Cruise Report of the 2022 P02E US GO-SHIP Reoccupation

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CHAPTER

ONE

GO-SHIP P02E 2022 HYDROGRAPHIC PROGRAM

1.1 Summary

The 2022 reoccupation of leg 2 of the GO-SHIP P02 hydrographic line, RR2205 (*Fig. 1*), included 130 profiles collected on 89 stations using a 36-bottle rosette. This includes a shallow test dip carried out on the way to the first station of the section, reoccupation of 10 stations in the California Current region near the eastern end of the section, as well as 1000-m casts for the BIO-GO-SHIP[1] program collected on every third station. Additionally, four GO_BGC floats with biochemical sensors were deployed. All floats were deployed on stations with bio profiles, using an extended bottle sampling schedule. Most of the P2 section, including the entire zonal component along 30N, was collected with the target 30nm station spacing. For the 2022 occupation it was decided to follow mostly the original cross-slope/-shelf approach to the Californian coast from the 1993 WOCE cruises, which coincides with the southernmost repeat section of the CalCOFI program. One of the stations had to be moved slightly because of Navy operations in the area. Stations along this approach were spaced less than 30nm apart, with particularly close spacing over the steep continental slope. The rosette instruments included a pumped CTD with dual temperature and conductivity lines, one with oxygen (SBE43), a secondary separate RINKO oxygen sensor, fluorometer, transmissometer, upward and downward-looking LADCPs, an underwater vision profiler (UVP), two upward-looking and one downward-looking Chi-POD. Niskin bottle samples were collected and analyzed for the standard GO-SHIP set of parameters. Along all transits continuous underway shipboard multibeam bathymetry, TSG, met and pCO2 data were collected and a flow-through cytometer was run. The SADCP ran continuously. The EK-80 ran during each cast. There was also discrete underway sampling three times a day that included HPLC, POM, POC/N and DNA/RNA. See individual sections for further detail.

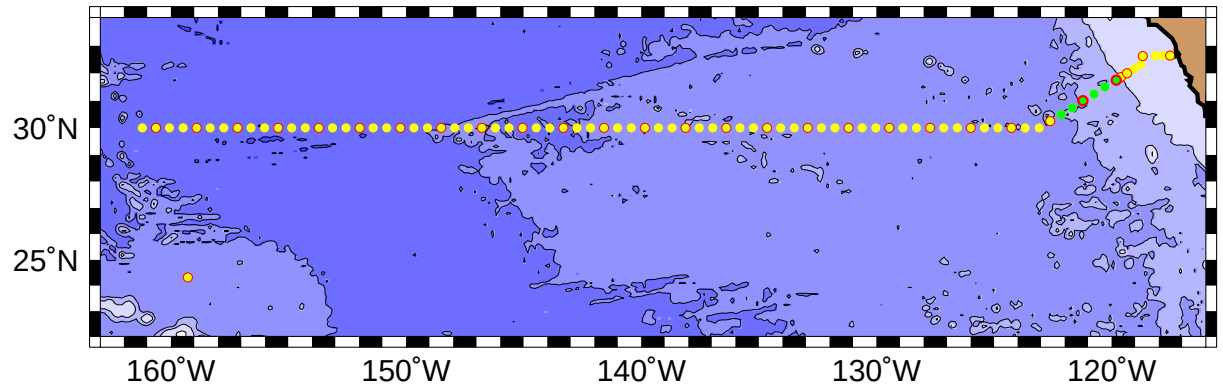

Fig. 1: Red rings: Bio stations. Green: stations of the partial re-occupation of the CCS with two full profiles (bio stations also have 2 bio profiles).

[1] Throughout "core" refers to the regular (GO-SHIP levels 1-2) sampling and "bio" refers to the biology sampling performed by the Bio GO-SHIP team. See Bio section of this report for the details on the bio sampling.

In spite of the failure of the primary winch after the first deep profile there were no significant delays due to technical problems. Therefore, and also because of the perfect weather and sea state prevailing during the cruise, the full science plan could be carried out, including an optional partial second crossing of the California Current system. Preliminary results include observations of strong climate-change trends in the abyssal temperatures and salinities in the subtropical gyre since the previous occupation of P02 in 2013, as well as the mapping of a large plume of SF6 in the eastern part of the section, that is likely caused by the propulsion system of a particular type of Navy torpedoes.

1.2 Programs and Principal Investigators

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CHAPTER

TWO

CRUISE NARRATIVE

After mobilization on June 12 the R/V Roger Revelle left Honolulu port around 1900 and headed toward the final station of leg one (station 117), which was to be re-occupied as the first station of leg 2. Before reaching the first station, shortly after noon on June 13 two shallow test dips of the CTD rosette were carried out along the way (station 901) to provide training for the student watch standers, to verify that all instruments are working and to provide the new cruise participants the opportunity to become familiar with the CTD cast logistics and sampling. After successful completion the vessel proceeded to the first station of the P2 section.

While the first CTD cast of the P2 section (station 118) was collected without problems, soon after the CTD was on deck it was discovered that the arm of the primary winch system (CAST6) was leaking hydraulic oil, which took it out of commission for the remainder of the cruise. The first two attempts at collecting a profile with the backup winch (DESH5) had to be aborted due to communications problems between the fish and the deck box. After solving the underlying problem by removing 100m of CTD wire the system performed well for the remainder of the cruise. Due to necessity of training new winch operators, many of the profiles collected during the first week had winch stops during the downcasts, usually near 100m but sometimes also about 200m above the sea bed. Additionally a conservative wire tension limit of 4000lbs prevented winch speeds greater than 20m/min during the initial parts of the upcasts until it was determined that the slow speed did not actually decrease wire tension significantly. Also during the first week there were many Niskin bottle problems including several broken lanyards and one bottle that was lost entirely, presumably because it inadvertently closed during the deployment with air trapped inside. The bottle problems persisted until most of the lanyards were replaced.

Progressing eastward along 30N stations were occupied every 30nm. The 2022 re-occupation of P2 is the first US GO-SHIP cruise carried out with additional sampling time allocated to the recently funded Bio GO-SHIP program. Beginning on station 120 every third full-depth CTD cast was therefore preceded by a “bio cast” to 1000m, where water was collected for a variety of biologically relevant parameters, some of which require large sampling volumes. Samples of the same parameters were also collected several times per day, guided by solar day time, using the flow-through system fed by a diaphragm pump (instead of the usual impeller pump) in order to preserve planktonic particles for sampling. Additionally, while on station the multifrequency EK80 sonar system was used to record vertical distributions of backscattering organisms in the water column.

Profiles 118-142 were collected inside the subtropical gyre, characterized by warm sea surface temperatures and generally low particle loads throughout the water column, as indicated by low levels of acoustic backscatter in the LADCP data. After an oblique crossing of the subtropical front on stations 143-153 the vessel entered waters affected by the California Current System, as indicated by a salinity minimum near 200m and colder sea surface temperatures (Fig. 1). The cruise track continued eastward along 30N to 123W (station 185) where it turned northeastward to follow the original WOCE line from 1993 across the continental slope, which is also sampled as part of the CalCOFI program as line 93.3. (A request for a somewhat more northerly crossing of the continental slope along CalCOFI line 90, which has been sampled continuously with gliders since 2007, was denied by the Navy.) Between 119W and 120W the cruise crossed the steep continental slope where station spacing was reduced considerably (min 0.98 nm) in order to avoid bottom-depth steps greater than 500m between adjacent profiles. The track continued on the shelf along the same heading up to 118:45 W where a northward dog-leg was required in order to avoid Navy operations in the FLETA HOT area. As a result, station 200 planned at 32:28.44 N 118:27.18 W was shifted northwestward by the Navy to 32:37.33 N 118:40.68 W, from where the remaining stations were collected in final zonal section following the final approach

to San Diego carried out during the 2004 (CLIVAR) and 2013 (GO-SHIP) occupations of the P2 repeat-hydrography section.

Due to a lack of weather and significant technical delays the vessel arrived at the easternmost station (#204) several days before the scheduled end of the cruise, even though additional sampling time between CTD profiles had been added beginning at station 186 in order to allow for a more complete sampling of the Niskin bottles by the CFC and carbon parameter analysis groups. The available time was used to re-sample part of the California Current System, starting at station 191 and working westward until station 186.

During the cruise, four BGC Argo Floats were deployed along the P2 section near 159W, 145 W, 131 W and 120 W, all without problems. All four floats returned their first profiles within a few hours of deployment, indicating that the sensors were working correctly.

The main purpose of the GO-SHIP repeat-hydrography program is to monitor the full depth ocean for long-term changes, includes the effects of global warming. Based on a subsection along 30 N between 160 and 145 W in the subtropical gyre, the upper ocean has warmed considerably compared to the base-line measurements collected during WOCE in 1993 with most of the change occurring between 2004 and 2013 (Fig. 2). In contrast to the upper ocean, the temperature at depths below 4000m has been increasing consistently since 1993, with the bottom-intensified warming rate increasing with time (Fig. 3). This abyssal warming is likely the result of a reduction in the volume of bottom water. Based on bottle salinities it appears that the abyssal warming has been accompanied by a freshening (Fig. 4) but it must be noted that the differences are smaller than the uncertainty of the salinity calibration, which include differences between different batches of standard sea water. CTD salinity differences compared to 1993 and 2004 are dominated by measurement artifacts (not shown) but the apparent abyssal differences between the 2013 and 2022 occupations of P2 are consistent with a freshening accompanying the recent warming of abyssal waters (Fig. 5).

A variety of tracers are measured as part of GO-SHIP, including SF6 (Sulfur Hexafluoride). On two stations on the California shelf (200 and 203) large concentrations of SF6 peaking at the seabed were observed (Fig. 6). The near-bottom SF6 concentration on station 200 peaks at more than twice atmospheric values, implying a source on or near the seabed. A google search revealed that SF6 is used in the propulsion system of Navy Mark 50 torpedoes making this the most likely source. While the highest SF6 concentrations were observed on the shelf, anomalies near 1000m most likely related to this source were observed several hundreds of miles off shore. A plan to re-sample station 200 at the end of the cruise in order to verify persistence of the signal there had to be aborted because the SF6 analysis system broke upon arriving at the station and repair was not feasible within the available time.

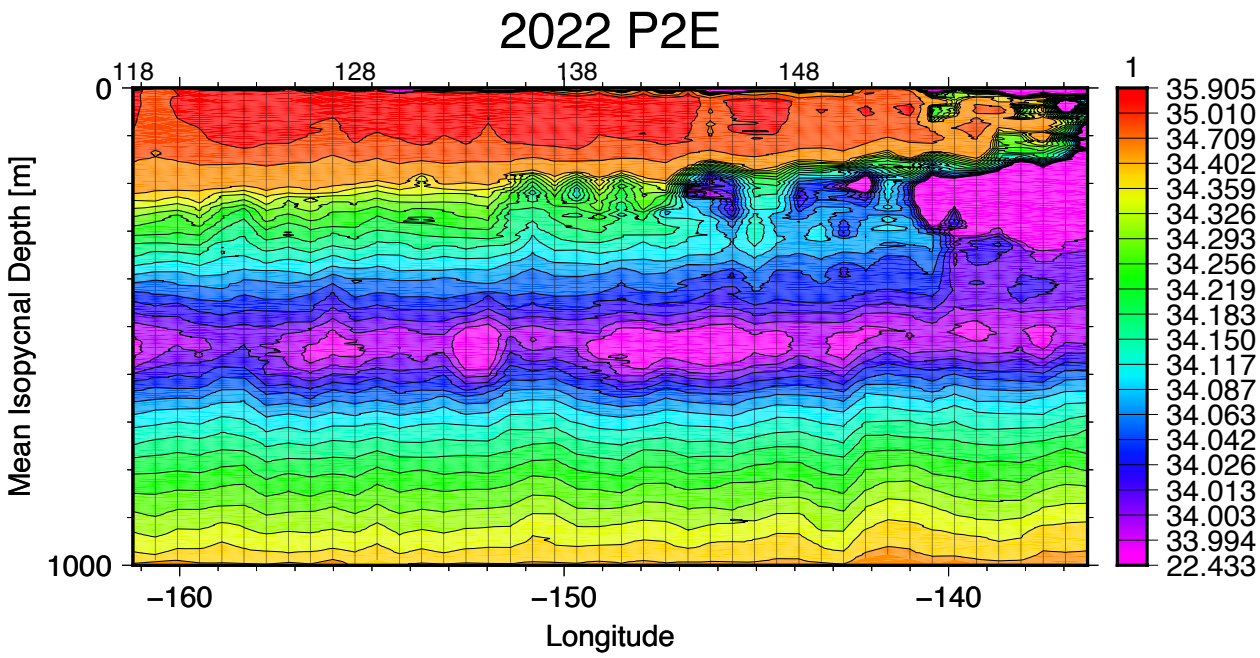

Fig. 1: Isopycnally mapped upper-ocean salinity along 30N.

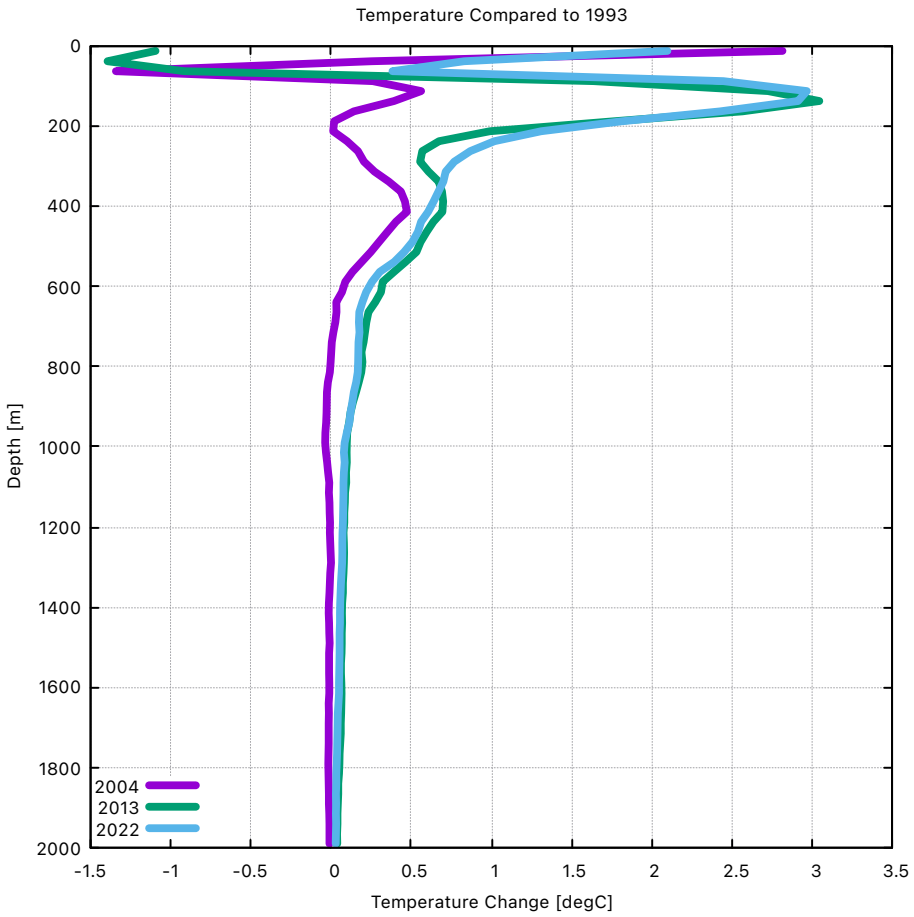

Fig. 2: Upper-ocean profiles of average temperature differences between 160 and 145W compared to the WOCE baseline hydrography collected in 1993.

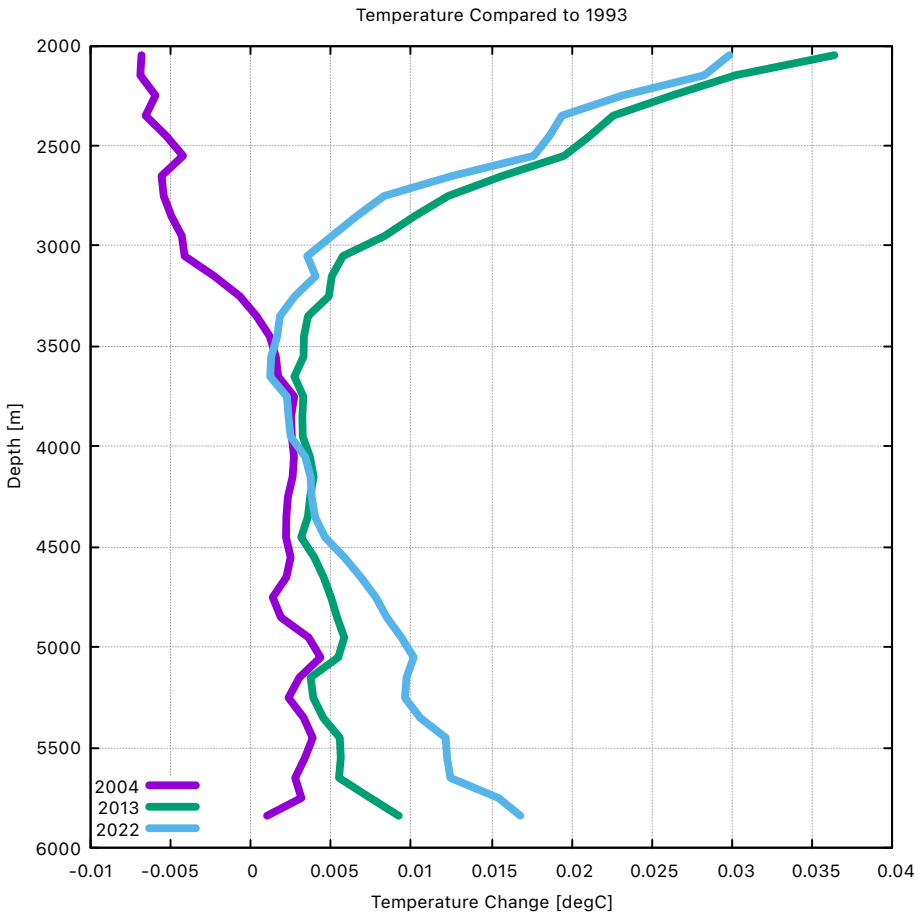

Fig. 3: Abyssal-ocean profiles of average temperature differences between 160 and 145W compared to the WOCE base-line hydrography collected in 1993.

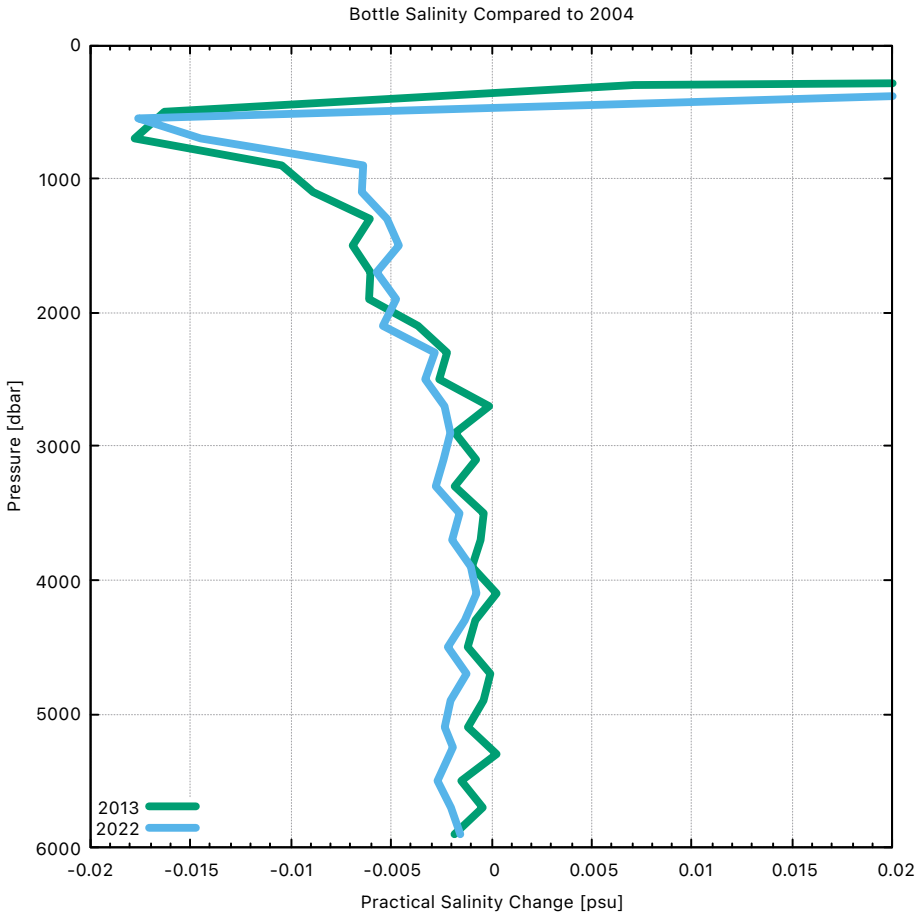

Fig. 4: Profiles of average salinity differences from bottle samples between 160 and 145W compared to the CLIVAR hydrography collected in 2004. (The 1993 WOCE bottle salinities are not consistent with the apparent freshening trend.)

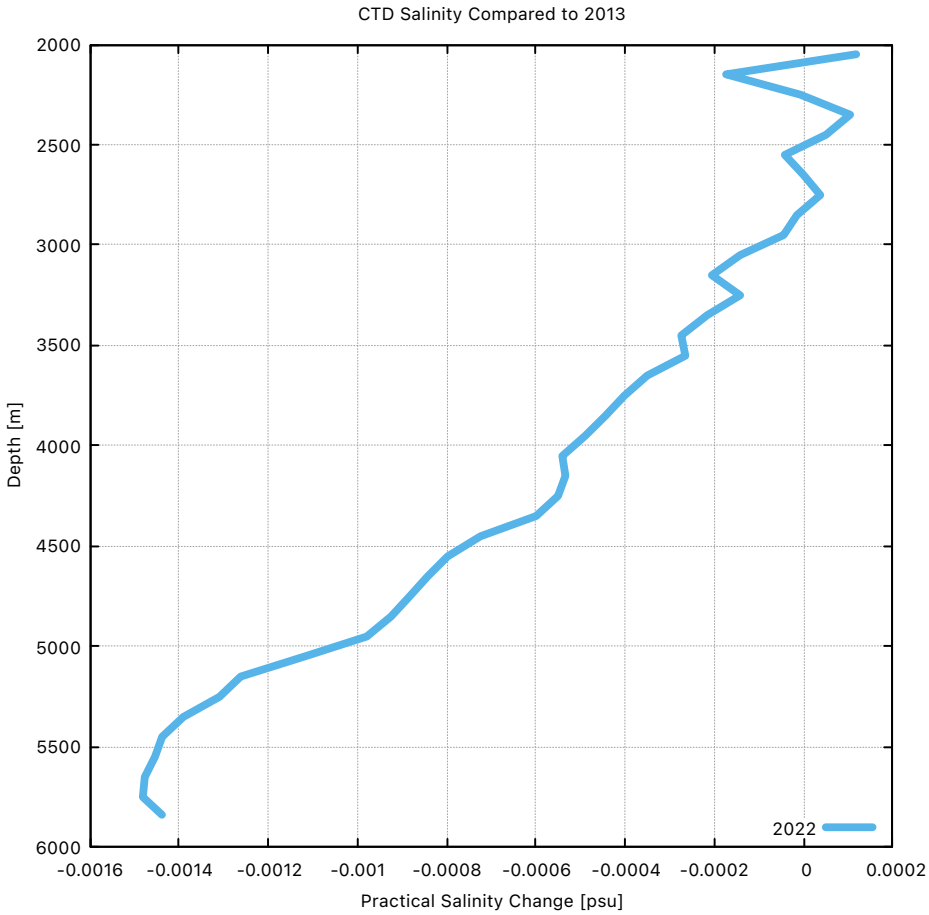

Fig. 5: Abyssal-ocean profiles of average salinity differences from CTD measurements between 160 and 145W compared to the CLIVAR hydrography collected in 2013. (The CTD salinities collected in 1993 and 2004 are not consistent with the apparent freshening trend.)

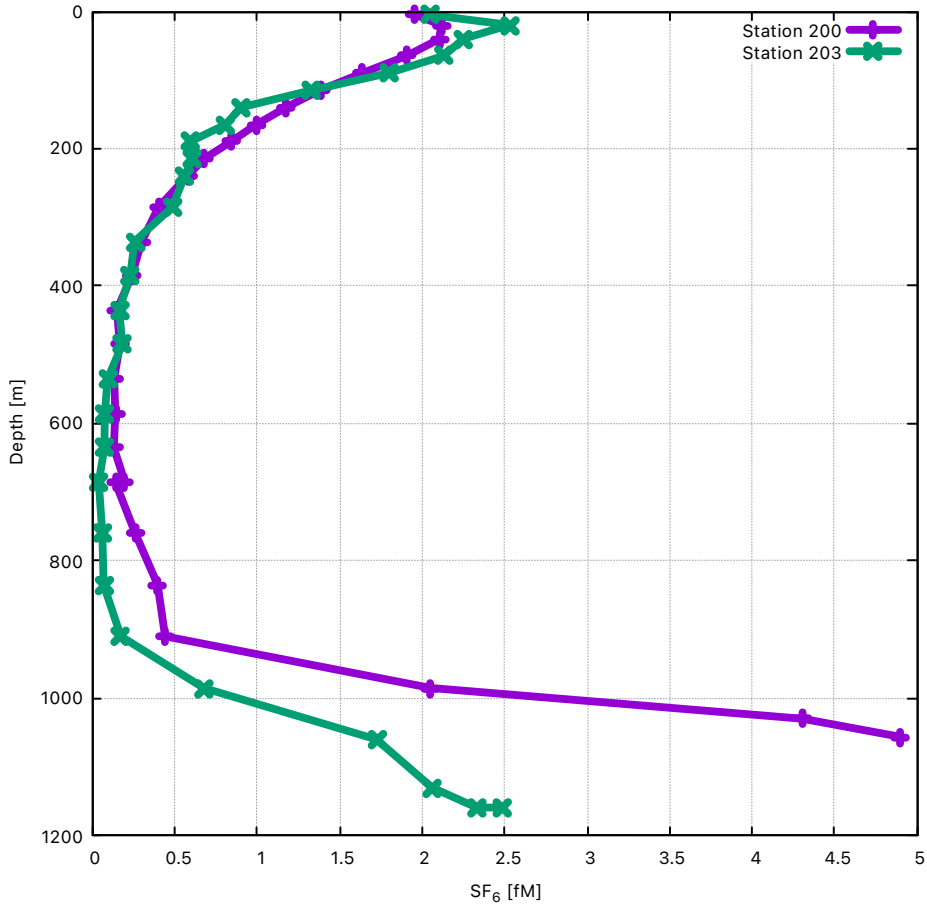

Fig. 6: Profiles of sulfur hexafluoride (SF6) collected on two stations on the California shelf.

CHAPTER

THREE

ATMOSPHERIC CONDITIONS

Between the cruise departure on June 13 and until about June 22, weather conditions were typical of the Trade Winds regime, driven by the anticyclonic atmospheric circulation around the subtropical high pressure system (North Pacific High) that was centered in the northeastern Pacific. Meteorological conditions measured onboard R/V Revelle included easterly winds around 15 knots, while sea surface and air temperature (26.5 ºC and 24.5 ºC respectively at the start of the cruise) gradually decreased as we steamed eastward. We also observed predominantly cumulus clouds during the day.

Between June 26 and 28, measurements from the ship sensors indicated a gradual increase in atmospheric pressure and wind speed values falling down to 3 m/s. At that time, the ship's track entered the southern edge of the North Pacific High. The low wind conditions combined with high daily shortwave radiation and reduced cloud cover led to intensified heating of the upper ocean as seen in higher sea surface temperature values. The calmest sea state of the cruise were observed during this period.

In early July, as the ship was entering its southeastern corner, the North Pacific High started moving west (as seen in weather forecast imagery from the www.PassageWeather.com, and kindly provided by Shuwen, the co-chief scientist from leg 1). The weather conditions we experienced were not tropical anymore, as the wind became more northerly while air relative humidity increased and stratus clouds became predominant. Sea surface and air temperature dropped to their coldest values of the cruise (17.5 ºC and 15 ºC respectively) near July 10. As the ship entered the shelf off California on July 12, warmer sea surface and air temperatures increased again.

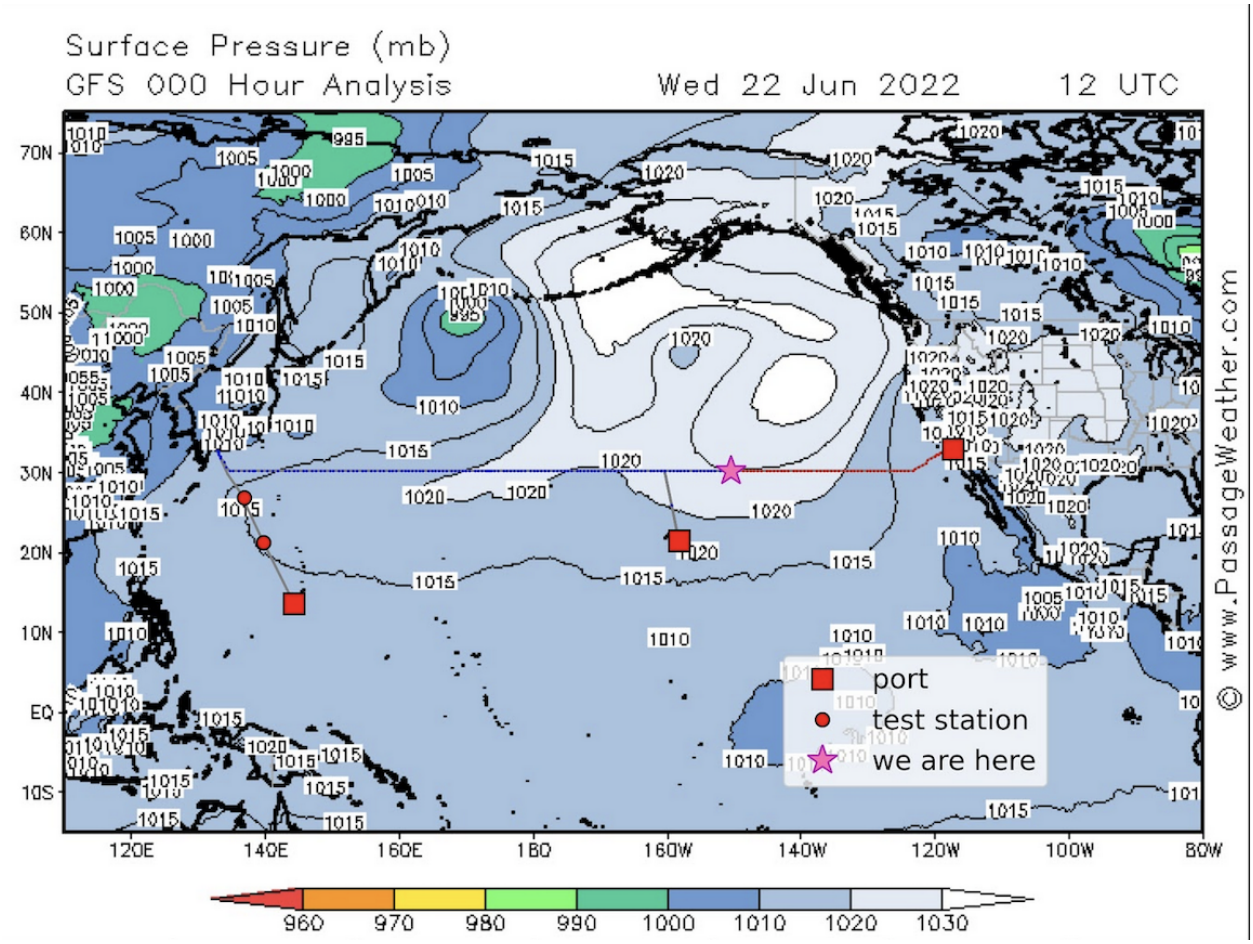

Fig. 1: Pressure on June 22 2022 from the Global Forecast System (GFS) weather forecast model at the National Centers for Environmental Prediction (NCEP). Imagery provided from www.PassageWeather.com. Track of R/V Revelle during leg 2 (red line). Ship's location on June 22 (pink star) is to the southwest of the North Pacific High anticyclone.

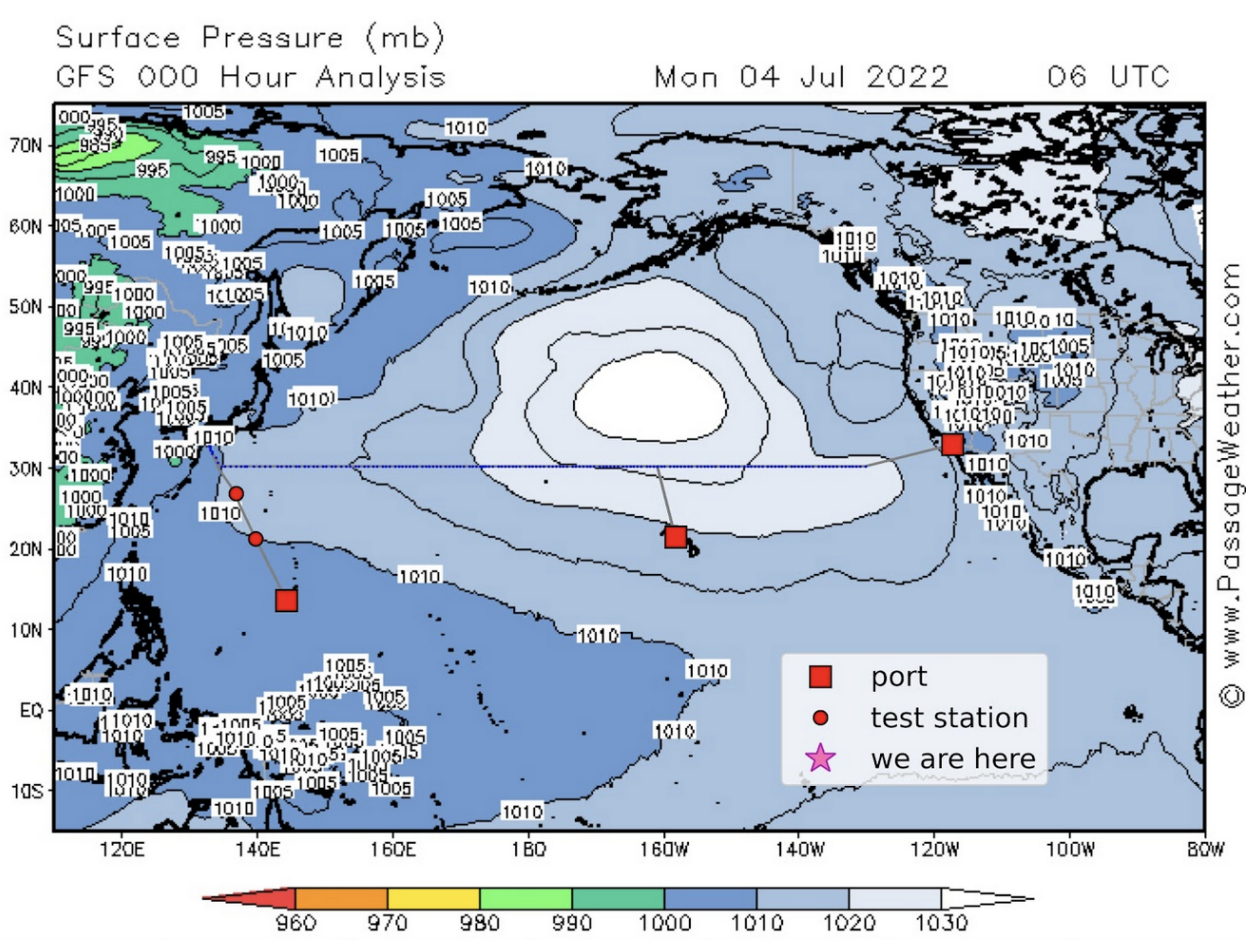

Fig. 2: Same as figure above, but for July 4 2022. The North Pacific High has moved west.

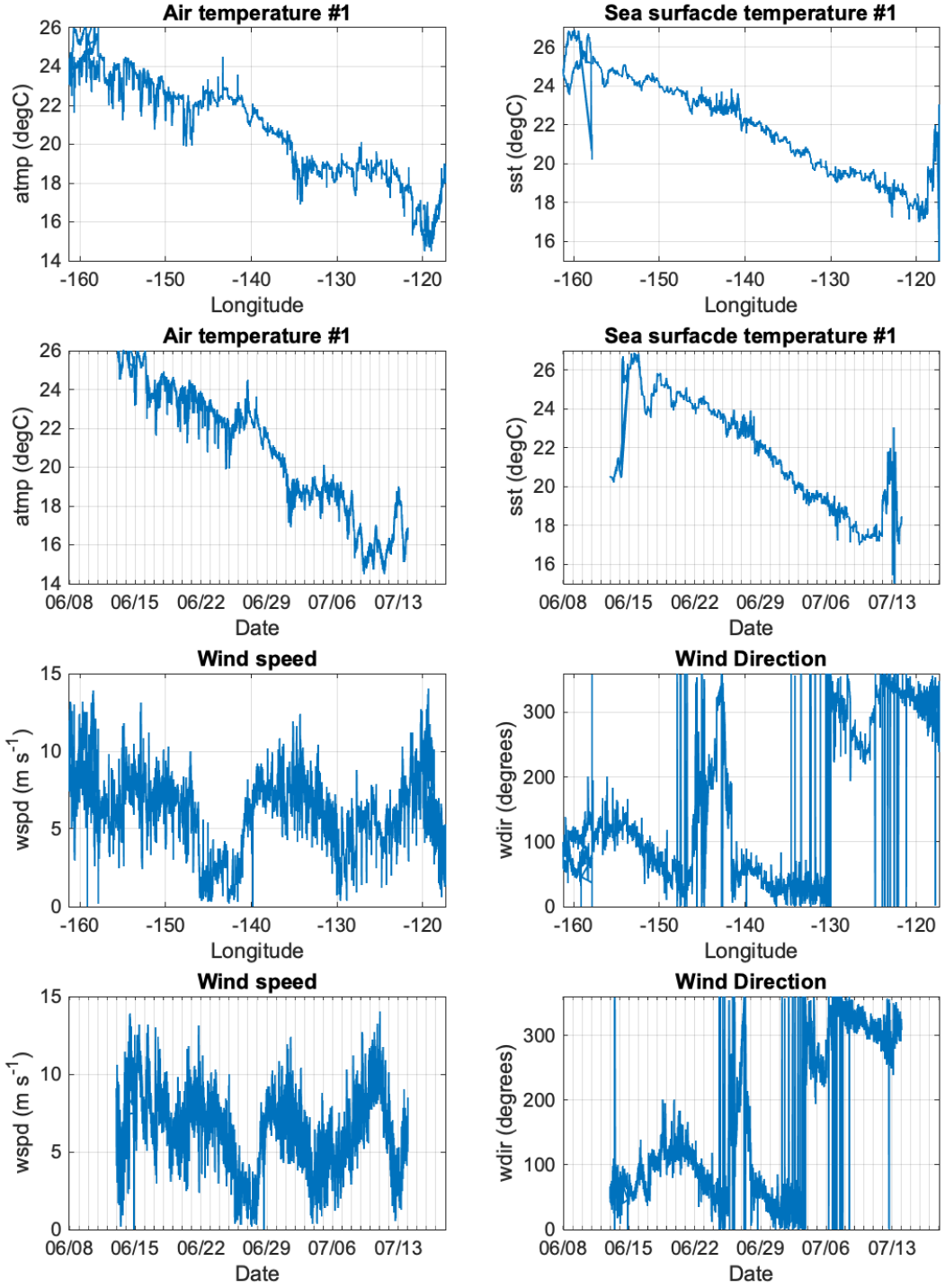

Fig. 3: Meteorological measurements from R/V Revelle during GOSHIP P02 leg 2 in 2022, shown as function of longitude (top subplot) and time (bottom subplot). Air temperature (top left), sea surface temperature (top right), wind speed (bottom left), wind speed (bottom right).

CHAPTER

FOUR

CTD AND ROSETTE SETUP

For P02E-2022 a *SIO STS* 36-place yellow rosette and bottles were used. The rosette was sent to Guam in early January, 2022 for P02W. The rosette and bottles were built before P06 2017, making this the fourteenth time this package has been deployed. A steel bridle was added to the top of the rosette to adapt to the winch head. The bottles were made with new PVC, with new non-baked o-rings and electro-polished steel springs. Springs within the Bullister-style Niskin bottles were electropolished stainless steel. Bottle lanyards were made from 300-pound monofilament. No sample contamination has been noticed by the change in o-rings and springs. The package used on P02E-2022 weighs roughly 1500 lbs in air without water and 2350 lbs in air with water. The package used on P02E-2022 weighs roughly 950 lbs in water. In addition to the standard *CTDO* package on GO-SHIP cruises three chipods, two *LADCP*, and one *UVP* were mounted on the rosette.

During the cruise we encountered a handful of problems, most notably noise between the primary and secondary CTD lines. We describe all of the above in more detail in the sections below.

4.1 Underwater Sampling Package

CTDO/rosette/LADCP/UVP/chipod casts were performed with a package consisting of a 36 bottle rosette frame, a 36-place carousel and 36 Bullister style Niskin bottles with an absolute volume of 10.6 L. 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, RINKO oxygen optode, transmissometer, chlorophyll-a fluorometer, and altimeter were also mounted on the rosette. Chipod, LADCP, and UVP instruments were deployed with the CTD/rosette package and their use is outlined in sections of this document specific to their titled analysis.

