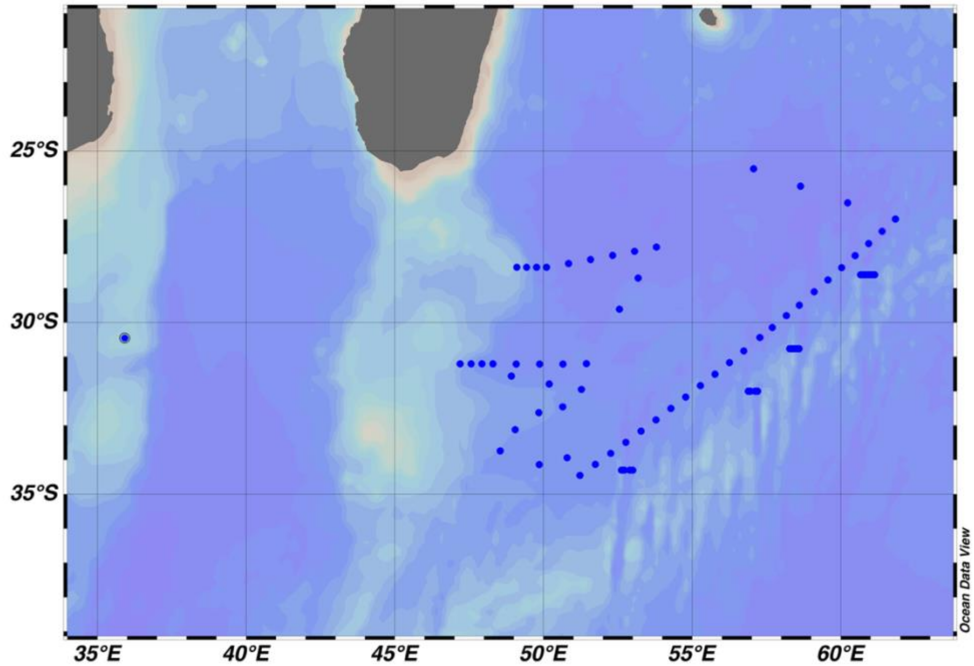
CRUISE REPORT: DMB_2023

Created: November 2025



Highlights

Cruise Summary Information

Section Designation	DMB_2023
Expedition Designation (ExpoCode)	**33RR20230409**
Chief Scientists	**Viviane Menezes, WHOI**
Dates	9 April – 13 May 2023
Ship	R/V *Roger Revelle*
Ports of Call	Cape Town, South Africa –,Port Louis, Mauritius
Geographic Boundaries	25° 52"S 35° 92"E 61° 84"E 34° 45"S
Stations	76
Floats and Drifters Deployed	11 Floats (5 Deep SOLOs, 4 Argo, 2 BGC)
Moorings Deployed and Recovered	5 deployments, 1 recovery (RAFOS float 1572)

Contact Information:

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Report assembled by Savannah Lewis

WHOI-2025-10

Deep Madagascar Basin Expedition Cruise Report

by
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Dan Torres, Jim Happell, Aaron Mau, Andrew Barna,
Megan Roadman, Kelcey Chung, Nick Matthews, Liisa Shangheta,
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Woods Hole Oceanographic Institution
Woods Hole, MA 02543

July 2025

Technical Report

Funding was provided by NSF Grants OCE-1924431 & OCE-2122964

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Approved for Distribution:

Young-Oh Kwon, Chair
Department of Physical Oceanography

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27 June 2025

Science Party

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Naval Observer	LTJG HERINDRAINY Jospin Radhasman	Malagasy National Navy	herindrainyradhasman@yahoo.com

In addition, the following programs joined us at sea as 'piggyback' science, or science from other institutions and funding sources that could be done without compromising the funded DMB program science goals:

Program	Affiliation	Contact
Core and BGC Argo	WHOI	Pelle Robbins, Aiden Thayer, Deb West-Mack, Bill Dullea
Scripps Deep Argo	SIO	Sarah Purkey, John Gilson, Nathalie Zilberman
NO_3/DON Isotopes	UCT	Sarah Fawcett, Tanya Marshall
eDNA	ARBRE	Estelle Crochelet, Natacha Nikolic, Océane Desbonnes
HPLC/POC	SIO	Susan Becker, Lynne Talley
PE Ridge Multibeam Survey	UKZN, SANBI	Andrew Green, Jock Currie, Kerry Sink

Acknowledgements

The science party of DMB-2023 would like to thank and acknowledge the crew of the R/V *Roger Revelle*, without which the scientific objectives would not be possible. We thank the National Science Foundation (NSF) for supporting the DMB cruise through Grants OCE-1924431 and OCE-2122964.

Duty	Name
Master	Captain David Murline
Chief Mate	Heather Galiher
2nd Mate	Trey Jackson
3rd Mate	Henry Kraus
Chief Engineer	John Clifford
1st A/E	Susan Swader
2nd A/E	Geoff Dickgieser
3rd A/E	James Gallagher
Boatswain	Joseph Martino
A/B	Brandon Ignacio
A/B	Brian Nellis
A/B	Teva Kurth
O/S	James Hopkins
Electrician	Shaun Morris
Oiler	Gabriel Bisconner
Oiler	Jake Pate
Oiler	Robert Juhasz
Oiler	Chandler Chamberlain
Wiper	Kristen “Fievel” Woetzel
Sr. Cook	Robin “Twinki” Allen

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Section 1. Cruise Narrative

1.1 Overview: Scientific Objectives and Background

The DMB-2023 cruise, aboard the UNOLS vessel R/V Roger Revelle, took place from April 9 to May 13, 2023, as a key component of the “Deep Madagascar Basin (DMB) Experiment – A Quest to Find the Abyssal Water Pathways in the Southwest Indian Ocean”, a project funded by the National Science Foundation (NSF).

The DMB Experiment aims to understand the still largely unknown abyssal circulation of the Madagascar Basin in the Southwest Indian Ocean (Figure 1.1), how abyssal temperature varies within the basin interior, and how the complex seafloor topography shapes the abyssal circulation patterns there. The primary objective is to determine the pathway(s) by which younger abyssal water of southern origin, entering the basin through deep fracture zones on the Southwest Indian Ridge (SWIR), spreads northward across the basin. This knowledge is essential for characterizing the Indian Ocean Meridional Overturning Circulation (IMOC) and its variability.

The experiment focuses on two existing and conflicting hypotheses in the literature about the abyssal circulation patterns in the Southwest Indian Ocean. One hypothesis is that the southern-originating water, after entering the Madagascar Basin through the SWIR deep fracture zones, is mainly transported northward by a narrow, continuous, and permanent Deep Western Boundary Current along the Madagascar Plateau on the western side of the basin (Figure 1.1). The second hypothesis is that northwestward interior flows between 30°S and 23°S also exist and contribute to the northward spreading of the younger, southern-originated abyssal water across the basin.

The DMB Experiment includes a fieldwork component, which this report details, along with a state-of-the-art modeling component, both of which are used to investigate the fundamental dynamics and development of the deep flow field. The specific goals of the overall experiment are to:

1. Determine the pathways of the abyssal water entering the Madagascar Basin through the SWIR fracture zones in observations and model simulations, and investigate the physical mechanisms that control those pathways— e.g., lower-layer potential vorticity, bottom topography, and eddies;
2. Statistically evaluate the abyssal circulation obtained from the model simulation against the in situ observations;
3. Quantify the time scales associated with the younger abyssal water pathways and the residence time of these waters in observations and models;
4. Determine the variability of temperature, salinity, and layer thickness of the SWIR-originated abyssal water;
5. Characterize the abyssal temperature variability in sub-annual time scales as a baseline to better understand the temperature changes obtained from repeat hydrographic sections;
6. Quantify the primary sources of abyssal water to the Madagascar Basin and test the hypothesis of whether the Cape Darnley site (65°E-69°E) contributes to the Madagascar Basin using particle tracking simulations.

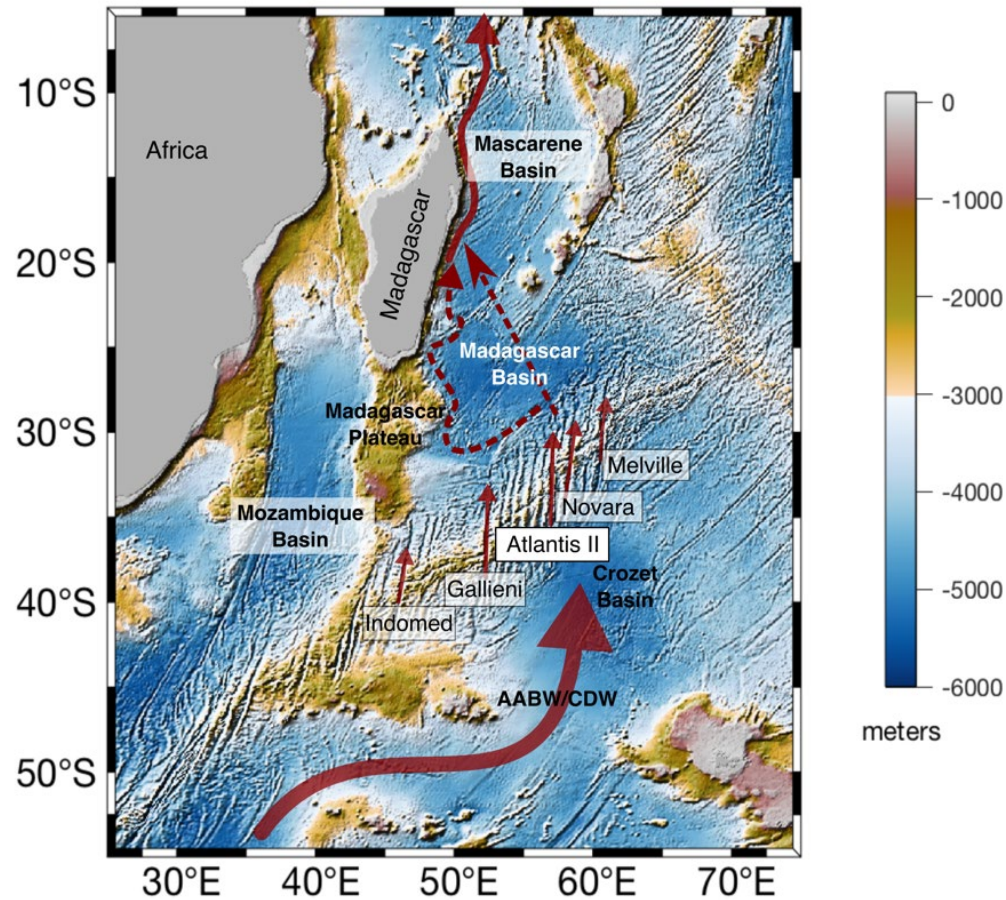


Figure 1.1. Schematic diagram of abyssal circulation in the Southwest Indian Ocean and main bottom features. AABW stands for Antarctic Bottom Water, and CDW for Circumpolar Deep Water.

