C for T1-T2.

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 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.

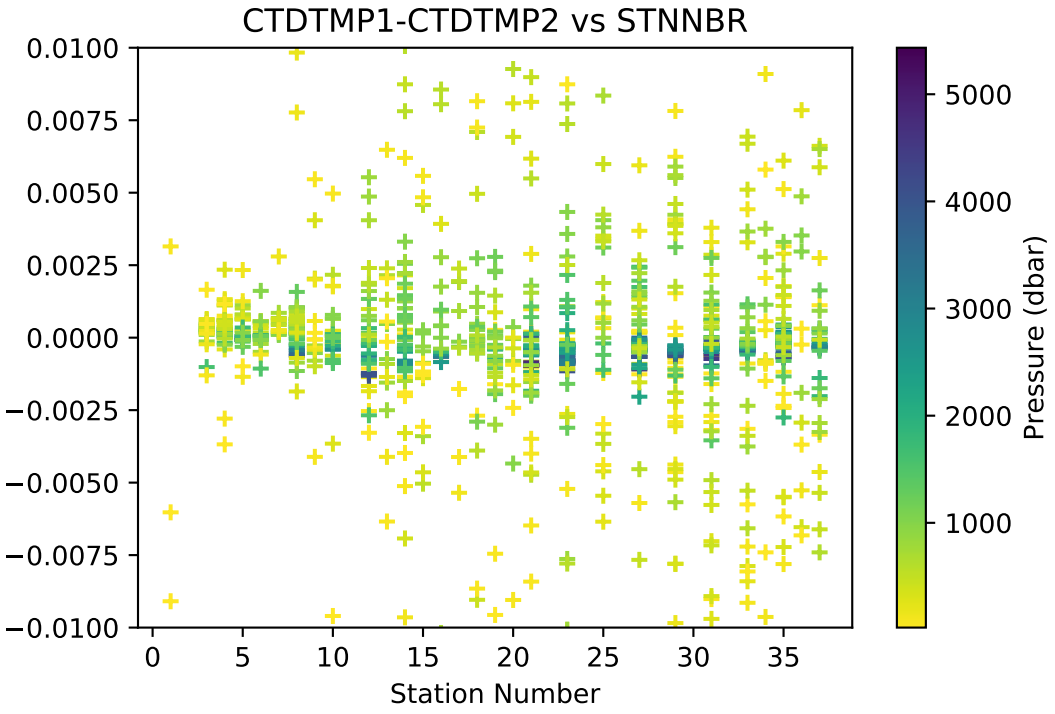

Fig. 3.1: T1-T2 by station (-0.002°C $\leq$ T1-T2 $\leq$ 0.002°C).

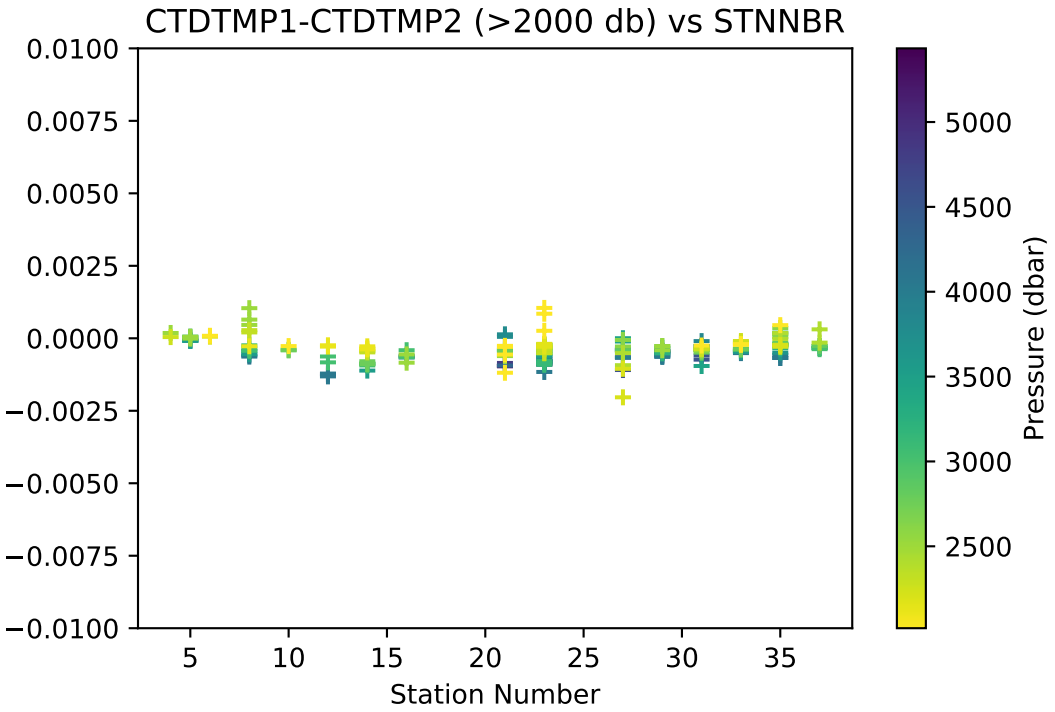

Fig. 3.2: Deep T1-T2 by station (Pressure $\geq$ 2000dbar).

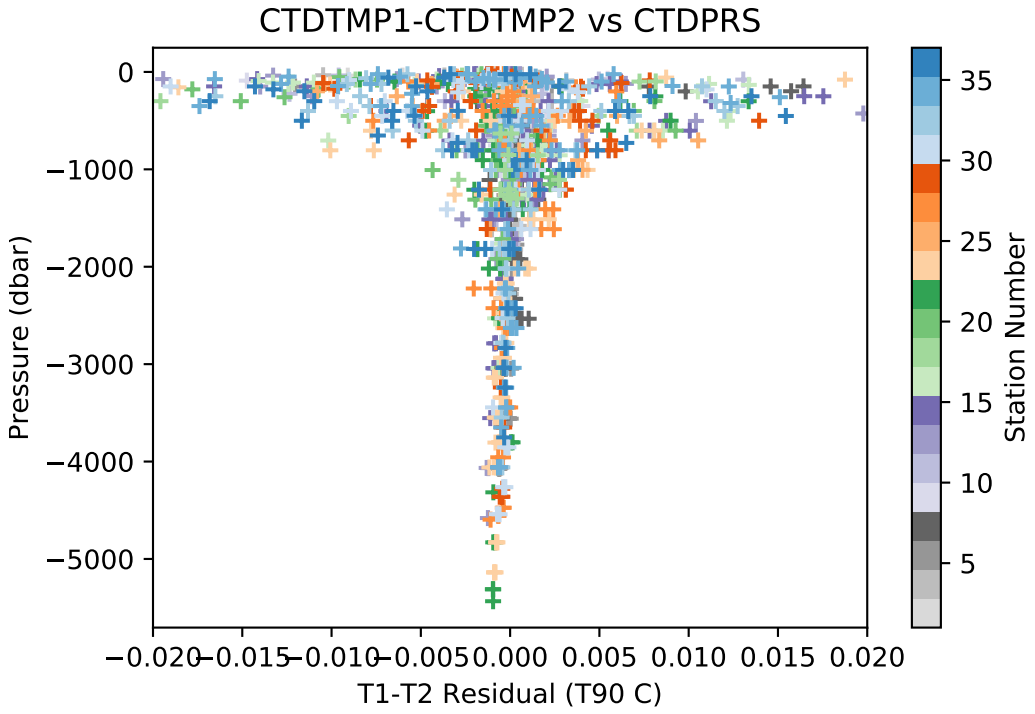

Fig. 3.3: T1-T2 by pressure (-0.002°C $\leq$ T1-T2 $\leq$ 0.002°C).

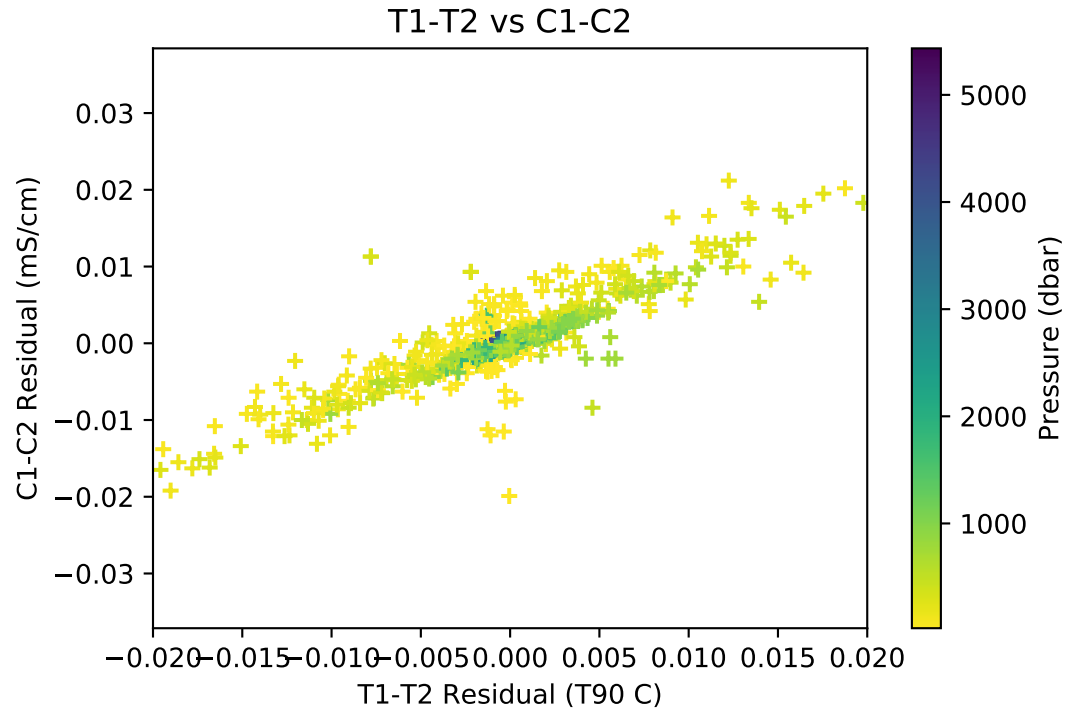

Fig. 3.4: Coherence of conductivity differences as a function of temperature differences.

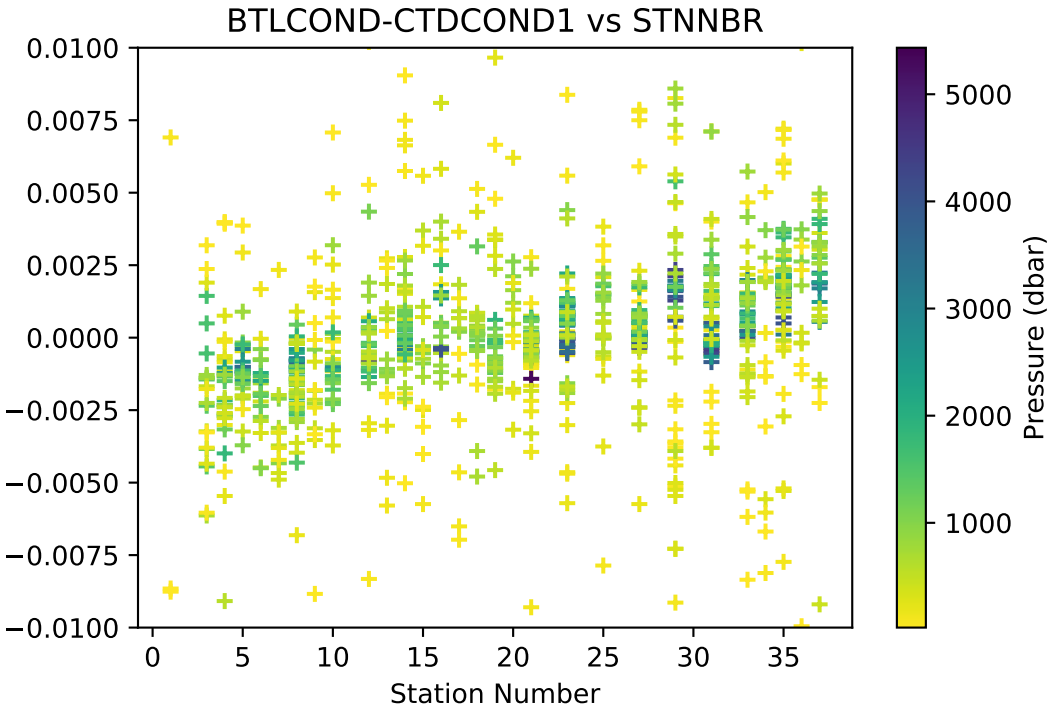

Fig. 3.5: C_{Bottle} - C1 by station (-0.002 mS/cm $\leq$ BTLCOND-C1 $\leq$ 0.002 mS/cm).

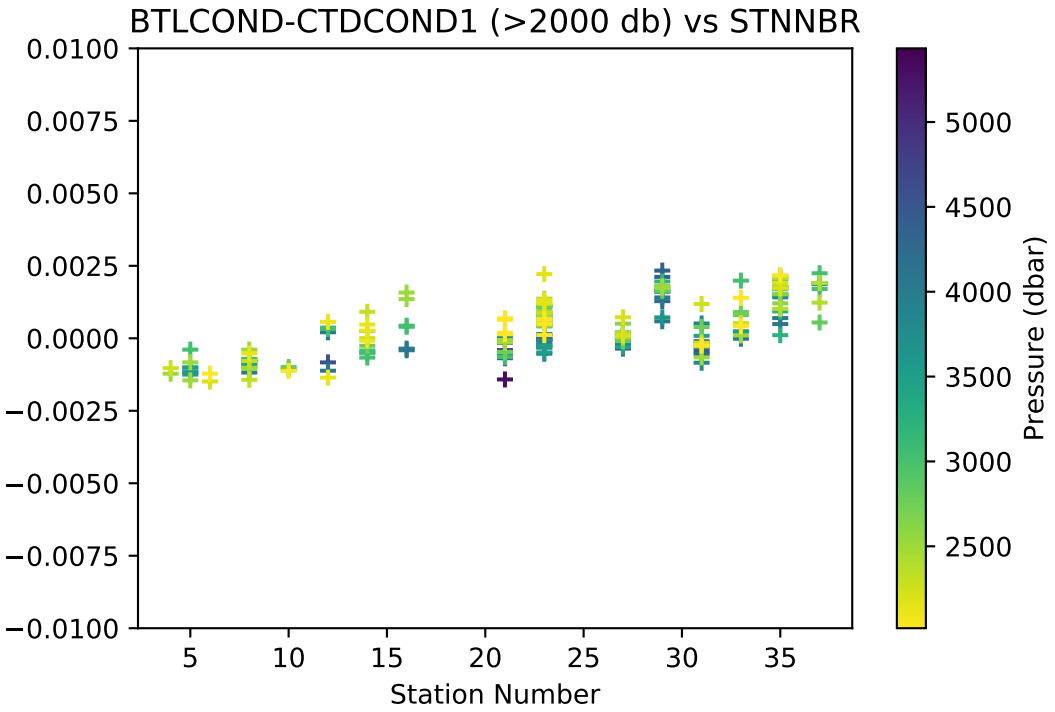

Fig. 3.6: Deep C_{Bottle} - C1 by station (Pressure >= 2000dbar).