CTD and cage were 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 intakes for the pumped temperature sensors. The transmissometer was mounted horizontally on the lower LADCP brace with hose clamps, avoiding shiny metal inside that would introduce noise in the signal. The hose clamps for the transmissometer were covered in black electrical tape. The oxygen optode, fluorometer, and altimeter were mounted vertically inside the bottom ring of the rosette frames, with nothing obstructing their line of sight. One 300 KHz bi-directional Broadband LADCP (RDI) unit was mounted vertically on the bottom side of the frame. Another 300 KHz bi-directional Broadband LADCP (RDI) unit was mounted vertically on the top side of the frame. The LADCP battery pack was also mounted on the bottom of the frame. The LADCP and LADCP battery pack were mounted near (90°) each other at the beginning of the cruise. Imagining the bow of the ship to be north, the LADCP battery was mounted on the south side of the rosette, the up/down LADCPs were on the west side, the UVP on the east, and CTD mounted to the north (Figure 1).

Table 1: (*) LADCP was swapped for the partial re-occupation of the California Current System following station 205.

Equipment	Model	S/N	Cal Date	Stations	Group
Rosette	36-place	Yellow	–	118-205	*STS*/*ODF*
CTD	SBE9+	1281	–	118-205	*STS*/*ODF*
Pressure Sensor	Digiquartz	136428	Dec 7, 2021	118-205	*STS*/*ODF*
Primary Temperature	SBE3+	36049	Mar 17, 2022	118-205	*STS*/*ODF*
Primary Conductivity	SBE4C	43578	Mar 22, 2022	118-205	*STS*/*ODF*
Primary Pump	SBE5	51892	–	118-196	*STS*/*ODF*
Primary Pump	SBE5	51781	–	197-205	*STS*/*ODF*
Secondary Temperature	SBE3+	34138	Mar 17, 2022	118-205	*STS*/*ODF*
Secondary Conductivity	SBE4C	42569	Mar 17, 2022	118-205	*STS*/*ODF*
Secondary Pump	SBE5	53626	–	118-205	*STS*/*ODF*
Transmissometer	Cstar	1873DR	Jan 5, 2022	118-205	*TAMU*
Fluorometer Chlorophyll	WetLabs ECO-FL-RTD	4334	–	118-205	*STS*/*ODF*
Dissolved Oxygen	SBE43	431508	Oct 8, 2021	118-205	*STS*/*ODF*
Oxygen Optode	JFE Advantech Rinko-III	0251	Apr 7, 2017	118-205	*ODF*
Reference Temperature	SBE35	0105	Mar 15, 2022	118-205	*STS*/*ODF*
Carousel	SBE32	1178	–	118-205	*STS*/*ODF*
Altimeter	Valeport 500	53821	–	118-205	*STS*/*ODF*
UVP	–	201	–	118-205	*UAF*
LADCP (uplooker)	WHM300kHZ	12734		118-205	*LDEO*
LADCP (downlooker)	WHM300kHZ	3441		118-205	*LDEO*
LADCP (downlooker)	WHM300kHZ	24477		186-191(*)	*LDEO*
Chipods	Chipod	2014 Ti44-8	–	118-162	*OSU*
Chipods	Chipod	2013 TI44-12	–	118-162	*OSU*
Chipods	Chipod	2032 Ti44-15	–	118-162	*OSU*
Chipods	Chipod	2025 Ti44-7	–	163-205	*OSU*
Chipods	Chipod	2017 TI44-6	–	163-205	*OSU*
Chipods	Chipod	2027 Ti44-?	–	163-205	*OSU*

4.2 Winch and Deployment

The CAST6 winch and deployment system was used for the two test stations and the first core station. After a hydraulic oil leak was found, the rosette was switched to the DESH5 winch for remaining stations. The rosette system was suspended from a UNOLS-standard three-conductor 0.322" electro-mechanical sea cable. The sea cable was terminated with an Evergrip (primary), Guy Grip (secondary), and set of Crosby Clips (tertiary). No electrical issues occurred on P02E.

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 outside of the rosette before the next cast, and the inside of the bottles were checked for biofouling and sprayed down. The LADCP technician would check for LADCP battery charge, prepare instrument for data acquisition, and disconnect cables. The LADCP technician also dealt with the UVP, disconnecting cables at the same time. Once stopped on station, the Marine Technician would check the sea state prior to cast and decide if conditions were acceptable for deployment. The rosette was moved from the sampling bay out to the deck using the *Revelle's* tugger-driven cart while using the CAST6. Following the switch to the DESH5, the rosette was moved from the sampling bay using a pallet jack. Once on deck, sea cable slack was pulled up by the winch operator. CTD watch standers would then turn on the deckbox and begin data acquistion, and the cast would begin. For casts performed with the DESH5, members of the science party used taglines to assist with deployment and recovery. Recovering the package at the end of the deployment was the reverse of launching.

Fig. 1: Package sensor setup from south (for all rosette figures, orientation is defined as north being toward the bow).

Fig. 2: Package sensor setup from east.

Fig. 3: Package sensor setup from north.

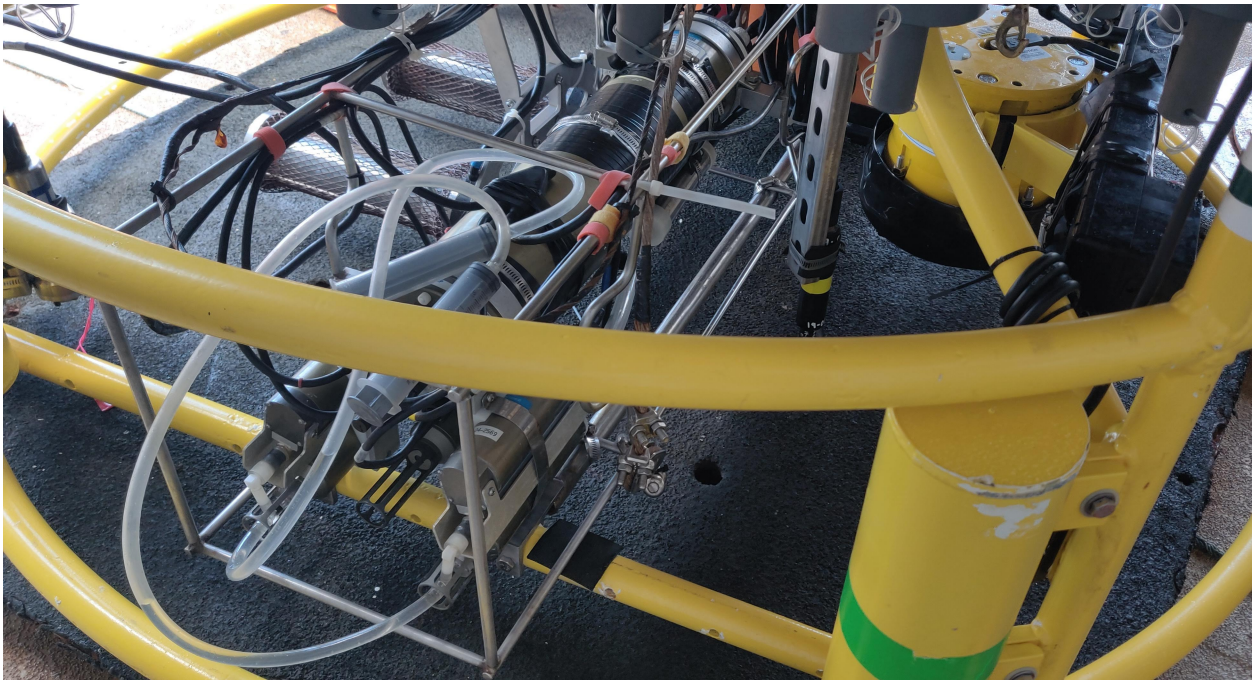

Fig. 4: Package setup from southwest, from left to right: CTD cage, downward facing chipod, downward facing LADCP, transmissometer bar.

Fig. 5: Package setup from southwest, from left to right: (Foreground) ECO fluorometer, UVP, RINKO, altimeter.

Fig. 6: Package setup from west.

Fig. 7: Package setup from west, top view.

Once rolled back into the sampling bay, a technician secured the cart to the deck using additional ratchet straps. The carousel was rinsed and sensors were cleaned (as described below) after every cast, and then samplers were allowed to begin collecting water.

4.3 Maintenance and Calibrations

During P02E-2022 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 and adjusting hose clamps and guide rings as needed such that lanyards had appropriate tension. 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, syringes of fresh water were connected to the plumbed lines to rinse the sensors and allow them to soak between casts. The rosette was routinely examined for valve and o-ring leaks, which were maintained as needed. SBE35RT temperature data was routinely downloaded each day.

Every 20 stations, the transmissometer windows were cleaned and on deck blocked and un-blocked voltage readings were recorded prior to the cast. The transmissometer was also calibrated before the start and after the end of science operations.

“Dark” bio casts were performed periodically, where the fluorometer sensor face was covered with black electrical tape. Dark casts allowed for background noise to be measured as function of depth, since the fluorometer would not measure any signal.

4.4 Logs

In port: Preparation of the CTD and rosette was minimal as it had the same setup as P02W 2022, which had just been completed. Integrity checks on the rosette, such as checking lanyard angles, o-ring and lanyard replacement, and spigot movement were performed during fueling before transit to test station. We are using a new mounting system for the downward looking LADCP which has the LADCP clamped facing inward instead of outward, which will cause problems if we need to change that LADCP in rough weather.

June 14, 2022

90101 - Test bio cast to 1000 m. While cocking bottles, #19 top inner-lanyard came untied and suddenly released the spring tension. Deferred fixing lanyard until during transit to first station to save time.

90102 - Test core cast to 1000 m. No issues of note besides missing bottle #19.

June 16, 2022

11801 - Bottle #19 leaking from bottom o-ring; replacement inner-lanyard likely too long causing spring to be under-tensioned. CAST6 hydro boom found to be leaking hydraulic fluid after cast; swapping rosette to DESH5, which will require taglines for deployment and recovery, manual winch payout, and sampling out on deck instead of the hangar.

11901 - Bio cast aborted at 40 m due to modulo errors and RS-232 comms failure. Termination is bad and water was intruding under pressure; cut off 10 m of cable and there was water inside. Before next cast, deck was scrubbed with Simple Green to remove oil slick. Sensors were capped, bottles were closed, and rosette cover put on before scrubbing.

11902 - Bio cast aborted again at 40 m due to RS-232 comms failure. Cut off 100 m of cable and conductor wires had much less corrosion. Reterminated and attempting another cast.

11903 - Bio cast successful to 1000 m and back.

11904 - Bottle #34 outer lanyard broke from abrasion. Bottle #19 inner-lanyard swapped after cast.

June 17, 2022

12001 - Bottle #17 top knot came untied and released spring tension (same as 90101 bottle #19) during prep; cast performed with capless bottle #17. Bottle #19 leaking again upon recovery; swapped in a new Niskin bottle.

12101 - Swapped in new Niskin bottles for #17 and #19 before cast. Rosette came back to surface missing bottle #30. Bottle #17 leaking from bottom on recovery after opening air vent; outer lanyard may be too tight and preventing bottle from staying well sealed.

12201 - Bottle #19 swapped out and bottle #30 replaced, both are spares from Revelle's stockpile. Bio cast + float

12202 - Bottle #5 closed on ADCP cable and did not seal; was not sampled. Bottle #19 has low temp, likely closed early. Adjusted bottle downward before deployment such that it had sufficient tension when cocked without being overtensioned after being fired.

June 18, 2022

12301 - Bottle #19 draw temperature a little low; lanyard was a little loose and likely closed itself during downcast. Tightened up before next cast.

12401 - Bottle #11 did not fire, trigger is sticky.

12501 - Dark bio cast; fluorometer was not fully taped over and still had some response.

June 19, 2022

12502 - No issues noted.

12601 - Chipod #12 was flooded, swapped with #11. Bottle #10 lanyard was routed around neighboring standoff and bottom cap was stuck open; no water at all in bottle.

12701 - Lowered bottle #6 before cast, top handle was bumping into frame.

12801 - Bio cast; No issues noted.

12802 - No issues noted.

June 20, 2022

12901 - Bottle #30 had small leak; top bottle mating surface has a gouge in it, swapping in the original bottle #17. Replaced spigot on bottle #12.

13001 - No issues noted.

13101 - Bio cast; No issues noted.

13102 - Bottle #33 did not fire. Bottles #15 and 16 had vent caps left open. Bottle #28 CFC syringe broke so will not have a sample

June 21, 2022

13201 - No issues noted.

13301 - Bottle #2 exceptionally warm; check other params.

13401 - Bio cast; No issues noted.

13402 - Bottle top caps hit with hook during recovery. Oxygen data makes it appear to be #18 and 19.

June 22, 2022

13501 - No issues noted.

13601 - Altimeter a little spiky at bottom, could be ground composition causing bad returns.

13701 - Bio cast; No issues noted.

13702 - 1 modulo error around ~5700 m. Mistripped 8 bottles (27-34) at same depth, keyboard/user error.

13703 - Re-cast to 350 m. Bottle #10 bottom cap was left uncocked, flag bad.

June 23, 2022

13801 - Lowered bottles #17 and 19 before cast to prevent issue of hitting bottle tops with gaffing hooks.

13901 - Change out top o-rings and air vents on bottle #4 and 28 before cast.

14001 - Bio cast; No issues noted.

14002 - Bottle #17 top inner-cap lanyard broken at depth, came back missing spring.

June 24, 2022

14101 - No issues noted.

14201 - No issues noted.

14301 - Bio cast; No issues noted.

14302 - Outer lanyards on bottles #34 and 35 changed before due to visible chafing.

June 25, 2022

14401 - Noisy T/C residuals during soak, likely due to prop wash and/or the soak being very near the thermocline.

14501 - New spigot on bottle #1. Swapped clear monofilament on top cap of bottle #17 for newer, blue mono. New inner-cap lanyards on bottles #11, 22, and 32 due to slightly abrasion. Zeroes in SBE3+ primary are back

14601 - Bio cast; No issues noted.

14602 - Bottle #33 did not fire. Salinity bottle #9 from box B was chipped and replace after cast.

June 26, 2022

14701 - No issues noted.

14801 - Swap cables on T1 and T2 to see if zero frequency issue follows cable. Zeroes stayed on same sensor (T1), issue believed to be the SBE9+ (CTD).

14901 - Bio cast; No issues noted.

14902 - No issues noted.

15001 - No issues noted.

June 27, 2022

15101 - No issues noted.

15201 - Bio cast; No issues noted.

15202 - No issues noted.

15301 - No issues noted.

June 28, 2022

15401 - Bottle #14 leaking again, Gabe says PVC weld failing. Swapping in one from backup rosette.

15501 - Bio cast; No issues noted.

15502 - No issues noted.

15601 - Rusty spring found in bottle #14, replaced after cast.

15701 - RS-232 comms timeout error mid-cast @ 3870m

June 29, 2022

15801 - No issues noted.

15802 - No issues noted.

15901 - Bottle #6 leaking

16001 - Bottle #6 leaking again, changed bottom o-ring.

June 30, 2022

16101 - No issues noted.

16102 - Bottle #6 leaking, velcro stuck in cap.

16201 - No issues noted.

16301 - Swapped all chipod pressure cases before cast. Taglines wrapped around spigots during deployment.

16401 - Dark bio cast. CFCs sampled bottle #25 but syringe was left open and leaked.

July 1, 2022

16402 - RS-232 comms timeout error at 1650m, data acquisition was not interrupted.

16501 - Changed o-ring on bottle #19. O2 resampled bottle #31

16601 - Bottle #4 leaking; swap air vent and top cap o-rings.

16701 - No issues noted.

16702 - No issues noted.

July 2, 2022

16801 - No issues noted.

16901 - No issues noted.

17001 - Bio float; No issues noted.

17002 - No issues noted.

July 3, 2022

17101 - No issues noted.

17201 - Adjusted guide rings on bottles 2 and 22 to tighten up bottom handles.

17301 - Bio cast; No issues noted.

17302 - SeaSave stopped responding during bottle stop; mouse still working; fixed itself after 30s or so.

17401 - RS-232 comms timeout error at 750m

July 4, 2022

17501 - No issues noted.

17601 - Bio cast + sampling for “planktoscope”

17602 - No issues noted.

17701 - No issues noted.

17801 - No issues noted.

July 5, 2022

17901 - Bio cast; No issues noted.

17902 - No issues noted.

18001 - Salts sampled by multiple people, bottles in box out of order.

18101 - No issues noted.

18201 - Bio cast; No issues noted.

July 6, 2022

18202 - No issues noted.

18301 - Ship lost power during 20m soak; aborted and recovered.

18302 - No issues noted.

18401 - No issues noted.

18501 - Bio cast; No issues noted.

July 7, 2022

18601 - No issues noted.

18701 - No issues noted.

18801 - Bio cast; No issues noted.

July 8, 2022

18802 - No issues noted.

18901 - No issues noted.

19001 - No issues noted.

19101 - Bio cast, float; No issues noted.

July 9, 2022

19102 - No issues noted.

19201 - No issues noted.

19301 - Primary T/C/O extremely spiky at 300m on upcast, most likely clogged. Upon recovery, primary plumbing was opaque with biofouling. Tubes removed and cleaned; re-assembled plumbing and cleaned sensor line with with 1% Triton-X, flush with fresh water. Secondary line plumbing was loose from C to pump, slid pump forward to close gap.

July 10, 2022

19401 - Test cast to 100m to make sure plumbing is okay.

19402 - Bio cast; No issues noted.

19403 - Aborted, UVP shunt not removed

19404 - No issues noted.

19501 - No issues noted.

19601 - Primary pump problems again near bottom, no bio-fouling upon recovery. Top o-ring on impeller was broken with 1/3 fully missing; swapped in 05-1781.

19701 - Test cast to 100m to check new pump. Primary/secondary residuals still poor over full cast.

19702 - Swapped y-cable and rotated pump to have exhaust at 45º angle. Deck to ensure pump flow, looks fine. Test cast turned bio cast.

19703 - No issues noted.

July 11, 2022

19801 - Salt bottle #5 from box S dropped during sampling and broken; replaced with spare.

19901 - No issues noted.

20001 - Bio cast; No issues noted.

20002 - No issues noted.

July 12, 2022

20101 - RS-232 comms failure on upcast at ~400m, modulo error and overflow light on deckbox. Power cycled deckbox, restarted acquisition in 20101_2 file without issue for remainder of cast.

20201 - No issues noted.

20301 - Bio cast; No issues noted.

20302 - Bottle #3 bottom cap found unclipped during recovery, likely uncocked during deployment.

20401 - No issues noted.

July 13, 2022

19103 - Dark bio cast; No issues noted.

19104 - No issues noted.

19002 - No issues noted.

July 14, 2022

18902 - Salt bottle #33 from box S broken during sampling.

18803 - Bio cast; No issues noted.

18804 - No issues noted.

18702 - No issues noted.

18602 - No issues noted.

4.5 Sensor Problems

Biofouling: The SBE5 pump on the primary T/C/O line showed signs of bad flow starting during the upcast on 19301 (Fig. 1). Upon recovery, plumbing tubes were opaque with biofouling. Plumbing was disassembled and cleaned with 1% Triton-X. The lines were then re-attached to the T/C/O sensors and the entire line was flushed with the same 1% Triton-X and then flushed with fresh water.

Pump problems: The primary pump became an issue again on cast 19601 with what appeared to possibly be another clog. Upon recovery, no biofouling was found so the pump was removed and inspected. The top o-ring on the impeller was broken and assumed to be the cause. Pump 5-1781 was swapped in and deployed for a test cast. T/C residuals between primary and secondary line were erratic during test cast to 100m. Rosette was recovered and the pump exhaust was re-oriented to 45º and the y-cable was swapped. Deck test and test cast ensured pump was now working fine.

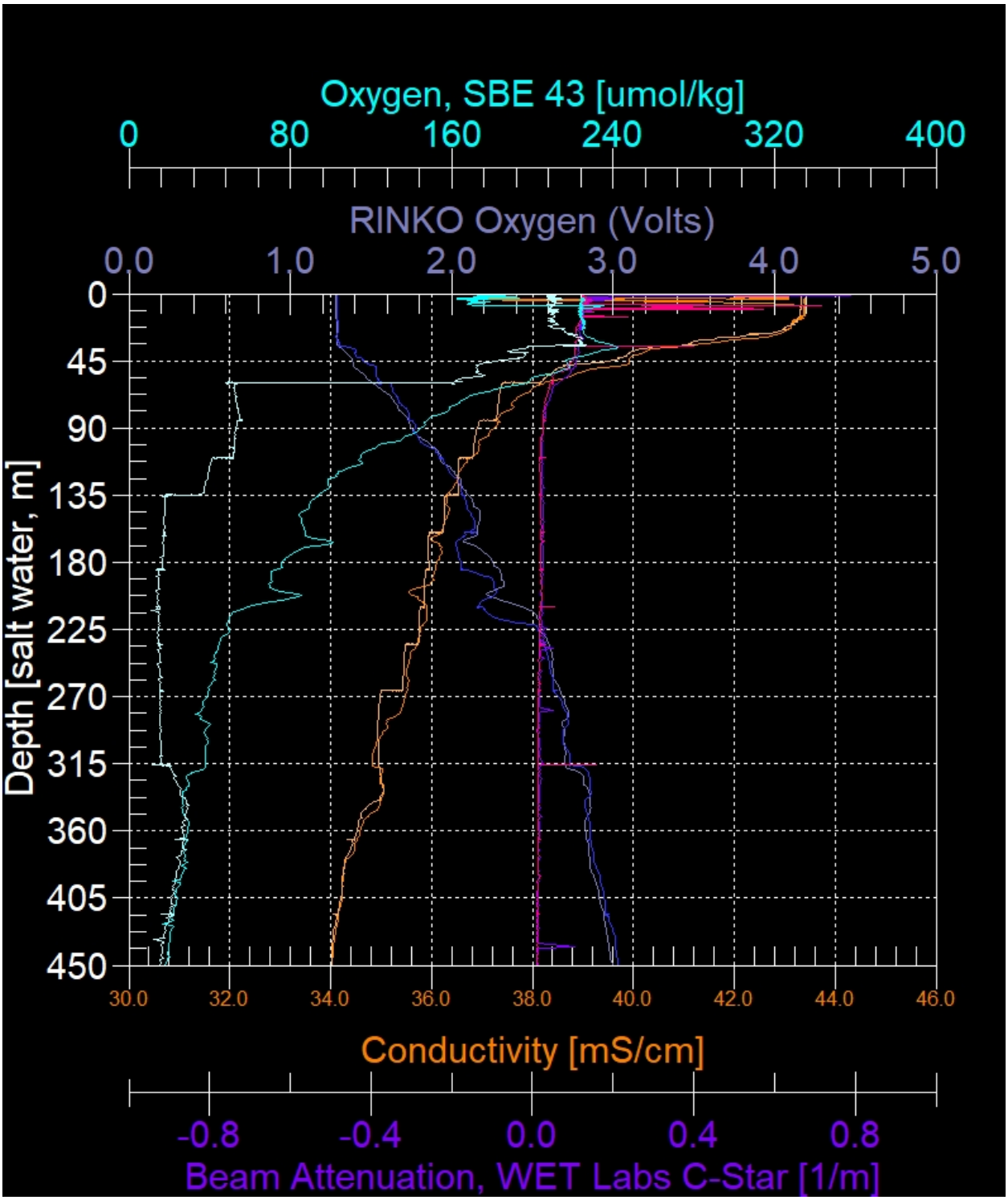

Fig. 8: Biofouling/clog evident at 315m due to oxygen decrease and staying constant during upcast.

CHAPTER

FIVE

CTDO AND HYDROGRAPHIC ANALYSIS

PIs

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5.1 CTDO and Bottle Data Acquisition

The CTD data acquisition system consisted of an SBE-11+ (V1) deck unit and a networked generic PC workstation running Windows 10. SBE SeaSave7 v.7.26.7.121 software was used for data acquisition and to close bottles on the rosette.

CTD deployments were initiated by the console watch operators (CWO) after the ship had stopped on station. The watch maintained a CTD cast log for each attempted cast containing a description of each deployment event and any problems encountered.

Once the deck watch had deployed the rosette, the winch operator would lower it to 20 meters. The CTD sensor pumps were configured to start 10 seconds after the primary conductivity cell reports salt water in the cell. The UVP was configured to turn on after it had descended to 20 meters, and was identified as on when the voltages went above a certain range. The CWO checked the CTD data for proper sensor operation, waited for sensors to stabilize, waited for the UVP to turn on, and then instructed the winch operator to bring the package to the surface in good weather or no more than 5 meters in high seas. The winch was then instructed to lower the package to the initial target wire-out at no more than 60 m/min after 100 m depending on depth, sea-cable tension, and the sea state.

The CWO monitored the progress of the deployment and quality of the CTD data through interactive graphics and operational displays. The altimeter channel, CTD pressure, wire-out and center multi-beam depth were all monitored to determine the distance of the package from the bottom. The winch was directed to slow decent rate to 30 m/min 100 m from the bottom, and 20 m/min 50 m from the bottom. The bottom of the CTD cast was usually to within 10-20 meters of the bottom determined by altimeter data. For each full upcast, the winch operator was directed to stop the winch at up to 36 predetermined sampling pressures. During upcasts specific to bio sampling, the winch operator was directed to stop at up to 21 predetermined sampling pressures. These standard depths were staggered every station using 3 sampling schemes. The CTD CWO waited a minimum of 30 seconds prior to tripping sample bottles, to ensure package had shed its wake (the effect of bottle stop time is discussed further at the end of Conductivity Analysis). 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 watch created a sample log for the deployment which recorded the depths bottles were tripped and correspondence between rosette bottles and analytical samples drawn.

The CTD sensors were rinsed after every cast using syringes of fresh water connected to Tygon tubing. The tubing was left on the CTD between casts, with the temperature and conductivity sensors immersed in fresh water.

Each bottle on the rosette had a unique serial number, independent of the bottle position on the rosette. Sampling for specific programs were outlined on sample log sheets prior to cast recovery or at the time of collection. The bottles and rosette were examined before samples were drawn. Any abnormalities were noted on the sample log, stored in the cruise database and reported in the APPENDIX.

5.2 CTDO Data Processing

Shipboard CTD data processing was performed after deployment using SIO/ODF CTD processing software "ctdcal" v. 0.1.3b. CTD acquisition data were copied onto a OS X system, and then processed. CTD data at bottle trips were extracted, and a 2-decibar downcast 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 88 CTD stations were occupied including one test station. A total of 128 CTDO/rosette/LADCP/UVP/chipod casts were completed.

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 conductivity and oxygen sensor calibrations.

Temperature, salinity and, dissolved O_2 comparisons were made between down and upcasts 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 P02E-2022 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.

5.3 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 lab calibration coefficients provided on the calibration report were used to convert frequencies to pressure. Initial 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 cast.

CTD #1281:

	Start P (dbar)	End P (dbar)
Min	-0.15	-0.41
Max	0.10	0.24
Average	0.01	-0.17

On-deck pressure reading varied from -0.15 to 0.10 dbar before the casts, and -0.41 to 0.24 dbar after the casts. The pressure offset varied from -0.18 to 0.21, with a mean value of -0.18 dbar.

5.4 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 systematic sensor bias. Two independent metrics of calibration accuracy were used to determine sensor bias. At each bottle closure, the primary and secondary temperature were compared with each other and with a SBE35RT reference temperature sensor.

The SBE35RT Digital Reversing Thermometer is an internally-recording temperature sensor that operates independently of the CTD. The SBE35RT was located equidistant between the two SBE3plus temperature sensors. The SBE35RT is triggered by the SBE32 carousel in response to a bottle closure. According to the manufacturer's specifications, the typical stability is 0.001 °C/year. The SBE35RT was set to internally average over 13 samples, approximately 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 and second-order with respect to temperature:

$$T_{cor} = T + cp_2P^2 + cp_1P + ct_2T^2 + ct_1T + c_0$$

Fit coefficients are shown in the following tables.

Table 1: Primary temperature (T1) coefficients.

Station	cp_2	cp_1	ct_2	ct_1	c_0
118-158	0.0	-1.8791e-8	0.0	-3.1674e-5	6.1881e-4
159-177	0.0	9.6475e-9	0.0	4.6552e-5	1.8018e-4
178-205	0.0	9.6475e-9	0.0	4.6552e-5	1.8018e-4
19103-18602	0.0	-1.1695e-7	0.0	-1.3419e-4	9.0745e-4

Table 2: Secondary temperature (T2) coefficients.

Station	cp_2	cp_1	ct_2	ct_1	c_0
118-155	0.0	4.8963e-8	0.0	-1.1044e-4	6.5189e-4
159-177	0.0	-1.3964e-8	0.0	-2.0099e-4	8.6626e-4
178-205	0.0	1.084e-7	0.0	3.7615e-5	5.0662e-5
19103-18602	0.e	-2.87e-8	0.0	-2.2966e-4	9.1661e-4

Corrected temperature differences are shown in the following figures.

The 95% confidence limits for the mean low-gradient (values -0.002 °C $\leq$ T1-T2 $\leq$ 0.002 °C) differences are $\pm$0.00527 °C for SBE35RT-T1, $\pm$0.00523 °C for SBE35RT-T2 and $\pm$0.00146 °C for T1-T2. The 95% confidence limits for the deep temperature residuals (where pressure $\geq$ 2000 dbar) are $\pm$0.00074 °C for SBE35RT-T1, $\pm$0.00076 °C for SBE35RT-T2 and $\pm$0.00063 °C for T1-T2.

No problems affected primary or secondary temperature sensor (SBE3) data.

Minor complications impacted the reference temperature sensor (SBE35) data.

- During casts designated for bio, many bottles were fired at the surface and sometimes were too fast (< 15 seconds) for a reading.

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

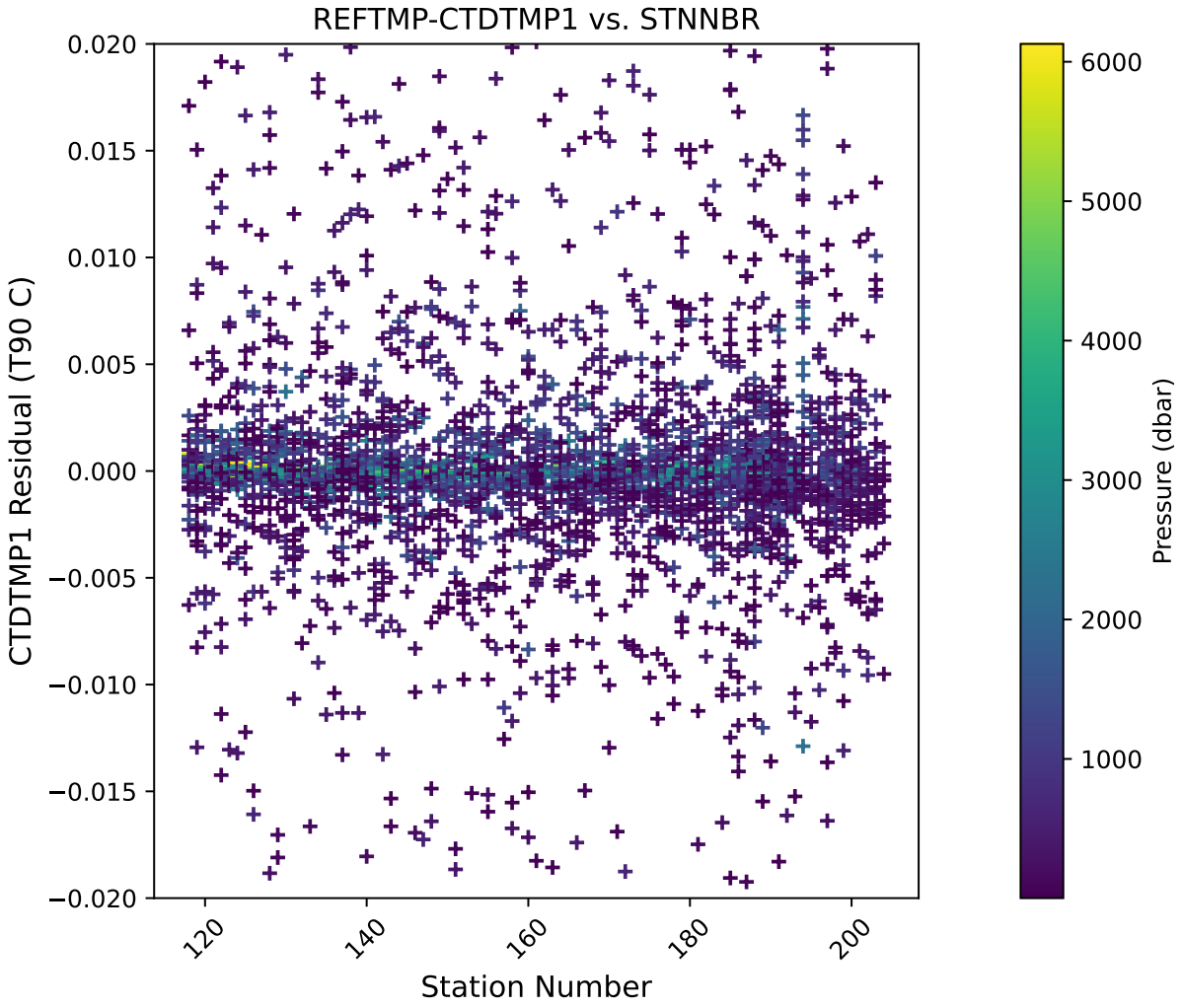

Fig. 1: SBE35RT-T1 versus station.

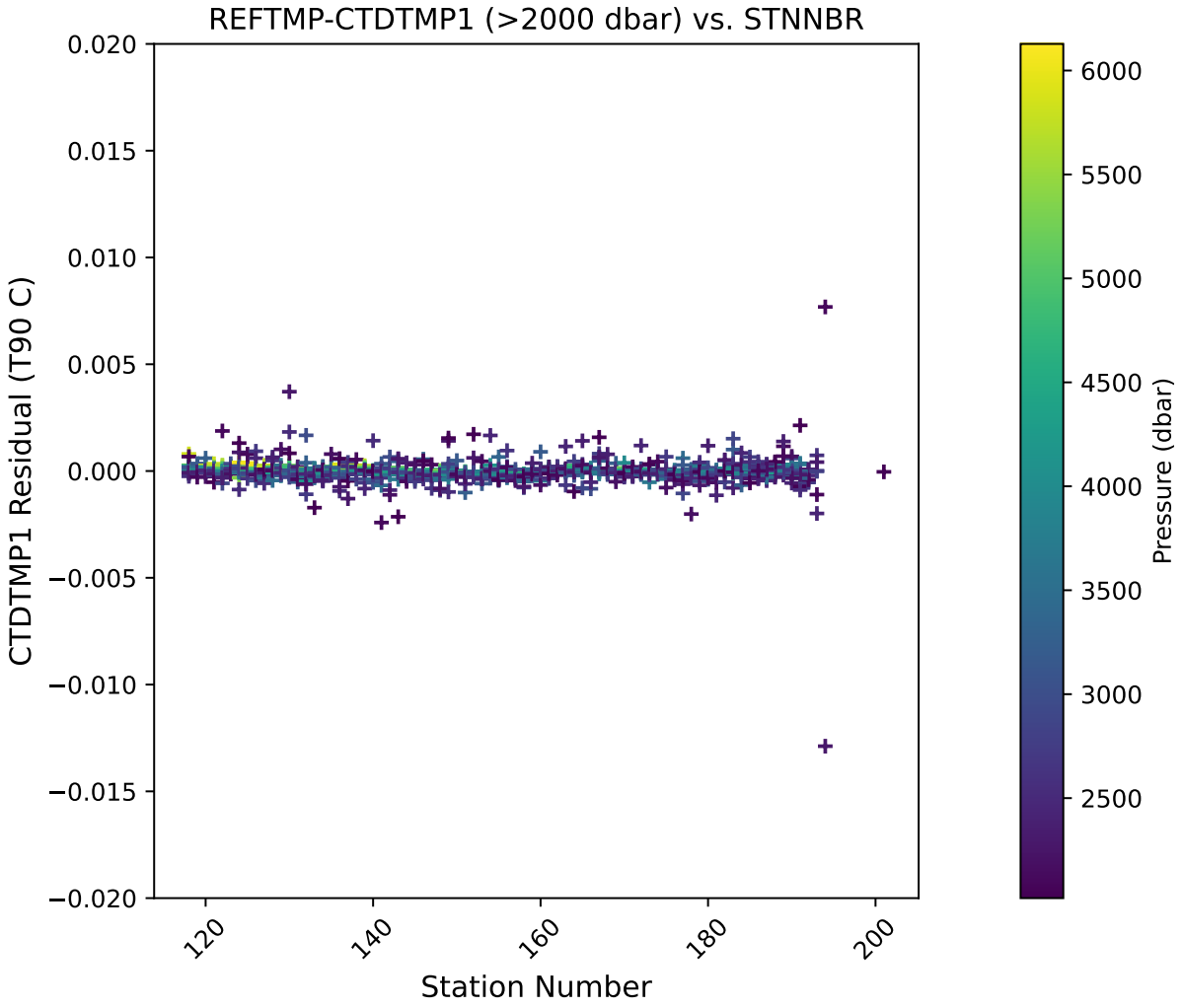

Fig. 2: Deep SBE35RT-T1 by station (Pressure $\geq$ 2000dbar).

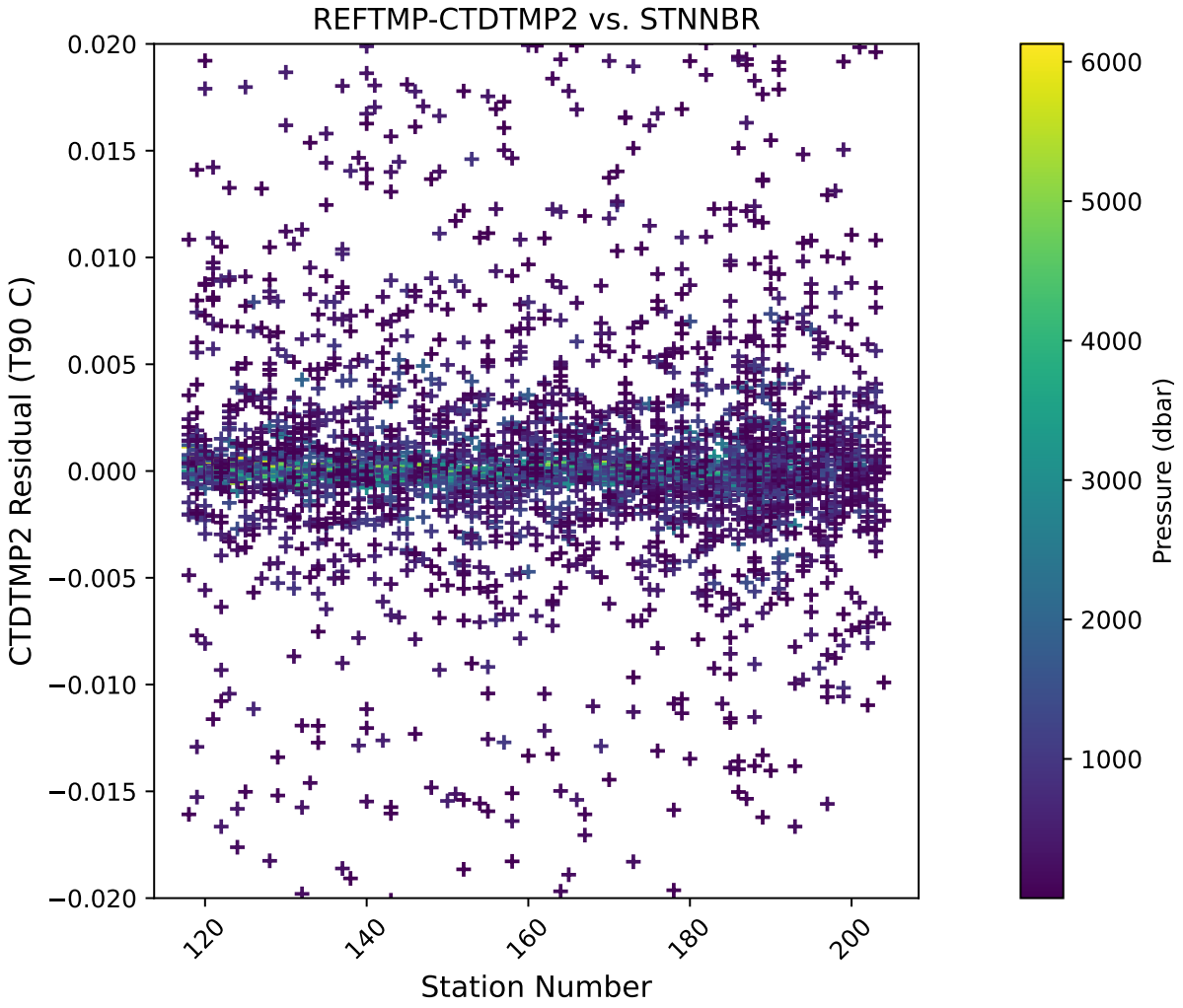

Fig. 3: SBE35RT-T2 versus station.