COVID-19 significantly impacted the DMB Experiment, which began a few months before the pandemic's onset in 2020. The pandemic and its related effects caused an unprecedented delay in all DMB scientific activities, especially those involving the DMB implementation described here, as all US scientific cruises were halted due to the pandemic. Although the pandemic subsided earlier in the US, it persisted much longer in Cape Town, South Africa, and Port Louis, Mauritius, the two home ports used for the DMB cruise. As a result, the cruise took place in 2023, more than three years after the project started, and several adjustments had to be made to the original plan due to technological, financial, and logistical challenges caused by the pandemic.

The DMB-2023 cruise had three separate components to better achieve the overall project goals. The first component included surface-to-bottom and high-quality CTD-O (Conductivity, Temperature, Depth, Oxygen)/LADCP (Lowered Acoustic Doppler Current Profiler)/tracer stations, aimed at characterizing circulation and water mass properties in key basin areas, as described below. The second component involved deploying the first Deep SOLO (Sounding Oceanographic Lagrangian Observer) floats in the basin to collect time series of temperature and salinity in the abyss, focusing on the SWIR fracture zones. The third component involved setting up a sound source mooring array and deploying acoustic-tracked deep RAFOS floats to track the possible presence of the Deep Western Boundary Current along the Madagascar Plateau.

Aside from the DMB-related activities, the cruise also supported another project of ours, also funded by NSF, titled "EMC Experiment: Examining the fate of the East Madagascar Current." While the DMB concentrates on the abyss, the EMC focuses on surface circulation. Its main goal is to determine whether the detached East Madagascar Current (EMC) near the southern tip of Madagascar retroflects eastward toward the South Indian Countercurrent (SICC) and/or breaks into a series of mesoscale (possibly dipolar) eddies that move westward across the Mozambique Basin (Figure 1.2) using a Lagrangian framework. For the EMC Experiment, the Madagascar government graciously granted permission to operate in its Exclusive Economic Zone (EEZ) and sent a Malagasy naval observer to accompany the DMB-2023 cruise operations.

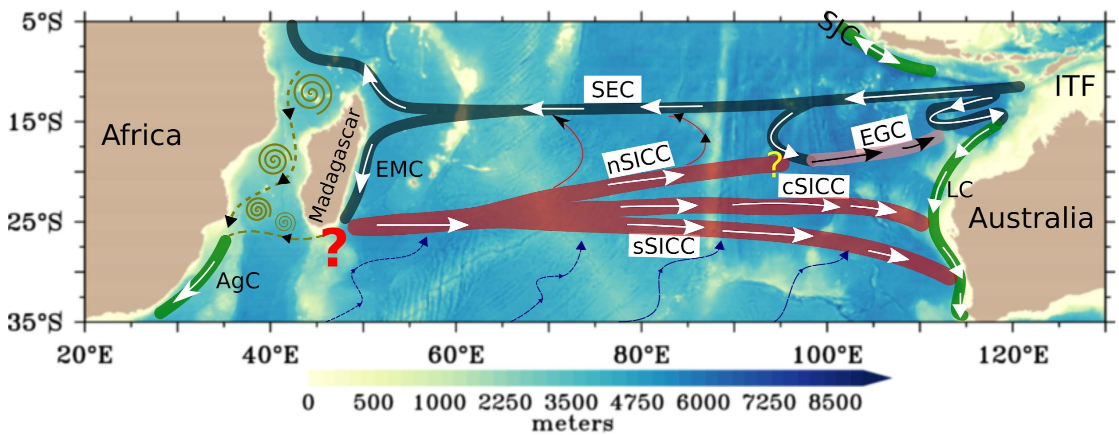


Figure 1.2. South Indian Ocean upper-layer circulation (modified from Menezes et al., 2014a). Currents indicated are the three branches of the South Indian Countercurrent (northern [nSICC], central [cSICC], and southern [sSICC]), the South Equatorial Current (SEC), the East Madagascar Current (EMC), the Agulhas Current (AgC), the seasonally reversing South Java Current (SJC), the Eastern Gyral Current (EGC), and the Leeuwin Current (LC). Blue shadings show bathymetry. The question mark symbol marks the general region to be investigated in the EMC Experiment.

During the DMB-2023 cruise, as part of EMC, we planned to release 20 surface drifters and 10 subsurface isopycnal RAFOS floats at the thermocline level into the core of the East Madagascar Current (22°S; 48.28°E-48.91°E). This would be the first of four releases. Unfortunately, due to the problems with the delayed arrival of our containers in Cape Town, which caused a 3-day late departure, a medical evacuation, and weather days that halted operations, we were unable to reach the Madagascar shelf break to release the surface drifters and isopycnal RAFOS floats at the Eastern Madagascar Current as initially planned. In the end, we decided to release 15 surface drifters in two longitudes at the SICC (green arrows in Figure 1.3) for a dispersion study (the SICC was well defined at that time, both in satellite altimetry maps and real-time Shipboard ADCP data) and deploy five triplets of drifter/RAFOS float stacked vertically in a strong anticyclonic eddy near Madagascar (green squares in Figure 1.3). To track the isopycnal RAFOS float in the Mozambique Basin, the EMC Experiment added a sound source mooring to the DMB array (M1 in Figure 1.3). Complementary to these Langrangian measurements, Shipboard ADCP (SADCP) observations were also collected and processed to obtain high-quality data, as described in the SADCP Section.

Additionally, we opened the DMB-2023 cruise to the broader oceanographic community and coordinated with colleagues to deploy their assets and conduct piggyback projects during the cruise. These included the

Argo and BGC groups, Scripps (for the deployment of two additional Deep SOLOs as part of their program), University of Cape Town (collection of additional biogeochemistry data), University of KwaZulu-Natal and South African National Biodiversity Institute (multibeam survey of Port Elizabeth Ridge), and Agence de Recherche pour la Biodiversité à La Réunion (environmental DNA).

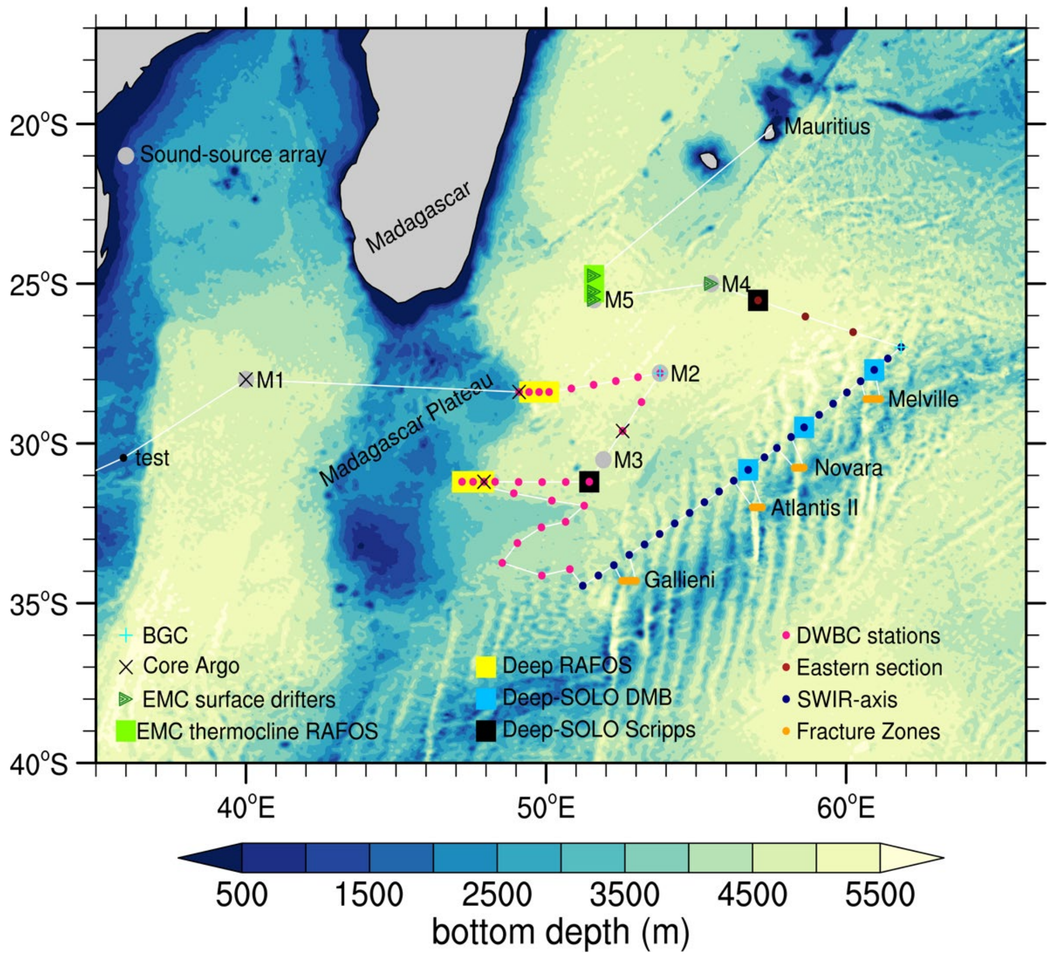


Figure 1.3. Cruise track (white line) in the Mozambique and Madagascar Basins in the Southwest Indian Ocean and the DMB-2023 main activities (as depicted in the legend).

