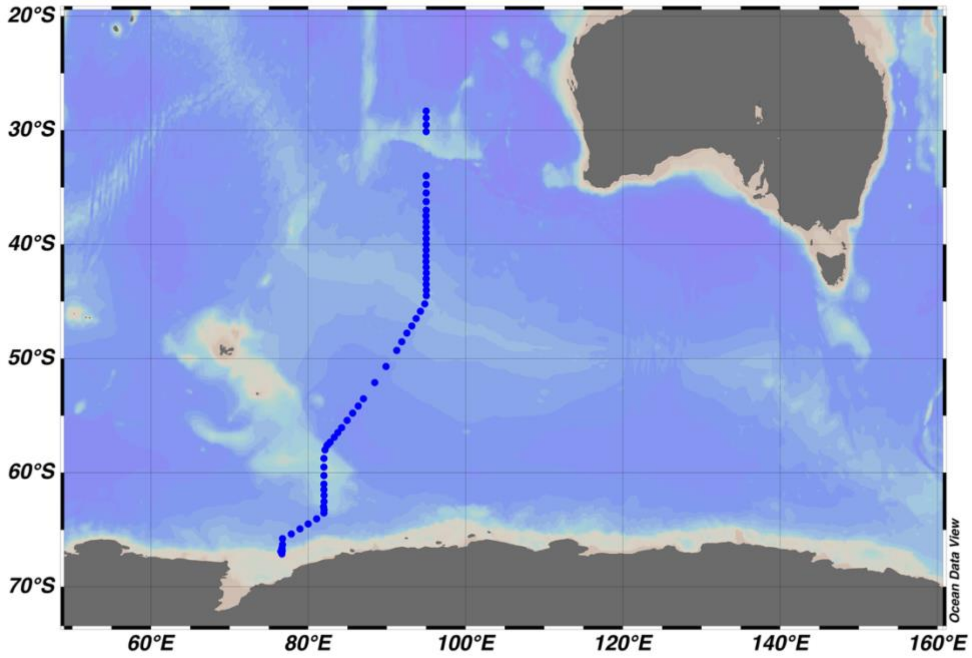
CRUISE REPORT: GO-SHIP I08S

Updated: May 2026



Highlights

Cruise Summary Information

Section Designation	I08S
Expedition Designation (ExpoCode)	**325020240221**
Chief Scientists	**Sebastien Bigorre, WHOI**
Dates	21 February – 1 April 2024
Ship	R/V *Thompson*
Ports of Call	Fremantle, Australia –,Fremantle, Australia
Geographic Boundaries	23.32°S 76.66°E 95.03°E 67.11°S
Stations	66
Floats and Drifters Deployed	15 (7 BGC, 7 core, 1 deep)
Moorings Deployed and Recovered	0

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*Additional DIC metadata and análisis details are appended to the end of this cruise report

Report assembled by Savannah Lewis

Cruise Report of the US-GOSHIP 2024 Reoccupation of I08S

Sebastien Bigorre

May 14, 2024

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ONE

GO-SHIP I08S 2024 HYDROGRAPHIC PROGRAM

1.1 Summary

On this I08S 2024 cruise we have completed 66 stations (Fig. 1.1), which include 66 core casts and 9 dedicated Bio casts. Twelve casts were combined core and Bio casts whereby 3 Niskins out of the 36 available were typically reserved for Bio samples. Over the 66 core casts, the average depth was 3,213 m and the rosette travelled 424,126 m (263.6 statute miles). The southernmost station (station 1) was completed on Mar 4 at 67.1°S, 76.6°E in 300 m of water inside Prydz Bay on the shelf of Antarctica. The northernmost station (station 66) was completed on Mar 28 at 28.3°S, 95°E. Fifteen Argo floats (7 BGC, 7 core, 1 deep) and 10 surface drifters were successfully deployed.

The cruise left Fremantle on Feb 21 and returned on Apr 1. During the cruise we encountered seven storms that directly impacted our work. Two storms during the transit south on Feb 26-28 delayed our arrival at the first station by one day (assuming a baseline direct transit at 10 knots). Five storms between Mar 8 and 27 prevented CTD work for a combined duration of 5.8 days. Average wire speed during our cruise was about 45 m/min; compared to a typical wire speed of 60 m/min in calm seas (not realistic in the Southern Ocean), an additional upper estimate for weather delay on the wire speed is 40 hours or 1.6 day. In total, weather delays were between 6.8 and 8.4 days.

Weather has definitely been a defining feature of the I08S cruise but we have learned a lot. We have also accomplished many goals and managed to keep the line continuous up to the crossover with I05. We have reached and sampled the shelf of Antarctica in a region where bottom water is formed. All the labs, including Bio, have been able to sample during the whole cruise. Cruise participants have acquired sea legs, crossed the southern polar circle and witnessed the beauty of its wilderness, and are coming back home enriched with these experiences and friendships.

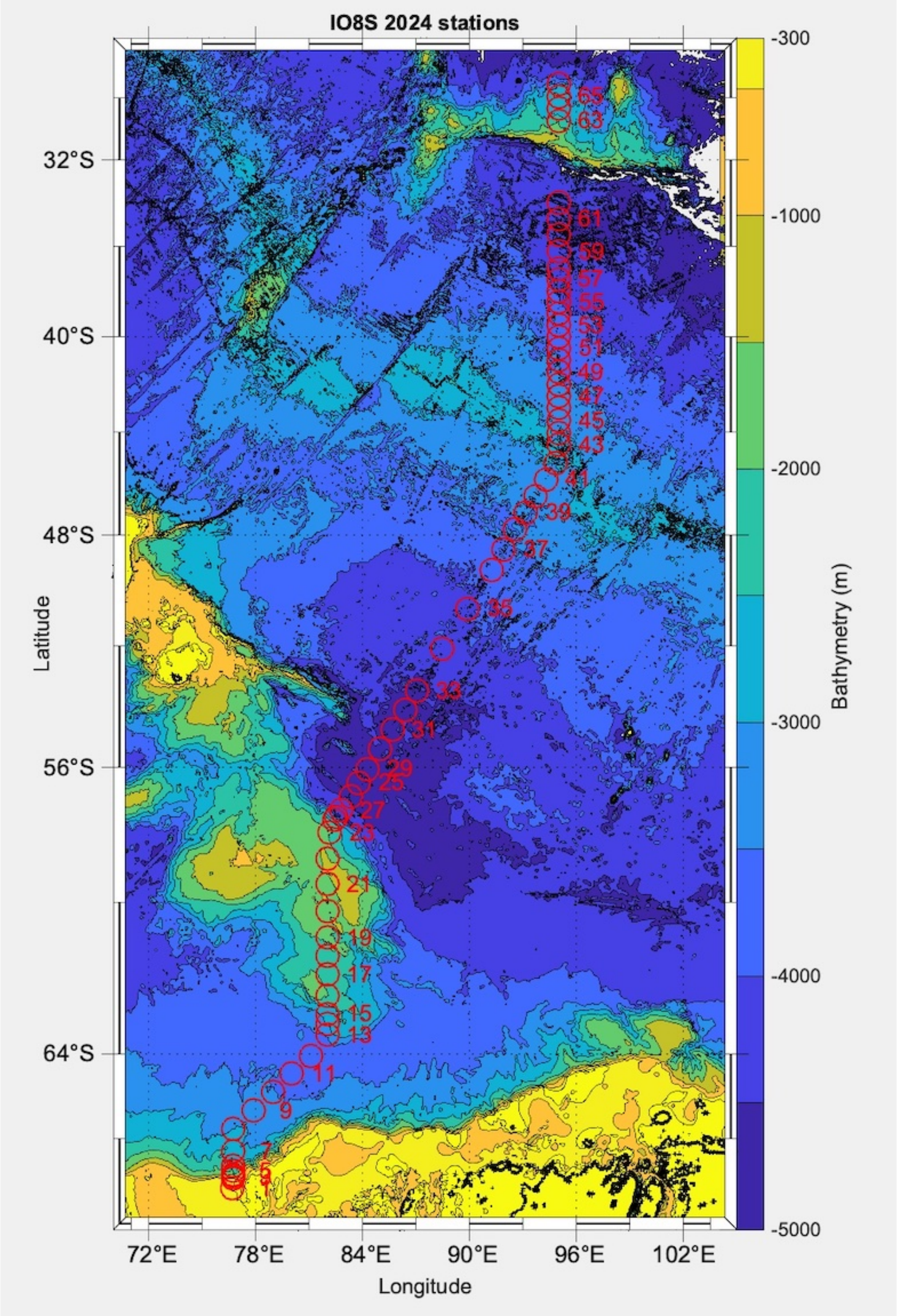

Fig. 1.1: Bathymetry map from GEBCO 2022 in colors. Red circles denote the 66 stations (labeled in chronological order) completed during I08S 2024 cruise.

1.2 Principal Investigators

Program	PI	Affiliation	PI email
BGC	Lynne Talley	SIO	ltalley@ucsd.edu
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1.3 Cruise Participants

Role	Name	Affiliation	Participant email
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CHAPTER

TWO

CRUISE NARRATIVE

Mobilization for the I08S cruise occurred from Feb 17 to 21 at the Australian Marine Complex where the R/V Thompson was berthed, about 15 km to the south of Fremantle. On Feb 17, most of the science lab leads arrived at the ship at 08:00 where equipment for ODF, CFC, pH/Talk, Bio, DOM, ^{14}C, and BGC floats was being delivered at the dock by the ship agent Gulf Agency Company (GAC). Loading started promptly and Jim Happell proceeded with SWAB testing (UNOLS program that checks the fleet for low level ^{3}H and ^{14}C contamination) inside the Main lab. In the high bay, a local contractor installed new roll up doors and the ship's engineers tested the accordion system that would move the Rosette to and from the starboard deck during the cruise. Lab setup continued indoors as much as possible as outdoor air temperature was routinely around 45°C during the day.

A few shipments arrived in the later part of the mobilization, most notably the five different backup shipments coming from PMEL, AOML, and UCSD for the DIC group. These were backup air shipments to the PMEL van lab which had been delayed in Singapore and would not make it on time in Fremantle for I08S. Finally, twelve Nitrogen and pure air gas tanks intended for the DIC analytical lab were delivered to the ship in the morning of Feb 21, and the R/V Thompson set sail at 14:50 local (UTC +8), marking the start of the I08S 2024 cruise.

Inside the EEZ, the Bio group started taking samples for eDNA analysis at solar sunrise, noon, and sunset from the underway system as permitted by research clearance from the Australian government. On Feb 22, fire drills were conducted in the morning and in the afternoon a CTD test cast was done 10 nm outside the Australian EEZ. This test cast was successful, and every group practiced their sampling skills. The six CTD watchstanders learned to cock the 10.2-Liter Niskin bottles, draw water from them for salt samples, and practiced the CTD operation from the control room. This cast also allowed us to test the CTD and LADCP instruments, as well as the accordion system for the rosette deployment and recovery, and gauge the sensitivity of the wire tension to the ship's motion and sea state. After the test cast, the ship resumed its transit to the southwest at 12 knots for the next couple of days. On Feb 24, a couple of BGC floats were decorated and a science meeting was held in the ship library. We deployed our first core Argo float in the morning of Feb 25. A couple of storms obliged the ship to divert to the west and slow down to 5 knots at times because of winds reaching 50 knots and waves above 12 m. Finally in the evening of Feb 28 the weather improved and the ship turned south and its speed increased to 11.5 and then 12 knots over the next few hours and days. Floats and surface drifters deployments resumed, near the I08S line since we had gone west quite a bit during the previous storm. The first BGC float was deployed on Feb 29 and underway samples were taken during deployment. On Mar 3, all scientific and navigation systems in the computer lab came down but restarted successfully after rebooting, except for the WAMOS wave sensor which stopped working for the rest of the cruise. The same day we crossed path with our first icebergs of the cruise as we approached 60 S. A storm developed to our north and moved south with us but we luckily manage to steam ahead of it in a tiny pocket of relatively good weather. This storm was forecast to create high winds in the Davis Sea, east of the West Ice shelf, which eventually obliged us to steam towards Prydz Bay where weather was predicted to be good for the next few days so we could do our first hydrographic stations near Antarctica's shelf.

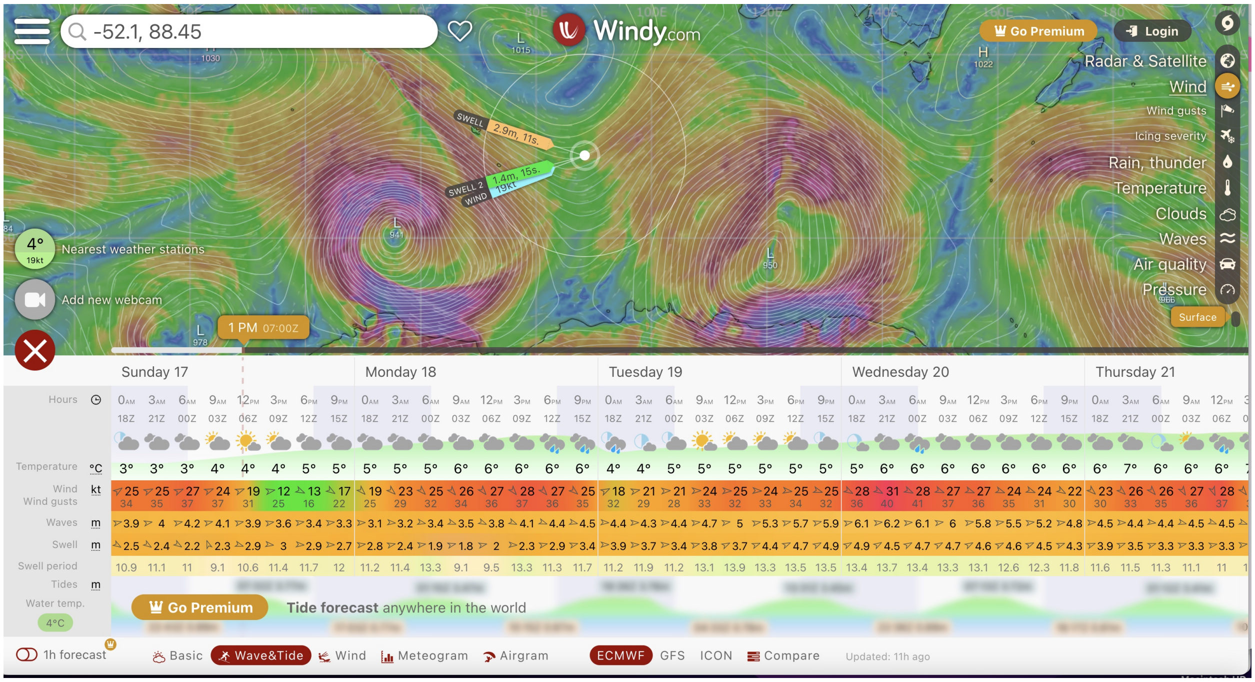
On Mar 4, clocks onboard moved back one hour to UTC+7. We conducted our first CTD station in the morning, in 317 m of water, on the shelf near the eastern side of Prydz Bay. The altimeter on the rosette did not detect the bottom so we did not lower the CTD past 300 m. Instead of conducting our second station on the 500 m isobath we went near the 1100 m isobath where we did a Bio cast that did not need to get close to the bottom and allowed us to safely test the altimeter again. Eventually, after a bit of tinkering with the altimeter we realized the configuration for the analog data stream was set with a 10 m bottom detection instead of 100 m, and the altimeter was made fully functional again for the third station. For station 3 we moved back south, inshore and in shallower water, near the 500 m isobath. Drifting ice approaching the ship in the afternoon obliged us to move 4 nm to the west of the planned location. During the following two days, CTD and lab work occurred at a high tempo as casts were conducted every 500 m of bathymetric change down the continental slope, which means stations were only a few nautical miles from each other. The stations down the slope being relatively shallow (less than 3,000 m), we did not need all 36 Niskins bottles for the first few casts which allowed us to fire multiple bottles at the same depths when one bottle would show signs of leakage at a previous cast.

The tempo of CTD stations decreased as stations crossed the deeper waters of the Princess Elizabeth Trough basin and allowed more time for troubleshooting and fixing issues. While transiting to station 8 a new pylon SBE32 was installed. Minor technical issues continued to be corrected, such as tweaking the tension on some of the Niskin's lanyards, or cleaning and draining the CTD's conductivity cells to prevent the formation of ice crystals after the rosette recovery. During sampling, the space heaters in the staging bay were turned off due to concern that the high temperature from one space heater just above the rosette could alter the quality of the seawater samples. The heaters would be turned back on between stations due to the freezing air temperatures outdoors. After recovering the rosette from station 8, Niskin#23 was missing with only collars and caps left and a new one was installed to replace it. Better communication with the winch operator was put in place to ensure that the surface bottle would not be exposed to air when the rosette came near the surface. We also told the bridge to allow for 200 m tolerance with respect to stations' locations to avoid lengthy maneuvers and improve our time to get on station. Eventually after a few casts, most technical issues were resolved and the personnel acquired routine skills that improved operational efficiency of the hydrographic work. At station 11 our first BGC float was deployed and additional sampling was done for POC and HPLC, and Styrofoam cups were shrunk. At station 15, the captain moved our CTD site about one mile to get away from surrounding icebergs.

Stations 13 to 23 were done on the relatively shallow Kerguelen plateau (~ 2,000 m depths) from Mar 7 to 13. Because of increasing sea states, heave compensation was now being used on the downcasts to mitigate variations between slack and higher tensions. On Mar 8 the weather deteriorated and the Bio cast at station 19 was incorporated into the core cast before CTD operations were stopped. The ship transited slowly south and then west away from the storm's eye but experienced winds above 50 knots and high and confused seas that created large rolls on the ship (the onboard tilt sensors saturated at 35 degrees). After 33.5 hours of interruption, CTD work resumed once the seas came down in the morning of Mar 10 with the deployment at station 20. Before the cast at station 21, the transmissometer windows were cleaned for a deck test and to reinitialize the calibration coefficients. A new station plan was designed with spacing increased to 45 nm to make up for lost time from weather delays accumulated since the beginning of the cruise. Standalone Bio casts were also cancelled and we instead incorporated them into core casts once a day around mid-day, providing the Bio group with Niskin bottles when possible and leftover seawater from the core bottles. When a BGC float was deployed, the Bio cast would sometimes be conducted but to a depth of 200 m, which gained about 30 min compared to a 1,000 m Bio cast. The 1,000 m sample for Bio was incorporated into the core CTD full cast subsequent to the Bio cast. CTD work stopped for another 17 hours after station 22 due to increased winds and an already elevated sea from the previous storm. A third storm then moved on us and stopped work after station 24 on Mar 11. We transited north for 9.5 hours to look for good weather along the line and then proceeded to do stations 25 through 28 on a southward track. On Mar 12 at station 26, the SeaSave program that runs the CTD sensors and communications stopped during our downcast and had to be rebooted; this prevented proper processing of the LADCP data but there was unfortunately no time to redo the cast. On Mar 13, after station 28 was completed, the ship steamed west and then northeast in the back of the large storm we had just avoided. During the transit, folks onboard were treated with clear skies and southern lights. On Mar 14, after 34.75 hours of work interruption from the third storm in a week and as soon as seas came down enough, we resumed CTD work with station 29, which was 45 nm northeast of station 25. Because of the sea state, wire speed was limited to 50 m/min during the ascent which added 40 min to our cast. At recovery a wave picked up the rosette in the air and dropped it suddenly creating a snap load measured at 4,500 lbs. There was no visible damage in the wire but the ship's marine technicians were very concerned. With these last few stations we were able to sample the northern end of the Kerguelen plateau, its continental slope and the associated boundary current.

From Mar 14 to 16, we sampled the deep Australian Antarctic Basin with stations spaced 45 nm apart, and the presence of Antarctic Bottom Water at the bottom of the basin was detected. On Mar 15 the Bio group personnel indicated they would not sample from the underway system for a while because of suspected iron contamination. There was unfortunately no remedy to this but the contamination disappeared a few days later. At station 31, samples were taken for Noble gases analysis at WHOI, but ship's motion from the waves made the weighing of the samples difficult. The

Total Alkanity lab started to have issues with the power supply to their Dosimat machine and after multiple unsuccessful troubleshooting steps they moved their operation to the Bio lab, port side and forward, where DIC was working, which seemed to fix the problem. On Mar 17, as we were moving northeast, going up the southern flank of the South Indian Ridge, weather deteriorated again and prevented us from deploying the CTD at the planned location of station 34. We opted to continue north for another ten miles to make up for lost time and tried to deploy the CTD again but to no avail. At the time our track was squeezing through two storms on our east and west (Fig. 2.1). Unfortunately, a patch of high winds trailing behind the eastern storm slowed us down, preventing us from working for another 17 hours. At this point the captain warned us that according to weather forecasts, following these two storms, the whole ocean basin would fill up with high wind and seas that would become dangerous with no place to shelter and prevent any work for five days. We scrutinized weather forecasts to find good weather pockets that would allow us the best chances of deploying the CTD, with relatively weaker winds below 30 knots and sea states below 4 m so that the dynamic positioning (DP) could be used for the deployments and to avoid shock loads on the CTD wire. We looked at the literature, the previous I08S line occupation, and the underway SST time-series to identify where the important oceanic fronts were so we could target them for sampling. To meet all these goals, we eventually had to skip some stations, which effectively increased spacing between stations 33 and 36 from 45 nm to 100 nm. We utilized the next few hours of relative good weather between the two storms to continue CTDs while progressing north and even managed to deploy a deep Argo float at station 34 using the ship crane. The pulley system from the accordion system broke on Mar 18 during recovery of the rosette and was replaced. Eventually on Mar 19 we were almost out of the storm and station spacing was reduced back to 45 nm, starting with station 37. It turns out the weather forecast correctly predicted that the large weather system stayed in the 50°S for several days and would have prevented any CTD work there until Mar 22.



Sunday 17		0AM	3AM	6AM	9AM	12PM	3PM	6PM	9PM
Hours		18Z	21Z	00Z	03Z	06Z	09Z	12Z	15Z
Temperature	°C	3°	3°	3°	4°	4°	4°	5°	5°
Wind	kt	25	25	27	24	19	12	13	17
Wind gusts		34	35	37	37	31	25	16	22
Waves	m	3.9	4	4.2	4.1	3.9	3.6	3.4	3.3
Swell	m	2.5	2.4	2.2	2.3	2.9	3	2.9	2.7
Swell period		10.9	11.1	11	9.1	10.6	11.4	11.7	12

Monday 18		0AM	3AM	6AM	9AM	12PM	3PM	6PM	9PM
Hours		18Z	21Z	00Z	03Z	06Z	09Z	12Z	15Z
Temperature	°C	5°	5°	5°	6°	6°	6°	6°	6°
Wind	kt	19	23	25	26	27	28	27	25
Wind gusts		25	29	32	34	36	37	36	35
Waves	m	3.1	3.2	3.4	3.5	3.8	4.1	4.4	4.5
Swell	m	2.8	2.4	1.9	1.8	2	2.3	2.9	3.4
Swell period		11.2	11.4	13.3	9.1	9.5	13.3	11.3	11.7

Tuesday 19		0AM	3AM	6AM	9AM	12PM	3PM	6PM	9PM
Hours		18Z	21Z	00Z	03Z	06Z	09Z	12Z	15Z
Temperature	°C	4°	4°	5°	5°	5°	5°	5°	5°
Wind	kt	18	21	21	24	25	24	25	25
Wind gusts		32	29	28	33	32	33	34	32
Waves	m	4.4	4.3	4.4	4.7	5	5.3	5.7	5.9
Swell	m	3.9	3.7	3.4	3.8	3.7	4.4	4.7	4.9
Swell period		11.2	11.9	11.2	13.1	13.9	13.3	13.5	13.5

Wednesday 20		0AM	3AM	6AM	9AM	12PM	3PM	6PM	9PM
Hours		18Z	21Z	00Z	03Z	06Z	09Z	12Z	15Z
Temperature	°C	5°	6°	6°	6°	6°	6°	6°	6°
Wind	kt	28	31	28	27	27	24	24	22
Wind gusts		36	40	41	37	36	35	31	30
Waves	m	6.1	6.2	6.1	6	5.8	5.5	5.2	4.8
Swell	m	4.9	4.5	4.7	4.7	4.6	4.6	4.5	4.3
Swell period		13.4	13.7	13.4	13.3	13.1	12.6	12.3	11.8

Thursday 21		0AM	3AM	6AM	9AM	12PM
Hours		18Z	21Z	00Z	03Z	06Z
Temperature	°C	6°	7°	6°	6°	6°
Wind	kt	23	26	26	27	28
Wind gusts		30	33	35	36	37
Waves	m	4.5	4.4	4.4	4.5	4.5
Swell	m	3.9	3.5	3.3	3.3	3.3
Swell period		11.6	11.5	11.3	11.1	11

Fig. 2.1: Wind forecast for mid-day on Mar 17. The white dot is the target location for station 34 that would allow continuous sampling along the I08S line while staying ahead of a storm coming from the west.

For us, now in the Forties, weather improved on Mar 20 as we were continuing the line northeastward up the South Indian Ridge. Swells from the storm to our south were still causing quite a bit of heave during CTD casts and the marine technicians kept the winch heave compensation turned on, which decreased the descent wire speed in upper 1,000-1,500 m. Even with the more clement weather, deployment and recovery of the CTD continued to be a bit more difficult at night as the winch operator could not see incoming waves. The transmissometer's coefficients were reset again prior to the CTD cast at station 38. At station 39 on Mar 21 and during daylight, as the rosette was coming back near the surface after soaking and prior to downcast, a wave picked it up and dropped it again. The peak tension reached 4,700 lbs during this event. The wire is rated for 10,000 lbs tension but there was concern that repeated snap loads like this and the ones occurring below the surface on downcasts could eventually break the wire deep. To avoid further such occurrences of snap load at deployments (and recoveries) on next casts, the 10 m soak and near surface initialization of the "zero wire" were done deeper.

On Mar 21 we started the final stretch of the I08S line which goes straight north along the longitude 95°E after crossing the summit of the South Indian Ridge. This segment started with station 43 at 44.5°S and the next stations were now 30 nm apart. A high-pressure atmospheric system sheltered us from the chaos of the Indian Ocean to the south and R/V Thompson cruised briskly between stations. Sea surface temperatures increased from less than 10°C the day prior to almost 14°C on Mar 22. With warmer temperatures, slimy biological material started to appear on the rosette after casts and the rosette was rinsed off regularly. With smaller station spacing, some labs started to be backed up with analysis and the ship's speed was reduced slightly during transit on a few occasions. Lanyards were replaced on a few Niskin bottles as they wore down faster than anticipated due to rubbing at the bottom of the bottles. The Seasave software froze again during station 49, as it had ten days prior at station 26. We left the Forties on Mar 23, completing station 52. Sea surface temperatures quickly rose from less than 15°C at 40°S to more than 21°C at 34°S only three days later. With the calm weather, the sea also became quieter, the emptiness of the blue, oligotrophic waters reflecting skies now devoid of any birds. Only a stubborn southern swell kept us company, a persistent reminder of the turbulent ocean we had left behind the week prior. During CTD casts, the ship's heave created by the swell caused variations in the CTD wire tension that caused concern to the ship's crew who continued to use the winch heave compensation in the upper 1,000 m or so during downcasts. By now, everyone onboard had now settled in a remarkably well-oiled routine and the CTD operations continued in a very efficient manner as we were completing four stations per day.

Occasionally, technical hurdles punctuated the cadence of the cruise. The secondary conductivity sensor developed an offset and was swapped with a spare sensor prior to station 54. Grease seeping from the CTD wire made its way to the rosette's frame when the crew handled its recovery and was now routinely cleaned up with a rag before sampling proceeded. CFC-11 levels which had been suspiciously elevated for a few casts returned to normal for unknown reasons. On Mar 25, the weather was so good (10 knots wind) that we sampled the cast from station 59 (latitude 36.25°S) outside of the staging bay for the first time on the cruise. The calm weather at this station also greatly facilitated the weighing of seawater samples for Noble gases.

On Mar 24, weather forecasts predicted a storm would cut our track to the north a couple of days later. We therefore spaced out station 59 and its followers to 45 nm to ensure we could at least complete the line with a station at 34°S, which was the crossover latitude with the I05 line. We managed to complete station 62 at 34°S on Mar 26, but unfortunately the storm moved east faster than the forecast had predicted and the neighboring station 63 was cancelled that same day. The size of the storm precluded any work in the area before the ship had to start its transit back to Fremantle, so we steamed north along our line and away from the center of the storm, looking for lesser winds and seas. After 28 hours transiting through the storm and a couple of failed attempts to deploy the CTD, we finally reached the storm's northern edge at 30.1°S where we proceeded with a CTD cast at station 63. The sea state was still elevated and the rosette hit the ship's hull during deployment but the cast was eventually successful. We were able to complete three more stations to the north and our last CTD, at station 66 (28.3°S, 95°E), was recovered in the early afternoon of Mar 28. We deployed the last Argo core float and R/V Thompson departed towards Fremantle. Clocks moved ahead one hour in the morning of Mar 29 to UTC+8. The ship arrived back in the AMC port on Apr 1 2024 at 15:00 UTC+8. The Bio group continued collecting underway samples at solar sunrise, noon, and sunset on the transit back, including another set of samples collected in Australia's EEZ.

CHAPTER

THREE

CTD AND ROSETTE SETUP

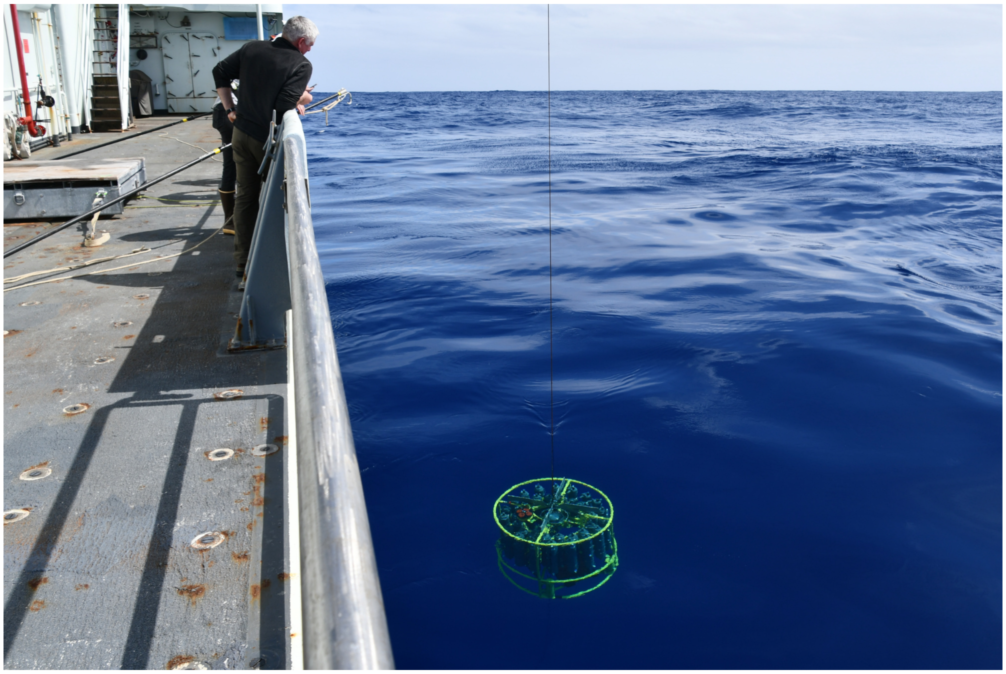


image Laura Cimoli

For I08S a SIO STS 36-place yellow rosette and bottles were used. 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 I08S weighs roughly 1500 lbs in air without water and 2350 lbs in air with water. The package used on I08S weighs roughly 950 lbs in water. In addition to the standard CTDO package on GO-SHIP cruises two LADCP were mounted on the rosette.

3.1 Underwater Sampling Package

Rosette/CTD/LADCP casts were performed with a package consisting of a 36-bottle rosette frame (SIO/STS), a 36-place carousel (SBE32), and 36 10.0L Bullister bottles (SIO/STS) with an absolute volume of 10.4L. Underwater electronic components consisted of a Sea-Bird Electronics SBE9plus CTD with dual pumps (SBE5T), dual temperature (SBE3plus), dual conductivity (SBE4C), dissolved oxygen (SBE43), transmissometer (Wetlabs), fluorometer (Wetlabs FLRTD), altimeter (Valeport VA500) and an optical oxygen sensor (RINKO). An SBE35RT reference temperature sensor was connected to the SBE32 carousel and recorded a temperature for each bottle closure. The sea cable armor was used for ground (return). Power to the SBE9plus CTD (and CTD sensors), SBE32 carousel, and auxiliary sensors was provided through the sea cable from the SBE11plus deck unit in the computer lab.

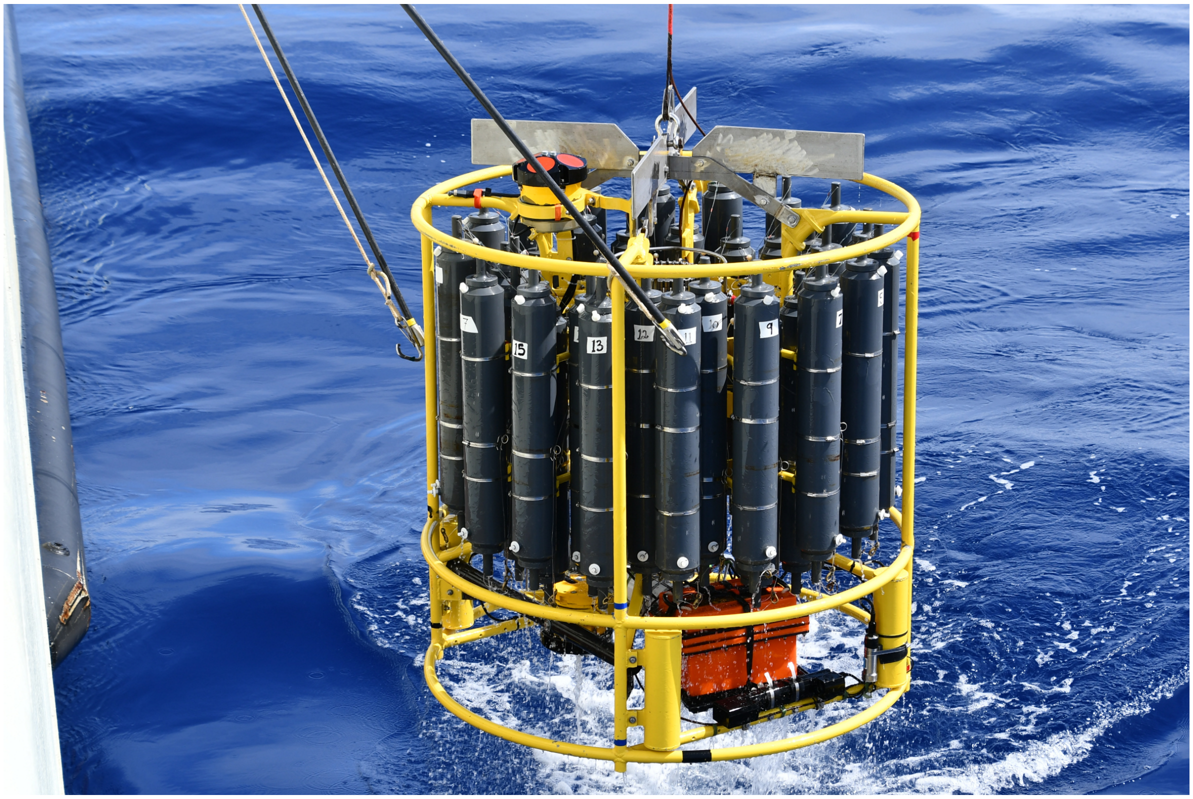
For the first couple of stations, the water sampler (SBE32) required replacement due to a bad solenoid seal on Bottle 12, causing all attempts to fire it to fail. This did not affect any science as this problem was noticed and remedied before station 00801 which never required 36 samples. After the 1st station, settings on the altimeter need to be verified and changed due to a static voltage for the duration of the cast. After cable and sensor swaps, altimeter settings were corrected to a 100m analog limit and the original altimeter (SN88426) was remounted to the CTD.