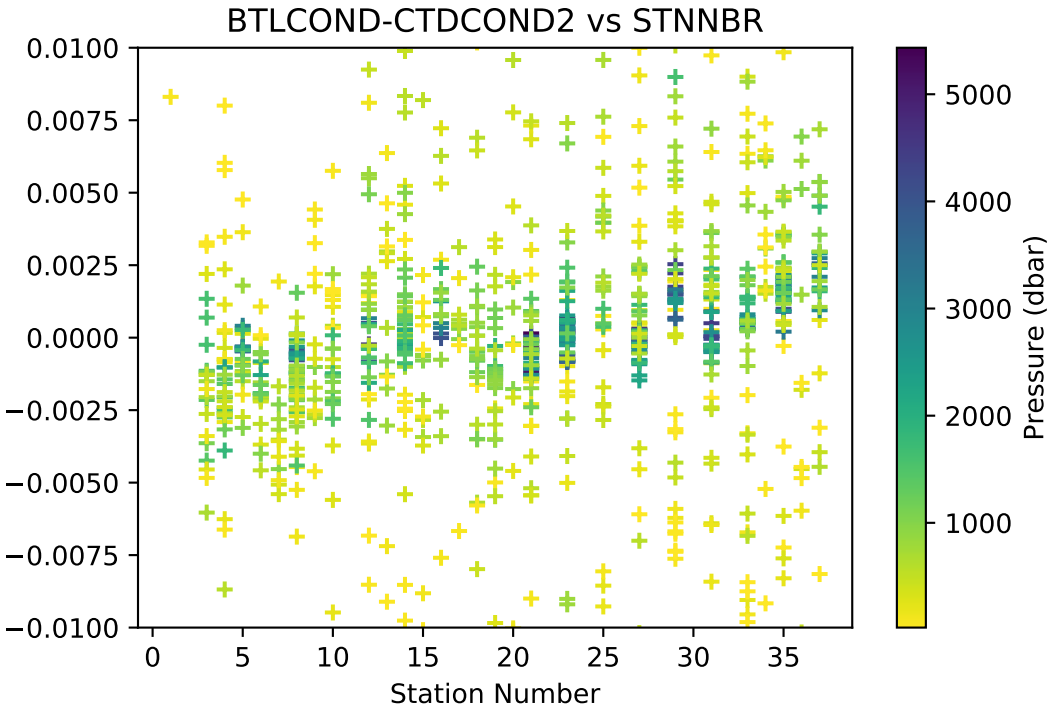

Fig. 3.7: C_{Bottle} - C2 by station (-0.002 mS/cm $\leq$ BTLCOND-C2 $\leq$ 0.002 mS/cm).

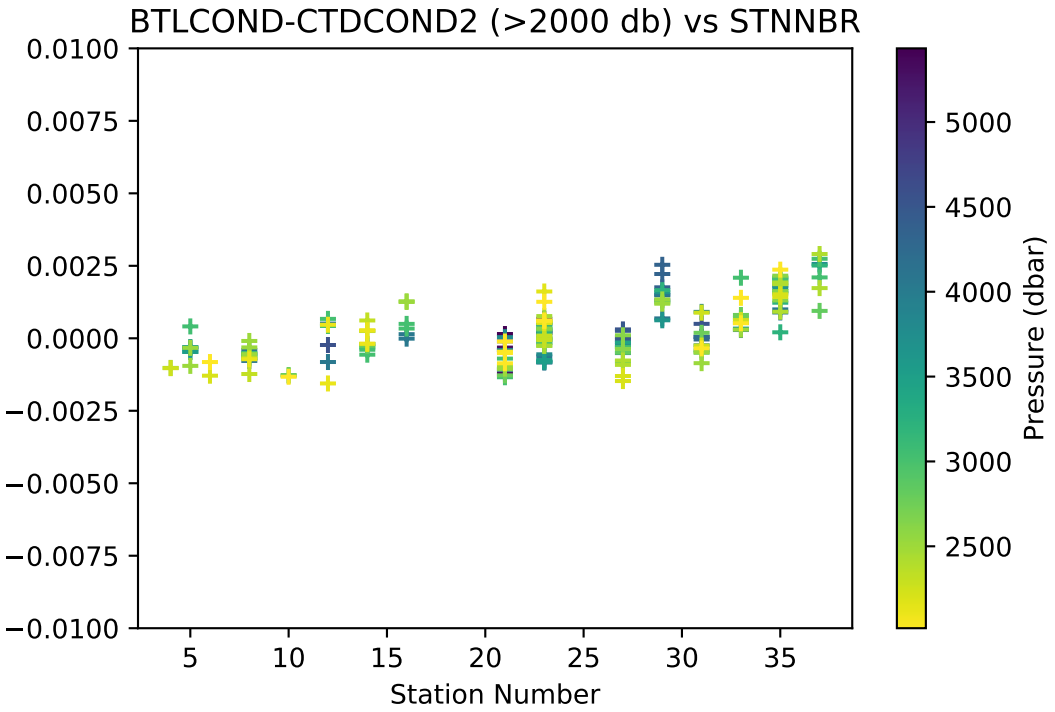

Fig. 3.8: Deep C_{Bottle} - C2 by station (Pressure >= 2000dbar).

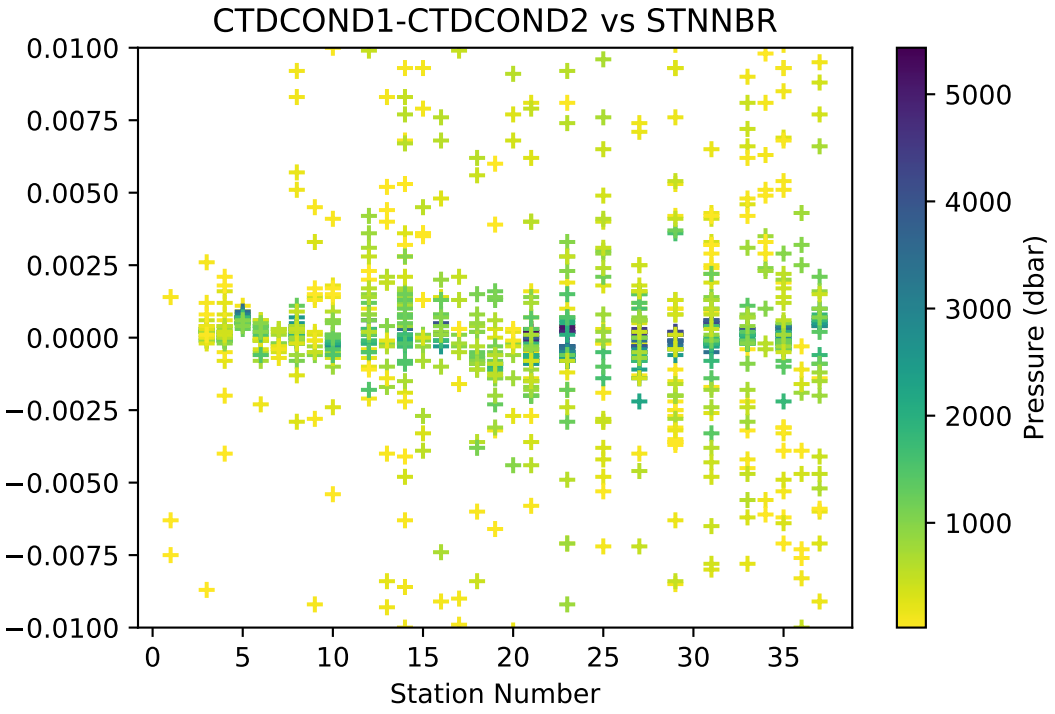

Fig. 3.9: C1-C2 by station (-0.002 mS/cm $\leq$ C1-C2 $\leq$ 0.002 mS/cm).

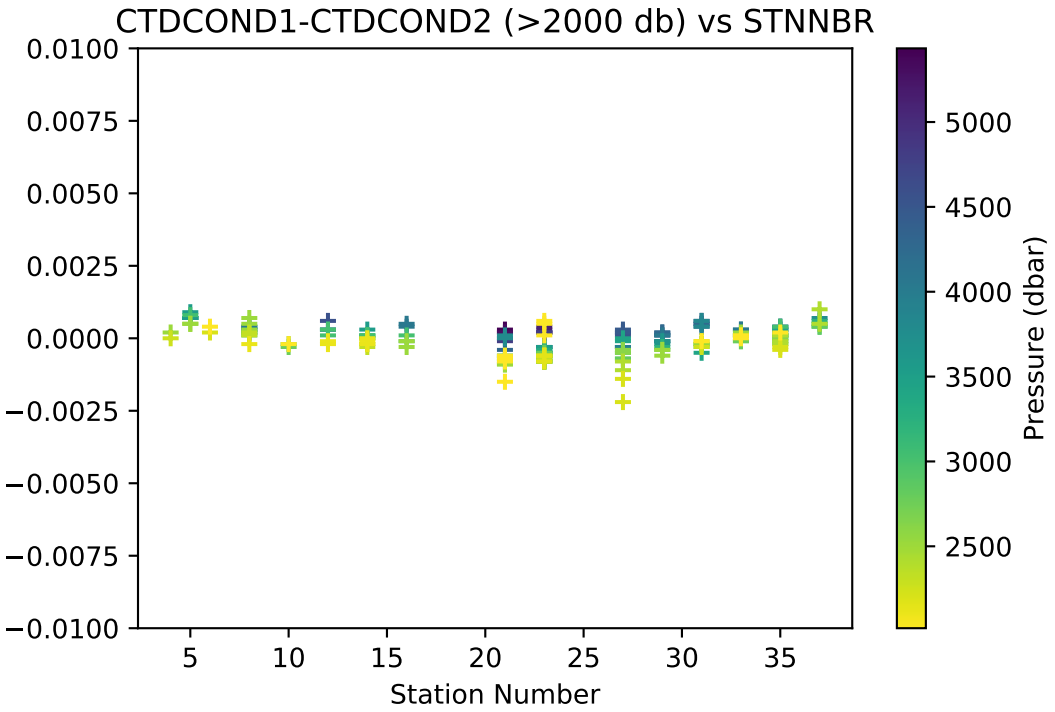

Fig. 3.10: Deep by station (Pressure >= 2000dbar).

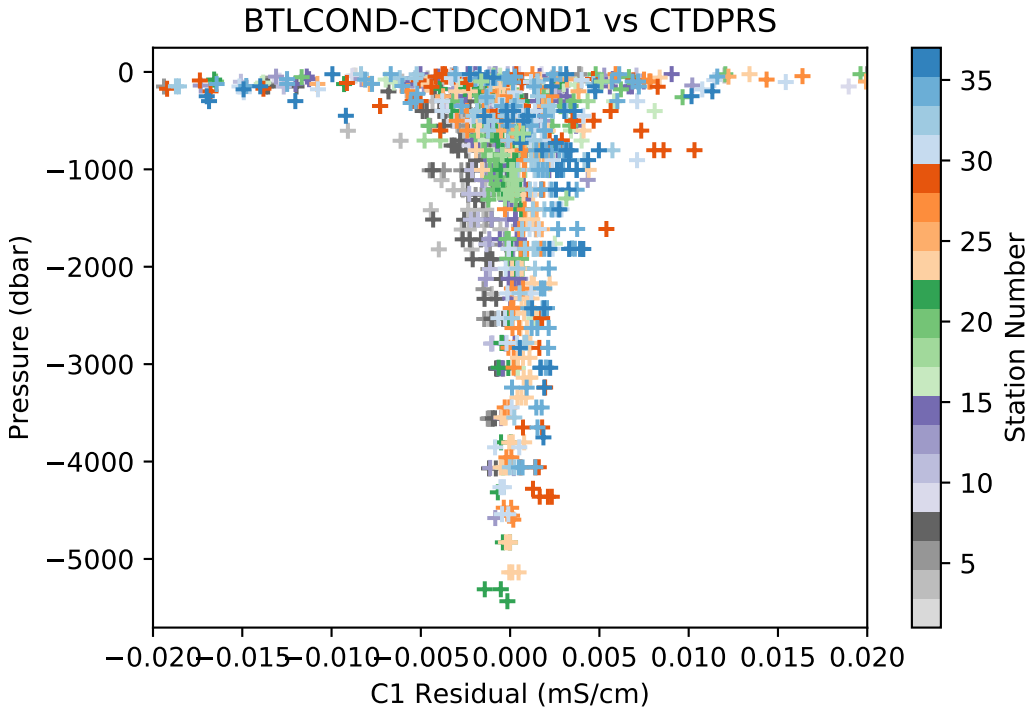

Fig. 3.11: C_{Bottle} - C1 by pressure (-0.002 mS/cm $\leq$ BTLCOND-C1 $\leq$ 0.002 mS/cm).