Together, the DMB and EMC projects supported 11 early-career scientists (ECRs) on the DMB-2023 Cruise for training. Six of these ECRs were specifically from countries in Southwest Africa (South Africa, Namibia, Mozambique, Madagascar, and Reunion Island). Three ECRs were from the UK, one from the US, and one from Brazil (Figure 1.4).

Figure 1.4. The science party posing in front of the R/V Revelle in Cape Town prior to departure.

1.1.1 CTD-O/LADCP/tracer Stations

Stations were established to cover key regions of potential pathways for abyssal water originating from the Southern Ocean, as identified from model simulations. The cruise track was then optimized to include the maximum number of stations possible under the cruise length while also encompassing the Deep SOLOs and RAFOS/mooring array component activities. Ultimately, 76 CTD-O/LADCP/tracers' stations were occupied across four domains (Figure 1.3):

1. **Western Boundary** to capture the Deep Western Boundary Current along the Madagascar Plateau. A total of 28 stations were occupied in this domain (pink dots in Figure 2). The two quasi-zonal sections (28.39°S and 31.2°S) have a spatial resolution of about 20 nm near the boundary and roughly 40 nm elsewhere. The northern section connecting the Madagascar Plateau (3863 m) to the M2 sound source mooring includes 9 stations, while the southern section at 31.2°S (initial bottom depth of 3630 m) consists of seven. The quasi-meridional section connecting the two sound source mooring positions (M2 and M3 in Figure 1.3) aimed to evaluate whether the off-boundary signature of younger abyssal waters could be identified. Stations in this slanted section are about 50 nm apart. South of 31.2°S, stations followed the 4000 m isobath along the Madagascar Plateau. The 4000 m isobath was obtained from the 2023 GEBCO (General Bathymetric Chart of the Oceans) gridded data. The stations were selected manually following the bathymetry, resulting in variable distances between them (38.9 to 80.6 nm).

2. **SWIR central axis** (X-Section). Section parallel to the central axis of the Southwest Indian Ridge to capture the entrance of younger abyssal water through the SWIR deep fracture

zones (navy blue dots in Figure 1.3). The X-Section extends from 34.452°S-51.224°E to 26.986°S-61.836°E (roughly 683 nm), and is composed of 23 stations with a nominal spatial resolution of 30 nm. It covers all SWIR deep fracture zones.

3. **Cross-trench sections**. High spatial resolution sections (4-5 nm) in the SWIR deep fracture zones interior, to capture less mixed, younger abyssal water, which has just been exported from the Southern Ocean. The selected fracture zones (Fz) included Gallieni, Atlantis II, Novara, and Melville (orange dots in Figure 1.3). A total of 22 stations were surveyed along these cross-trench sections. At each latitude, the longitudinal extent of a Fz was determined using GEBCO 2023 data before the cruise.
    i. Gallieni Fz is one of the most southwestward SWIR deep fracture zones, and has a much more complex bottom topography compared to Atlantis II, Novara, and Melville, according to GEBCO 2023 gridded data. No measurements of abyssal water properties existed in this Fz before the DMB-2023 cruise. The Gallieni section comprises six stations located at 34.30°S (52.525°E-53°E).
    ii. Atlantis II Fz was chosen because it is well known that younger abyssal water enters through this zone. It is regarded as the main pathway for the IMOC. Five stations were occupied in the Atlantis II Fz at 32°S (56.88°E to 57.2°E).
    iii. Novara Fz is a neighbor of Atlantis II and shares a similar bottom bathymetry; however, there were no measurements of abyssal water properties before the DMB-2023 cruise, and no information was available on whether younger water was also exported from the Southern Ocean through it. The Novara section includes five stations at 30.76°S (58.277°E-58.594°E).
    iv. Melville Fz was selected because seminal studies from the seventies suggested that younger abyssal water might enter through this fracture zone, although no additional measurements have been taken since then. Melville is the most northeastward of the SWIR fracture zones. The Melville section consisted of 6 stations at 28.61°S (60.66°E-61.138°E).

4. **Eastern Section**. This section aimed to characterize the physical properties on the eastern side of the basin to identify signs of younger abyssal water. However, due to our late departure from the port, medical evacuation, and weather delays, the Eastern section had a significantly lower spatial resolution (100 nm) than planned, with only three stations (indicated by brown dots in Figure 1.3). When we had to reduce the number of stations due to limited available time, we chose to cut stations in the Eastern Section, as the GO-SHIP I07N cruise covered a higher-resolution meridional section (30 nm) in the basin's central part (54.5°E) in 2018. By combining the DMB and GO-SHIP I07N data, we can still achieve the original proposal goals. The three locations in the Eastern Section were determined by the two endpoints (the end of the X-section and M4).

To accommodate the LADCP on the Rosette, we had to remove two 10L Niskin bottles, which are used for sampling water at discrete vertical levels. Therefore, tracers (Chlorofluorocarbons (CFC-11 and -12), Sulphur Hexafluoride (SF_6), salts, oxygen, silicate, phosphate, nitrate, and nitrite) were collected at up to 22 discrete depths, instead of the originally planned 24. However, the resolution in the deep ocean (below

3000 m) was maintained as planned, despite the reduction in the number of bottles. Discrete samples in the deep ocean were about 300 m apart.

1.1.2. DMB Deep SOLOs

Three Deep SOLO floats were deployed at the northern end of each SWIR deep fracture zone, where younger abyssal water is likely to intrude the Madagascar Basin (Atlantis II, Novara, and Melville). Deep SOLOs are a relatively new technology manufactured by MRV Systems and rated to 6000 dbar. They measure thermohaline water properties over almost the entire water column in a much higher temporal resolution (days) compared with traditional shipboard observations (years to decades). The solid blue squares in Figure 1.3 indicate the deployment locations, which align with the CTD-O/LADCP/tracer stations used to calibrate Deep SOLO salinity measurements, currently affected by a pressure-dependent freshening bias. Unfortunately, during the DMB-2023 cruise, the Atlantis float was accidentally deployed 67.8 km west of the center of the Atlantis II fracture zone, as indicated in Figure 1.3. The DMB Deep SOLOs are configured to collect data with a high vertical resolution (5 dbar) in the deep ocean (> 3000 dbar) and at more frequent timescales (3-5 days) than current regional arrays. Because bathymetry in our target region is very complex, our Deep SOLO floats have been closely monitored, and configuration is often adjusted via Iridium communication when the floats are at the surface. These are the first Deep SOLO floats operating over a rough terrain. Refer to the Profiling Floats Section for more information.

1.1.3. DMB RAFOS floats & Sound Source Mooring Array

Initially, we planned to deploy 75 acoustically tracked isobaric RAFOS floats ballasted for 4000 dbar in the Madagascar Basin to map the abyssal circulation. However, due to persistent mechanical issues faced by these floats, we conservatively deployed only 22 of them during the DMB-2023 cruise. These floats were ballasted for shallower depths (3000 dbar) and aimed to observe the Deep Western Boundary Current along the Madagascar Plateau. They were deployed near the Madagascar Plateau at CTD-O/LADCP/tracer stations, with local bottom depths ranging from 3600 to 4690 m (solid yellow squares in Figure 1.3). A detailed description can be found in the RAFOS Floats Section.

To track the RAFOS floats, a sound source mooring array composed of 5 moorings (M1-M5) fabricated at WHOI was implemented (grey dots in Figure 1.3). M1 is specifically positioned to track the EMC isopycnal RAFOS floats that reach the Mozambique Basin. See the Mooring Deployments Section for a detailed description of the array.

1.2 Cruise Narrative

The R/V Roger Revelle departed from Cape Town, South Africa, on April 9, 2023, at 12:00 local time (UTC+2) (Figure 1.5a). The departure was three days late (initially scheduled for April 6) because our two containers did not arrive on time, despite being shipped from Woods Hole to reach Cape Town approximately one month before the cruise. This delay was a consequence of the COVID-19 pandemic, which has disrupted the global container shipping industry. Since almost all the gear for the DMB and EMC activities were in those containers, we had to wait patiently in Cape Town. The mobilization began on April 8 at 10:00 a.m. local time, as soon as the containers were released from customs (Figure 1.5b), and relied on the hard work of the entire scientific team to accomplish in one day what was planned to take two.

(a) (b)

Figure 1.5. DMB Cruise: (a) Departure from Cape Town, South Africa on April 9, 2023; (b) Arrival of the DMB Containers on April 8, 2023.

Due to this unexpected late departure, we decided not to release the EMC floats and drifters at 22°S, as our calculations showed that we wouldn't be able to reach our end port in Mauritius (Port Louis) on time (May 13). Our calculations indicated that we needed to sail directly from the last mooring position (M5) to Port Louis (Figure 1.3). We informed the Malagasy Naval Observer before departure, who chose to participate in the cruise despite the fact that we would not be working inside the Madagascar EEZ.