All sensor data looked good throughout the duration of the cruise except for the secondary conductivity sensors, requiring multiple spare sensor swaps. During the cast, the sensor, SBE4C SN 4545, was notably shifting baselines, presumably due to a cracked cell. This was swapped out with SBE4C SN 3207, which had a larger calibration offset with the primary. This sensor was used until cast 05301, where there was a weird jump in the conductivity offset during the upcast (possibly another cracked cell). Another spare, SBE4C SN 2766, was swapped in before the next cast. The sensor serial numbers, calibration dates, and A/D channel are listed below.

Table 3.1: Rosette Sensors

Sensor & Serial Number	Cal. Date	A/D Channel
9plus SN 0381	9/29/2023	
3plus SN 6049 (primary)	12/29/2023	
3plus SN 5987 (secondary)	12/29/2023	
4C SN 1744 (primary)	12/12/2023	
4C SN 4545 (secondary – removed)	12/12/2023	
4C SN 3207 (secondary – removed)	12/7/2023	
4C SN 2766	12/7/2023	
5T SN 3343		
5T SN 1781		
5T SN 3626		
35RT SN 0011	1/4/2024	
43 SN 4479	10/24/2023	Aux4, V6
Transmissometer SN 2559	10/26/2023	Aux1 (low order), V0
Alt. VA500 SN 88426	10/19/2023	Aux3, V4
RINKO SN 0296	8/24/2022	Aux2, V2 & V3
FLRTD SN 4333	1/7/2022	Aux1 (high order), V1

All electronics were mounted below the carousel. The SBE9plus was mounted into its cage mount and attached to the bottom of the rosette frame across grid bars in the center of the rosette. The SBE4C conductivity, SBE3plus temperature, and SBE43 dissolved oxygen sensors and their respective pumps and tubing were assembled as recommended by SBE on the CTD cage. The SBE35 sensor was mounted to the SBE9 between the primary and secondary SBE3 sensors. The transmissometer was mounted horizontally, and the fluorometer, altimeter, and RINKO were mounted vertically along the bottom of the rosette frame. Both the upward-looking and the downward-looking ADCP's were mounted vertically on one side of the frame between the bottles and the CTD. The ADCP battery pack was located on the opposite side of the center grid bars, mounted on the bottom of the frame. In front of the battery pack, the transmissometer was mounted along a Unistrut on the bottom frame.



images courtesy of Laura Cimoli

The top, inside, and bottom end cap lanyards were all remeasured and replaced during the transit to the first station. Lanyard adjustments were needed with the addition of the lifting ring mounted to the frame above the water sampler. This ring ensures that all the bottles are cocked at the appropriate angle and will close when fired. To keep the sensors at risk of freezing (SBE43) as warm as possible, the heaters in the hangar were kept on and the staging bag doors closed until air temperatures were warm enough. The heaters were only turned off during sampling in the staging bay as it could have affected the temperature data recorded.

The rosette system was suspended from a UNOLS-standard three-conductor 0.322" electro-mechanical (EM) sea cable. The sea cable only underwent the preliminary full mechanical termination and no electrical terminations. Kinks in the EM cable are a result of the shock loading on sheaves at shallow depths during launch and recovery. Shock loading occurred during 2 separate casts but the cable remained free of kinks and in good working condition.

3.2 Deployment & Recovery Procedure

The CTD watchstanders prepared the rosette 15-30 minutes prior to each cast. The bottles were cocked and all spigots, vents, and lanyards were checked for proper orientation. LADCP technician would check for LADCP battery charge, prepare instruments for data acquisition, and disconnect cables. The Marine Technician would check the sea state ~15 minutes before station arrival and decide if conditions were acceptable for bringing out the rosette. The rosette was moved from the sampling bay out to the starboard side of the deck using the Thomspon's (accordion) deployment platform. Once on deck, sea cable slack was pulled up by the winch operator and taglines were manned by the AB's.

The CTD was powered-up and the data acquisition system started from the computer lab when directed by the marine technician from the deck. The rosette was unstrapped from the platform. The winch operator was directed by the deck to raise the package. Hydro boom and rosette were extended outboard, and the package was kept level quickly lowered into the water. At the surface, the technician told the winch operator to "zero" the wire out and lower the rosette to 10 meters, where it was held until the console operators determined that all sensors had turned on and data looked good. The winch operator was then directed to bring the package back to the surface and to begin the descent. Each rosette cast was lowered to within 10 meters of the bottom, using the altimeter, winch wireout, and multibeam depth to determine the distance.

For each upcast, the winch operator was directed to stop the winch at some number (between 10 and 36) of standard sampling depths. These standard depths were staggered at every station based on different schemes derived by the Chief Scientists. To ensure the package shed wake had dissipated, the CTD console operator waited 30 seconds prior to tripping sample bottles. Before moving to the next consecutive trip depth, an additional 15-second pause was observed. The marine technician directed the package to the surface for the last bottle trip. Recovering the package at the end of the deployment was essentially the reverse of launching. Once the rosette was on deck, the console operator terminated the data acquisition, turned off the deck unit, and assisted with rosette sampling. The rosette was secured on the cart and moved into the aft hanger for sampling. The bottles and rosette were examined before samples were taken, and anything unusual was noted on the sample log. Routine CTD maintenance included flushing the conductivity and oxygen sensors with freshwater between casts to maintain sensor stability and rinsing the rest of the sensors (including the carousel) with freshwater as well. The syringes used for flushing were drained while the heaters were still necessary due to one cast where it appeared that residual water had frozen and there was ice stuck in the conductivity sensor.

3.3 Maintenance and Issues

Rosette maintenance was performed regularly. Caps, spigots, and o-rings were inspected for leaks. Occasional reorientation of the bottles was required to ensure proper firing and sampling. Lanyards were replaced as needed. Multiple spigots and vents needed to be replaced after damage from tagline hooks during recovery. Within the first week of deploying the package, some of the top endcap lanyards were not fastened to the spring correctly after replacement causing leaks in various bottles. Once lanyards were resecured, leaks ceased.

At station 00801, the package was recovered without bottle 23 (presumably missing due to implosion). The end caps, hose clamps, and lanyards were all still in the rosette after getting caught onto the frame so a spare bottle was swapped in but the remaining parts of 23 were reused after being inspected. No other damage was seen. After theorizing, the bottle must have tripped at some point during the downcast which then caused the implosion. One of the CTD watchstanders had taken a picture of the rosette before deployment and shows bottle 23 fully cocked open. Another bottle swap was required for niskin 29 after a small leak from the bottom endcap was noticed during sampling. Once inspected, the face of the bottle where the o-ring needs to seal had scratches and a deep groove from a spring at some point during lanyard replacement. After removal, the bottle face has been sanded down with 250-grit sandpaper to refinish the surface. During station 06301, the CTD hit the boat during deployment, specifically on the niskins. After recovery, all bottles looked good except for scratches on Bottle 25. A spare bottle was swapped in just in case.

During recovery for cast 03601, the line for the accordion and cart that the rosette is on snapped from the pelican hook that mounted to the block on the deck. The Thompson Marine Technician and ABs reattached it before 03602. While testing the replacement shackle for the line, the cable from the ADCP battery to the power supply was yanked out the power supply. The power supply contacts that had damage were resoldered and the cable was reconnected before reinstallation. Supply worked as usual after this resolution.

CHAPTER

FOUR

CTDO AND HYDROGRAPHIC ANALYSIS

PIs

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4.1 CTDO and Bottle Data Acquisition

The CTD data acquisition system consisted of an SBE 11plus V2 deck unit and a networked Windows 10 PC workstation. Sea-Bird SeaSave V7 version 7.26.4.0 software was used for data acquisition and to close bottles on the rosette.

CTD deployments were initiated by the console watch operators (CWO) once the ship was positioned on each station. The CWO maintained a detailed console log for each attempted cast to record cast metadata, each bottle fired and any notable issues encountered.

CTD data acquisition was begun with the rosette on deck. Deck crew deployed the rosette and immediately lowered it to 10 meters. The CTD sensor pumps were configured to start 10 seconds after the primary conductivity cell detects salt water. The CWO checked the CTD data for proper sensor operation, waited for sensors to stabilize, and instructed the winch operator to bring the package back to the surface. Deck crew determined the surface depth based on their judgement of weather and sea state. The winch operator was then instructed to lower the rosette 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. During periods of higher sea states, automatic heave compensation was enabled on the winch, resulting in variable payout rates at a maximum of 50 m/min.

The CWO monitored the progress of the deployment and quality of the CTD data through real-time displays. The altimeter, CTD pressure, wire-out and multi-beam depth sounder 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 at 100 m from the bottom, and 20 m/min when 30 m from the bottom. The bottom depth of the cast was usually within 10 meters of the bottom as determined from the altimeter data. For each full upcast, the winch operator was directed to stop the winch at up to 36 predetermined depths. The CWO allowed 30 seconds at each stop before closing the sample bottle. An additional 15 seconds were allowed after bottle closure for the SBE35RT reference temperature sensor to record 13 samples and compute an average. The rosette was then raised to the next target depth. For the last bottle, the winch operator was instructed to return the rosette to the surface, and then used their judgement to bring the rosette as close to the surface as was possible in the wind and sea conditions at the time. After the last surface bottle was closed, the CWO directed the deck crew to recover the rosette.

Once the rosette was out of the water and on deck, the CWO terminated the data acquisition. Each bottle and the rosette were examined before sampling began. A sample log was kept during sampling, recording all analytical samples drawn from each bottle. The CTD sensors were rinsed after every cast using syringes of fresh water connected to Tygon tubing. When freezing temperatures were not expected, the tubing was left on between casts to keep 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. If a Niskin bottle was replaced, the new bottle was tracked in the cruise database.

4.2 CTDO Data Processing

Shipboard CTD data processing was performed after deployment. Sea-Bird SeaSoft V2 Data Processing software was used to generate bottle summary files and bin-averaged converted files in 1 Hz, 1, dbar, 2 dbar bins for immediate use aboard the ship following the cast. An additional converted raw file was generated with parameters specified by the LADCP group for their use.

Raw CTD data were manually fit and quality controlled using SIO/ODF CTD processing software ctdcal v. 0.1.4 running on an Apple MacOS system. CTD data at bottle stops were extracted to create a 2 decibar downcast pressure series. The pressure series data were submitted for CTD data distribution after corrections outlined in the following sections were applied.

A total of 66 CTD stations were occupied including one test station. A total of 75 casts were processed.

CTD data were examined at the completion of each cast 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 oxygen comparisons were made between upcasts and downcasts, as well as between groups of adjacent deployments. Vertical sections of measured and derived properties from sensor data were checked for consistency.

For Bio-GO-SHIP casts where ODF bottle sampling was not performed, fit coefficients were obtained from the subsequent cast, which in most cases occurred on the same station.

Issues that directly impacted CTD analysis are described in this report. Issues that affected bottle closures are detailed in the *CTD and Rosette Setup* section of this report. Temperature, conductivity and oxygen sensor issues are detailed in the subsections below.

4.3 Pressure Analysis

CTD pressure was provided by an SBE 9plus profiling CTD unit. Serial number 09-0381 was used for the duration of the cruise with no performance issues noted.

Laboratory calibrations of CTD pressure sensors were performed prior to the cruise. Dates of laboratory calibration are recorded in Table 3.1. Calibration documents are provided in the APPENDIX.

The lab calibration coefficients provided on the calibration report were used to convert raw sensor frequency to pressure. Initial SIO pressure lab calibration coefficients were entered into SeaSave configurations and applied to cast data during acquisition. Additionally, a cast-by-cast offset was applied to the converted pressures during subsequent processing with ctdcal. These offsets were determined from on-deck pressure data recorded at the start and end of each cast. Maximum, minimum and average offsets are presented in Table 4.1.

Table 4.1: CTD SN:09-0381 Pressure Offsets

	Start P (dbar)	End P (dbar)
Min	-1.18	-1.47
Max	-0.27	-0.47
Average	-0.56	-0.82

4.4 Temperature Analysis

CTD temperature was provided by primary and secondary SBE 3plus temperature sensor units. Serial number 03-6049 was used on the primary CTD channel, and serial number 03-5987 was used on the secondary channel. Both were used for the duration of the cruise with no performance issues noted. Reference temperatures were provided by an SBE35RT Digital Reversing Thermometer. Serial number 35-0011 was used for the duration of the cruise with no performance issues noted.

Laboratory calibrations of temperature sensors were performed prior to the cruise at the SIO Calibration Facility. Dates of laboratory calibration are recorded in Table 3.1. Calibration documents are provided in the APPENDIX.

The pre-cruise laboratory calibration coefficients were used to convert SBE3plus frequency 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 13 samples, which is approximately a 15 second period.

The SBE3plus sensor typically exhibits a consistent well-modeled response, which is second-order with respect to pressure and second-order with respect to temperature:

$$T_{cor} = T + cp_2 P^2 + cp_1 P + ct_2 T^2 + ct_1 T + c_0$$

Fit coefficients are shown in the following tables.

Table 4.2: Primary temperature (T1) coefficients.

Station	cp_2	cp_1	ct_2	ct_1	c_0
All	0.0	8.1466e-8	0.0	0.0	2.7174e-4

Table 4.3: Secondary temperature (T2) coefficients.

Station	cp_2	cp_1	ct_2	ct_1	c_0
All	0.0	-4.0805e-7	0.0	0.0	5.6541e-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 ±0.00465 °C for SBE35RT-T1, ±0.00472 °C for SBE35RT-T2 and ±0.00139 °C for T1-T2. The 95% confidence limits for the deep temperature residuals (where pressure $\geq$ 2000 dbar) are ±0.00130 °C for SBE35RT-T1, ±0.00147 °C for SBE35RT-T2 and ±0.00136 °C for T1-T2.

Issues affecting SBE35RT reference temperature data were:

- On several occasions, internal recorder memory was exceeded, resulting in incomplete or no samples recorded for some casts. Casts with incomplete reference samples were 02601 and 04301. Casts with no reference samples were 02701 and 04401.

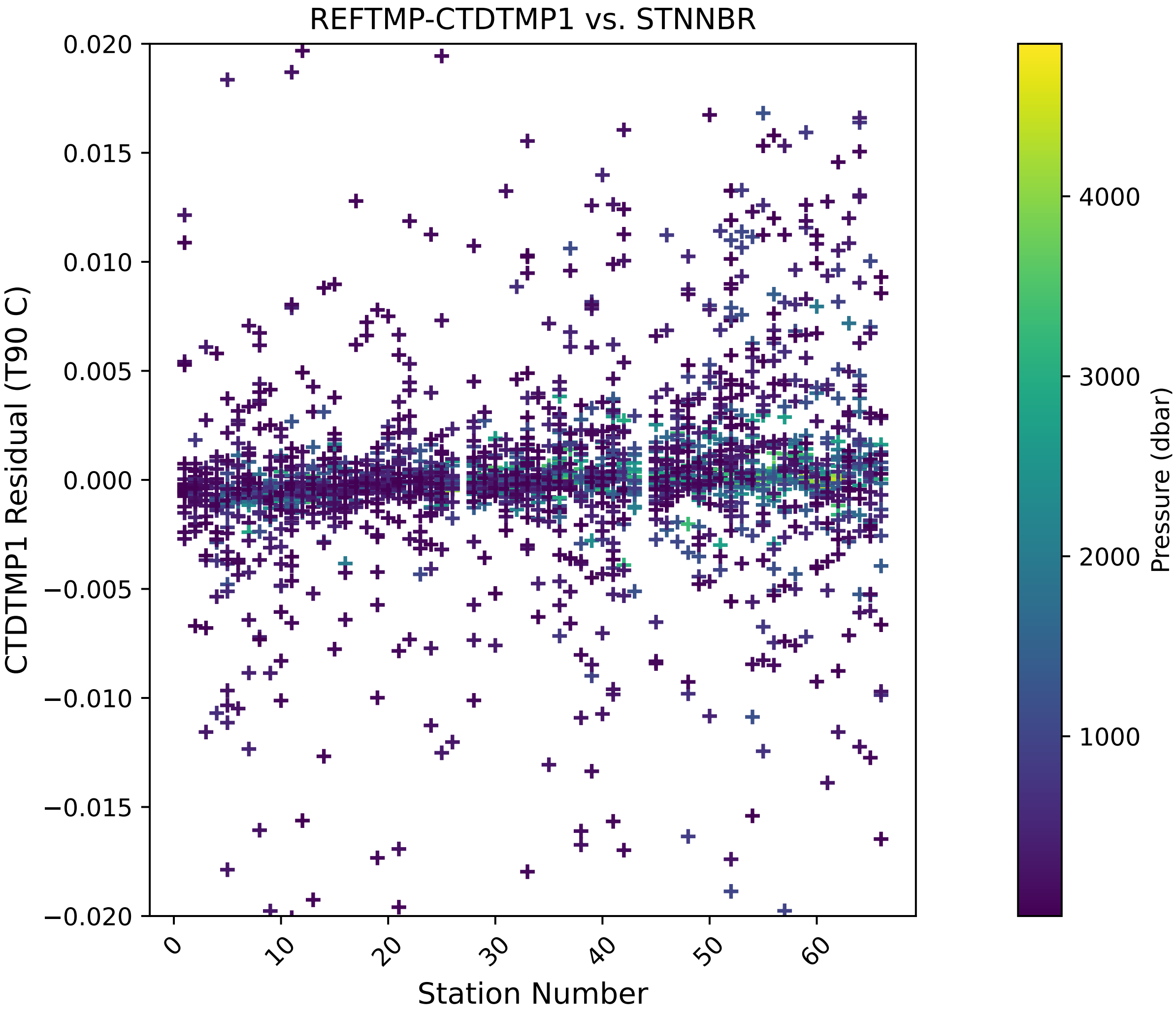


Fig. 4.1: SBE35RT-T1 versus station.

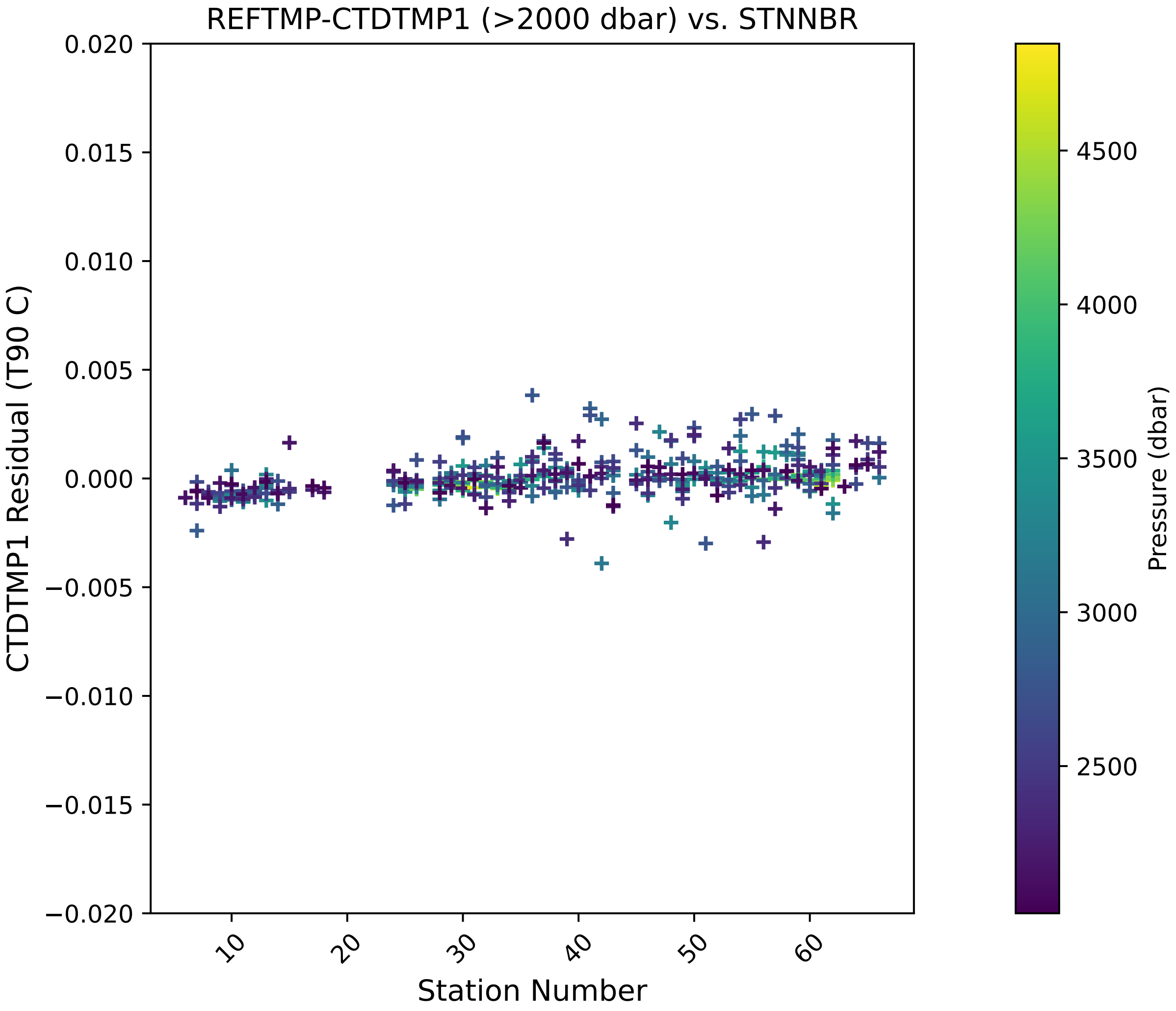


Fig. 4.2: Deep SBE35RT-T1 by station (Pressure ≥ 2000dbar).

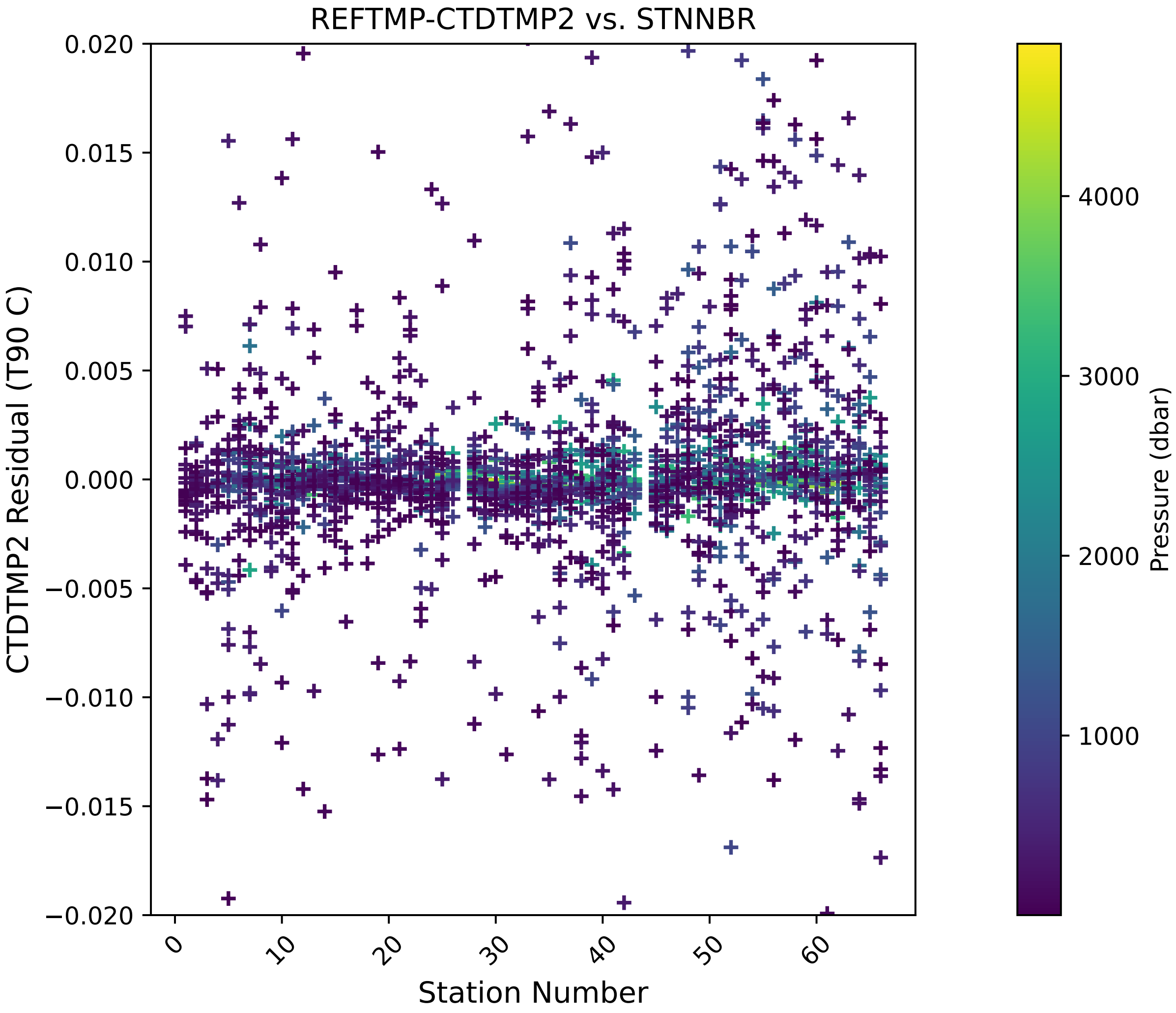


Fig. 4.3: SBE35RT-T2 versus station.

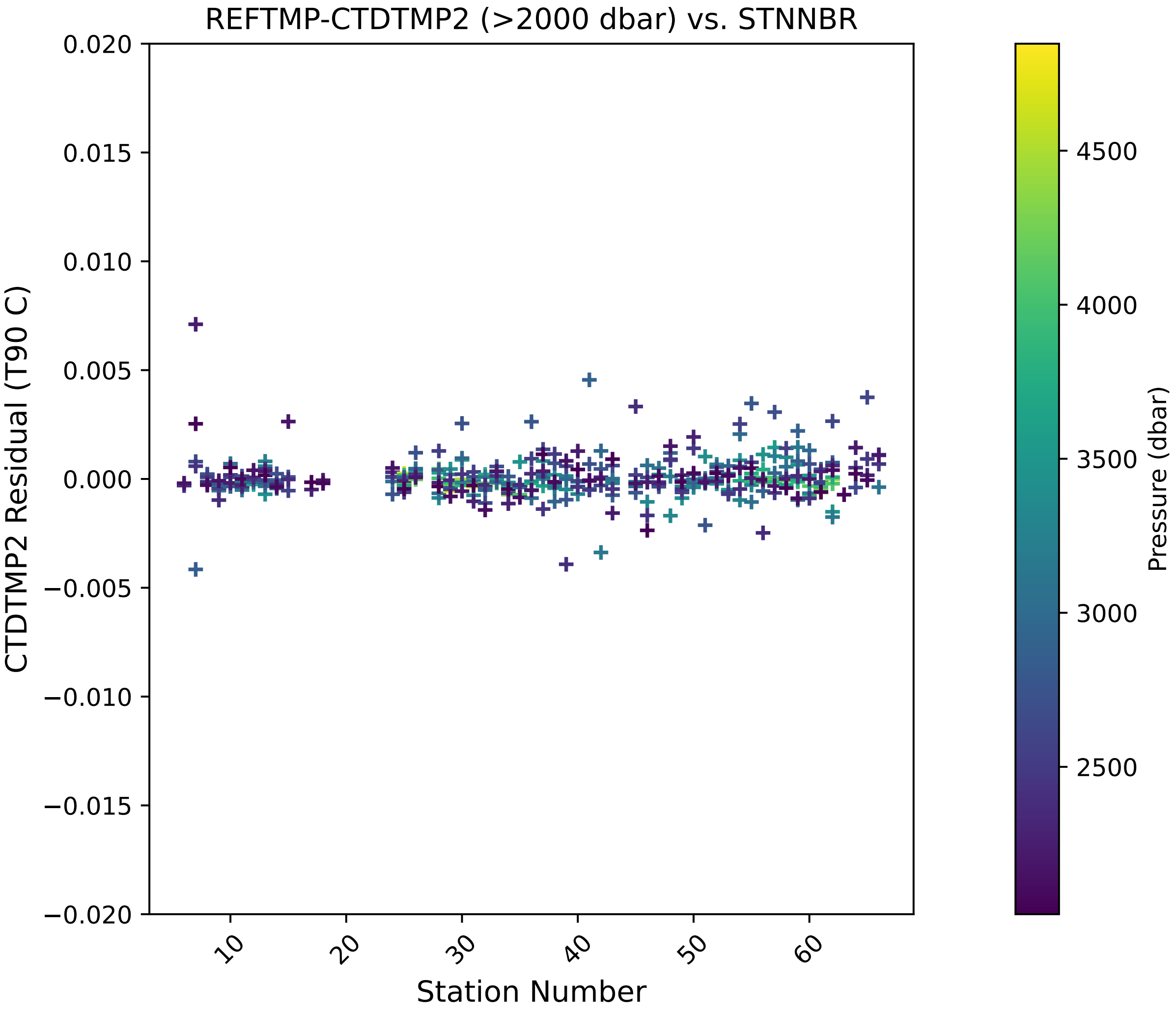


Fig. 4.4: Deep SBE35RT-T2 by station (Pressure $\geq$ 2000dbar).

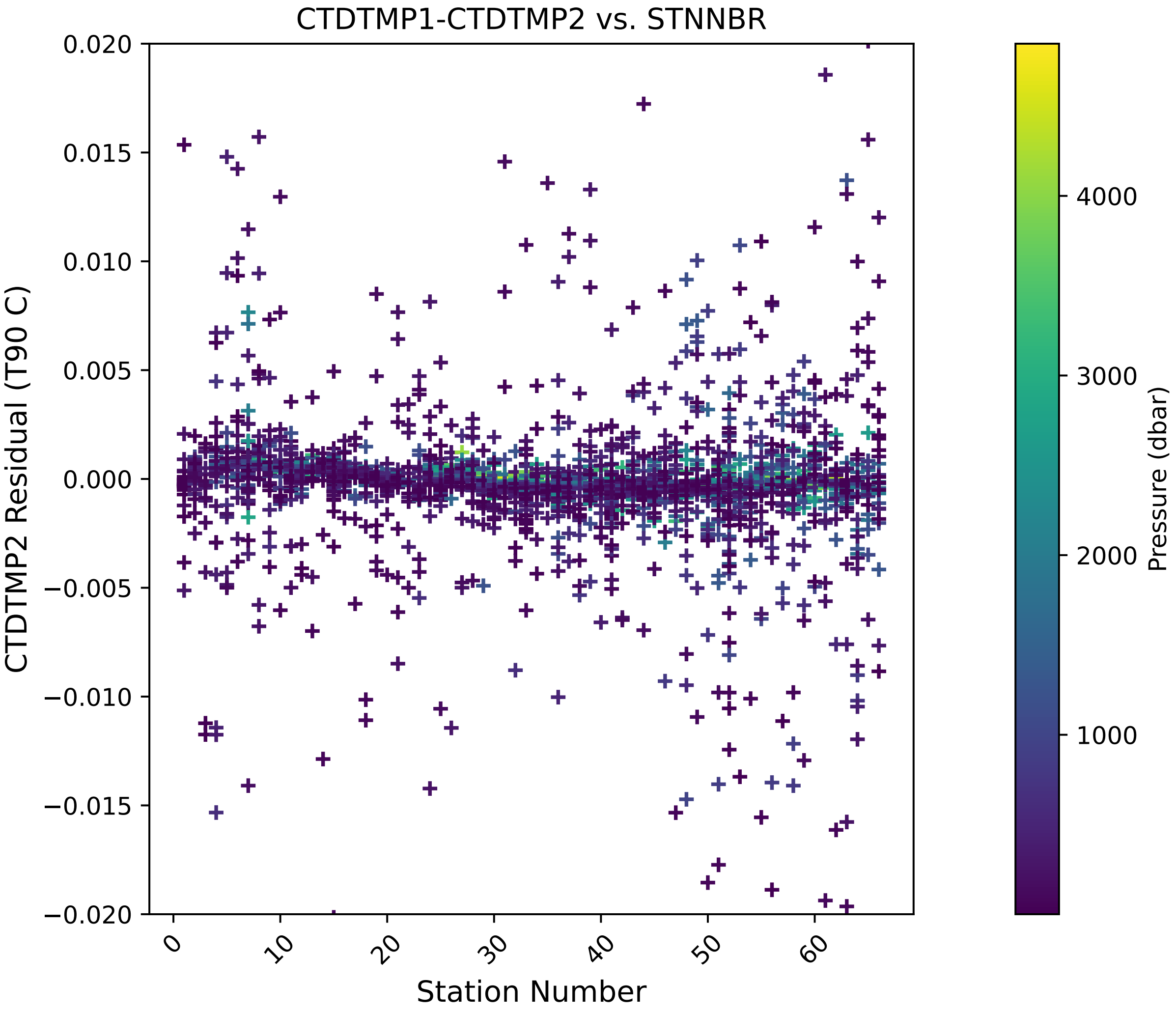


Fig. 4.5: T1-T2 versus station.