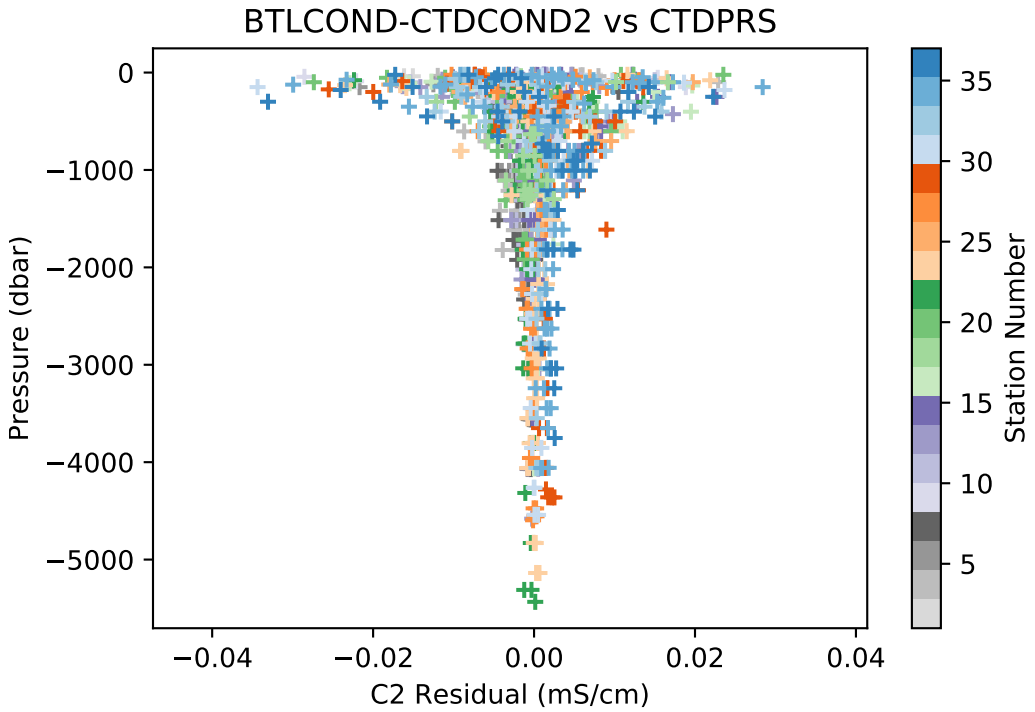

Fig. 3.12: C_{Bottle} - C2 by pressure (-0.002 mS/cm $\leq$ BTLCOND-C2 $\leq$ 0.002 mS/cm).

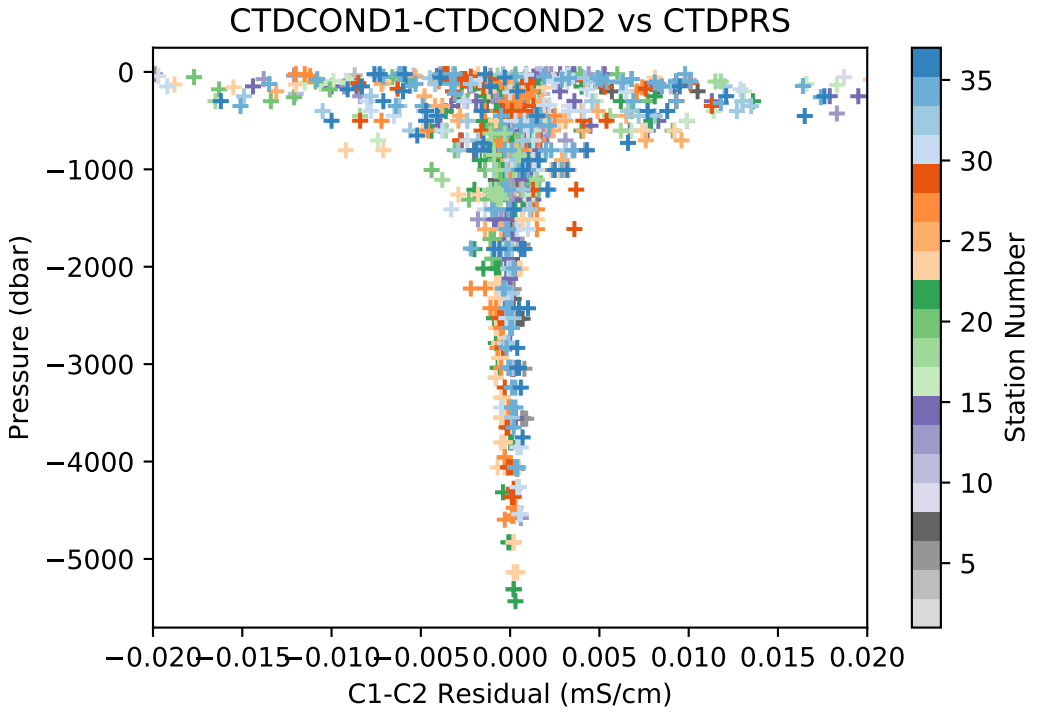

Fig. 3.13: C1-C2 by pressure (-0.002 mS/cm $\leq$ C1-C2 $\leq$ 0.002 mS/cm).

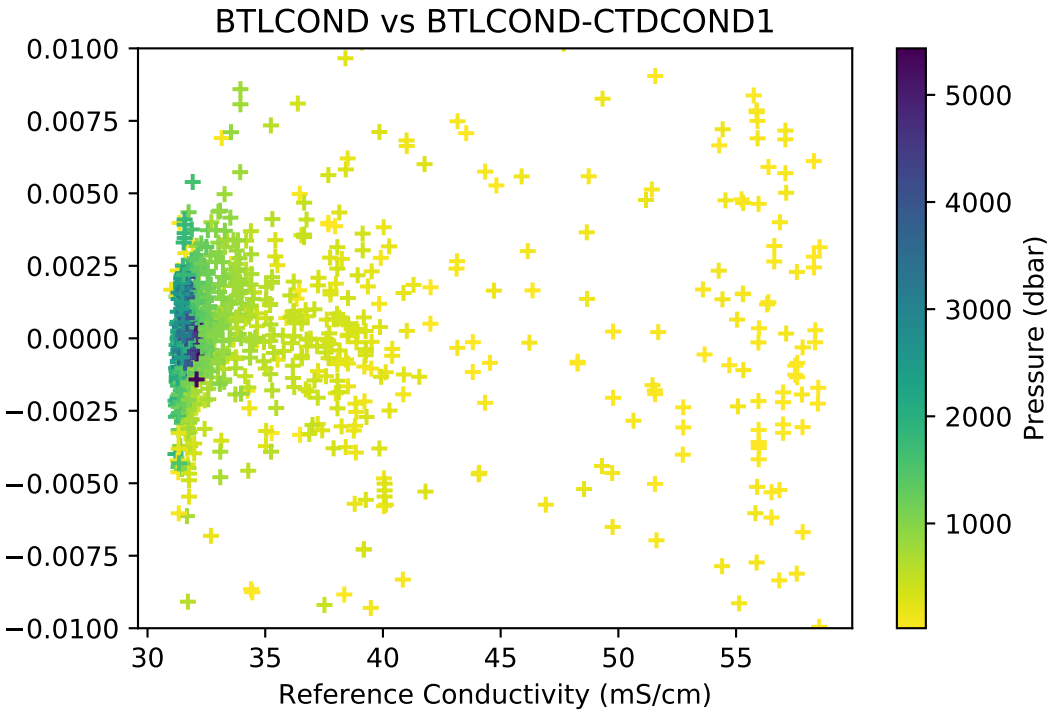

Fig. 3.14: C_{Bottle} - C1 by conductivity (-0.002 mS/cm $\leq$ BTLCOND-C1 $\leq$ 0.002 mS/cm).

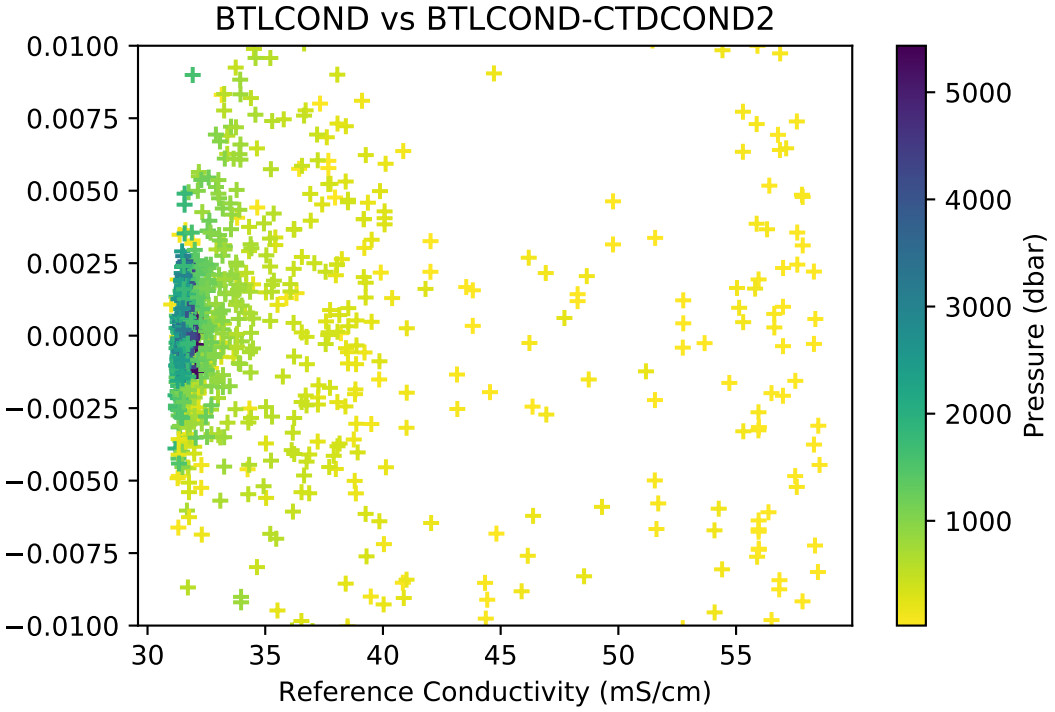

Fig. 3.15: C_{Bottle} - C2 by conductivity (-0.002 mS/cm $\leq$ BTLCOND-C2 $\leq$ 0.002 mS/cm).

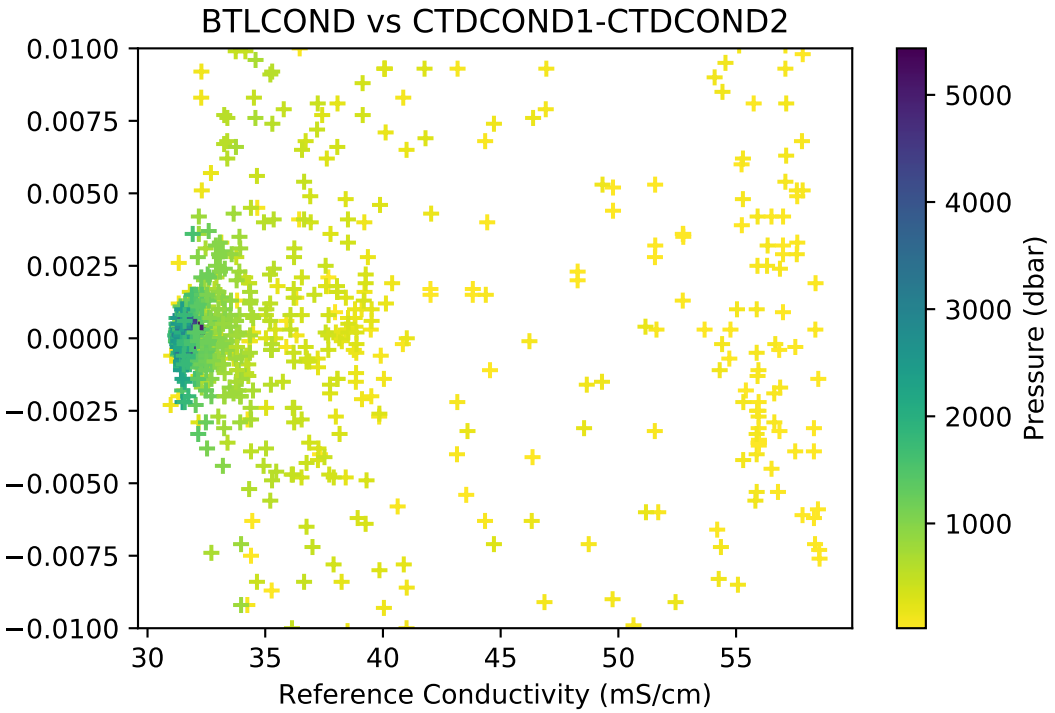

Fig. 3.16: C1-C2 by conductivity (-0.002 mS/cm $\leq$ C1-C2 $\leq$ 0.002 mS/cm).

The residual conductivity differences after calibration are shown in the following figures :

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

Corrections made to all conductivity sensors are of the form:

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

The 95% confidence limits for the whole water column differences are ±0.0033 mS/cm for BTLCOND-C1, ±0.0027 mS/cm for BTLCOND-C2, and ±0.0011 mS/cm for C1-C2. The 95% confidence limits for the deep conductivity residuals (where pressure ≥ 2000dbar) are ±0.00131 mS/cm for BTLCOND-C1, ±0.00127 mS/cm for SBTLCOND-C2, and ±0.00076 mS/cm for C1-C2.

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.

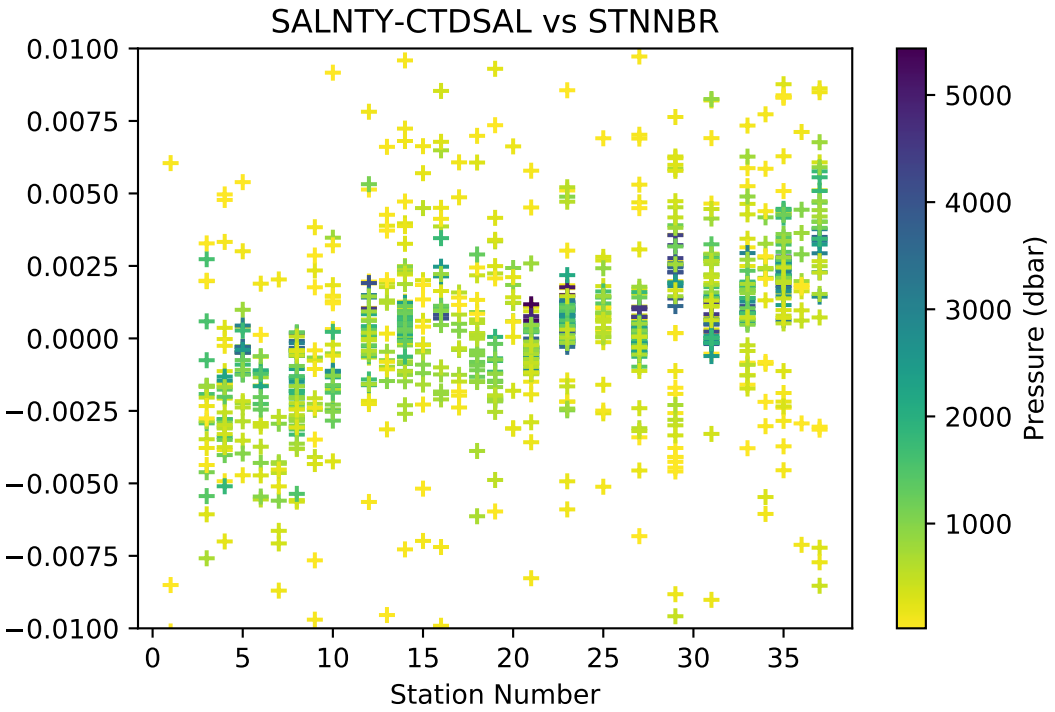

Fig. 3.17: Salinity residuals by station (-0.002 mPSU ≤ SALNTY-C1SAL ≤ 0.002 mPSU).