(a) (b)

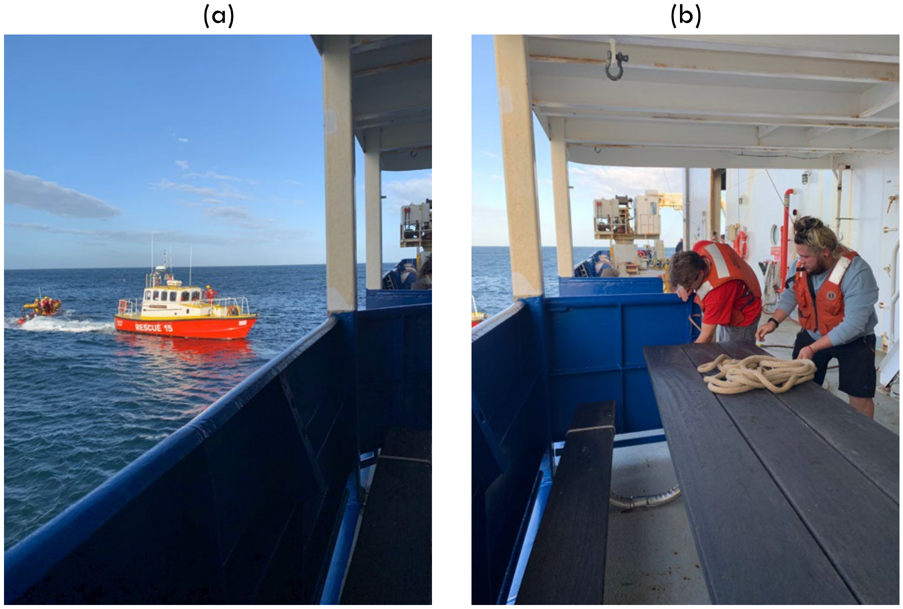


Figure 1.6. Medical Evacuation on April 10, 2023.

Due to exhausting work on the dock and deck all day on the April 9, during the Ship Safety Briefing in the Main Lab, just a few hours after our departure, one of our ECRs from the University of Cape Town, who was going to conduct a piggyback project, fainted and hit their head hard against the floor. Captain Murline and crew members with emergency medical training promptly assessed the situation. Considering the strong desire of the ECR to stay on the cruise and the fact that they were feeling well, we decided to continue sailing to our test station in the Mozambique Basin (Figure 1.3). The next day, the weather turned rough, and many ECRs felt extremely seasick, especially the ECR who fainted. The situation worsened over time. After discussions with Captain Murline and medical doctors on land, the best course of action was to return to land for a medical evacuation, arranged by the ECR supervisor in Cape Town to take place in Mossel Bay (Figure 1.6). While preparing for the evacuation of the science party member, the Chief Steward also experienced a medical issue requiring evacuation. Upon arriving in Mossel Bay, three people were transferred to a small boat (another ECR had decided to disembark due to seasickness) and taken ashore, where ambulances were waiting. All three recovered. However, because of this, we had to sail with only one cook, Twinki, who did an incredible job keeping everyone fed throughout the cruise (Figure 1.7). The DMB Cruise wouldn't have been successful without her.

Figure 1.7. Twinki, who kept us going, solo.

After this detour, which caused us to lose another working day, we finally set sail for our test station in the Mozambique Basin. While *en route*, we conducted a multibeam survey of the Port Elizabeth Ridge as a piggyback project with our colleagues at the University of KwaZulu-Natal and the South African National Biodiversity Institute. The multibeam survey lasted approximately 9 hours.

We arrived at the test station (30.45°S; 35.87°E; bottom depth of 1770 m), located outside the South African EEZ, in the early hours of April 14 (local time). We have finally left the bad weather behind (Figure 1.8). At the test station, all rosette-attached electronic sensors were tested, and all bottles were fired. ECRs received training from ODF (Ocean Data Facility)/Scripps on how to operate the system. During this cruise, ODF was responsible for CTD operations and onboard analysis of salts, dissolved oxygen, and major nutrients, as described in later sections of this report. Water collected at discrete depths was used to set up the labs. No noticeable problems occurred during our test station.

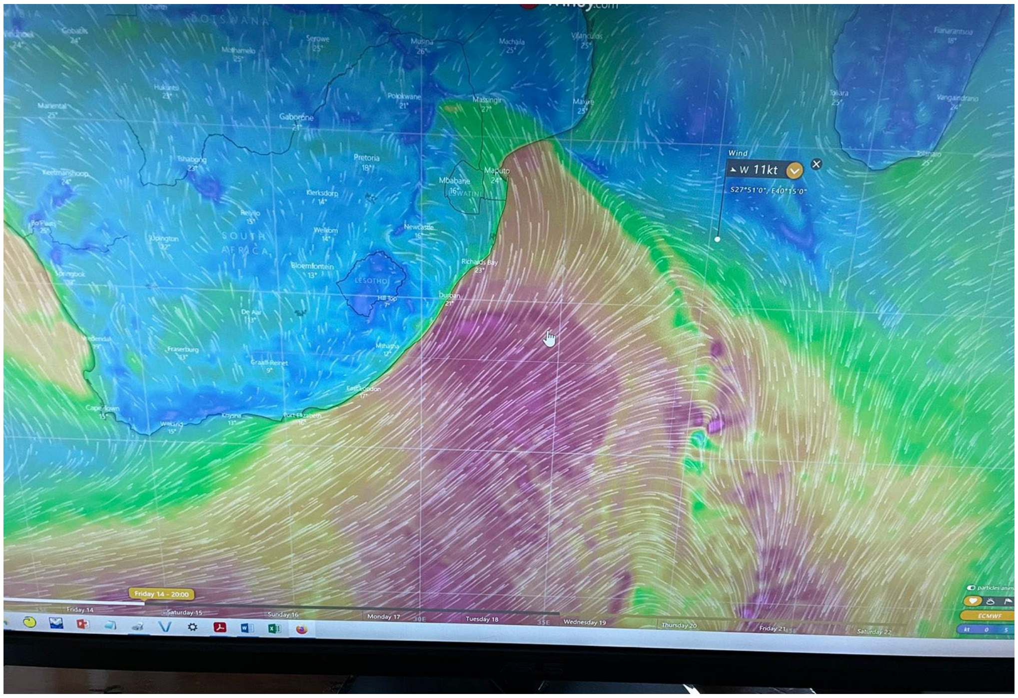


Figure 1.8. Weather forecast for April 14, 2023, from Windy.com based on the ECMWF Weather Forecast Model. Marked on the map is the Test Station position.

Following the success of the test station, we continue to sail towards the first mooring implementation in the central part of the Mozambique Basin (Figures 1.3, 1.9). We reached the mooring position on April 14 at around 13:00 (local time) under calm weather conditions. After the successful mooring work, the first Core Argo float was deployed with the help of our ECRs. Details about the mooring and Argo float deployment can be found at the respective sections in this report.

We reached our first CTD-O/LADCP/tracer station on the eastern side of the Madagascar Plateau at 02:00 am on April 16 (local time). The station went smoothly, and on leaving the station, a second Core Argo float was deployed. We then sail to our next station at the quasi-zonal line at 28.39°S, where we performed two casts: one for CTD-O/LADCP/tracer measurements and another for the eDNA sampling, a piggyback project from the Agence de Recherche pour la Biodiversité à La Réunion. We deployed the first DMB RAFOS floats at this station as described in detail in the RAFOS section of this report.

Figure 1.9. The Early Career Researchers were phenomenal. Vatasoa Raheriarilala is pictured helping during the first mooring deployment.

Activities in Stations #3 and #4 were similar to Station #2, except that there were no eDNA dedicated casts. In leaving stations, additional DMB RAFOS were released (Figure 1.3). Stations #5-8 also went smoothly, given the gorgeous weather.

After Station #8, which took place on April 18 at 6:00 a.m. local time, we discovered that two of the DMB RAFOS floats that had been released the previous day had resurfaced. Following intense discussions, we decided to return and attempt to rescue at least one of these floats, taking advantage of the perfect weather conditions. The issues with the DMB RAFOS floats have troubled us over the past few years, and recovering the floats provided an opportunity to analyze what went wrong. However, we knew it would be difficult to locate them, like searching for a needle in a haystack. Led by Andy Davies, we located one of the resurfaced RAFOS floats with the first light on April 19 and successfully recovered it, as detailed later. After this incredible luck, we did not attempt to go further back to find the second float. The downside is that we lost an additional day of CTD stations.

Following the successful RAFOS recovery mission, we returned to our quasi-zonal section and sailed to Station #9, where we also deployed our second mooring (Figure 1.3). Leaving the station, we deployed the first of two BGC floats on the late hours of April 19. There were no significant issues at the next couple of stations, but on Station #11, a catastrophic failure of the winch occurred during the Rosette recovery in the early hours of April 21. The third Core Argo float was deployed on leaving Station 11.

Despite the winch failure, we sailed to Station #12, where the mooring M3 would be deployed. There was some miscommunication between the science party and the crew about when the mooring operation would start. We planned to start at sunrise, while the crew assumed we would start as soon as we arrived at the station. After an intense discussion, mooring preparation started, but its deployment only occurred after sunrise. The mooring operation was successful and ended in the afternoon. After the mooring deployment, the winch was still not ready for rosette deployment, and the CTD hangar required cleaning due to unsafe conditions caused by the hydraulic fluid. Ultimately, we aborted the Rosette operation on Station #12 and switched the deployment of the Scripps Deep SOLO float to Station #13. Thus, there is no station #12 in the data files.