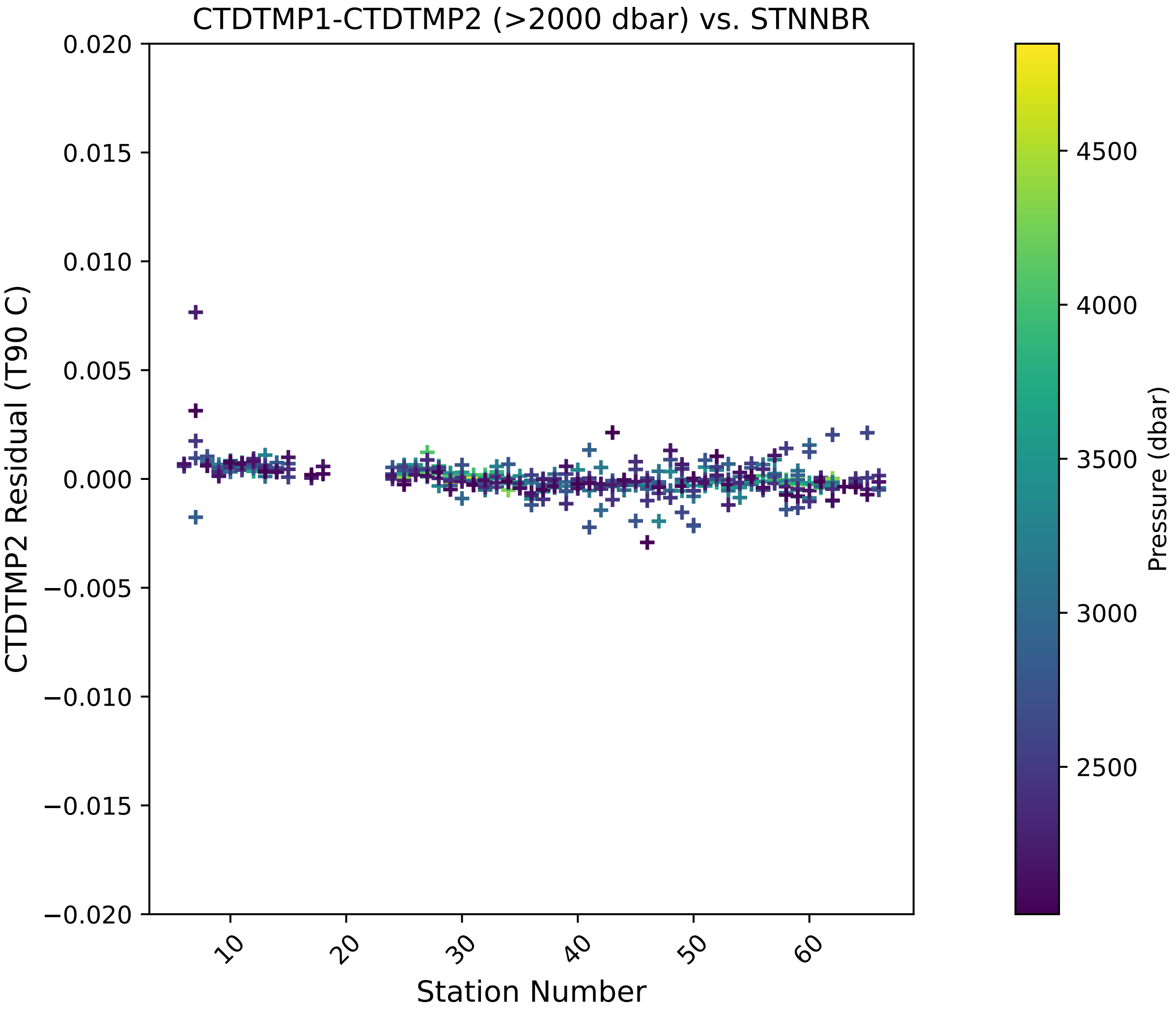


Fig. 4.6: Deep T1-T2 versus station (Pressure ≥ 2000dbar).

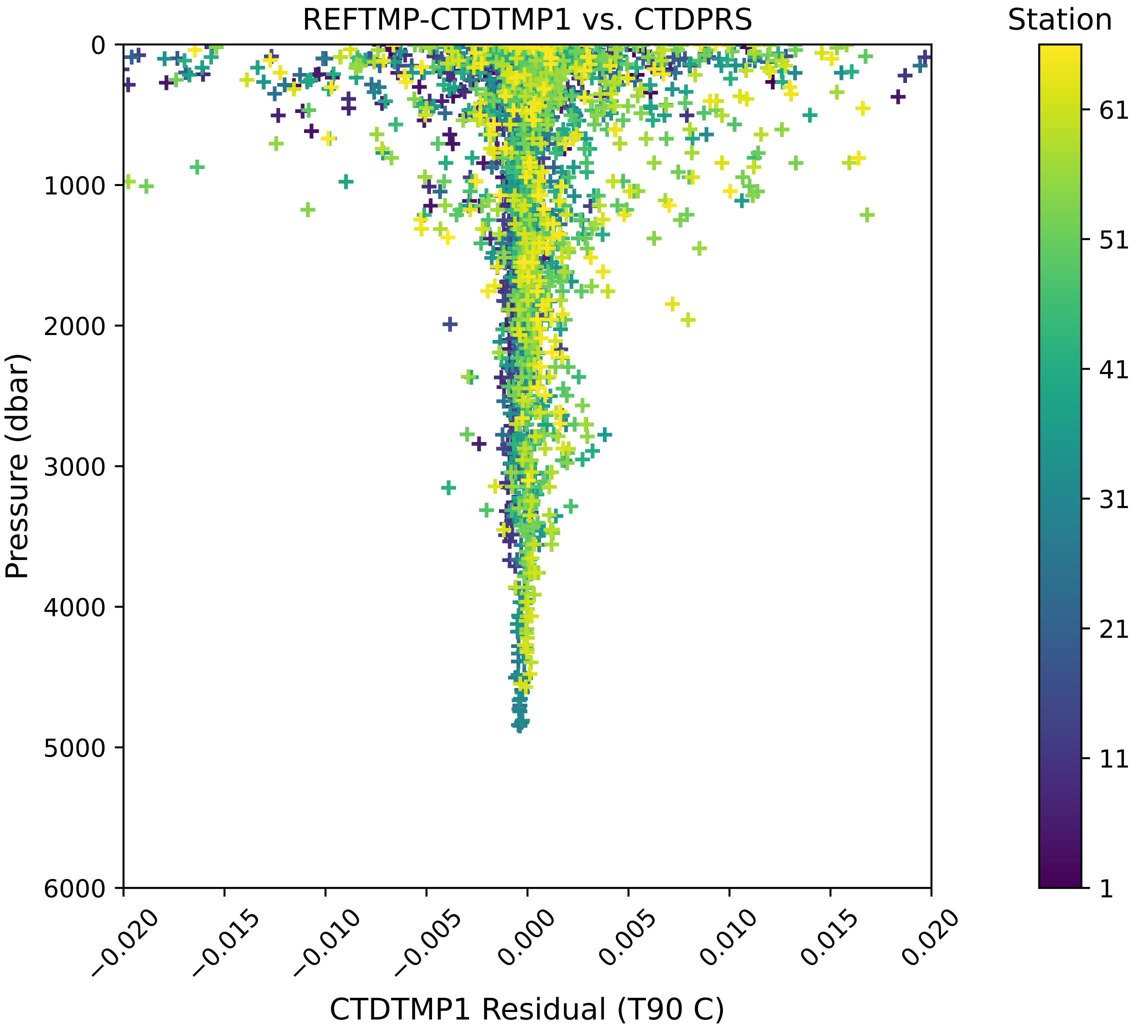


Fig. 4.7: SBE35RT-T1 versus pressure.

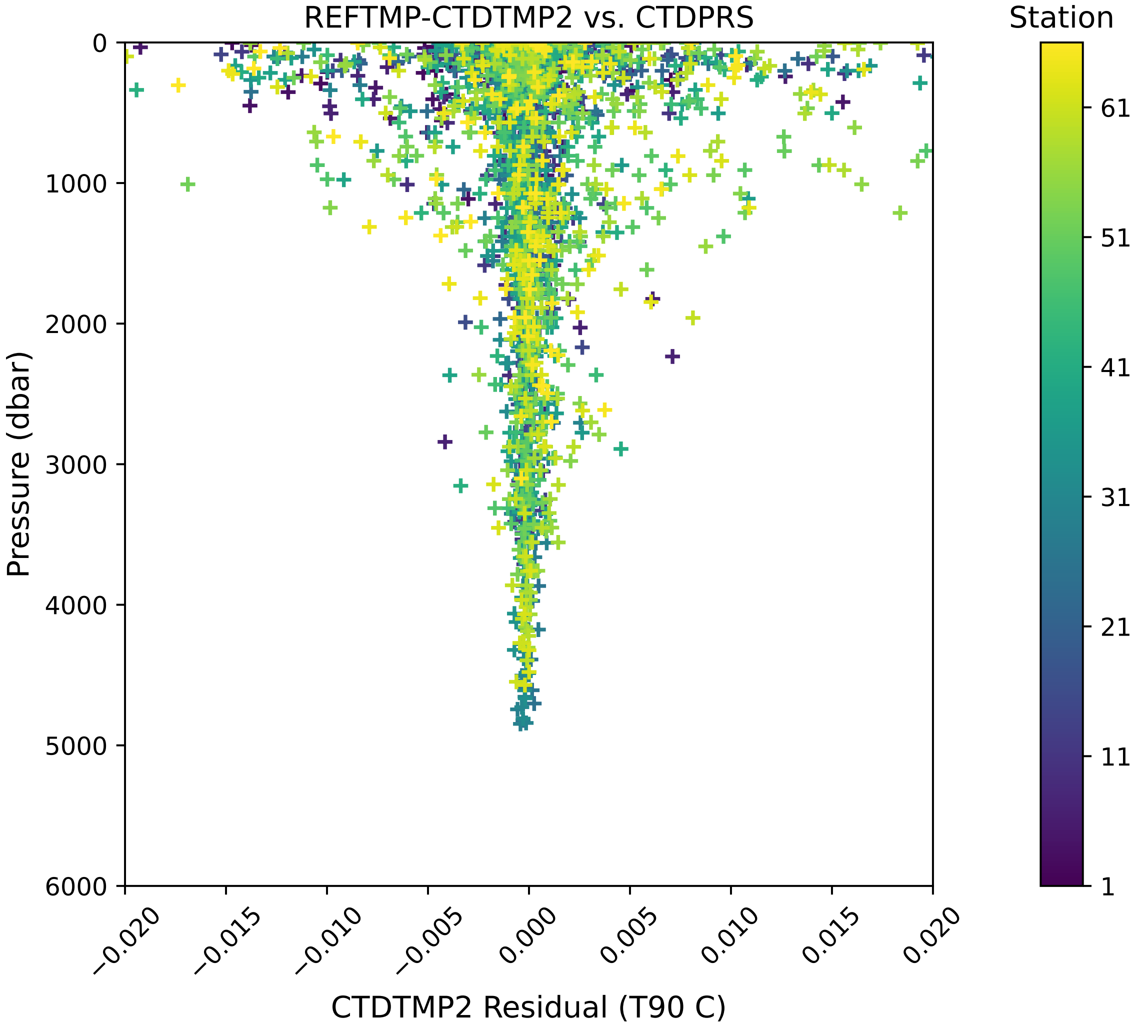


Fig. 4.8: SBE35RT-T2 versus pressure.

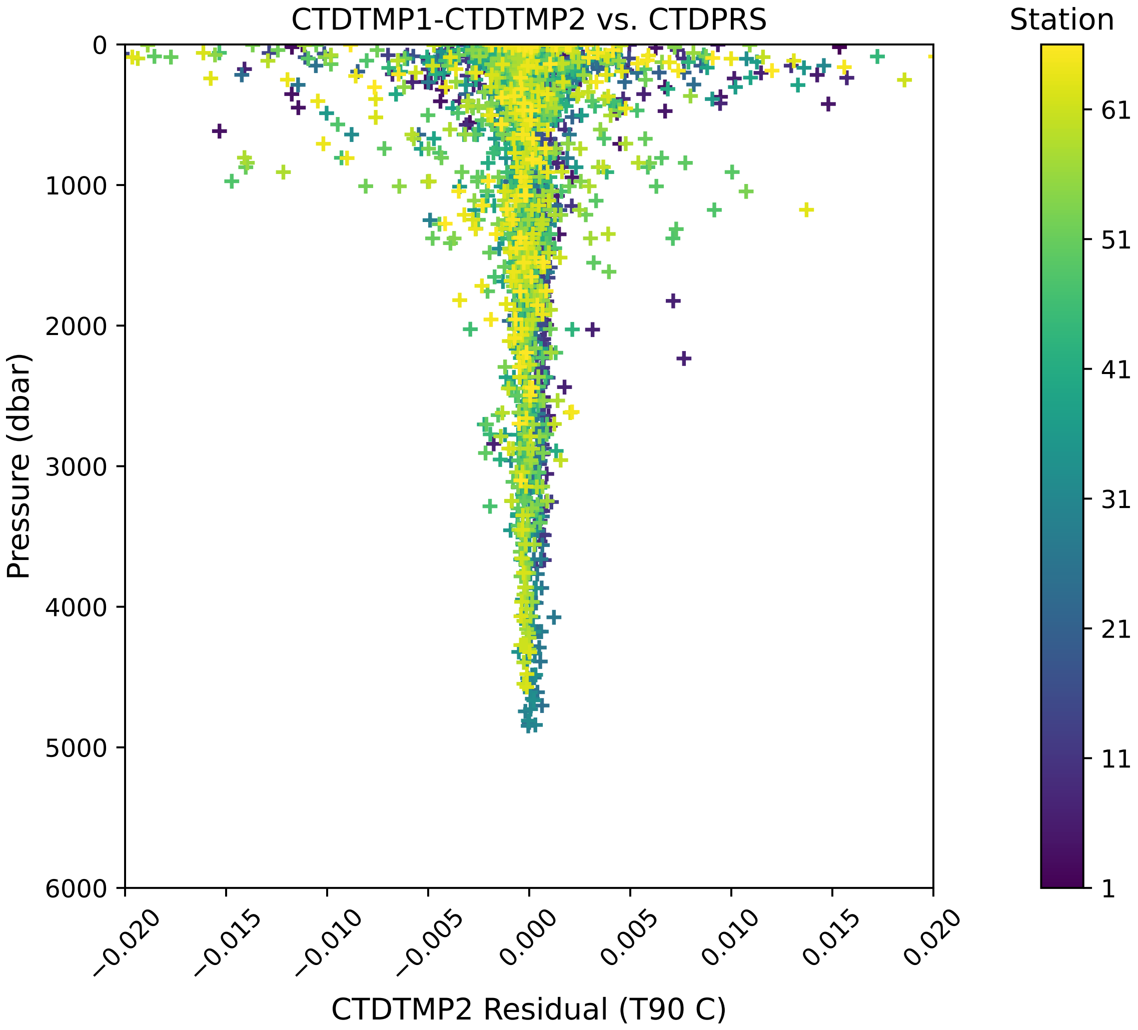


Fig. 4.9: T1-T2 versus pressure.

4.5 Conductivity Analysis

CTD conductivity was provided by primary and secondary SBE 4C conductivity sensor units. Serial number 04-1744 was used on the primary CTD channel, and serial numbers 04-4545, 04-2766 and 04-3207 were used on the secondary channel. Issues with the secondary conductivity sensors are detailed later in this section.

Laboratory calibrations of conductivity sensors were performed prior to the cruise at the Sea-Bird calibration facility. Dates of laboratory calibration are recorded in Table 3.1. Calibration documents are provided in the APPENDIX.

The pre-cruise laboratory calibration coefficients were used to convert SBE 4C frequency to mS/cm. 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 bottle sample salinity 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.

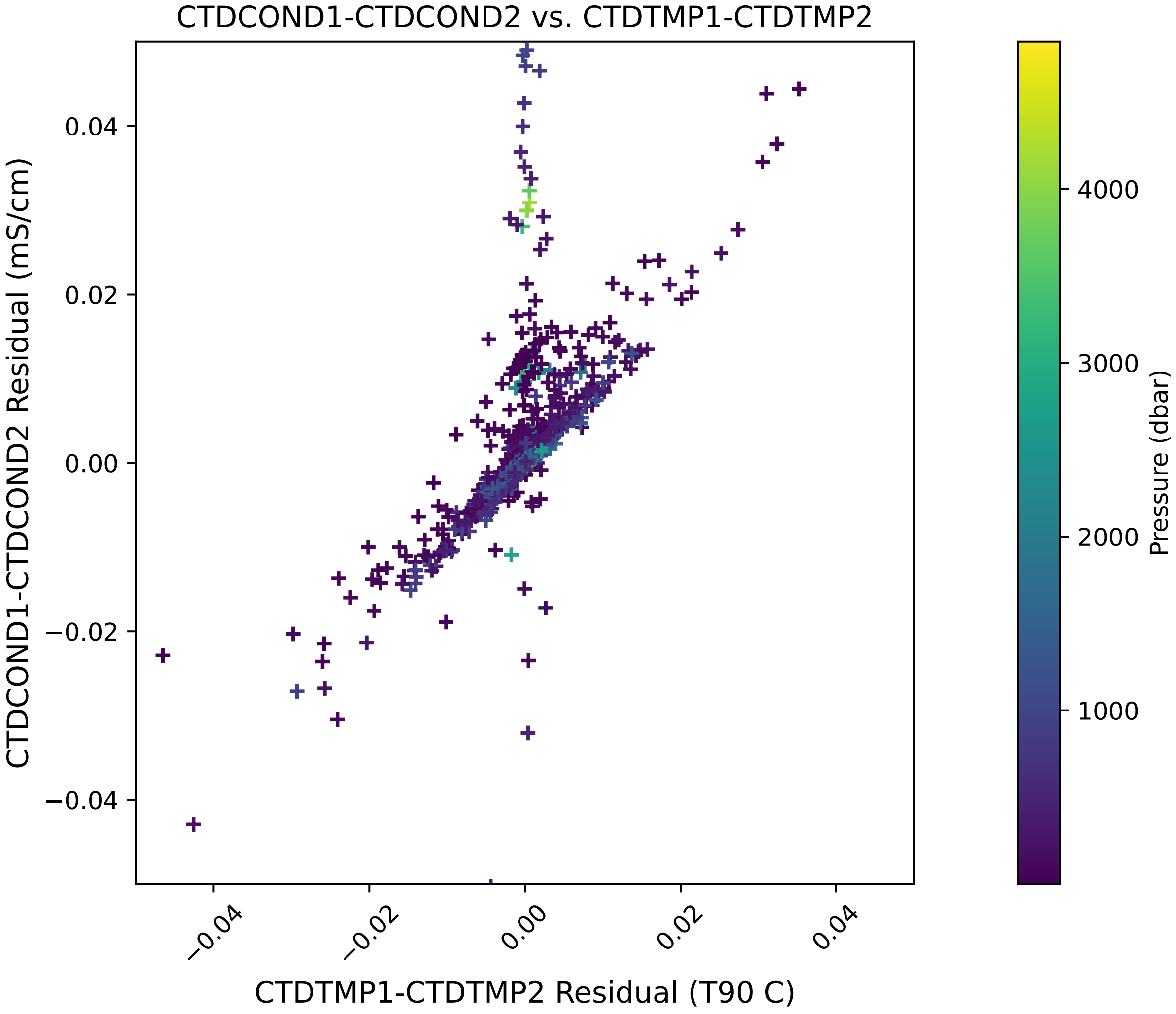


Fig. 4.10: Coherence of conductivity differences as a function of temperature differences.

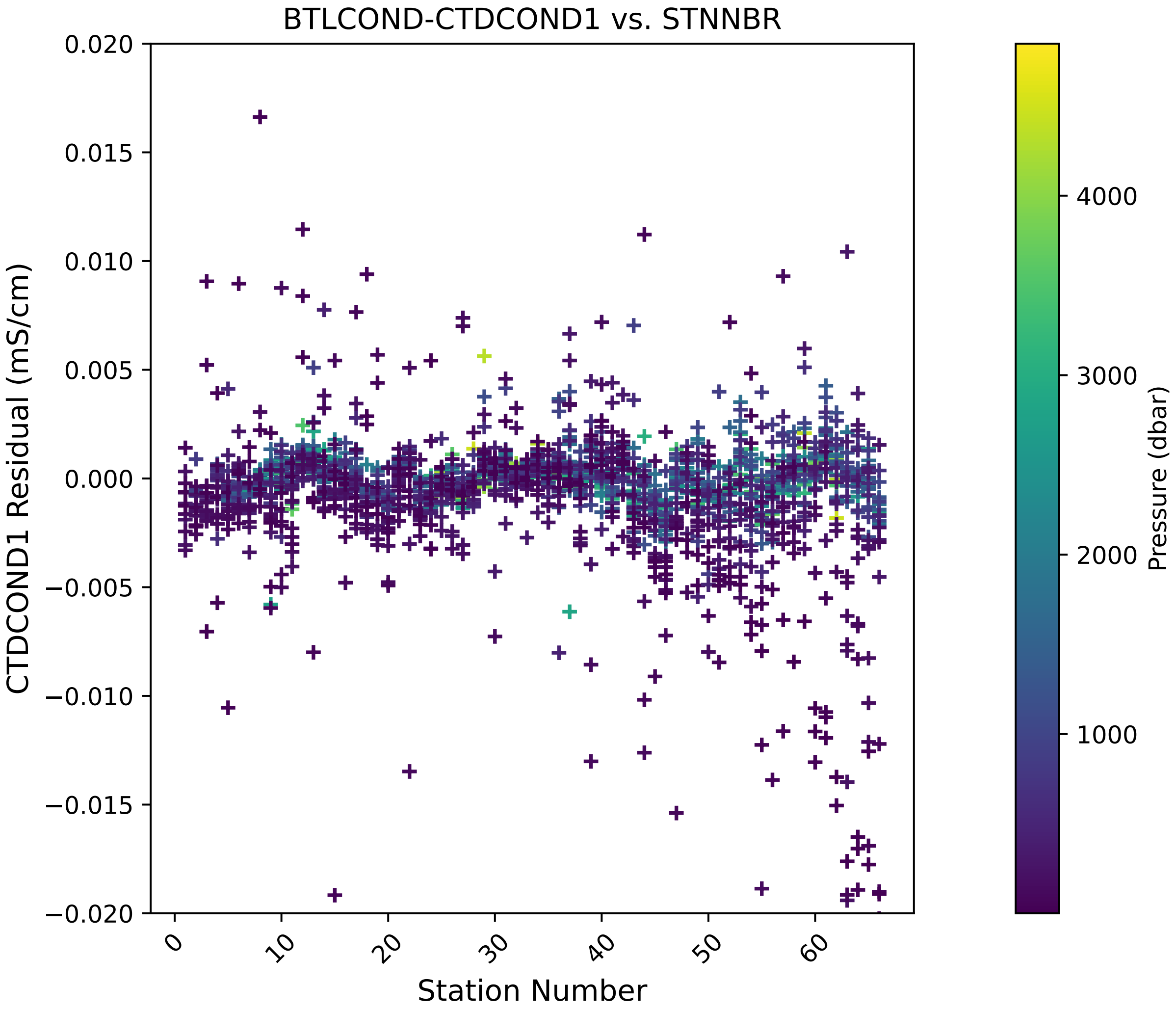


Fig. 4.11: Corrected C_{Bottle} - C1 versus station.

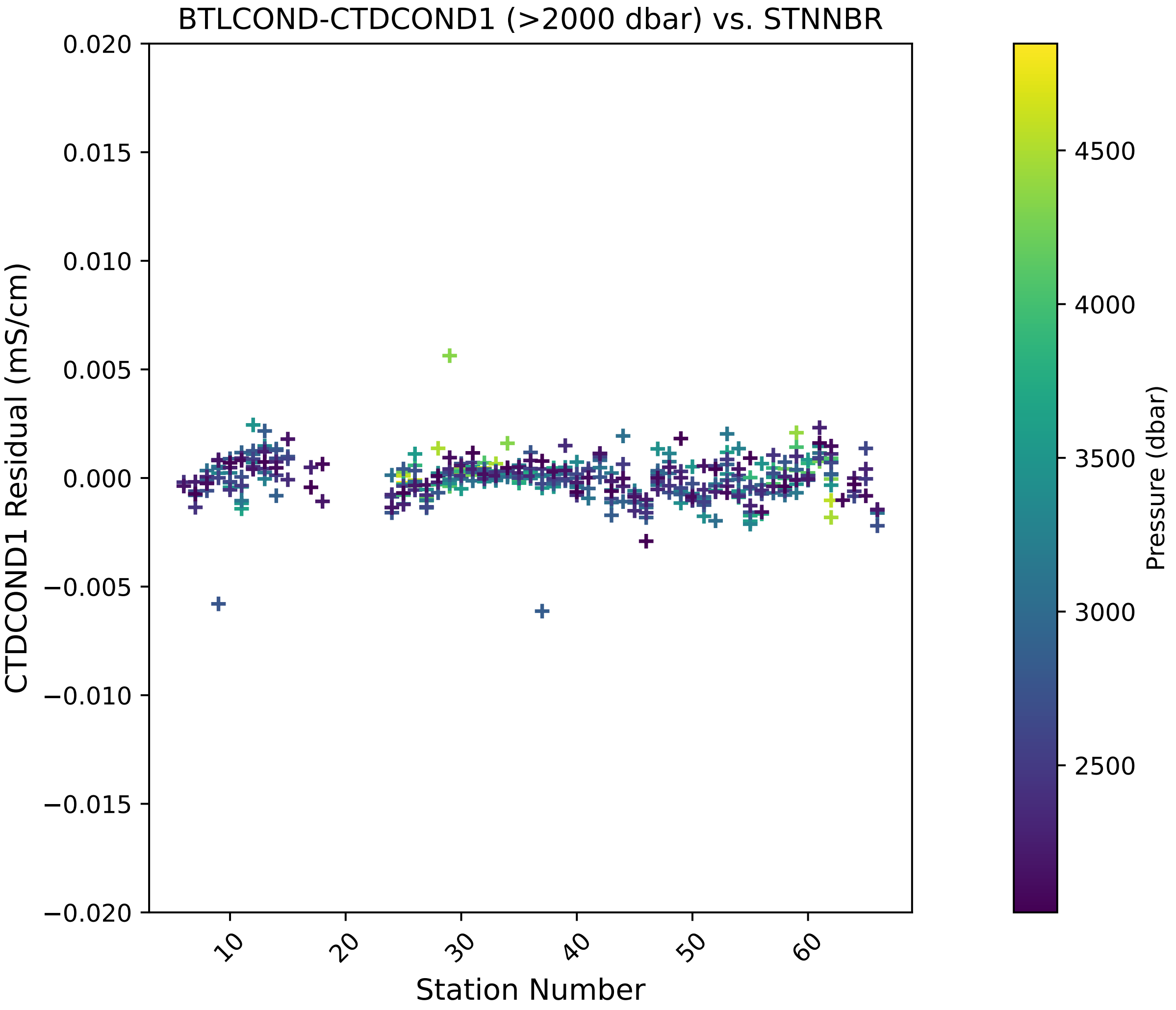


Fig. 4.12: Deep Corrected C_{Bottle} - C1 versus station (Pressure >= 2000dbar).

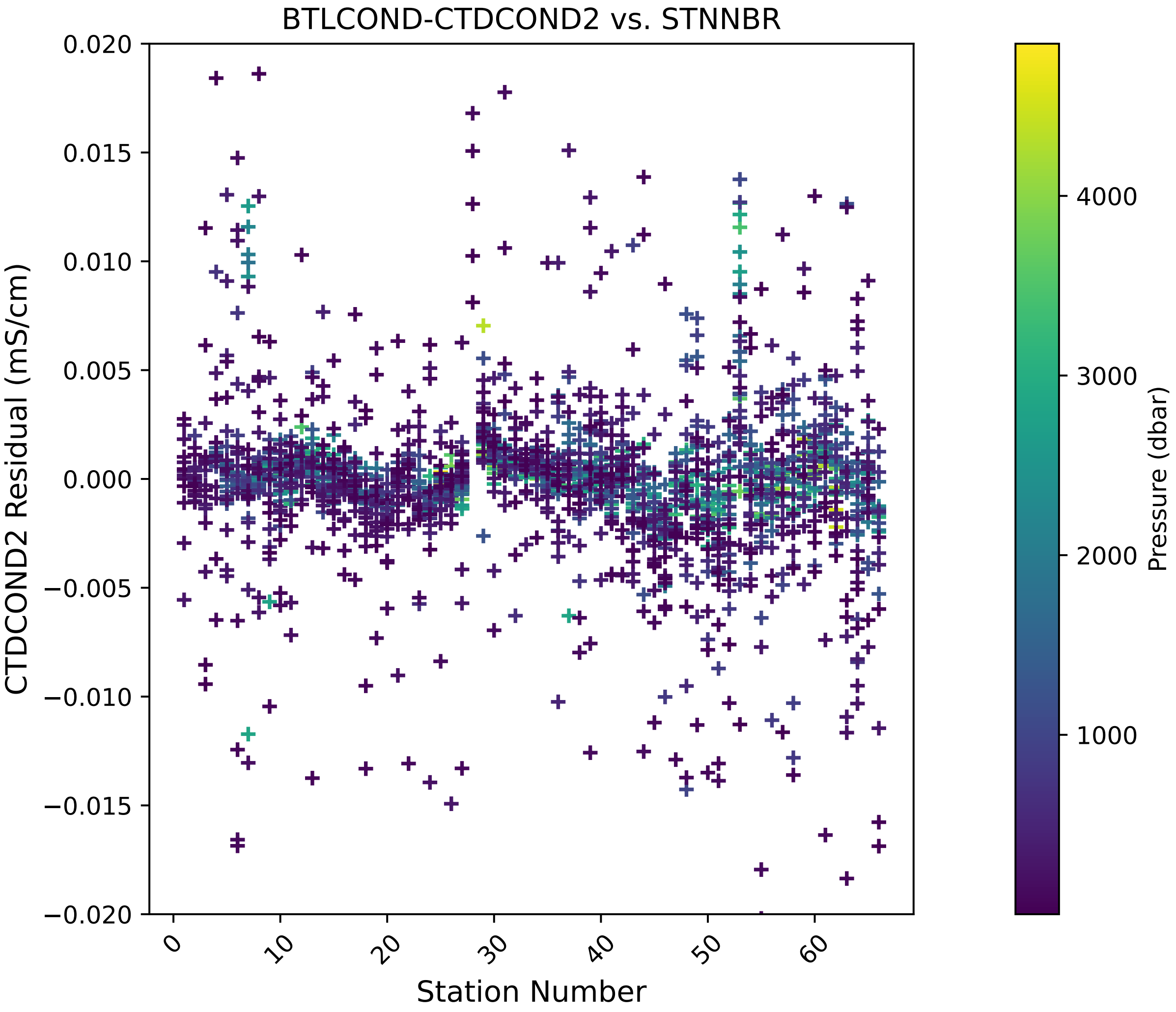


Fig. 4.13: Corrected C_{Bottle} - C2 versus station.

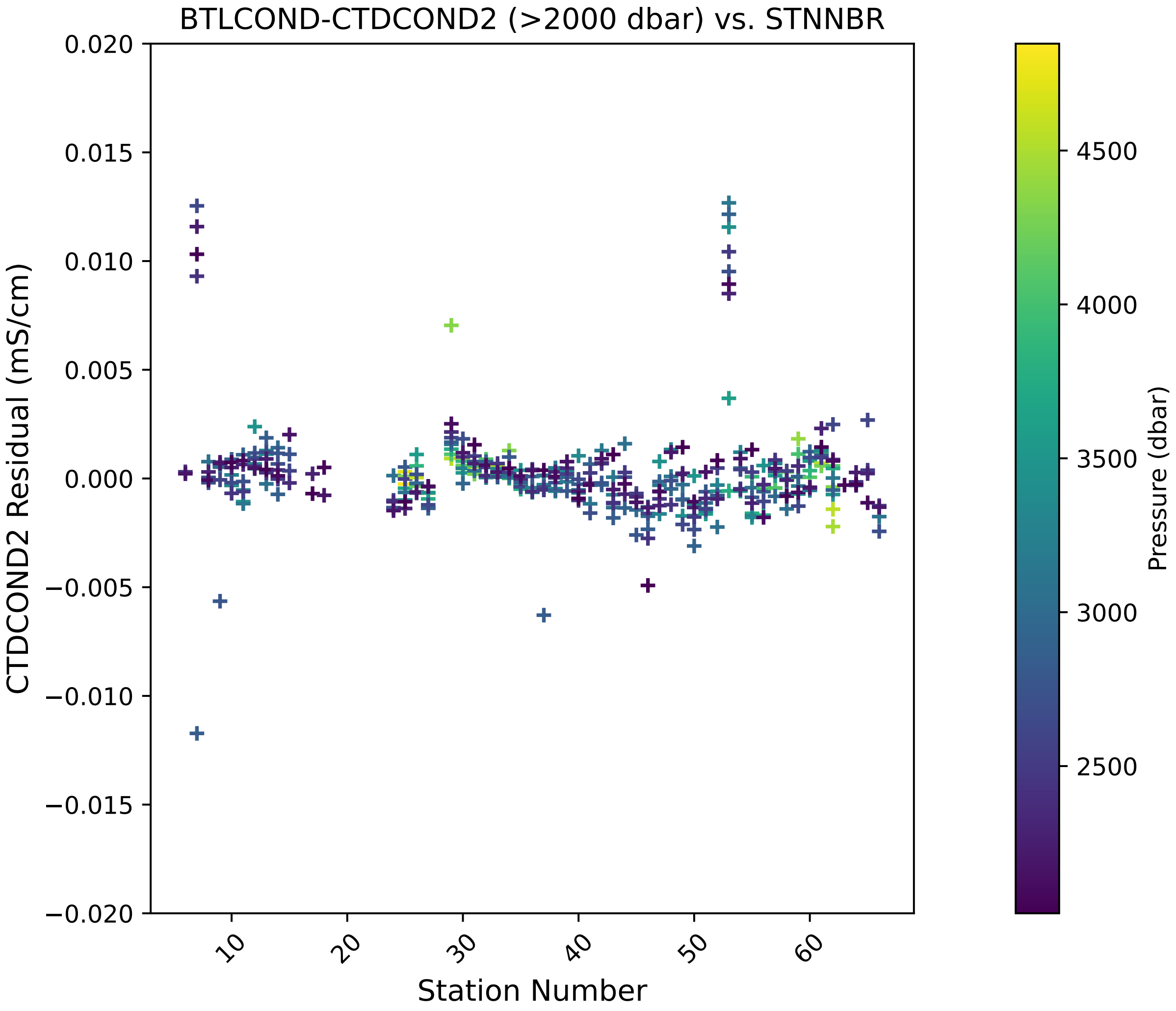


Fig. 4.14: Deep Corrected C_{Bottle} - C2 versus station (Pressure >= 2000dbar).

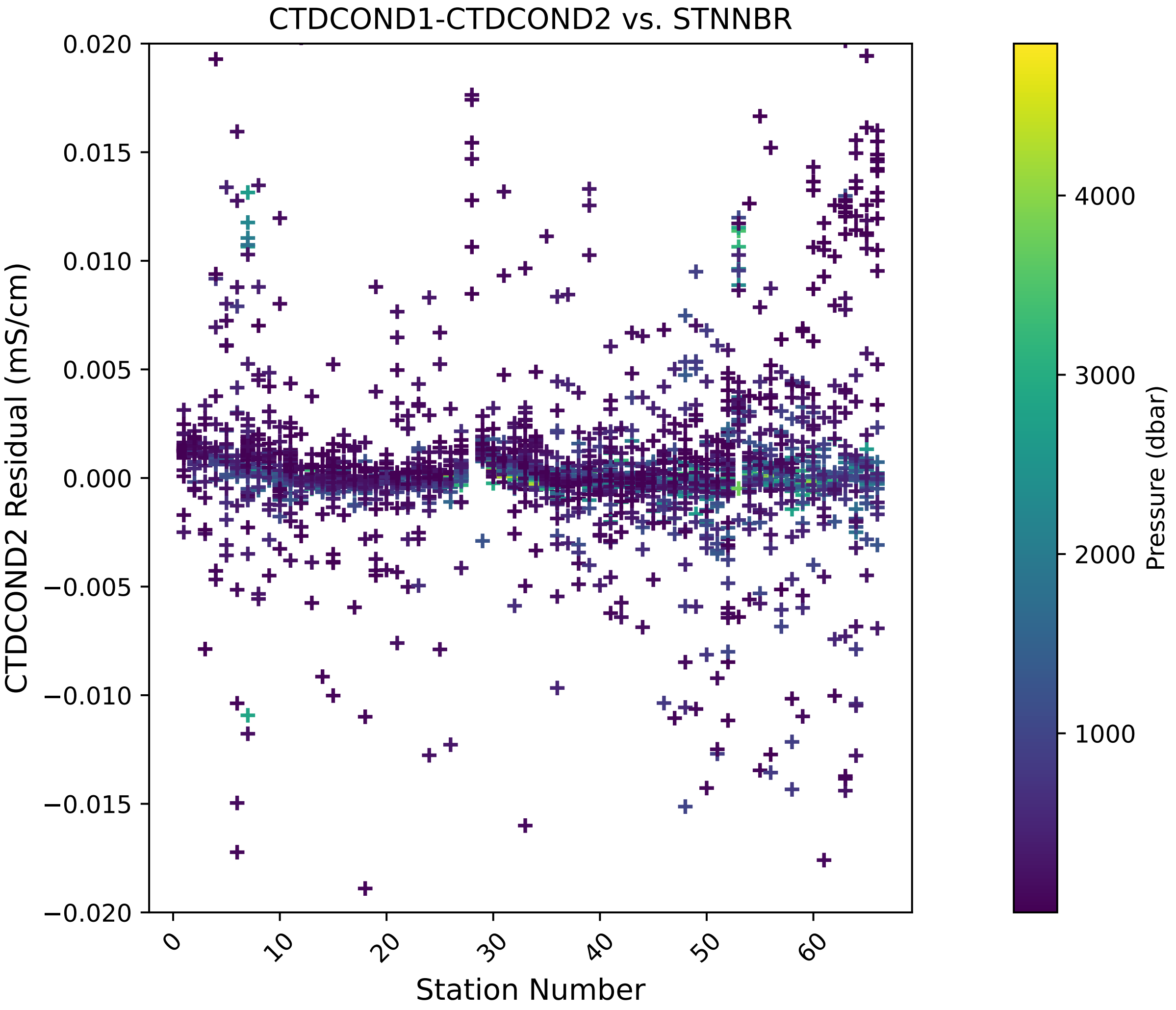


Fig. 4.15: Corrected C1-C2 versus station.