The 95% confidence limits for the whole water column differences are ±0.0064 PSU for salinity-C2SAL. The 95% confidence limits for the deep salinity residuals (where pressure ≥ 2000dbar) are ±0.00215 PSU for salinity-C2SAL.

All compromised data signals were recorded and coded in the data files.

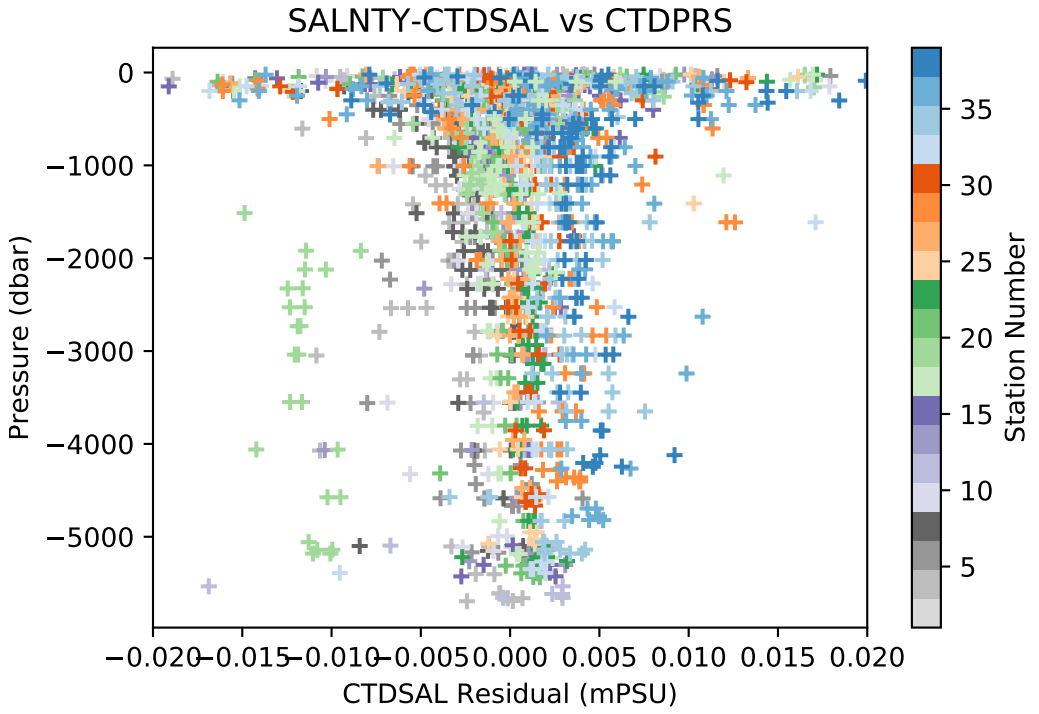

Fig. 3.18: Salinity residuals by pressure (-0.002 mPSU $\leq$ SALNTY-C1SAL $\leq$ 0.002 mPSU).

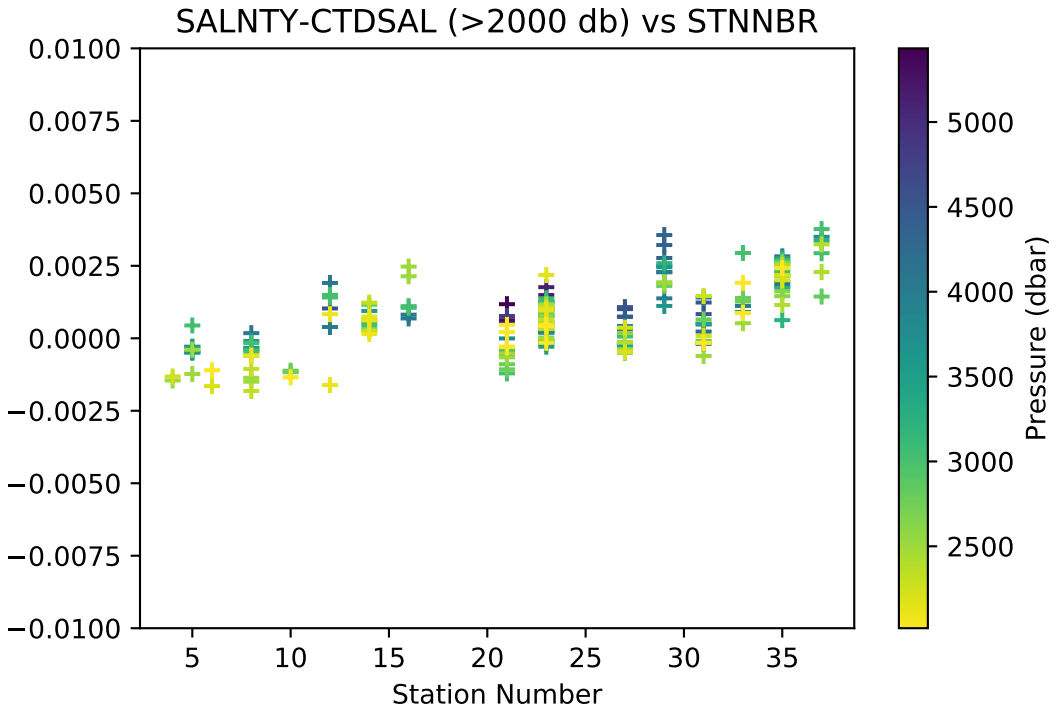

Fig. 3.19: Deep Salinity residuals by station (Pressure >= 2000dbar).

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 µmol/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 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 O_2 was then calculated using Clark Cell MPOD O_2 sensor response model for Beckman/SensorMedics and SBE43 dissolved O_2 sensors. The residual differences of bottle check value versus CTD dissolved O_2 values are minimized by optimizing the SIO DO sensor response model coefficients with a Levenberg-Marquardt non-linear least-squares fitting procedure.

The general form of the SIO DO sensor response model equation for Clark cells follows Brown and Morrison *[Millard82]* and Owens *[Owens85]* 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 (τ_p), a slow τ_{Tf} and fast τ_{Ts} thermal response, package velocity τ_{dP}, thermal diffusion τ_{dT} and pressure hysteresis τ_h are fitting parameters. Once determined for a given sensor, these time constants typically remain constant for a cruise. The thermal diffusion term is derived by low-pass filtering the difference between the 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 O_2 concentration is then calculated:

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

Where:

- O_2 ml/l Dissolved O_2 concentration in ml/l
- V_{DO} Raw sensor output
- C_1 Sensor slope
- C_2 Hysteresis response coefficient
- C_3 Sensor offset
- f_{sat} (T , P)|O2| saturation at T,P (ml/l)
- T In-situ temperature (°C)
- P In-situ pressure (decibars)
- P_h Low-pass filtered hysteresis pressure (decibars)
- T_l Long-response low-pass filtered temperature (°C)
- T_s Short-response low-pass filtered temperature (°C)
- P_l Low-pass filtered pressure (decibars)
- dO_c / dt Sensor current gradient (µamps/sec)
- dP/dt Filtered package velocity (db/sec)
- dT Low-pass filtered thermal diffusion estimate (T_s - T_l)
- C_4 - C_9 response coefficients

Note:

- Winkler O_2 samples were primarily taken from the ODF rosette for this cruise, as a result, there may be a bias in the GTC O_2 data.

CTD dissolved O_2 residuals are shown in the following figures *O2 residuals by station (-0.01 µmol/kg OXYGEN-BTLOXY 0.01 µmol/kg).* through *Deep O2 residuals by station (Pressure >= 2000dbar).*.

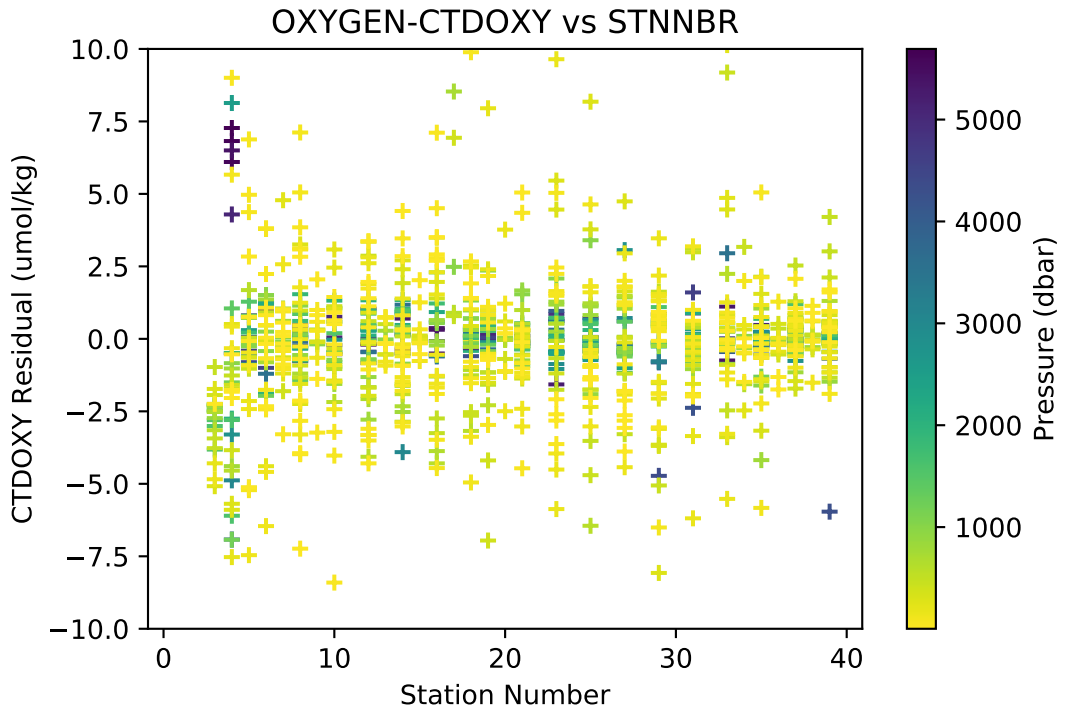

Fig. 3.20: O_2 residuals by station (-0.01 µmol/kg $\leq$ OXYGEN-BTLOXY $\leq$ 0.01 µmol/kg).

The second standard deviations of 4.78 (µmol/kg) for all dissolved oxygen bottle data values and 1.07 (µmol/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_2 lab measurements.

All compromised data signals were recorded and coded in the data files.

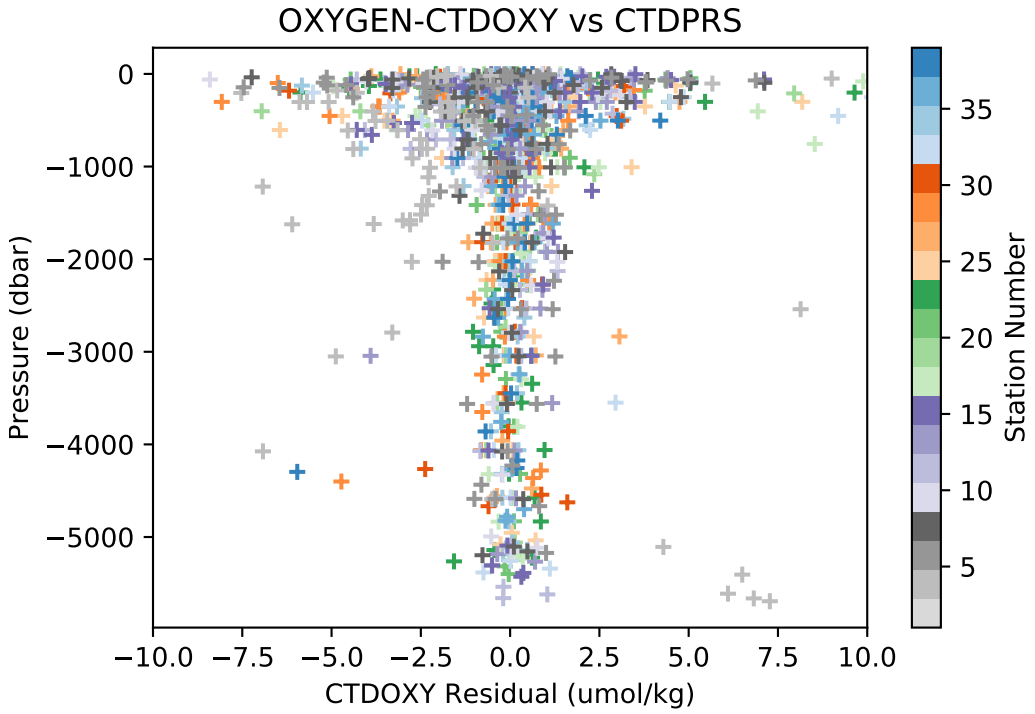

Fig. 3.21: O_2 residuals by pressure (-0.01 µmol/kg $\leq$ OXYGEN-BTLOXY $\leq$ 0.01 µmol/kg).

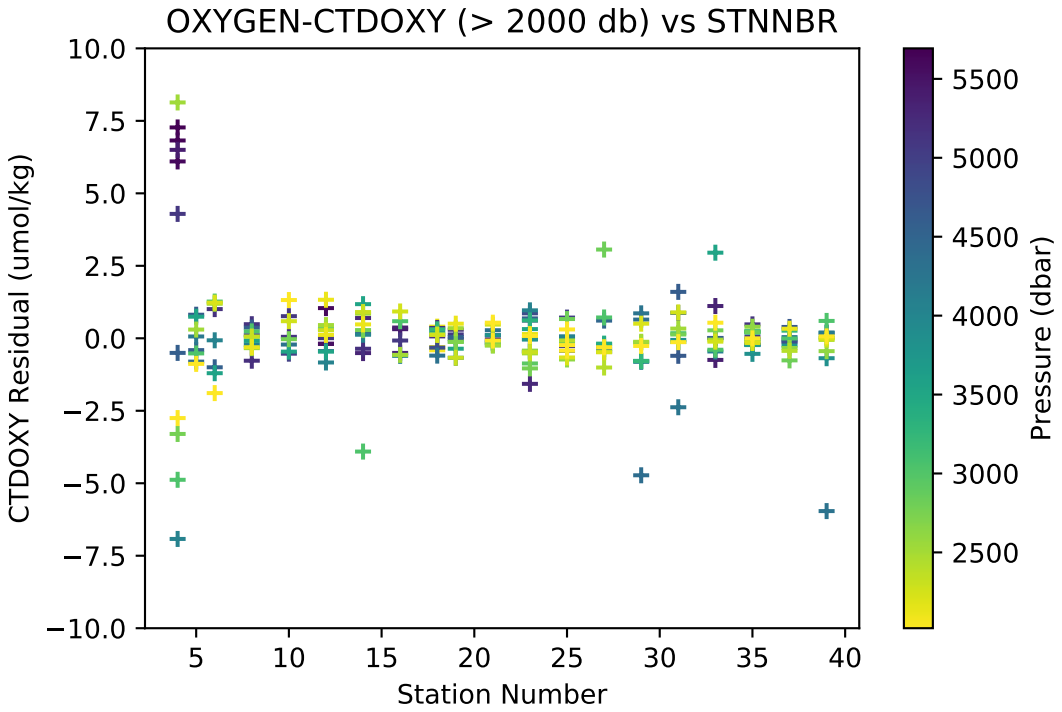

Fig. 3.22: Deep O_2 residuals by station (Pressure >= 2000dbar).