Although hydraulic fluids were still present (Figure 1.10), which required attention, operations could resume at Station #13. The first of two Scripps Deep SOLO floats was deployed while leaving the station.

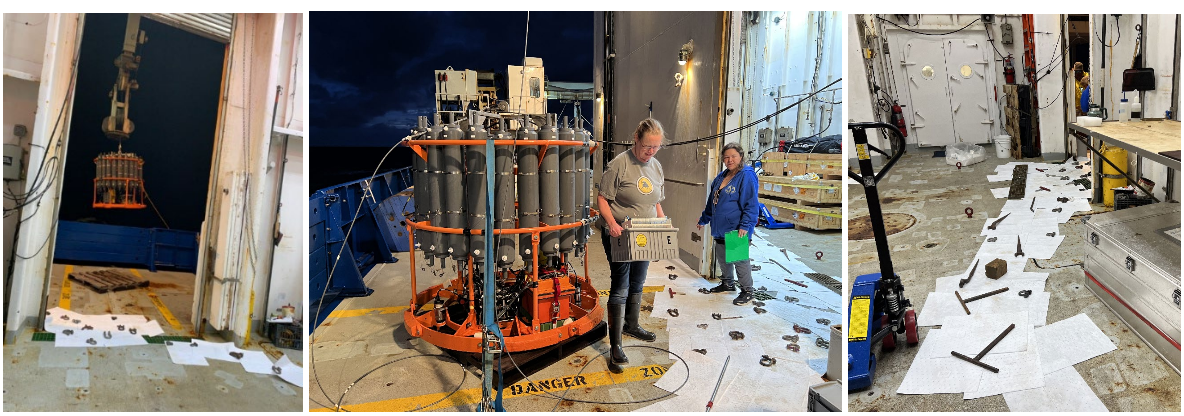


Figure 1.10. Rosette recovery on Station #13. Oil absorbent pads are on the floor due to slippery deck conditions resulting from the hydraulic fluid leakage at Station #11.

After this incident, the operations were smooth overall. On Station #18, we deployed the last of the Core Argo floats and another batch of DMB RAFOS floats near the Madagascar Plateau from Station #18 to

#20 (Figure 1.3). As the ship approached the southern latitudes, sea conditions began to worsen, resulting in a few delays along the way. On April 26, at Station #27, we initiated the X-section. Along the way, we entered four deep SWIR fracture zones (Gallieni, Atlantis II, Novara, and Melville) to perform sections of much higher resolution (Figure 1.3). Due to a combination of circumstances as previously described, we lost several working days. Given the reduced time available for these fracture zone sections, we decided to collect tracers only at one station out of every two, as the stations were very close in space. In all fracture zones, we favored the deepest stations for tracer collection. Unfortunately, CFC/SF6 sampling was compromised in a few stations in the fracture zones due to issues with the system, as described later. Despite that, we were able to collect at least 1 CFC/SF6 profile in each fracture zone.

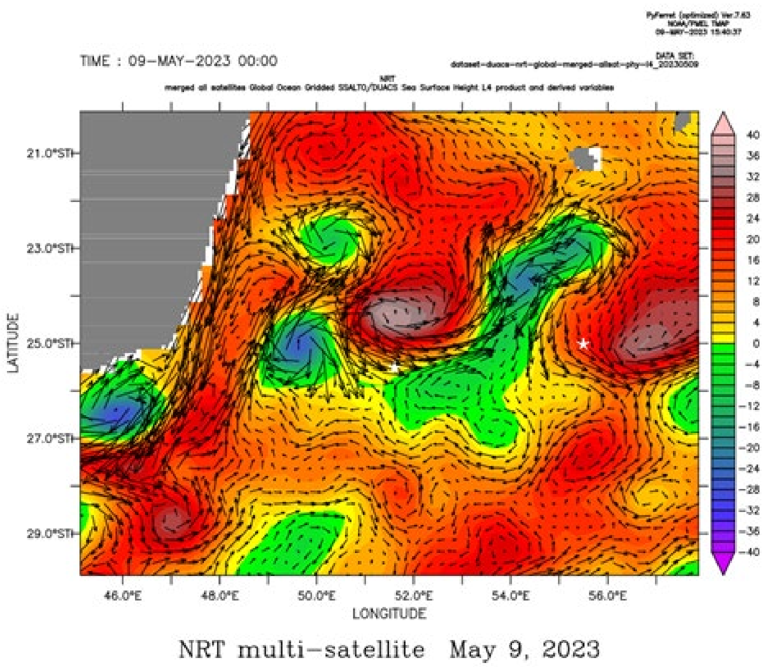


Figure 1.11. Near-Real-Time (NRT) multi-satellite altimeter for May 9, 2023, plotted on May 10, 2023. Colors indicate current speeds in cm/s and vectors their directions. White stars show the M5 (western) and M4 (eastern) mooring positions.

At the northern end of Atlantis II, Novara and Melville, we deployed our Deep SOLO floats (one float for each fracture zone). Accidentally, the Atlantis Deep SOLO was deployed on Station #61 instead of #62. On Station #74 (May 8, 2023), we deployed the second of the two BGC floats.

At the end of the X-section, we had to make some decisions on how best to use the remaining cruise time, as we wouldn't be able to complete the entire plan. For the DMB, we cut most stations of the Eastern Section, focusing on the fourth and fifth mooring deployments (Figure 1.3). For the EMC, using near-real-time satellite altimetry data, we identified two regions near the mooring deployments with features of interest: a meander of the SICC near M4 and an anti-cyclonic eddy just north of M5 (Figure 1.11). To study these features, we divided the EMC assets as follows: (i) seven surface drifters deployed in the SICC meander at the M4 position, all deployed together for a dispersion study; (ii) eight concurrent surface drifters at M5 on the edge of the anticyclonic eddy, also targeting dispersion; (iii) five surface drifters and ten isopycnal EMC RAFOS floats north of M5 within the anticyclonic eddy, as described in the RAFOS Section.

After deploying the last surface drifters and EMC isopycnal RAFOS floats, we sailed directly to Port Louis, Mauritius, where we arrived on Saturday, May 13, 2023, around 16:00 (local time; Figure 1.12). Since the port did not operate on weekends, our demobilization took place on Monday and Tuesday. However, the science party decided to disembark on May 13.

Figure 1.12. (upper) Science party at end of cruise. (lower) R/V Revelle in Port Louis, on May 13 16:53 (local time), by the end of the DMB-2023 cruise.

Section 2. Mooring deployments

Team Leader
Andrew Davies, WHOI

An array of five moorings was deployed to support underwater tracking of RAFOS floats. Each mooring was equipped with a single sound source, nominally placed at 1250 m depth, at approximately the sound speed maximum to enhance sound propagation. The sources are the URI-Valdes configuration, and emit a low-frequency 286 Hz 80-second-long signal two times per day. All sources deployed had been previously used in the OSNAP program. Mooring deployments were led by Andy Davies, assisted by Research Technician Josh Manger. Frank Bahr and Heather Furey helped with the winch and tag lines. Students helped with A-frame, recording times on the clipboard, and with photo documentation (Lois Baker, Lizzie Ellison, Liisa Shangheta, Nick Reynard, Rouane Brokensha, Vatosoa Aratra; Oceane Desbonnes, Gesica Canivete).

2.1 Deck Setup for Deployment Operations

A TSE winch from the West Coast Winch Pool was used for all of the mooring operations and was located behind the hangar on center with the A-frame. To run a traveling block system, a large Ingersoll Rand EU air winch was mounted to the deck just behind one side of the A-frame. The air winch line was then passed around the main trawl sheave on the frame and attached to a large snatch block. This allowed the block to be set at different heights off the deck during the deployments. Deck cleats were mounted on each side of the working area for stopper lines that ran up to an 8" snatch block near the TSE. The anchors were secured on the starboard side of the A-frame inside metal tracks. An HTOT 20' container with removable top was placed forward of the HIAB crane for storage of glass balls and wire spools during the cruise.

2.2 Mooring Deployment Operations

The upper sections of the DMB moorings utilize 3/16" (5mm) 3 x 19 plastic-jacketed galvanized wire rope supplied by the WHOI Mooring Lab, with an outer diameter of 6.5 mm, and swaged sockets to fit ½" shackles. Lower portions consist of 3/8" Yalex 12-stand line, with spliced eyes, and galvanized thimbles. All of the wire and line was pre-wound onto the TSE drum with 500 pounds of tension using a WHOI supplied cart. The multiple sets of (4) glass balls on chain used for top flotation were craned out of the container using the ship's HIAB crane. The sets were all then connected together and attached to the wire on the TSE prior to the deployment during deck setup. At the start of the deployment, the top flotation was slipped overboard using the lines and cleats. Once all the glass was clear of the ship, the wire was stopped off, the Sound Source was moved into position and fastened in-line. The traveling block was then raised high off the deck, the TSE and A-frame were used to hoist the source and lower it to the water. These methods were used for all the flotation and sound source deployments. The mooring wire was then payed out, stopping occasionally to remove protective canvas wraps and install stainless steel cotter pins. For the connections on the Yalex line, the cotter pins were double bent and wrapped with electrical tape to prevent any snags during the deployment. Once the end of the mooring line was reached, two stopper lines were attached, and the block was removed and set aside. The final section of 5m 3/8" mooring chain was attached to a 2333 lb. anchor and the end of the wire. The TSE winch leader was passed up through the large sheave on the A-frame, with a quick release attached, and used to pick the anchor up with two tag lines attached to each side to prevent sway. Once in position, the anchor was lowered into the water and released. As there were no acoustic releases present on the moorings, no survey operations were conducted post-deployment.