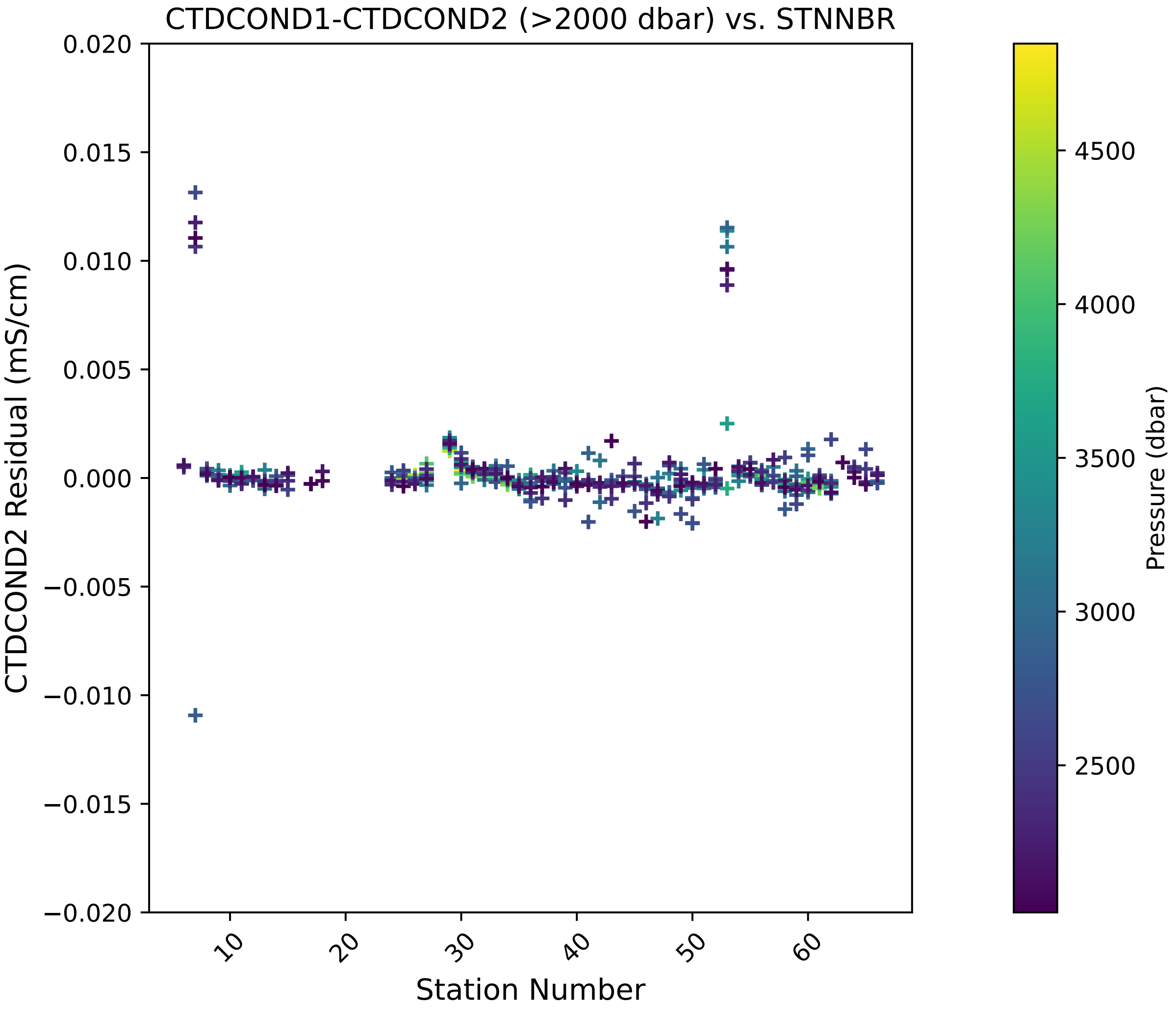


Fig. 4.16: Deep Corrected C1-C2 versus station (Pressure >= 2000dbar).

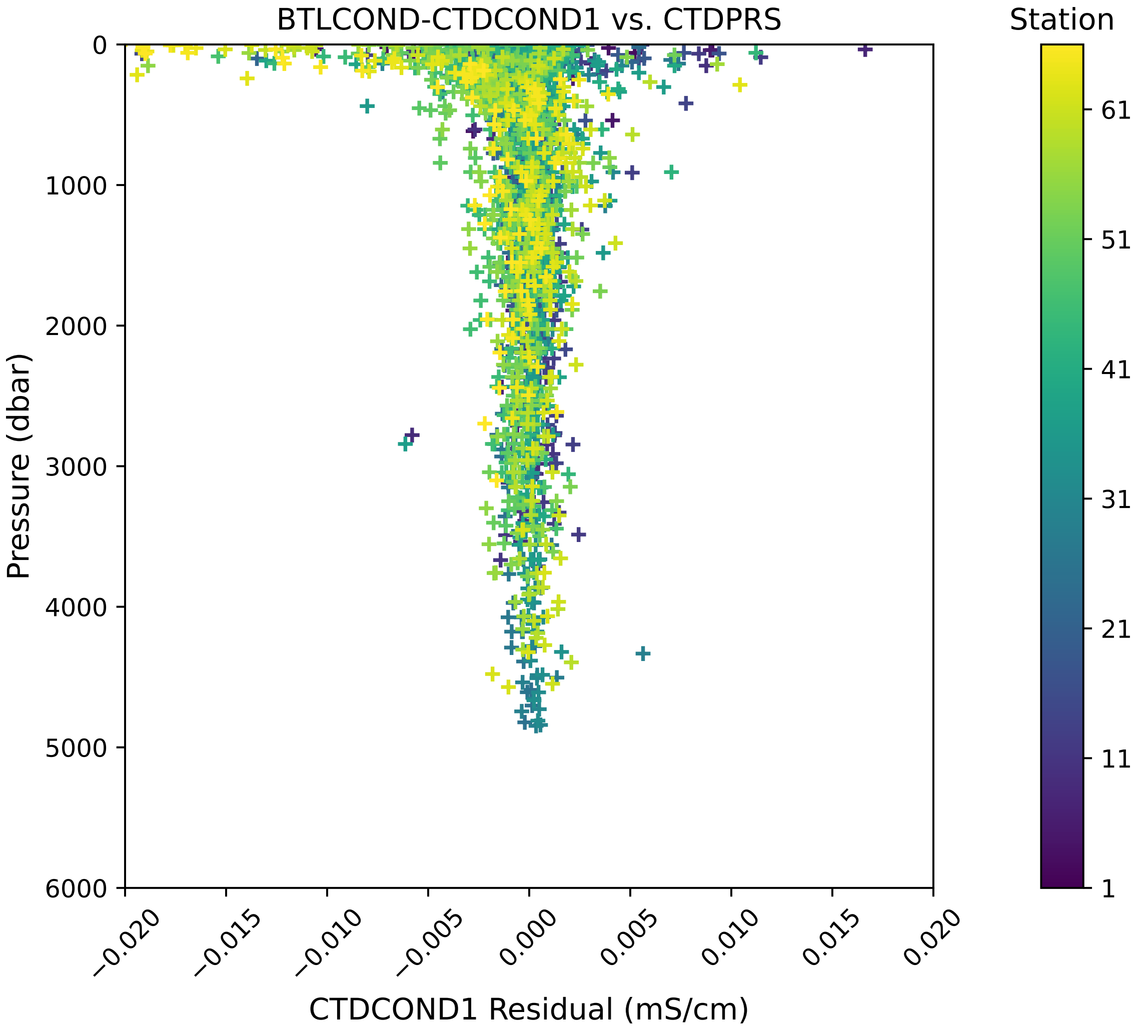


Fig. 4.17: Corrected C_{Bottle} - C1 versus pressure.

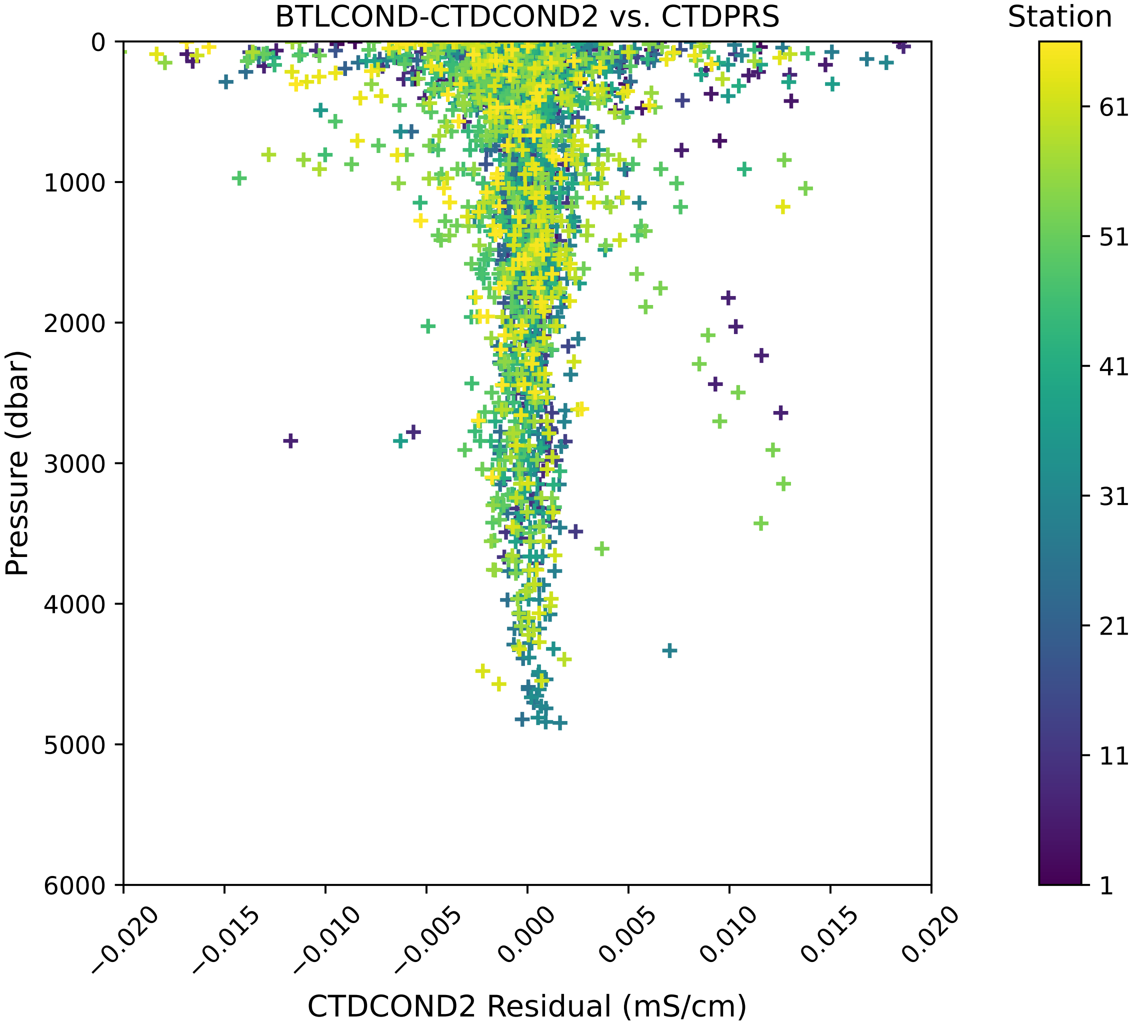


Fig. 4.18: Corrected C_{Bottle} - C2 versus pressure.

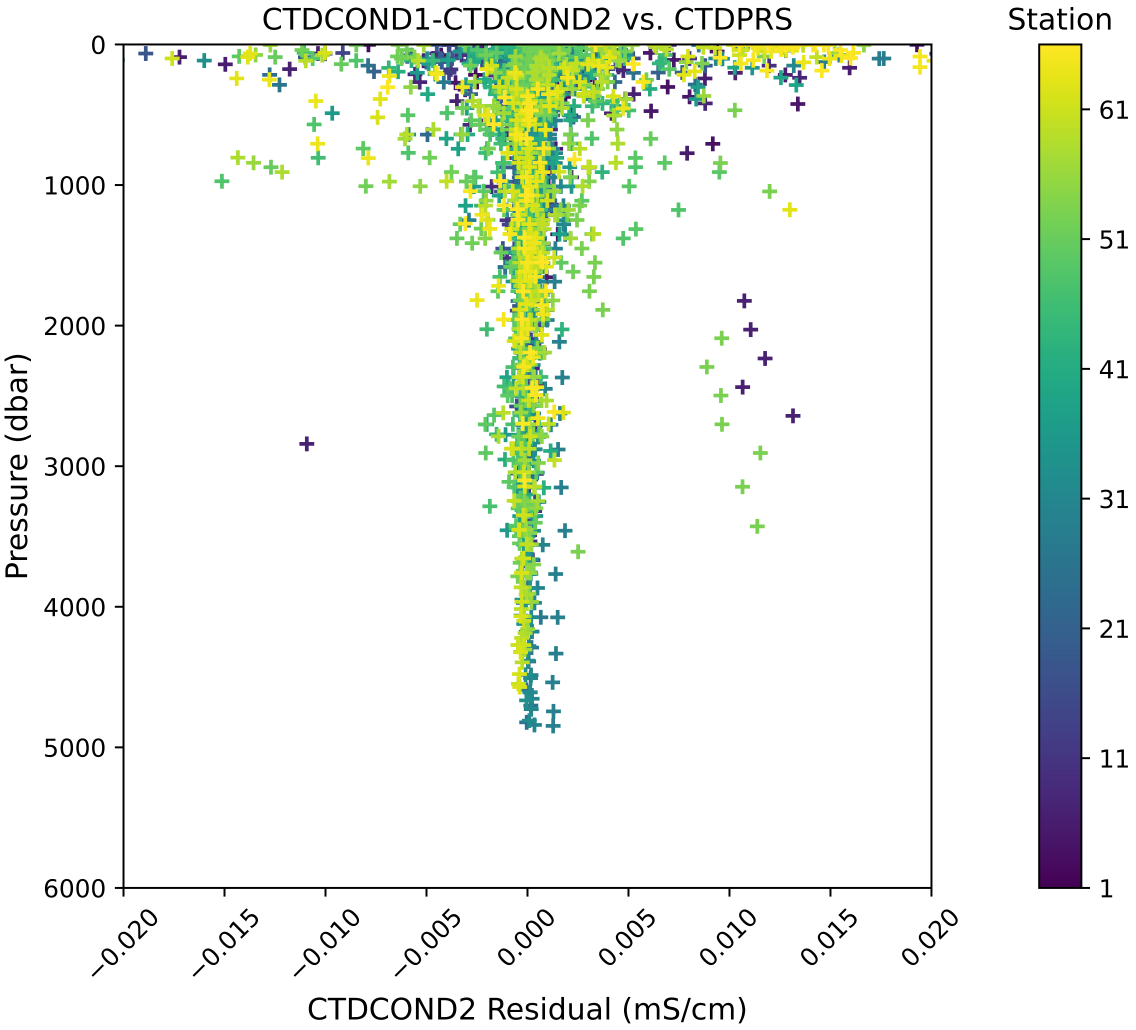


Fig. 4.19: Corrected C1-C2 versus pressure.

The SBE 4C sensor typically exhibits a predictable modeled response. Offsets for each sensor were determined using C_{Bottle} - C_{CTD} differences in a deeper pressure range (500 or more dbars).

After conductivity offsets were applied to all casts, response to pressure, temperature and conductivity were examined for each conductivity sensor. The response model is second-order with respect to pressure, second-order with respect to temperature, 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 4.4: Primary conductivity (C1) coefficients.

Station	cp_2	cp_1	ct_2	ct_1	cc_2	cc_1	c_0
1-28	0.0	-1.0453e-7	0.0	0.0	0.0	0.0	-2.2392e-4
29-53	0.0	-1.6283e-8	0.0	0.0	0.0	0.0	-1.0801e-3
54-66	0.0	6.6123e-8	0.0	0.0	0.0	0.0	-1.3959e-3

Table 4.5: Secondary conductivity (C2) coefficients.

Station	cp_2	cp_1	ct_2	ct_1	cc_2	cc_1	c_0
1-28	0.0	-6.6677e-7	0.0	0.0	0.0	0.0	-2.1616e-3
29-53	0.0	5.8382e-10	0.0	0.0	0.0	0.0	2.6648e-3
54-66	0.0	-2.698e-7	0.0	0.0	0.0	0.0	2.3827e-4

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.

The 95% confidence limits for the mean low-gradient (values -0.002 ºC $\leq$ T1-T2 $\leq$ 0.002 ºC) differences are $\pm$0.00439 mPSU for salinity-C1SAL. The 95% confidence limits for the deep salinity residuals (where pressure $\geq$ 2000 dbar) are $\pm$0.0015 mPSU for salinity-C1SAL.

Issues affecting SBE 4C salinity data were:

- The secondary conductivity sensor, serial number 04-4545, experienced a cell failure during cast 02801, resulting in sporadic punctuated offsets in the data. The sensor was replaced with serial number 04-3207 for cast 02901 and was used through cast 05301. A small constant offset was noted in the factory calibration with respect to the primary sensor, however this was not judged to be detrimental.
- The replacement secondary sensor, 04-3207, failed during cast 05301, resulting in sporadic punctuated offsets in the data. The sensor was replaced with serial number 04-2766 and was used without issue for the remainder of the cruise.

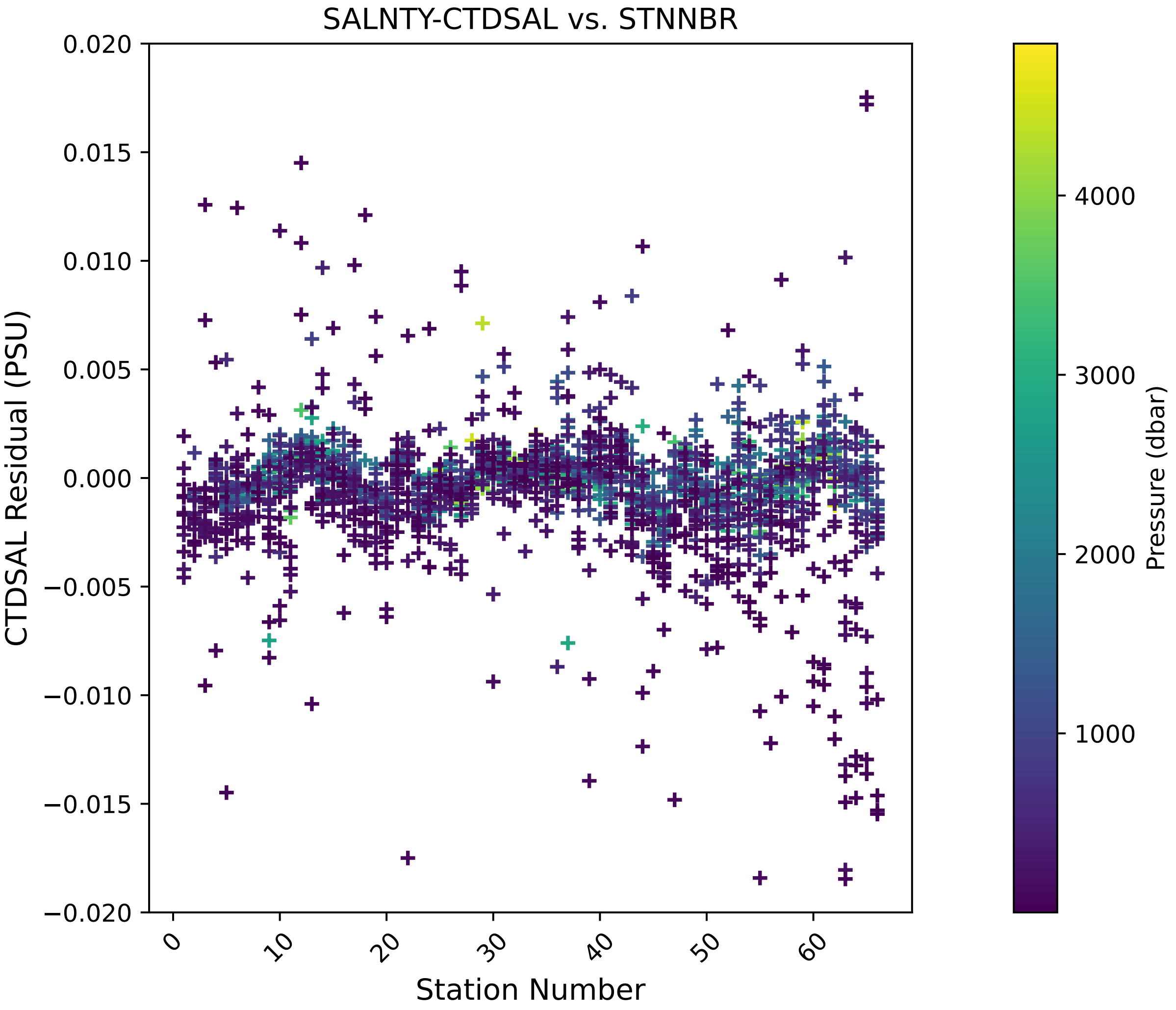


Fig. 4.20: Salinity residuals versus station.

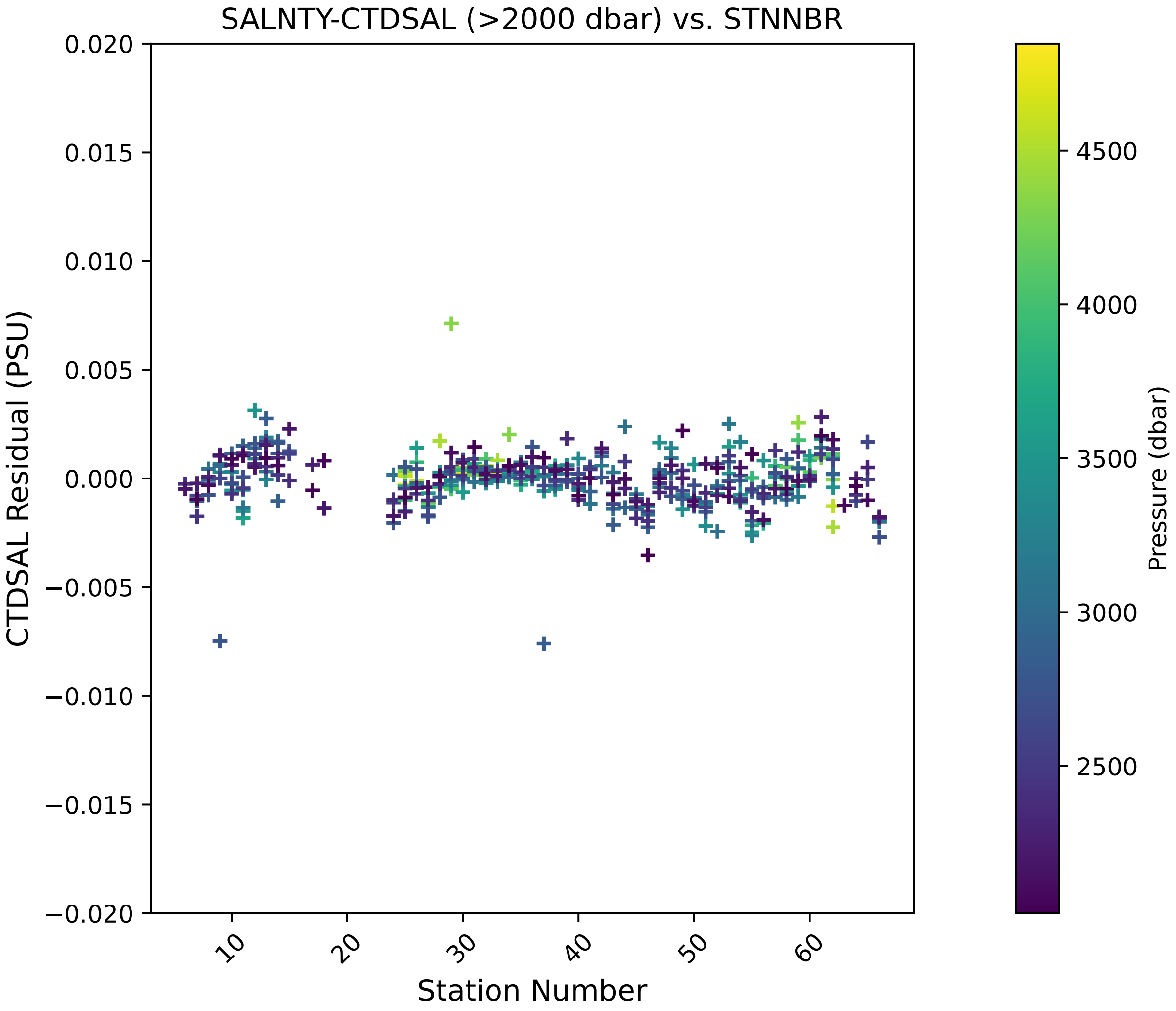


Fig. 4.21: Deep Salinity residuals versus station (Pressure >= 2000dbar).

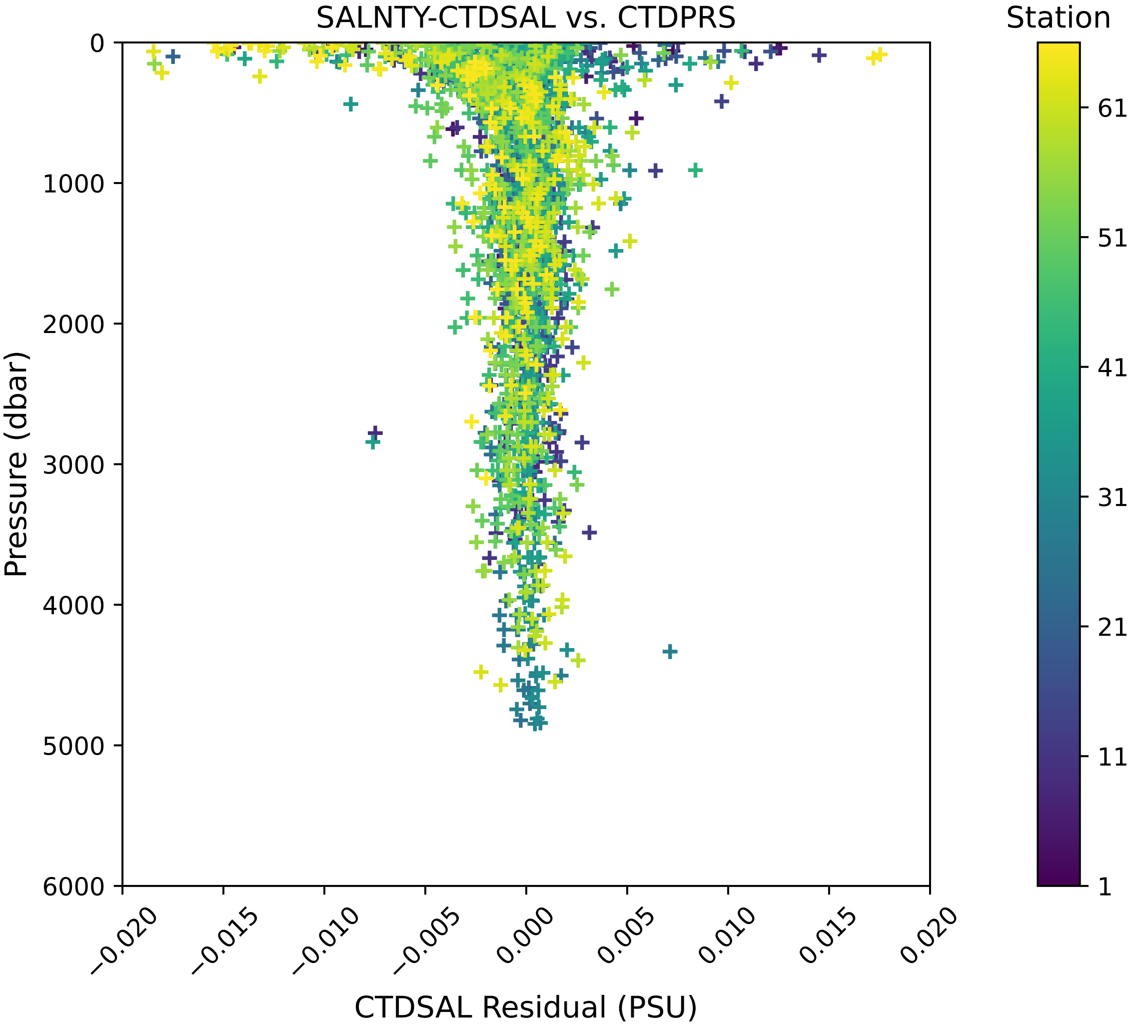


Fig. 4.22: Salinity residuals versus pressure.

4.6 CTD Dissolved Oxygen (SBE43)

A Sea-Bird SBE 43 oxygen sensor installed on the CTD primary T-C channel provided one of two sources of dissolved oxygen data. Serial number 43-4479 was used for the duration of the cruise with no performance issues noted.

Laboratory calibrations of the dissolved oxygen sensors were performed prior to the cruise at the SBE calibration facility. Dates of laboratory calibration are recorded in Table 3.1. Calibration documents are provided in the APPENDIX.

The pre-cruise laboratory calibration coefficients were used to convert SBE 43 frequency to µmol/kg oxygen values for acquisition only. Additional shipboard fitting was performed to correct for the sensor's non-linear response and for calibration drift over the course of the cruise. 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 SBE 43 sensor data were compared to dissolved oxygen bottle samples by matching the downcast CTD data to the upcast bottle stop locations along isopycnal surfaces. CTD dissolved oxygen was then calculated using Clark Cell MPOD oxygen sensor response model for Beckman/SensorMedics and SBE 43 dissolved oxygen sensors. The residual differences of bottle values versus CTD dissolved oxygen 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 Millard [Mill82] and Owens [Owen85]. Dissolved oxygen 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 individual cast's coefficients yielded worse residuals, they were reverted to the original group fit coefficients.

Table 4.6: SBE43 group fit coefficients. Coefficients were further refined station-by-station.

Station	S $_{oc}$	V $_{off}$	tau $_{20}$	T $_{cor}$	E
All	4.3343e-1	-4.8306e-1	1.1300e+0	-8.3742e-4	3.9634e-2

CTD dissolved O_2 residuals are shown in figures Fig. 4.23 through Fig. 4.25.

The 95% confidence limits of 1.63 (µmol/kg) for all acceptable (flag 2) dissolved oxygen bottle data values and 1.09 (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 titration measurements.

No performance issues were noted with the SBE 43 sensor.