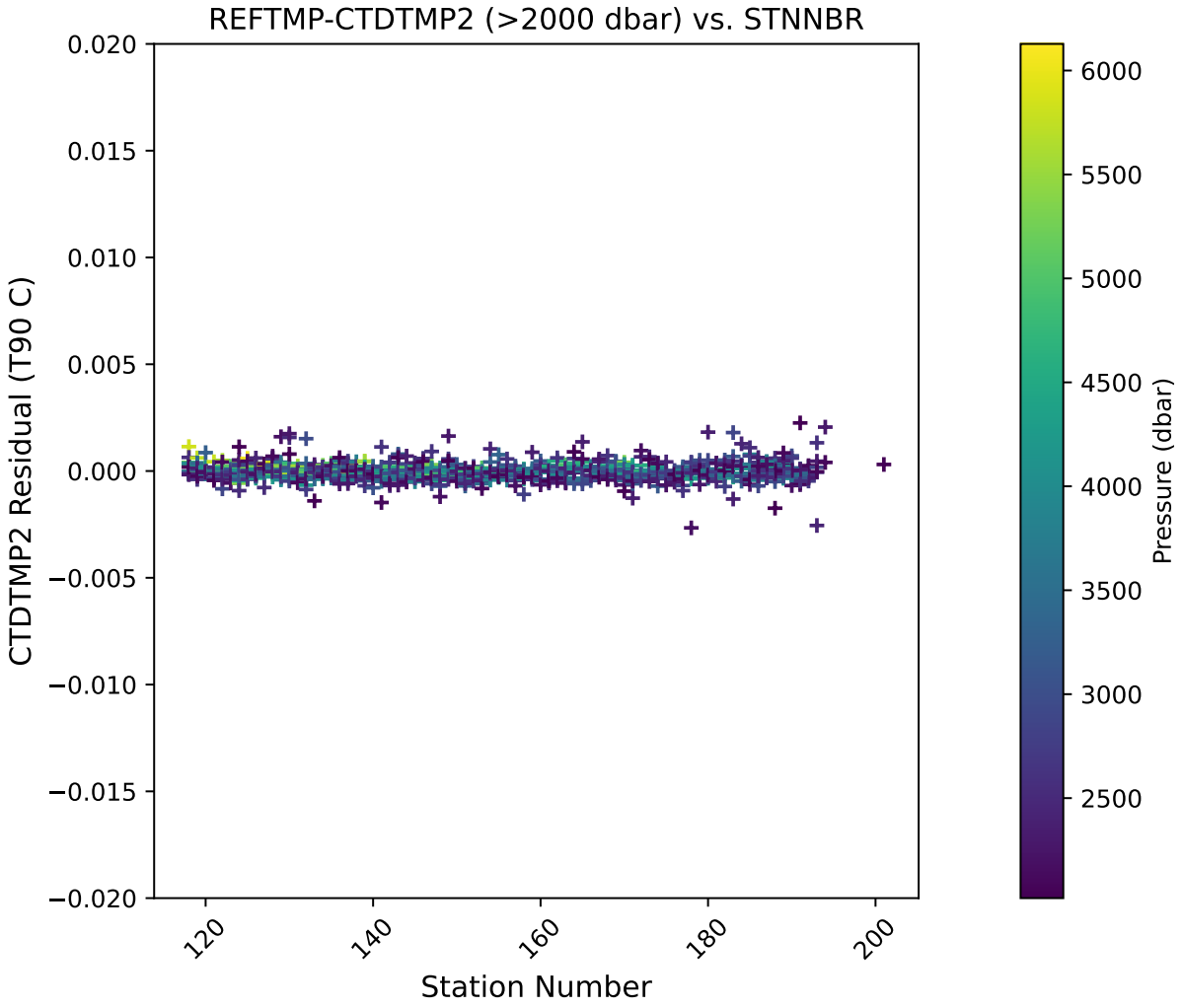

Fig. 4: Deep SBE35RT-T2 by station (Pressure $\geq$ 2000dbar).

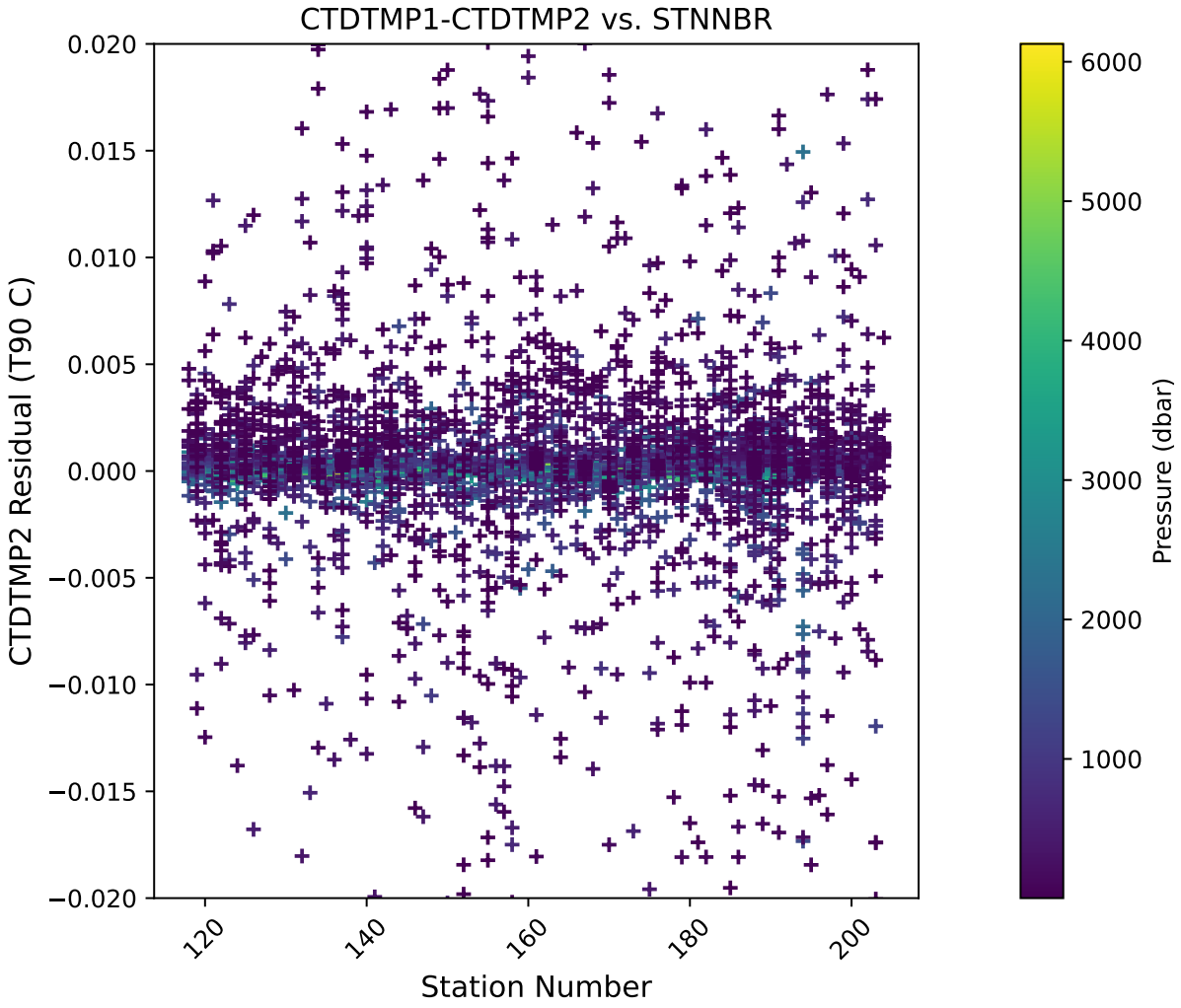

Fig. 5: T1-T2 versus station.

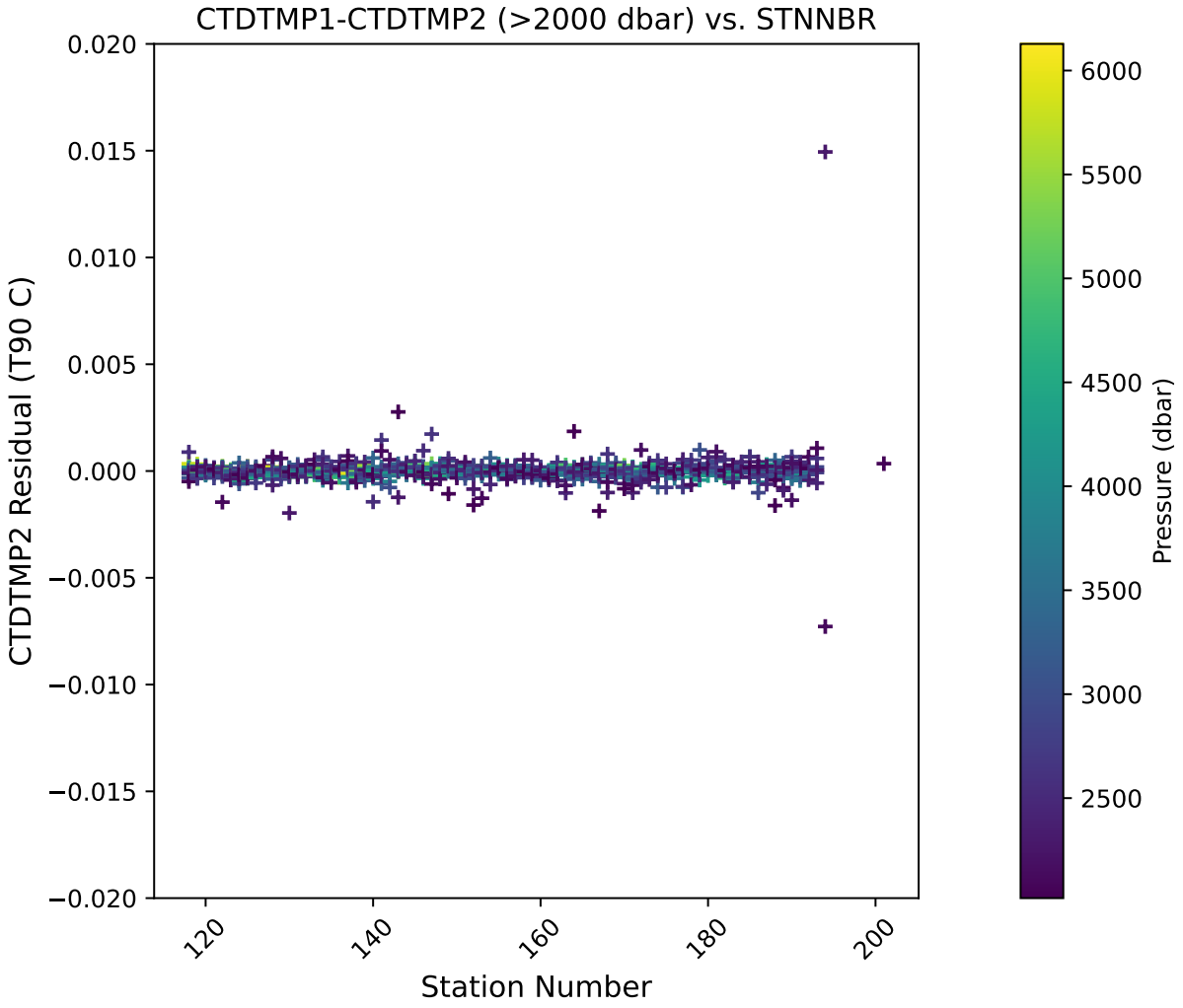

Fig. 6: Deep T1-T2 versus station (Pressure $\geq$ 2000dbar).

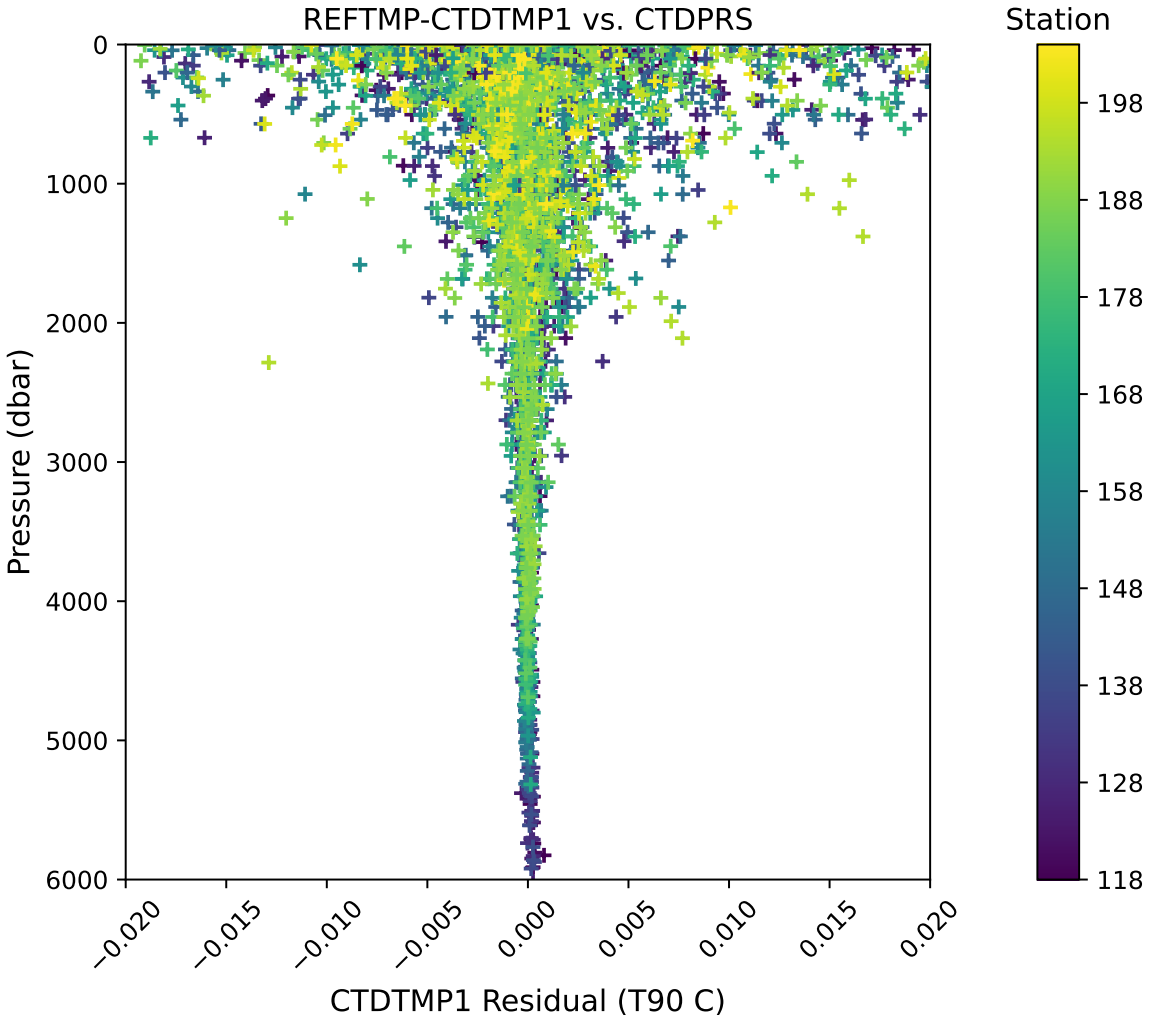

Fig. 7: SBE35RT-T1 versus pressure.

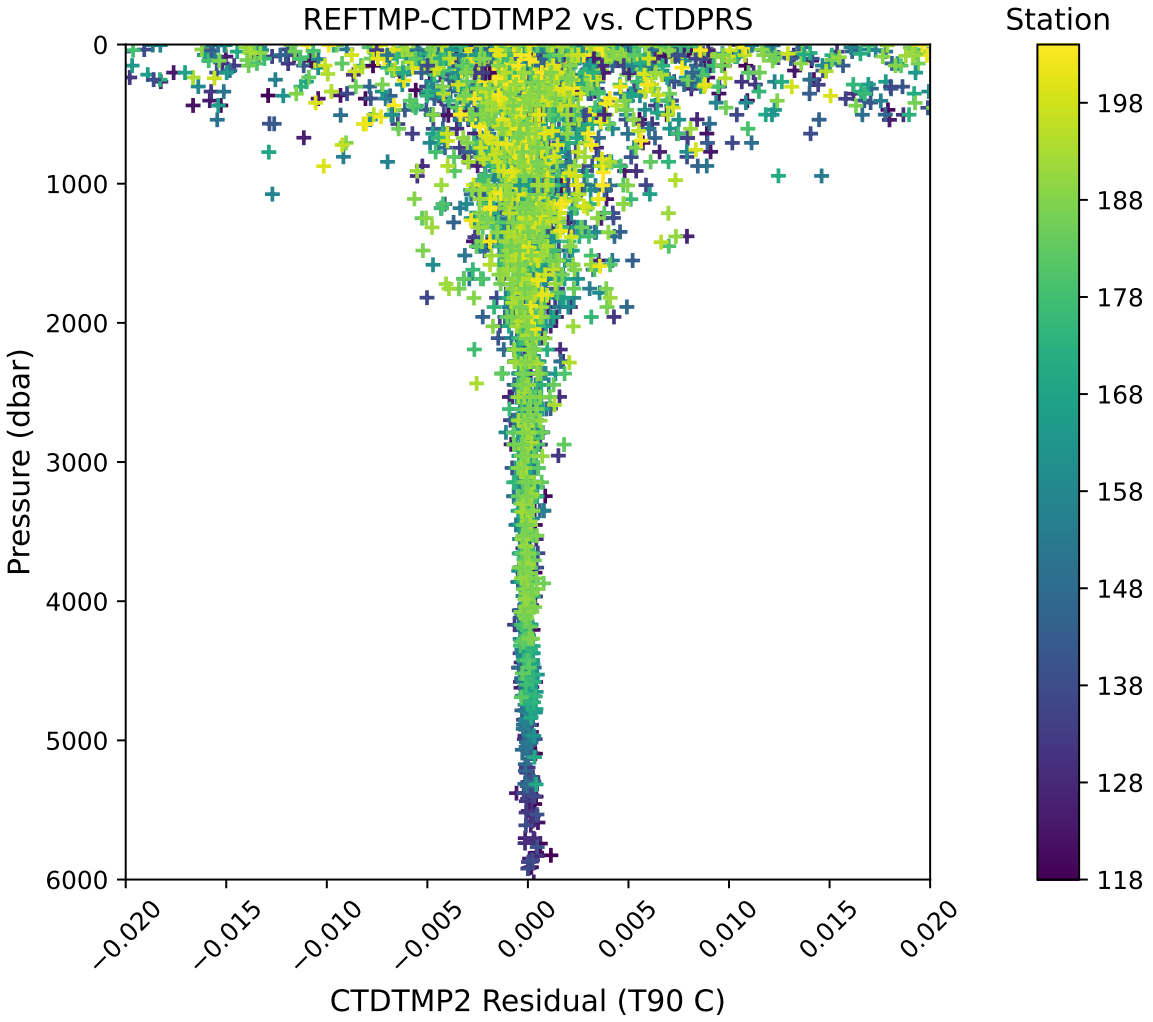

Fig. 8: SBE35RT-T2 versus pressure.

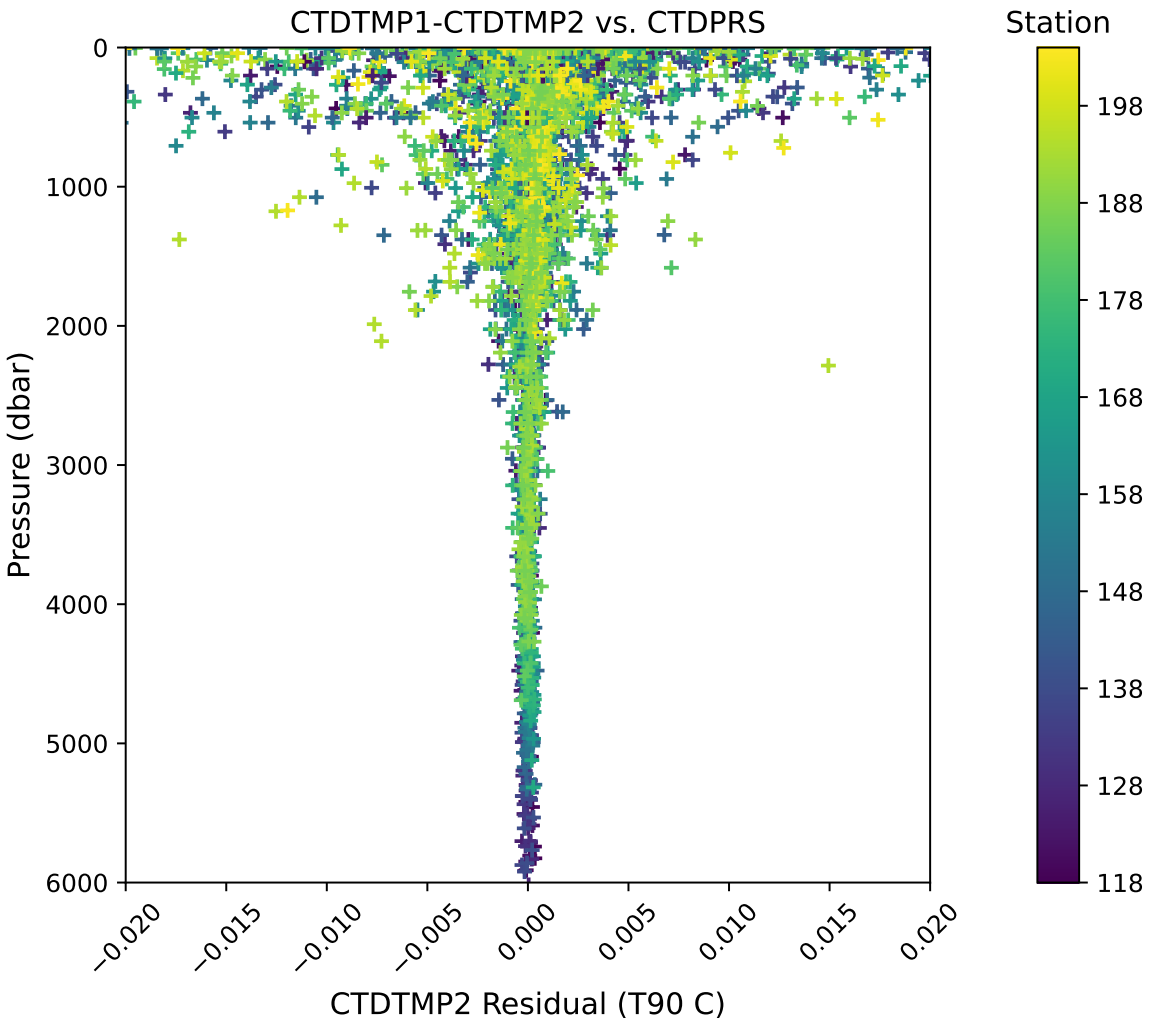

Fig. 9: T1-T2 versus pressure.

5.5 Conductivity Analysis

Laboratory calibrations of conductivity sensors were performed prior to the cruise at the Sea-Bird 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 shipboard calibrations were performed to correct sensor bias. Corrections for both pressure and temperature sensors were finalized before analyzing conductivity differences. Two independent metrics of calibration accuracy were examined. At each bottle closure, the primary and secondary conductivity were compared with each other. Each sensor was also compared to conductivity calculated from check sample salinities using CTD pressure and temperature.

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

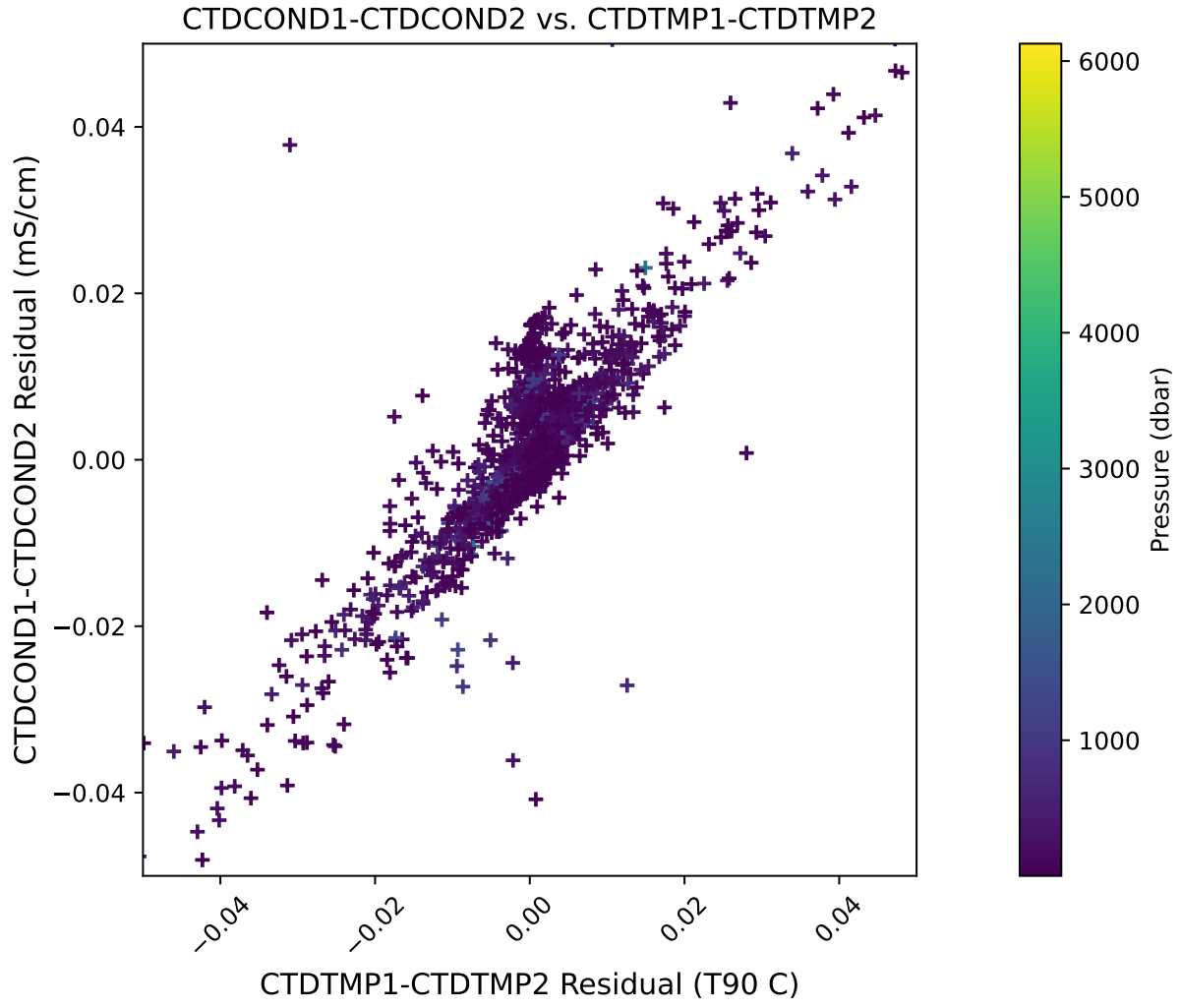

Fig. 10: Coherence of conductivity differences as a function of temperature differences.

A functioning SBE4C sensor typically exhibit a predictable modeled response. Offsets for each C sensor were deter-

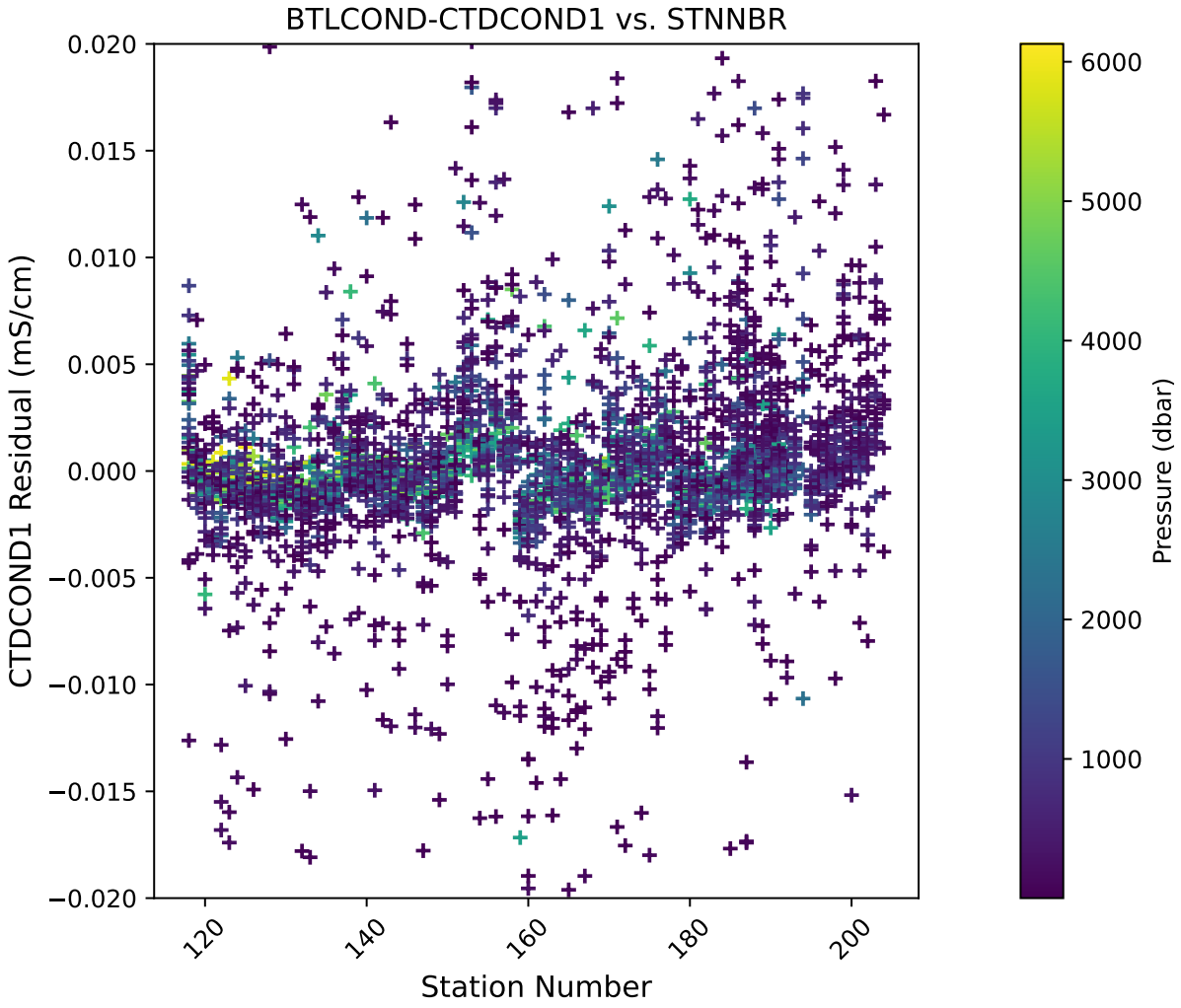

Fig. 11: Corrected C_{Bottle} - C1 versus station.

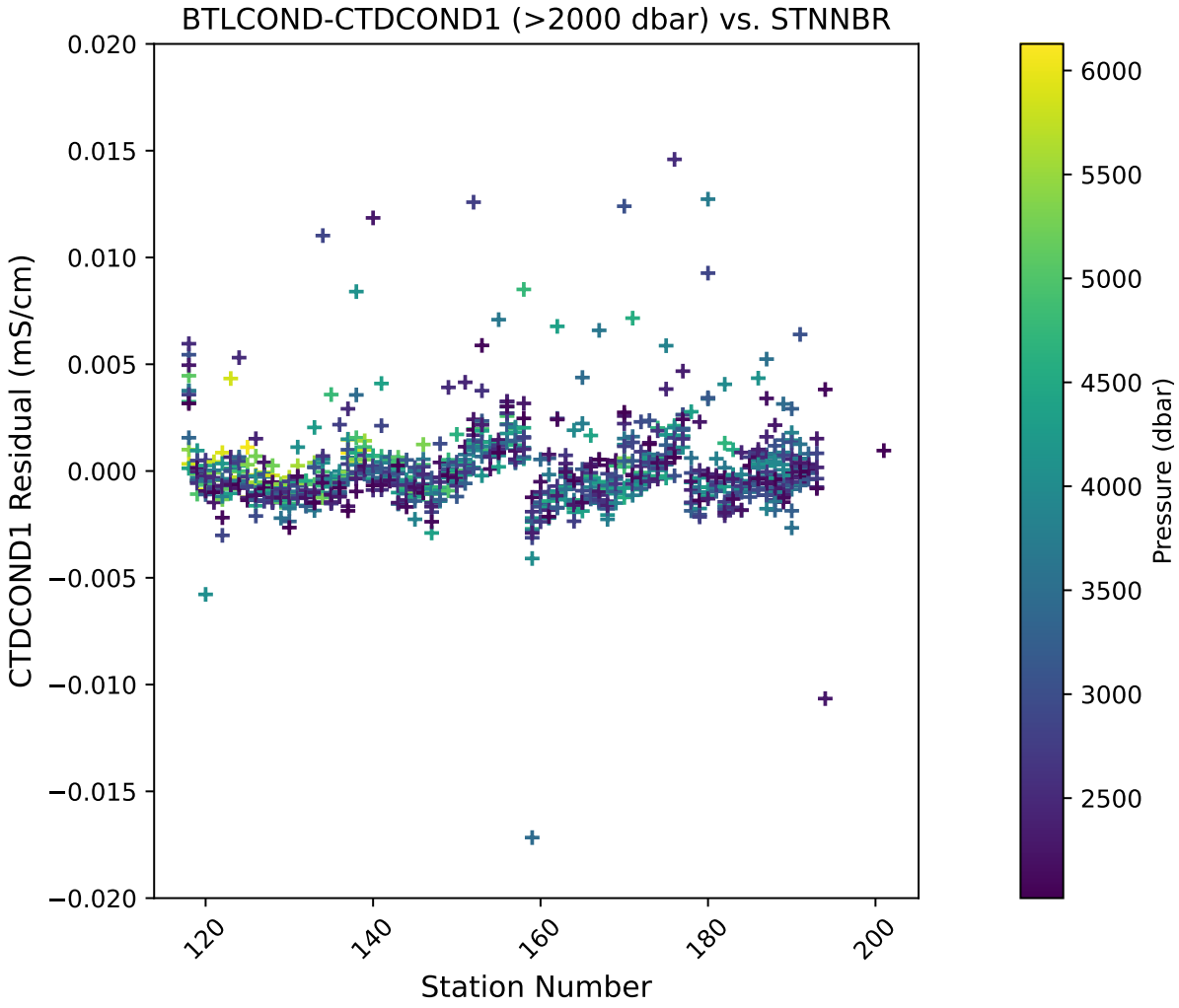

Fig. 12: Deep Corrected C_{Bottle} - C1 versus station (Pressure >= 2000dbar).

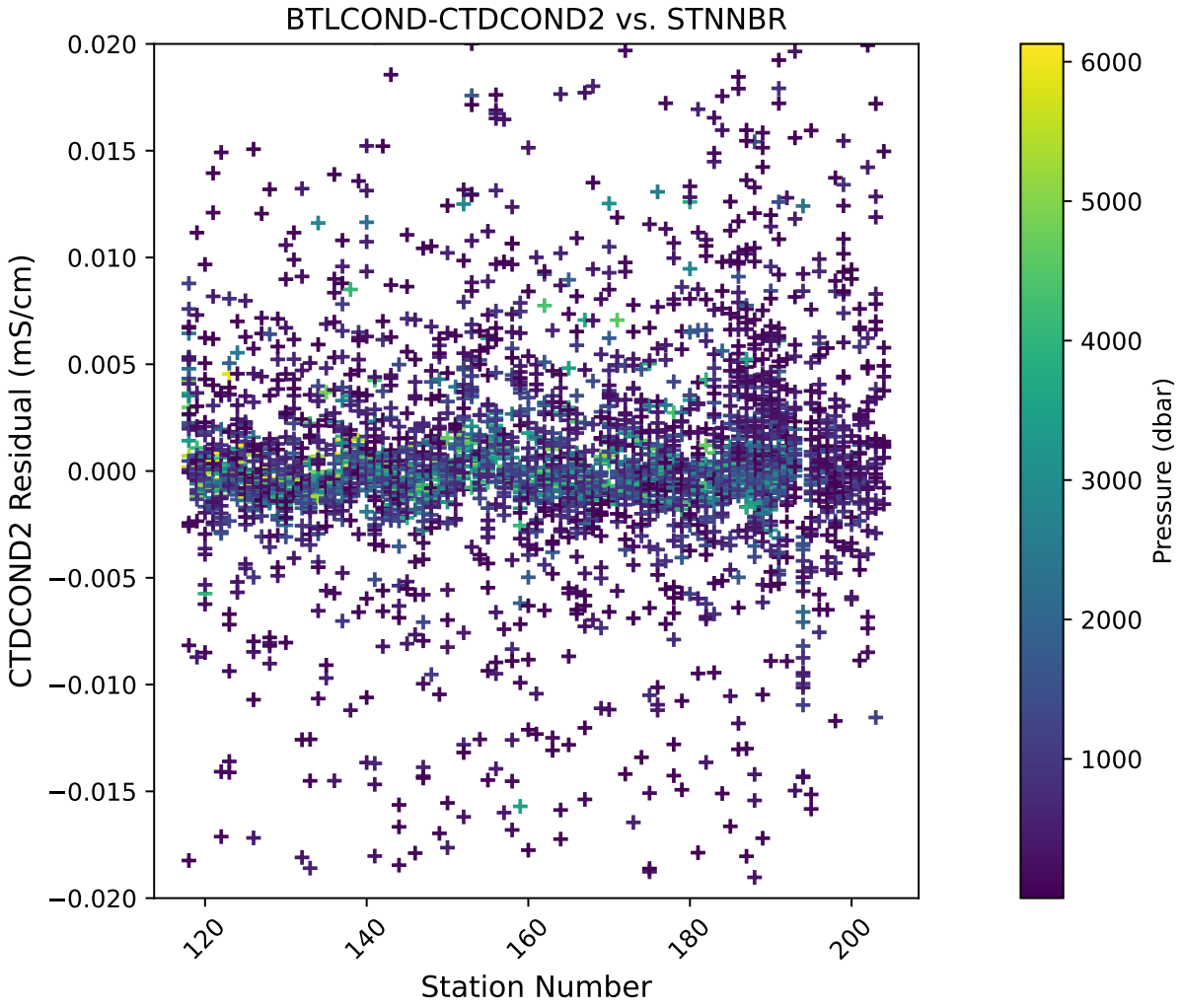

Fig. 13: Corrected C_{Bottle} - C2 versus station.

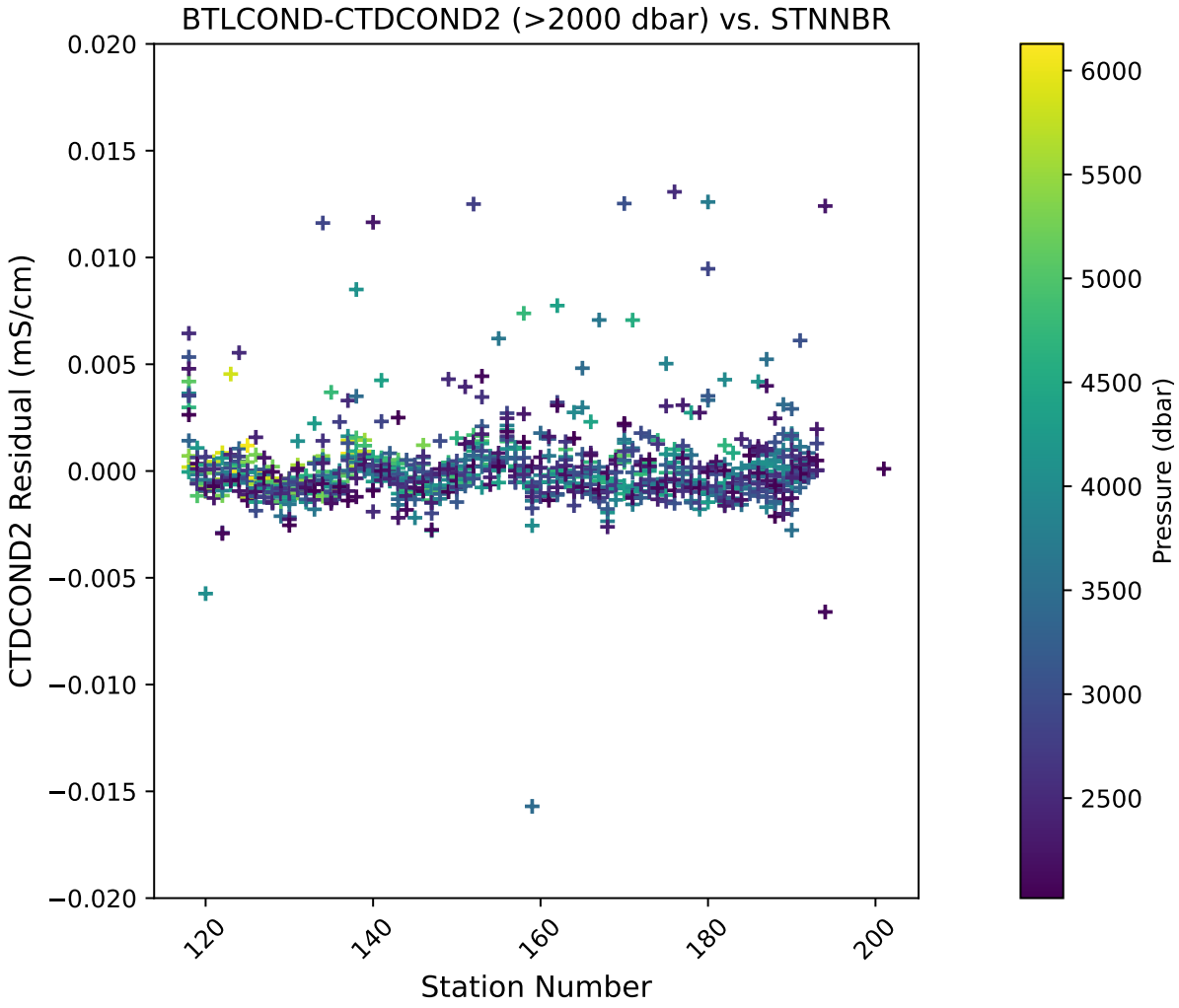

Fig. 14: Deep Corrected C_{Bottle} - C2 versus station (Pressure >= 2000dbar).