Note on shackle shortage: we almost ran out of ½" shackles. This is due to two causes: (1) There is no hardware designation on the sound source in the morning drawings, and each source needs 6 additional ½" shackles. Andy Davies will talk to Chris Ross and correct this. In the past, Jim Valdes would have asked for these shackles to be included. (2) The additional shot added to compensate for the varying seafloor depth needed ½" shackles to connect to mooring.

Note on deployment: We found it helpful to wrap the bridle chains on the side of the source with the Tygon sheaths. This helped the bridle stay untangled while the source was being moved around on deck during deployment. The electrical tape was cut just before the source went over the transom. We also found it helpful to use a handcart, where the electronics pod was rested on a chock, to move the source into place on the aft deck. The source was then chocked as shown below– to support the electronics pod and prevent rolling.

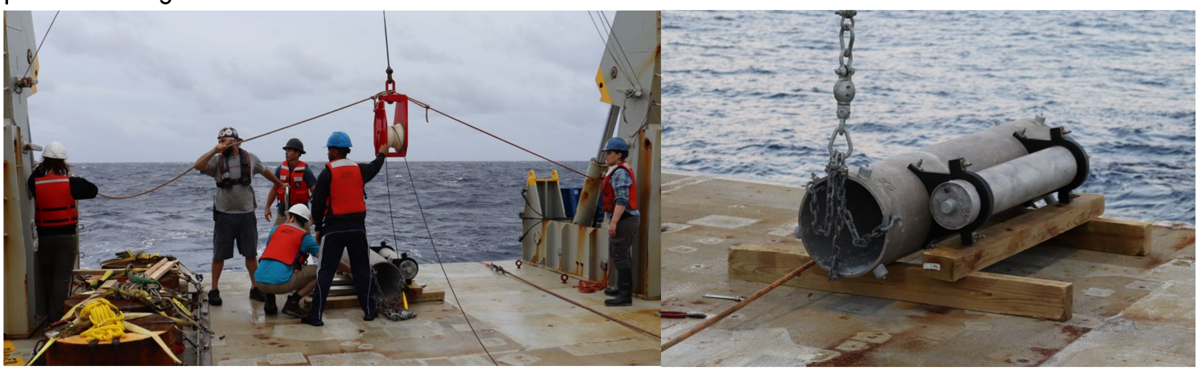


Figure 2.1. The chocking system for the sound source instrument during deployment.

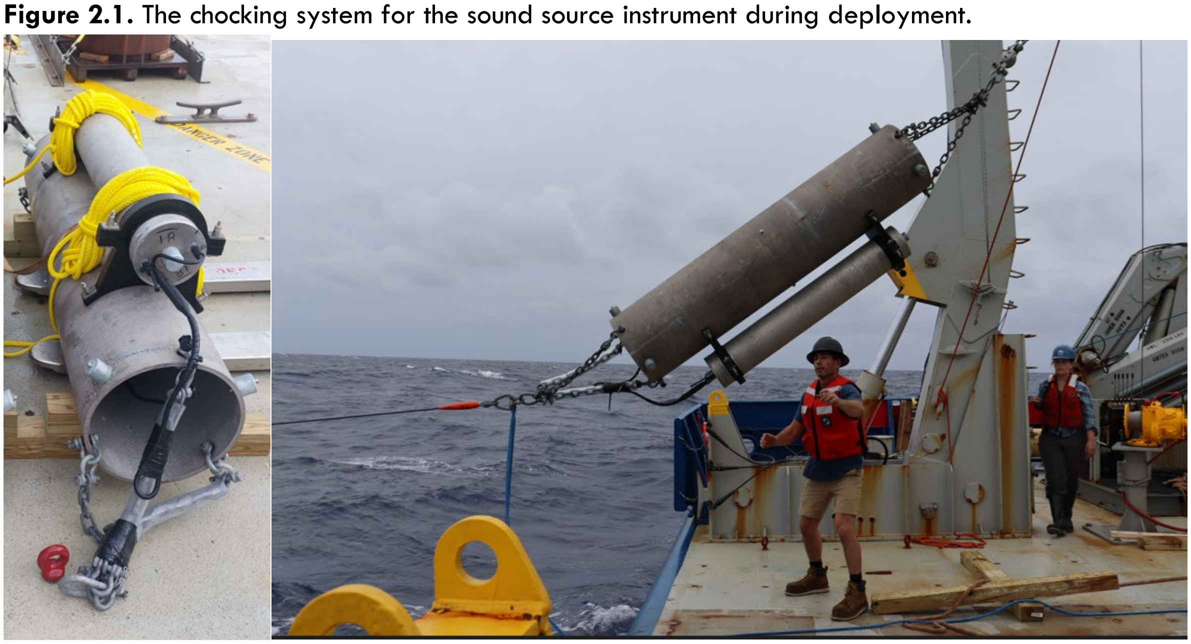


Figure 2.2. (left) The extra taping on the bridle, and (right) co-chief looking on while the mooring lead keeps things under control.

Mooring M1

Mooring M1, in the Mozambique Basin, was deployed on 14 April 2023. The mooring, along with all other moorings on this cruise, are single instrument sound source moorings. They are not equipped with acoustic releases and will not be recovered. The seafloor was smooth, and water depth was within 6 meters of target depth. The ship set up about 7 nm from target area to give a 3.5-hour window for deployment. The first floatation was over at 14:10LT, and the last wire was over at 16:36LT. The ship steamed for an hour to get to the target, and the anchor was dropped 500-m past target at 17:37LT. Total deployment time was 3 hours and 27 minutes.

The sound source deployed was serial number 87, with pong schedule 01:15 and 13:15 UCT. The source was initialized on 13 April 2023. Due to lightening and rain, the source was turned on later than hoped. The log file was saved and sent to J Valdes (WHOI), the engineer who built the sources, and he gave the OK to deploy. Vacuum and battery looked good, programmed schedule looked good, arming sequence looked good. Due to the co-chief scientist's error decoding UTC to local time, the initial pong was missed, and the source was deployed before the second pong transmitted, thus, no clock delay was recorded during listening. The decision to deploy despite not having heard a pong was supported by V. Menezes, Chief Scientist, and by co-PI A. Bower on land. We would have had to hold up a mooring deployment by several hours, run mooring deployment into the dark, and sound sources have been deployed before without the final '*in situ* listening' check.

Mooring M2

Mooring M2, in the central Madagascar Basin, was deployed on 20 April 2023. The seafloor was smooth, but the water depth was deeper than estimated, 5252 m measured on site, compared with 5209 m estimated prior to cruise, a 43-meter difference. Two 20-meter 3/16" lengths were added between the bottom 100 meter 3/16" wirerope and the 1/4" wirerope to keep the sound source as close to 1250-m as possible. We asked for a 3-hour steam time to deploy the mooring, knowing that the mooring was 500-m deeper and we had spent an hour steaming during M1. The ship set up about 7 nm from target area. The first flotation was over at 06:42LT, and the last wire was over at 09:15LT. This start time for the first flotation over the transom, which had been planned for 08:00LT, was rushed by the captain. The deck crew (Andy Davies, Josh Manger, Frank Bahr, Heather Furey) shook it off. A group meeting followed the deployment, and deck crew and captain met regularly before remaining mooring deployments. The ship steamed for about 30 minutes to get to the target, and the anchor was dropped 500-m past target at 09:49LT. Total deployment time was 3 hours and 5 minutes.

The sound source deployed was serial number 81, with pong schedule 00:15 and 12:15 UCT. The source was initialized, shut down, initialized, shut down, and initialized again due to delayed mooring deployment, which was due to RAFOS float recovery. Pong #2 was listened to and heard twice during the first and second startups, no clock delay was recorded during listening. There was no opportunity to listen to the pong on the final startup on 19 April 2023. The log files were saved and sent to J Valdes (WHOI), and he gave the OK to deploy. Vacuum and battery looked good, programmed schedule looked good, arming sequence looked good. Deployment of the source was modified by taping the three bridle legs together so they would not twist up during the deployment process. Additionally, the source was moved into place using the pallet jack and wooden chalks, which went much smoother than moving the source using the crane as was done on the first mooring deployment. One strong downpour occurred during the winch out phase of deployment.

Mooring M3

Mooring M3, in the southwest Madagascar Basin, was deployed on 21 April 2023. We anticipated that the seafloor would have a different bottom depth than estimated. We swapped the 100-m bottom 3/16" segment for a 50-m 3/16 m, and Andy pre-wound the mooring on the reel with the 50-m in place of the 100-m segment. We decided that it would be more efficient to adjust once we had a multibeam-measured bottom depth. The seafloor was smooth, and the water depth was shallower than estimated, 4874 m on initial drive-over of target position, compared with 4909 m estimated prior to cruise, a 35-meter difference. With the adjusted segment, the resulting depth of the sound source was 15 m deeper than estimated, and we decided this was acceptable tolerance. We asked for a 3-hour steam time to deploy the mooring, and the ship set up about 7 nm from target area. The first flotation was over at ~10:35LT, and the last wire was over at 12:48LT. The ship steamed for about 50 minutes to get to the target, and the anchor was dropped 500-m past target at 13:41LT. Total deployment time was ~3 hours and 6 minutes.

The sound source deployed was serial number 83, with pong schedule 00:30 and 12:30 UCT. Pong #2 was heard; no clock delay was recorded during listening. Vacuum and battery looked good, programmed schedule looked good, arming sequence looked good.