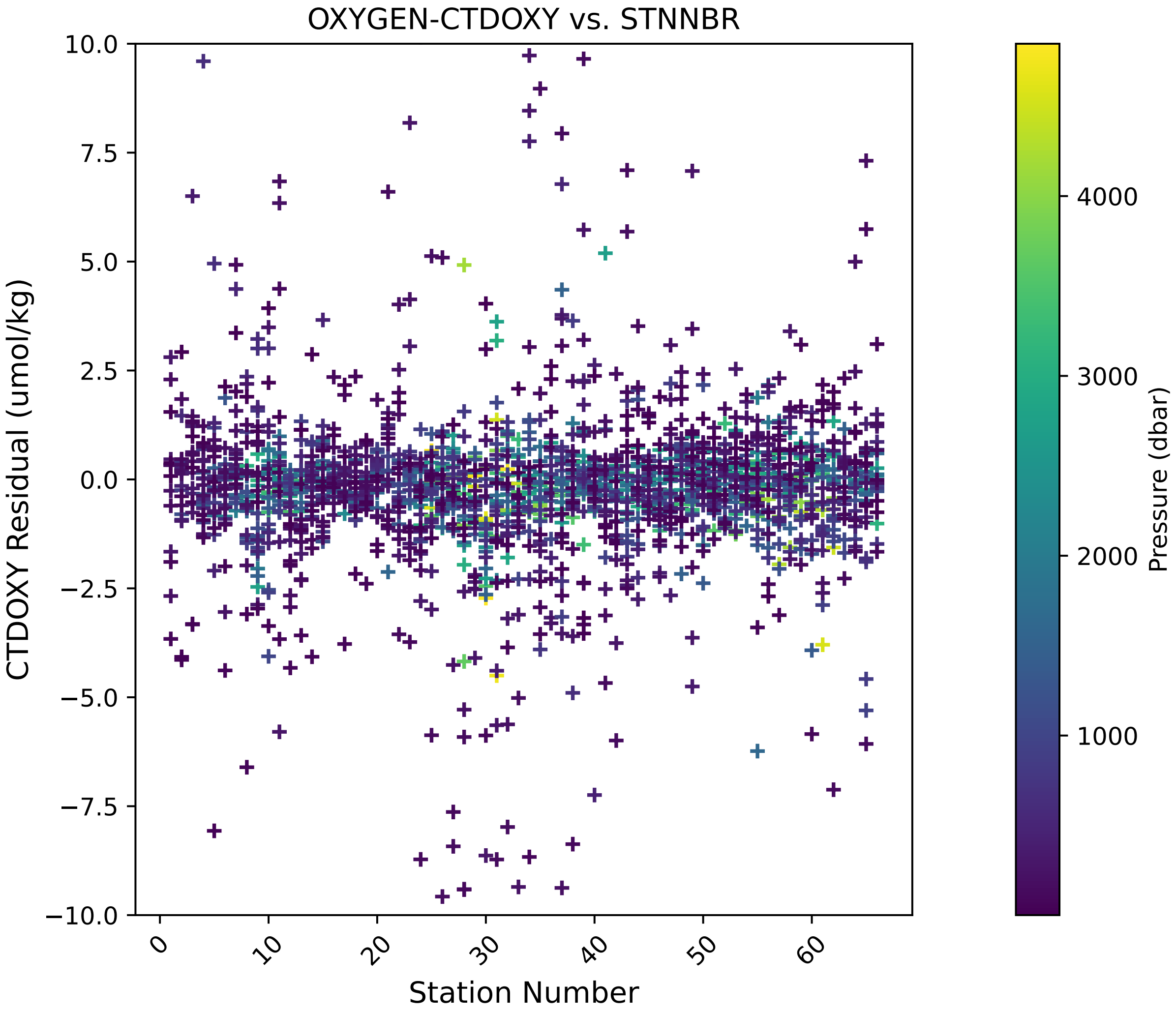


Fig. 4.23: CTD (SBE43) O_2 residuals versus station

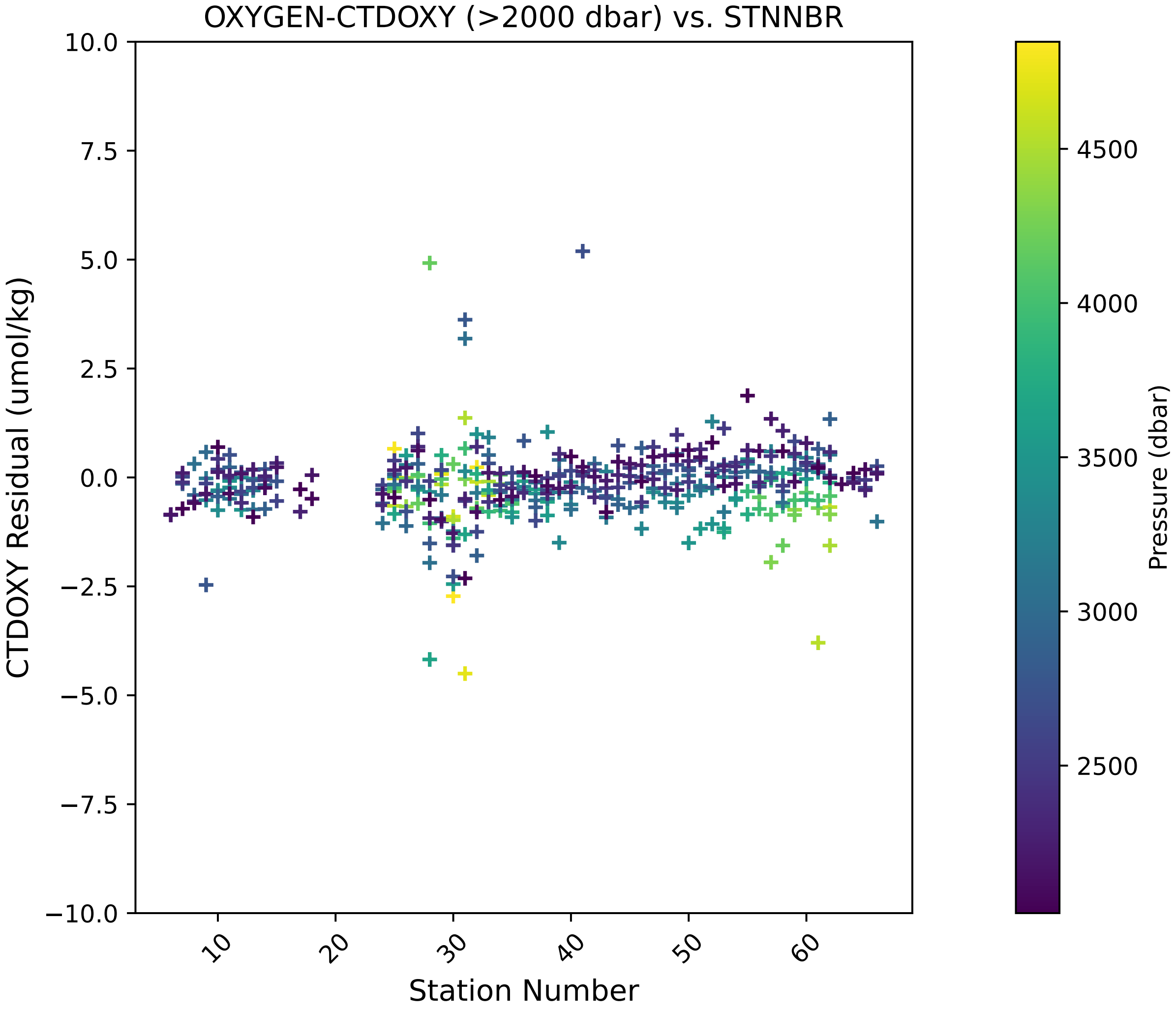


Fig. 4.24: CTD (SBE43) deep O_2 residuals versus station (Pressure >= 2000dbar)

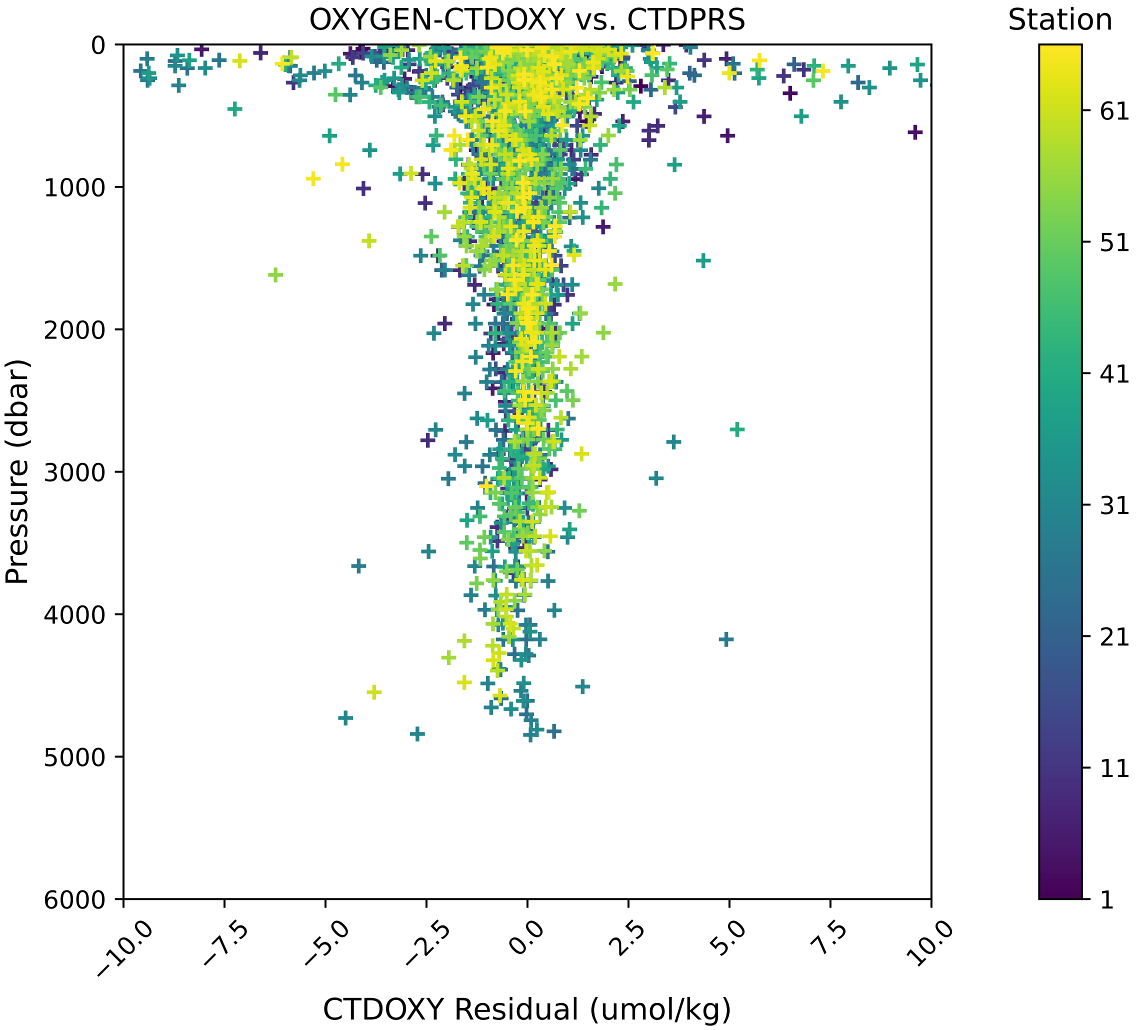


Fig. 4.25: CTD (SBE43) O_2 residuals versus pressure.

4.7 CTD Dissolved Oxygen (RINKO)

A JFE Advantech Co., LTD RINKO III (ARO-CAV) provided the second of two sources of dissolved oxygen data. Serial number 0297 was used for the duration of the cruise with no performance issues noted.

RINKO data are reported as primary CTD oxygen for all stations.

RINKO raw voltage data were acquired, converted to oxygen saturation, and then multiplied by the oxygen solubility to give 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 were fit together to get an initial coefficient estimate. Station 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 residuals than the group, they were reverted to the original group fit coefficients.

Table 4.7: 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
1-9	9.6314e-1	4.7949e-2	4.1940e-5	1.5899e-2	-5.9143e-2	3.1744e-1	8.1895e-2
10-35	9.4417e-1	1.0912e-2	-1.3237e-3	-6.5006e-3	-4.2580e-2	3.0936e-1	6.1018e-2
36-43	9.5947e-1	-1.3654e-2	7.9964e-5	-1.3114e-2	-7.3636e-3	2.9240e-1	7.3773e-2
44-62	9.4677e-1	-5.8679e-3	-9.2278e-5	-1.1622e-2	-2.4016e-2	3.0034e-1	5.6867e-2
63-66	9.6578e-1	-1.2305e-2	-3.6774e-5	-1.2853e-2	4.5356e-3	2.8637e-1	5.3456e-2

CTD (Rinko) dissolved O_2 residuals are shown in figures Fig. 4.26 through Fig. 4.28.

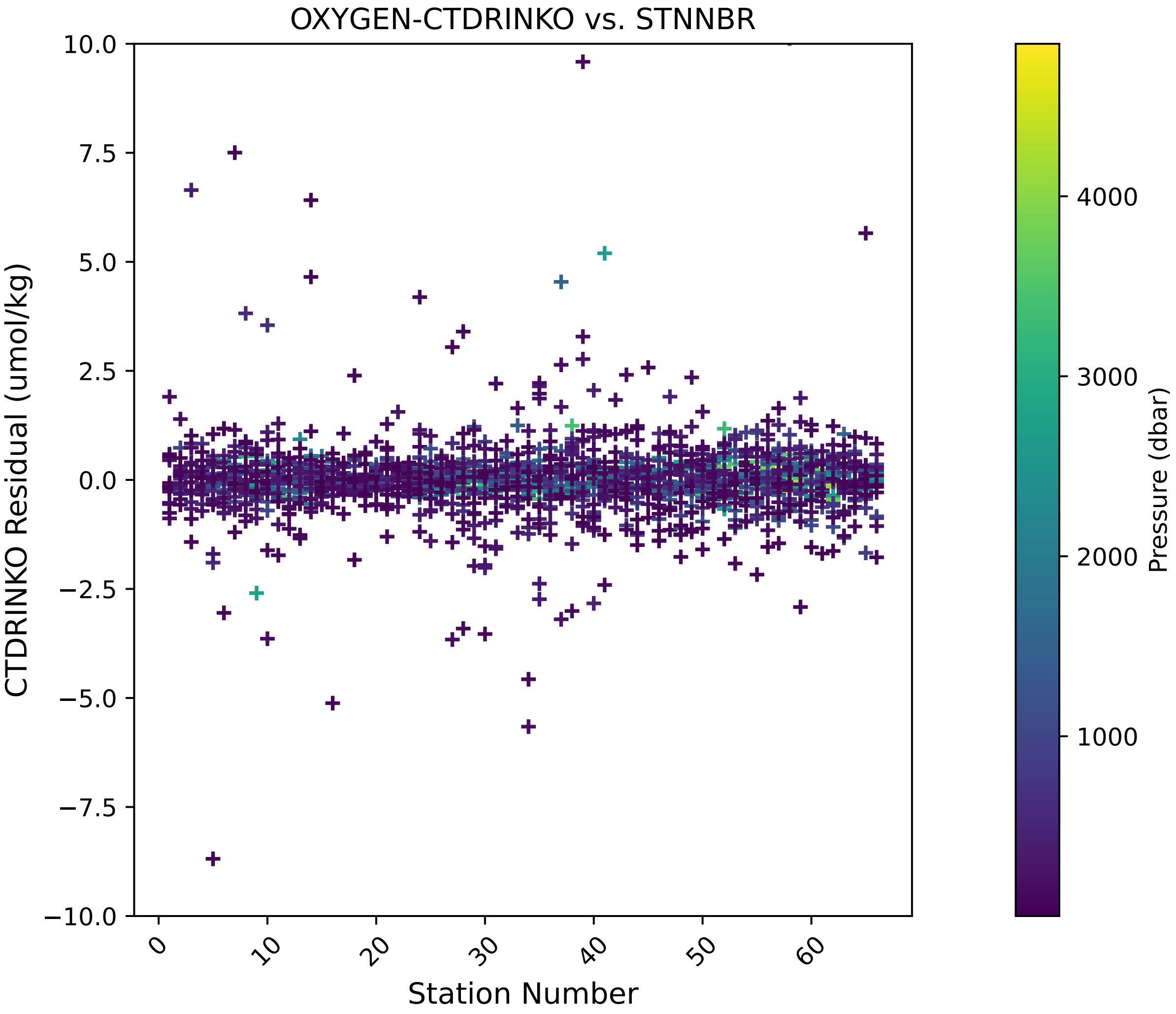


Fig. 4.26: CTD (Rinko) O_2 residuals versus station.

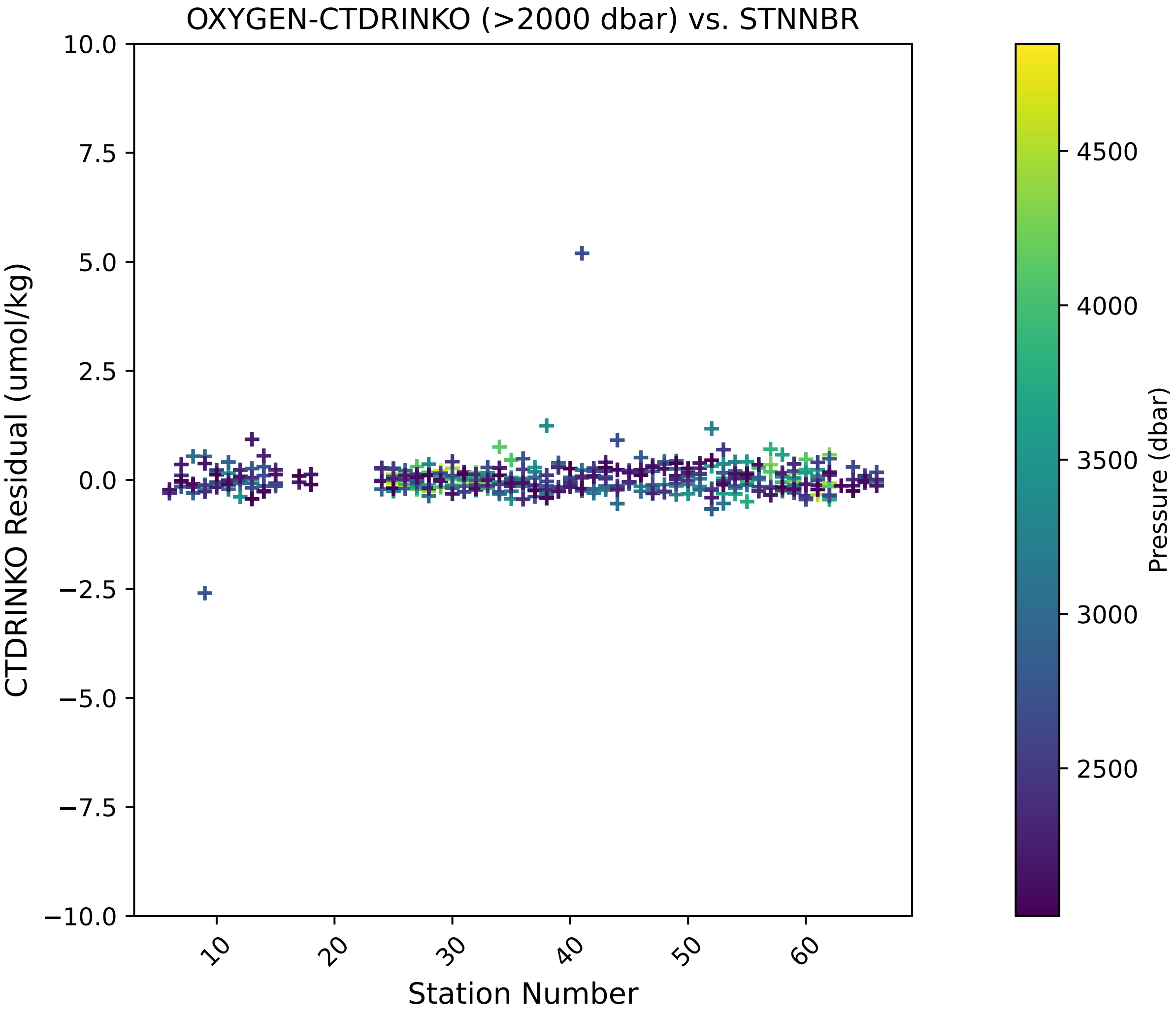


Fig. 4.27: CTD (Rinko) deep O_2 residuals versus station (Pressure >= 2000dbar).

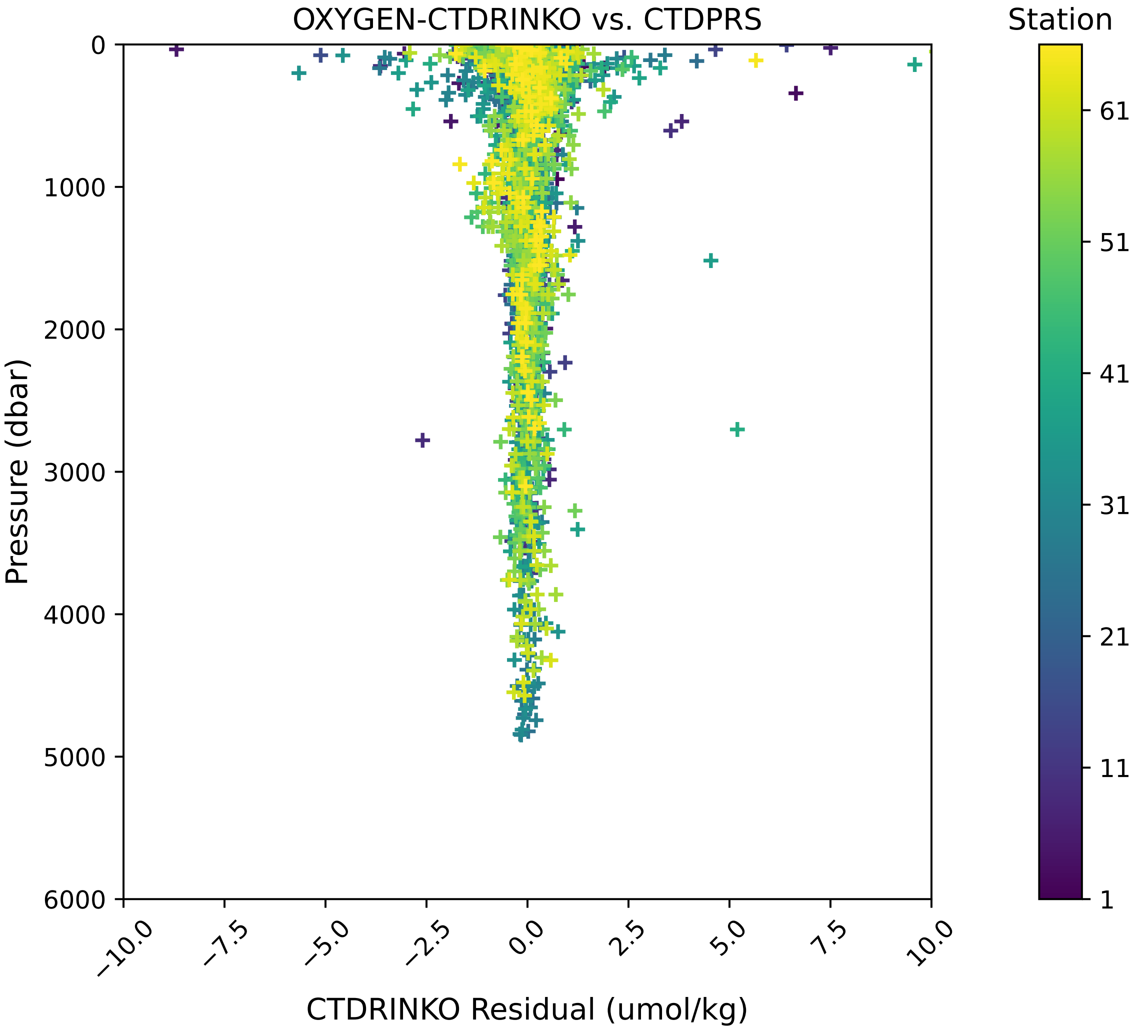


Fig. 4.28: CTD (Rinko) O_2 residuals versus pressure.

The 95% confidence limits of 1.00 (µmol/kg) for all acceptable (flag 2) dissolved oxygen bottle data values and 0.50 (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 titration measurements.

No performance issues were noted with the RINKO III sensor.

CHAPTER FIVE

SALINITY

PIs

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

Technicians

- John Calderwood (SIO)
- Jessica McLaughlin (SIO)

5.1 Equipment and Techniques

Two Guildline Autosals were on board and operational, SIO-owned 8400B S/N 74309 and 8400B S/N 57-526. S/N 74309 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 Bioanalytical Lab. The chamber temperature varied between about 22 and 25 degrees Celsius around 3 times each hour, with an average (based on measuring temperatures of items in the chamber) of about 23.5°C. IAPSO Standard Seawater Batch P167 was used for all calibrations: K15 = 0.99988, Practical salinity = 34.995, expiration 2026-02-21. 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 a laboratory temperature of 24°C, 8 hours or more after collection. Samples were placed under fans to speed their acclimatization to the set room temperature. The salinometer was standardized for each group of samples analyzed (up to 2 casts, or 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. Standardization conductivity offsets did not exceed 0.00005 mS/cm for all casts. Between runs, the water from the last standard was left in the cell.

5.2 Sampling and Data Processing

The salinity samples were collected in 200 ml Kimax high-alumina borosilicate bottles that had been rinsed at least three times with sample water prior to filling. The bottles were sealed with 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 were replaced to ensure 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. During I08, approximately 86 bottles of standard seawater we used for analysis.

5.3 Narrative

No major problems were encountered during this cruise. There were 2,187 samples analyzed this cruise. Three sample bottles were broken over the course of this cruise.

CHAPTER

SIX

OXYGEN ANALYSIS

PIs

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

Technicians

- Elisa Aitoro (SIO)
- Vincent Johnson (SIO)

6.1 Equipment and Techniques

Dissolved oxygen analyses were performed with an SIO/ODF-designed automated oxygen titrator using photometric end-point detection based on the absorption of 365nm wavelength ultra-violet light.

The titration of the samples and the data logging were controlled by PC LabView software. Thiosulfate was dispensed by a Dosimat 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.

6.2 Sampling and Data Processing

A total of 2,179 oxygen measurements were made, all of which were niskin samples. One sample was lost due to an issue with the H_2SO_4 pump.

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 $MnCl_2$ 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.

6.3 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.

6.4 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.

6.5 Narrative

The oxygen analytical rig was setup in the main lab of the R/V Thompson. 2L of each reagent were made during mobilization in Fremantle. Additional batches were made as needed throughout the cruise.

Some power issues were encountered during the first couple of stations, changing the outlet all equipment was plugged into solved the issue.

The stir plate began having issues with consistency at station 19. Stir plate was initially swapped for a backup which worked until it started having issues again at station 24. Stir plate then swapped for one from the Dickson Lab which was used until the end of the cruise.

A few high end points occurred and were corrected for.

The thiosulfate stability was considered in 3 batches and showed remarkable stability throughout the entire cruise.

No trends were observed or corrected for.

No data updates are expected.

CHAPTER
SEVEN

NUTRIENTS

PIs

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

Technicians

- Megan Roadman (SIO)
- Tania Leung (SIO)

7.1 Summary of Analysis

- 2184 samples from 66 CTD stations
- The cruise started with new pump tubes and they were changed twice, before stations 29 and 53.
- 3 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 95%-100%. Columns were changed when the efficiency fell below 95%. Three columns were used for this cruise.

7.2 Equipment and Techniques

Nutrient analyses (phosphate, silicate, nitrate+nitrite, ammonium 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 Brij, a surfactant. Store at room temperature in a dark poly bottle.

Note: 35% Brij - 35g 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). 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 5% SDS 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) [Armstrong1967]. 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 5% 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 Ammonium Analysis

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

Reagents

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

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

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

Working reagent:
In the following order and proportions combine: 1L borate buffer 20ml stock orthophthalaldehyde, 2 ml stock sodium sulfite, 1-2 drops Brij surfactant and mix. Store in a glass bottle and protect from light. Replace weekly.

7.7 Sampling

Nutrient samples were drawn into 30 ml polypropylene screw-capped centrifuge tubes. The tubes and caps were cleaned with 10% HCl and rinsed 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.

7.8 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.

7.9 Standards and Glassware Calibration

Primary standards for silicate (Na_2SiF_6), nitrate (KNO_3), nitrite ($NaNO_2$), phosphate (KH_2PO_4) and ammonium ($(NH_4)_2SO_4$)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). One batch of LNSW was used on the cruise. It was collected off shore of coastal California and 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 LNSW was brought in multiple 5L bottles.

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

-	N+N (uM)	PO_4 (uM)	SIL (uM)	NO_2 (uM)	NH_4 (uM)
0	0.0	0.0	0.0	0.0	0.0
3	15.50	1.2	60	0.50	2.00
5	31.00	2.4	120	1.00	4.00
7	46.50	3.6	180	1.50	6.00

7.10 Quality Control

All final data was reported in micro-moles/kg. NO^3, PO_4, NO_2, and NH_4 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
NH_4	0.03 µM

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

Parameter	Concentration (µM)	stddev
NO^3	33.87	0.30
PO_4	2.38	0.02
SIL	68.4	0.4

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 2 runs 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	0.15	33.2
PO_4	2.38	0.03	2.38
SIL	100.9	0.4	100.5
NO_2	0.029	0.009	0.02

7.11 Analytical Problems

Occasional baseline drift on phosphate channel was resolved with a series of cleaning procedures and monitored throughout cruise. 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.

CHAPTER

EIGHT

TOTAL ALKALINITY

PIs

- Andrew G. Dickson (SIO)

Technicians

- Daniela Nestory (SIO)
- Marshal Thrasher (SIO)

8.1 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 $K < 10E\text{-}4.5$ at 25°C and zero ionic strength) over proton donors (acids with $K > 10E\text{-}4.5$) in 1 kilogram of sample.

8.2 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 (Dickson, 2007).

A Thermo Scientific Isotemp water bath is connected to the water-jacketed open cell to maintain a cell temperature of approximately 20°C. 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.

8.3 Sample Collection

Alkalinity samples are drawn using silicone tubing connected to the niskin bottle 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 0.125 mL of 100% 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 where a core cast was completed.

Alkalinity samples were collected from each niskin where DIC and pH were collected, to completely characterize the CO_2 system. The sampling scheme followed the Dissolved Inorganic Carbon (DIC) team, taking full (36 niksins) or partial (24 niskins) based on machine capacity.

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

8.4 Problems and Troubleshooting

While analyzing samples from station 31, voltage readings from the pH electrode became extremely unstable presumably due to a sudden large EMF interference. In attempt to find an unaffected area of the ship, the alkalinity system was moved from the main lab to bio-analytical lab. Voltage readings thereafter returned to normal and CRM values were within the usual range.

8.5 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) Batch 213 were used to determine the accuracy of the total alkalinity analyses. The total alkalinity certified values for these batches are:

- Batch 213: 2203.56 ± 0.75 µmol/kg (35; 16)

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

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.

The average measured total alkalinity value for each batch is:

- Batch 213: 2204.10 ± 1.34 µmol/kg (188; 101)

Duplicate samples were also used to check the reproducibility of the system. The pooled standard deviation of duplicate samples is given below.

Duplicate precision: ± 1.23 µmol kg-1 (n = 125 pairs)

1767 total alkalinity values were submitted for I08S.

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

CHAPTER

NINE

DISCRETE PH ANALYSES (TOTAL SCALE)

PI

- Dr. Andrew Dickson (SIO)

Technicians

- Daniela Nestory (SIO)
- Abigail Tinari (SIO)
- Cora McKean (SIO)

9.1 Analysis

pH_T 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 VWR 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 dye 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. The salinity data used was obtained from the salinity analysis conducted on board.

9.2 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 dye batches were used during I08S. The pH_T of these batches was 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].

9.3 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:

$R = (A_{578} - A_{base})/(A_{434} - A_{base})$

and

$R = A_{488} - A_{base}$

The change in R for a given change in A_{iso}, $\Delta R/(\Delta A)_{iso}$, 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:

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

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

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

9.4 Sample Collection

Samples were collected in 250 mL Pyrex glass bottles and sealed using 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 0.125 mL of oversaturated 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 to completely characterize the carbon system. Additionally, duplicate samples were collected from all stations for quality control purposes. The sampling scheme followed the Dissolved Inorganic Carbon (DIC) team, taking full (36 niksins) or partial (24 niskins) based on machine capacity.

9.5 Problems and Troubleshooting

While running testing the system during transit, the Agilent 8453 spectrophotometer's self-test via Chem Station software failed the RMS noise test. This resulted in multiple changes of the spectrophotometer, deuterium bulbs and tungsten bulbs. Again, the RMS noise test did not pass. CRM values were precise and accurate so it was decided to continue running with the original spectrophotometer.

During station 4 the Kloehn started leaking and was replaced with no further issues.

While analyzing samples taken from stations 7-11 and 60 we experienced room temperatures fluctuations causing some analyses to be measured outside of the ideal range of 298.15 ± 0.05K . Analysis stopped until the room temperatures stabilized.

9.6 Standardization/Results

The precision of the data was assessed from measurements of duplicate analyses and certified reference material (CRM) Batch 213 (provided by Dr. Andrew Dickson, UCSD).

To evaluate the reproducibility of the pH system, two duplicate samples (two samples from one niskin bottle) were collected on each cast, except for casts with fewer than 20 niskins, in which one duplicate sample was collected.

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

The precision statistics for I08S are:

Duplicate precision ± 0.0006 (n = 122 pairs)

CRM Batch 213 7.8350 ± 0.0012 (n = 57)

1767 pH values were submitted for I08S.

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
TEN

DISSOLVED INORGANIC CARBON (DIC)

PIs

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

Technicians

- Julian Herndon (UW-CICOES/NOAA-PMEL)
- Alison MacLeod (UM/NOAA-AOML)

10.1 Introduction

The Pacific Marine Environmental Lab (PMEL) Carbon Group Dissolved Inorganic Carbon (DIC) mobile container-based laboratory slated for deployment on this cruise was delayed in Singapore during transit between Seattle, WA, USA and Perth, WA, AU. In order to avoid delaying the departure of the cruise and missing the ice minimum window at the southernmost station, carbon chemistry laboratories at PMEL, AOML and SIO air shipped backup analytical instruments and sample bottles directly to the vessel in port in Fremantle, WA, AU. The two-tiered backup plan was to ship two available analytical instruments, one from PMEL and one from AOML, as a primary backup for the delayed van and also over 2,200 sample bottles to be used to collect samples and bring them back to PMEL in the event that the backup analytical instruments did not operate correctly. The instrument from PMEL had recently been built, and while it was calibrated in the laboratory, had not yet been used to analyze any samples. The instrument from AOML was actively used in the laboratory, but had not been sent to sea for an extended period of time. The shipments included all the necessary supplies including Certified Reference Material (CRM), and most chemicals and gases required to conduct analysis aboard the ship or collect the samples in bottles. Additional chemicals and gases were sourced locally in Perth, AU.

NOTE: Due to difficulties associated with the calibration factors for both instruments while on the ship and a small error in the calibrated volume of the sample pipette for the AOML instrument as a result of damage sustained during shipping, the preliminary data submitted aboard the vessel at the end of the cruise has been labelled with QC flags of 3 (questionable). The values are expected to change after both DICE instruments undergo post-cruise calibrations back in their respective laboratories. For this reason, there is limited data presented in this report for the estimates of precision and accuracy of the measurements that typically accompany our results. These statistics will be included with the metadata for the DIC samples analyzed on this cruise when the final data product is submitted.

10.2 Sample collection

DIC measurements were drawn according to procedures outlined in the PICES Publication, Guide to Best Practices for Ocean CO_2 Measurements [Dickson07], from Niskin bottles into 540 ml borosilicate glass bottles using silicone tubing. The flasks were rinsed three times and filled from the bottom with care not to entrain any bubbles, overflowing by one half- to one full-volume. The sample tube was pinched off and withdrawn, creating a ~6 ml headspace, followed by the addition of 0.2 ml of saturated $HgCl_2$ solution as a preservative. The sample bottles were then sealed with glass stoppers lightly coated with Apiezon-L grease and were stored at room temperature for a maximum of 12-24 hours until analysis.

10.3 Equipment

The analysis was done by coulometry with two analytical systems (PMEL DICE 3 “Eagle” and AOML DICE 6) used simultaneously on the cruise. Each system consisted of a coulometer (CM5011 on DICE 3 and CM50170 on DICE 6, UIC Inc) coupled with a Dissolved Inorganic Carbon Extractor (DICE). The DICE system was developed by Esa Peltola and Denis Pierrot of NOAA/AOML and Dana Greeley of NOAA/PMEL to modernize a carbon extractor called SOMMA (Johnson et al. [Johnson85], [Johnson87], [Johnson93], and [Johnson99]; Johnson [Johnson92]). The two DICE systems were set up in the forward, port side Bio Lab onboard the RV Thomas G. Thompson.

10.4 DIC Analysis

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

10.5 DIC Calculation

Calculation of the amount of CO_2 injected was according to the CO_2 handbook [DOE94]. The concentration of CO_2 ($[CO_2]$) in the samples was determined according to:

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

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

All DIC values were recalculated to a molar weight (µmol/kg) using density derived from the CTD’s salinity sensor. The DIC values were corrected for dilution due to the addition of 0.2 ml of saturated $HgCl_2$ used for sample preservation. A correction was also applied for the offset from the CRM. This additive correction was applied for each cell using the CRM value obtained at the beginning of the cell. The coulometer cell solution was replaced after 25 – 28 mg of carbon was titrated, typically after 9 – 12 hours of continuous use.

10.6 Calibration, Accuracy and Precision

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

1) Gas loops were run at the beginning of each cell.
2) CRMs supplied by Dr. A. Dickson of SIO, were analyzed at the beginning of the cell before sample analysis.
3) Duplicate samples from the same Niskin, were measured near the beginning, middle and end of each cell.

Each coulometer was calibrated by injecting aliquots of pure CO_2 (99.999%) by means of an 8-port valve (Wilke et al., [Wilke93]) outfitted with two calibrated sample loops of different sizes (~1ml and ~2ml). The instruments were each separately calibrated at the beginning of each cell with a minimum of two sets of these gas loop injections.