CHAPTER

FOUR

TRANSMISSOMETER

PI

- Jim Bishop

Cruise Technician

- Joseph Gum (ODF Leg 1)
- Kenneth Jackson (ODF Leg 2)
- Kyle McQuiggan (GTC)

The following summarizes the air calibration and regular operation procedures for the CST-1873DR transmissometer.

4.1 Air Calibration

- Check that in air temperature and instrument temperature has been stable before starting calibration, and record air temperature
- Connect transmissometer to a pigtail or CTD for air calibration, and power up
- Remove protective red caps from windows
- Rinse lenses with DI water and tap dry with lab wipes
- Compare transmissometer readings with previous readings. If readings are substantially different, wash with slightly soapy water (2-3 drops of soap) or alcohol, then rinse with DI water and tap dry.
- Repeat rinsing and wiping procedure until voltage stabilizes, then record voltage in log
- Completely block light between two lenses, and record voltage
- Check that air temperature, unblocked voltage, and blocked voltage have been recorded

Great care must be taken to clean the transmissometer windows and get a stable reading in a couple of rinse and wipe cycles. The method used on GP15 ODF involved folding a Kimwipe neatly into a small square 1/8 the starting size of the rectangle, with no creases or fingerprints on the wiping surface. The lenses were rinsed with DI water then tapped dry, taking care to hold the Kimwipe at the corners. A new Kimwipe was then folded, soaked with ethanol or isopropyl alcohol, and then the lenses were tapped, taking care to use one side of the Kimwipe per lens. Each Kimwipe was discarded after one use to prevent reintroducing contaminants onto the lenses. Following this method a lens would have a reliable voltage in two to four cleanings.

One point of note is that a rinsing fluid of significantly different temperature than the transmissometer seemed to cause the reading to change by 0.1 to 0.3 volts. This forced the technician to wait for some period of time until the voltage reading stabilized. This change in reading might also be due to ship roll changing the atmosphere temperature around the transmissometer.

4.2 Daily Operations

Before a cast the CTD watchstanders would remove the red caps and rinse the windows with lightly soapy water, taking care to do this as close as possible to the cast to prevent the windows from drying. This was done to prevent bubbles from forming on the face of the windows. Post the windows were rinsed with DI water and the red caps were placed on the windows. At the end of the cruise the transmissometer was rinsed with fresh water before packing.

4.3 Calibration Results

An air calibration was performed for both the GTC transmissometer and the ODF transmissometer by connecting it to a 12V power supply, cleaning the windows and taking measurements. The results are shown in the table below.

Table 4.1: Calibration results for Transmissometer

Date	Time (Local)	Transmissometer	Unblocked Value (Volts)	Air Temp	Remarks
20-Nov-18	0827	GTC	4.8391	23	No Cleaning wiped
20-Nov-18	0833	GTC	4.896	23	Cleaned with soap and MQ water
20-Nov-18	0833	GTC	4.8451	23	Cleaned with soap and MQ water
20-Nov-18	0840	GTC	4.8454	23	MQ rinse and wipe
20-Nov-18	1027	GTC	4.8339	23	Reading from CTD
20-Nov-18	0857	ODF	4.6524	23	Before wipe
20-Nov-18	0858	ODF	4.7533	23	MQ rinse and wipe
20-Nov-18	0858	ODF	4.7277	23	Cleaned with soap and MQ water
20-Nov-18	0902	ODF	4.7573	23	Cleaned with soap and MQ water
20-Nov-18	0916	ODF	4.74	23	On CTD Measurement

CHAPTER

FIVE

SALINITY

PIs

- Susan Becker

Technicians

- John Calderwood
- Kelsey Vogel
- Erin Hunt

5.1 Equipment and Techniques

Two Guildline Autosals, model 8400B salinometer (S/N 69-180) and model 8400A salinometer (S/N 57-396) located in the hydro laboratory, were used for all salinity measurements.

Autosal model 8400B and 8400A were serviced prior to GT15.

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 21°C at the beginning of the cruise and then swapped to 24r°C The laboratory's temperature was also set and maintained between 18-25°C, dependent on our longitude. This is to ensure stabilize reading values and improve accuracy. Salinity analyses were performed after samples had equilibrated to laboratory temperature ranges of 18-25 °C, depending on Autosal water bath temperature (21 or 24°C), usually 8 hours after collection.

The salinometer was standardized for each group of samples analyzed (usually 2 casts and up to 48 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-161 was used to standardize all casts.

5.2 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.

5.3 Narrative

Autosal 8400B was used to perform the salinity analysis at the beginning of the cruise. Issues on the 8400B were recognized during GT15's first sample test station. During this station, the 8400B would fill up the cell while also empty out the cell. Leading to a in proper seal and filled cell chamber. The 8400B was swapped out for the 8400A immediately after this issue was recognized. Autosal 8400A was used to perform the salinity analysis for the entirety of GT15, Stations 1-39.

Room and bottle temperatures proved difficult to keep consistent throughout the cruise, causing certain changes to be made throughout GT15. During Leg one, the Autosal water bath temperature was set to 21°C from Station/cast: 01/01-16/03 with the room temperature varying from 18-22°C. As we approached the equator, the Autosal water bath temperature was set to 24°C from Station/Cast: 16/04-39/12 with the room temperature varying between 22-25°C.

CHAPTER

SIX

NUTRIENTS

PIs

- Susan Becker
- James Swift

Technicians

- Melissa Miller
- Susan Becker
- Erin Hunt

6.1 Summary of Analysis

- 5454 samples from 039 stations and underway sampling.
- The cruise started with new pump tubes and they were changed prior to stations 06,12, 21, 29, and 38.
- 6 sets of nitrate, phosphate, and silicate Primary/Secondary standards were made up over the course of the cruise.
- 4 sets of Primary nitrite standards were made up over the course of the cruise.
- The cadmium column efficiency was checked periodically and ranged between 87%-100%.

A new column was put on when the efficiency fell below 97%, nitrate respsonse dropped noticably or if the column was injected with air.

6.2 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]* and the latest version of the GO-SHIP manual (Becker et al 2018) *[Becker2018]*.

6.3 Nitrate/Nitrite Analysis

A modification of the Armstrong et al. (1967) *[Armstrong1967]* procedure was used for the analysis of nitrate and nitrite. For nitrate analysis, a seawater sample was passed through a cadmium column where the nitrate was reduced to

nitrite. This nitrite was then diazotized with sulfanilamide and coupled with N-(1-naphthyl)-ethylenediamine to form a red dye. The sample was then passed through a 10mm flowcell and absorbance measured at 540nm. The procedure was the same for the nitrite analysis but without the cadmium column.

REAGENTS

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

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

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

Imidazole Buffer Dissolve 13.6g imidazole in ~3.8 liters DIW. Stir for at least 30 minutes to completely dissolve. Add 60 ml of CuSO4 + NH4Cl mix (see below). Add 4 drops 40% Surfynol 465/485 surfactant. Let sit overnight before proceeding. Using a calibrated pH meter, adjust to pH of 7.83-7.85 with 10% (1.2N) HCl (about 10 ml of acid, depending on exact strength). Bring final solution to 4L with DIW. Store at room temperature.

NH4Cl + CuSO4 mix Dissolve 2g cupric sulfate in DIW, bring to 100 m1 volume (2%). Dissolve 250g ammonium chloride in DIW, bring to l liter volume. Add 5ml of 2% CuSO4 solution to this NH4Cl stock. This should last many months.

6.4 Phosphate Analysis

Ortho-Phosphate was analyzed using a modification of the Bernhardt and Wilhelms (1967) *[Bernhardt1967]* method. Acidified ammonium molybdate was added to a seawater sample to produce phosphomolybdic acid, which was then reduced to phosphomolybdous acid (a blue compound) following the addition of dihydrazine sulfate. The sample was passed through a 10mm flowcell and absorbance measured at 820nm (880nm after station 59, see section on analytical problems for details).

REAGENTS

Ammonium Molybdate H2SO4 sol'n Pour 420 ml of DIW into a 2 liter Ehrlenmeyer flask or beaker, place this flask or beaker into an ice bath. SLOWLY add 330 ml of conc H2SO4. This solution gets VERY HOT!! Cool in the ice bath. Make up as much as necessary in the above proportions.

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

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

6.5 Silicate Analysis

Silicate was analyzed using the basic method of Armstrong et al. (1967). Acidified ammonium molybdate was added to a seawater sample to produce silicomolybdic acid which was then reduced to silicomolybdous acid (a blue compound) following the addition of stannous chloride. The sample was passed through a 10mm flowcell and measured at 660nm.

REAGENTS

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

Ammonium Molybdate Dissolve 10.8g Ammonium Molybdate Tetrahydrate in 1000ml dilute H2SO4. (Dilute H2SO4 = 2.8ml conc H2SO4 or 6.4ml of H2SO4 diluted for PO4 moly per liter DW) (dissolve powder, then add H2SO4) Add 3-5 drops 15% SDS surfactant per liter of solution.

Stannous Chloride stock: (as needed)

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

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

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

6.6 Sampling

Nutrient samples were drawn into 30 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 2-12 hours after sample collection, allowing sufficient time for all samples to reach room temperature. The centrifuge tubes fit directly onto the sampler.

6.7 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. The value for the check sample and reference material were monitored and any adjustments that were needed were preformed for an entire station station before data was merged with other bottle data. Adjustments were noted in data file the analysts maintain.

6.8 Standards and Glassware Calibration

Primary standards for silicate (Na2SiF6), nitrate (KNO3), nitrite (NaNO2), and phosphate (KH2PO4) were obtained from Johnson Matthey Chemical Co. and/or Fisher Scientific. The supplier reports purities of >98%, 99.999%, 97%, and 99.999 respectively.

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

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

Standardizations were performed at the beginning of each group of analyses with working standards prepared every 10-12 hours from a secondary. Working standards were made up in low nutrient seawater (LNSW). Three batches of LNSW were used on the cruise. Two the the batches were collected and filtered prior to the cruise. The third batch was surface seawter collected from the ship's underway uncontaminted seawater system prior to the mid-cruie port stop inHil, Hawaii. 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_4 (uM)	SIL (uM)	NO_2 (uM)	NH_4 (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

6.9 Quality Control

All final data was reported in micro-moles/kg. NO^3, PO_4, and NO_2 were reported to two decimals places and SIL to one. Accuracy is based on the quality of the standards the levels are:

NO^3	0.05 µM (micro moles/Liter)
PO_4	0.004 µM
SIL	2-4 µM
NO_2	0.05 µM

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

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 CF 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
-	(µmol/l)	-	(µmol/l)
NO^3	44.41	0.14	44.46
PO_4	3.127	0.019	3.13
Sil	163.0	0.68	163.6
NO_2	0.09	0.01	0.07

6.10 Analytical Problems

There were problems with the phosphate analysis at various times throughout the cruise. Despite confirming stable baselines and obtaining signal during the initial instrument checks during set up in port, there was no signal for phosphate when the instrument was started for analysis of the test cast samples. Various pieces of old glassware and tubing on the manifold were replaced. There was still no signal on the phosphate channel. Components of the detector were replaced one at a time, flowcell, lamps, filters, and HR3 colorimeter base. The heater on the manifold was replaced and that seemed to solve the problem. The baseline and response were still variable and posed a challenge. Trouble shooting continued and the practice of running a short ?warm up? run was put into place. The values for the deep check sample and the reference material were with the acceptable limits and sample analysis proceeded. After the test cast and first station the analysis continued without any major problems for the rest of the first leg. The second leg started without any issues. Phosphate problems arose again at station 031. The original components for the detector were re-installed and the entire system was cleaned with a dilute bleach solution but the signal was still unacceptable. The heater was replaced and set to a slightly lower temperature. The tubing from the colorimter to the wast drainage was replaced and monitored to maintain the flow and bubble pattern. All connections were checked to ensure they were flush and there were no gaps between glass pieces or between tubing and glass. This alleviated apparent build of back-pressure in the flowcell and solved the issue.

CHAPTER

SEVEN

OXYGEN ANALYSIS

PIs

- Susan Becker

Technicians

- Erin Hunt (Leg 1)
- Andrew Barna (Leg 2)

7.1 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 665 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 of station work (approximately every 3-4 stations), unless changes were made to the system or reagents. Reagent/distilled water blanks were determined with every standardization or more often if a change in reagents required it to account for presence of oxidizing or reducing agents.

7.2 Sampling and Data Processing

1157 oxygen measurements were made. Samples were collected exclusivly from the ODF 36 place rosette for dissolved oxygen analyses soon after it was brought on board. Using a silicone drawing tube, nominal 125ml volume-calibrated iodine flasks were rinsed 3 times with minimal agitation, then filled and allowed to overflow for at least 3 flask volumes. The sample drawing temperatures were measured with an electronic resistance temperature detector (RTD) embedded in the drawing tube. These temperatures were used to calculate umol/kg concentrations, and as a diagnostic check of bottle integrity. Reagents ($MnCl_2$ then NaI/NaOH) were added to fix the oxygen before stoppering. The flasks were shaken twice (10-12 inversions) to assure thorough dispersion of the precipitate, once immediately after drawing, and then again after about 30-40 minutes.

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

Thiosulfate normalities were calculated for each standardization and corrected to 20°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.

7.3 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.

7.4 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.