Mooring M4

Mooring M4 was deployed early morning 2023-05-10. Deck setup happened between 05:30-06:30LT, and first flotation was over at 06:35LT. Anchor drop occurred 2 hours and 36 minutes later, at 09:13LT. The ship had moved into mooring start position in the early morning hours, so a good estimate of depth at target was difficult. We estimated depth by looking back in the met data collected overnight, and by questioning the bridge for the time they steamed over target (04:45LT). The depth estimate was gleaned from the current day's *.met data file, which includes multibeam depth ('MB') saved every minute. The MB data saved during the passover was not good – 5124 m - the value did not make sense for the region we were in, and the values were static for too long a period to be trusted (not enough natural variability). The ETOPO2 estimate was 4814 m. We decided to add a 50 m shot, to raise the source higher. In the end, the depth values at the target were ~4970 m, deeper than expected. The sound source is therefore about 100 m deeper than planned. During deployment, the sound source came very close to pinching the power wire between the source and the resonator, due to a miscommunication between deck lead and winch operator. Andy had to manually lift the source at the deck edge, and the wire was not compromised. At the end of the deployment, a slippery line got wedged in an anchor shackle, and the line had to be cut. So, the anchor has a small section of blue line (2 meters?) still entangled in the hardware. The anchor was dropped ~500 meters past target. Total deployment time was 2 hours and 26 minutes.

The sound source deployed was serial number 86, with pong schedule 01:00 and 13:00 UCT. Pong #2 was heard, with no source clock delay. Vacuum and battery looked good, programmed schedule looked good, arming sequence looked good. This source was configured with one ½" shackle attaching the resonator tube to each of three bridle chains, rather than two, to conserve shackles.

Mooring M5

We moved Mooring M5 one half-hour earlier to make up time for the afternoon float deployments, as we had a hard deadline of 17:00LT to depart for home port. The deployment went very smoothly. The early-morning bathymetry survey (single shiptrack line to mooring site) indicated a flat level seafloor across the region. The setup was two miles, as the ship was running against a two-knot current - the South Indian Counter Current, or SICC. We started setup at 05:00LT, and deployment and first glass over at 06:10LT. The sound source was lifted high off the deck, with no possibility of compromising the sound source. We were ready to deploy the anchor by 08:14LT, but were faced with a two-hour steam to the anchor drop site. As the bathymetry was smooth, and the depth was within 10 meters of the target depth, we decided to release the anchor where we were. A 'hot drop'. Final sound source site is slightly different than the target location, with no compromise to the RAFOS float tracking. Total deployment time was 2 hours 16 minutes. We used ship's MET data to backout probable anchor location based on 500-m fallback estimate.

The sound source deployed was serial number 89, with pong schedule 00:45 and 12:45 UCT. Pong #2 was heard, with a 4 second source clock delay. Vacuum and battery looked good, programmed schedule looked good, arming sequence looked good. This source was configured with one ½" shackle attaching the resonator tube to each of three bridle chains, rather than two, to conserve shackles.

Table 2.1 Mooring Deployment

Mooring	Date (YYYY-MM-DD)	Lat (S)	Lon (E)	Sound Source	Pong Schedule (UTC)	Expected water depth (m)	Measured water depth (m)	Additional Shot	Depth of source (m)
M1	2023-04-14	28.000	40.000	#87	01:15; 13:15	4651	4657	none	1256
M2	2023-04-20	27.800	53.800	#81	00:15; 12:15	5209	5245	+20	1266
M3	2023-04-21	30.510	51.910	#83	00:30; 12:30	4909	4880	-50	1229
M4	2023-05-10	25.000	55.500	#86	01:00; 13:00	4814	4970	+50	1356
M5	2023-05-11	25.489*	51.616*	#89	00:45; 12:45	5148	5140	none	1242

* this location is post-500-m fallback calculation using ship's MET data on 20230511.

Section 3. Profiling Floats & Surface Drifters

Team Leader
Heather Furey, WHOI

On the DMB-2023 cruise, we also deployed floats for programs other than the three DMB-funded Deep SOLOs (Table 3.1). Four standard Argo for WHOI were deployed to contribute temperature/salinity/pressure data to the global Argo array. Two biogeochemical (BGC) Argo floats were deployed as part of the Global Ocean Biogeochemistry (GO-BGC) program (https://go-bgc.org). GO-BGC contributes to the international and US BGC-Argo programs, and all floats conform to the Argo mission requirements. HPLC, POC, pH, and alkalinity were sampled from CTD bottles on casts 009 and 074, prior to the deployment of GO-BGC floats for data validation (Figure 3.1).

In total, five Deep SOLO floats were deployed on the DMB-2023 cruise, two of which were for the Deep Argo program. The other three deep SOLOs were deployed as part of the core DMB Experiment, with modified drift depths, sampling rates, and profiling frequencies to address the science objectives of this experiment. Heather Furey was responsible for the five deep SOLO float start-ups while in port prior to the cruise, and Aidan Thayer (WHOI) visited the ship while in Cape Town to start up the S2A and BGC floats. All floats were deployed with the assistance of an STS marine technician and ECRs.

Table 3.1. Profiling Float Deployment

Deployment	Institution	Type	Float Serial	Lat	Lon	Date and Time (GMT)	CTD Station
1	WHOI Argo	Core / S2A	7786	27° 59.042'S	40° 00.351'E	04/14/2023 14:53	Test
2	WHOI Argo	Core / S2A	7778	28° 23.465'S	49° 05.963'E	04/16/2023 06:42	001
3	WHOI GO-BGC	NAVIS BGC	1487	27° 48.079'S	53° 48.542'E	04/20/2023 07:02	009
4	WHOI Argo	Core / S2A	7785	29° 36.480'S	52° 33.340'E	04/21/2023 01:56	011
5	SIO	Deep SOLO	6106	31° 11.942'S	51° 26.358'E	04/21/2023 18:30	013
6	WHOI Argo	Core / S2A	7784	31° 12.248'S	47° 55.637'E	04/23/2023 04:07	018
7	WHOI DMB	Deep SOLO	12046	30° 49.591'S	56° 43.972'E	05/02/2023 02:58	052
8	WHOI DMB	Deep SOLO	12047	29° 29.821'S	58° 36.170'E	05/05/2023 00:57	061
9	WHOI DMB	Deep SOLO	12048	27° 41.947'S	60° 56.366'E	05/07/2023 20:08	072
10	WHOI GO-BGC	NAVIS BGC	1488	26° 59.170'S	61° 50.15'E	05/08/2023 08:45	074
11	SIO	Deep SOLO	6107	25° 31.278'S	57° 03.905'E	05/09/2023 17:16	077

Under the EMC umbrella, we also deployed 20 surface drifters (SVPs with 15m drogues) manufactured by Scripps's Lagrangian Drifter Laboratory (https://gdp.ucsd.edu/ldl/) for the EMC project. These floats were deployed by the end of the cruise (Figure 3.2). There were three deployments: one at the M4 position consisting of 7 drifters deployed at the same time; another at the M5 position (8 drifters); and another together with an isopycnal RAFOS float described in the next section (Table 3.2).

(a) Core Argo **(b) Deep SOLO**

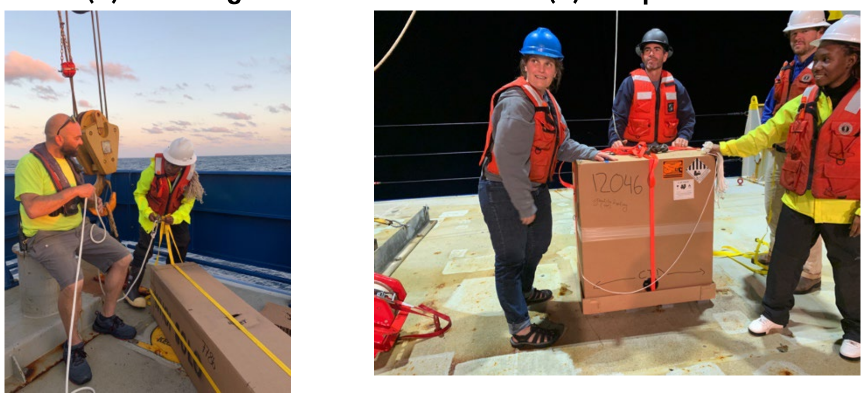


Figure 3.1. Examples of profile float deployments during the DMB-2023 cruise.

Figure 3.2. Example of a surface drifter deployment cluster (M4) during the DMB-2023 cruise.

Table 3.2. Surface Drifter Deployment

		ID (3005340*)	Lat	Lon	Date and Time (GMT)*
M4	1	64013350	25.001°S	55.508°E	2023-05-10 05:19:00
	2	64013320			
	3	64019020			
	4	64018100			
	5	64017330			
	6	64100880			
	7	64019200			
M5	1	64017350	25.494°S	51.609°E	2023-05-11 04:50:00
	2	64100930			
	3	64100940			
	4	64013360			
	5	64013280			
	6	64018090			
	7	64019330			
	8	64018230			
EMC RAFOS STACK	1	64019170	25.250°S	51.598°E	2023-05-11 06:23:00
	2	64100910	25.249°S	51.596°E	2023-05-11 06:29:00
	3	64019300	24.750°S	51.600°E	2023-05-11 09:15:00
	4	64019340	24.749°S	51.601°E	2023-05-11 09:23:00
	5	64019250	24.748°S	51.602°E	2023-05-11 09:30:00

* First transmission

Section 4. RAFOS Floats

Team Leader
Heather Furey, WHOI

RAFOS floats, which drift underwater for up to two years and measure temperature, pressure, and acoustic signal times-of-arrival, were deployed for both the DMB and EMC experiments. In the DMB experiment, the RAFOS float model was isobaric, or pressure-following, and in the EMC experiment, the float model was isopycnal, or density-following.

4.1 DMB RAFOS Float Narrative

The DMB floats were deployed at two cross-slope sections along the western side of the Madagascar Basin south of Madagascar, to tag the northward-flowing Deep Western Boundary Current at 3000-dbar. The cross-slope sections were located at approximately 28.4°S and 31.2°S. Along each section, the RAFOS were deployed at three stations, with redundancy in mind. We deployed, from west to east, 4, 4, and 3 RAFOS per station. In addition, we deployed two monitor floats along the southerly section.