The accuracy of the DICE measurement is evaluated with the use of CRMs, consisting of filtered and UV irradiated seawater, supplied by Dr. A. Dickson of Scripps Institution of Oceanography (SIO). The CRM accuracy is determined manometrically on land in San Diego and the DIC data reported to the data base have been corrected to the CRM values for the two batches used (213 and 208). The CRM value for these batches are 2024.67 and 2059.66 µmol/kg respectively.

The precision of the two DICE systems can be demonstrated via the replicate samples. Approximately 13% of the Niskins sampled had analytical replicates 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 pipette volume was determined by taking aliquots of distilled water from volumes at known temperatures. The weights with the appropriate densities were used to determine the volume of the pipettes.

10.7 Summary

The overall performance of the analytical equipment during I08S 2024 was good despite issues with calibration factors and the added challenges of setting up and operating backup instrumentation in less than an ideal environment aboard the vessel. Including the analytical replicates, 1,949 samples were analyzed from 66 CTD casts for dissolved inorganic carbon (DIC). Excluding the Niskins that were dedicated for biological analysis, we sampled 74% of the Niskins made available for us to sample. The DIC data reported to the ODF database directly from the ship are to be considered preliminary until a more thorough post-cruise data quality review can be completed ashore.

CHAPTER

ELEVEN

DISSOLVED ORGANIC MATTER (DOM)

PIs

- Craig Carlson (UCSB)

Technician

- Vic Dina (UCSB)

11.1 Project Goals

The goal of the DOM project is to provide high resolution, long term monitoring of DOC/TDN distribution throughout the water column, in order to help better understand biogeochemical cycling in global oceans. For 2024 the Carlson Lab at UCSB will evaluate dissolved organic carbon (DOC) and total dissolved nitrogen (TDN) concentrations along the US GO-SHIP IO8S transect.

11.2 Sampling Plan

Over the course of the IO8S cruise, DOC/TDN was sampled at every other station in conjunction with DIC, Alkalinity, and pH. For these, DOM was sampled from up to 36 unique Niskins ranging the full depth of the water column, with two duplicates randomly selected for a total of 38 samples collected per these casts. In addition, at intermediate stations where DOM was not collected for the full depth profile, a single surface sample was collected (in replicate) to increase surface resolution across this section. DOM was sampled at 33 stations for full depth profiles, and an additional 33 surface sample-only stations were also collected. In total 1,243 individual DOC samples were collected.

11.3 Sampling Details

DOC samples were passed through an inline filter holding a combusted GF/F filter attached directly to the Niskin for samples shallower than 500 meters. This was done to eliminate particles larger than 0.7 µm from the sample. Samples from deeper depths were not filtered. Previous work has demonstrated that there is no resolvable difference between filtered and unfiltered samples in waters below the upper 500 m at the µmol kg 1 resolution.

To avoid contamination, nitrile gloves were used when handling all sampling equipment and clean lab surfaces were used for processing samples. After each station, all equipment used for sampling was rinsed with 10% hydrochloric acid and MilliQ water in preparation for the following station. All samples were rinsed 3 times with ~5 mL of seawater and collected into 40 mL glass EPA vials.

Sample vials were prepared in advance for this cruise by combusting at 450°C for 4 hours to remove any organic matter. Vial caps were cleaned by soaking in 10% hydrochloric acid, followed by a soak in Nanopure water overnight, followed by a 3 times rinse with Nanopure water and left out to dry. Samples were fixed with 50 µL of 4M hydrochloric acid and stored upright in well sealed pelican coolers just below room temperature (~12-15° C) on board. Samples were never frozen. Samples will be shipped back to UCSB for analysis via high temperature combustion on Shimadzu TOC-V or TOC L analyzers.

11.4 Standard Operating Procedure for DOM analyses (Carlson Lab, UCSB)

DOC samples will be analyzed via high temperature combustion using a Shimadzu TOC-V or Shimadzu TOC-L in a shore based laboratory at the University of California, Santa Barbara. The operating conditions of the Shimadzu TOC-V have been slightly modified from the manufacturer's model system. These methods have been added to the GO SHIP Practices collection and are fully detailed in Halewood et. al, 2022 [Halewood2022], and previously ([Carlson2010], [Hansell2005], [Hansell1998]).

Final results are reported in units of µmol kg-1. Where possible direct measures of sample salinity and analytical temperature are used to calculate average seawater density. In practice we have found that applying an average seawater density of 1.027 kg m-3 to open ocean water column DOM samples, compared to direct measure of sample density results in a difference of less than 0.01 µmol kg-1 (i.e., less than analytical resolution). However, when salinity and an average analytical lab temperature are available or in regions where salinity varies strongly, a more accurate density correction is determined and applied for each sample. Each parameter includes a field for quality control flags.

CHAPTER

TWELVE

CARBON ISOTOPES (C14)

PIs

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

Technician

- Vic Dina (WHOI)

A total of 480 samples were collected from 20 stations. $^{14}C/^{13}C$ samples were collected every 2 degrees change in latitude, from 66 to 28 South. Samples were collected in 100 ml airtight glass bottles. Using silicone tubing, the flasks were rinsed 3 times with the water from the sample bottle. While keeping the tubing near the bottom of the flask, the flask is filled and flushed by allowing it to overflow one and a half times its full volume. 22 unique depths were selected from the 36 niskin rosette utilized, and two duplicate samples were collected at every station at the upper and lower halves of the eater column, respectively. Once the samples were taken, a small amount of water (~5 ml) was removed to create a headspace and 100 ul of 50% saturated mercuric chloride solution was added in the sampling bay. This is the same supply of mercuric chloride solution used for the other DIC samples collected. After all samples are collected from a cast the glass stoppers are dried and greased using Apiezon M high vacuum seal grease, and rubber banded shut to keep the glass stoppers in place during shipping. The filled bottles are stored in NOSAMS crates inside the ship's main laboratory prior to being loaded into a container and shipped back to the United States for analysis.

CHAPTER

THIRTEEN

CFC-11, CFC-12, AND SF_6

Analysts

- Jim Happell
- Laura Cimoli
- Israela Musan

13.1 Sample Collection

CFC/SF_6 samples were collected first from all Niskin bottles This avoids contamination by air introduced at the top of the Niskin bottle as water was being removed. A water sample was collected from the Niskin bottle petcock using silicon tubing to fill a 300 ml BOD bottle. The silcone tubing was flushed of air bubbles. The BOD bottle was placed into a plastic overflow container. Water was allowed to fill BOD bottle from the bottom into the overflow container. The stopper was held in the overflow container to be rinsed. Once water started to flow out of the overflow container the overflow container/BOD bottle was moved down so the tubing came out and the bottle was stoppered under water while still in the overflow container. A plastic cap was snapped on to hold the stopper in place. One duplicate sample was taken on every other station from random Niskin bottles. Air samples, pumped into the system using an Air Cadet pump from a polyethylene air intake tubing mounted high on the foremast, were run when time permitted. Air measurements are used as a check on accuracy.

13.2 Equipment and Technique

CFC-11, CFC-12, and SF_6 were measured on 65 of 66 stations for a total of ~1900 samples. Analyses were performed on a gas chromatograph (GC) equipped with an electron capture detector (ECD). Samples were introduced into the GC-EDC via a purge and dual trap system. Water samples were purged with nitrogen and the compounds of interest were trapped on a main Porapack Q/Carboxen 1000/Molesieve 5A trap held at ~ -20°C with a Vortec Tube cooler. After the sample had been purged and trapped for 6 minutes at 250ml/min flow, the gas stream was stripped of any water vapor via a Nafion dryer prior to transfer to the main trap. The main trap was isolated and heated by direct resistance to 150°C. The desorbed contents of the main trap were back-flushed and transferred, with helium gas, over a short period of time, to a small volume focus trap in order to improve chromatographic peak shape. The focus trap was Porapak N and is held at ~ -20°C with a Vortec Tube cooler. The focus trap was flash heated by direct resistance to 180°C to release the compounds of interest onto the analytical pre-column. The pre-column was the first 5 meters of a 60 m Gaspro capillary column with the main column consisting of the remaining 55 meters. This was followed by a 6m length of a molesieve 5A column to delay the N_2O peak until the end of the chromatographic run. The analytical pre-columns were held in-line with the main analytical column for the first 45 seconds of the chromatographic run. After 45 seconds, all of the compounds of interest were on the main column and the pre-column was switched out of line and back-flushed with a relatively high flow of nitrogen gas. This prevented later eluting compounds from building up on the analytical column, eventually eluting and causing the detector baseline signal to increase.

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

13.3 Calibration

A gas phase standard, 426505, was used for calibration. The concentrations of the compounds in this standard are reported on the SIO 2005 absolute calibration scale. Five calibration curves were run over the course of the cruise. Estimated accuracy is ±2%. Precision for CFC-12, CFC-11and SF_6 was 2%. Estimated limit of detection is 5 fmol/kg for CFC-11, 3 fmol/kg for CFC-12, and 0.05 fmol/kg for SF_6.

CHAPTER

FOURTEEN

NOBLE GASSES

PIs

- Alan M. Seltzer (WHOI)

Technicians

- Israela Musan (WHOI)

14.1 Rationale

We are interested in collecting a few pilot samples for dissolved noble gas isotope and elemental ratio analysis in the Seltzer Lab at Woods Hole Oceanographic Institution (WHOI), using a new technique that allows for high precision measurements (Seltzer & Bekaert, 2022) [Seltzer22]. The noble gases are excellent tracers of physical mechanisms of air-sea interaction, because they lack sources or sinks in the ocean interior and are chemically and biologically unreactive. Thus, their composition (e.g., the ratio of 40Ar to 36Ar) is set exclusively by physical processes at the air-sea interface at the time and place of deep water formation and is preserved as a parcel of seawater travels within the ocean. Recent measurements have indicated that noble gas (elemental) abundances are slightly out of equilibrium throughout the global deep ocean, and we are now able to reproduce the general magnitude and pattern of this disequilibrium with ocean circulation models coupled to an atmosphere, implementing diffusive and bubble-mediated gas parameterizations. However, the problem remains underconstrained, and open questions remain about whether there is meaningful spatial variability in noble gas disequilibria throughout the deep ocean and, if so, what this may tell us about different air-sea gas exchange processes in norther and southern deep water formation regions, for example. These new GOSHIP samples from this cruise will be analyzed at the same time as we measure new deep water samples from GEOTRACES GP17 (Amundsen Sea), BELS (Labrador Sea), and CLIOMZ (Eastern Equatorial Pacific), providing a unique opportunity to search for spatial gradients in noble gas disequilibria.

14.2 Sampling and Analysis

Samples were taken twice during the cruise (Table 1). The stations were chosen so they sampled water from the Circumpolar Deep Water masse (CDW, Station 32), and from the deep water column of the cruise northern section (Station 60). Triplicates were sampled on each station from two deep Niskin bottles (around 3000 m).

Sampling was followed Seltzer et al. (2023) [Seltzer23]. Briefly, Samples were collected by filling pre-evacuated 6-liter stainless steel canisters with ~3.5 kg of seawater subsampled from 10-L Niskin bottles. Prior to sampling, Tygon tubing was attached the Niskin bottle and flushed before connecting directly to the sample canister. Upstream of the sample, a valve was then opened (connected in line with a tee) to purge any air and ensure a direct, bubble-free connection between the Niskin bottle and sample canister. The sample was then collected by opening the canister valve (Swagelok SS-4H bellows-sealed valve) until the sample weight was ~3.5 kg, after which point the valve was closed, and the neck above the valve was flushed with deionized water and capped.

All sample processing and analysis for heavy noble gases (Ar, Kr, and Xe) isotopes and elemental ratio were performed in the Seltzer Lab in the Department of Marine Chemistry and Geochemistry at Woods Hole Oceanographic Institution (Woods Hole, MA, USA), following an established method for the purification, transfer, and analysis of heavy noble gas isotope and elemental ratios in water (Seltzer & Bekaert, 2022) [Seltzer22].

Table 14.1: List of stations sampled for Noble Gases.

Sta. Num	Cast Num	Date	Longitude (E)	Latitude (S)	Niskin Num	Depth
32	01	2024-03-15/16	86° 21.5’	54° 09.8’	9-10	2835
59	01	2024-03-25	95° 00.3’	36° 15.0’	8-9	2835

CHAPTER

FIFTEEN

LOWERED ADCP (LADCP)

PIs

- Andreas Thurnherr (LDEO)

Technicians

- Hayden Kinkade (WHOI)

15.1 Data Acquisition and QC

LADCP data were collected with a dual-headed system during all bio casts and full depth CTD casts. The dual-headed system consisted of an up-looking (UL) and down-looking (DL) Teledyne RDI WHM300 instrument. The DL was mounted on the bottom of the rosette, approximately 6 inches above the bottom ring of the rosette, with transducer beams 1 and 4 facing outwards. The UL was mounted approximately 6 inches above the top ring of the rosette. While the UL did not display orientation information, beams were positioned to ensure the rosette cable did not interfere with the beam's path. A DeepSea lead-acid SeaBattery battery pack was affixed to the bottom of the rosette, and connected to the instruments using a star cable. Two comms/power cables were routed from an acquisition computer in the wet lab to the high bay where the rosette was stored during transit, and a third battery charging cable was installed in the high bay next to the rosette. All instrument programming and data acquisition was performed on a Mac running the LDEO Acquisition software.

During sampling, several comms and hardware failures occurred. Two profiles were partially lost due to CTD software failures, all others were able to be correctly processed.

- Station 01, a problem occurred with a failing serial adapter and faulty communication with the instrument preventing configuration commands from being uploaded correctly to the instrument.
- Station 26, the CTD was restarted during the cast, at approximately 3000 meters during the downcast. This prevented the profile from being able to be processed.
- Station 35, the cable used to charge the battery was broken off and had to be repaired during transit.
- Station 49, the CTD was restarted during the cast, at approximately 1900 meters during the upcast. The data files from before and after the restart were merged. Data from the downcast was processed, the upcast data was unable to be processed.
- Stations 51-53, there were numerous comms failures. Data had to be downloaded through a direct connection to the instrument, and instruments could not receive configuration commands without direct connection. Failing cables were identified as the problem and removed.
- On the remaining stations, occasional gaps were observed in vertical velocity data due to low backscatter.

All LADCP data, shipboard ADCP data, and CTD data files were sent to A. Thurnherr after each cast for preliminary processing to verify data quality during sampling. Further post-cruise processing of horizontal and vertical velocities, as well as further QC will be done at LDEO.

Fig. 15.1 and Fig. 15.2 show a horizontal and vertical velocity summary plot, respectively, for station 04001

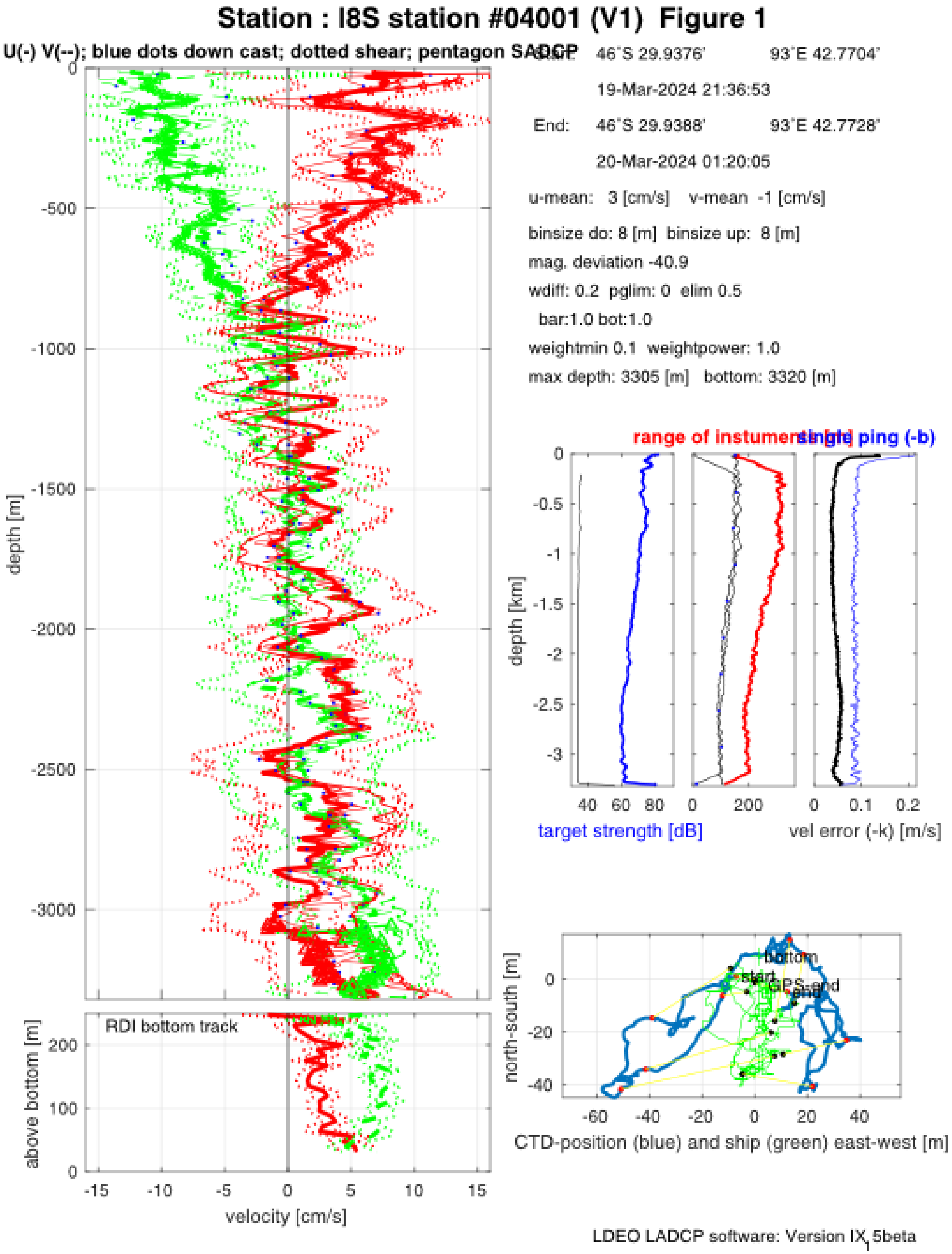


Fig. 15.1: Station 04001 Horizontal velocity summary plot

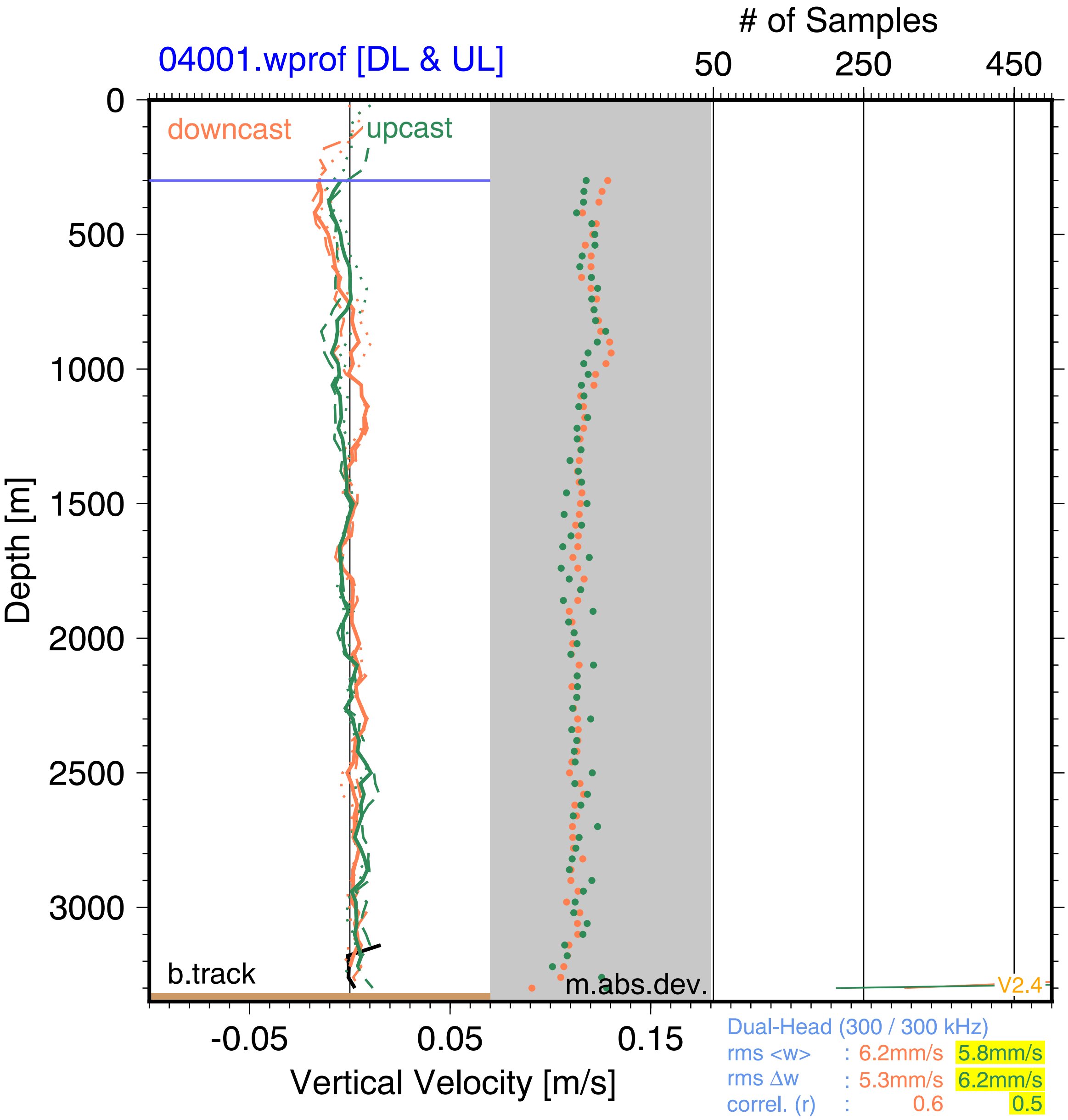


Fig. 15.2: Station 04001 Vertical velocity summary plot

CHAPTER

SIXTEEN

BIO-GO-SHIP

PIs

- Adam Martiny (UC Irvine)
- Nicole Poulton (Bigelow Laboratory for Ocean Sciences)
- Jason Graff (OSU)

Technicians

- Deepika Sahoo (Colorado State University)
- Robert Bremer (NOAA/AOML, University of Miami)

16.1 Introduction

The elemental stoichiometry i.e., carbon (C): nitrogen (N): phosphorus (P) ratio in phytoplankton and particulate organic matter plays a vital role in the elemental cycling of ocean. It was once thought that the C:N:P:-O2 ratios in deep water nutrients and particulate organic matter (POM) were constant at 106:16:1:-138, widely known as the Redfield Ratio ([Redfield1934], [Redfield1958]). The ratio highlights the interaction between phytoplankton and nutrient availability, such that the elemental ratios in biological uptake relative to those in the supply determine the nutrient that limits the cellular growth. Additionally, the ratio of C to nutrients elucidates the amount of C that can be fixed and exported for a given supply of nutrients. Thus, it is used in export production and nutrient based flux rate calculations ([Sautery2022]).

The elemental ratios in POM vary with space and time. Temperature and nutrient availability are the primary environmental factors that regulate the global distribution of phytoplankton community structure ([Acevdo-Trejos2013]; [Sautery2022]). The physiological response of phytoplankton to warming (cooling) and nutrient deficiency (nutrient-rich) leads to an increase (decrease) in C:N:P ratios in POM in the ocean ([Matsumoto2020]). However, paucity of observations prohibits understanding the stoichiometric variations across oceanographic regimes and predict the future C:N:P ratios in POM accurately.

16.2 Objective

The objective of this study is to ascertain the C:N:P variation of POM and phytoplankton diversity of the southern Indian Ocean. The IO8S transect, starting from the polar to subtropical ocean regime, ideally display gradients in temperature and nutrients. Furthermore, the oceanic mesoscale activities along transect would have a significant effect on the elemental ratios in POM and phytoplankton diversity.

16.3 Sampling

We collected water samples for particulate chemical oxygen demand (PCOD), and particulate organic C, N, and P (POC, PON, and POP) analyses. Additionally we sampled for DNA/RNA, flow cytometry, and algal pigments analyses. Surface seawater was collected using the inline system, while seawater at 5-1000 m depth was collected from CTD Niskin Rosettes during biocasts or combined bio and core casts. Seawater from the inline water system was collected thrice in a day i.e., during sun rise, noon, and sunset. A sample log was maintained for sampling and the volume of seawater filtered onto each filter.

Sample preparation protocols for each parameter are as follows:

16.3.1 PCOD, POC and N, and POP

Roughly 8 L discrete water samples were collected in carboys and filtered onto pre-combusted (500 °C, 5 hr) 25 mm glass fiber filters in triplicates using a filtration set up. After filtration, filters were secured in a foil packet and kept frozen at -80°C until analysis. In case of POP, the filters were rinsed with 5 mL Na_2SO_4 solution to remove dissolved P, before placing in foil packets.

16.3.2 High Performance Liquid Chromatography phytoplankton pigments

Seawater was collected from CTD and inline water system in 2 L dark sample bottles and filtered onto pre-combusted (450 °C, 4 hr) 25 mm glass fiber filters using a manifold filtration set up connected to a vacuum pump. The samples were collected for 5 m (in triplicates during noon sampling), 40 m, and 100 m depths. The filters were secured in a pre-labelled foil packet and preserved in -80 °C freezer.

16.3.3 DNA/RNA

Seawaters of 5, 100, 200, and 1000 m depths were collected from CTD Niskin Rosettes and surface water samples were collected from the inline water system with sterile ~8 L pre-rinsed carboys. The water samples were pumped through a Sterivex filter (loaded with Zymo ZR Bashing Beads) using a peristaltic pump. 1000 µL DNA/RNA Shield was added into the Sterivex filter after filtration and preserved in -80 °C freezer.

16.3.4 Flow Cytometry

Seawater samples of 5, 40, 75, 100, 150, 200, 500, and 1000 m were collected from the CTD Niskin Rosettes and surface waters were collected from the inline water system. The samples were initially collected in 50 mL dark centrifuge tubes. Later, 1.8 mL of the sample waters were dispensed into 2 mL cryovials. The cryovials were further added with 18 µL of preservation mixture. The preservation mixture consists of Glutaraldehyde (25%) and Kolliphor P188(2%) in equal proportions. The cryovials were preserved in -80 °C freezer.

CHAPTER SEVENTEEN

EDS

PIs

- Ed Hall (Colorado State)
- Adam Martiny (UC Irvine)

Technicians

- Deepika Sahoo (Colorado State University)

17.1 Introduction

The carbon (C): nitrogen (N): phosphorus (P) ratios in phytoplankton vary with space and time with varying environmental and biological factors in the global ocean. However, the vast majority of studies to date have focused on mean values of composite seston C:N:P from diverse microbial communities or from pelleted populations studied in the laboratory. However, bulk measurements may mask complex responses at the individual and population levels with important implications for the regulation of ecosystem and global links between the carbon and nutrient cycles in the ocean (Deutsch and Weber, 2012 [Deutsch2012]). Cellular level C:N:P stoichiometry certainly aid to understand the effect of changing environmental variables on individual microbial biomass

17.2 Objective

Investigation of C:N:P stoichiometry of microbes at cellular level. The IO8S transect, starting from the polar to subtropical oceanic regime, ideally display gradients in temperature and nutrients. Furthermore, the mesoscale activities along transect would have a significant effect on the elemental ratios and diversity of phytoplankton. The samples collected on the cruise will be analyzed in a scanning electron microscope for the identification of potential microbes and further analyzed using energy dispersive spectroscopy for the C, N, and P content in microbes.

17.3 Sampling and Grid Preparation

Seawater samples from 5 m and 40 m were collected from the CTD Niskin Rosettes in 15 mL centrifuge tubes in duplicates. 1 µL of the seawater was deposited onto Nickel grid (SF200-Ni, Electron Microscopy Sciences) and air dried up to 50-60 seconds. Extra water was pulled out by a tapered end of Kimwipe to avoid the accumulation of excess salt. The procedure was repeated for 3-4 times to ensure sufficient microbes deposited onto grids. The grids were air dried and secured in grid box.

CHAPTER

EIGHTEEN

UNDERWAY SURFACE PCO$_2$

PI

- Simone Alin (NOAA/PMEL)

Technician

- Julian Herndon (UW-CICOES/NOAA-PMEL)

The partial pressure of Carbon dioxide (pCO$_2$) in the surface ocean was measured throughout the cruise track with a General Oceanics 8050 pCO$_2$ Measuring System. Uncontaminated seawater was continuously passed (~2.5-3.5 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 18.1). 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. Approximately twice a day, the infrared analyzer was zeroed and spanned using the nitrogen gas and the highest concentration CO$_2$ standard (704.20 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 pressure and temperature, etc.). For more detail on the general design and operation of this underway pCO$_2$ system, see Pierrot et al [Pierrot09].

Before departing from Fremantle, the pCO$_2$ system received routine maintenance. Some of the maintenance items were: replaced the Norgren valve, reconnected the EQU return line from the dry box to the wet box (found disconnected), reconnected the tubing between the secondary EQU flow meter and the water trap (found disconnected), fixed assorted small leaks in the standard supply tubing and replaced some filters. Adjusted all standard gas and atmospheric air flows and water flows, disassembled and cleaned the water flow meter which was stuck due to salt build up inside the impeller housing, etc. 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.

The pCO$_2$ system on this cruise was installed in the aft, port side Hydrolab. Uncontaminated seawater from the bow of the vessel is pumped to the system via the ship's uncontaminated seawater system. On this cruise, the pump used was a baffle/diaphragm pump at the request of the onboard biologists, who were concerned about damage to the organisms by the centrifugal pump normally used for this purpose. This pump was delivering sufficient water volume to the pCO$_2$ system on this cruise. The vessel provides meteorological data, salinity (TSG45), intake temperature (SBE38) and GPS information from vessel owned and maintained instruments and is recorded in the data file alongside every sample measurement.

There were a number of separate interruptions in data collection throughout the cruise during periods where adjustments were made to gas flows and when troubleshooting was necessary to ensure the best quality data. Whenever possible, these interruptions were done when the vessel was on station. A day worth of data may be affected due to a loss of reference standard supply as a result of the supply tubing being severed during rough weather. Measurements of gas standards were generally within 1% of their certified value throughout the duration of the cruise.

Table 18.1: Standard gases for I08S cruise uw pCO_2 system

Standard	Concentration (ppm)	Tank Serial Numbers
1	304.26	LL122869
2	493.30	LL122858
3	639.36	LL122359
4	704.20	LL132516
5	0.0	Praxair 5.0 Ultra High Purity N_2

While the raw data is not reported here or included in the Scripps Ocean Data Facility (SIO-ODF) database for this cruise, it has been collected and will be analyzed using MATLAB® routines developed by Dr. Pierrot of the Atlantic Oceanographic and Meteorological Lab (AOML) in Miami, FL. The data will be submitted along with other cruise data and also submitted to the Surface Ocean CO_2 Atlas (SOCAT).

CHAPTER

NINETEEN

NOAA DRIFTERS

PIs:

- Rick Lumpkin (NOAA)
- Shaun Dolk (NOAA-AOML)

Ten drifters were provided to be launched at approximate locations selected and confirmed by the PIs. Nine drifters were deployed on the initial transit and one was deployed at a station. Drifter details and deployment information are available in Table 1. Real-time data and visualization are available through the Observing System Monitoring Center (OSMC) at https://viz.pmel.noaa.gov/osmc/?color_by=platform_type. More tools are also found at https://www.aoml.noaa.gov/phod/gdp/real-time_data.php.

All drifters were brought on deck and unpacked from their plastic wrapping shortly before launch. In three instances, two drifters were deployed at the same location, a few minutes apart. All NOAA drifters were tossed overboard by two people, and all deployments went smoothly.

Table 19.1: Drifter deployments

Drifter number	Lat °S	Long °E	Station number	Drifter ID	Deployment Date, Time UTC
1	48.04	92.17	Transit	300534064807240	2/28/24, 04:35
2	50.28	90.63	Transit	64807070	2/29/24, 00:34
3	52.07	89.78	Transit	64807270	2/29/24, 09:47
4	53.92	86.62	32	300534062786460	3/16/24, 03:54
5	56	86.56	Transit	64807660	3/1/24, 08:13
6	56	86.56	Transit	64807080	3/1/24, 08:13
7	57.99	84.57	Transit	300534062786240	3/1/24, 19:41
8	57.99	84.57	Transit	300534062786210	3/1/24, 19:41
9	59.5	82.77	Transit	62786610	3/2/24, 04:24
10	59.5	82.77	Transit	62786450	3/2/24, 04:24

CHAPTER

TWENTY

FLOAT DEPLOYMENTS

A total of 15 OneArgo profiling floats from 3 different institutions were deployed during the 2024 I08S research cruise. 7 are biogeochemical (BGC) Argo floats, of which 4 are part of the Southern Ocean Carbon and Climate Observations and Modeling (SOCCOM) project (https://soccom.princeton.edu/), and 3 are part of the Global Ocean Biogeochemical (GO-BGC) array (https://www.go-bgc.org/). 7 of the remaining floats are part of the Core Argo program (https://argo.ucsd.edu/), and the final one is part of the Deep Argo mission (https://argo.ucsd.edu/expansion/deep-argo-mission/). All Argo floats measure temperature, salinity, and pressure. BGC floats additionally measure O_2, NO^3, pH, and bio-optics. Details for each float type follow.

20.1 BGC Argo Floats

PIs:

- Kenneth Johnson (MBARI)
- Steve Riser (UW)
- Lynne Talley (SIO/UCSD)

Shipboard personnel:

- Jennifer Magnusson (MBARI)

Four BGC Argo floats were deployed as part of the SOCCOM project. The Southern Ocean Carbon and Climate Observations and Modeling project (SOCCOM) is a multi-institutional program focused on unlocking the mysteries of the Southern Ocean and determining its influence on climate. Housed at Princeton University, SOCCOM is supported by the National Science Foundation under NSF Award PLR-1425989 and OPP-1936222.

Three BGC Argo floats were deployed as part of the GO-BGC array. Global Ocean Biogeochemical (GO-BGC) utilizes autonomous robotic floats to measure temperature, salinity, pH, nitrate, chlorophyll, suspended particles, light, and derived parameters DIC, pCO_2 and total alkalinity in the ocean from the surface to 2000m. These floats can operate continuously for years in all weather conditions, providing near real-time observations of ocean biogeochemistry and ecosystems throughout the world's oceans. GO-BGC will deploy 500 autonomous floats in the world's oceans between 2021 and 2026 as part of the OneArgo array (https://argo.ucsd.edu/oneargo/). GO-BGC is supported by NSF award 1946578.

All floats deployed were UW-modified Teledyne Webb Apex floats equipped with SBE41-CP CTDs, O_2, NO^3, pH, and FLBB bio-optical sensors. The floats for the I08S cruise were readied at the UW float lab (S. Riser Argo lab) and shipped to the R/V Thompson in Fremantle, Australia. Once the floats were loaded onto the R/V Thompson, Argo engineer Rick Rupan (UW) tested each float and armed them for deployment. Deployment training and an introduction to the float program were provided by Rick Rupan in person before departure.