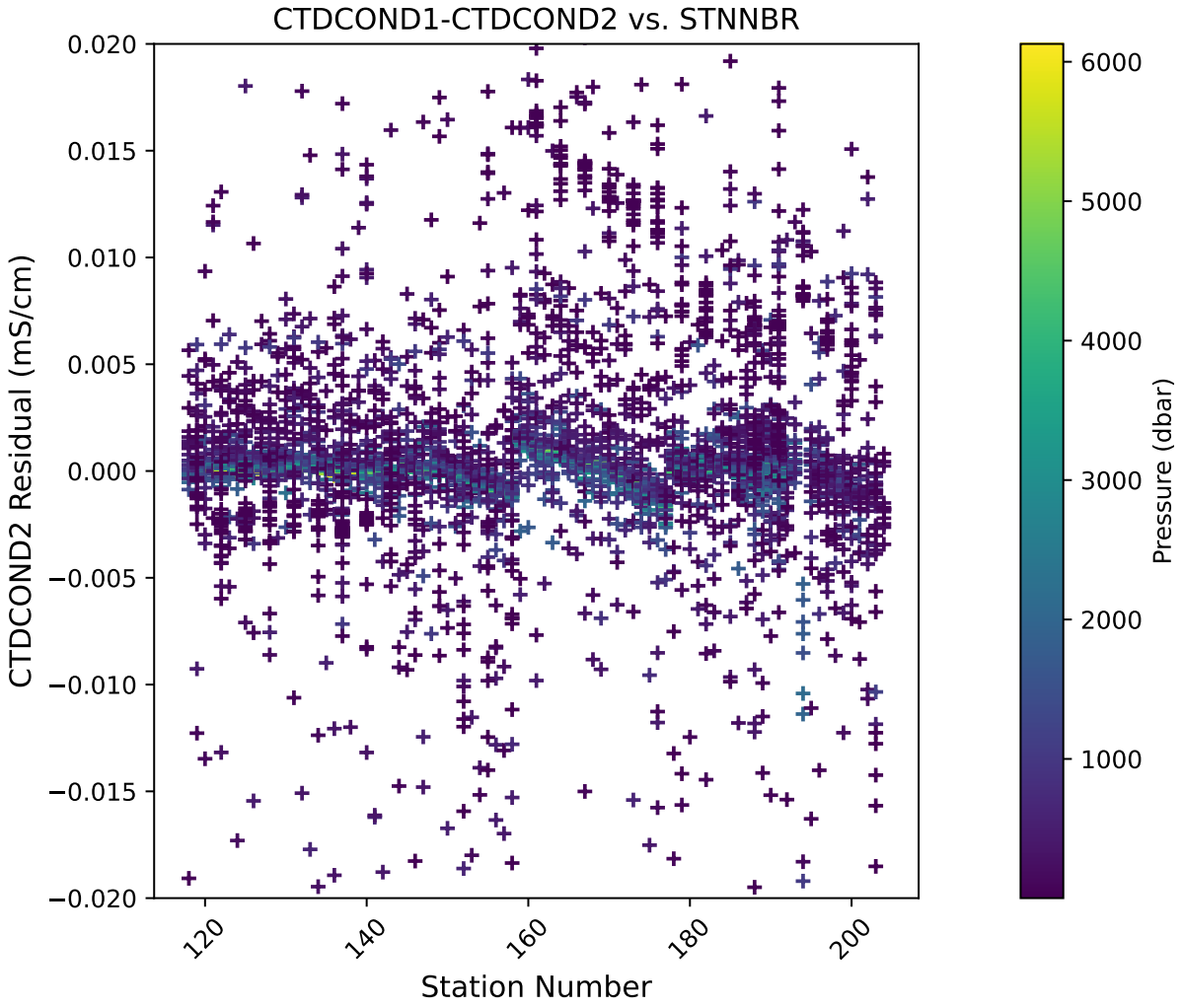

Fig. 15: Corrected C1-C2 versus station.

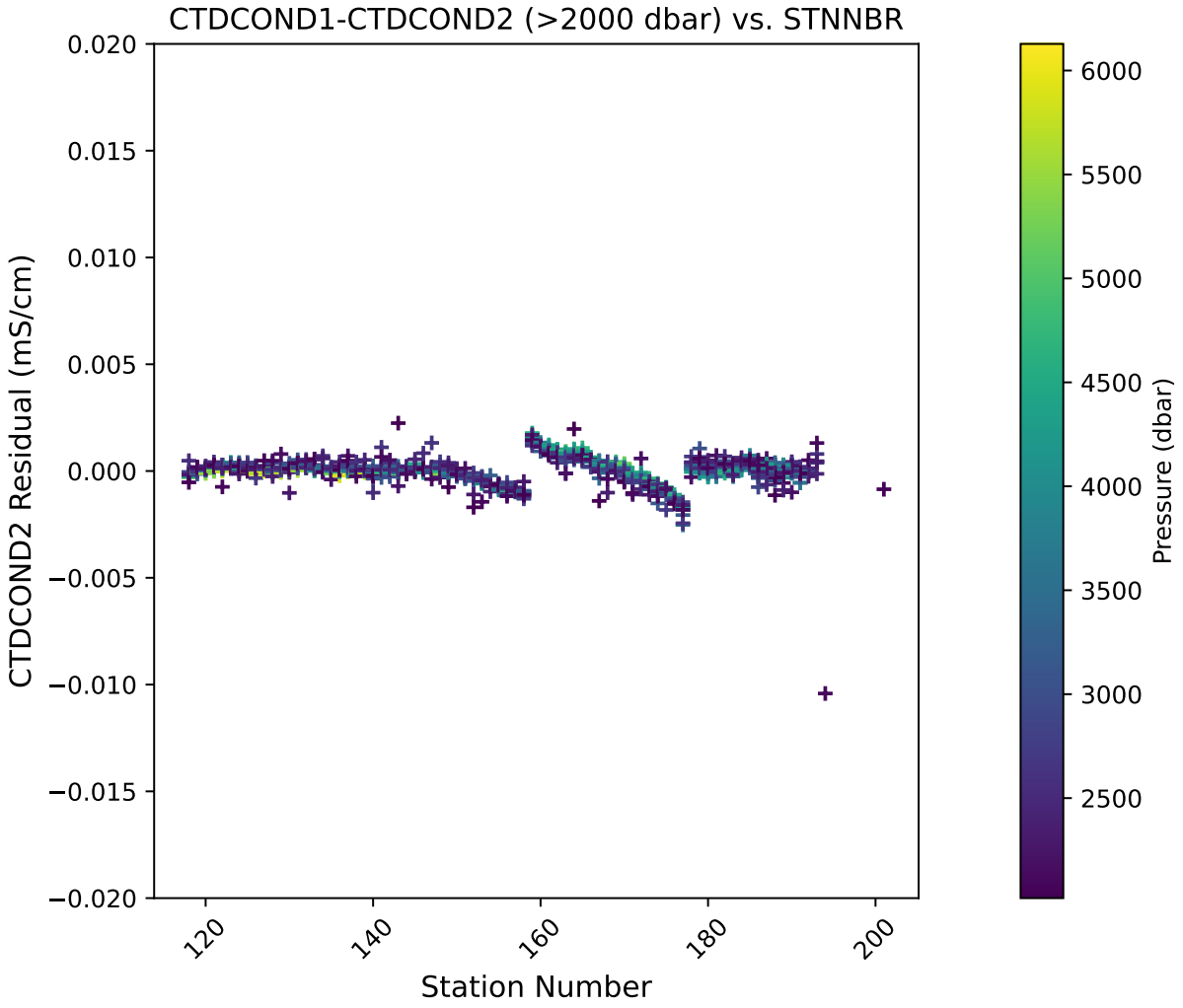

Fig. 16: Deep Corrected C1-C2 versus station (Pressure >= 2000dbar).

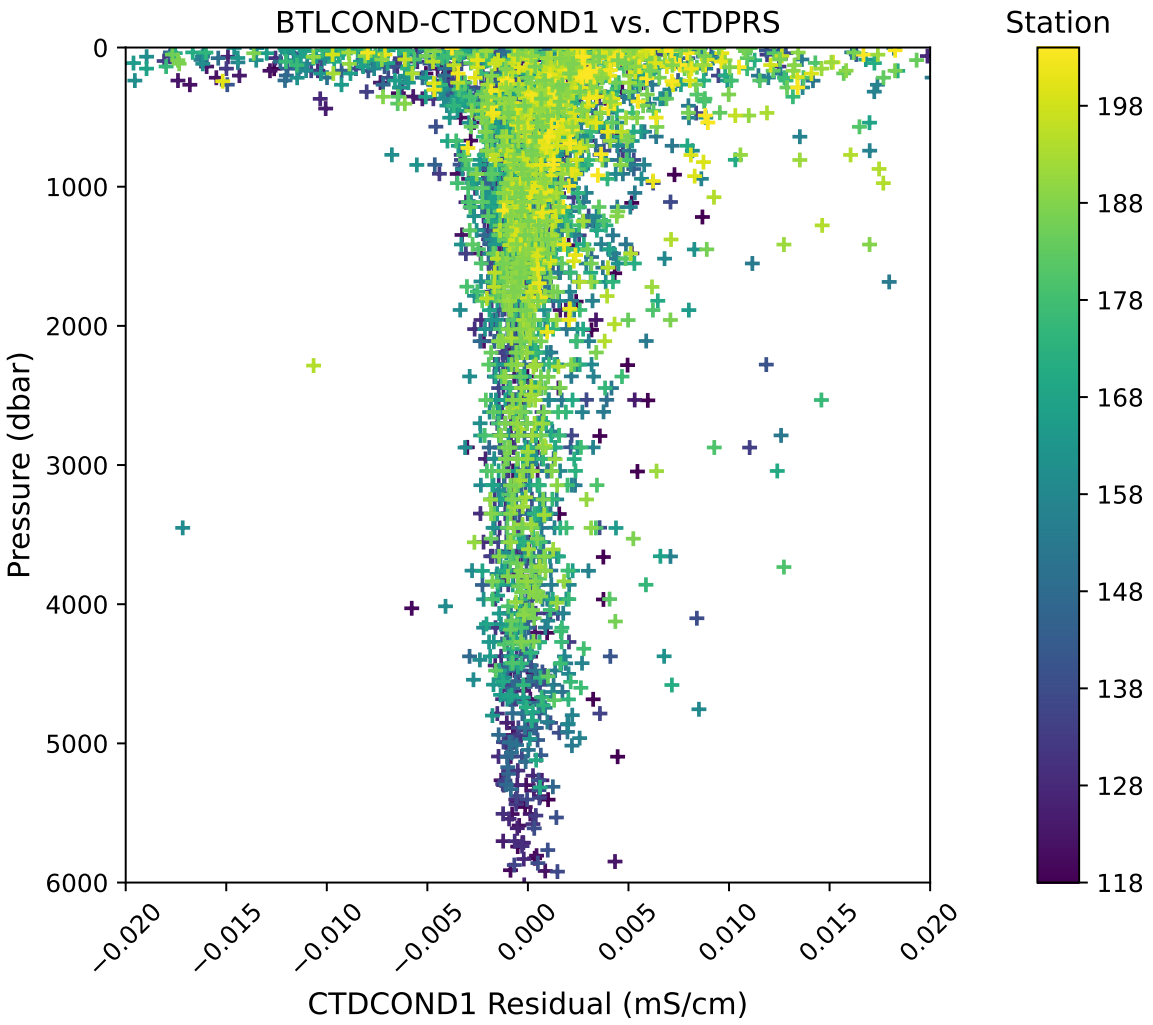

Fig. 17: Corrected C_{Bottle} - C1 versus pressure.

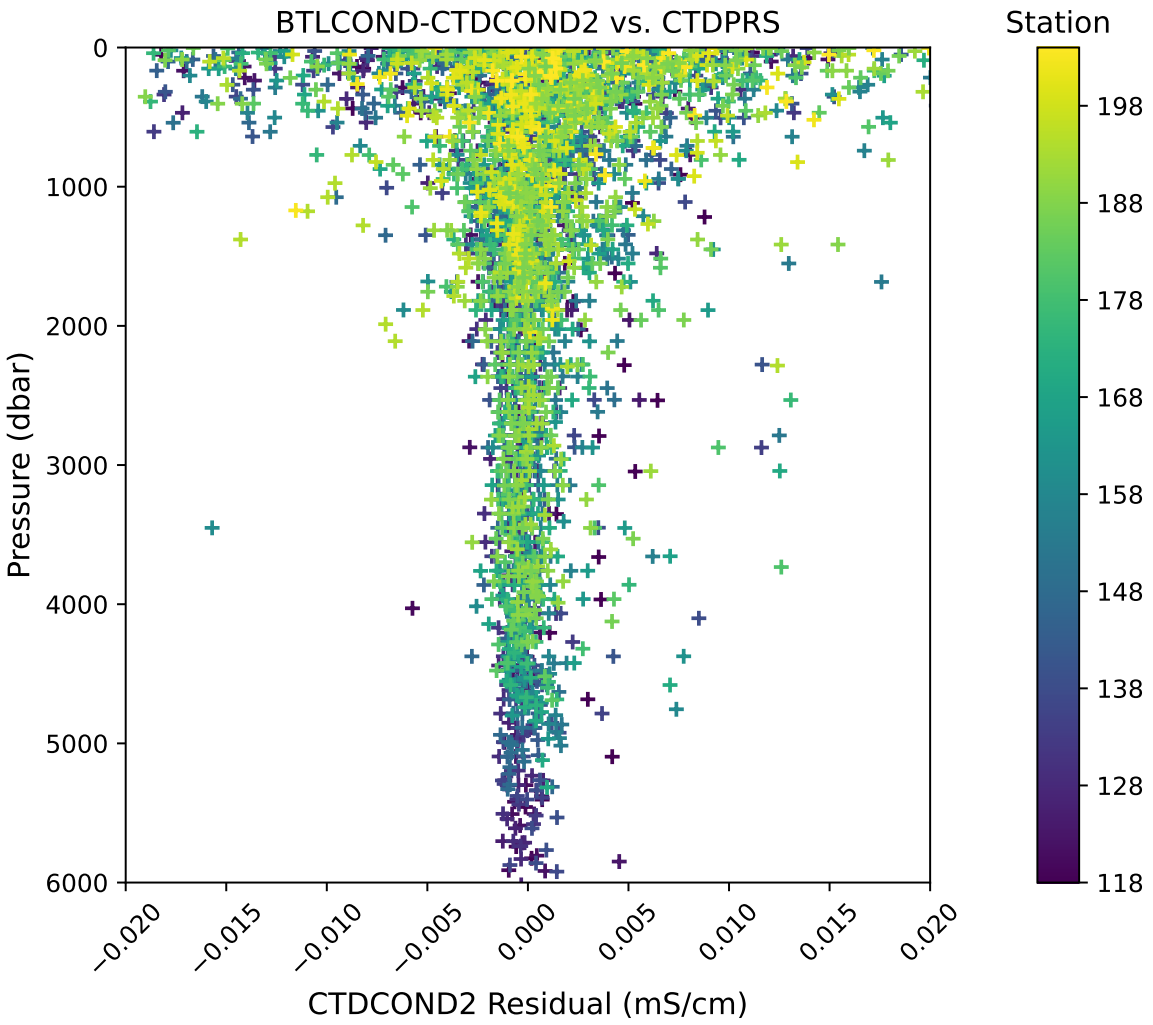

Fig. 18: Corrected C_{Bottle} - C2 versus pressure.

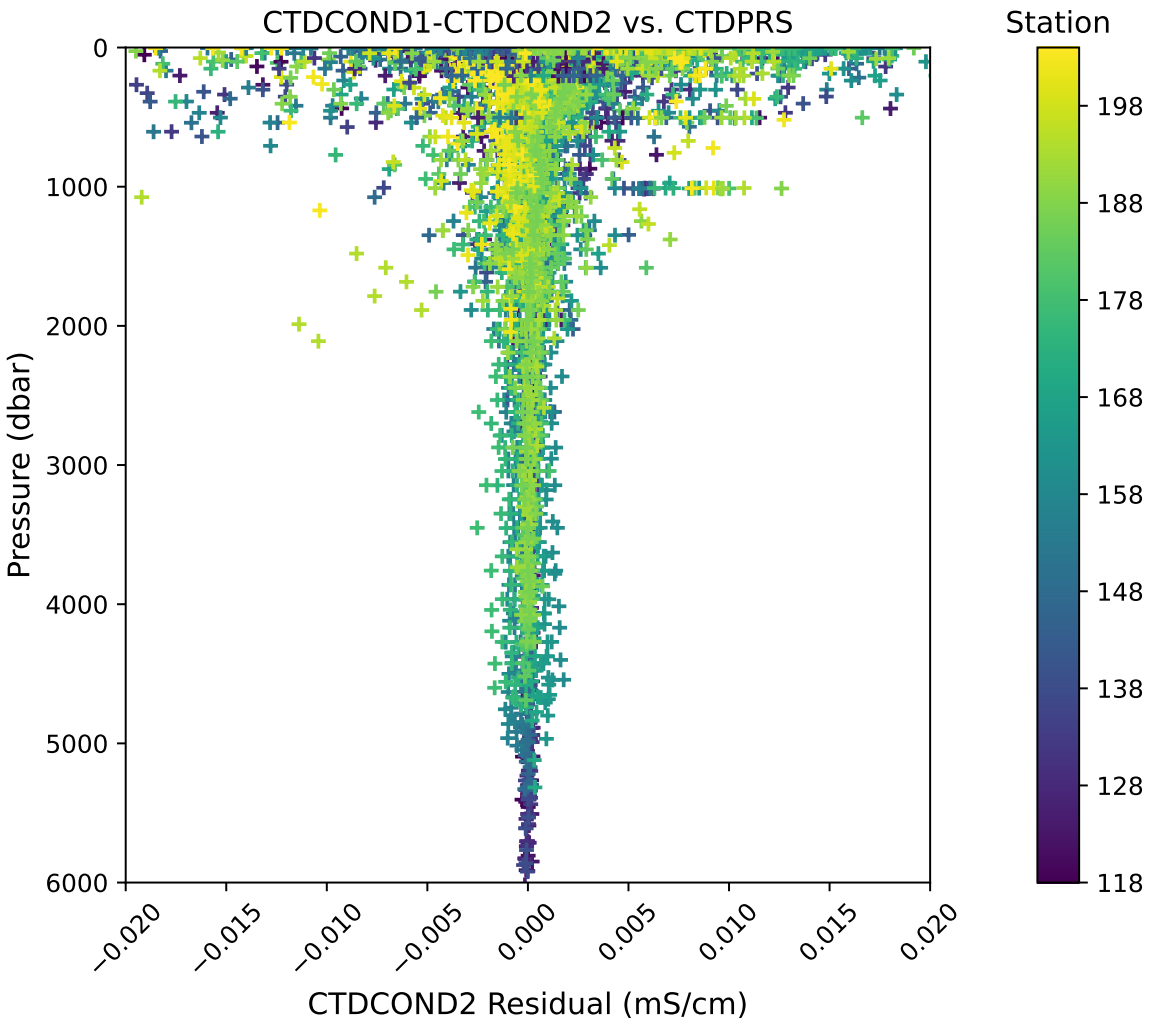

Fig. 19: Corrected C1-C2 versus pressure.

mined 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, and second-order with respect to conductivity:

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

Fit coefficients are shown in the following tables.

Table 3: Primary conductivity (C1) coefficients.

Station	cp_2	cp_1	ct_2	ct_1	cc_2	cc_1	c_0
118-158	8.3873e-11	-6.2573e-7	0.0	0.0	0.0	-4.7561e-4	1.6742e-2
159-177	0.0	2.8021e-8	0.0	0.0	0.0	4.6701e-4	-9.5951e-3
178-205	0.0	-4.2272e-7	0.0	0.0	0.0	-1.8211e-4	1.6624e-2
19103-18602	0.0	-3.3734e-7	0.0	0.0	0.0	-6.8688e-4	3.3427e-2

Table 4: Secondary conductivity (C2) coefficients.

Station	cp_2	cp_1	ct_2	ct_1	cc_2	cc_1	c_0
118-158	1.1950e-10	-1.0338e-6	0.0	0.0	0.0	-5.3619e-4	2.3234e-2
159-177	0.0	-2.5469e-7	0.0	0.0	0.0	2.9271e-5	6.2111e-3
178-205	0.0	-4.8145e-7	0.0	0.0	0.0	-4.2052e-5	1.0867e-2
19103-18602	0.0	-5.5344e-7	0.0	0.0	0.0	-1.2683e-3	5.0528e-2

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.

The 95% confidence limits for the mean low-gradient (values -0.002 ºC $\leq$ T1-T2 $\leq$ 0.002 ºC) differences are $\pm$0.00581 mPSU for salinity-C1SAL. The 95% confidence limits for the deep salinity residuals (where pressure $\geq$ 2000 dbar) are $\pm$0.00192 mPSU for salinity-C1SAL.

Minimal issues affected conductivity and calculated CTD salinities during this cruise.

- Bottle stops in halocline may have had insufficient stop time during some casts, leading to measurements biased toward lower depth measurements.

Bottle salinity measurements will be biased high relative to the CTD if salinity is decreasing toward the surface, or biased low if salinity is increasing toward the surface. Bottle stop time was increased from 30 seconds to 60 seconds in the halocline from station 187 through the end of the cruise. Preliminary results show a smaller residual between CTD salinity and reference salinity at the longer bottle stops, suggesting 30 seconds is insufficient. This result is consistent with the findings of [Paver2020]. This hypothesis will continue to be tested on future cruises.

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

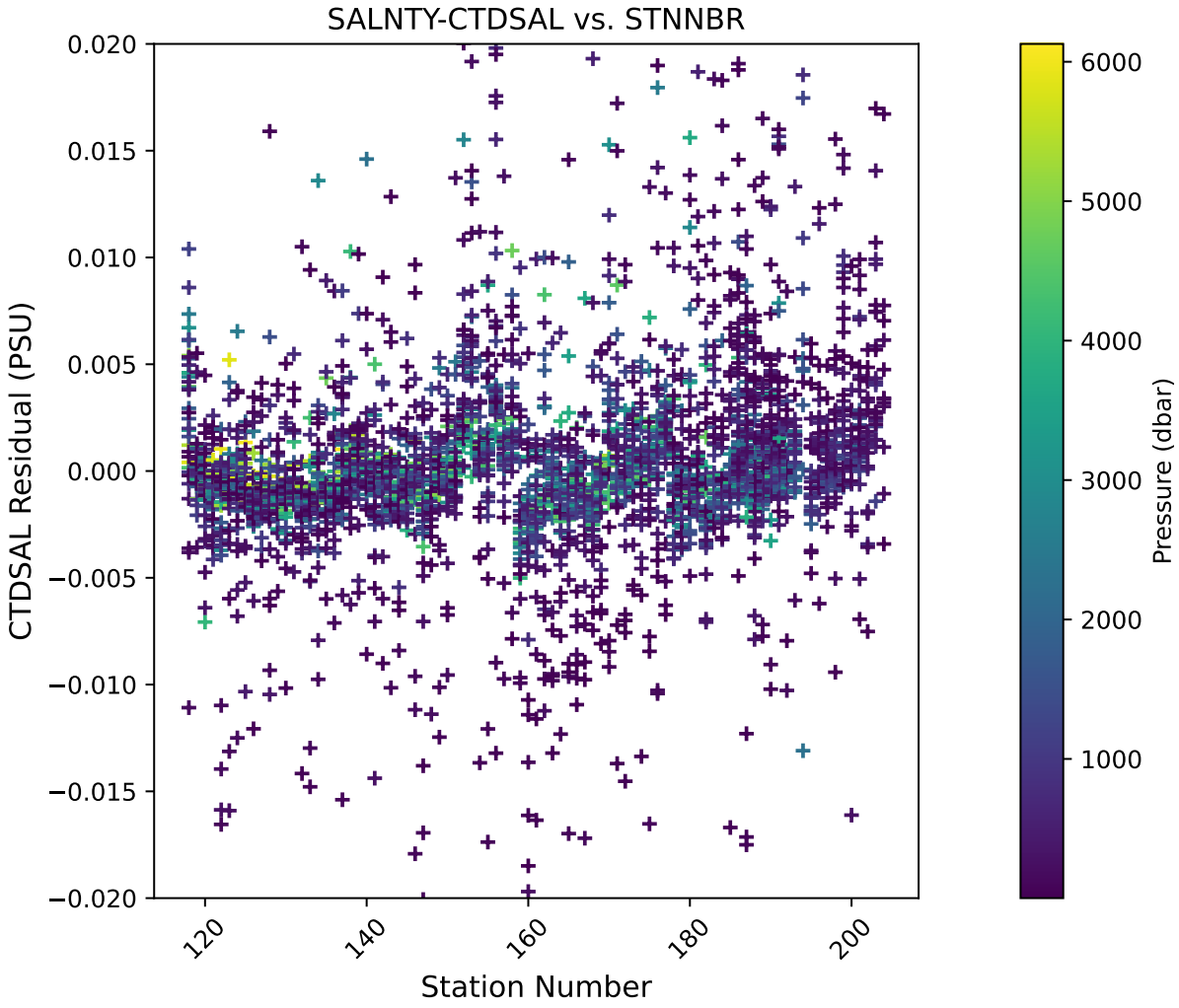

Fig. 20: Salinity residuals versus station.

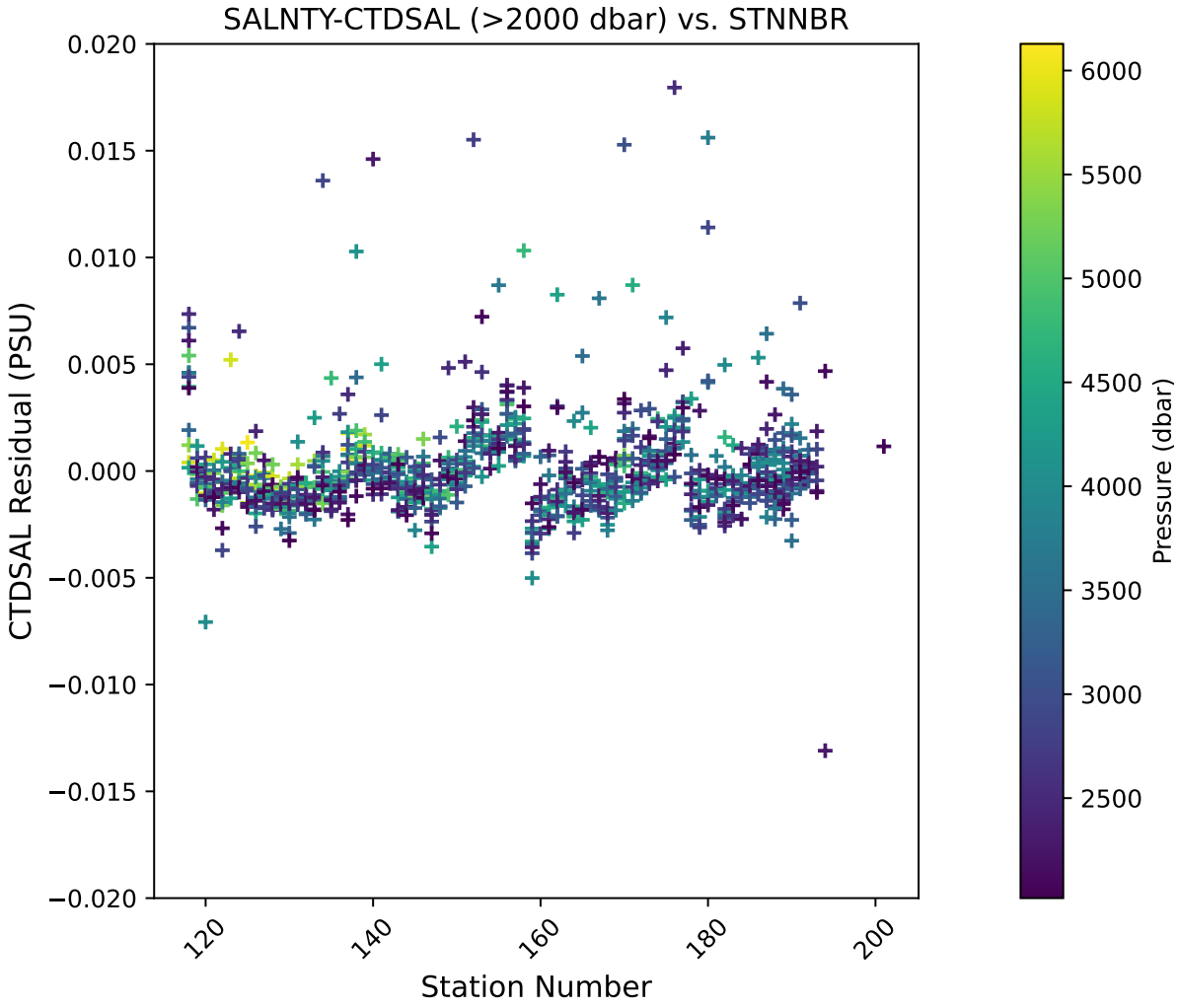

Fig. 21: Deep Salinity residuals versus station (Pressure >= 2000dbar).

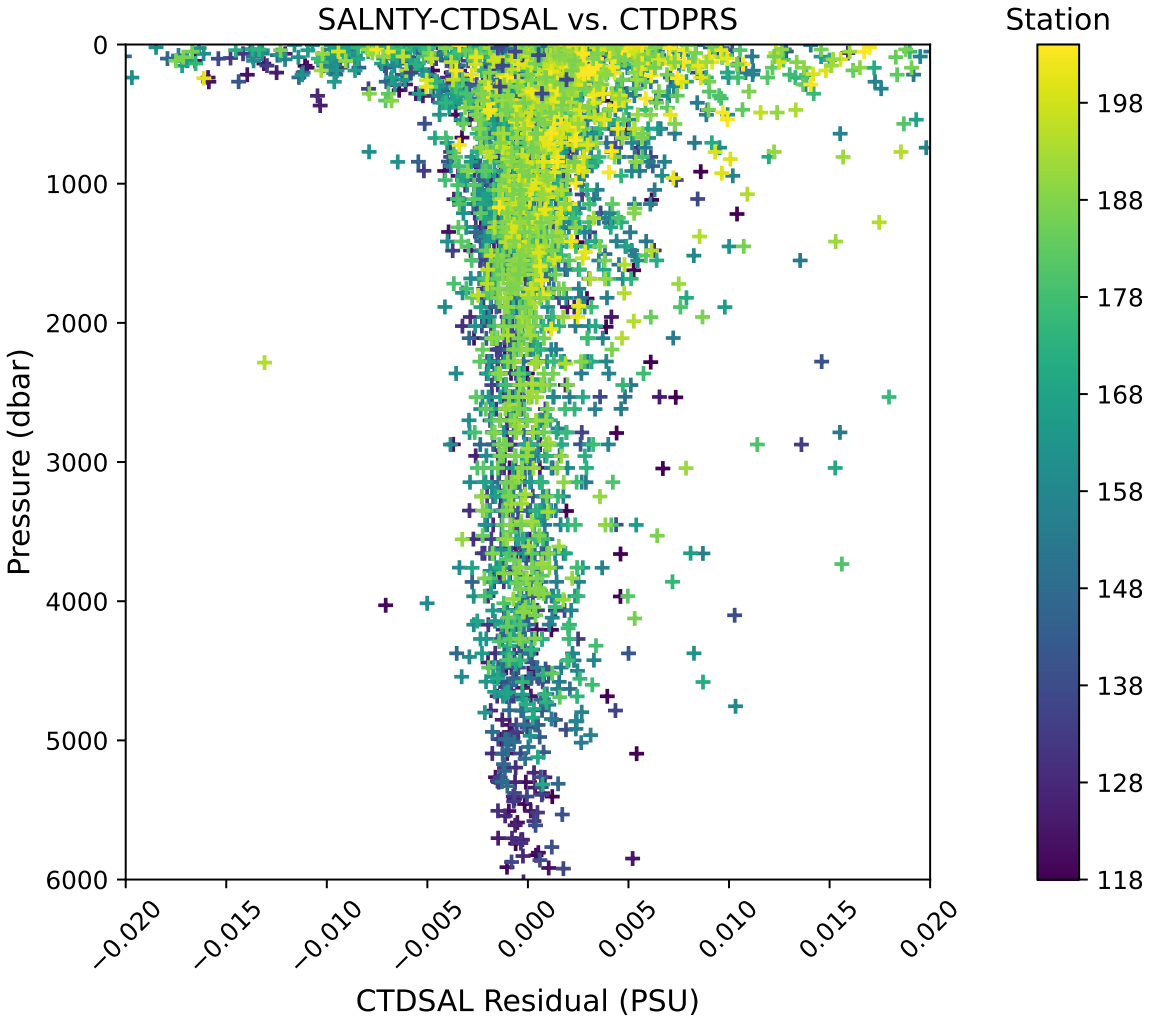

Fig. 22: Salinity residuals versus pressure.

5.6 CTD Dissolved Oxygen (SBE43)

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. Corrections for hysteresis are applied following Sea-Bird Application Note 64-3. The SBE43 sensor data were compared to dissolved O_2 check samples taken at bottle stops by matching the downcast CTD data to the upcast 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 PMEL DO sensor response model coefficients using the BFGS non-linear least-squares fitting procedure.

The general form of the PMEL DO sensor response model equation for Clark cells follows Brown and Morrison [Mill82] and Owens [Owen85]. Dissolved O_2 concentration is then calculated:

$$O_2 = S_{oc} \cdot (V + V_{\text{off}} + \tau_{20} \cdot e^{(D_1 \cdot p + D_2 \cdot (T-20))} \cdot dV/dt) \cdot O_{sat} \cdot e^{T_{cor} \cdot T} \cdot e^{[(E \cdot p)/(273.15+T)]}$$

Where:

- V is oxygen voltage (V)
- D_1 and D_2 are (fixed) SBE calibration coefficients
- T is corrected CTD temperature (°C)
- p is corrected CTD pressure (dbar)
- dV/dt is the time-derivative of voltage (V/s)
- O_{sat} is oxygen saturation
- S_{oc}, V_{off}, τ_{20}, T_{cor}, and E are fit coefficients

All stations were fit together to get an initial coefficient estimate. Stations were then fit individually to refine the coefficients as the membrane does not deform the same way with each cast. If the fit of the individual cast had worse resdiuals than the group, they were reverted to the original group fit coefficients.

Table 5: SBE43 group fit coefficients. Coefficients were further refined station-by-station.

Station	S_{oc}	V_{off}	tau_{20}	T_{cor}	E
118-205	6.0036e-1	-5.0138e-1	1.4500e+0	-1.5908e-3	3.713e-2

CTD dissolved O_2 residuals are shown in the following figures *O2 residuals versus station.* through *Deep O2 residuals versus station (Pressure >= 2000dbar).*.

The 95% confidence limits of 1.50 (µmol/kg) for all acceptable (flag 2) dissolved oxygen bottle data values and 1.15 (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.

No issues arose with the acquisition and processing of CTD dissolved oxygen data (SBE43).

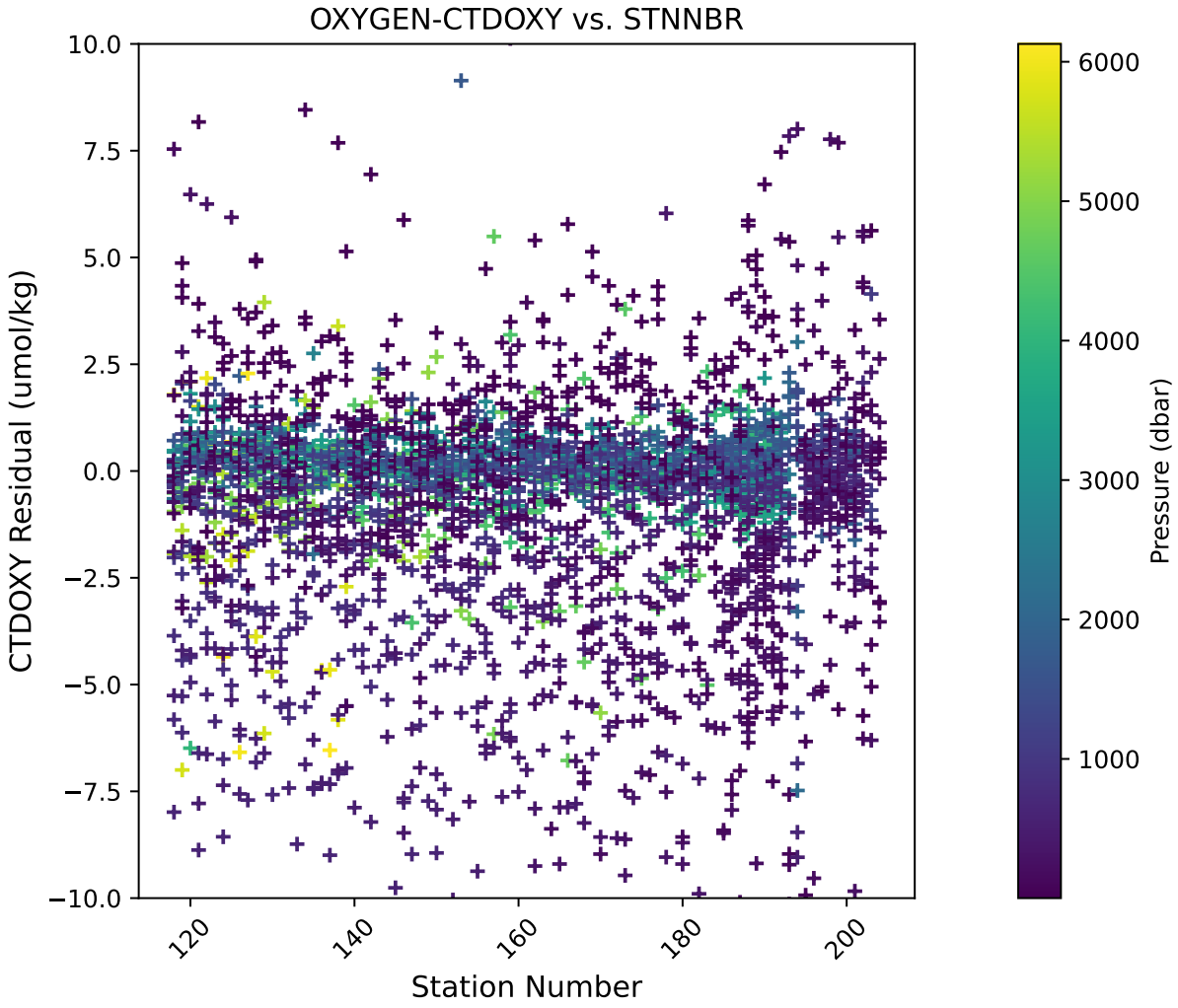

Fig. 23: O_2 residuals versus station.

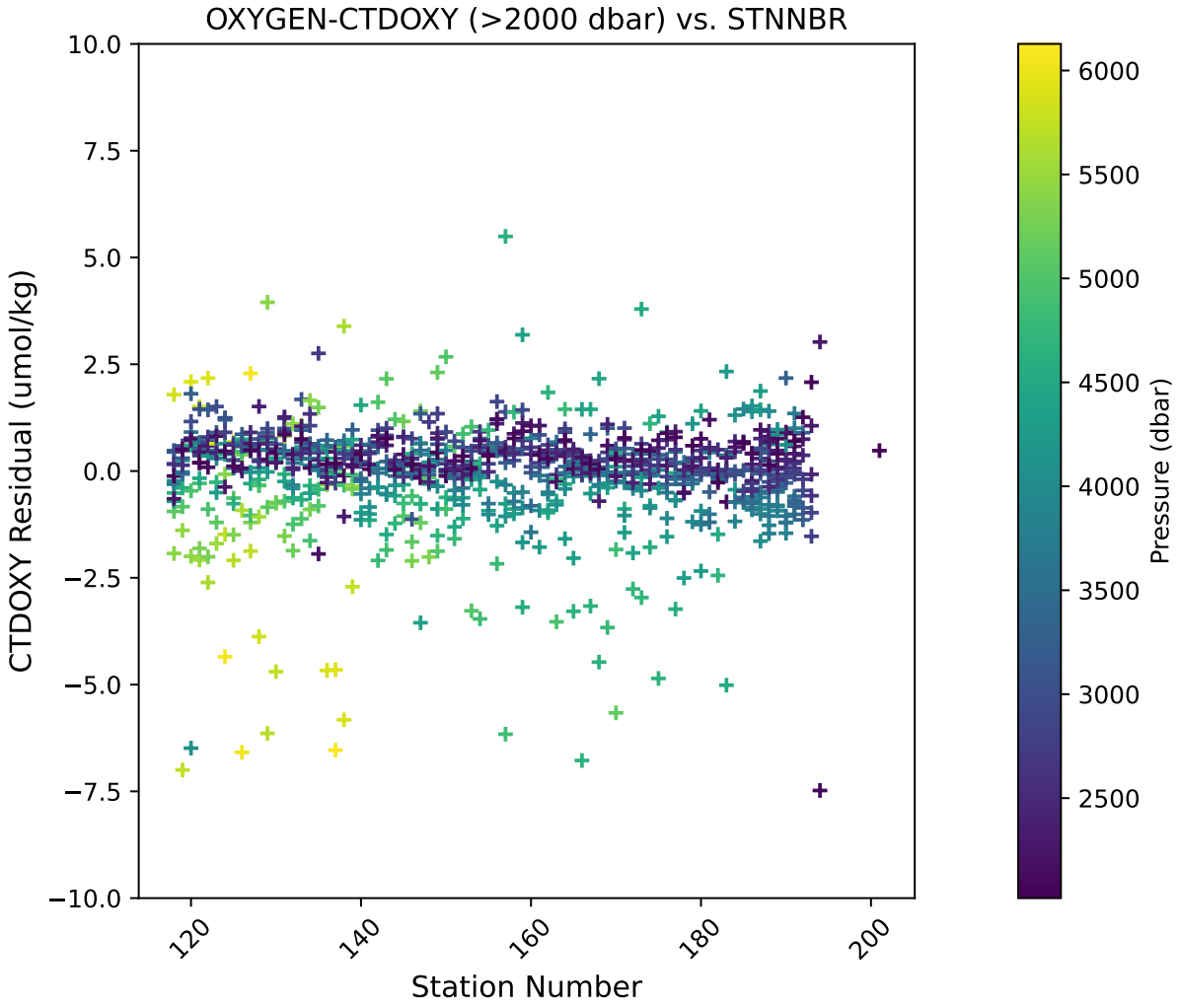

Fig. 24: Deep O_2 residuals versus station (Pressure >= 2000dbar).