7.5 Narrative

Setup occurred in Seattle, WA and the analysis rig was secured in the hydro lab of the R/V Roger Revelle. Large batches of the oxygen reagents were made such that none would need to be made while at sea. During the port stop in Hilo, HI, more reagents were made to ensure adequate supply for the remainder of the cruise. There were no major analytical problems other than an analyst error resulting in the loss of a sample.

APPENDIX

A

ABBREVIATIONS

ADCP Acoustic Doppler Current Profiler

ANU Australian National University

AOML Atlantic Oceanographic and Meteorological Laboratory - *NOAA*

AP Particulate Absorbtion Spectra

APL Applied Physics Laboratory

ASC Antarctic Support Contract

AWI Alfred Wegener Institute - Alfred-Wegener-Institut, Helmholtz-Zentrum für Polar- und Meeresforschung

Bigelow Bigelow Laboratory for Ocean Sciences

CDOM Chromophoric Dissolved Organic Matter

CFCs Chlorofluorocarbons

CTDO Conductivity Temperature Depth Oxygen

DIC Dissolved Inorganic Carbon

DIP Dissolved Inorganic Phosphorus

DOC Dissolved Organic Carbon

DON Dissolved Organic Nitrogen

DOP Dissolved Organic Phosphorus

ECO Edison Chouest Offshore

ENSTA ENSTA ParisTech

ETHZ Edgenössische Technische Hochschule Zürich

eNd Neodymium Samples

FSU Florida State University

HPLC High-Performance Liquid Chromatography

JAMSTEC Japan Agency for Marine-Earth Science and Technology Kokuritsu-Kenkyū-Kaihatsu-Hōjin Kaiyō Kenkyū Kaihatsu Kikō

LDEO Lamont-Doherty Earth Observatory - Columbia University

LADCP Lowered Acoustic Doppler Profiler

MBARI Monterey Bay Aquarium Research Institute

MPIC Max Planck Institute of Chemistry

N2O Nitrous Oxide

NASA National Aeronautics and Space Administration

NOAA National Oceanographic Atmospheric Administration

NBP RVIB Nathaniel B Palmer

NSF National Science Foundation

ODF Ocean Data Facility - *SIO*

OSU Oregon State University

Oxford Oxford University

PMEL Pacific Marine Environmental Laboratory - *NOAA*

POC Particulate Organic Carbon

POM Particulate Organic Matter

POP Particulate Organic Phosphorus

Princeton Princeton University

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

SEG Shipboard Electronics Group

SF_6 Sulfur Hexafluoride

SIO Scripps Institution of Oceanography

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

STS Shipboard Technical Support - *SIO*

TAMU Texas A&M University

TDN Total Dissolved Nitrogen

U Alaska University of Alaska

U Arizona University of Arizona

UCI University of California Irvine

UCSB University of California Santa Barbara

UCSD University of California San Diego

U Colorado University of Colorado

UdeC University of Concepción, Chile

U Edin. University of Edinburgh

UH University of Hawaii

U Maine University of Maine

U Miami University of Miami

UNAB Universidad Nacional Andres Bello

UNSW University of New South Wales

U Puerto Rico University of Puerto Rico

USAP United States Antarctic Program

USCG United States Coast Guard

USF University of South Florida

UT University of Texas

UVP Underwater Vision Profiler

UW University of Washington

UWA University of Western Australia

U. Wisconsin University of Wisconsin

VIMS Virginia Institute of Marine Science

VUB Vrije Universiteit Brüssel

WHOI Woods Hole Oceanographic Institution

W&M College of William & Mary

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APPENDIX

B

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)
```

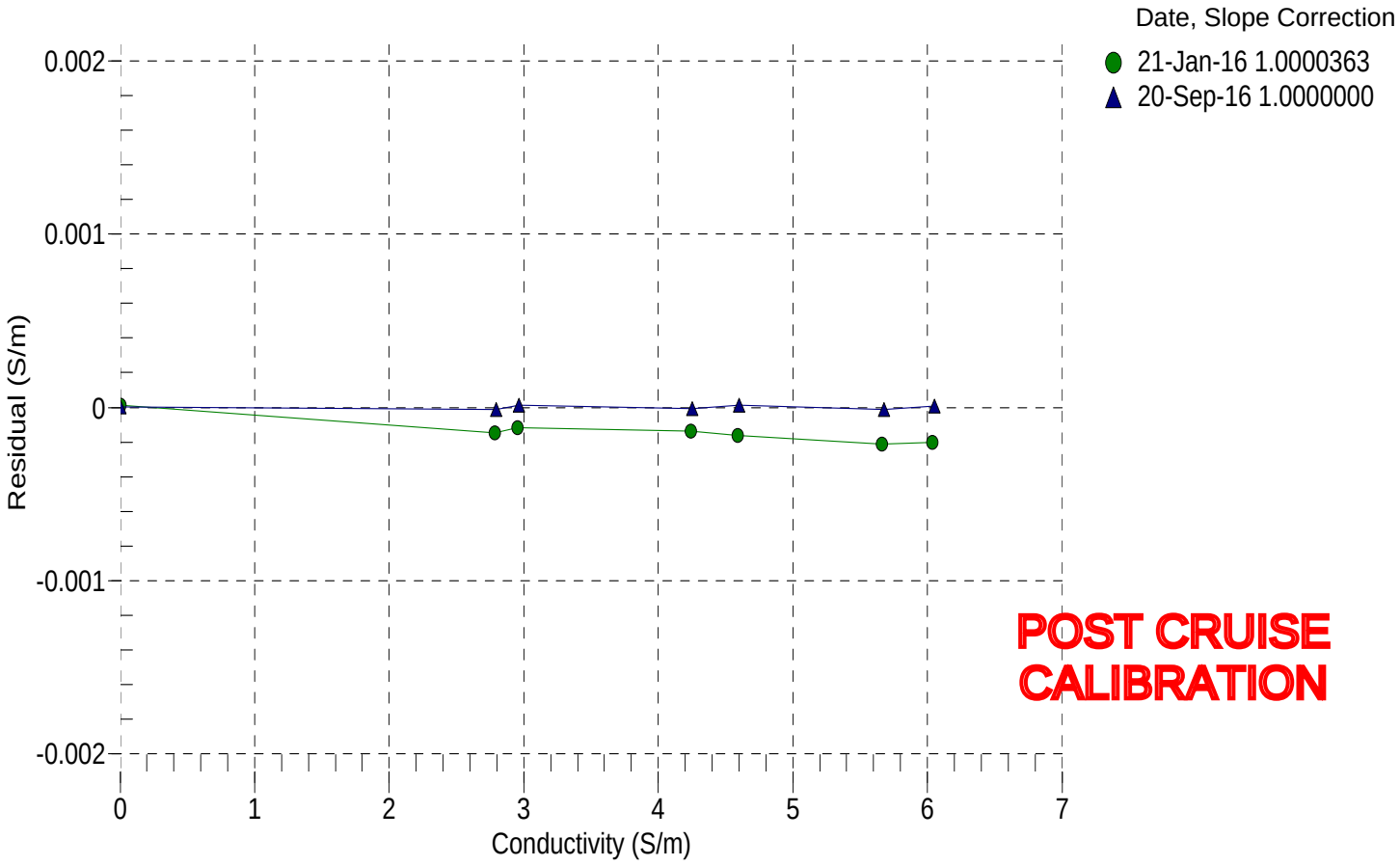
BATH TEMP (° C)	BATH SAL (PSU)	BATH COND (S/m)	INSTRUMENT OUTPUT (kHz)	INSTRUMENT COND (S/m)	RESIDUAL (S/m)
0.0000	0.0000	0.00000	2.56859	0.00000	0.00000
-1.0000	34.6548	2.79278	4.91464	2.79277	-0.00001
1.0000	34.6551	2.96350	5.02254	2.96351	0.00001
15.0000	34.6566	4.25409	5.77286	4.25408	-0.00001
18.5000	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); δ = CTcor; ε = CPcor;

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

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



Sea-Bird Electronics, Inc.

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

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

SENSOR SERIAL NUMBER: 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)
```

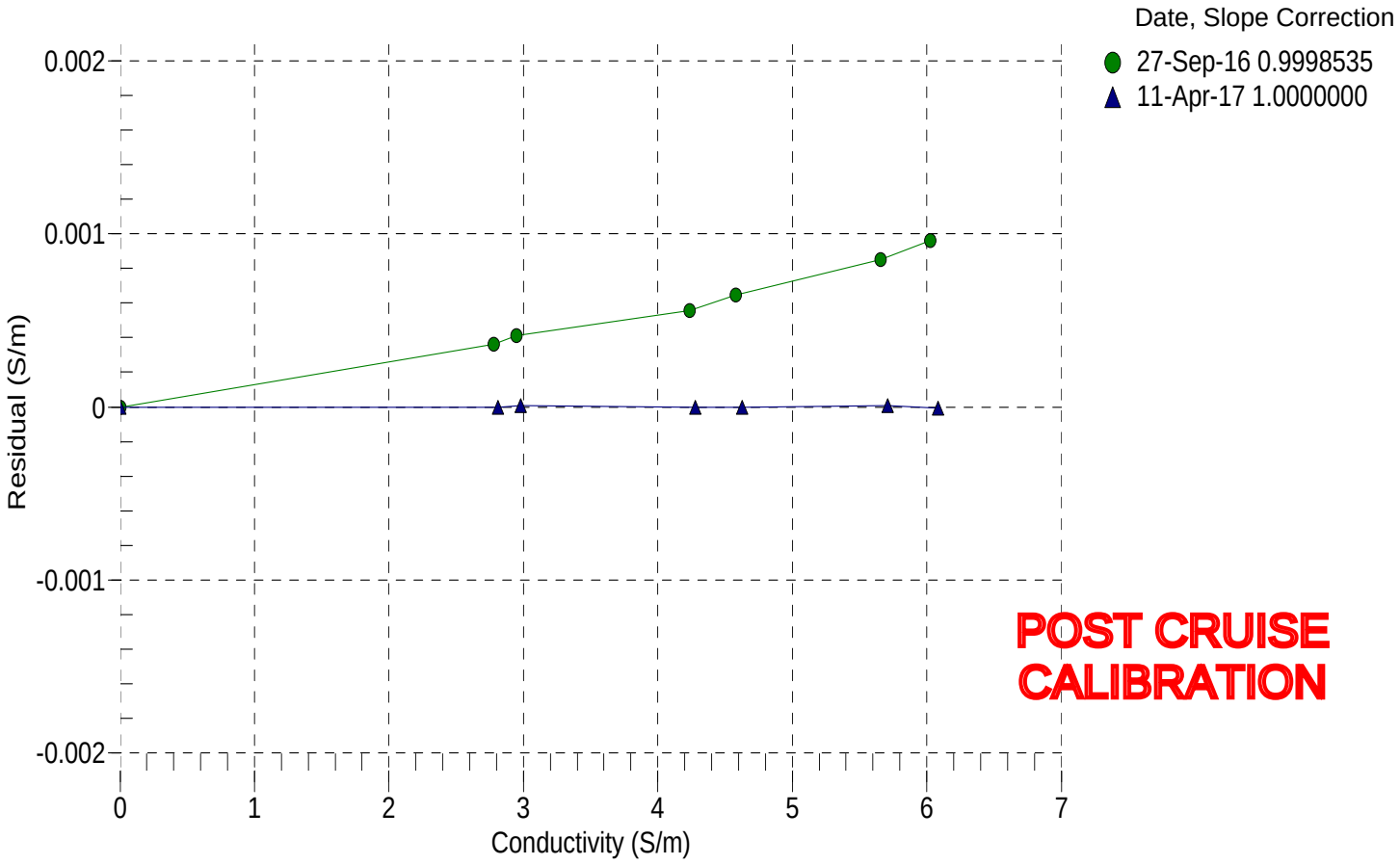
BATH TEMP (° C)	BATH SAL (PSU)	BATH COND (S/m)	INSTRUMENT OUTPUT (kHz)	INSTRUMENT COND (S/m)	RESIDUAL (S/m)
0.0000	0.0000	0.00000	2.67093	0.00000	0.00000
-1.0000	34.8911	2.81004	5.23758	2.81003	-0.00000
1.0000	34.8911	2.98175	5.35456	2.98175	0.00001
15.0000	34.8899	4.27968	6.16707	4.27968	-0.00000
18.5000	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); δ = CTcor; ε = CPcor;

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

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



Sea-Bird Electronics, Inc.