At sea, Jennifer Magnusson (MBARI) was in charge of coordinating float deployments, and R/V Thompson SSSGs Elizabeth Ricci and Emmett Dixon were in charge of executing the deployments with the help of ABs.

Fig. 20.1: Jennifer Magnusson stands with the Belmont Bullkelp BGC float (WMO ID 4903751)

Deployment locations were determined by Lynne Talley (SIO/UCSD) based on the climatological front structures of the Antarctic Circumpolar Current, current position of SOCCOM/GO-BGC floats, and trajectories of all Argo floats including past SOCCOM floats. Before each deployment, Jennifer Magnusson carefully cleaned the NO^3 and FLBB bio-optical sensors. Each sensor was rinsed with DI water, wiped/dabbed with lens wipes, rinsed with DI water again, then wiped/dabbed with lens paper. The floats were set to self-activate, so sensor cleaning was the only pre-deployment preparation required. Floats were deployed from the leeward side of the stern as the ship steamed slowly away from the CTD station. Floats were lifted over the stern, then carefully lowered into the water with a slip-line strung through the deployment collar of the float. Most deployments were clean with no tangling or hangups of the slip-line, with the exception of float #21865, which needed to be hauled back aboard, detangled, and then redeployed.

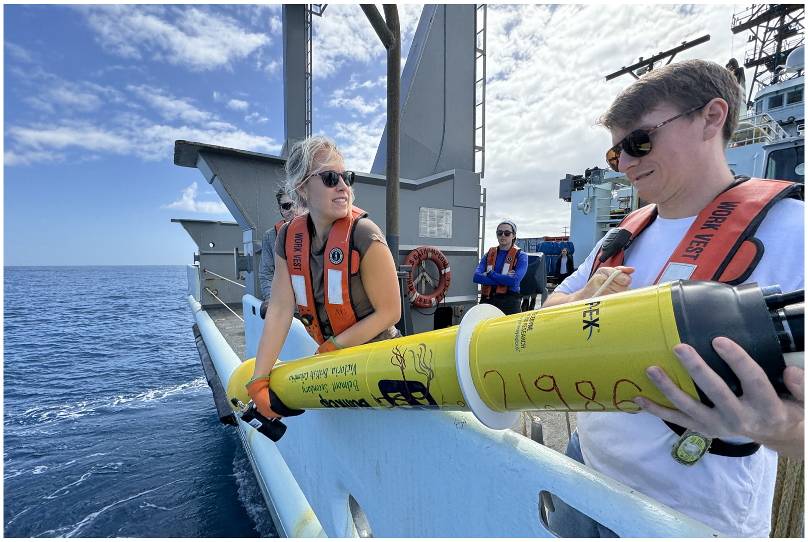


Fig. 20.2: SSSG Emmett Dixon deploys a float with the R/V Thompson ABs

All floats operate on a standard Argo profiling 10-day cycle. After an initial test dive, the floats descend to a parking depth of 1000 m, and then drift for 10 days with the ocean currents. After 10-days, the floats dive to 2000 m and then ascend to the surface, during which data are measured and saved. The data are then sent to shore via Iridium Satellite communication. All of the floats, with the exception of SOCCOM float 21960 (WMO ID 2903871), began reporting data immediately and the sensors are operating well. All data are publicly available via the GO-BGC and SOCCOM data portals and the Argo GDAC.

With the exception of the first deployment (which was during the transit south) for which there was no CTD/rosette station, all deployments occurred at "full" carbon stations so that all GO-SHIP carbon parameters were analyzed for each depth sampled (36 depths from surface to 10 m off bottom). In addition, each float station had a separate bio cast, during which bottles were tripped at the depth of the chlorophyll maximum, at the base of the mixed layer, between the mixed layer and the chlorophyll maximum, and at the chlorophyll max + 50m to allow for additional sampling of POC and HPLC at these stations. During the transit, surface samples were obtained from the underway system. These POC and HPLC samples were collected and filtered onboard by Jennifer Magnusson. In addition to these samples, the bio team (Deepika Sahoo, Colorado State University, and Rob Bremer, NOAA/University of Miami) collected and processed samples from 5m, 40m, and 100m (HPLC) and the surface (POC) from the bio cast at these stations. All HPLC and POC samples will be sent frozen for analysis at NASA for HPLC and SIO/UCSD for POC. Full-depth samples of other ocean properties (salts, pH, total alkalinity, nitrate, oxygen) were collected and analyzed by the different groups on board and will be used to calibrate the floats' sensors.

SOCCOM and GO-BGC are partnering with teachers and classrooms across the country and around the world to inspire and educate students about global ocean biogeochemistry and climate change through our "Adopt-A-Float" initiative (https://www.go-bgc.org/outreach/adopt-a-float). This program creates a powerful opportunity for students of all ages to engage directly with world-class scientists and learn about their research by naming and tracking BGC (biogeochemical) floats. There is no financial cost to adopting a float. Teachers, students and scientists have expressed strong support for the program, citing a unique opportunity to interact around a shared passion for not only better understanding the Southern Ocean's outsized role in our climate system but also improving climate models for the global ocean. All floats on I08S were adopted by different schools and organizations in the US and Canada. Names and images provided by the adoptees were skillfully drawn onto the floats by Jennifer Magnusson and several members of the science party. After each deployment, Jennifer Magnusson sent details and photographs to onshore personnel George Matsumoto (MBARI) for posting on the GO-BGC and SOCCOM social media pages. Each class received the details of their deployment via email. Together with their teachers, the students will follow the float data, which can be easily downloaded and plotted from the website (https://www.go-bgc.org/outreach/for-educators).

Table 20.1: Summary of the deployment details of the BGC Argo floats

Float ID (UW)	WMO	Program	Sta #	Date Time (UTC)	Latitude	Longitude	Adopt-a-float name
20075	1902650	SOCCOM	UW1	2024-03-01 2:18	-54.9377	87.3453	Trieste
21499	5907052	SOCCOM	11	2024-03-06 10:54	-64.4715	80.0367	Raphael
21905	2903870	SOCCOM	25	2024-03-12 12:45	-56.4889	83.7763	Fishstick!
21960	2903871	SOCCOM	33	2024-03-16 12:30	-53.5119	87.0408	Swampii
21865	2903865	GO-BGC	36	2024-03-18 14:04	-49.2683	91.2690	Seawolves Explore
21848	2903864	GO-BGC	41	2024-03-20 10:09	-45.8455	94.2863	Ferruccio
21986	4903751	GO-BGC	52	2024-03-23 06:58	-39.9777	94.9948	Belmont Bullkelp

Six floats have successfully returned initial profiles, and the parameter and diagnostic data all look good. A seventh (21960) has internal CTD connector issues on the first 2 profiles and might not be salvageable. One float (21905) is apparently not correctly ballasted and will be profiling to only 1100 m.

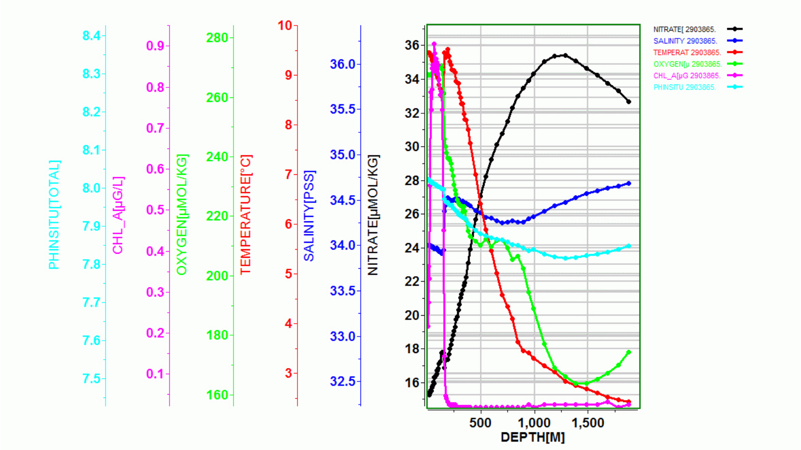


Fig. 20.3: Example of a profile completed by float #21865, Seawolves Explore.

20.2 WHOI Core Argo Floats

PIs

- Susan Wijffels (WHOI)
- Steven Jayne (WHOI)
- Pelle Robbins (WHOI)

Shipboard personnel:

- Jennifer Magnusson (MBARI)

A total of 7 WHOI Core Argo floats were deployed during the I08S cruise. All floats were MRV Systems Solo II (S2-A) floats equipped with Seabird SBE41-CP CTDs and Iridium antennas. Parameters measured are temperature, salinity, and pressure. These floats were readied for deployment by the skilled members of the WHOI float lab and shipped to the R/V Thompson in Fremantle, WA. Shock watches indicated that the floats were handled properly during transport from the WHOI float lab to the R/V Thompson. Deployment training was provided via print and video resources prior to ship departure. All floats were armed once onboard by Jennifer Magnusson (MBARI), with the assistance of Chief Scientist Seb Bigorre (WHOI) and I08S CTD watchstanders. Deborah West-Mack (WHOI) determined float deployment locations for I08S, prioritizing regions with coverage gaps for the target Argo spatial coverage.

At sea, Jennifer Magnusson (MBARI) was in charge of coordinating the float deployments, and R/V Thompson SSGs Elizabeth Ricci and Emmett Dixon were in charge of executing the deployments, with additional assistance provided by ABs. Float deployment boxes were packaged in plastic bags and wrap to protect the cardboard boxes and cornstarch release harness. The plastic layers were removed just before deployment. The first float deployment was attempted using the water release method, in which a slip-line and the 4 deployment bridle loops were passed through a carabiner and used to lift the box over the stern lower it to water level using the slip-line. Unfortunately, the first cornstarch water release did not work properly. The float needed to be hauled back aboard and re-deployed using the sling method, in which two parallel lines are used as slings at either end of the float to roll the float gently down the side of the ship to the water. At that point, it was determined that all subsequent floats would be deployed using the sling method in case other water releases were faulty. Deployments occurred from the leeward stern while the ship slowly steamed away from station.

All floats will complete standard Argo missions. The floats will drift at 1,000 m then dive to 2,000 m before collecting data on the way back up to the surface every 10 days.

Table 20.2: Summary of the deployment details of the Core Argo floats

S/N	WMO	Sta #	Date Time (UTC)	Latitude	Longitude
7710	4903482	T1	2024-02-24 20:55	-42.9951	102.9963
7799	1902524	T2	2024-02-26 00:56	-45.5045	98.4743
7795	1902523	T3	2024-02-28 01:45	-47.9769	92.4250
7831	3902256	T4	2024-02-29 00:30	-50.2759	90.6304
7775	5904387	24	2024-03-11 19:50	-57.6090	82.3885
7830	3902255	40	2024-03-20 01:33	-46.4995	93.7096
7832	3902257	66	2024-03-28 07:41	-28.3250	95.0267

So far, all floats have reported in and are working properly. The data reported by the floats are publicly available via the Argo program GDACs and can be found under https://argo.whoi.edu/wmo/3902255/, substituting the appropriate WMO number.

Fig. 20.4: ABs deploy our final Argo float in the Indian Ocean

20.3 Deep Argo Float

PIs

- Gregory Johnson (NOAA/PMEL)

Deep Argo floats are designed to autonomously profile to 6000m every 10 days, collecting a full CTD profile as they do so with an SBE-61 CTD designed for 6000m, and returning that data via satellite. They have the capability to perform this function for 6-8 years. We deployed a Deep SOLO float, developed at Scripps Institution of Oceanography, and licensed to MRV Systems for commercial production. Because they rely on glass for their hulls, they are exceptionally fragile. Due to the frequent cycling to such crushing depths, any damage to the glass is likely to result in eventual failure of the instrument. As such, extreme care must be taken during handling and deployment, and floats are deployed inside a biodegradable deployment box. Deployment training was provided via print and video resources. Deployment was completed using the crane. The box containing the float was surrounded by four straps, which were attached to the hook of the deploying crane. A light line was then attached to the release loop on the strapping. Using the crane on the starboard side, the box was moved as far outboard as possible and lowered into the water. When the bottom of the box was in contact with the water, the water release triggered, and the release line was also given a sharp tug to ensure the float released properly. The box floated away from the ship, until the float inside was seen to release from the bottom of the box and descend below the surface.

The deep float has successfully connected via satellite, and everything seems to be functioning properly. The oil ballasting has been refined during its first 10 cycles, engineering parameters are looking good, and it has recently been set to a 10-day cycle, full-depth profile mission.

Table 20.3: Summary of the deployment details of the Deep Argo float

S/N	Sta #	Date Time (UTC)	Latitude	Longitude
12072	34	2024-03-17 11:21	-52.1043	88.4664

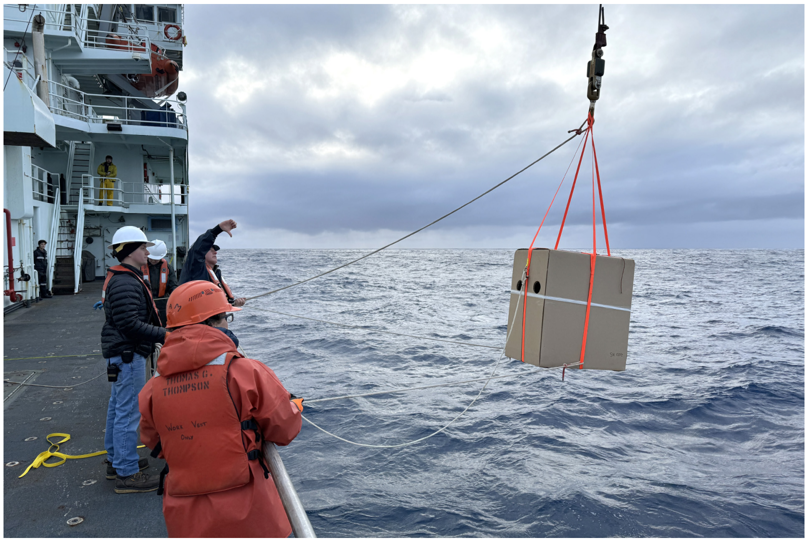


Fig. 20.5: The Deep Argo float is deployed from the crane of the R/V Thompson.

CHAPTER

TWENTYONE

STUDENT STATEMENTS

U.S. GO-SHIP thanks all of the students who participated on the cruise for their important contribution to collection of this essential global ocean data set, used as the benchmark for accuracy of all other deep ocean observing systems. The training opportunity for students and leadership is an important part of US GO-SHIP's mission. We are committed to do so in a fair, cooperative and professional environment, ensuring an inclusive, safe and productive climate at sea. We thank the students for their honest reflections on their experiences that are included in this section. We have reached out to those who expressed concerns and are taking issues raised seriously, by working to address and prevent these issues from occurring in the future. We also thank them for their feedback in the anonymous post-cruise survey, which we are using to continue to improve our program. This will include ongoing education for all members of our community to create a more inclusive environment.

21.1 Nektaria Ntaganou

Florida State University - Center for Ocean-Atmospheric Prediction Studies (COAPS)

As an ocean modeler, I am rarely exposed to the opportunity to go to sea and experience that other, more immersive part of physical oceanography that is so generously offered by collecting data in real time and living onboard. An early-career scientist myself, I started having an interest in and studying physical oceanography by the end of my undergraduate studies, with that interest ending up being my career. In my day-to-day life, I work on mesoscale (and smaller) dynamics and Lagrangian processes mainly in the Gulf of Mexico, as well ocean prediction and data assimilation. All that with the greater goal to better understand several oceanic phenomena that characterize the region and affect life and operations at sea, as well as coastal economies onshore.

Onboard, I was one of the CTD watchstanders, and along with another two watchstanders on the night shift, was responsible for communicating with the winch operator during CTD casts. The communication regarded pausing the ascend of the rosette on certain depths for bottle firing and water collection, as well as timely recovery and deployment. Other duties included preparing the rosette for deployment and sampling. I had never had hands-on experience with oceanographic instrumentation before, and I must say that I am more than glad to realize first-hand the hard work it takes to collect oceanographic data around the clock and in harsh weather conditions. Such experience is crucial to appreciate the time and effort from all those involved in a research cruise, science party or crew members.

In between operations and during the many days we were running away from storms, high seas, and strong winds, I got to get to know many interesting and exciting people that I share the same passions with and the same love about exploring the ocean and the life within it. Spending time outside whenever possible (the night shift and the foul weather made the outside harder to access than I would have thought) as well as being fortunate enough to experience the majestic Southern Lights undoubtedly made up for the bumpy ride, and the -seemingly endless- waiting at stations for the weather to improve.

Many thanks to everyone involved and especially the night shift that made the days (or nights) fun, easy-going, and educational, all at the same time. It was an invaluable experience that I feel more than lucky to have been part of.

21.2 María Sánchez Urrea

Institute of Marine Sciences – Spanish National Research Council (ICM-CSIC)

My journey onboard the R/V Thomas G. Thompson for the I08S 2024 cruise has been both an immersive and valuable experience for my academic and professional growth. As a PhD student specializing in polar ocean physics using satellite and model simulation data, my opportunities to have some at-sea experience are limited. Validation campaigns are rare in satellite-based projects, although in situ measurements are essential to improve the quality of satellite retrievals and reduce their uncertainty. Being selected as one of the CTD Watchstander students for this cruise has provided me with significant hands-on experience operating oceanographic instrumentation, as well as new practical knowledge and confidence. I have learned the basis of all the working activities behind a CTD cast, including the preparation of the rosette before deployment and after sampling, how to communicate with the winch operator during the different stages of the cast, how to collect a wide variety of oceanographic variables (e.g., salts, alkalinity, or biological samples), and the standard procedure for firing bottles and monitoring the profile and the sensor outcomes. In addition to assisting with CTD watch procedures and sample collection, I have also learned how to process and plot in situ data, and, as we also deployed different types of buoys, I had the opportunity to decorate some of the BGC-ARGO floats from the Adopt-A-Float program.

Throughout this seven-week journey, I found myself immersed in the dynamic environment of ship life, surrounded by a very supportive community of scientists and crew members. Even though the weather conditions can be quite rough in this section of the ocean, I really enjoy my time outside. I saw for the first time the stunning Southern Lights, juvenile Emperor penguins, a group of King penguins, humpback whales, and several species of the majestic albatross. I am grateful to everyone involved in the I08S GO-SHIP cruise for their support, expertise, and moments of joy. This experience has not only enriched my academic journey but has also provided me with new practical skills and improved knowledge about the Southern Ocean water masses and dynamics.

21.3 Soumyadeep Dutta

National Centre for Polar and Ocean Research, India

I am a PhD student in India working on Antarctic Polynyas in the Indian Sector of the Southern Ocean. As a student, this IO8S cruise to the Southern Ocean will play an essential role in shaping my future career as this allowed me to witness the research in ocean sciences very closely, all the people's hard work that goes behind collecting and compiling oceanographic datasets, which we can just download easily off the internet.

As a CTD watchstander, I worked with two other watchstanders during the night shift. Our main job was to prepare the CTD by cocking the Niskin bottles and then, during deployment, firing the Niskin bottles at specific depths to collect water samples which will then be sub-sampled by the lab people for further analysis. Sometimes, we also helped the other labs collect the water samples from the CTD, which gave me the opportunity to learn different sampling techniques for DOC, ^{14}C, salts, etc. I also got the chance to get experience with different oceanographic instruments. As a first-year oceanography student, I found this very helpful.

Given that this was not only my first cruise but also my first international travel, it held extra significance for me even though the first two weeks were quite challenging for me due to seasickness and the long journey to our first station. Also, we experienced a lot of difficult weather days. Then, as I acclimatized to the sea, I began to love the ride. We witnessed the Milky Way, the Southern Lights, stunning dawns and sunsets, and several animals, including dolphins, whales, and penguins.

It would not have been easy to get through this night shift without the fun and laughter shared among the night shift people. I will cherish the memories made and the knowledge gained during this cruise for the rest of my research career.

21.4 Jacob Knight

MIT-WHOI Physical Oceanography Second Year PhD Student

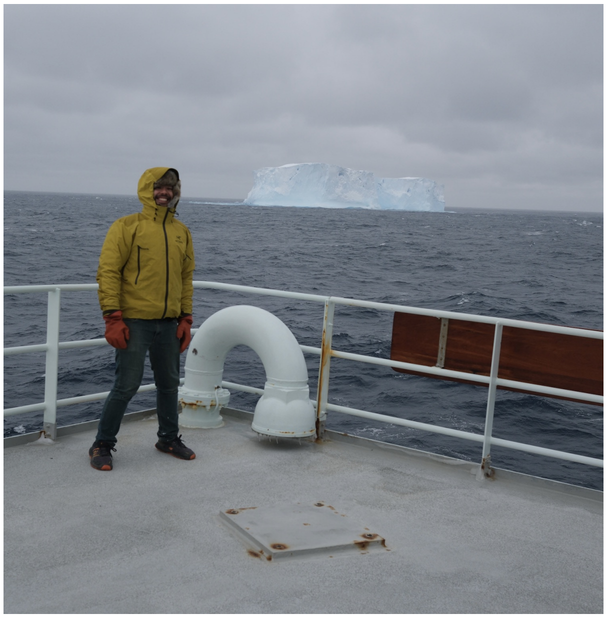
First and foremost I would like to thank the crew, who have kept us safe, fed, navigated and deployed the CTD in some fairly foul weather all while being joyful and patient (especially during the early days). It has also been a joy working and sometimes dancing alongside our Chief Scientist whose humour and smile was much appreciated at three in the morning. Seb's ability to maintain decorum during multiple days of cancelled science helped keep us on track and light hearted despite the frustration this caused us. Because of the organisation, leadership and teamwork between the crew and scientists I08S has been on the whole a great first experience of long term life at sea, thank you.

Since I was young I have always wanted to head to sea. To experience the grandeur of the waves and the deep abyss. Having now sailed over 40ft waves, through the majesty of iceberg fields, under the Southern Lights and alongside penguins, I can say, with deep gratitude to US-GOSHIP, I have not only fulfilled a long held dream but far surpassed it. This cruise has brought to life my computational PhD work and theory I have long studied. My research is focussed on modelling the response of the Southern Ocean and North Atlantic to large scale freshwater melt similar to scenarios predicted under RCP8.5 climate projections. I specifically investigate how Antarctic Deep Water and Sea Ice production will change. The models and theory I use are based on long term observations of this region, so to become a part of this aspect the scientific endeavour has been a real privilege.

On board I was a CTD watch stander, which involved working alongside the labs and crew to safely and accurately deploy, retrieve and sample from the CTD (the central instrument of our cruise). Over the course of the 40 odd days at sea we have formed close bonds that only moderate cabin fever and exhaustion can foster. I can now see why, despite my childhood attempts, my parents never let me become nocturnal. One other highlight of the night shift was witnessing the beauty of the southern lights multiple nights in a row. Living in close quarters for an extended period of time has certainly been a formative experience unique to sailing, the space station and nursing homes. Fortunately, despite its challenges it has been a great joy and, as I am far from retirement, I look forward to heading to sea again soon.

21.5 Tatsu Monkman

University of Chicago



First of all I would like to thank Katelyn Schockman, Sebastien Bigorre, and the rest of the science team for inviting me to take part in this cruise. I have learned a great deal over these weeks and have found the practical challenges of observational oceanography both exhilarating and humbling. Particular thanks to Hayden Kinkade for letting me fumble with the LADCP and Jess McLaughlin for saving my neck when the LADCP's battery cable got yanked out of the power supply. I am grateful to my fellow day-shift watch standers, Maria and Ruth, and everyone in the computer lab for their humor, conversation, and for making every day enjoyable.

Over the last two months we in the R/V Thomas G. Thompson crossed the infamous Southern Ocean, taking physical and biological samples along the previous I08S meridional transect. Our sample line ran north from the Antarctic Continental Shelf, across the southern tip of the Kerguelen Plateau, and further north across the Australian-Antarctic Ridge, ending a degree or two north of our port of departure, Perth Australia. The I08S transect thus cuts a meridional cross section of the Southern Ocean, excepting for the small eastward excursion across the tip of Kerguelen Plateau.

The Southern Ocean is a fascinating place for a physical oceanographer. With the absence of a meridional continental barrier in Drake Passage powerful westerly winds blow unimpeded in a great counterclockwise circle around Antarctica. Surface drag by these winds transfers zonal momentum to the ocean surface, driving the Antarctic Circumpolar Current and the large-scale northward Ekman transport of Southern Ocean surface waters. The divergence that develops at the surface of the Southern Ocean is so strong that it can only be balanced by the transport of deep ocean water from the northern basins to the Southern Ocean surface along sloped isopycnals. This wind-driven upwelling is a defining feature of our modern ocean, ventilating the abyssal ocean and driving the Atlantic Meridional Overturning. The transect we have collected in I08S gives us a snapshot of these dynamics, and will be invaluable to future researchers studying the Southern Ocean's response to a changing climate.

The same environment that makes the Southern Ocean a dynamic and energetic region pose practical challenges for observations. During an average 6 hour period there are around 37 cyclones in existence between 30 and 70 degrees South, and these storms delayed us on both the southward transit and the northward sampling phase. Along the way we battled seasickness, 10 meter waves, boredom, and the difficult tradeoffs that come with reconciling ambitious scientific goals with an uncooperative and dangerous environment.

Our modern understanding of the ocean circulation is thus built off of long hours of hard work in difficult environments. I am humbled to have met and worked with the many talented scientists and and crew who make these efforts possible. Thank you!

APPENDIX

A

CALIBRATION DOCUMENTS

Sea-Bird Scientific
13431 NE 20th Street
Bellevue, WA 98005
USA

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

SENSOR SERIAL NUMBER: 0381
CALIBRATION DATE: 29-Sep-23

SBE 9plus PRESSURE CALIBRATION DATA
10000 psia S/N 58952

DIGIQUARTZ COEFFICIENTS:

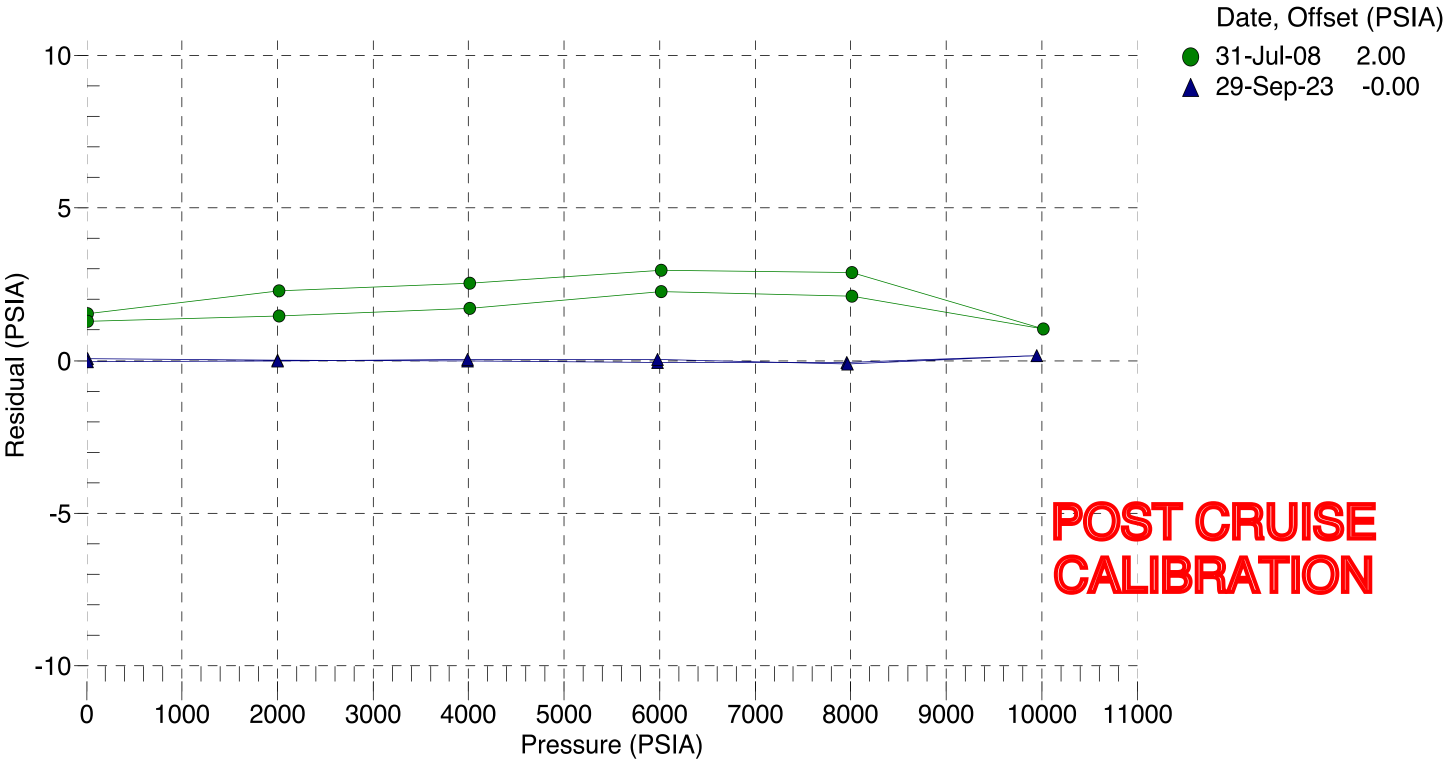
C1 = -5.136813e+004
C2 = 1.927312e-001
C3 = 1.549040e-002
D1 = 4.234600e-002
D2 = 0.000000e+000
T1 = 3.002156e+001
T2 = -2.996327e-004
T3 = 4.043490e-006
T4 = 2.578570e-009
T5 = 0.000000e+000

AD590M, AD590B, SLOPE AND OFFSET:

AD590M = 1.28081e-002
AD590B = -9.41513e+000
Slope = 1.00007
Offset = 1.0611 (dbars)

PRESSURE (PSIA)	INSTRUMENT OUTPUT (Hz)	INSTRUMENT TEMPERATURE (°C)	INSTRUMENT PRESSURE (PSIA)	CORRECTED PRESSURE (PSIA)	RESIDUAL (PSIA)
14.466	33319.10	25.3	12.997	14.536	0.070
2000.750	33956.10	25.3	1999.087	2000.762	0.012
3987.804	34579.60	25.4	3985.975	3987.786	-0.018
5974.889	35190.10	25.4	5972.878	5974.825	-0.064
7961.999	35788.30	25.4	7959.855	7961.939	-0.060
9949.903	36375.10	25.5	9947.844	9950.064	0.161
7963.048	35788.60	25.5	7960.842	7962.926	-0.122
5975.422	35190.30	25.5	5973.500	5975.448	0.026
3988.339	34579.80	25.5	3986.567	3988.378	0.039
2001.346	33956.30	25.5	1999.653	2001.328	-0.018
14.465	33319.10	25.6	12.899	14.438	-0.027

Residual (PSIA) = corrected instrument pressure - reference pressure



POST CRUISE CALIBRATION

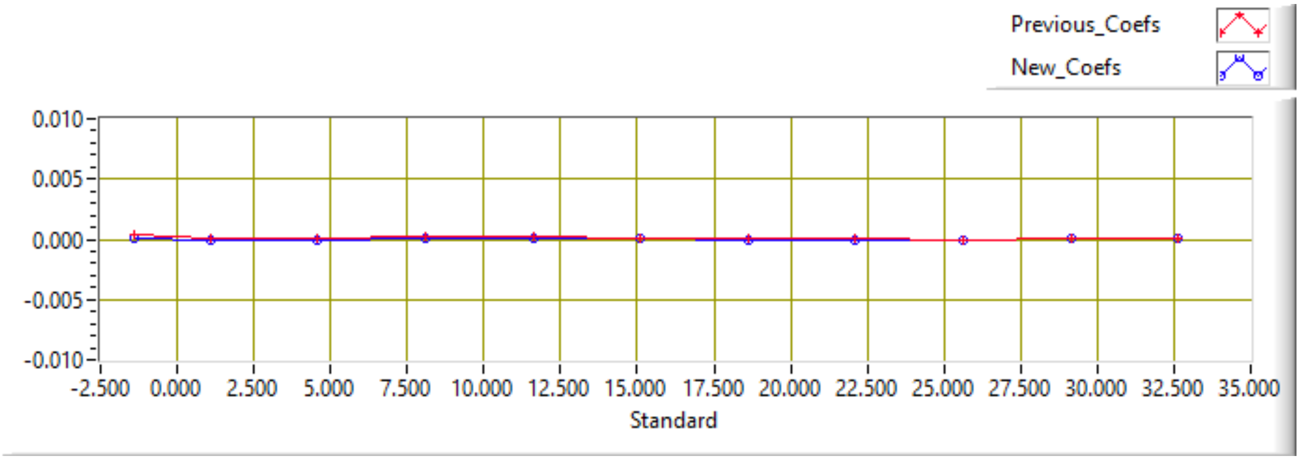
Temperature Calibration Report
STS Calibration Facility

SENSOR SERIAL NUMBER: 6049
CALIBRATION DATE: 29-Dec-2023
Mfg: SEABIRD   Model: 03
Previous cal: 19-Jul-23
Calibration Tech: CAL

ITS-90_COEFFICIENTS	IPTS-68_COEFFICIENTS ITS-T90	
g = 4.31232946E-3	a = 4.31251314E-3	
h = 6.26694788E-4	b = 6.26897382E-4	
i = 1.95103632E-5	c = 1.95409690E-5	
j = 1.45732339E-6	d = 1.45865864E-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
2827.9400	-1.4326	-1.4328	0.00037	0.00013
2993.7135	1.0714	1.0716	0.00005	-0.00015
3237.5352	4.5778	4.5780	0.00002	-0.00012
3495.5216	8.0861	8.0860	0.00018	0.00007
3768.0806	11.5955	11.5954	0.00020	0.00011
4054.8378	15.0968	15.0967	0.00012	0.00004
4357.7788	18.6092	18.6093	0.00003	-0.00004
4676.1650	22.1194	22.1194	0.00007	-0.00000
5010.7997	25.6317	25.6318	-0.00001	-0.00008
5361.4445	29.1404	29.1404	0.00008	0.00002
5729.1776	32.6524	32.6524	0.00007	0.00002



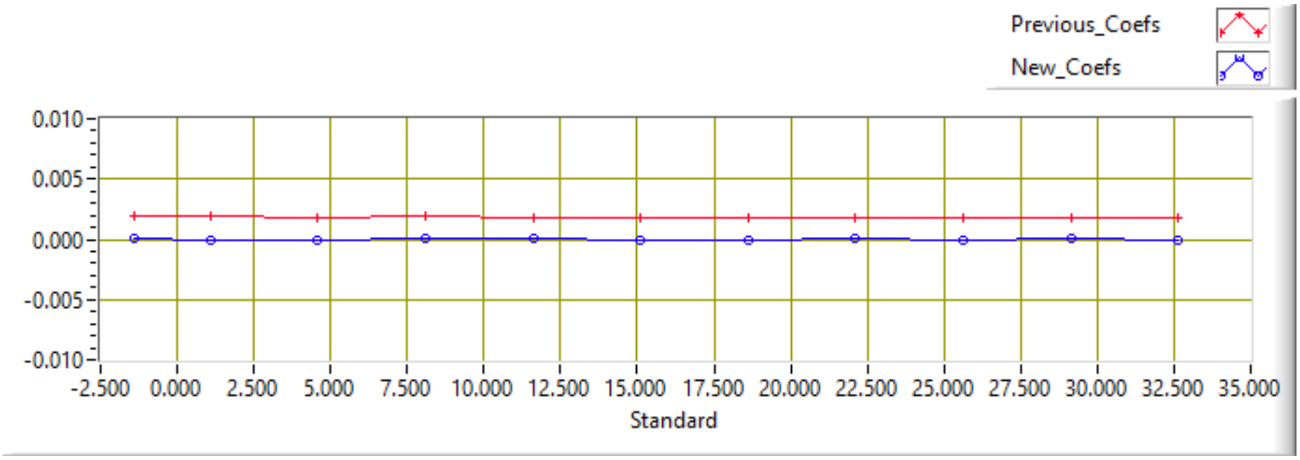
Temperature Calibration Report
STS Calibration Facility