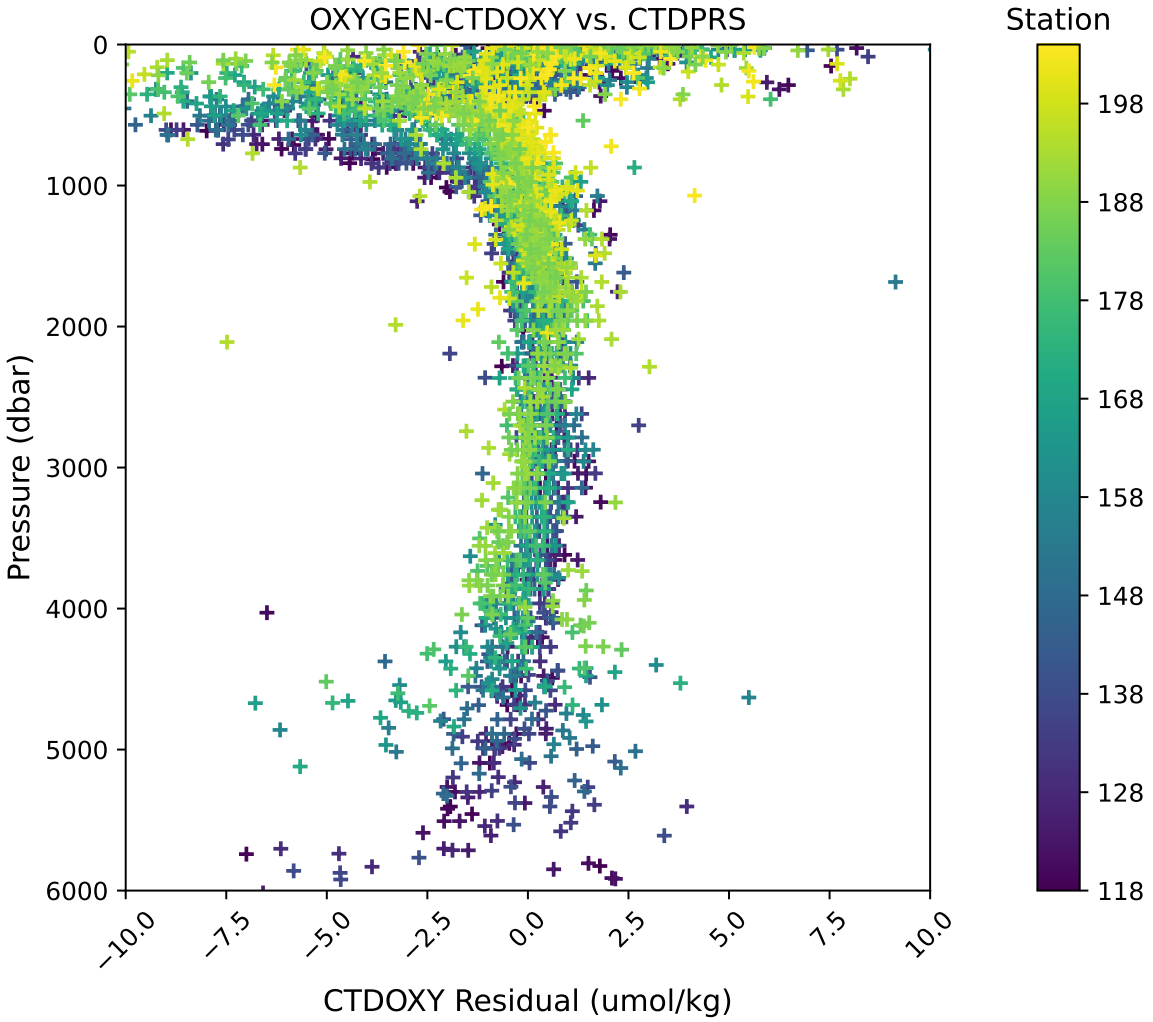

Fig. 25: O_2 residuals versus pressure.

5.7 CTD Dissolved Oxygen (RINKO)

A two-point calibration was performed prior and after deployment on the rosette. These calibrations produced sets of calibration coefficients (G and H) to adjust factory calibration of dissolved oxygen raw voltage. The calibrations also provided an assessment of foil degradation over the course of the 90 stations. As per manufacturer (JFE Advantech Co., Ltd.) recommendation, 100% saturation points were obtained via bubbling ambient air in a stirred beaker of tap water about 30 minutes, removing air stone, then submersing the powered Rinko. Zero point calibrations also followed general manufacturer recommendations, using a sodium sulfite solution (25g in 500mL deionized water). Dissolved oxygen raw voltage (DOout), atmospheric pressure, and solution temperature were recorded for calculation of new oxygen sensor coefficients (G and H).

Rinko temperature (factory coefficients) was used for pre-cruise calibration. Generally, the Rinko III sensor appears to have performed as expected with no major problems or sharp drift throughout the deployment. An SBE 43 dissolved oxygen sensor was deployed simultaneously. Both oxygen sensor data sets were analyzed and quality controlled with Winkler bottle oxygen data. RinkoIII data used as primary oxygen for all stations (118-205), excluding stations 10-12 when the RINKO cable needed to be changed.

RINKO data was acquired, converted from volts to oxygen saturation, and then multipled by the oxygen solubility to find values in µmol/kg. The resulting data were then fitted using the equations developed by [Uchida08]:

$$[O_2] = (V_0/V_c - 1)/K_{sv}$$

$$K_{sv} = c_0 + c_1 T + c_2 T^2, \quad V_0 = 1 + d_0 T, \quad V_c = d_1 + d_2 V_r$$

where:

- T is temperature (ºC)
- V_r is raw voltage (V)
- V_0 is voltage at zero O_2 (V)
- c_0, c_1, c_2, d_0, d_1, d_2 are calibration coefficients

Oxygen is further corrected for pressure effects:

$$[O_2]_c = [O_2](1 + c_p P/1000)^{1/3}$$

where:

- P is pressure (dbar)
- c_p is pressure compensation coefficient

Lastly, salinity corrections are applied [GarciaGordon1992]:

$$[O_2]_{sc} = [O_2]_c \exp[S(B_0 + B_1 T_S + B_2 T_S^2 + B_3 T_S^3) + C_0 S^2]$$

where:

- T_S is scaled temperature (T_S = ln[(298.15 – T)/(273.15 + T)])
- B_0, B_1, B_2, B_3, C_0 are solubility coefficients

All stations excluding 10-12 were fit together to get an initial coefficient estimate. Stations were then fit in groups of similar profiles to get a further refined estimate. Individual casts were then fit to remove the noticeable time drift in coefficients If the fit of the individual cast had worse resdiuals than the group, they were reverted to the original group fit coefficients.

Table 6: Rinko group fit coefficients. Coefficients were further refined station-by-station.

Station	c_0	c_1	c_2	d_0	d_1	d_2	c_p
118-205	1.3182e+0	1.8002e-2	1.7002e-4	-1.4178e-3	-1.2641e-1	3.3973e-1	8.8540e-2

CTD dissolved O_2 residuals are shown in the following figures.

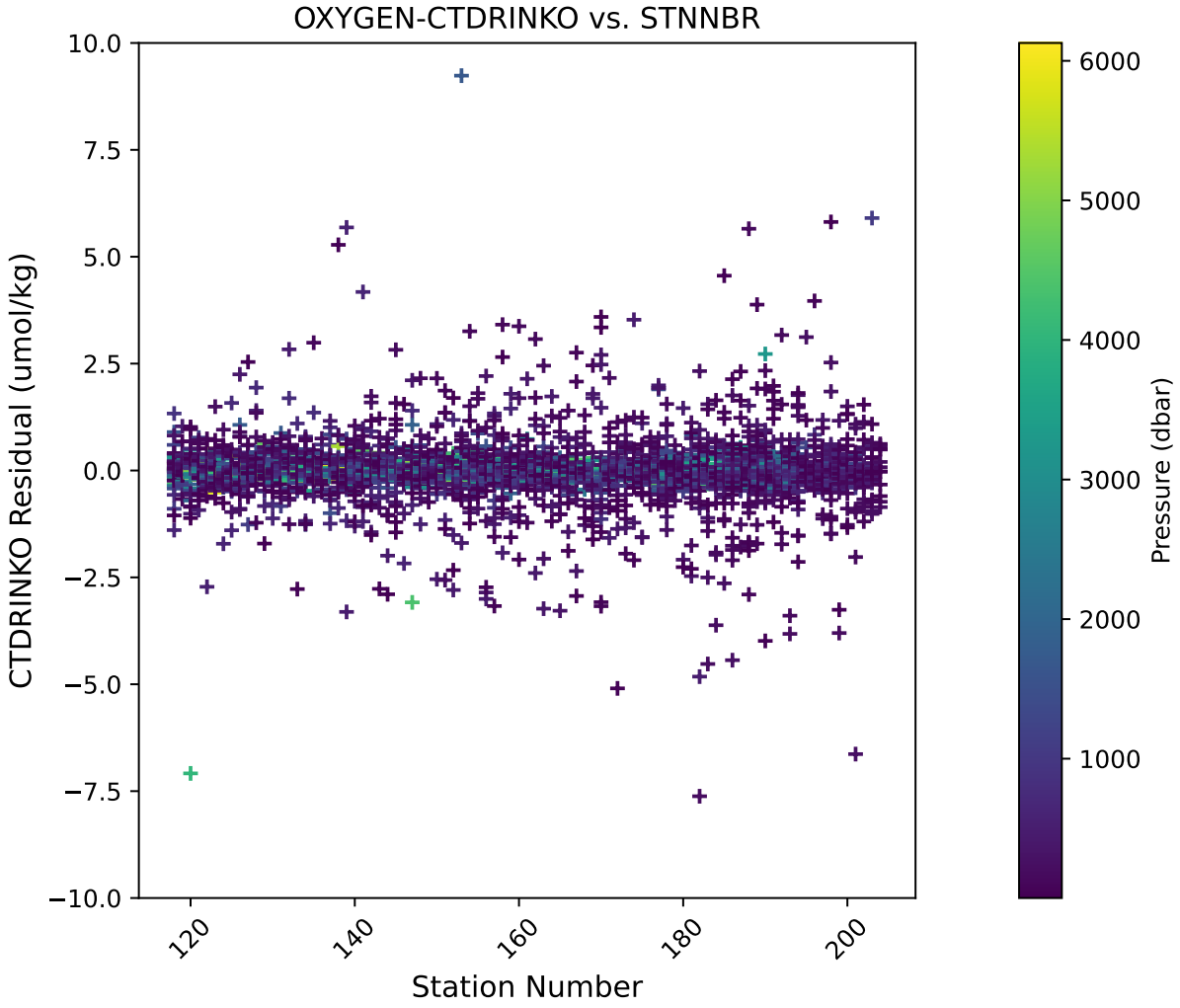

Fig. 26: O_2 residuals versus station.

The 95% confidence limits of 0.86 (µmol/kg) for all acceptable (flag 2) dissolved oxygen bottle data values and 0.36 (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.

No issues arose with the acquisition and processing of CTD dissolved oxygen data (RINKO).

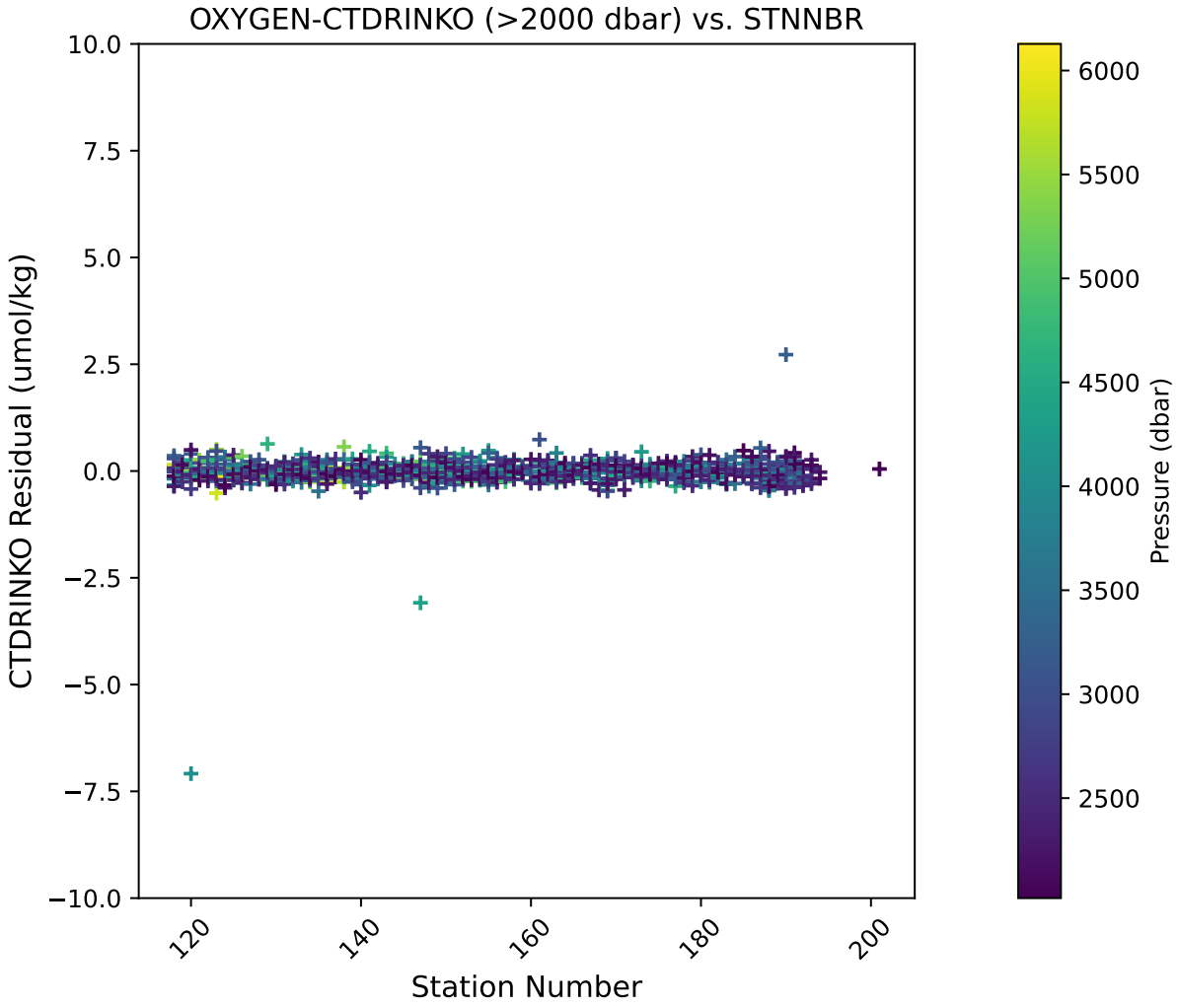

Fig. 27: Deep O_2 residuals versus station (Pressure >= 2000dbar).

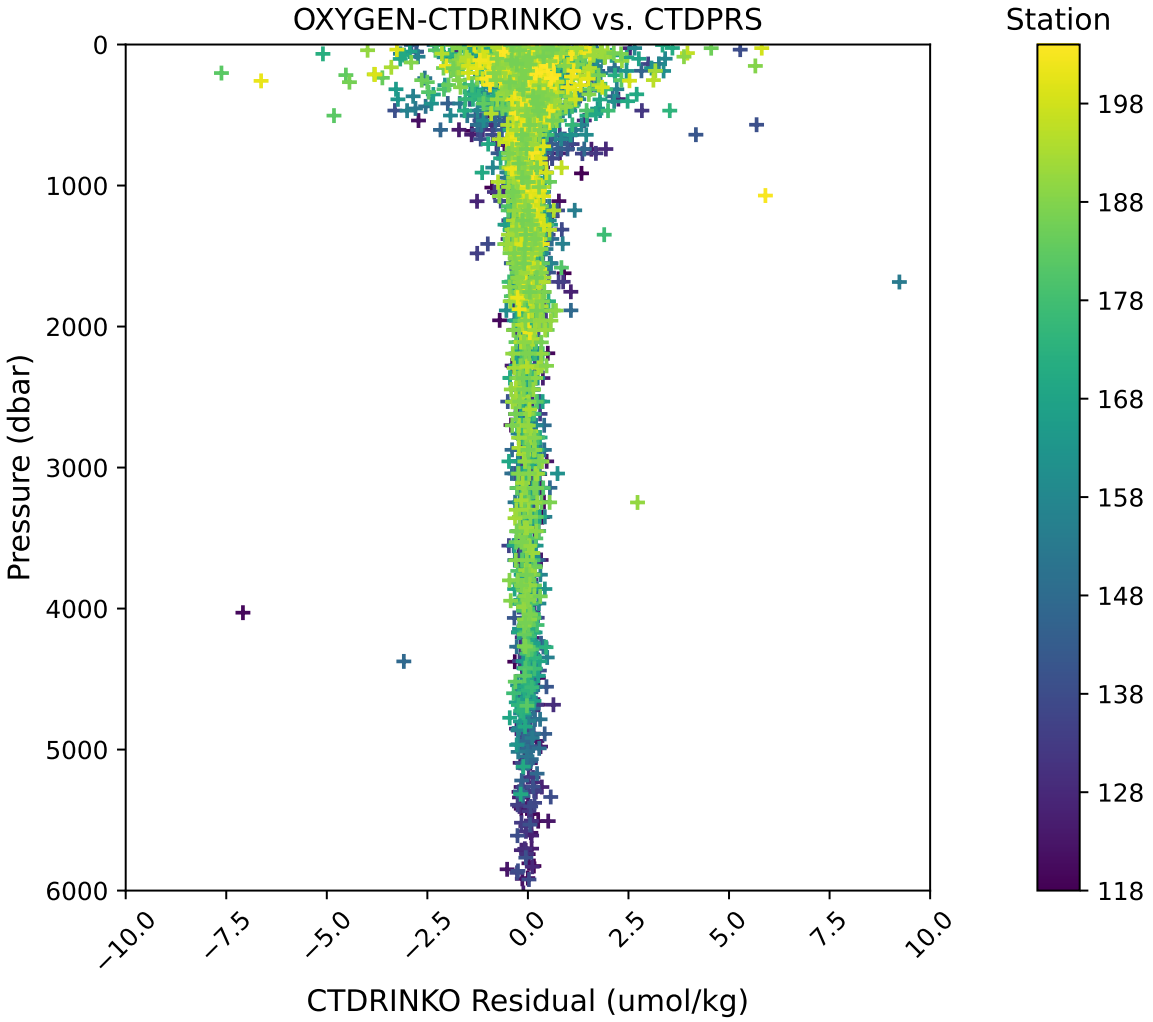

Fig. 28: O_2 residuals versus pressure.

5.8 BIO Casts

Throughout P02E-2022, 31 bio casts were taken prior to the full cast for separate, large volumes of water for biological analyses. The first bio cast was cast 3 at station 119. The last bio cast was cast 1 at station 203. Bio casts were done at re-occupations of station 191 and 188. Salinity and oxygen analyses were not performed during these casts and therefore the CTD was not fit for those parameters.

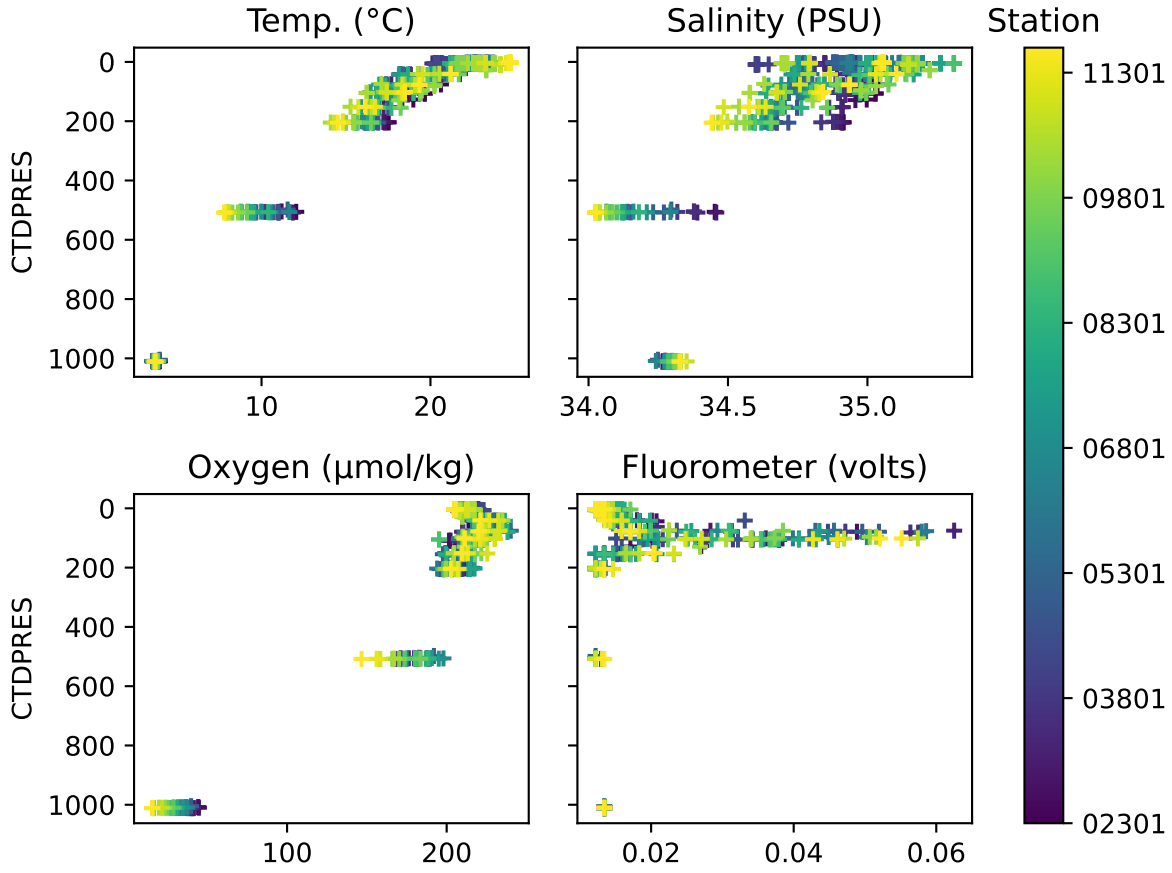

Fig. 29: CTD bottle values for temperature, salinity, oxygen, and fluorometer voltage plotted against CTD pressure across all bottle casts.

CHAPTER

SIX

SALINITY

PIs

- Todd Martz (SIO)
- Susan Becker (SIO)

Technicians

- Laurette Roy (Tech Pool)
- Gabriel Matthias (Tech Pool)

6.1 Equipment and Techniques

Two Guildline Autosals were on board and operational, SIO-owned 8400A S/N 57-526 and S/N 55-564. S/N 57-526 was used for all salinity measurements during this cruise. The salinity analysis was run in the ship's Climate Controlled Chamber, a refrigerator port and amidships between the Computer Lab and Analytical Lab. The chamber temperature varied between about 21 and 25 degrees Celcius around 3 times each hour, with an average (based on measuring temperatures of items in the chamber) of about 23°C.

Both instruments were serviced prior to the cruise by their respective institutions. S/N 57-526 was shipped to Guam and was the primary on the first leg of the PO2 occupation. S/N 55-654 was shipped to Hawaii with other equipment in March. IAPSO Standard Seawater Batch P-165 was used for all calibrations: K15 = 0.99986, salinity 34.994, expiration 2024-04-15. A LabView program developed by Carl Mattson was used for monitoring temperatures, logging data and prompting the operator. Salinity analyses were performed after samples had equilibrated to laboratory temperature of 23°C, usually 8 hours or more after collection.

The salinometer was standardized for each group of samples analyzed (normally 1 or 2 casts, up to 72 samples) using two bottles of standard seawater: one at the beginning and one at the end of each set of measurements. For each calibration standard and sample reading, the salinometer cell was initially flushed at least 2 times before a set of conductivity ratio readings was recorded. Between runs the water from the last standard was left in the cell.

6.2 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 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 function of elapsed run time. The corrected salinity data was then incorporated into the cruise database.

6.3 Narrative

No major problems were encountered during this cruise. Some red algae was seen growing in one case of sample bottles. Acid washing (10% HCl) solved the problem. Additional red algae was seen at the drain tube of the salinometer. Solved by leaving DI water in the machine for 8 hours. Capillary tubes were carefully cleaned with MilliQ, followed by air, 3 times during the course of the cruise, to help with cell filling. The first cleaning included a run with diluted Triton-X. 3,265 total salinity samples were taken from 128 CTD casts. Four sample bottles were broken over the course of this cruise.

CHAPTER

SEVEN

NUTRIENTS

Technicians

- John Ballard: Scripps Institution of Oceanography
- Tanya Leung: Scripps Institution of Oceanography

7.1 Summary of Analysis

- 3265 samples from 94 CTD stations
- The cruise started with new pump tubes and they were changed twice, before stations 158, 176, and 200.
- 5 sets of Primary/Secondary mixed standards and 2 sets of primary Nitrite standards were made up over the course of the cruise.
- The cadmium column efficiency was checked periodically and ranged between 93%-100%.

7.2 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 updated GO-SHIP repeat hydrography manual (Becker et al., 2019, [Becker2019]).

7.3 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 520nm. 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 $CuSO_4$ + NH_4Cl mix (see below). Add 4 drops 40% Surfynol 465/485 surfactant. Let sit overnight before proceeding. Using a calibrated pH meter, adjust to pH of 7.83-7.85 with 10% (1.2N) HCl (about 10 ml of acid, depending on exact strength). Bring final solution to 4L with DIW. Store at room temperature.

NH_4Cl + $CuSO_4$ mix Dissolve 2g cupric sulfate in DIW, bring to 100 m1 volume (2%). Dissolve 250g ammonium chloride in DIW, bring to 1l liter volume. Add 5ml of 2% $CuSO_4$ solution to this NH_4Cl stock. This should last many months.

7.4 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.

REAGENTS

Ammonium Molybdate H_2SO_4 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 H_2SO_4. This solution gets VERY HOT!! Cool in the ice bath. Make up as much as necessary in the above proportions.

Dissolve 27g ammonium molybdate in 250ml of DIW. Bring to 1 liter volume with the cooled sulfuric acid 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.

7.5 Silicate Analysis

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

REAGENTS

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

Ammonium Molybdate Dissolve 10.8g Ammonium Molybdate Tetrahydrate in 1000ml dilute H_2SO_4. (Dilute H_2SO_4 = 2.8ml conc H_2SO_4 or 6.4ml of H_2SO_4 diluted for PO_4 moly per liter DW) (dissolve powder, then add H_2SO_4) 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.

7.6 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 4 hours after sample collection, allowing sufficient time for all samples to reach room temperature. The centrifuge tubes fit directly onto the sampler.

7.7 Data Collection and Processing

Data collection and processing was done with the software provided with the instrument from Seal Analytical (AACE). 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.

7.8 Standards and Glassware Calibration

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

All glass volumetric flasks and pipettes were gravimetrically calibrated prior to the cruise. The primary standards were dried and weighed out to 0.1mg 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. 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 12-16 hours from a secondary. Working standards were made up in low nutrient seawater (LNSW). Multiple batches of LNSW were used on the cruise. The first batch of LNSW was treated in the lab. The water was re-circulated for ~8 hours through a 0.2 micron filter, passed a UV lamp and through a second 0.2 micron filter. The actual concentration of nutrients in this water was empirically determined during the standardization calculations.

The concentrations in micro-moles per liter of the working standards used were:

-	N+N (uM)	PO_4 (uM)	SIL (uM)	NO_2 (uM)
0	0.0	0.0	0.0	0.0
3	15.50	1.2	60	0.50
5	31.00	2.4	120	1.00
7	46.50	3.6	180	1.50

7.9 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

Reference materials for nutrients in seawater (RMNS) were used as a check sample run with every station. The RMNS preparation, verification, and suggested protocol for use of the material are described by [Aoyama2006] [Aoyama2007], [Aoyama2008], Sato [Sato2010] and Becker et al. [Becker2019]. RMNS batch CM was used on this cruise, with each bottle being used for all runs in one day before being discarded and a new one opened. Data are tabulated below.

Parameter	Concentration	stddev	assigned conc
-	(µmol/kg)	-	(µmol/kg)
NO_3	33.16	0.13	33.2
PO_4	2.38	0.01	2.38
Sil	100.4	0.61	100.5
NO_2	0.019	0.008	0.02

7.10 Analytical Problems

Occasional excess carryover on phosphate channel was resolved with a series of cleaning procedures and monitored throughout cruise. A contamination issue created problems for silicate measurement from a few individual sample tubes beginning at station 132. The contaminant (suspect winch wire grease) eventually spread to other sample tubes and affected about 15 individual silicate measurements between station 132-153. Once tubes were replaced at station 154, the issue was resolved. The values of the reference material and were used to monitor data quality. Adjustments based on the values obtained for the reference material were made as necessary. Final QC checks were not completed until after the cruise. Comparison of data from adjacent stations and to historical data revealed that phosphate data for stations 12-147 was bad due to a bad reagent preparation.

CHAPTER

EIGHT

OXYGEN ANALYSIS

PIs

- Todd Martz (SIO)
- Susan Becker (SIO)

Technicians

- Elisa Aitoro (SIO)
- Robert "Ben" Freiberger (SIO)

8.1 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 (~0.012 N), and thiosulfate solution (~55 g/L).

Pre-made liquid potassium iodate standards and reagent/distilled water blanks were run every day (approximately every 3-4 stations), with samples analysed within 24 hours of the last standard.

8.2 Sampling and Data Processing

A total of 3262 oxygen measurements were made, all of which were niskin samples. Niskin samples were collected soon after the rosette was secured on deck, either from fresh niskins or immediately following CFC sampling.

Nominal 125 mL volume-calibrated biological oxygen demand (BOD) flasks were rinsed 3 times with minimal agitation using a silicone draw tube, then filled and allowed to overflow for at least 3 flask volumes, ensuring no bubbles remained. Pickling reagents MnCl2 and NaI/NaOH (1 mL of each) were added via bottle-top dispensers to fix samples before stoppering. Flasks were shaken twice (10-12 inversions) to assure thorough dispersion of the precipitate - once immediately after drawing and then again after 30-60 minutes.

Sample draw temperatures, measured with an electronic resistance temperature detector (RTD) embedded in the draw tube, were used to calculate umol/kg concentrations, and as a diagnostic check of bottle integrity.

Niskin samples were analysed within 2-12 hours of collection, and the data incorporated into the cruise database.

Thiosulfate normalities were calculated for each standardisation and corrected to 20°C. The 20°C thiosulfate normalities and blanks were plotted versus time and were reviewed for possible problems, and were subsequently determined to be stable enough that no smoothing was required.

8.3 Volumetric Calibration

Oxygen flask volumes were determined gravimetrically with degassed deionised 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 10 mL Dosimat buret used to dispense standard iodate solution was calibrated using the same method.

8.4 Standards

Liquid potassium iodate standards were prepared in 6 L 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 oxidising and reducing impurities prior to use.

8.5 Narrative

The oxygen analytical rig was setup in the main lab of the Revelle. During the transit into Honolulu during leg 1, 4L batches were made of each reagent.

No major analytical issues were encountered. A few high end points occurred and were corrected for. The analytical computer would freeze occasionally, but never while doing analysis.

The thiosulfate stability was considered in 3 batches and showed remarkable stability throughout the entire cruise. No trends were observed or corrected for.

An OSIL standard was run against the usual ODF working standard using a hand pipetter. The agreement between the OSIL and the ODF standard was just within the daily tolerance.

No data updates are expected.

CHAPTER

NINE

TOTAL ALKALINITY

PIs

- Andrew G. Dickson (SIO)

Technicians

- Daniela Nestory (SIO)
- Sidney Wayne (HPU)

9.1 Total Alkalinity

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

9.2 Total Alkalinity Measurement System

Sample Delivery System:

Samples are dispensed using a Sample Delivery System (SDS) which has been calibrated for volume in the lab prior to the cruise. Its volume is confirmed immediately before use at sea to ensure a consistent volume will be delivered for each sample. The SDS consists of a volumetric pipette, various relay valves, an air pump, and is controlled by a program in LabVIEW 2012.

Before attaching a sample bottle to the SDS, the volumetric pipette is cleared of any residual solution. The pipette is then rinsed and filled with the sample. The sample overflows and time is allowed for the sample temperature to equilibrate.

The sample bottle temperature is measured using a DirecTemp thermistor probe inserted into the sample bottle and the volumetric pipette temperature is measured using a DirecTemp surface probe placed directly on the pipette. These temperature measurements, along with the bottle salinity, are used to convert the sample volume to mass for analysis.

Samples are delivered into a 250-mL water-jacketed open cell for titration analysis. While one sample is undergoing titration, a second sample is prepared with the SDS and equilibrated to 20°C for analysis.

Open-Cell Titration:

The total alkalinity is measured through an open-cell titration with a dilute hydrochloric acid titrant of known concentration. A Metrohm 876 Dosimat Plus is used for all standardized hydrochloric acid additions.

An initial aliquot of approximately 2.3-2.4 mL of standardized hydrochloric acid (~0.1M HCl in ~0.6M NaCl solution) is first delivered and the sample is stirred for 5 minutes while air is bubbled into at a rate of 200 scc/m to remove any liberated carbon dioxide gas.

After equilibration, ~19 aliquots of 0.035 ml are added. Between the pH range of 3.5 to 3.0, the progress of the titration is monitored using a pH glass electrode/reference electrode cell, and the total alkalinity is computed from the titrant volume and e.m.f. measurements using a non-linear least-squares approach ([Dickson2007]).

A Thermo Scientific Isotemp water bath is connected to the water-jacketed open cell to maintain a cell temperature of approximately 20oC. An Agilent 34970A Data Acquisition/Switch Unit with a 34901A multiplexer is used to read the voltage measurements from the electrode and monitor the temperatures from the sample, acid, and room.

The calculations for this procedure are performed automatically using LabVIEW 2012.

9.3 Sample Collection

Alkalinity samples are drawn using silicone tubing connected to the Niskin bottles and collected into 250 mL Pyrex bottles. The sample bottles and Teflon-sleeved glass stoppers were rinsed at least twice before the final filling. A headspace of approximately 3 mL was removed and 0.1 mL of 50% saturated mercuric chloride solution was added to each sample for preservation. The samples were equilibrated prior to analysis at approximately 20°C using a Thermo Scientific Isotemp water bath.

Samples for total alkalinity were taken at all stations during Leg 2 of P02 (118-204). Except for a few instances, alkalinity samples were collected from all niskins where DIC and pH were collected, to over-characterize the CO2 system. The typical sample scheme of partial collection on all stations (26 bottles), with the exception of a full collection (36 bottles) on select stations, was followed.

In order to evaluate the reproducibility of the alkalinity system, 2 duplicate samples (two separate alkalinity bottles) were collected on each cast, with the exception of casts with fewer than 18 bottles, in which 1 duplicate sample was collected.

9.4 Problems and Troubleshooting

The alkalinity system was set up in the hydro lab. Around station 124, voltage readings from the system's electrode were suddenly noisy and values were affected. All parts of the alkalinity system were changed in hopes of remedying the noise, but to no avail. The system was moved to the analytical lab around station 125 and the voltage readings / CRM values were once again normal. Analyses for stations 124 and 125 were the only stations affected by this issue.

9.5 Quality Control

Certified Reference Material (CRMs) and duplicate samples (two bottles collected from one niskin) were used to quality check the functioning of the total alkalinity system throughout the cruise.

Dickson laboratory Certified Reference Material (CRM) Batches 200 and 201 were used to determine the accuracy of the total alkalinity analyses. The total alkalinity certified value for these batches are:

- Batch 200 2186.43 $\pm$ 0.42 µmol/kg
- Batch 201 2207.56 $\pm$ 0.47 µmol/kg

The cited uncertainties represent the standard deviation.

A CRM sample was analyzed at a minimum frequency of once per every 20 runs, but more often once per every 15 runs. Because total alkalinity is not affected by gas-exchange, brand new CRM bottles were reserved for pH and DIC analysis. These pre-opened bottles were subsequently used for alkalinity analysis.

198 reference material samples were analyzed on Leg 2 of P02.

The average measured total alkalinity value for each batch is:

- Batch 200 2186.59 $\pm$ 1.39 µmol/kg (n = 133, 70)
- Batch 201 2208.24 $\pm$ 1.25 µmol/kg (n = 65, 40)

Figures in parentheses are the number of analyses made (total number of analyses; number of separate bottles analyzed).

Duplicate samples were also used to check the reproducibility of the system. The absolute value of the mean offset between duplicate samples and the standard deviation are given below.

Mean duplicate sample offset: 1.08 $\pm$ 1.00 µmol/kg (n = 164)

2396 total alkalinity values were submitted for Leg 2 of P02.

Further dilution corrections need to be applied to this data back onshore, therefore, this data is to be considered preliminary.

CHAPTER

TEN

DISCRETE PH ANALYSES (TOTAL SCALE)

PI

- Dr. Andrew Dickson (SIO)

Technicians

- Albert Ortiz (RSMAS)
- Brison Grey (RSMAS)

10.1 Sampling

Samples were collected in 250 mL Pyrex glass bottles and sealed using grey butyl rubber stoppers held in place by aluminum-crimped caps. Each bottle was rinsed two times and allowed to overflow by one half additional bottle volume. Prior to sealing, each sample was given a 1% headspace and 0.1 mL of 50% saturated mercuric chloride solution was added to each sample for preservation. Samples were collected only from Niskin bottles that were also being sampled for both total alkalinity and dissolved inorganic carbon in order to completely characterize the carbon system. Additionally, duplicate samples were collected from all stations for quality control purposes.

10.2 Analysis

pH was measured spectrophotometrically on the total hydrogen scale using an Agilent 8453 spectrophotometer and in accordance with the methods outlined by Carter et al, 2013. [Carter2013]. A Kloehn V6 syringe pump was used to autonomously fill, mix, and dispense sample through the custom 10cm flow-through jacketed cell. A Thermo Fisher Isotemp recirculating water bath was used to maintain the cell temperature at 25.0°C during analyses, and a YSI 4600 precision thermometer and probe were used to monitor and record the temperature of each sample during the spectrophotometric measurements. Purified meta-cresol purple (mCP) was the indicator used to measure the absorbance of light measured at two different wavelengths (434 nm, 578 nm) corresponding to the maximum absorbance peaks for the acidic and basic forms of the indicator dye. A baseline absorbance was also measured and subtracted from these wavelengths. The baseline absorbance was determined by averaging the absorbances from 725-735nm. The ratio of the absorbances was then used to calculate pH on the total scale using the equations outlined in Liu et al., 2011 [Liu2011]. The salinity data used was obtained from the salinity analysis conducted on board.

10.3 Reagents

The mCP indicator dye was made up to a concentration of approximately 2.0mM and a total ionic strength of 0.7 M. A total of two batches were used during Leg 2 of P02. The pHs of these batches were adjusted with 0.1 mol kg^{-1} solutions of HCl and NaOH (in 0.6 mol kg^{-1} NaCl background) to approximately 7.80, measured with a pH meter calibrated with NBS buffers. The indicator was obtained from Dr. Robert Byrne at the University of Southern Florida and was purified using the flash chromatography technique described by Patsavas et al., 2013. [Patsavas2013].

10.4 Data Processing

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

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

and

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

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

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

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

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

10.5 Problems and Troubleshooting

There were no major issues encountered during Leg 2 of P02.

10.6 Standardization/Results

The precision of the data was assessed from measurements of duplicate analyses and certified reference material (CRM) Batch 200 (provided by Dr. Andrew Dickson, UCSD).

In order to evaluate the reproducibility of the alkalinity system, 2 duplicate samples (two separate alkalinity bottles) were collected on each cast, with the exception of casts with fewer than 18 niskins, in which 1 duplicate sample was collected.

CRMs were measured at the beginning and ending of each day.

The precision statistics for Leg 2 of P02 are:

Duplicate precision	$\pm$ 0.0008 (n= 183)
B200	7.7987 $\pm$ 0.0010 (n= 40)

2451 pH values were submitted for Leg 2 of P02. Additional corrections will need to be performed and these data should be considered preliminary until a more thorough analysis of the data can take place on shore.

CHAPTER

ELEVEN

DISSOLVED INORGANIC CARBON (DIC)

PI's

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

Technicians

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

11.1 Sample Collection

Samples for *DIC* measurements were drawn (according to procedures outlined in the PICES Special Publication, Guide to Best Practices for Ocean CO_2 Measurements [Dickson2007]) from Bullister style niskin bottles into ~310ml borosilicate glass flasks using platinum-cured silicone tubing. The flasks were rinsed once and filled from the bottom with care not to entrain any bubbles, overflowing by at least one-half volume. The sample tube was pinched off and withdrawn, creating a 6ml headspace and 0.12 ml of saturated $HgCl_2$ solution was added as a preservative. The sample bottles were then sealed with glass stoppers lightly covered with Apiezon-L grease. DIC samples were collected from a variety of depths with approximately 10% of these samples taken as duplicates.

11.2 Equipment

The analysis was done by coulometry with two analytical systems (PMEL1 and PMEL2) used simultaneously on the cruise. Each system consisted of a coulometer (5015O UIC Inc) coupled with a Dissolved Inorganic Carbon Extractor (DICE). The DICE system was developed by Esa Peltola and Denis Pierrot of NOAA/AOML and Dana Greeley of NOAA/PMEL to modernize a carbon extractor called SOMMA ([Johnson1985], [Johnson1987], [Johnson1993], [Johnson1992], [Johnson1999]). The two DICE systems were set up in a seagoing container modified for use as a shipboard laboratory on the aft main working deck of the *RV Roger Revelle*.

11.3 DIC Analysis

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

11.4 DIC Calculation

The amount of CO_2 injected was calculated according to the 2007 PICES Special Publication. Each DICE instrument has a modified SBE45 salinity sensor, but all DIC values were recalculated to a molar weight (µmol kg^{-1}) using density obtained from the CTD's salinity.