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

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

SENSOR SERIAL NUMBER: 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)
```

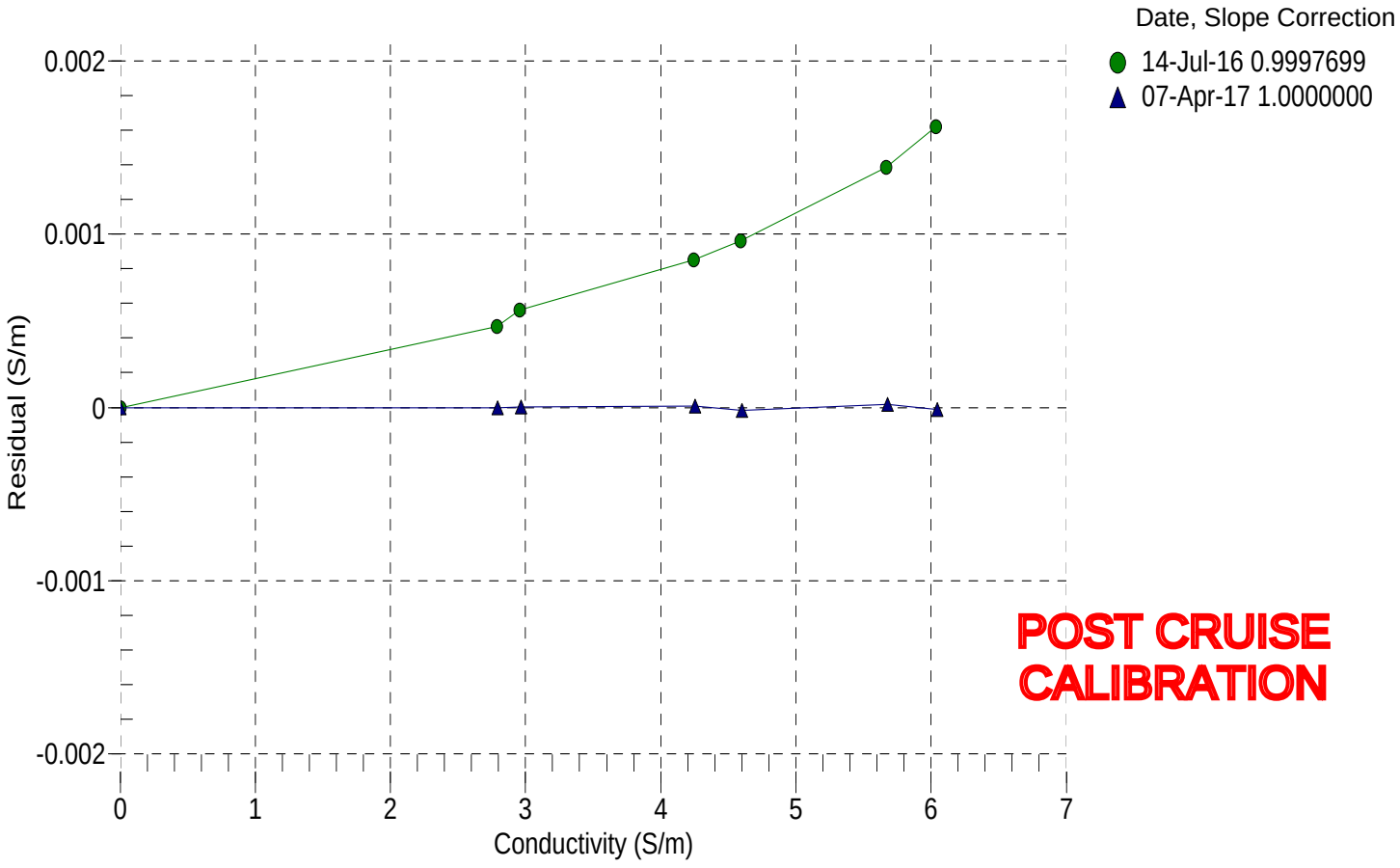
BATH TEMP (° C)	BATH SAL (PSU)	BATH COND (S/m)	INSTRUMENT OUTPUT (kHz)	INSTRUMENT COND (S/m)	RESIDUAL (S/m)
0.0000	0.0000	0.00000	2.57479	0.00000	0.00000
-1.0000	34.6606	2.79320	5.03482	2.79320	-0.00000
1.0000	34.6613	2.96398	5.14715	2.96398	0.00000
15.0001	34.6616	4.25465	5.92723	4.25466	0.00001
18.5000	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); δ = CTcor; ε = CPcor;

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

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



PO Box 518
620 Applegate St.
Philomath, OR 97370

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

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:

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

• **Scale Factor for 700 nm**	=	1.662E-06 ($m^{-1}sr^{-1}$)/counts	1.362E-03 ($m^{-1}sr^{-1}$)/volts
• **Output**	=	meter output counts	meter output volts
• **Dark Counts**	=	43 counts	0.0708 volts
Instrument Resolution	=	1.0 counts 1.0651 mV	1.66E-06 ($m^{-1}sr^{-1}$)

Definitions:

- **Scale Factor**: Calibration scale factor, $\beta(\theta_c)$/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.

PO Box 518
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Philomath, OR 97370

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www.wetlabs.com

ECO Chlorophyll Fluorometer Characterization Sheet

Date: 9/23/2014 S/N: FLBBRTD-3698

Chlorophyll concentration expressed in µg/l can be derived using the equation:

CHL (µg/l) = Scale Factor * (Output - Dark counts)

	Analog		Digital	
Dark counts	0.057	V	40	counts
Scale Factor (SF)	6	µg/l/V	0.0072	µg/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: SF = x ÷ (output - dark counts), where x is the concentration of the solution used during instrument characterization. SF is used to derive instrument output concentration from the raw signal output of the fluorometer.

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

Resolution: Standard deviation of 1 minute of collected data.

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

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 K. Shimotsu

Approved A. Fukuoka

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 × 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: ±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	±1.00	Passed
2nd	1023.7	0.00	0.04	0.04	±1.00	Passed
3rd	1023.8	0.00	0.04	0.04	±1.00	Passed

Test for DO 100 %

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

Examined R. Kashida

Approved A. Fukuoka

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
CALIBRATION DATE: 07-Apr-17

SBE 43 OXYGEN CALIBRATION DATA

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

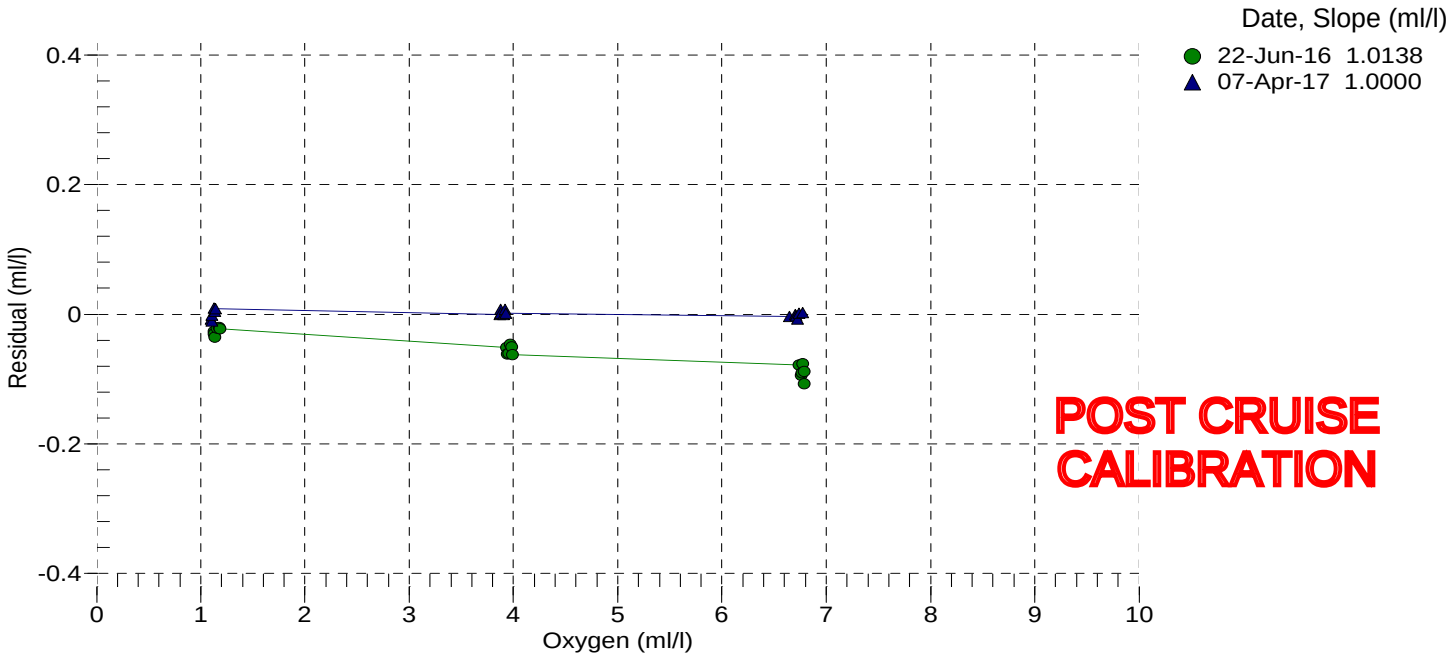
BATH OXYGEN (ml/l)	BATH TEMPERATURE (° C)	BATH SALINITY (PSU)	INSTRUMENT OUTPUT (volts)	INSTRUMENT OXYGEN (ml/l)	RESIDUAL (ml/l)
1.10	6.00	0.00	0.777	1.09	-0.01
1.10	2.00	0.00	0.748	1.09	-0.01
1.10	12.00	0.00	0.821	1.10	-0.00
1.13	26.00	0.00	0.932	1.14	0.01
1.13	20.00	0.00	0.888	1.14	0.00
1.14	30.00	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)

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

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



Sea-Bird Electronics, Inc.

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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
D2 = -4.64803e-2

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

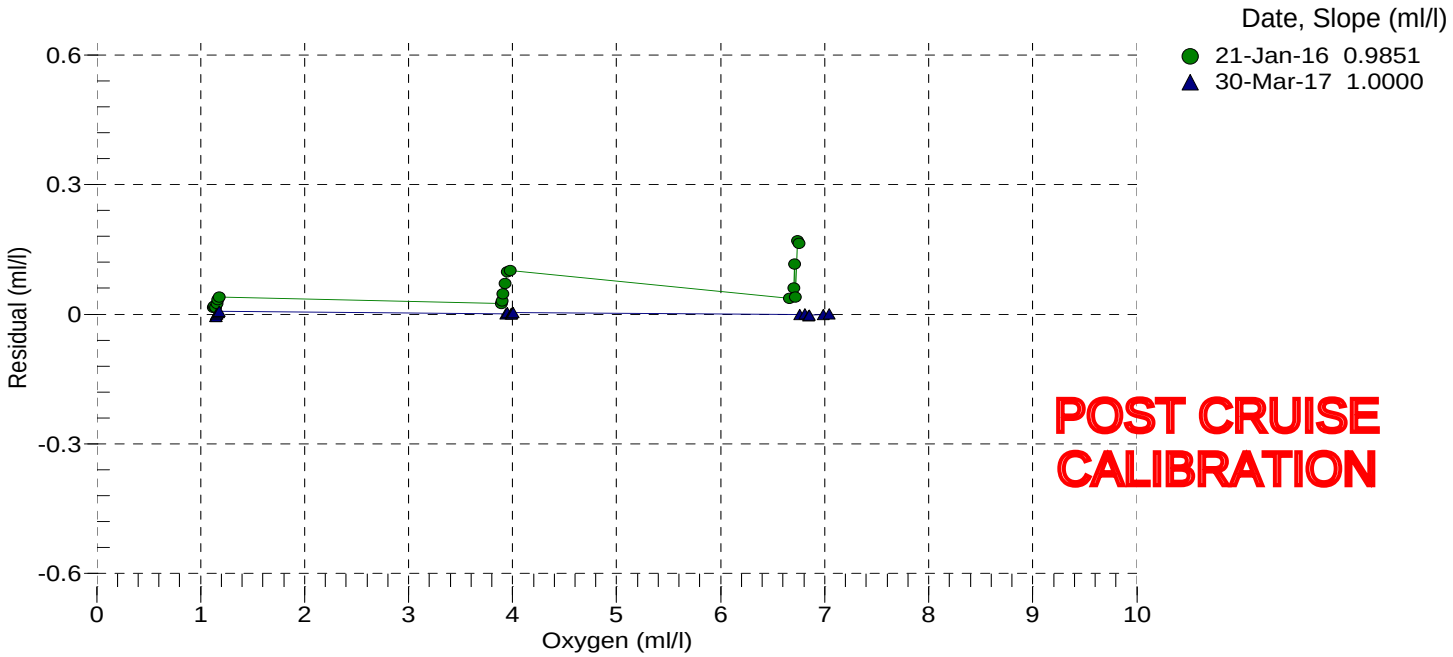
BATH OXYGEN (ml/l)	BATH TEMPERATURE (° C)	BATH SALINITY (PSU)	INSTRUMENT OUTPUT (volts)	INSTRUMENT OXYGEN (ml/l)	RESIDUAL (ml/l)
1.14	2.00	0.00	0.719	1.14	-0.00
1.15	12.00	0.00	0.788	1.15	-0.00
1.15	6.00	0.00	0.747	1.15	-0.00
1.16	20.00	0.00	0.844	1.16	0.00
1.17	26.00	0.00	0.889	1.17	0.00
1.18	30.00	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)

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