SENSOR SERIAL NUMBER: 5987
CALIBRATION DATE: 29-Dec-2023
Mfg: SEABIRD Model: 03
Previous cal: 19-Jul-23
Calibration Tech: CAL

ITS-90_COEFFICIENTS	IPTS-68_COEFFICIENTS ITS-T90	
g = 4.35815041E-3	a = 4.35834885E-3	
h = 6.40402795E-4	b = 6.40612921E-4	
i = 2.27119954E-5	c = 2.27441454E-5	
j = 2.05620991E-6	d = 2.05771238E-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
2994.9187	-1.4326	-1.4327	0.00201	0.00004
3168.3197	1.0714	1.0715	0.00188	-0.00005
3423.2063	4.5778	4.5779	0.00182	-0.00005
3692.6881	8.0861	8.0860	0.00189	0.00006
3977.1585	11.5955	11.5954	0.00186	0.00006
4276.2054	15.0968	15.0969	0.00171	-0.00008
4591.8453	18.6092	18.6092	0.00179	0.00000
4923.3156	22.1194	22.1193	0.00182	0.00004
5271.4064	25.6317	25.6318	0.00172	-0.00006
5635.8322	29.1404	29.1403	0.00182	0.00004
6017.6897	32.6524	32.6524	0.00175	-0.00001



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SENSOR SERIAL NUMBER: 1744
CALIBRATION DATE: 12-Dec-23

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

COEFFICIENTS:

g = -4.09999755e+000
h = 4.66706435e-001
i = -1.38123069e-003
j = 8.97171433e-005

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

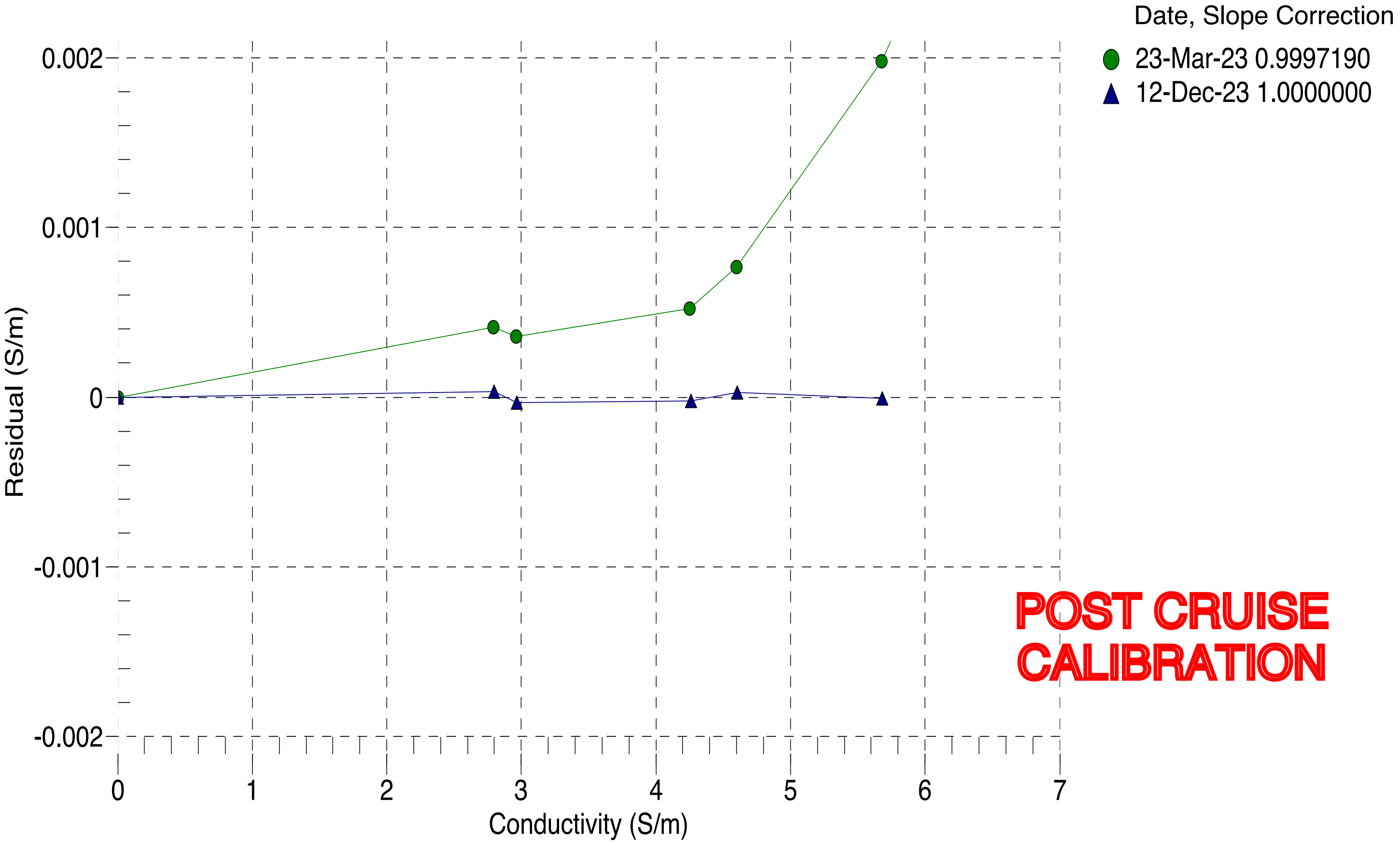
BATH TEMP (° C)	BATH SAL (PSU)	BATH COND (S/m)	INSTRUMENT OUTPUT (kHz)	INSTRUMENT COND (S/m)	RESIDUAL (S/m)
0.0000	0.0000	0.00000	2.97452	0.00000	0.00000
-1.0000	34.7088	2.79672	8.33644	2.79675	0.00003
0.9999	34.7086	2.96763	8.55537	2.96759	-0.00003
15.0000	34.7066	4.25958	10.05492	4.25956	-0.00002
18.5000	34.7041	4.60509	10.41852	4.60512	0.00003
28.9999	34.6902	5.68397	11.47711	5.68397	-0.00001
32.5000	34.6653	6.05263	11.81584	6.05226	-0.00037

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



POST CRUISE CALIBRATION

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www.seabird.com

SENSOR SERIAL NUMBER: 4545
CALIBRATION DATE: 12-Dec-23

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

COEFFICIENTS:
g = -9.98131027e+000
h =   1.43929443e+000
i = -3.91639720e-003
j =   3.82555825e-004

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

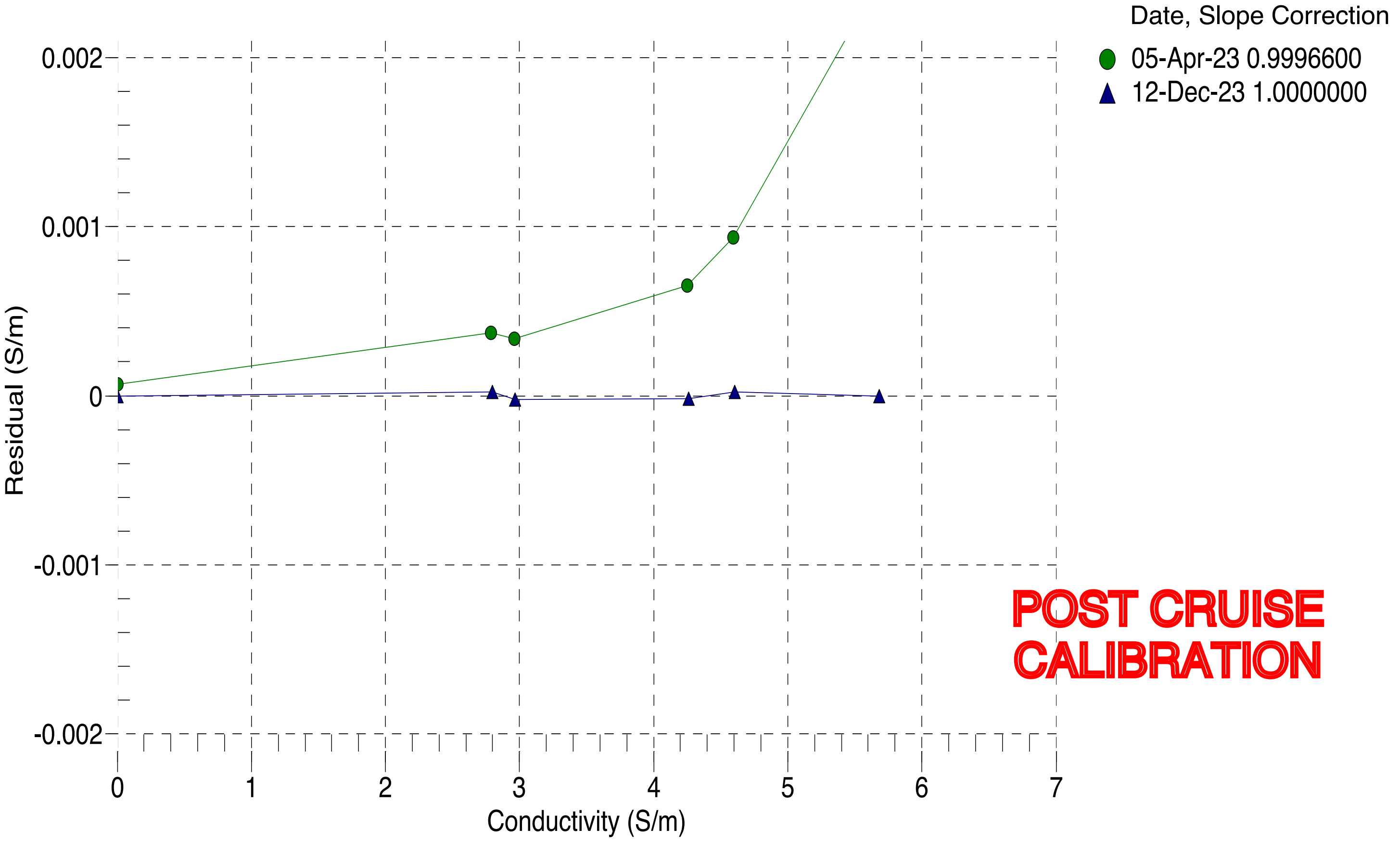
BATH TEMP (° C)	BATH SAL (PSU)	BATH COND (S/m)	INSTRUMENT OUTPUT (kHz)	INSTRUMENT COND (S/m)	RESIDUAL (S/m)
0.0000	0.0000	0.00000	2.64046	0.00000	0.00000
-1.0000	34.7088	2.79672	5.15277	2.79675	0.00002
0.9999	34.7086	2.96763	5.26749	2.96760	-0.00002
15.0000	34.7066	4.25958	6.06452	4.25956	-0.00002
18.5000	34.7041	4.60509	6.26033	4.60511	0.00002
28.9999	34.6902	5.68397	6.83511	5.68397	-0.00000
32.5000	34.6653	6.05263	7.02040	6.05235	-0.00028

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



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seabird@seabird.com
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SENSOR SERIAL NUMBER: 3207
CALIBRATION DATE: 07-Dec-23

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

COEFFICIENTS:
g = -1.01279705e+001
h = 1.35739608e+000
i = 5.43010832e-004
j = 3.24854806e-005

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

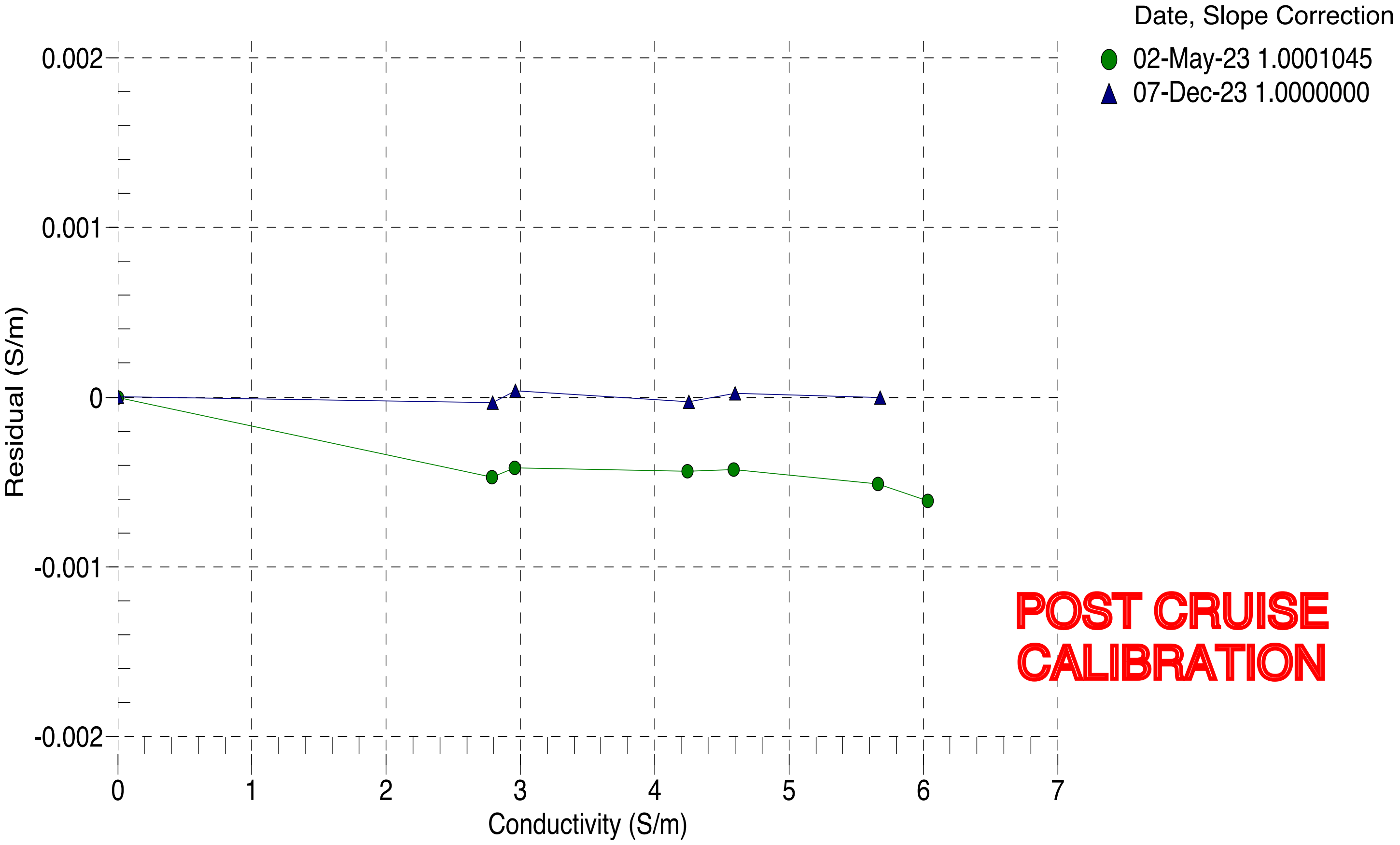
BATH TEMP (° C)	BATH SAL (PSU)	BATH COND (S/m)	INSTRUMENT OUTPUT (kHz)	INSTRUMENT COND (S/m)	RESIDUAL (S/m)
0.0000	0.0000	0.00000	2.72981	0.00000	0.00000
-1.0000	34.6458	2.79212	5.28705	2.79209	-0.00003
1.0000	34.6456	2.96276	5.40416	2.96280	0.00004
15.0000	34.6475	4.25309	6.21799	4.25306	-0.00003
18.5000	34.6467	4.59829	6.41817	4.59831	0.00002
29.0000	34.6417	5.67693	7.00658	5.67693	-0.00000
32.5001	34.6320	6.04749	7.19721	6.04681	-0.00068

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



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

SENSOR SERIAL NUMBER: 2766
CALIBRATION DATE: 07-Dec-23

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

COEFFICIENTS:
g = -1.02381305e+001
h = 1.43610180e+000
i = -2.61197707e-004
j = 1.01893594e-004

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

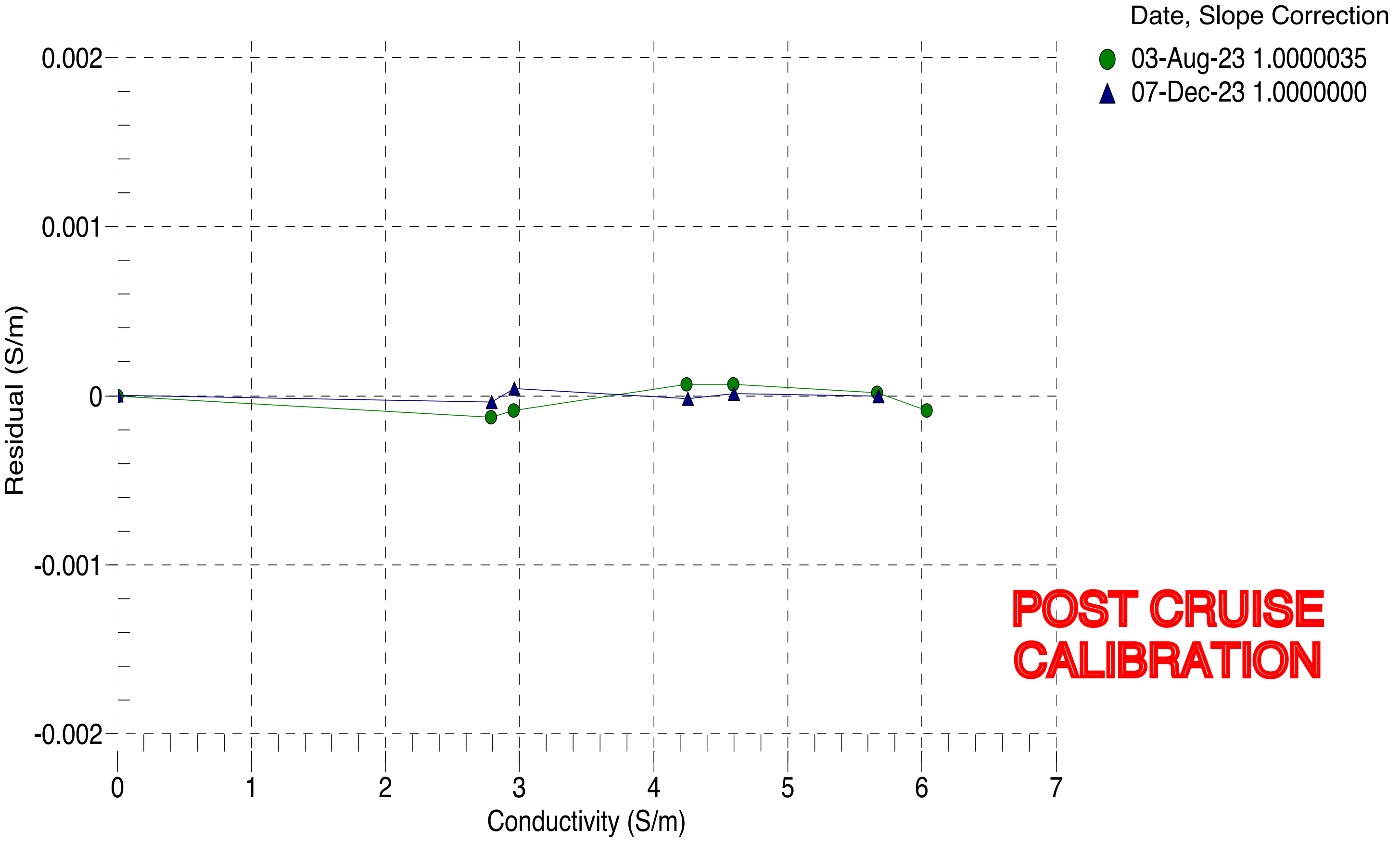
BATH TEMP (° C)	BATH SAL (PSU)	BATH COND (S/m)	INSTRUMENT OUTPUT (kHz)	INSTRUMENT COND (S/m)	RESIDUAL (S/m)
0.0000	0.0000	0.00000	2.67001	0.00000	0.00000
-1.0000	34.6458	2.79212	5.15228	2.79208	-0.00004
1.0000	34.6456	2.96276	5.26612	2.96280	0.00004
15.0000	34.6475	4.25309	6.05730	4.25307	-0.00002
18.5000	34.6467	4.59829	6.25191	4.59830	0.00001
29.0000	34.6417	5.67693	6.82400	5.67693	-0.00000
32.5001	34.6320	6.04749	7.00932	6.04680	-0.00069

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



POST CRUISE CALIBRATION

Temperature Calibration Report
STS Calibration Facility

SENSOR SERIAL NUMBER: 0011
CALIBRATION DATE: 04-Jan-2024
Mfg: SEABIRD   Model: 35
Previous cal: 06-Jul-23
Calibration Tech: CAL

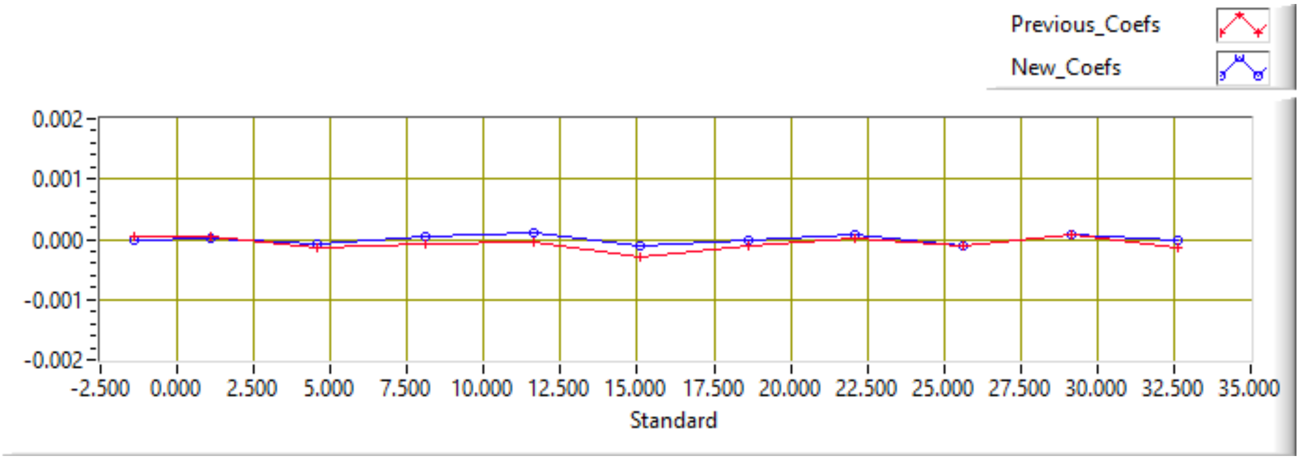
ITS-90_COEFFICIENTS

a0 = 5.561004676E-3
a1 = -1.551579941E-3
a2 = 2.231440745E-4
a3 = -1.227693046E-5
a4 = 2.583187299E-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
787807.8185	-1.4329	-1.4329	0.00005	0.00000
705235.5041	1.0711	1.0711	0.00004	0.00002
605309.0005	4.5778	4.5779	-0.00015	-0.00009
520904.9837	8.0860	8.0859	-0.00009	0.00005
449450.4345	11.5955	11.5954	-0.00006	0.00010
388961.6637	15.0971	15.0973	-0.00028	-0.00012
337369.1629	18.6096	18.6096	-0.00012	-0.00000
293426.4872	22.1196	22.1195	0.00003	0.00008
255848.5434	25.6319	25.6320	-0.00010	-0.00010
223701.9408	29.1395	29.1395	0.00008	0.00008
196051.0775	32.6519	32.6519	-0.00014	-0.00002



Sea-Bird Scientific
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SENSOR SERIAL NUMBER: 4479
CALIBRATION DATE: 24-Oct-23

SBE 43 OXYGEN CALIBRATION DATA

COEFFICIENTS:
Soc = 0.4263
Voffset = -0.5007
Tau20 = 1.13

A = -3.8189e-003
B = 1.6299e-004
C = -2.2295e-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

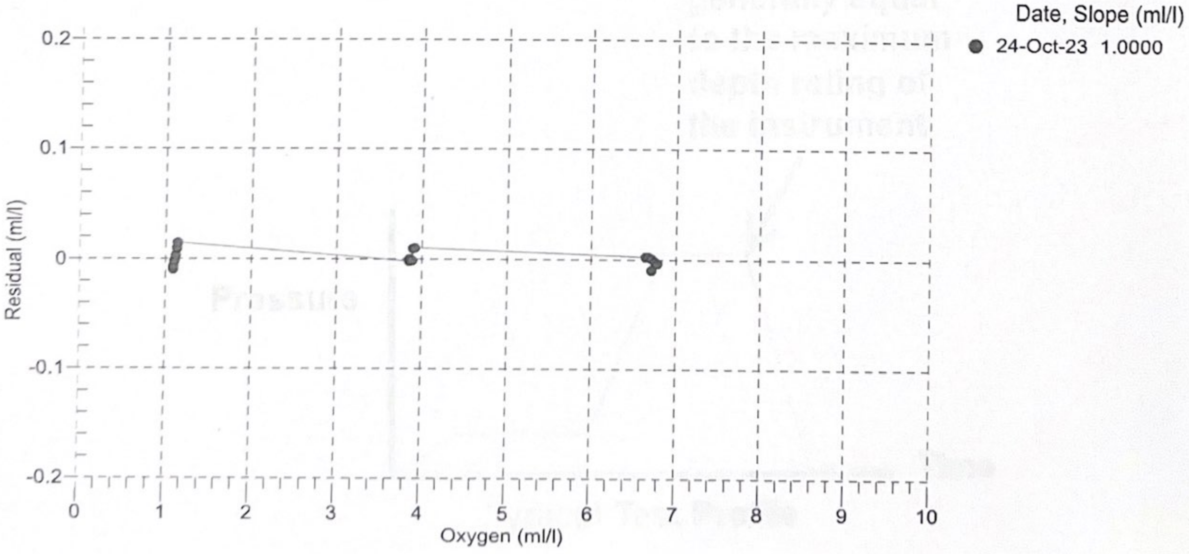
BATH OXYGEN (ml/l)	BATH TEMPERATURE (° C)	BATH SALINITY (PSU)	INSTRUMENT OUTPUT (volts)	INSTRUMENT OXYGEN (ml/l)	RESIDUAL (ml/l)
1.09	2.00	0.00	0.764	1.08	-0.01
1.09	6.00	0.00	0.799	1.09	-0.01
1.11	12.00	0.00	0.853	1.10	-0.00
1.12	20.00	0.00	0.928	1.12	0.00
1.13	26.00	0.00	0.986	1.14	0.01
1.14	30.00	0.00	1.027	1.15	0.01
3.85	2.00	0.00	1.440	3.85	-0.00
3.85	6.00	0.00	1.556	3.85	-0.00
3.87	12.00	0.00	1.737	3.87	-0.00
3.88	20.00	0.00	1.975	3.88	-0.00
3.90	26.00	0.00	2.161	3.91	0.01
3.92	30.00	0.00	2.292	3.93	0.01
6.64	2.00	0.00	2.122	6.64	0.00
6.68	6.00	0.00	2.331	6.68	0.00
6.71	12.00	0.00	2.645	6.71	0.00
6.71	30.00	0.00	3.559	6.70	-0.01
6.75	20.00	0.00	3.064	6.75	-0.00
6.78	26.00	0.00	3.382	6.78	-0.00

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

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

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

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



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C-Star Calibration

Date October 26, 2023 S/N# **CST-2559DR** Pathlength 25 cm

	Analog output	Digital output		
$\mathbf{V_{dark}}$	**0.009 V**	**0 counts**		
$\mathbf{V_{air}}$	**4.802 V**	**15754 counts**		
$\mathbf{V_{ref}}$	**4.702 V**	**15425 counts**		
Temperature of calibration water			**22.2**	°C
Ambient temperature during calibration			**21.7**	°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: $\mathbf{c = -1/x * \ln (Tr)}$

$\mathbf{V_{dark}}$	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.

CALIBRATION CERTIFICATE

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.

Instrument

Instrument Serial Number

Calibrated By

Certificate Number

Date

Signed

This summary certificate should be kept with the instrument.

Altimeter Build and Calibration Record

Instrument type	Altimeter
Serial number	88426
Baud rate set ex factory	9600

Calibration History:	Certificate	Date
	79400	19/10/2023

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
PSU board	0430502	D1	1067174													
Micro board	0430501	E0	1066949	ACTEL 0430707												
				ATMEL 0430704A16												
Transducer Assembly	500kHz		48627	100m												

Name E.Laight	Name	Name	Name
Date 16/10/2023	Date	Date	Date
Signed	Signed	Signed	Signed

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

Instrument Serial Number	**88426**
Sensor Type	**500kHz**
Altimeter Range (m)	**100m**
Certificate Number	**79400**

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	1469.325

Input SOS value to the altimeter using: **#830;1469.3250**

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	1	0	Pass
5	5	0	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:	19/10/2023

Sea Bird Altimeter Setup, Test & Check Instructions	Document: 0430840 Revision: A Issued: 11/12/2013	Page #: 1 of 2	VALEPORT

Serial Number	Contract Number	Calibration Number
88426	37285	79400

1 SEA BIRD SPECIFIC SETUP COMMANDS

Command	Description	Initial When Done
#059;9600<cr><lf>	Sets baud rate to 9600	EL
#034<cr><lf>	Should return correct instrument serial number	EL
#082;BENTHOS<cr><lf>	Sets Benthos data output string	EL
#094;0<cr><lf>	Sets 0 – 5V analogue output	EL
#095<cr><lf>	Reads the analogue output setup	EL
#089<cr><lf>	Reads current output format	EL
#032<cr><lf>	Should return (0430704A16) as the firmware version	EL
M4<cr><lf>	Sets continuous sampling at 4Hz	EL
#083;0<cr><lf>	Turns off pressure output	EL
#824<cr><lf>	Reads maximum set range	EL
#0841<cr><lf>	Reads minimum set range	EL

2 FINAL CHECKS

Description	**Initial When Done**
Verify that Calibration and warranty documents are provided	EL
Verify that running supply current is between 100 and 140mA at 12V (.137mA.)	EL
Pressure test to 100bar for 30 minutes	EL
Check that resistance between 0V supply (Pin 6) and body is >1MΩ	EL
Ensure main serial number is engraved on the Altimeter housing	EL
Check that the sensor is adequately packed in its transit case before being boxed	EL

3 SIGNATURE

I verify that the instrument referred to in this document has been assembled, tested and checked according to the procedure defined herein, and is ready for shipment to the customer

Signature:………. ....

Print Name:…………ELLIS LAIGHT...................

Date:……………20th October 2023 ....

CALIBRATION CERTIFICATE

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

JFE Advantech Co., Ltd.

Temperature Calibration Certificate

Model : ARO-CAV
Serial No. : 0296
Date : August 24, 2022
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 ℃.

1. Equation

Instrument temperature[℃] = $A+B\times V+C\times V^2+D\times V^3$ V: Instrument voltage[V]

2. Coefficients

A = −5.300923e+00
B = +1.669897e+01
C = −2.175381e+00
D = +4.669594e−01

3. Calibration results

Reference temperature [℃]	Instrument voltage [V]	Instrument temperature [℃]	Residual error [℃]	Acceptance [℃]	OK/NG
2.839	0.51862	2.840	0.001	±0.020	OK
9.763	1.00519	9.761	−0.002	±0.020	OK
16.374	1.49609	16.377	0.003	±0.020	OK
23.681	2.04022	23.679	−0.002	±0.020	OK
31.049	2.56158	31.049	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 [℃]	Instrument temperature [℃]	Residual error [℃]	Acceptance [℃]	Judgement
20.719	20.737	0.018	±0.020	Passed

Examined M. Akiyama

Approved M. Ujinaki

JFE Advantech Co., Ltd.

Dissolved Oxygen Calibration Certificate

Model : ARO-CAV
Serial No. : 0296
Date : August 25, 2022
Location : Production Section
Method : Calibration is performed with the nitrogen gas (zero) and the oxygen saturated water (span) kept by air bubbling.
Film No. : 220245BA

1. Equation

DO[%] =G+H × P'

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

2. Coefficients

A = −4.369925e+01
B = +1.387041e+02
C = −3.392487e−01
D = +1.044300e−02
E = +4.300000e−03
F = +6.810000e−05
G = +0.000000e+00
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	1004.0	0.00	−0.03	−0.03	±1.00	Passed
2nd	1004.0	0.00	−0.04	−0.04	±1.00	Passed
3rd	1004.1	0.00	−0.05	−0.05	±1.00	Passed

Test for DO 100 %

	Test condition			Instrument DO [%]	Residual error [%]	Acceptance [%]	Judgement
	Water T. [℃]	Atm. pressure [hPa]	Reference DO [%]				
1st	25.2	1003.5	99.01	99.16	0.15	±1.00	Passed
2nd	25.2	1003.5	99.01	98.98	−0.03	±1.00	Passed
3rd	25.2	1003.5	99.01	98.94	−0.07	±1.00	Passed

Examined M. FUJITA

Approved M. Ujinaki

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ECO Chlorophyll Fluorometer Characterization Sheet

Date: 1/7/2022   S/N: FLRTD-4333

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	0.063	0.035	0.021 V	43 counts
Scale Factor (SF)	7	13	27 µg/l/V	0.0082 µg/l/count
Maximum Output	4.99	4.99	4.99 V	16380 counts
Resolution	1.0	1.0	1.0 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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DISSOLVED INORGANIC CARBON (DIC) I08S 2024 (Fremantle to Fremantle)

PI's: Dr. Richard A. Feely (NOAA/PMEL) and Dr. Rik Wanninkhof (NOAA/AOML)
Technicians: Julian Herndon (UW-CICOES/NOAA-PMEL) and Alison MacLeod (UM/NOAA-AOML)

Final Data Submission Parameters (JH 02/21/2025):

Including the analytical replicates, 1,956 samples were analyzed from 66 CTD casts for dissolved inorganic carbon (DIC) on the I08S 2024 GO-SHIP cruise. Excluding the Niskins that were dedicated for biological analysis, 74% of the remaining available Niskins were sampled. Due to difficulties with the backup DICE instruments from PMEL and AOML deployed on this cruise (see DIC section of the cruise report) the instrument gas loops were not used as the primary calibrations for this dataset. Instead, the accuracy (instrument calibration) of DIC data reported relied on using a multiplicative correction of the sample counts to the counts of the Certified Reference Material (CRMs) supplied by the laboratory of Dr. A. Dickson at Scripps Institution of Oceanography (SIO). The average multiplicative correction applied across all the samples was 0.99867 with a range of +/- 0.01023. The two CRM batches used were 213 and 208 with values of 2024.67 and 2059.66 µmol/kg respectively. We collected replicate samples from 12% of the Niskins and these analytical replicates were analyzed near the beginning, middle and end of each cell to serve as a measure of precision. The combined difference from the mean of these replicate measurements was 1.01 µmol/kg (1.45 and 0.61 for each individual DICE).