The DIC values were corrected for dilution resulting from the addition of 0.12 ml of saturated $HgCl_2$ used for sample preservation. The correction factor used for this dilution is 1.000397. A correction was also applied for the offset from the Certified Reference Material (CRM). This additive correction was applied for each cell using the value of the CRM obtained at the beginning of the cell. The coulometer cell solution was replaced after 24-28 mg of carbon was titrated, typically after 10-12 hours of continuous use. The blanks (background noise per cell) ranged from 20-62.6 on DICE1 and 30-82.3 on DICE2.

11.5 Calibration, Accuracy, and Precision

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

1) Gas loops were always run at the beginning and usually at the end of each cell;

2) CRM's supplied by Dr. A. Dickson of SIO, were measured near the beginning; and

3) Duplicate samples were run throughout the life of the cell solution.

Each coulometer was calibrated by injecting aliquots of pure CO_2 (99.999%), as a standard, by means of an 8-port valve ([Wilke1993]) outfitted with two calibrated sample loops of different sizes (~1ml and ~2ml). The instruments were each separately calibrated at the beginning of each cell with a minimum of two sets of these gas loop injections; and when time allowed at the end of each cell to ensure no drift during the life of the cell.

The accuracy of the DICE measurement is determined with the use of standards, Certified Reference Materials (CRMs) consisting of filtered and UV irradiated seawater, supplied by Dr. A. Dickson of Scripps Institution of Oceanography (SIO). The CRM accuracy is determined manometrically on land in San Diego and the DIC data reported have been corrected to batches 200 and 201 CRM values. Batch 200 was used for the first 44 stations and batch 201 for the remaining 48. The CRM certified values for batches 200 and 201 are 2022.46 µmol kg^{-1} and 2048.19 µmol kg^{-1}. The summary table below[1] lists information for the CRMs.

The precision of the two DICE systems can be demonstrated via the replicate samples. Approximately 5% of the niskins sampled were duplicates taken as a check of our precision. These replicate samples were interspersed throughout the station analysis for quality assurance and integrity of the coulometer cell solutions. The average absolute difference from the mean of these replicates is 0.86 µmol kg^{-1}; No systematic differences between the replicates were observed[2].

11.6 Summary

The overall performance of the analytical equipment was good during the cruise. No major equipment problems were encountered, nor other problems that wound up compromising the quality of the data we collected. As is standard operating procedure, the pipette calibrations will need to be repeated upon return to shore. Both systems ran with slightly higher than normal background noise (blanks) than we are used to seeing. It is believed this extra noise is due to the new bow thruster the Revelle had installed during the mid-life refit and the need for all thrusters (Z-drive included) to be calibrated so they work as a team. This extra instrument noise is apparent while on station but not while the ship is underway. Further supporting this belief, we had no extra background noise in Seattle or while tied up at the pier while in Guam before the first leg of P02. Even with this additional background noise, the overall precision and accuracy and comparison to the 2013 P02 data set leads us to believe the systems were not compromised by this higher blank. Including the duplicates, 2,672 samples were analyzed for dissolved inorganic carbon. Therefore, DIC analyzed approximately 75% of the niskins made available to us. The DIC data reported to the database directly from the ship are to be considered preliminary until a more thorough quality assurance can be completed shore side.

Calibration data during this cruise:

SYSTEM	Average Gas Loop Cal Factor	Pipette Volume	Observed
PMEL1	1.00535	27.571 ml	0.80
PMEL2	1.00394	26.363 ml	0.91

CRM Info	PMEL1			PMEL2		
Batch - Cert.	Ave	N	Std Dev	Ave	N	Std Dev
200 - 2022.46	2022.76	21	1.53	2022.07	21	1.59
201 - 2048.19	2047.92	26	1.12	2048.61	25	1.88

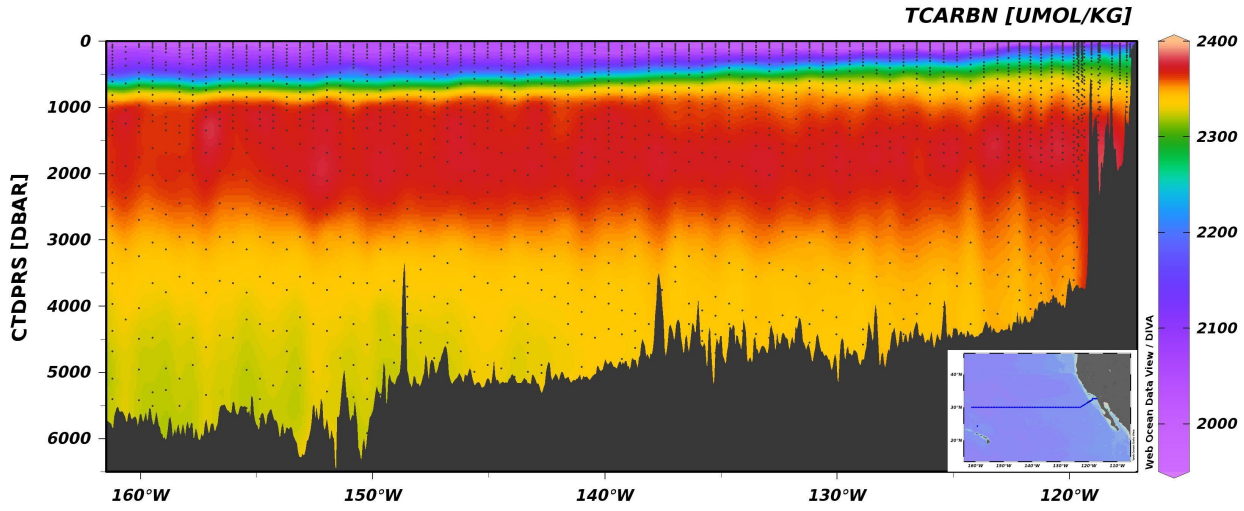

Fig. 1: Section plot of DIC from Leg 2 of P02.

CHAPTER

TWELVE

DISSOLVED ORGANIC CARBON AND TOTAL DISSOLVED NITROGEN

PI

- Craig Carson (UCSB)

Technician

- Michelle Michelsen (UoE/UCSB)

Analysts

- Keri Opalk (UCSB)
- Elisa Halewood (UCSB)

Support NSF

12.1 Project Goals

The goal of the DOM project is to evaluate dissolved organic carbon (DOC) and total dissolved nitrogen (TDN) concentrations along the P02 zonal transect.

12.2 Sampling

DOC profiles were taken from every other stations from 12-36 niskins ranging the full depth of the water column with two duplicates (47 of 94 stations; 1449 DOC/TDN samples). All samples collected above 250 meters were filtered through an inline filter holding a combusted GF/F filter attached directly to the niskin.

This was done to eliminate particles larger than 0.7 µm from the sample. To reduce contamination by the filter or filter holder, a new filter and holder was used for every station. All samples were rinsed 3 times with about 5 mL of seawater and collected into combusted 40 mL glass EPA vials. Samples were fixed with 50 µL of 4M Hydrochloric acid and stored at 4ºC on board. Samples were shipped back to UCSB for analysis via high temperature combustion Shimadzu TOC-V or TOC L analyzers.

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

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

12.3 Standard Operating Procedure for DOC analyses – Carlson Lab UCSB

DOC samples will be analyzed via high temperature combustion using a Shimadzu TOC-V or Shimadzu TOC-L at an inshore based laboratory at the University of California, Santa Barbara. The operating conditions of the Shimadzu TOC-V have been slightly modified from the manufacturer's model system. The condensation coil has been removed and the headspace of an internal water trap was reduced to minimize the system's dead space. The combustion tube contains 0.5 cm Pt pillow on top of Pt alumina beads to improve peak shape and to reduce alteration of combustion matrix throughout the run. CO_2 free carrier gas is produced with a Whatman® gas generator ([Carlson2010]). Samples are drawn into a 5 mL injection syringe and acidified with 2M HCL (1.5%) and sparged for 1.5 minutes with CO_2 free gas. Three to five replicate 100 µL of sample are injected into a combustion tube headed to 680°C. The resulting gas stream is passed through several water and halide traps, including an added magnesium perchlorate trap. The CO_2 in the carrier gas is analyzed with a non-dispersive infrared detector and the resulting peak area is integrated with Shimadzu chromatographic software. Injections continue until at least three injections meet the specified range of a SD of 0.1 area counts, CV $\leq$ 2% or best 3 of 5 injections.

Extensive conditioning of the combustion tube with repeated injection of low carbon water (LCW) and deep seawater is essential to minimize the machine blanks. After conditioning, the system blank is assessed with UV oxidized low carbon water. The system response is standardized daily with a four-point calibration curve of potassium hydrogen phthalate solution in LCW. All samples are systematically referenced against low carbon water and deep Sargasso Sea (2600 m) reference waters and surface Sargasso Sea water every 6 – 8 analyses ([Hansell 1998]_). The standard deviation of the deep and surface references analyzed throughout a run generally have a coefficient of variation ranging between 1-3% over the 3-7 independent analyses (number of references depends on the size of the run). Daily references waters were calibrated with DOC CRM provided by D. Hansell (University of Miami; ([Hansell 2005]_)).

12.3.1 DOC Calculation

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

12.4 Standard Operating Procedure for TDN analyses – Carlson Lab UCSB

TDN samples were analyzed via high temperature combustion using Shimadzu TOC-V with attached Shimadzu TNMI unit at an inshore based laboratory at the University of California, Santa Barbara. The operating conditions of the Shimadzu TOC-V were slightly modified from the manufacturer's model system. The condensation coil was removed and the headspace of an internal water trap was reduced to minimize the system's dead space. The combustion tube contained 0.5 cm Pt pillows placed on top of Pt alumina beads to improve peak shape and to resuce alteration of combustion matrix throughout the run. Carrier gas was produced with a Whatman® gas generator ([Carlson2010]) and ozone was generated by the TNMI unite at 0.5L/min flow rate. Three to five replicate 100 µL of sample were injected at 130 mL/min flow rate into the combustion tube headed to 680°C, where the TN in the sample was converted to nitric oxide (NO). The resulting gas stream was passed through an electronic dehumidifier. The dried NO gas then reacted with ozone producing an excited chemiluminescence NO_2 species ([Walsh1989]) and the fluorescence signal was detected with a Shimadzu TNMI chemiluminescence detector. The resulting peak area was integrated with Shimadzu chromatographic software. Injections continue until at least three injections meet the specified range of a SD of 0.1 area counts, CV $\leq$ 2% or best 3 of 5 injections.

Extensive conditioning of the combustion tube with repeated injections of low nitrogen water and deep seawater was essential to minimize the machine blanks. After conditioning, the system blank was assessed with UV oxidized low nitrogen water. The system response was standardized daily with a four-point calibration curve of potassium nitrate solution in blank water. All samples were systematically referenced against low nitrogen water and deep Sargasso Sea

reference waters (2600 m) and surface Sargasso Sea water ever 6-8 analyses ([Hansell1998]). Daily references waters were calibrated with deep CRM provided by D. Hansell (University of Miami; [Hansell2005])).

12.4.1 TDN calculation

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

CHAPTER

THIRTEEN

CARBON ISOTOPES IN SEAWATER (14/13C)

PI

- Roberta Hansman (WHOI)
- Rolf Sonnerup (UW)

Technician

- Michelle Michelsen (UoE/UCSB)

A total of 512 samples were collected along the P02 transect between station 188-198. Radiocarbon profiles were 32 samples from each station with one duplicate and five randomised skips between 4000m-1600m. Station locations mostly followed previous P02 transects.

Samples were collected in 500 mL airtight glass bottles. Using silicone tubing, the flasks were rinsed 3 times with seawater. While keeping the tubing at the bottom of the flask, the flask was filled and flushed by allowing it to overflow 1.5 times its volume. Once the sample was taken, about 10 mL of water was removed to create a headspace and 120 µL of saturate mercuric chloride solution was added to the sample. To avoid contamination, gloves were used when handling all sampling equipment and plastic bags were used to cover any surface where sampling or processing occurred.

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

The radiocarbon/DIC content of the seawater ($\delta^{14}C$) is measured by extracting the inorganic carbon as CO_2 gas, converting the gas to graphite and then counting the number of ^{14}C atoms in the sample directly using an accelerated mass spectrometer (AMS).

Radiocarbon values will be reported as ^{14}C using established procedures modified for AMS applications. The $^{13}C/^{12}C$ of the CO_2 extracted from seawater is measured relative to the $^{13}C/^{12}C$ of a CO_2 gas standard calibrated to the PDB standard using and isotope radio mass spectrometer (IRMS) at NOSAMS.

CHAPTER

FOURTEEN

CFC, SF_6, AND N_2O

PIs

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Analysts

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Samples for the analyses of the dissolved chlorofluorocarbons (CFCs, freons) F11 and F12, sulfur hexafluoride (SF_6) and nitrous oxide (N_2O) were collected and analyzed during RR2205. Seawater samples were taken from all casts, with full profiles generally taken from alternating casts and strategically determined bottles sampled from the remaining casts. These measurements are complemented by periodic measurements of air samples.

Seawater samples were drawn from 10 liter Niskin bottles. Samples for CFC and SF_6 were the first samples drawn, taking care to check the integrity of the sample and coordinate the sampling analysts to minimize any time between the initial opening of each bottle and the completion of sample drawing. To minimize contact with air, the CFC samples were drawn directly through the stopcocks of the Niskin bottles into 250 ml precision glass syringes. Syringes were rinsed and filled via three-way plastic stopcocks. The syringes were subsequently held at 0-5 degrees C until 30 minutes before being analyzed. At that time, the syringe was placed in a bath of surface seawater heated at approximately 28 °C.

For atmospheric sampling, a ~90 m length of 3/8" OD Dekaron tubing was run from the main lab to the bow of the ship. A flow of air was drawn through this line into the main laboratory using an air-cadet pump. The air was compressed in the pump, with the downstream pressure held at ~1.5 atm. using a backpressure regulator. A tee allowed a flow (100 ml min-1) of the compressed air to be directed to the gas sample valve of the CFC analytical system, while the bulk flow of the air (>7 l min-1) was vented through the backpressure regulator. Analysis of bow air was performed at several locations along the cruise track. Approximately five measurements were made at each location to increase the precision. Atmospheric data were not submitted to the database, but were found to be in excellent agreement with current global databases.

Concentrations of CFC-1l, CFC-12, SF_6 and N_2O in air samples, seawater samples and gas standards were measured by shipboard electron capture gas chromatography (ECD-GC) using techniques described by [Bullister2008]. This method has been modified with the addition of an extra ECD to accommodate N_2O analysis. For seawater analyses, water was transferred from a glass syringe to a glass sparging chamber (~200 ml). The dissolved gases in the seawater sample were extracted by passing a supply of CFC-free purge gas through the sparging chamber for a period of 6 minutes at 120 - 140 ml/min. Water vapor was removed from the purge gas by passage through a Nafion drier, backed up by a 18 cm long, 3/8" diameter glass tube packed with the desiccant magnesium perchlorate. This tube also contained a short length of Ascarite to remove carbon dioxide, a potential interferent in N_2O analysis. The sample gases were concentrated on a cold-trap consisting of a 1/16" OD stainless steel tube with a ~5 cm section packed tightly with Porapak Q (60-80 mesh), a 22 cm section packed with Carboxen 1004 and a 2.5 cm section packed with molecular sieve MS5A. A neslab cryocool was used to cool the trap, to below -50°C. After 6 minutes of purging, the trap was

isolated, and it was heated electrically to ~150°C. The sample gases held in the trap were then injected onto a precolumn (~60 cm of 1/8" O.D. stainless steel tubing packed with 80-100 mesh Porasil B, held at 80°C) for the initial separation of CFC-12 and CFC-11 from later eluting peaks. After the F12 had passed from the pre-column through the second pre-column (22 cm of 1/8" O.D. Stainless steel tubing packed with Molecular Sieve 5A, 100/120 mesh) and into the analytical column #1 (~170 cm of 1/8" OD stainless steel tubing packed with MS5A and held at 80°C) the outflow from the first precolumn was diverted to the second analytical column (~150 cm 1/8" OD stainless steel tubing packed with Carbograph 1AC, 80-100 mesh, held at 80°C). After F11 had passed through the first precolumn, the flow was diverted to a third analytical column (1/8" stainless steel tube with 30cm Molecular Sieve 5A, 60/80 mesh) for N_2O analysis. The first pre-column was then backflushed and vented. The first two analytical columns and precolumn 1 were held isothermal at 80 degrees C in an Agilent (HP) 6890N gas chromatograph with two electron capture detectors (250°C). The third analytical column and second pre-column were held at 160C in a Shimadzu GC-8A gas chromatogram. The ECD in the Shimadzu was held at 250°C.

The analytical system was calibrated using a blended standard gas (seawater ratio, PMEL 464568), with available further reference to a second atmospheric ratio standard. Gas sample loops of known volume were thoroughly flushed with standard gas and injected into the system. The temperature and pressure was recorded so that the amount of gas injected could be calculated. The procedures used to transfer the standard gas to the trap, precolumn, main chromatographic column, and EC detector were similar to those used for analyzing water samples. Four sizes of gas sample loops were used. Multiple injections of these loop volumes could be made to allow the system to be calibrated over a relatively wide range of concentrations. Air samples and system blanks (injections of loops of CFC-free gas) were injected and analyzed in a similar manner. The typical analysis time for seawater, air, standard or blank samples was ~12 minutes. Concentrations of the CFCs in air, seawater samples, and gas standards are reported relative to the SIO98 calibration scale (e.g. [Bullister2010]). Concentrations in air and standard gas are reported in units of mole fraction CFC in dry gas, and are typically in the parts per trillion (ppt) range. Dissolved CFC concentrations are given in units of picomoles per kilogram seawater (pmol kg-1). CFC concentrations in air and seawater samples were determined by fitting their chromatographic peak areas to multi-point calibration curves, generated by injecting multiple sample loops of gas from a working standard (PMEL cylinder 464568) into the analytical instrument. The response of the detector to the range of moles of CFC passing through the detector remained relatively constant during the cruise. Full-and partial-range calibration curves were run several times during the cruise. Single injections of a fixed volume of standard gas at one atmosphere were run much more frequently (at intervals of ~90 minutes) to monitor short-term changes in detector sensitivity.

The purging efficiency of the stripper was estimated by re-purging a water sample in the upper concentration range and measuring the residual signal. At a flow rate of 120 cc/min for 6 minutes, the purging efficiency for SF_6 and F12 was greater than 99% and the efficiency for F11 was about 99%. The purging efficiency for N_2O was about 95%, but subject to some degree of variability due to changes in flow rate and purging temperature. Although correction is made for this variability, N_2O data from stations 1-22 were rather more compromised than subsequent data.

Results of 2795 seawater samples are reported from 86 of the 87 original stations, with station 185 omitted due to system problems, and 5 of the 6 re-occupation stations. Duplicates were taken from 55 stations to estimate precision and variability. Low-level samples were selected from deep samples and higher level (surface) samples were mostly taken from the upper water column. Based on similar data from PO2 Leg 1, we calculate the average deviation to be less than 1.0% from the mean of the pairs for F12, F11 and N_2O measurements in the higher concentration samples, and 2.0% from the mean for SF_6 measurements. Deviation from the mean of pairs from deeper samples averaged less than 5% (or 0.01 pM) from the mean for F12 and F11 and approximately 10% for SF_6. Due to the exceedingly low levels of SF_6 present in deeper water, accurate estimates of precision are not possible. A small number of additional water samples had anomalous SF_6 or CFC concentrations relative to adjacent samples. These samples occurred sporadically during the cruise, were not clearly associated with other features in the water column (e.g., anomalous dissolved oxygen, salinity, or temperature features) and are omitted from the reported data.

CHAPTER

FIFTEEN

LADCP

PI

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Cruise Participant (Responsible for LADCP Data Acquisition)

- Lily Dove (Caltech)

15.1 Data Acquisition and QC

In order to collect full-depth profiles of horizontal and vertical ocean velocity, two Acoustic Doppler Current Profilers (ADCPs), one facing upward (uplooker, UL) and the other downward (downlooker, DL), as well as a Deep Sea Power And Light rechargeable 48V battery and cables were installed on the CTD rosette. This lowered ADCP (LADCP) system was provided by the Lamont-Doherty Earth Observatory (LDEO). The LADCP system is self-contained, requiring on-deck cable connections to charge the battery and for communicating with the acquisition computer. The battery charger was affixed to an elevated cable run in the CTD bay and connected, via a waterproof power switch, to an outdoor extension power cable connected to vessel power inside the wet lab. The LADCP data acquisition computer, a Mac Mini, as well as a bench-top power supply for the ADCPs connected to a waterproof power switch were installed on a bench in the same lab.

Between casts the LADCP system in the CTD bay was left unpowered, with the battery connected to the (usually powered) battery charger, and the two deck cables leading to the data acquisition computer also connected, but with the bench top power supply turned off. A dummy plug was installed to protect the male battery connector pins on the rosette.

A few minutes before the CTD rosette was moved out of the hangar for deployment, the charger was turned off, the battery was disconnected from the charger and connected to the ADCPs on the rosette, and the now free dummy was used to dummy up the battery charger. Then data acquisition was started on the computer in the wet lab using a set of operator scripts created by the PI. After verifying that the data from the previous cast had been fully downloaded and backed up, the old data files were deleted from the instruments, before these were programmed to acquire data for the new cast. Due to weak backscatter observed in many of the profiles from leg 1, the instrument setup was optimized for range, with 10-m bins and 4-m blanking, rather than the stardard 8-m bins without blanking used in regions of sufficient backscatter. The two ADCPs on the rosette used synchronized pings and they followed a staggered ping rate alternating between 1.3 and 1.6 seconds, which is designed to mitigate contamination from acoustic reflection from the sea bed. With the instruments pinging the rosette was disconnected from the LADCP deck cables, and all four ends were dummied up. The loose cables on the rosette were secured with orange Velcro strap to prevent whiplashing during the casts. The same type of Velcro strap was also used to attach some of the permanently installed LADCP cables to the rosettes in an attempt to minimize plastic waste (zip ties). Once everything was set up, the CTD operator and the ResTech were notified that the LADCP system was ready for deployment. Deployment information was logged on LADCP log sheets once the rosette had entered the water.

After recovery of the CTD the Velcro straps securing the dummied pig-tail ends to the rosette were removed, the connectors were rinsed with fresh water, the dummy plugs were removed and the ADCPs on the rosette were connected to the deck cables. The battery was then disconnected from the rosette cable and connected to the charger, with the dummy being switched from charger to the rosette in the process. After turning on the bench-top power supply, LADCP data acquisition was stopped on the acquisition computer and the data download was initiated.

After the data from the cast had finished downloading (after about 20 minutes for deep casts, 5 minutes for bio casts), the bench top power supply was turned off with power toggle switch. Then the data files, one for each the UL and DL, were checked by integrating the measured vertical velocities in time, which yields estimates for the maximum depth (zmax) and the end depth (zend) of the profile, both of which were recorded on the log sheet. Occasionally, after the battery was fully charged (usually about an hour after charging was initiated, as indicated by LEDs on the charger) the charger was disconnected from power in the wet lab and the time was noted on the log sheet. The battery was more often left on the charger in trickle-charge mode, however.

Communication between the acquisition computer and the ADCPs was handled by the "acquire2" set of software scripts, implemented as a set of UNIX shell commands designed to minimize the possibility of operator errors. Five different commands are available:

Ldir: Lists the status of the LADCP memory, including number of files, file size, etc. Used primarily to verify that the LADCP is operational while connected to the bench power.

Lstart: Wakes the instruments, lists their memory contents, clears the memory (after operator confirmation) and programs the instruments to start pinging by uploading command files. CTD station and cast numbers must be provided by the operator since the LADCP files use an independent numbering scheme.

Ldownload: Interrupts the running data acquisition, downloads the data, and backs up the data files to a network drive.

Lcheck: Integrates the measured vertical velocities from both ADCPs to estimate zmax and zend, which are displayed together with other useful profile statistics before the data files are backed up on the network drive.

Lreset: Reset the ADCPs after swapping instruments and in case of communications problems.

During the night watch, the LADCP data were processed for horizontal velocity using the LDEO_IX processing software and for vertical velocity using the LADCP_w processing software, both installed on the acquisition computer and accessed on a personal computer using Screen Sharing. CTD .cnv data were obtained from the ship's shared drive and processed into 1 and 6 Hz formats using the LADCP_w processing software. In addition to the zend and zmax processing diagnostics, LADCP data quality was monitored by creating section plots, seen in Figure 1. Over most of the section the LADCP data quality appears to be good, although the lack of backscattering particles throughout the intermediate and abyssal depths of the water column off the shelf lead to potentially unconstrained velocities. A more comprehensive post-cruise LADCP QC will be carried out by Thurnherr in his lab before submission of the combined P02 leg 1 and 2 data to the archives.

15.2 Instrumentation

Two 300kHz Teledyne RDI Workhorse Monitor ADCPs (WHM300) were used for all profiles up to 20401, which covers the full extent of the P2 section: a primary/DL (S/N 3441) and secondary/UL (S/N 12734). The UL instrument replaced another instrument used on leg 1 (S/N 754) before any profiles began on leg 2. The replacement UL (S/N 12734) was fitted with a custom self-recording accelerometer/magnetometer package called Independent Measurement Package (IMP). Due to a hardware fault the IMP did not record any data up to profile 13001. After repairing the instrument its performance was monitored using its built-in WiFi access point. Wireless data download with rsync proved easy with data rates at 20 feet distance typically around 700Mbps. However, the initial connection with a laptop could not be made at any distance until first another connection had been made with an iPhone, which typically was no problems at distances of 2-3 feet. After profile 20401, the final cast of the full P02 transect, the DL instrument was replaced with a different instrument (S/N 24477), this one fitted with the most recent prototype of the IMP, which includes MEMS gyros. This DL was used for the remainder of the profiles, during which a partial repeat sample of the California Current

system was collected. The data from the IMPs will be merged with the ADCP data for final post-cruise processing and QC.

A single Deep Sea Power And Light rechargeable 48V battery (S/N 1223) experienced no problems with charging or operation over the duration of the cruise.

15.3 Preliminary Results

ADCPs rely on particles, such as marine life and sinking detritus, in the water column in order to measure the water velocities. The measure of particles in the water is called backscatter. Backscatter is variable across the global ocean and throughout the water column. Figure 2 shows the backscatter from Leg 2 of P02. Note the double layer of backscatter in the upper 1000 meters from station 11801 to station 18401. There is also a significant increase in backscatter at intermediate and abyssal depths near the coast (stations 18901 onwards). Regions with low backscatter make it difficult to constrain the calculated horizontal velocities, so further quality control is needed in the intermediate and abyssal depths of the first part of Leg 2.

There are three "boundary conditions" imposed on the calculation of horizontal velocities from the LADCP: the GPS, the bottom track, and the shipboard ADCP (SADCP). Figure 3 shows the root mean squared error [m/s] from the removal of the bottom track and SADCP from calculations of the horizontal velocities. Note the decrease of error upon approach to the shelf (past station 18401), likely as a result of increased backscatter.

15.4 Figures

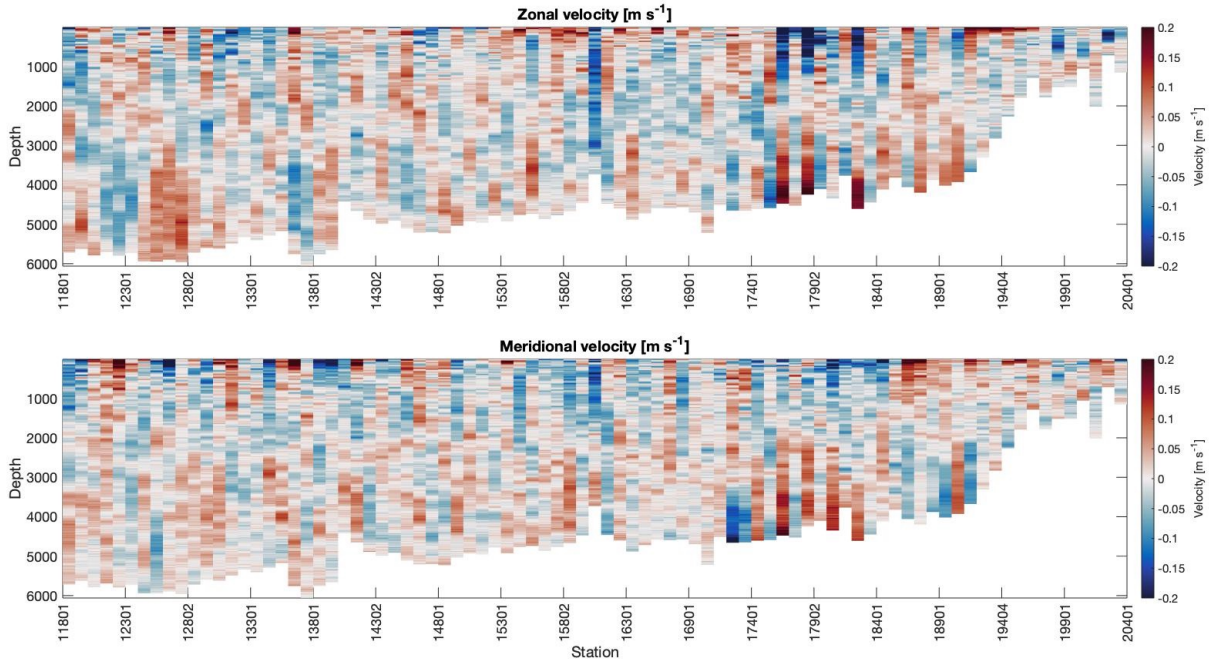

Fig. 1: Figure 1: (a) Zonal (east-west) and (b) meridional (north-south) velocities calculated from the LADCP across the full Leg 2 of P02.

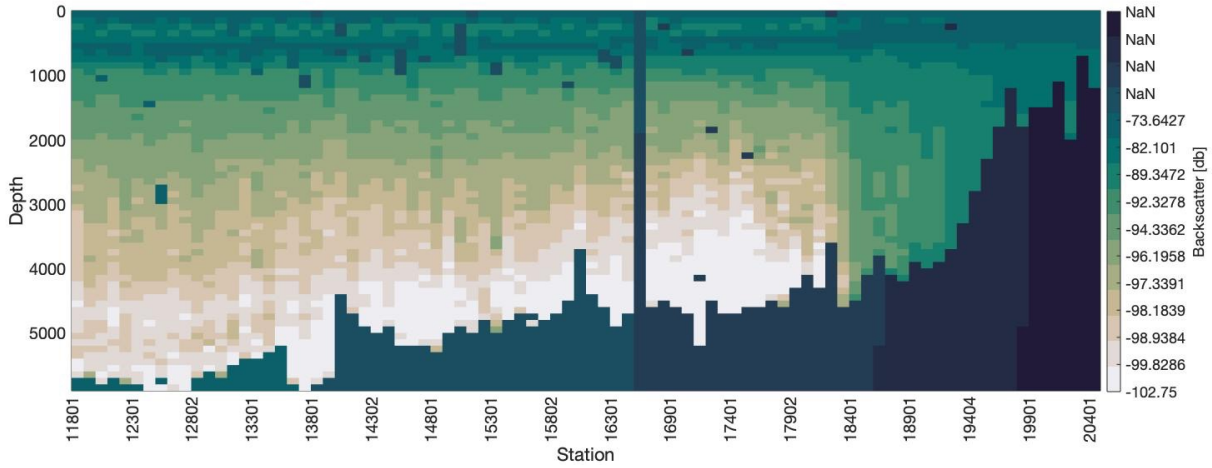

Fig. 2: Figure 2: Backscatter [decibels] along the P02 Leg 2 transect. The colorbar is designed so each block of color contains an equal number of points.

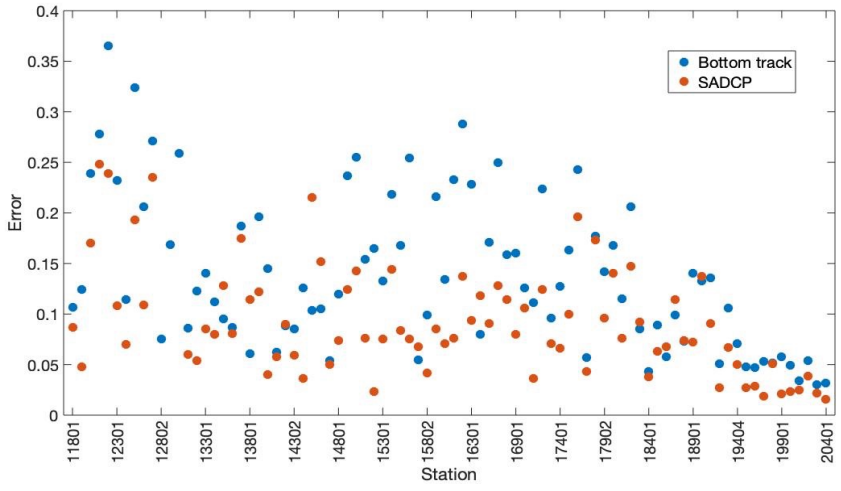

Fig. 3: Figure 3: Root mean squared error [m/s] resulting from the removal of the bottom track (blue) and shipboard ADCP (orange) boundary conditions.

CHAPTER

SIXTEEN

BIO GO-SHIP

PIs

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Samplers

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16.1 Underway Sampling

DNA/RNA, Large Volume Particulate Organic Matter (POC, PON, POP, PCOD), HPLC, and FCM samples were collected at approximately 0600, 1200, and 2000 local time via the underway tap (59 stations). The underway system was pumped with a diaphragm pump instead of the impeller pump so that organic matter would not be shredded up. The timing for collecting samples around 2000 was based on each day's solar noon + 8 hours. Underway samplings were skipped if the CTD rosette were to collect biological samples within a three to four hour window of an underway sampling time.

16.2 Bio CTD Station Sampling

At every third GO-SHIP P2 station, the CTD rosette was casted twice (32 stations). The first cast only collected biological samples (called the "bio cast") and the second cast only collected core GO-SHIP samples (pH, nutrients, etc.). For the bio cast, the CTD rosette was sent to a maximum depth of 1000 m. As the rosette surfaced, it collected seawater only to be used for biological samples (ie. DNA/RNA, Large Volume POM, HPLC, and FCM). Niskin bottles were fired at depths of 1000 m, 500 m, 200 m, 150 m, 100 m, 75 m, 40 m, and 5 m. The CTD rosette was then recovered, the seawater was collected, and then the CTD was cast again to collect the core GO-SHIP samples.

16.3 BGC Argo Float Station Sampling

At each station where a BGC Argo float was deployed, the sampling scheme for DNA/RNA, Large Volume Particulate Organic Matter (POC, PON, POP, PCOD), HPLC, and FCM was different than the usual bio cast sampling. For every bio cast at a float station, Niskin bottles were fired at depths of 1000 m, 500 m, 200 m, ~30 m below the chlorophyl maximum depth, at the chlorophyl maximum depth, ~ 30 m above the chlorophyl maximum depth, at the bottom of the mixed layer, and 5 m. For Leg 2, four out of the thirty-two bio cast stations were float stations (GO-SHIP P2 stations 122, 146, 170, and 191).

16.4 DNA/RNA

DNA/RNA samples were collected at each underway sampling, with duplicates collected at 2000. For bio casts, seawater for DNA/RNA was collected at depths of 1000 m, 200 m, 100 m and 5 m. For bio casts at float stations, seawater for DNA/RNA was collected at depths of 1000 m, 200 m, at the chlorophyll maximum depth, and 5 m. 100 DNA/RNA samples were collected from the underway and 120 were collected from the rosette, resulting in a total of 220 DNA/RNA samples collected throughout Leg 2.

Each sample was a Sterivex 0.22µm filter cartridge that had seawater filtered through it. For DNA/RNA, seawater was transported from the underway or rosette to the filtration system using 4L plastic cubitainers. Volumes of 4 - 8L of seawater were filtered through a Sterivex 0.22µm filter cartridge via a peristaltic pump set to a low speed. After the seawater had been filtered, air was pumped out of the filter cartridge using a 5 mL syringe. The cartridge bottom was then sealed with Crito-Seal before pipetting 1620µL of sterile lysis buffer into the cartridge. The cartridge was then capped with a luer-lock. 10 of the 100 underway samples were duplicates that had RNA/DNA Shield buffer added instead of lysis buffer in order to compare these two buffer types. Each filter was placed in a Ziplok bag and stored at -80 °C until time for analysis. Final filtration volume was recorded for all samples. Samplers wore nitrile gloves throughout the entirety of sample collection and filtration.

Before Leg 1, all silicone tubing, Omnifit caps and cubitainers were soaked with soap water, 10% HCl acid, and Milli-Q water. At the end of every week of the cruise, the peristaltic pump tubing and Omnifit caps were cleaned with 10% bleach solution and then rinsed with Milli-Q water. All cubitainers were rinsed three times with sample water before being filled.

16.5 Large Volume Particulate Organic Matter (POM)

Whatman GF/F filters (pore size 0.7 µm, diameter of 25 mm) were filtered with 2 - 8 L of seawater to serve as particulate organic matter (POM) samples. Filters were collected for post-cruise analyses that determined either particulate organic carbon/nitrogen (POC/N), phosphorous (POP) or particulate chemical oxygen demand (PCOD). POM samples were collected via the underway tap or the CTD rosette at a depth of 5 m (91 stations). A total of 801 samples was collected (297 from the underway and 504 from the rosette).

Nine 8 L carboys were filled with 2 - 8 L of seawater for each POM filtration. The carboys were divided into three groups for desired sample type: POC/N, POP, and PCOD. As a result, triplicates were collected for POC/N, POP, and PCOD at each sampling. Seawater was drawn through the filters using an aspirator pump with a vacuum setting of -0.06 to -0.08 MPa. After all seawater had been filtered, filters for POP were rinsed with 5 mL of 0.017 M Na2SO4 to remove any dissolved organic phosphorous. PCOD filters were rinsed with 5 mL of Milli-Q water to remove excess chloride. Filters were folded and then stored at -80°C in pre-combusted aluminum foil.

Before starting Leg 2, GF/F filters and foil squares were precombusted at 500°C for 5 hours. All silicone tubing, filter cartridges, and carboys were soaked with soap water, 10% HCl acid, and then Milli-Q water. Samplers wore nitrile gloves throughout the entirety of sample filtration. All carboys were rinsed three times with sample water before being filled.

16.6 Small Volume Particulate Organic Carbon/Nitrogen (POC/N)

Small volume particulate organic carbon/nitrogen (POC/N) samples were only collected at the four float stations. The CTD rosette collected seawater for these samples at a depth of 200 m, ~30 m below the chlorophyl maximum depth, at the chlorophyl maximum depth, ~30 m above the chlorophyl maximum depth, at the bottom of the mixed layer, and at a depth of 5 m. From each of these depths, 2 L of seawater was collected and a single duplicate of 2 L was collected from one of these depths. The depth from which the duplicate was collected was decided at random and varied across float stations. Small volume POC/N were collected to compare the carbon/nitrogen quantified from large volume POC/N samples.

Seawater was transported from the rosette to a filtration manifold using 1 -2 L clear plastic bottles. The filtration manifold was hooked to a vacuum pump set at 100 mmHg. Seawater was filtered onto pre-combusted Whatman GF/F filters (pore size 0.7 µm, diameter of 25 mm). A dry blank and a wet blank were also collected at each float station. A dry blank consisted of taking a GF/F filter out of the pre-combusted foil it was stored in, and then putting it pack into the foil without filtering any seawater. The wet blank consisted of placing another GF/F filter below one of the GF/F filters before filtering seawater through them. The bottom filter was collected and saved as the wet blank. For Leg 2, the wet blank was always placed under the duplicate sample filter, thus the seawater filtered through it also came from a random depth and varied across float stations. All filters were then stored at -80 °C in pre-combusted aluminum foil. Samplers wore nitrile gloves throughout the entirety of seawater collection and filtration. All bottles were rinsed three times with sample water before being filled.

16.7 Particulate Chemical Oxygen Demand (PCOD) Volume Trial

Volume trials for PCOD samples were performed three times during Leg 2. These trials happened randomly when there was enough time in-between underway or rosette sampling. The volume trial consisted of filling the POM carboys via the underway with volumes ranging from 1 - 8 L. Starting with a carboy filled with 8 L, each consecutive carboy was filled with 1 L less than the carboy filled before it (ie. the second carboy was filled with 7 L, the third was filled with 6 L, etc.). The seawater from each carboy was filtered onto a Whatman GF/F (pore size 0.7 µm, diameter of 25 mm) in the same method for POM filtration. Filters were then rinsed with 5 mL of Milli-Q water to remove excess chloride. The purpose of the volume trials is to test the sensitivity of the PCOD analysis after the cruise.

All carboys were rinsed three times with sample water before being filled. GF/F filters and foil squares were also pre-combusted and then stored at - 80 °C. Nitrile gloves were worn for all steps mentioned above.

16.8 High Performance Liquid Chromatography (HPLC)

HPLC samples were collected with each underway sampling and at each bio cast. For bio casts, seawater for HPLC samples was collected at 100 m, 40 m, and 5 m. For float stations, seawater for HPLC samples was collected at a depth of 200 m, ~30 m below the chlorophyl maximum depth, at the chlorophyl maximum depth, ~30 m above the chlorophyl maximum depth, at bottom of the mixed layer, and at a depth of 5. A total of 181 samples was collected (111 from the rosette and 70 from the underway). The purpose of HPLC samples was to quantify photosynthetic pigment content.

For HPLC samples, 2 L of seawater was transported from the underway or rosette with 1 L amber HPDE bottles. Seawater was then filtered with Whatman GF/F filters (pore size 0.7 µm, diameter of 25 mm) using a vacuum pump set at 100 mmHg. Filters were folded twice, placed into 1 mL cryovials, and then stored at -80 °C. Nitrile gloves were worn throughout seawater collection and filtration. All HPDE bottles were rinsed three times with sample water before being filled.