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



Sea-Bird Electronics, Inc.

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SENSOR SERIAL NUMBER: 1136
CALIBRATION DATE: 11-Apr-17

SBE 43 OXYGEN CALIBRATION DATA

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

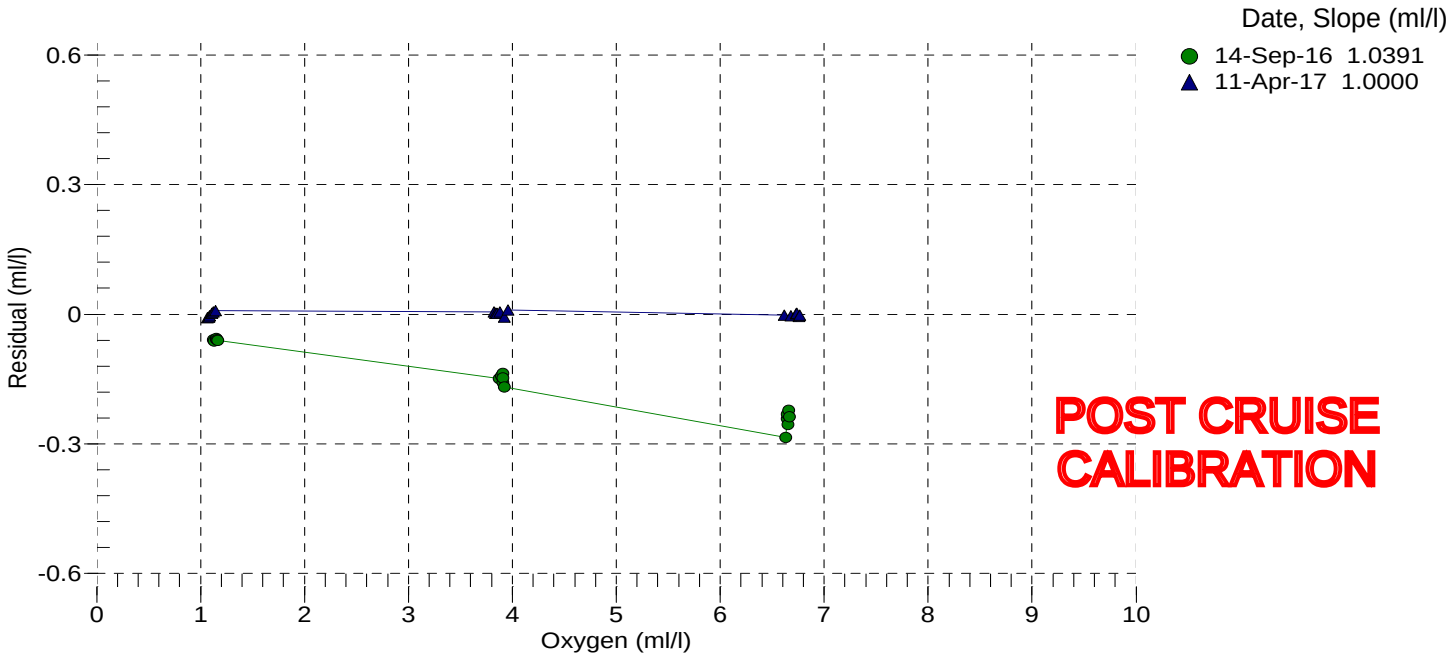
BATH OXYGEN (ml/l)	BATH TEMPERATURE (° C)	BATH SALINITY (PSU)	INSTRUMENT OUTPUT (volts)	INSTRUMENT OXYGEN (ml/l)	RESIDUAL (ml/l)
1.07	2.00	0.00	0.779	1.06	-0.01
1.08	6.00	0.00	0.811	1.07	-0.01
1.08	12.00	0.00	0.858	1.08	-0.00
1.11	20.00	0.00	0.926	1.11	0.00
1.13	26.00	0.00	0.980	1.13	0.01
1.14	30.00	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)

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

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



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

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

SENSOR SERIAL NUMBER: 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

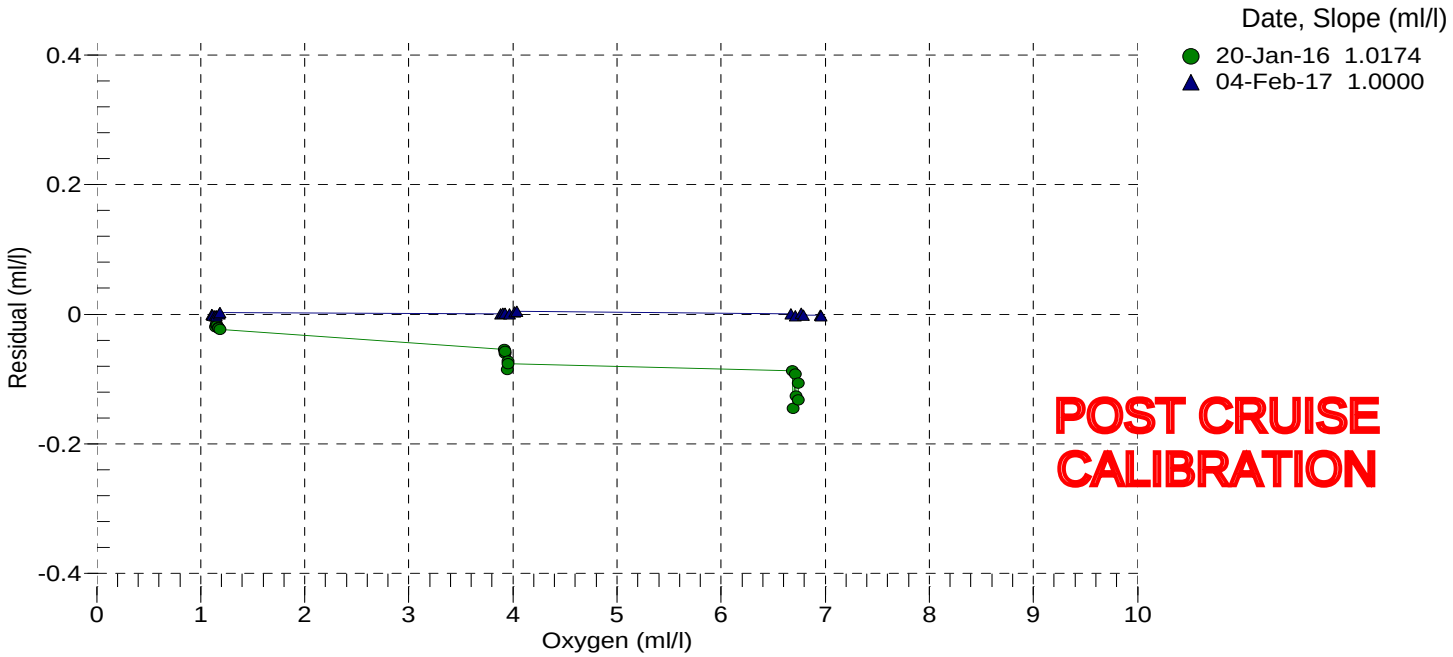
BATH OXYGEN (ml/l)	BATH TEMPERATURE (° C)	BATH SALINITY (PSU)	INSTRUMENT OUTPUT (volts)	INSTRUMENT OXYGEN (ml/l)	RESIDUAL (ml/l)
1.11	2.00	0.00	0.712	1.11	-0.00
1.12	12.00	0.00	0.777	1.12	-0.00
1.13	6.00	0.00	0.741	1.13	-0.00
1.15	20.00	0.00	0.838	1.15	-0.00
1.18	26.00	0.00	0.888	1.18	0.00
1.18	30.00	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)

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

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



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

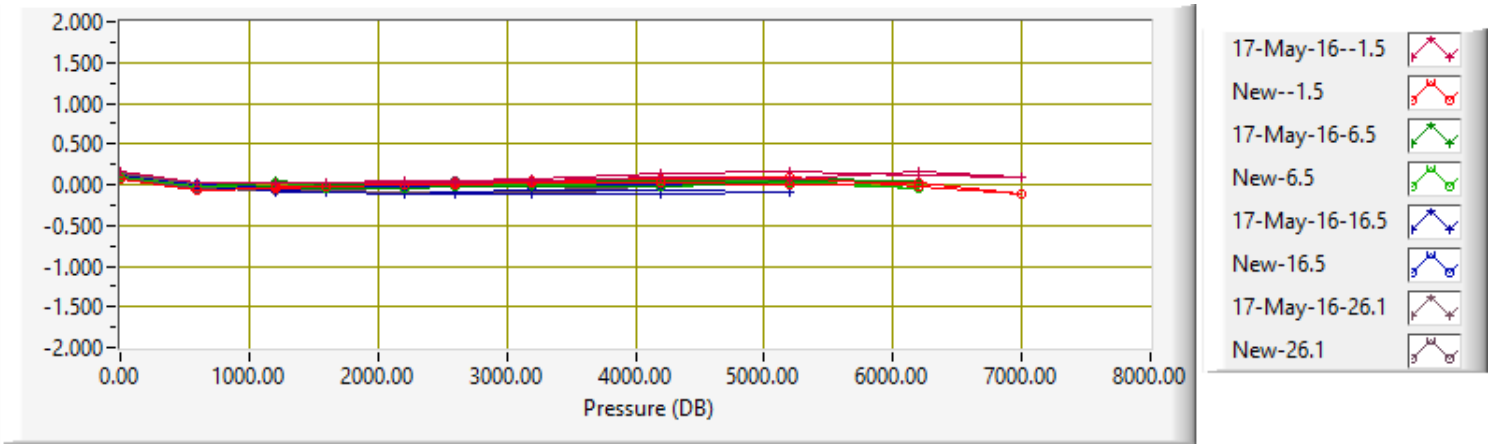
C1= -4.160528E+4
C2= -4.007210E-1
C3= 1.424636E-2
D1= 3.538591E-2
D2= 0.000000E+0
T1= 3.014002E+1
T2= -3.931397E-4
T3= 3.774435E-6
T4= 1.842545E-8
T5= 0.000000E+0
AD590M= 1.27846E-2
AD590B= -9.25586E+0
Slope = 1.00000000E+0
Offset = 0.00000000E+0

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



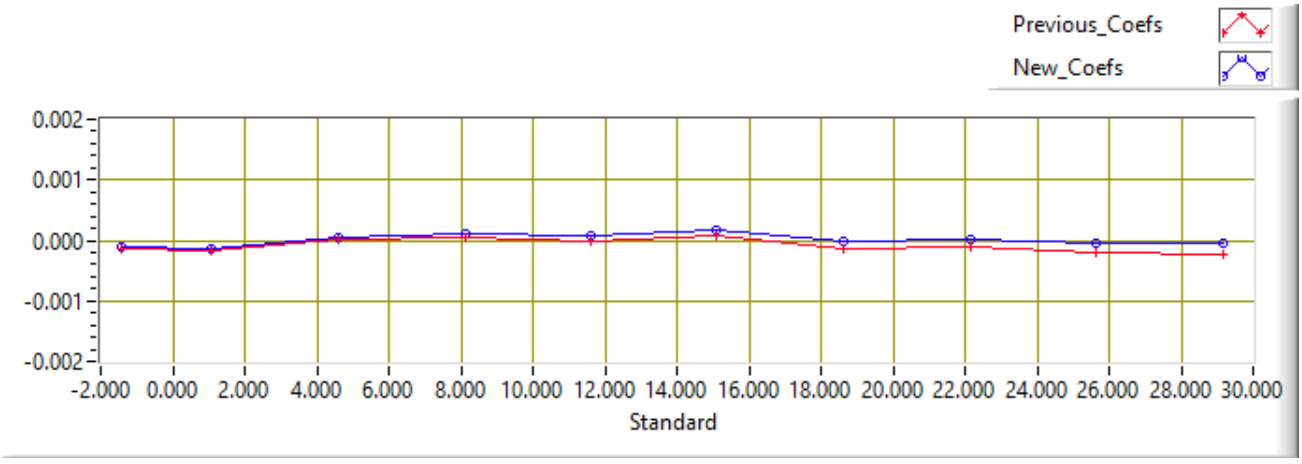
Temperature Calibration Report
STS/ODF Calibration Facility

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

SBE35 Count	SPRT ITS-T90	SBE35 ITS-T90	SPRT-SBE35 OLD_Coefs	SPRT-SBE35 NEW_Coefs
-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



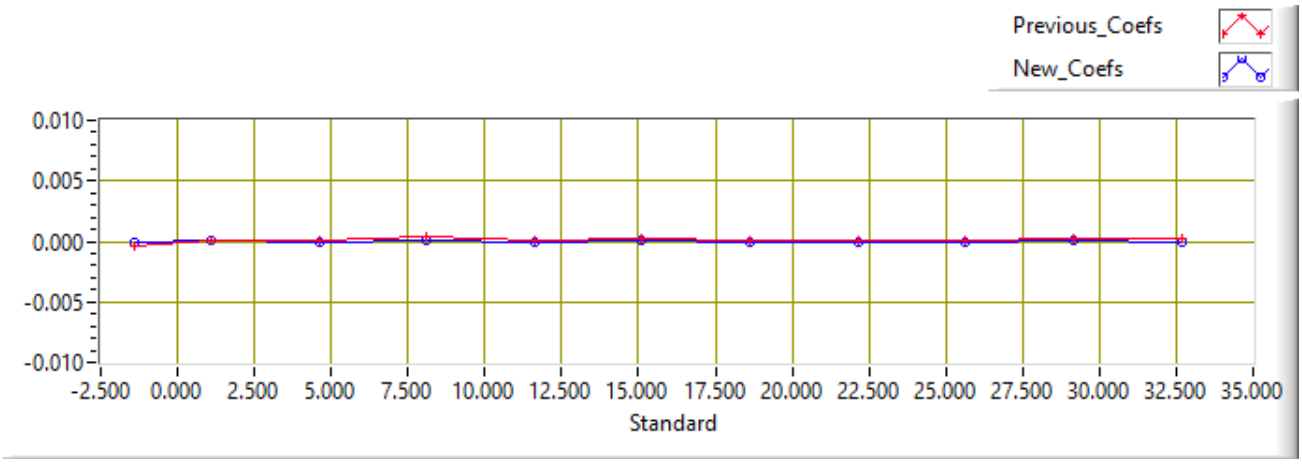
Temperature Calibration Report
STS/ODF Calibration Facility

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(f0/f)]+i[ln2(f0/f)]+j[ln3(f0/f)]} - 273.15 (°C)
Temperature IPTS-68 = 1/{a+b[ln(f0/f)]+c[ln2(f0/f)]+d[ln3(f0/f)]} - 273.15 (°C)
T68 = 1.00024 * T90 (-2 to -35 Deg C)

SBE3 Freq	SPRT ITS-T90	SBE3 ITS-T90	SPRT-SBE3 OLD_Coefs	SPRT-SBE3 NEW_Coefs
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



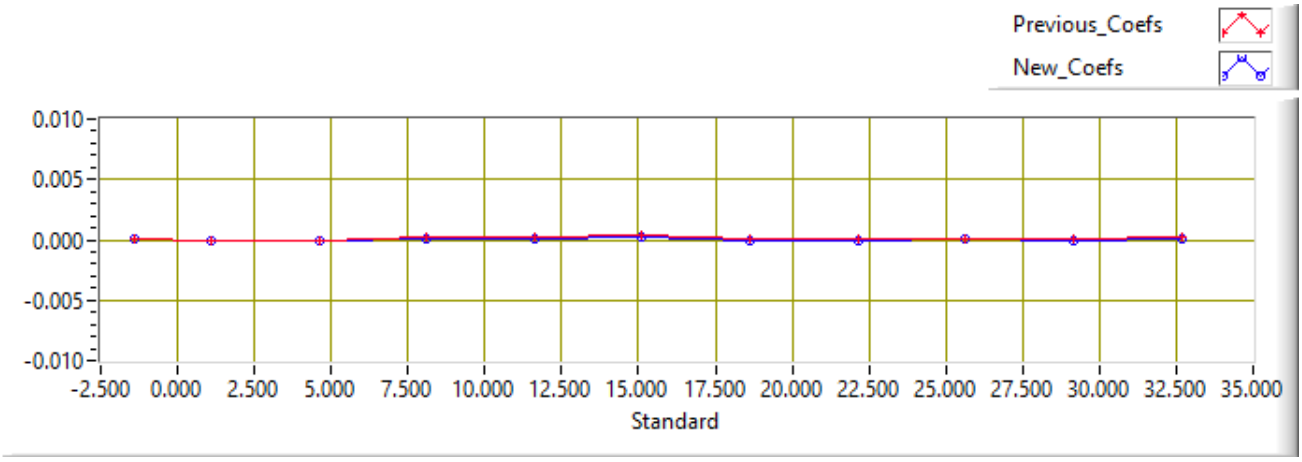
Temperature Calibration Report
STS/ODF Calibration Facility

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(f0/f)]+i[ln2(f0/f)]+j[ln3(f0/f)]} - 273.15 (°C)
Temperature IPTS-68 = 1/{a+b[ln(f0/f)]+c[ln2(f0/f)]+d[ln3(f0/f)]} - 273.15 (°C)
T68 = 1.00024 * T90 (-2 to -35 Deg C)

SBE3 Freq	SPRT ITS-T90	SBE3 ITS-T90	SPRT-SBE3 OLD_Coefs	SPRT-SBE3 NEW_Coefs
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



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WET Labs

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www.wetlabs.com

C-Star Calibration

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

	Analog output	Digital output	
V_d	0.008 V	0 counts	
V_{air}	4.813 V	15801 counts	
V_{ref}	4.699 V	15426 counts	
Temperature of calibration water			21.4 ℃
Ambient temperature during calibration			21.6 ℃

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

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

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

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

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

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

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

Ambient temperature: meter temperature in air during the calibration.

V_{sig} Measured signal output of meter.

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V

W