A duplicate HPLC sample was collected for every other underway sampling. This was to ensure that roughly 10% of total HPLC samples were duplicates. At float stations, a single duplicate of 2 L was also collected from one of the depths chosen by random. The depth chosen for the duplicate varied across float stations.

16.9 Flow Cytometry (FCM)

FCM samples were collected with each underway sampling and at each bio cast. For bio casts, seawater for FCM samples was collected at depths of 1000 m, 500 m, 200 m, 150 m, 100 m, 75 m, 40 m, and 5 m. For float stations, seawater for FCM samples was collected at depths of 1000 m, 500 m, 200 m, ~30 m below the chlorophyl maximum depth, at the chlorophyl maximum depth, ~30 m above the chlorophyl maximum depth, at bottom of the mixed layer, and 5 m. A total of 305 samples was collected (245 from the rosette and 59 from the underway). FCM samples were to be analysed after the cruise with a flow cytometer.

Seawater for FCM samples was collected with 50 mL tinted falcon tubes. From the tubes, 1.8 mL of seawater was pipetted into a 2 mL cryovial. While under a fume hood, 18 µL of a preservation mixture (half 25% Glutaraldehyde and half 2% Kolliphor) was added to each cryovial. The cryovial was then inverted several times and then placed on a vial stand for about for 10 minutes. The vials were then flash frozen with liquid nitrogen and stored at -80 °C.

16.10 Planktoscope

At most stations with a bio cast, 40 - 100 L of seawater from the underway tap was filtered by a 10 µm mesh to concentrate >10 µm particles into a volume of ~250 mL (27 stations). The volume used from the underway was determined by filling a 20 L carboy multiple times. For two of the twenty-seven stations, about 4 L of seawater from the chlorophyl maximum depth was concentrated to ~250 mL instead. Chlorophyl maximum depth seawater was collected via the CTD rosette. 100 mL from the ~250 mL was preserved with 0.5 mL of Lugols solution for post-cruise analysis. 1.8 mL was also taken from the ~250 mL and preserved by the same method used for FCM samples. About 5 - 20 mL of the ~250 mL was also fed into a planktoscope. The purpose of the planktoscope was to quantify plankton abundance.

The planktoscope took 100 pictures as 5 mL of seawater flowed in front of a 20 mm tube lens and a 16 mm objective lens. Seawater was set to flow at a rate of 2 mL/min. The planktoscope then segmented parts of the pictures that contained distinct outlines and dark shapes against a white background. The segmenting program was optimized to detect objects in the size range of 40 µm - 200 µm. The lens were focused and a white-balanced was performed before filming each sample

CHAPTER

SEVENTEEN

UNDERWATER VISION PROFILER 5 HD (UVP)

PI

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Cruise Participant

- Lily Dove (Caltech)

17.1 System Configuration and Sampling

The Underwater Vision Profiler 5 (UVP5) HD (High Definition) serial number 201 was programmed, mounted on the rosette, and charged. This instrument is owned by Emmanuel Boss at University of Maine. The UVP5 is outfitted with a High Definition 4 Mp camera with an acquisition frequency of up to 20 Hz. This optical imaging device obtains in situ concentrations and images of marine particles and plankton throughout the water column, capturing objects sized ~100 µm to several cm in diameter. The camera of the UVP5 HD is different from the previous non-HD version, but the operations are identical for both. The instrument and data processing are described in [Picheral2010]. Depth trigger mode was used throughout the entirety of the cruise, programmed to turn on at 15 m with a maximum depth of 6000 m. A 20 m soak for one minute was used throughout the cruise.

17.2 Problems

See Leg 1 report for details on UVP problems.

No data were downloaded during Leg 2 due to inability to establish communication with the unit. The intrument was run on all core stations and left off for bio stations. The instrument will be sent to the manufacturers for maintenance who will open the bulkhead and hopefully download the data from the remaining stations.

17.3 Future Data Analysis

A combination of machine learning and manual validation will be used to sort images using the Ecotaxa database. Images will be sorted into various zooplankton taxa and detrital categories. Zooplankton categories will include crustacea (including copepods and krill), gelatinous (larvacean, jellyfish, salps), and rhizaria. Examples of these images are shown in Fig. 1.

17.4 Figures

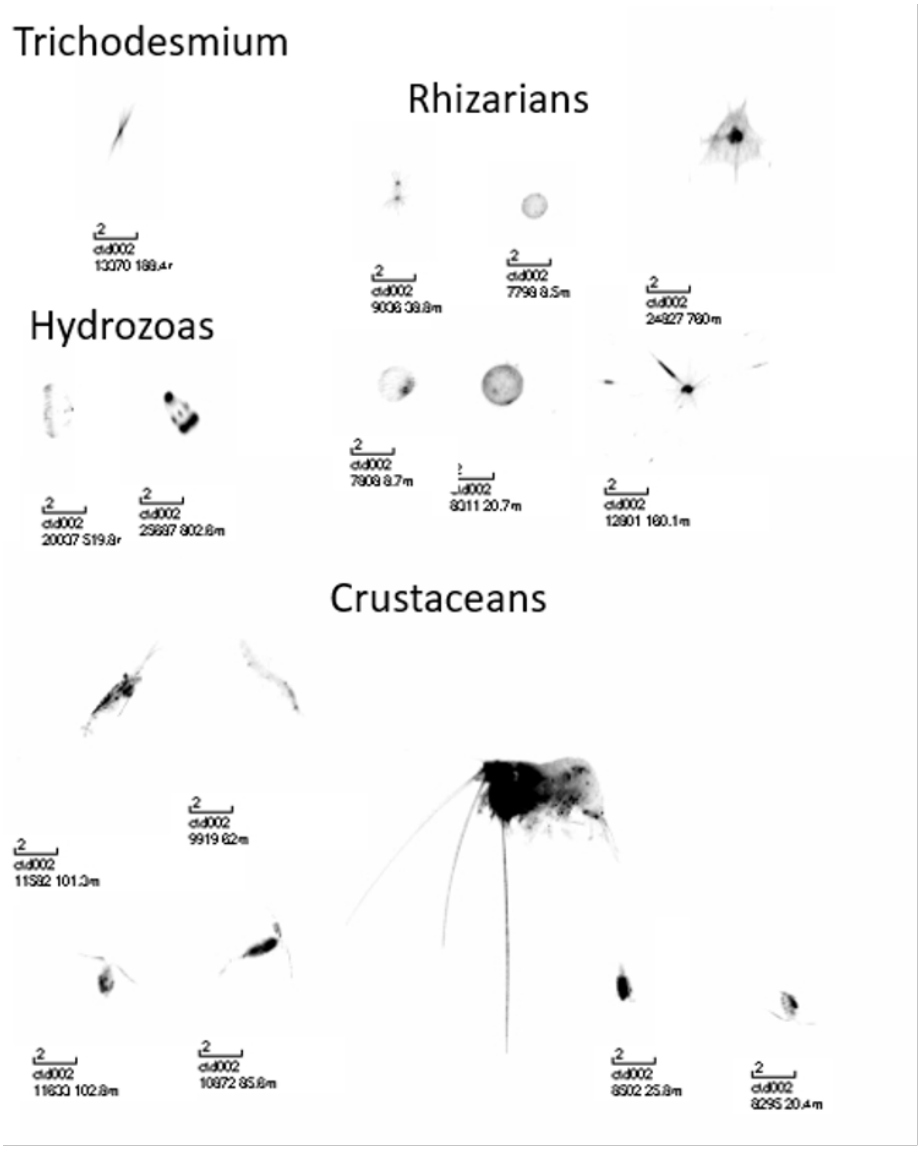


Fig. 1: Fig. 1: Examples of particle and plankton images captured by the UVP5HD and processed by custom software. The scale bar indicates 2 millimeters. Station number, image number for that cast, and depth at which the image was captured are also given in the image.

CHAPTER

EIGHTEEN

UNDERWAY PCO_2

PIs

- Simone Alin (NOAA/PMEL)

Technicians

- Julian Herndon (UW/NOAA/PMEL)
- Andrew Collins (UW/NOAA/PMEL)

The partial pressure of carbon dioxide (pCO_2) in the surface ocean was measured throughout the cruise track of this cruise with a General Oceanics 8050 pCO_2 Measuring System. Uncontaminated seawater was continuously passed (~1.7-2.1 L/min) through a chamber where the seawater concentration of dissolved CO_2 was equilibrated with an overlaying headspace gas. The CO_2 mole fraction of this headspace gas (xCO_2) was measured every two minutes via a non-dispersive infrared analyzer (LiCor 7000) for 60 consecutive measurements. At the end of these 60 discrete measurements, a set of five standard gases was analyzed; four of these standards have known CO_2 concentrations certified by the NOAA Earth Science Research Laboratory (ESRL) ranging from ~300 to ~900 ppm CO_2 (see Table 1). The fifth standard is a tank of 99.9995% ultra-high purity nitrogen gas, used as a baseline 0% CO_2. Following the measurements of standard gases, six consecutive measurements of atmospheric xCO_2 were made of air supplied through tubing fastened to the ships forward jack staff. Twice a day, the infrared analyzer was zeroed and spanned using the nitrogen gas and the highest concentration CO_2 standard (911.41 ppm). In addition to measurements of seawater xCO_2, atmospheric xCO_2, and standard gases, other variables were monitored to evaluate system performance (e.g. gas and water flow rates, pump speeds, equilibrator pressures, etc.). For more detail on the general design and operation of this underway pCO_2 system, see [Pierrot2009].

Throughout the duration of the research cruise, the system performed well. Initial problems with non-ideal water flow (i.e. <1.5 L/min) add some uncertainty to some of these measurements and will need to be carefully evaluated before determining their suitability for inclusion in the dataset (see details regarding water flow below). Of approximately 18,730 sea surface xCO_2 measurements, 243 have been flagged questionable (quality flag 3) and 51 have been flagged bad (quality flag 4) during this preliminary round of data quality control and assurance.

18.1 Notes on seawater source and data:

For details regarding the source of seawater to the pCO2 system, see Julian Herndon's report from Leg One of this research cruise. During the first several days of this leg, substantial effort was made by research technicians and the chief engineer to establish sufficient water flow to the system. Initial efforts included trying to balance the water flow to meet the needs of the various (i.e. biological, chemical, shipboard) users onboard. However, insufficient flow persisted to the pCO_2 system. Flow was increased by closing down a forward overflow drain, but quickly dropped below 1.5 L/min. After exhausting nearly every possible avenue by balancing flows, adjusting pump speeds and pressures, it was determined that an obstruction must be preventing sufficient flow to the system. John Ballard and Andrew Collins disassembled the primary equilibrator in the pCO_2 system to learn that it was indeed obstructed. After cleaning, the flow to the pCO_2 system was greatly enhanced and remained sufficient for the remainder of the cruise. No other major

problems were encountered during the cruise that affected data quality. One issue that persists relates to occasional dropouts from the MET system, likely due to a timing mismatch in the communications setup.

The Resident Technicians onboard used bleach to clean/sanitize the scientific seawater system after we departed Hawaii and prior to the pCO_2 system being turned on. Model and serial numbers for the pCO_2 instrument components and ancillary instruments have been recorded in a separate Excel file and will reported as part of the metadata that will accompany the final/processed pCO_2 data submission. This pCO_2 system does not have a Druck or other external barometer installed in the dry box to measure the pressure in the LiCor cell. The primary equilibrator in this pCO_2 system is an older, non-jacketed equilibrator built using a clear plastic filter housing.

To facilitate data processing and future troubleshooting of the Revelle pCO_2 system, the column headings for data in the pCO_2 files sourced from the ship are identified in Table #2. Serial numbers and additional details for the instruments in table #2 are in a separate excel file and will be reported as part of the metadata for pCO_2 data submitted from this cruise.

Table 1: Table 1: Standard gases for P02 2022 cruise UW pCO_2 system.

Standard	Concentration (ppm)	Tank Serial Numbers
1	0.0	Praxair 5.0 Ultra High Purity N2
2	283.42	LL55868
3	399.51	LL127199
4	539.97	LL127204
5	911.41	LL127176

Table 2: Table 2: pCO_2 system ship supplied data column headers for P02 2022 cruise, Leg 1. MWL = mean water level.

Column Header	Instrument	System	Location
TSGF1	SW flow meter	3	Bow
TSGT2	TSG45 temperature	2 and 3	Hydrolab
TSGS2	TSG45 salinity	2 and 3	Hydrolab
TSGF2	SW flow meter to TSG45	2 and 3	Hydrolab
PCO2F	SW flow meter to pCO_2	2 and 3	Hydrolab
SST	SBE 38 temperature	3	Bow
AT	RM Young temperature	MET	56’ above MWL*
BP	RM Young barometer	MET	56’ above MWL*
HDG	Konsberg GPS		
SOG	Speed over ground		

While the raw data is not reported here, it has been collected and will be analyzed using MATLAB® routines developed by Dr. Denis Pierrot of the Atlantic Oceanographic and Meteorological Lab in Miami, FL. Measurements of gas standards were generally within 1% of their certified value throughout the duration of the cruise.

The data from the pCO_2 system that is included as part of the ships data supplied by the onboard Resident Technicians is xCO_2 (not pCO_2) that has not been processed or evaluated for QA/QC and as such should be considered preliminary.

CHAPTER

NINETEEN

CHIPODS

PI

- Jonathan Nash (OSU)

19.1 Overview

Chipods are instrument packages that measure turbulence and mixing in the ocean. Specifically, they are used to compute turbulent diffusivity of heat (K) which is inferred from measuring dissipation rate of temperature variance (χ) from a shipboard CTD. Chipods are self-contained, robust and record temperature and derivative signals from FP07 thermistors at 100 Hz; they also record sensor motion at the same sampling rate. Details of the measurement and our methods for processing χ can be found in [Moum_and_Nash2009]. In an effort to expand our global coverage of deep ocean turbulence measurements, the ocean mixing group at Oregon State University has supported chipod measurements on all of the major global repeat hydrography cruises since December 2013.

19.2 System Configuration and Sampling

Three chipods were mounted on the rosette to measure temperature (T), its time derivative (dT/dt), and x and z (horizontal and vertical) accelerations at a sampling rate of 100 Hz. Two chipods were oriented such that their sensors pointed upward. The third one was pointed downward.

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

The chipods from Leg 1 were left on through station 16301, at which point all pressure cases were swapped. They continuously recorded data until the end of the leg. Only one issue occurred with the chipods following the recovery of cast 12601. The sensor tip on chipod #12 had popped out and flooded the sensor. Sensor was swapped for chipod #11.

Upward-looking chipod sensors attached to the rosette.

Downward-looking chipod sensor attached to the rosette.

Logger Board SN	Pressure Case SN	Up/Down Looker	Cast Used
2013	Ti 44-12	Up	118-162
2032	Ti 44-15	Up	118-162
2014	Ti 44-08	Down	118-162
2027	Ti 44-3	Up	163-205
2017	Ti 44-6	Up	163-205
2025	Ti 44-7	Down	163-205

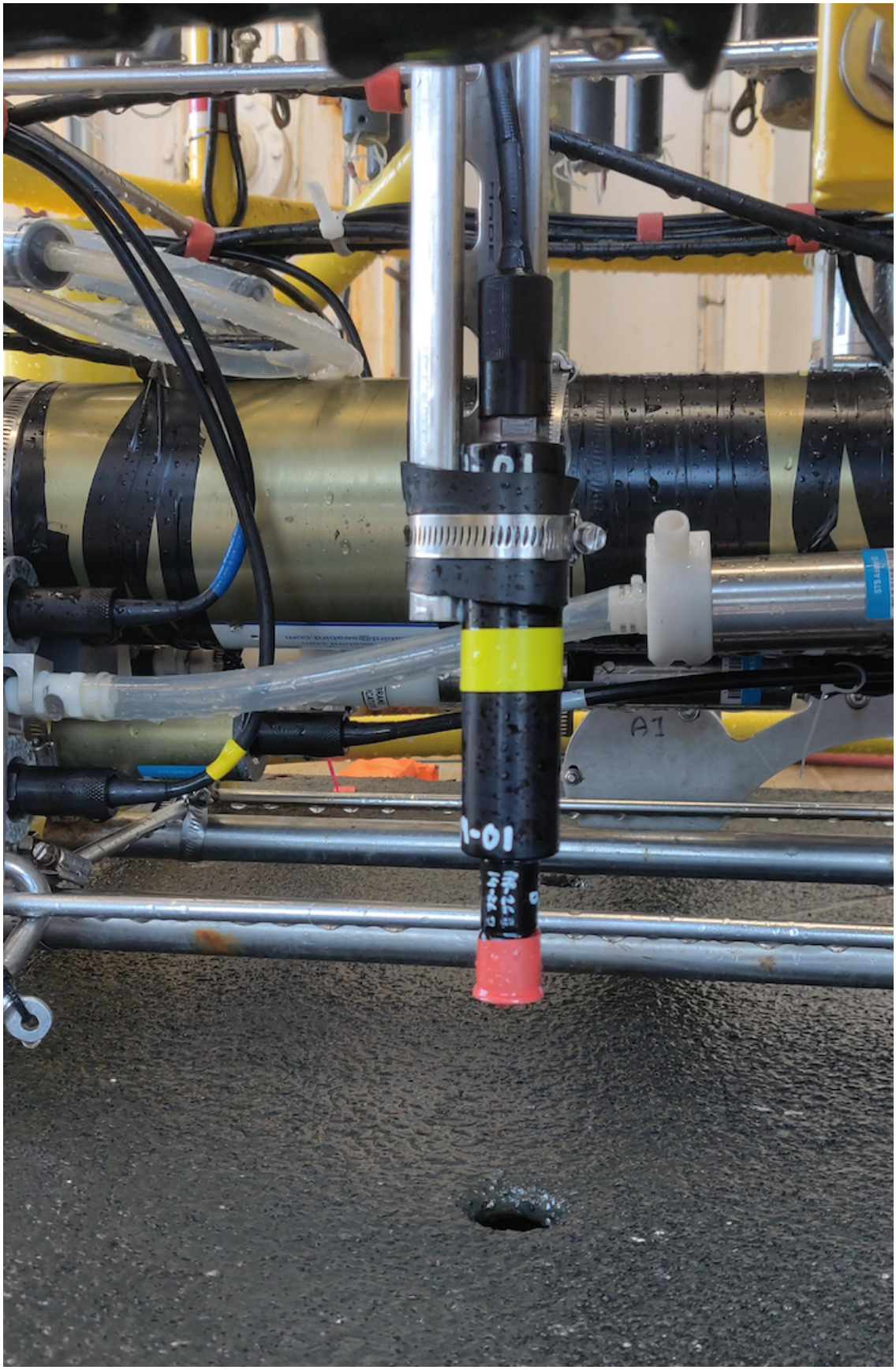

A1

Fig. 1: Highly sensitive temperature probe, which is sampled at 100Hz.

CHAPTER

TWENTY

FLOAT DEPLOYMENTS

20.1 GO-BGC Argo Floats

PIs

- Kenneth Johnson (MBARI)
- Lynne Talley (UCSD/SIO)
- Susan Wijffels (WHOI)
- Curtis Deutsch (Princeton)
- Steven Riser (UW)
- Jorge Sarmiento (Princeton)

Four GO-BGC Argo floats were deployed during the cruise with the float numbers continuing from leg-1 (table below). All floats were UW-modified Teledyne Webb Apex floats equipped with SBE41-CP CTDs, O_2, NO_3, pH, and FLBB bio-optical sensors, and provided by the UW float lab (S. Riser Argo lab). Before deployment the float sensors were prepared (cleaned) according to the written instructions provided with the floats. Floats were deployed from the aft deck after the last CTD profile for that station with the ship steaming at 0.5kts. The floats were lifted over the stern, then carefully lowered into the water with a slip-line strung through the deployment collar of the float. All of the floats began reporting data immediately and the initial profiles indicate that all sensors were operating well.

All deployments occurred at stations where bio casts were carried out. In addition to the standard bio-cast sampling, additional water samples were collected below the mixed layer as well as at, above and below the chlorophyll maximum. The additional samples were analyzed for FCM, POC and POCN.

All floats were adopted by different schools as part of the adopt-a-float program (https://www.go-bgc.org/outreach/adopt-a-float). Names and images provided by the schools were drawn on the floats before deployment. Each school received details from their deployment via posts on the GO-BGC expeditions webpage, handled by George Matsumoto (MBARI) and Jennifer Magnusson.

Table 1: Float deployments.

Deployment	WMO	Lat	Lon	Date and Time (UTC)	CTD Station
11	9382	30:00 N	158:54 W	2022/06/18 08:25	122
12	9419	30:00 N	145:03 W	2022/06/26 04:45	146
13	9422	30:00 N	131:11 W	2022/07/03 06:08	170
14	9414	31:45 N	119:49 W	2022/07/09 11:28	191

CHAPTER

TWENTYONE

VIRAL ABUNDANCES

PI

- Ben Temperton (UoE)

Technician

- Michelle Michelsen (UoE)

Analyst

- Michelle Michelsen (UoE)

Support NSF

21.1 Project Goals

The goal of this project is to evaluate viral abundances within the cellular fraction (0.22µ Sterivex PC filter) and viral fraction (0.02µ Anotop Filter).

21.2 Sampling

Two liters of water were taken from the surface from every other bio-cast, and the last three bio-cast for a total of 14 stations sampled. Samples were sequentially filtered through a 0.22µ sterivex and 0.02µ anotop filter for 1.5-2.5 hours or when the filter clogged. Below is a table of stations and amount filtered. The filters were then frozen at -80ºC and hand carried back to UCSB to organize shipping to University of Exeter for further analysis. The filters will then be used for DNA extractions at University of Exeter to describe cell associated viruses and free viral particles [Martinez-Hernandez].

Station_Cast	Amount Filtered	Amount of Time
131_01	650mL	1.5 hours
137_01	600mL	1.5 hours
143_01	500mL	1.5 hours
149_01	800mL	2 hours
155_01	500mL	2 hours
161_01	550mL	1.75 hours
167_01	500mL	1.5 hours
173_01	600mL	2 hours
179_01	600mL	1.5 hours
185_01	600mL	1.5 hours
191_01	400mL	2 hours
197_02	500mL	2 hours
200_01	250mL	2.5 hours
203_01	270mL	1.5 hours

APPENDIX

A

ABBREVIATIONS

ADCP Acoustic Doppler Current Profiler

AOML Atlantic Oceanographic and Meteorological Laboratory

AP Particulate Absorption Spectra

APL Applied Physics Laboratory

ASC Antarctic Support Contract

BAS British Antartic Survey

BGC Biogeochemical

Bigelow Bigelow Laboratory for Ocean Sciences

Caltech California Institute of Technology

CDOM Chromophoric Dissolved Organic Matter

CFCs Chlorofluorocarbons

CIMAS Cooperative Institute of Marine and Atmospheric Science

CTDO Conductivity Temperature Depth Oxygen

DIC Dissolved Inorganic Carbon

DOC Dissolved Organic Carbon

ECO Edison Chouest Offshore

ENSTA ENSTA ParisTech

ETHZ Eidgenössische Technische Hochschule Zürich

FSU Florida State University

GO-BGC Global Ocean Biogeochemistry Array

HPLC High-Performance Liquid Chromatography

HPU Hawaii Pacific University

LDEO Lamont-Doherty Earth Observatory - Columbia University

LADCP Lowered Accoustic Doppler Current Profiler

MBARI Monterey Bay Aquarium Research Institute

MIT Massachussetts Institute of Technology

N2O Nitrous oxide

NOAA National Oceanographic Atmospheric Administration

NBP RVIB Nathaniel B Palmer

NSF National Science Foundation

ODF Oceanographic Data Facility - *SIO*

ODU Old Dominion University

OSU Oregon State University

PMEL Pacific Marine Environmental Laboratory

POC Particulate Organic Carbon

POM Particulate Organic Matter

Princeton Princeton University

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

SADCP Shipboard Acoustic Doppler Current Profiler

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

UArizona University of Arizona

UAF University of Alaska Fairbanks

U ALASKA University of Alaska

UCI University of California Irvine

U Colorado University of Colorado

UCLA University of California Los Angeles

UCSB University of California Santa Barbara

UCSC University of California Santa Cruz

UCSD University of California San Diego

UH University of Hawaii

U Miami University of Miami

UoE University of Exeter

UOG University of Guam

USAP United States Antarctic Program

USCG United States Coast Guard

UT University of Texas

UVic University of Victoria

UVP Underwater Vision Profiler

UW University of Washington

WHOI Woods Hole Oceanographic Institution

APPENDIX

B

BOTTLE QUALITY COMMENTS

APPENDIX

C

CALIBRATION DOCUMENTS

Pressure Calibration Report
STS Calibration Facility

SENSOR SERIAL NUMBER: 1281
CALIBRATION DATE: 07-DEC-2021
Mfg: SEABIRD Model: 09P CTD Prs s/n: 136428

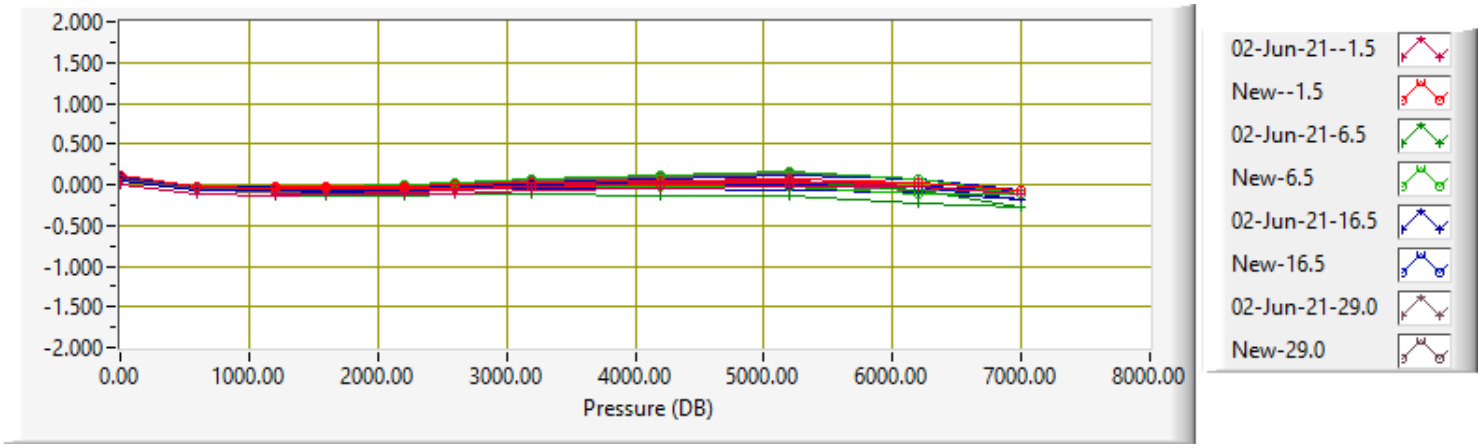
C1= -4.160481E+4
C2= -3.219786E-1
C3= 1.105909E-2
D1= 3.538794E-2
D2= 0.000000E+0
T1= 3.013965E+1
T2= -3.914456E-4
T3= 4.524706E-6
T4= -6.654717E-9
T5= 0.000000E+0
AD590M= 1.27846E-2
AD590B= -9.25586E+0
Slope = 1.00000000E+0
Offset = 0.00000000E+0

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	DWT	Sensor New_Coefs	DWT-Sensor Prev_Coefs	DWT-Sensor NEW_Coefs	PT-DegC	Bath_Temp
33184.484	0.27	0.15	-0.01	0.12	-0.79	-1.522
33529.461	600.32	600.33	-0.12	-0.01	-0.79	-1.523
33870.352	1200.35	1200.38	-0.13	-0.04	-0.79	-1.523
34095.434	1600.37	1600.41	-0.12	-0.04	-0.79	-1.523
34429.896	2200.40	2200.44	-0.11	-0.04	-0.78	-1.523
34650.800	2600.41	2600.46	-0.10	-0.04	-0.78	-1.523
34979.159	3200.48	3200.50	-0.08	-0.03	-0.78	-1.523
35518.611	4200.53	4200.53	-0.05	-0.01	-0.78	-1.523
36048.722	5200.59	5200.57	-0.02	0.02	-0.78	-1.523
36569.891	6200.60	6200.59	-0.02	0.02	-0.78	-1.523
36980.687	7000.60	7000.66	-0.11	-0.06	-0.78	-1.522
36569.868	6200.57	6200.54	-0.01	0.03	-0.78	-1.522
36048.668	5200.56	5200.48	0.04	0.08	-0.79	-1.522
35518.570	4200.53	4200.47	0.02	0.06	-0.79	-1.522
34979.128	3200.49	3200.46	-0.02	0.03	-0.79	-1.522
34650.795	2600.45	2600.45	-0.07	-0.01	-0.79	-1.522
34429.893	2200.42	2200.45	-0.09	-0.03	-0.79	-1.522
34095.434	1600.38	1600.41	-0.11	-0.03	-0.79	-1.522

Sensor Output	DWT	Sensor New_Coefs	DWT-Sensor Prev_Coefs	DWT-Sensor NEW_Coefs	PT-DegC	Bath_Temp
33870.344	1200.35	1200.38	-0.11	-0.02	-0.79	-1.523
33529.450	600.32	600.31	-0.10	0.01	-0.79	-1.523
33187.695	0.27	0.15	0.01	0.12	7.25	6.485
33532.691	600.32	600.34	-0.12	-0.02	7.25	6.485
33873.596	1200.35	1200.39	-0.13	-0.04	7.25	6.485
34098.690	1600.37	1600.41	-0.13	-0.04	7.25	6.485
34433.169	2200.41	2200.46	-0.14	-0.05	7.25	6.484
34654.079	2600.42	2600.46	-0.13	-0.04	7.25	6.484
34982.435	3200.45	3200.47	-0.11	-0.02	7.25	6.484
35521.908	4200.46	4200.49	-0.13	-0.03	7.25	6.484
36052.022	5200.46	5200.48	-0.13	-0.02	7.25	6.484
36573.272	6200.48	6200.59	-0.24	-0.11	7.25	6.484
36984.076	7000.51	7000.64	-0.28	-0.13	7.25	6.484
36573.222	6200.57	6200.50	-0.06	0.07	7.25	6.485
36051.999	5200.59	5200.43	0.05	0.16	7.25	6.485
35521.885	4200.57	4200.45	0.02	0.12	7.25	6.485
34982.416	3200.51	3200.44	-0.01	0.08	7.25	6.485
34654.069	2600.46	2600.45	-0.07	0.02	7.24	6.485
34433.161	2200.44	2200.44	-0.10	-0.01	7.24	6.485
34098.685	1600.39	1600.41	-0.11	-0.02	7.24	6.485
33873.587	1200.36	1200.38	-0.11	-0.02	7.24	6.485
33532.679	600.32	600.32	-0.10	-0.00	7.24	6.485
33190.832	0.27	0.18	0.04	0.09	17.23	16.491
33535.848	600.33	600.35	-0.07	-0.02	17.24	16.493
33876.777	1200.36	1200.39	-0.07	-0.03	17.25	16.492
34101.892	1600.39	1600.41	-0.06	-0.03	17.25	16.492
34436.397	2200.43	2200.45	-0.07	-0.03	17.26	16.492
34657.327	2600.44	2600.46	-0.06	-0.02	17.25	16.492
34985.713	3200.47	3200.48	-0.05	-0.00	17.26	16.491
35525.226	4200.48	4200.48	-0.05	-0.00	17.26	16.491
36055.397	5200.49	5200.50	-0.07	-0.01	17.26	16.491
36576.653	6200.53	6200.54	-0.10	-0.01	17.26	16.491
36987.507	7000.54	7000.62	-0.19	-0.08	17.26	16.491
36576.636	6200.57	6200.51	-0.03	0.06	17.26	16.491
36055.374	5200.57	5200.46	0.04	0.11	17.25	16.492
35525.205	4200.52	4200.46	0.01	0.07	17.23	16.492
34985.697	3200.49	3200.46	-0.01	0.03	17.23	16.492
34657.320	2600.45	2600.46	-0.05	-0.01	17.23	16.492
34436.391	2200.42	2200.45	-0.07	-0.03	17.23	16.492
34101.893	1600.38	1600.43	-0.08	-0.05	17.23	16.491
33876.773	1200.35	1200.39	-0.08	-0.04	17.23	16.491
33535.836	600.32	600.33	-0.05	-0.01	17.23	16.491
33193.464	0.27	0.19	-0.01	0.08	29.78	29.003
33538.531	600.33	600.37	-0.10	-0.04	29.78	29.002
33879.505	1200.36	1200.41	-0.10	-0.05	29.78	29.002
34104.652	1600.39	1600.44	-0.09	-0.05	29.78	29.002

Sensor Output	DWT	Sensor New_Coefs	DWT-Sensor Prev_Coefs	DWT-Sensor NEW_Coefs	PT-DegC	Bath_Temp
34439.199	2200.43	2200.47	-0.07	-0.04	29.78	29.002
34660.159	2600.44	2600.48	-0.05	-0.04	29.78	29.002
34988.587	3200.48	3200.49	-0.02	-0.02	29.78	29.002
35528.174	4200.49	4200.50	-0.01	-0.01	29.78	29.002
36058.400	5200.48	5200.49	0.01	-0.00	29.79	29.001
36579.741	6200.49	6200.56	-0.06	-0.07	29.79	29.000
36990.617	7000.49	7000.57	-0.07	-0.08	29.79	29.001
36579.691	6200.52	6200.46	0.07	0.06	29.79	29.001
36058.364	5200.55	5200.42	0.14	0.13	29.78	29.002
35528.137	4200.53	4200.44	0.10	0.09	29.78	29.003
34988.564	3200.49	3200.45	0.04	0.04	29.78	29.002
34660.145	2600.45	2600.45	-0.02	-0.00	29.78	29.002
34439.185	2200.42	2200.45	-0.05	-0.03	29.78	29.001
34104.645	1600.38	1600.43	-0.08	-0.05	29.78	29.001
33879.496	1200.35	1200.40	-0.09	-0.04	29.78	29.002
33538.512	600.32	600.33	-0.08	-0.01	29.78	29.001
33193.437	0.27	0.14	0.04	0.12	29.78	29.000



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SENSOR SERIAL NUMBER: 2569
CALIBRATION DATE: 17-Mar-22

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

COEFFICIENTS:

```
g =  -1.04574666e+001
h =   1.58020915e+000
i =   1.92446352e-003
j =  -2.24202625e-005

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

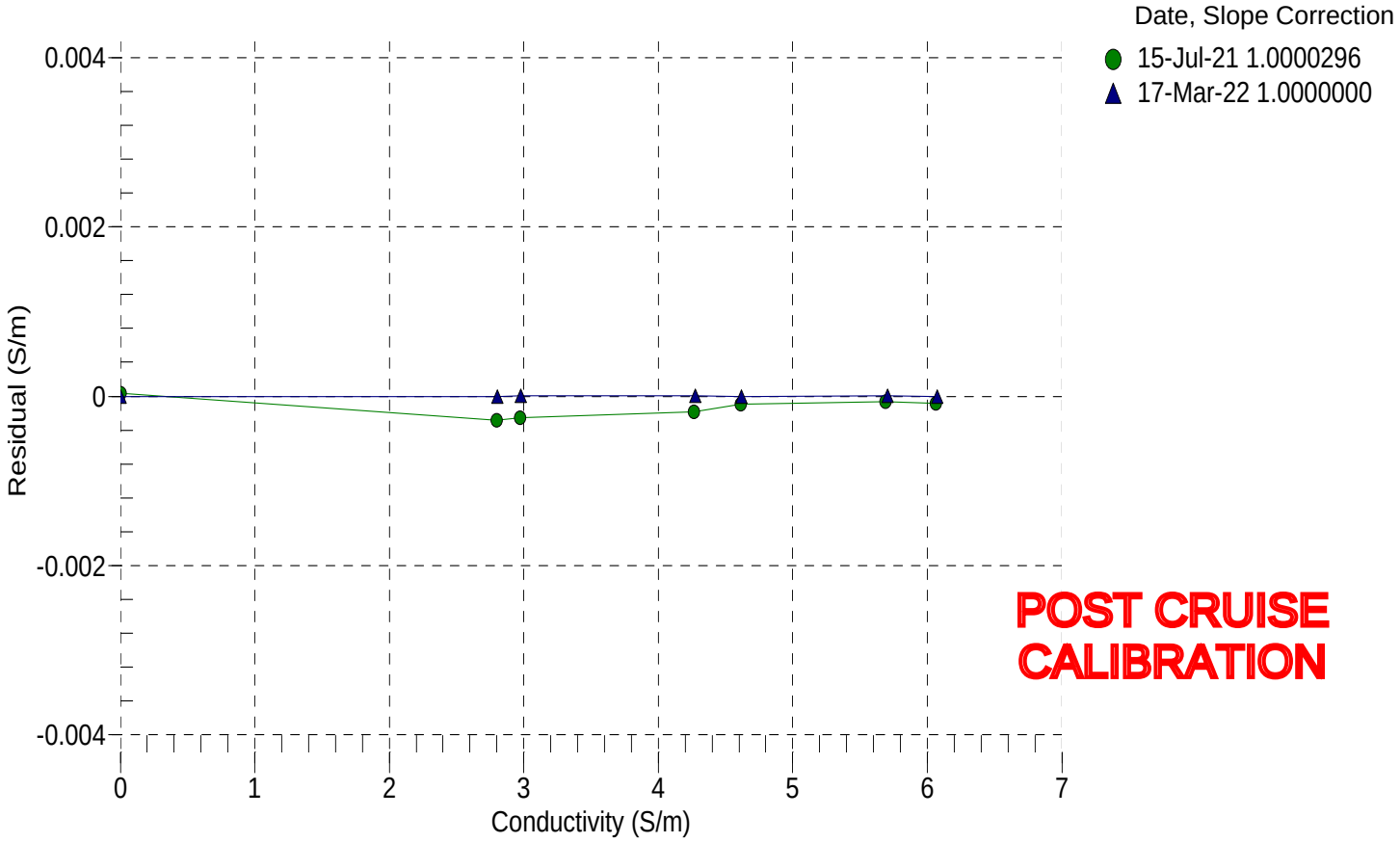
BATH TEMP (° C)	BATH SAL (PSU)	BATH COND (S/m)	INSTRUMENT OUTPUT (kHz)	INSTRUMENT COND (S/m)	RESIDUAL (S/m)
0.0000	0.0000	0.00000	2.56861	0.00000	0.00000
-1.0001	34.8352	2.80595	4.92316	2.80595	-0.00000
0.9999	34.8357	2.97746	5.03130	2.97746	0.00000
14.9999	34.8360	4.27376	5.78316	4.27377	0.00000
18.4999	34.8361	4.62070	5.96822	4.62070	-0.00000
29.0000	34.8319	5.70459	6.51234	5.70459	0.00001
32.5000	34.8212	6.07675	6.68888	6.07674	-0.00000

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 Scientific
13431 NE 20th Street
Bellevue, WA 98005
USA

+1 425-643-9866
seabird@seabird.com
www.seabird.com

SENSOR SERIAL NUMBER: 3578
CALIBRATION DATE: 22-Mar-22

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

COEFFICIENTS:

```
g =  -9.47463002e+000
h =   1.14725777e+000
i =  -5.49238016e-004
j =   1.02257222e-004

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

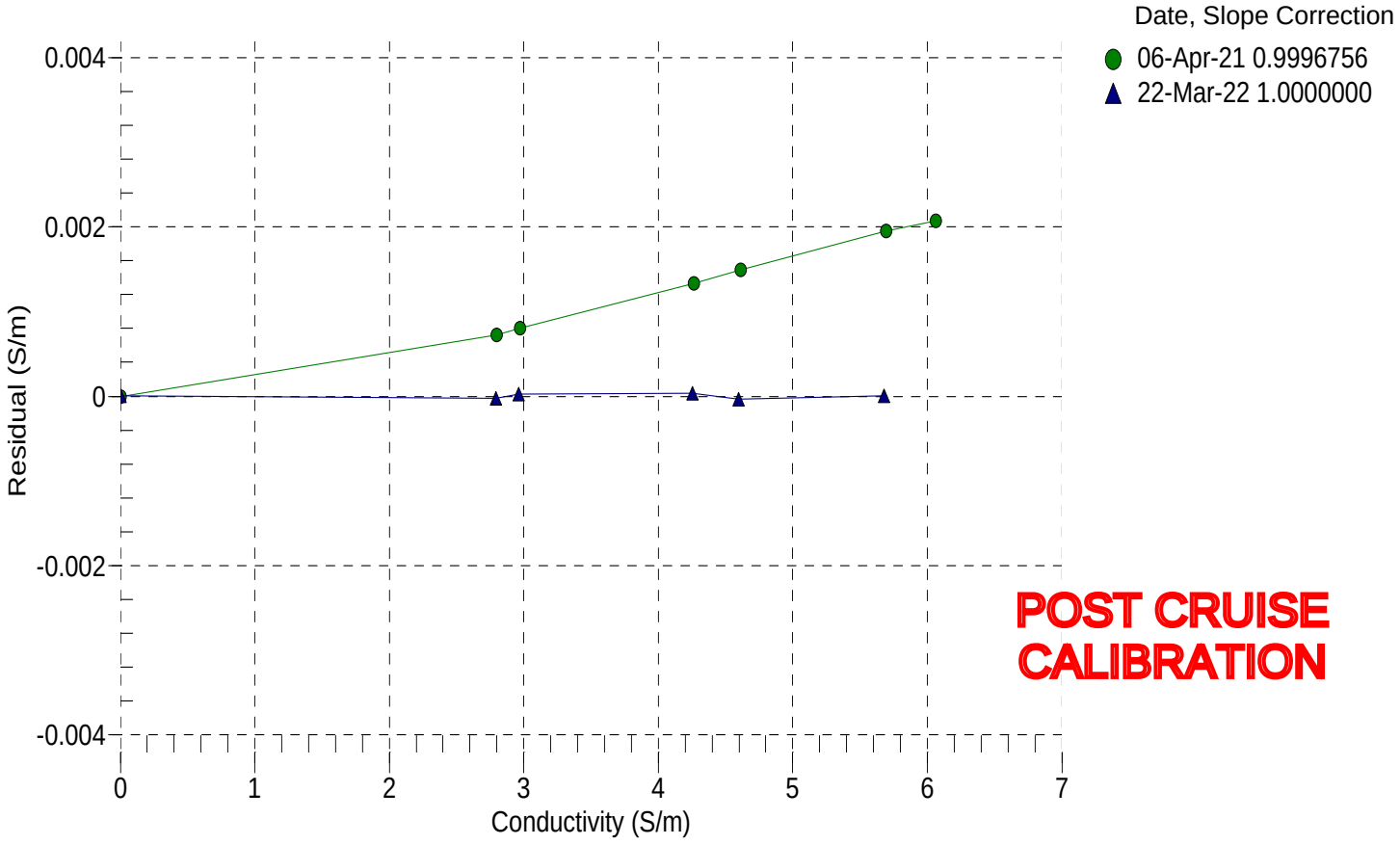
BATH TEMP (° C)	BATH SAL (PSU)	BATH COND (S/m)	INSTRUMENT OUTPUT (kHz)	INSTRUMENT COND (S/m)	RESIDUAL (S/m)
0.0000	0.0000	0.00000	2.87468	0.00000	0.00000
-1.0000	34.6472	2.79222	5.70884	2.79219	-0.00003
1.0000	34.6471	2.96288	5.83749	2.96290	0.00003
15.0000	34.6463	4.25296	6.73011	4.25299	0.00003
18.5001	34.6449	4.59809	6.94927	4.59805	-0.00004
29.0000	34.6383	5.67644	7.59308	5.67644	0.00001
32.5000	34.6230	6.04608	7.80118	6.04573	-0.00035

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



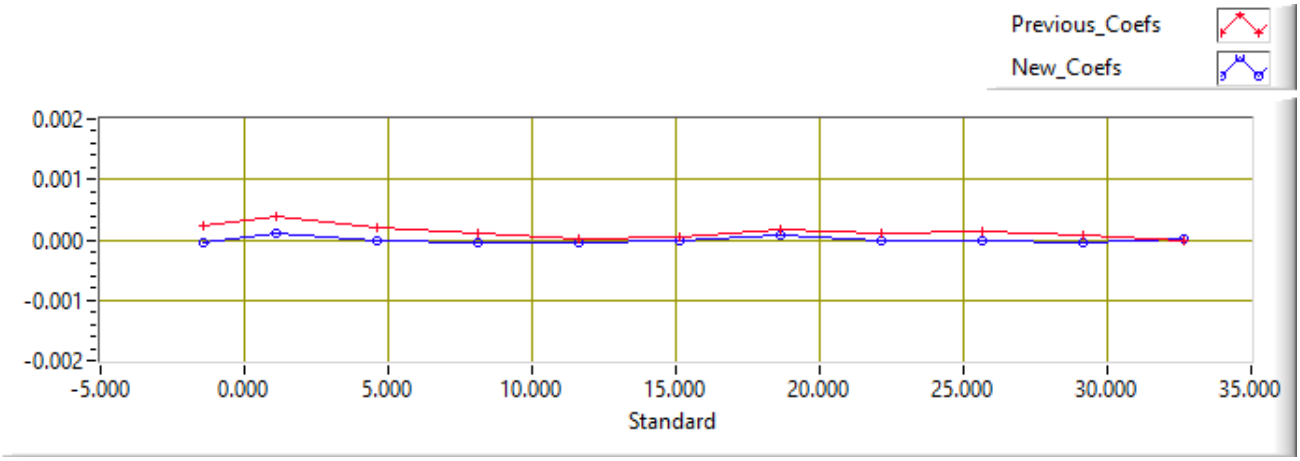
Temperature Calibration Report
STS Calibration Facility

SENSOR SERIAL NUMBER: 0105
CALIBRATION DATE: 15-Mar-2022
Mfg: SEABIRD Model: 35
Previous cal: 09-Feb-21
Calibration Tech: MVK

ITS-90_COEFFICIENTS
a0 = 6.524193824E-3
a1 = -1.849038085E-3
a2 = 2.569536069E-4
a3 = -1.400059014E-5
a4 = 2.909840456E-7
Slope = 1.000000 Offset = 0.000000
Calibration Standard: Mfg: Isotech Model: MicroK100 s/n: 291088-2

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
921181.3716	-1.4298	-1.4298	0.00024	-0.00006
823747.7314	1.0749	1.0748	0.00040	0.00011
705943.7767	4.5815	4.5815	0.00021	-0.00001
606521.2201	8.0900	8.0900	0.00010	-0.00004
522477.9212	11.5985	11.5986	0.00003	-0.00005
451384.5810	15.1014	15.1014	0.00004	-0.00002
390849.1226	18.6137	18.6136	0.00017	0.00009
339363.4042	22.1233	22.1233	0.00012	0.00000
295402.2109	25.6355	25.6355	0.00014	-0.00001
257832.7582	29.1445	29.1446	0.00008	-0.00004
225602.7730	32.6547	32.6547	-0.00000	0.00002



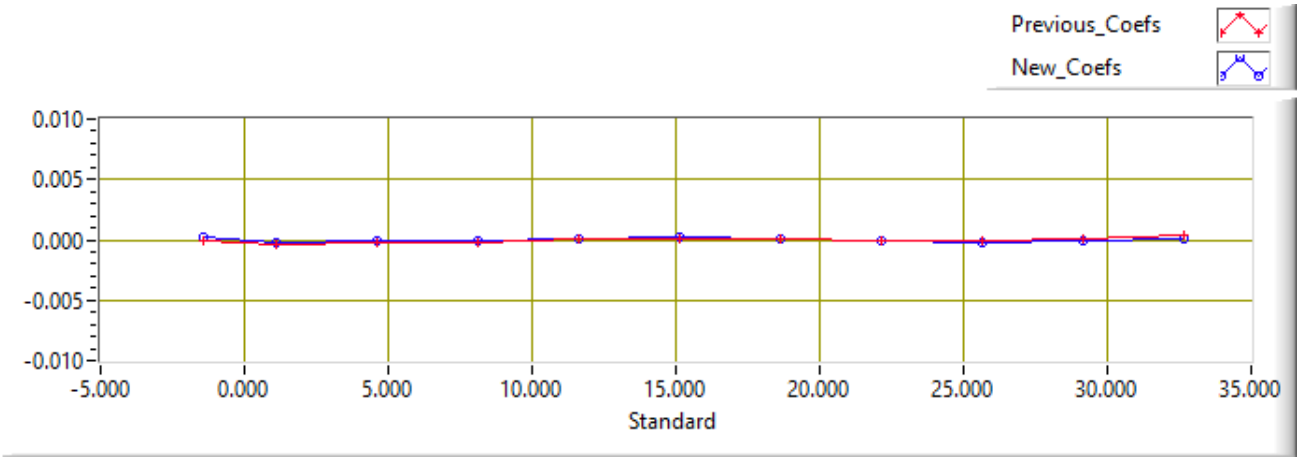
Temperature Calibration Report
STS Calibration Facility

SENSOR SERIAL NUMBER: 4138
CALIBRATION DATE: 17-Mar-2022
Mfg: SEABIRD Model: 03
Previous cal: 31-Aug-21
Calibration Tech: AJM

ITS-90_COEFFICIENTS	IPTS-68_COEFFICIENTS ITS-T90	
g = 4.32516790E-3	a = 4.32535573E-3	
h = 6.27336486E-4	b = 6.27540205E-4	
i = 2.00203041E-5	c = 2.00510291E-5	
j = 1.55382422E-6	d = 1.55518090E-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
2889.1750	-1.4300	-1.4302	-0.00002	0.00020
3058.7838	1.0742	1.0744	-0.00039	-0.00022
3308.2564	4.5810	4.5811	-0.00019	-0.00007
3572.2452	8.0890	8.0891	-0.00022	-0.00014
3851.2432	11.5994	11.5993	0.00007	0.00013
4144.7378	15.1008	15.1006	0.00014	0.00019
4454.8273	18.6132	18.6131	0.00005	0.00008
4780.7934	22.1234	22.1234	-0.00001	-0.00002
5123.3570	25.6352	25.6354	-0.00011	-0.00017
5482.4267	29.1442	29.1443	0.00002	-0.00013
5858.9713	32.6564	32.6562	0.00042	0.00015



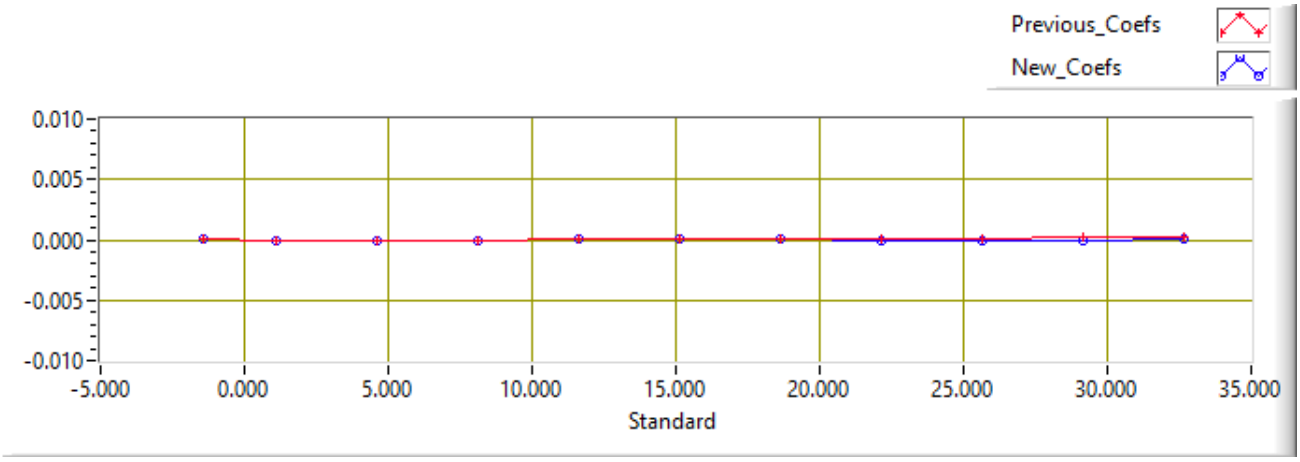
Temperature Calibration Report
STS Calibration Facility

SENSOR SERIAL NUMBER: 4941
CALIBRATION DATE: 09-Mar-2022
Mfg: SEABIRD Model: 03
Previous cal: 31-Aug-21
Calibration Tech: AJM

ITS-90_COEFFICIENTS	IPTS-68_COEFFICIENTS ITS-T90	
g = 4.36052717E-3	a = 4.36072637E-3	
h = 6.41687693E-4	b = 6.41898355E-4	
i = 2.28813698E-5	c = 2.29135945E-5	
j = 2.15275286E-6	d = 2.15425958E-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
3000.3682	-1.4293	-1.4293	0.00010	0.00005
3173.7371	1.0751	1.0751	-0.00000	-0.00003
3428.5184	4.5817	4.5818	-0.00009	-0.00010
3697.8770	8.0908	8.0908	-0.00001	-0.00001
3982.1314	11.6009	11.6008	0.00011	0.00010
4280.7697	15.1016	15.1016	0.00006	0.00003
4595.9846	18.6143	18.6143	0.00007	0.00001
4926.8615	22.1239	22.1240	0.00005	-0.00005
5274.2376	25.6360	25.6360	0.00014	-0.00001
5637.7164	29.1432	29.1433	0.00016	-0.00004
6018.7425	32.6565	32.6565	0.00029	0.00004



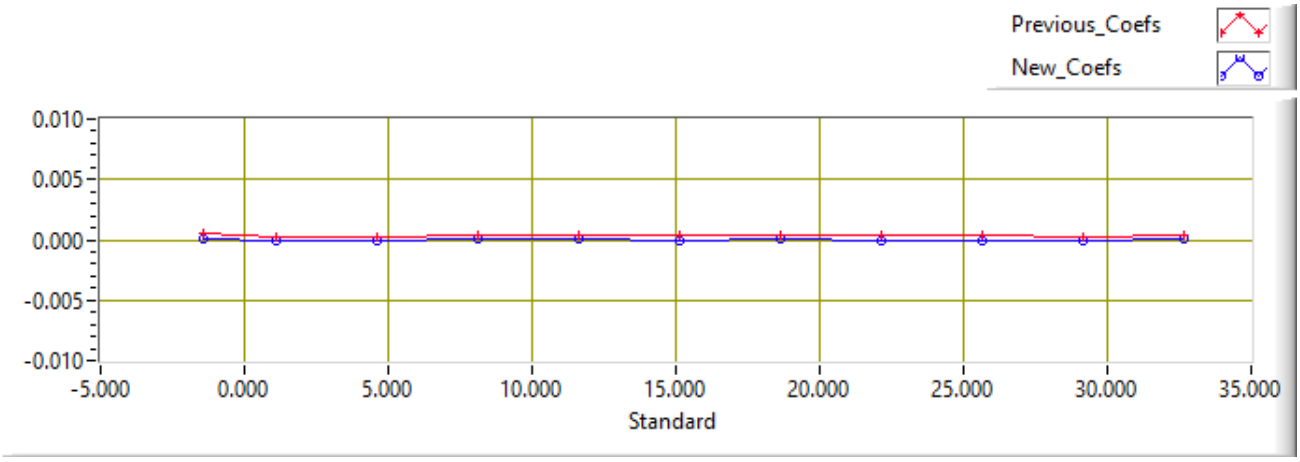
Temperature Calibration Report
STS Calibration Facility

SENSOR SERIAL NUMBER: 5046
CALIBRATION DATE: 02-Mar-2022
Mfg: SEABIRD Model: 03
Previous cal: 24-Feb-21
Calibration Tech: MVK

ITS-90_COEFFICIENTS	IPTS-68_COEFFICIENTS ITS-T90	
g = 4.41636859E-3	a = 4.41658635E-3	
h = 6.44196855E-4	b = 6.44412734E-4	
i = 2.26266614E-5	c = 2.26589816E-5	
j = 2.07106898E-6	d = 2.07252479E-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
3276.5574	-1.4290	-1.4291	0.00053	0.00008
3465.8594	1.0752	1.0752	0.00030	-0.00009
3744.0916	4.5827	4.5828	0.00026	-0.00007
4038.0594	8.0910	8.0909	0.00037	0.00004
4348.2547	11.6005	11.6004	0.00043	0.00008
4674.1811	15.1015	15.1015	0.00032	-0.00006
5018.1189	18.6143	18.6143	0.00044	0.00004
5379.1382	22.1246	22.1246	0.00043	0.00000
5757.8618	25.6350	25.6350	0.00042	0.00000
6154.5491	29.1447	29.1448	0.00027	-0.00009
6569.8498	32.6566	32.6565	0.00032	0.00006



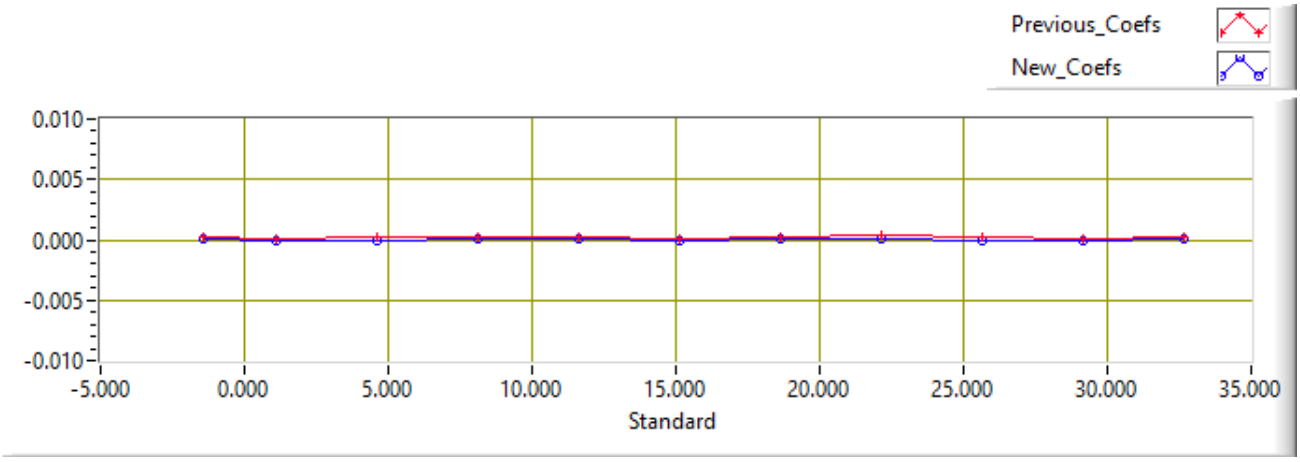
Temperature Calibration Report
STS Calibration Facility

SENSOR SERIAL NUMBER: 6018
CALIBRATION DATE: 02-Mar-2022
Mfg: SEABIRD Model: 03
Previous cal: 24-Feb-21
Calibration Tech: MVK

ITS-90_COEFFICIENTS	IPTS-68_COEFFICIENTS ITS-T90	
g = 4.36187980E-3	a = 4.36207948E-3	
h = 6.37713526E-4	b = 6.37923075E-4	
i = 2.21508074E-5	c = 2.21825746E-5	
j = 2.03138571E-6	d = 2.03284160E-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
3025.6386	-1.4290	-1.4291	0.00027	0.00006
3201.3846	1.0752	1.0752	0.00012	-0.00009
3459.8000	4.5827	4.5827	0.00018	-0.00003
3732.9699	8.0910	8.0909	0.00028	0.00006
4021.3636	11.6005	11.6004	0.00027	0.00004
4324.5238	15.1015	15.1016	0.00014	-0.00010
4644.5878	18.6143	18.6143	0.00028	0.00003
4980.7012	22.1246	22.1245	0.00036	0.00010
5333.4873	25.6350	25.6350	0.00023	-0.00002
5703.1694	29.1447	29.1448	0.00010	-0.00012
6090.3748	32.6566	32.6565	0.00023	0.00006



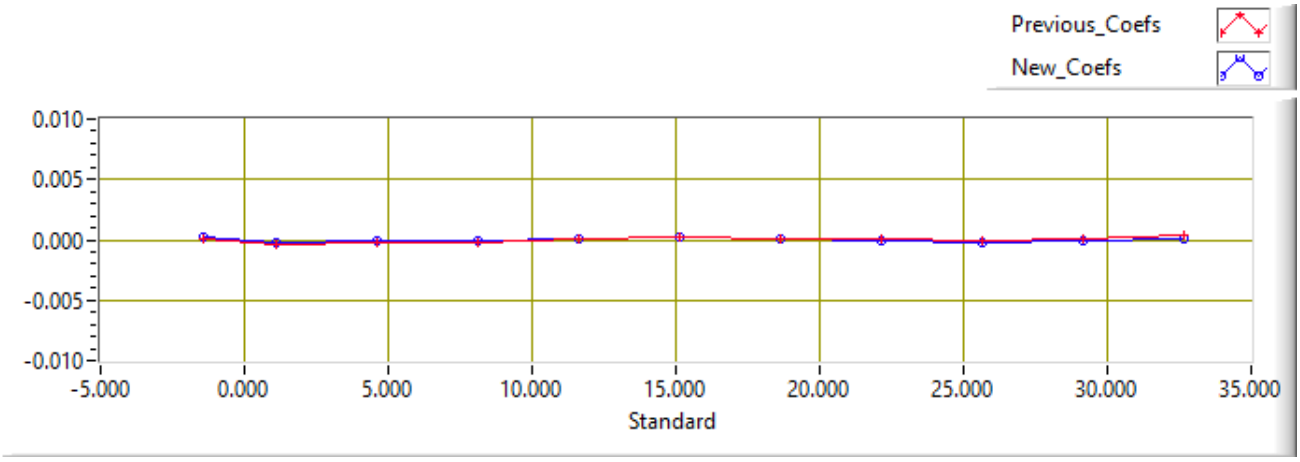
Temperature Calibration Report
STS Calibration Facility

SENSOR SERIAL NUMBER: 6049
CALIBRATION DATE: 17-Mar-2022
Mfg: SEABIRD Model: 03
Previous cal: 31-Aug-21
Calibration Tech: AJM

ITS-90_COEFFICIENTS	IPTS-68_COEFFICIENTS ITS-T90	
g = 4.31264709E-3	a = 4.31283085E-3	
h = 6.27365760E-4	b = 6.27568511E-4	
i = 1.99855976E-5	c = 2.00163145E-5	
j = 1.56729241E-6	d = 1.56865339E-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
2828.1534	-1.4300	-1.4302	0.00001	0.00020
2993.9491	1.0742	1.0744	-0.00033	-0.00020
3237.7958	4.5810	4.5811	-0.00018	-0.00010
3495.7969	8.0890	8.0891	-0.00018	-0.00012
3768.4416	11.5994	11.5993	0.00009	0.00012
4055.2179	15.1008	15.1006	0.00020	0.00021
4358.1828	18.6132	18.6131	0.00007	0.00006
4676.6220	22.1234	22.1234	0.00002	-0.00002
5011.2402	25.6352	25.6354	-0.00006	-0.00016
5361.9492	29.1442	29.1443	0.00004	-0.00014
5729.6864	32.6564	32.6562	0.00045	0.00015



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

CALIBRATION CERTIFICATE

NAME	:	RINKO Ⅲ
MODEL	:	ARO-CAV
SERIAL No.	:	0296
Parameter	:	Temperature Dissolved Oxygen

JFE

JFE Advantech Co., Ltd.

Temperature Calibration Certificate

Model	:	ARO-CAV
Serial No.	:	0296
Date	:	April 07, 2017
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 = −5.305905e+00
B = +1.666857e+01
C = −2.142681e+00
D = +4.582805e−01

3. Calibration results

Reference temperature [°C]	Instrument voltage [V]	Instrument temperature [°C]	Residual error [°C]	Acceptance [°C]	OK/NG
2.437	0.49243	2.437	0.000	±0.020	OK
10.737	1.07715	10.735	−0.002	±0.020	OK
17.463	1.57825	17.466	0.003	±0.020	OK
24.123	2.07288	24.121	−0.002	±0.020	OK
31.105	2.56635	31.105	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
20.068	20.086	0.018	±0.020	Passed

Examined R. Kashida

Approved A. Fukuoka

Dissolved Oxygen Calibration Certificate

Model	:	ARO-CAV
Serial No.	:	0296
Date	:	April 10, 2017
Location	:	Production Section
Method	:	Calibration is performed with the nitrogen gas (zero) and the oxygen saturated water (span) kept by air bubbling.
Film No.	:	164312BA

1. Equation

DO[%] =G+H × P'

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

2. Coefficients

A =	−4.524084e+01	E =	+4.000000e−03
B =	+1.449377e+02	F =	+6.250000e−05
C =	−3.051590e−01	G =	+0.000000e+00
D =	+1.065300e−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	1015.7	0.00	0.02	0.02	±1.00	Passed
2nd	1015.7	0.00	0.02	0.02	±1.00	Passed
3rd	1015.7	0.00	0.02	0.02	±1.00	Passed

Test for DO 100 %

	Test condition			Instrument DO [%]	Residual error [%]	Acceptance [%]	Judgement
	Water T. [°C]	Atm. pressure [hPa]	Reference DO [%]				
1st	25.1	1015.0	100.18	99.89	−0.29	±1.00	Passed
2nd	25.1	1015.0	100.18	99.94	−0.24	±1.00	Passed
3rd	25.1	1014.9	100.17	99.95	−0.22	±1.00	Passed

Examined M. TAKEISHI

Approved A. Fukuoka

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SENSOR SERIAL NUMBER: 0060
CALIBRATION DATE: 15-Mar-22

SBE 43 OXYGEN CALIBRATION DATA

COEFFICIENTS:
Soc = 0.5069
Voffset = -0.4968
Tau20 = 1.20

A = -4.5924e-003
B = 1.9638e-004
C = -2.9709e-006
E nominal = 0.036

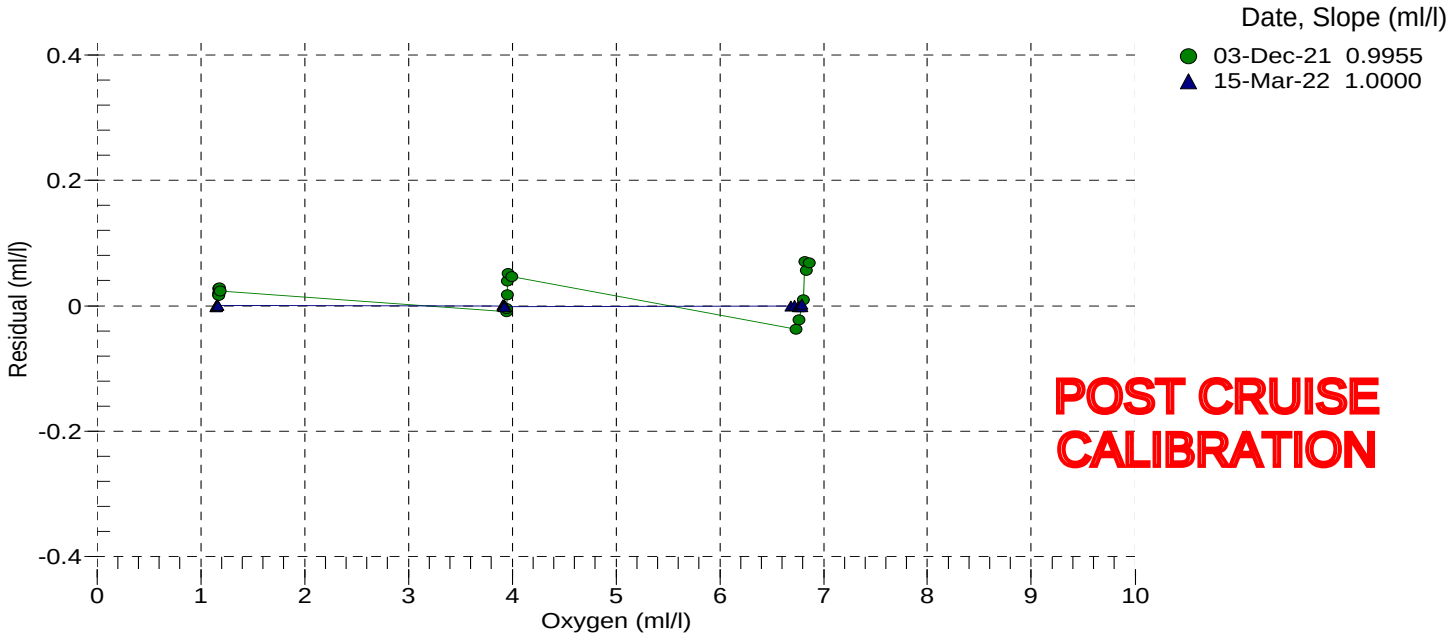
NOMINAL DYNAMIC COEFFICIENTS
D1 = 1.92634e-4
D2 = -4.64803e-2
H1 = -3.300000e-2
H2 = 5.00000e+3
H3 = 1.45000e+3

BATH OXYGEN (ml/l)	BATH TEMPERATURE (° C)	BATH SALINITY (PSU)	INSTRUMENT OUTPUT (volts)	INSTRUMENT OXYGEN (ml/l)	RESIDUAL (ml/l)
1.15	2.00	0.00	0.733	1.15	-0.00
1.15	6.00	0.00	0.763	1.15	0.00
1.15	12.00	0.00	0.808	1.15	-0.00
1.16	20.00	0.00	0.870	1.16	0.00
1.16	26.00	0.00	0.916	1.16	0.00
1.17	30.00	0.00	0.951	1.17	0.00
3.91	2.00	0.00	1.301	3.91	-0.00
3.91	6.00	0.00	1.403	3.92	0.00
3.92	20.00	0.00	1.759	3.92	0.00
3.92	30.00	0.00	2.023	3.92	0.00
3.92	12.00	0.00	1.557	3.92	0.00
3.92	26.00	0.00	1.915	3.92	-0.00
6.69	2.00	0.00	1.872	6.69	-0.00
6.72	6.00	0.00	2.052	6.72	0.00
6.76	12.00	0.00	2.323	6.76	-0.00
6.77	20.00	0.00	2.676	6.77	-0.00
6.79	30.00	0.00	3.137	6.79	-0.00
6.79	26.00	0.00	2.952	6.79	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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SENSOR SERIAL NUMBER: 0185
CALIBRATION DATE: 15-Mar-22

SBE 43 OXYGEN CALIBRATION DATA

COEFFICIENTS:
Soc = 0.4772
Voffset = -0.5018
Tau20 = 1.54

A = -3.8659e-003
B = 1.6601e-004
C = -2.5194e-006
E nominal = 0.036

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

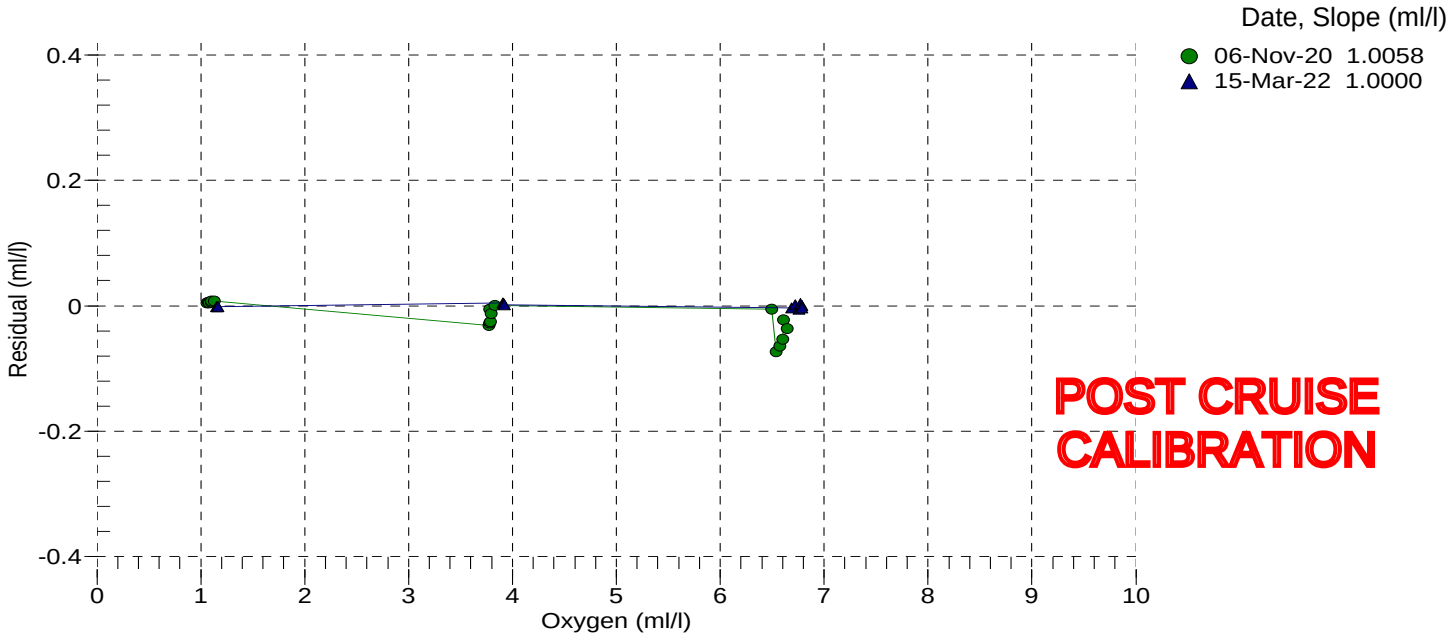
BATH OXYGEN (ml/l)	BATH TEMPERATURE (° C)	BATH SALINITY (PSU)	INSTRUMENT OUTPUT (volts)	INSTRUMENT OXYGEN (ml/l)	RESIDUAL (ml/l)
1.15	2.00	0.00	0.752	1.15	-0.00
1.15	6.00	0.00	0.784	1.15	-0.00
1.15	12.00	0.00	0.831	1.15	-0.00
1.16	20.00	0.00	0.894	1.15	-0.00
1.16	26.00	0.00	0.944	1.16	-0.00
1.17	30.00	0.00	0.980	1.17	-0.00
3.91	2.00	0.00	1.355	3.91	0.00
3.91	6.00	0.00	1.461	3.92	0.00
3.92	20.00	0.00	1.835	3.92	0.00
3.92	30.00	0.00	2.112	3.92	0.00
3.92	12.00	0.00	1.623	3.93	0.00
3.92	26.00	0.00	2.000	3.93	0.00
6.69	2.00	0.00	1.960	6.68	-0.00
6.72	6.00	0.00	2.148	6.72	0.00
6.76	12.00	0.00	2.430	6.75	-0.01
6.77	20.00	0.00	2.804	6.77	0.00
6.79	30.00	0.00	3.288	6.79	0.00
6.79	26.00	0.00	3.091	6.79	-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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SENSOR SERIAL NUMBER: 1508
CALIBRATION DATE: 08-Oct-21

SBE 43 OXYGEN CALIBRATION DATA

COEFFICIENTS:
Soc = 0.5690
Voffset = -0.5028
Tau20 = 1.45
A = -3.7769e-003
B = 1.3435e-004
C = -1.6085e-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

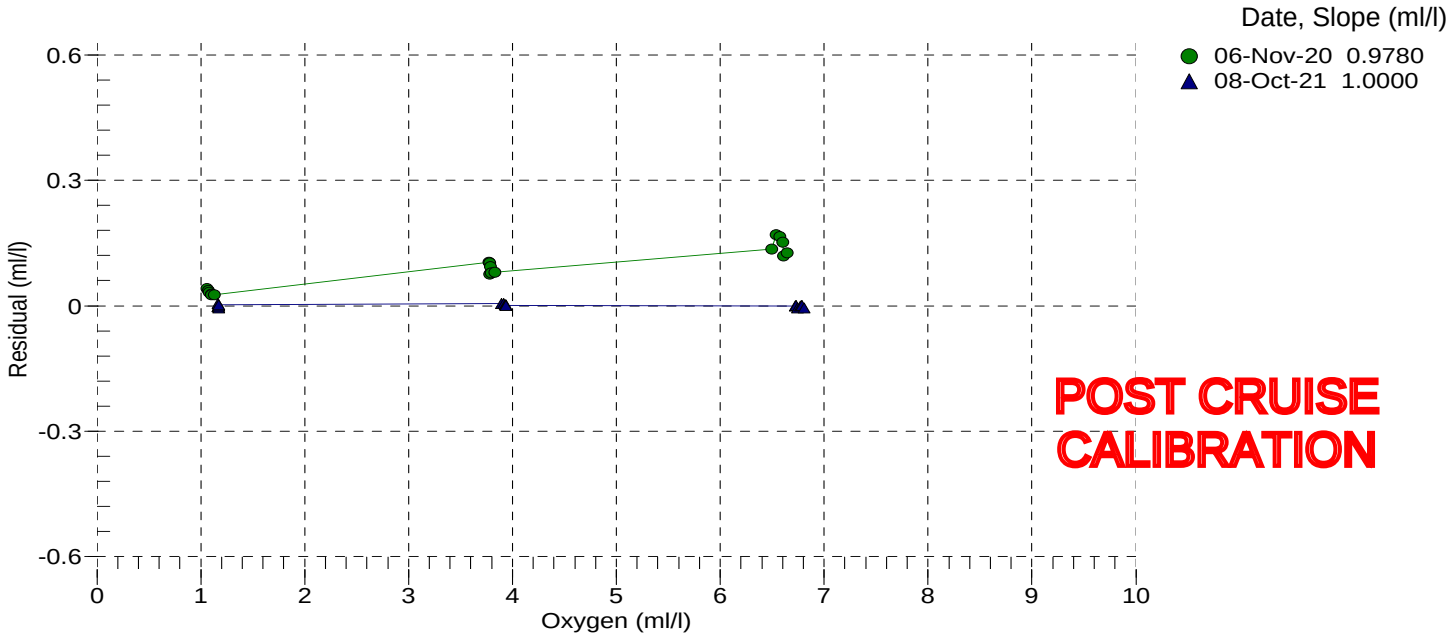
BATH OXYGEN (ml/l)	BATH TEMPERATURE (° C)	BATH SALINITY (PSU)	INSTRUMENT OUTPUT (volts)	INSTRUMENT OXYGEN (ml/l)	RESIDUAL (ml/l)
1.16	12.00	0.00	0.781	1.16	-0.00
1.17	30.00	0.00	0.907	1.17	0.01
1.17	6.00	0.00	0.742	1.17	-0.00
1.17	2.00	0.00	0.716	1.16	-0.01
1.17	20.00	0.00	0.838	1.17	-0.00
1.18	26.00	0.00	0.881	1.18	0.00
3.90	30.00	0.00	1.848	3.90	0.01
3.91	26.00	0.00	1.761	3.92	0.01
3.93	20.00	0.00	1.628	3.93	0.00
3.93	6.00	0.00	1.311	3.94	0.00
3.94	12.00	0.00	1.447	3.94	0.00
3.94	2.00	0.00	1.223	3.94	0.00
6.72	6.00	0.00	1.884	6.72	-0.00
6.73	2.00	0.00	1.733	6.73	0.00
6.74	30.00	0.00	2.824	6.74	-0.01
6.77	26.00	0.00	2.677	6.77	-0.00
6.78	12.00	0.00	2.131	6.78	0.00
6.81	20.00	0.00	2.449	6.80	-0.01

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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ECO Chlorophyll Fluorometer Characterization Sheet

Date: 1/7/2022 S/N: FLRTD-4334

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

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

	Analog Range 1	Analog Range 2	Analog Range 4 (default)		Digital	
Dark Counts	0.060	0.031	0.017	V	45	counts
Scale Factor (SF)	7	13	26	µg/l/V	0.0079	µg/l/count
Maximum Output	4.97	4.97	4.97	V	16380	counts
Resolution	0.9	0.9	0.9	mV	1.0	counts

Ambient temperature during characterization 21.0 °C

Analog Range: 1 (most sensitive, 0–4,000 counts), 2 (midrange, 0–8,000 counts), 4 (entire range, 0–16,000 counts).

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.

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C-Star Calibration

Date January 5, 2022 S/N# CST-1873DR Pathlength 25cm

	Analog output	Digital output
V_d	0.008 V	0 counts
V_{air}	4.800 V	15729 counts
V_{ref}	4.700 V	15398 counts

Temperature of calibration water	21.9	°C
Ambient temperature during calibration	22.0	°C

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

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

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

$\mathbf{V_d}$ Meter output with the beam blocked. This is the offset.
$\mathbf{V_{air}}$ Meter output in air with a clear beam path.
$\mathbf{V_{ref}}$ Meter output with clean water in the path.
Temperature of calibration water: temperature of clean water used to obtain V_{ref}.
Ambient temperature: meter temperature in air during the calibration.
$\mathbf{V_{sig}}$ Measured signal output of meter.

VALEPORT

This document certifies that the instrument detailed below has been calibrated according to Valeport Limited's Standard Procedures, using equipment with calibrations traceable to UKAS or National Standards.

Calibration Certificate Number:	43900
Instrument Type:	Altimeter
Instrument Serial Number:	53821
Calibrated By:	J.Harper
Date:	28/01/2016
Signed:	

Full details of the results from the calibration procedure applied to each fitted sensor are available, on request, via email. This summary certificate should be kept with the instrument.

Valeport Ltd | St Peter's Quay | Totnes | Devon | TQ9 5EW | UK
T: +44 (0) 1803 869292 | F: +44 (0) 1803 869293

Instrument Serial Number	53821
Sensor Type	500kHz Neptune
Altimeter Range (m)	100m
Certificate Number	43900

Stage 1

Test the assembled altimeter in a body of water to ensure a signal is recieved at the minimum range. Taking direct readings from the unit immerse the head till it is roughly 0.1m from the bottom, readings should come through - if not then the signal is being saturated and there is a problem

To inhibit spurious readings set using: #226;40

	Pass/Fail
Bench Test Min Range <0.1m	Pass

Stage 2

Using a mini SVS or similar, measure the average sound velocity for the water in the tow tank and input the value in the cell below.

Enter the SOS	1481.712

Input SOS value to the altimeter using: #830;1481.7120

Stage 3

Fit the altimeter into the calibration fixture and lower the assembly into the tank till it is about 0.5m down facing the far end of the tow tank and clamp in place. Using the distance markers on the wall align the front edge of the trolley with the datum line to set the front of the altimeter at stated distance from the wall.

To determine the Range Offset		
Distance m	Measured Range m	Measured Offset m
1	1.018	-0.018

Stage 4: Enter the Offset Correction
#828;-0.0180

Stage 5 - Range Check after Offset Correction			
Distance m	Measured Range m	Measured Offset m	Pass/Fail
1	0.998	0.002	Pass
5	5.003	-0.003	Pass

Stage 6: Reset the SOS
#830;1500

Stage 7: Reset maximum range to 105m		Stage 8: Reset spurious range
#823;105	(500kHz units)	#226;0

Calibrated by:	J.Harper	Date:	28/01/2016

ltimeter Build and Calibration Record

ument type	Altimeter
al number	53821
d rate set ex factory	115200

Calibration History:	Certificate	Date
	43900	28/01/2016

System Components	Original Manufacture				Modification				Modification				Modification			
	Part (Blank=Not Fitted)	Iss	Serial Number	Range / Firmware	Part (Blank=Not Fitted)	Iss	Serial Number	Range / Firmware	Part (Blank=Not Fitted)	Iss	Serial Number	Range / Firmware	Part (Blank=Not Fitted)	Iss	Serial Number	Range / Firmware
board	0430502	C	110929													
board	0430501	C	78627	ACTEL 0430707												
				ATMEL 0430704A13												
ducer Assembly	500kHz Neptune		31059	100m												
ure sensor	PAA - 10LX		N/A	N/A												
	Name			P Tremlett	Name				Name				Name			
	Date			28/01/2016	Date				Date				Date			
	Signed				Signed				Signed				Signed			

Calibrated to Valeport's procedures using test equipment with calibrations traceable to UKAS or national standards

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