After the northern section deployments, two DMB floats [1549, 1572] surfaced a few hours after deployment: rfs1549 bailed out after satisfying the surface detect criteria (reported 2 hours after deployment), and rfs1572 bailed out due to overpressure (reported 5 hours after deployment). After careful examination of the ballasting data, calculations, and final checkout notes, Jim was able to confirm that the near-surface float rfs1572 was light (underballasted) due to a mistake in the ballasting process. There was no obvious reason for float rfs1572 to have gone to deep, the vacuum and battery were both as they were upon deployment – no decreasing vacuum indicated no leak in the housing. We recovered the overpressure float (rfs1572) from the first section, and will bring home for further investigation (see below). In his review of the ballasting data for all floats, Jim also found three other floats [1573 1604 1605] that needed additional ballast that had not yet been deployed. Andy Davies had the correct hardware onboard, and we worked to get the additional ballast installed on the three floats that needed remediation (see below for details).

We then completed the southern section, deploying 13 floats at three stations: from east to west 3, 4, and 4 DMB floats, along with 2 monitor floats at the middle and offshore stations. One of this last batch of floats, rfs1574, surfaced 5 hours after deployment. The recovered background data indicated that this float went too deep, triggered the overpressure condition, and bailed out. This behavior is similar to that recorded by float rfs1572.

Table 4.1. Nominal DMB Float Mission

```
      SCHEDULER TASK TABLE

Number of windows to acquire (<1000) = 730
Open window at =  00 00:00:00
 Offset  00 00:00:00   Listen Rcvr Duration 120
 Offset  00 02:01:00   GetCorr from Rcvr
 Offset  00 02:02:00   GetParam
 Offset  00 12:00:00   Listen Rcvr Duration 120
 Offset  00 14:01:00   GetCorr from Rcvr
 Offset  00 14:02:00   GetParam
 Offset  00 15:00:00   End of Window

R Sweep Length= 261 (Samples) Corr Sampling period= 30750 (x10 microS)
Number of correlations to retain= 6
Press Launch Threshold in dBars= 5
Surface assumed if T > 5000 and P < 100
Max_Depth= 3200
Forced_Start= 1440
*Initialized
```

4.2 Recovery of RAFOS Float 1572

With the failure mode of rfs1572 being unknown, we decided it was a good decision, after years of RAFOS troubles and uncertainty through the pandemic delay gearing up to the cruise, to spend a day of ship time to go recover the float. Although the glass type was different than the previous test float failures, it was still unknown why this float went overpressure. We will determine this back in the lab, once the ground shipment gets back from Mauritius.

The recovery was done by decoding the float's SBD messages, one message every 30 minutes, which contained position information using the floats internal GPS system. The float's surface position and date/time data gathered over the ~30 hours since the float had surfaced were sent to the bridge the night prior to recovery, to set the general search location. Then, from 04:00LT to 06:30LT the position data were updated by decoding the SBDs and sending them to the bridge. Sunrise was at about 06:30LT, and the float was located immediately by the Captain. The small boat was deployed with Andy Davies, the 3rd Mate and an AB, and the launch tube was rigged with the endcap closed and loaded in the boat. Recovery took about 45 minutes and the float was safely brought onboard inside the launch tube.

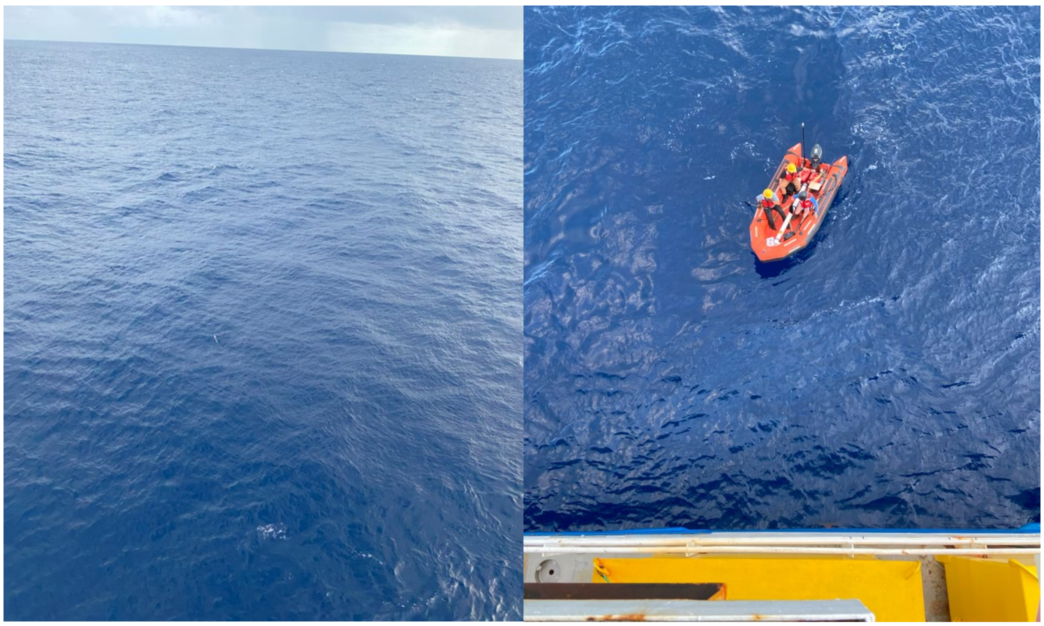


Figure 4.1. Photos of (left) the RAFOS at sea surface and (right) the rescue boat with RAFOS onboard.

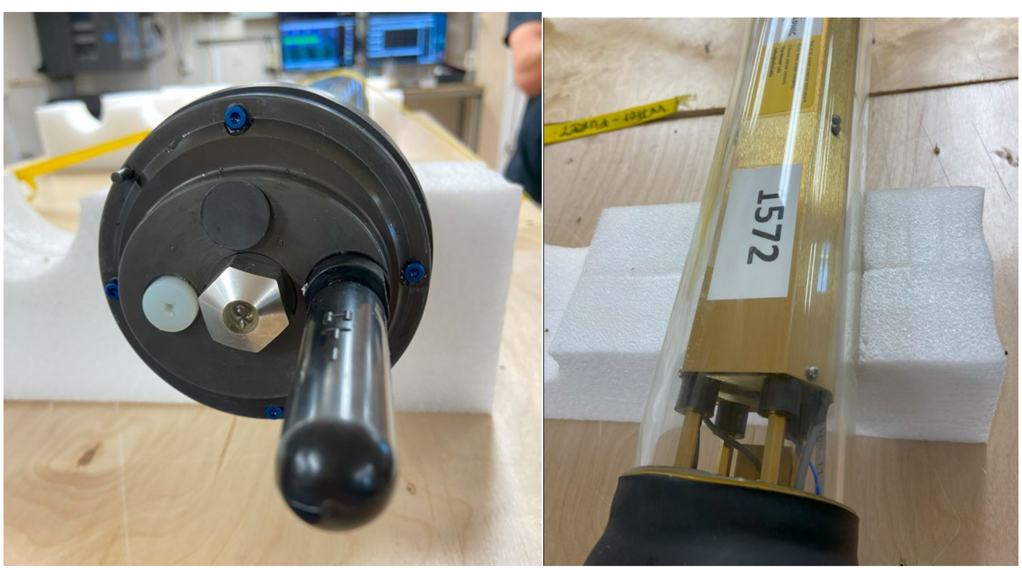


Figure 4.2. Photos of (left) the endcap and (right) float body in the float lab after recovery.

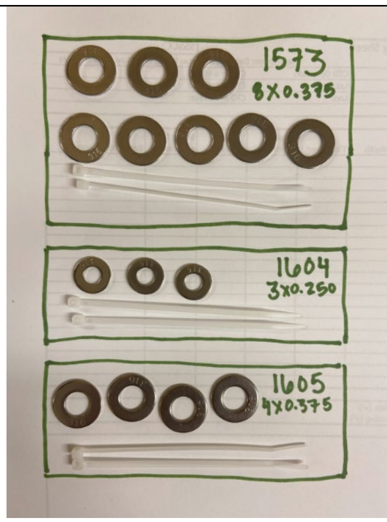
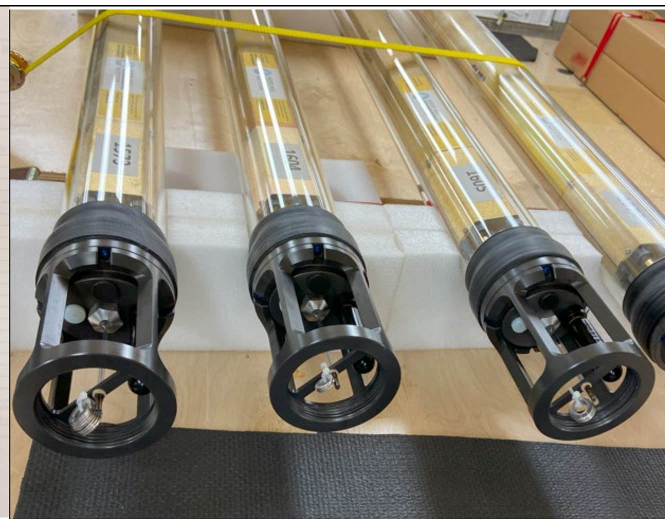
4.3 Adding Weight to Floats 1573, 1604, 1605

Jim Valdes reviewed ballasting output and found four floats that required additional ballast, e.g. four floats where mistakes had been made in the ballast calculations. One was float 1549, which had already been deployed (so no remediation possible), and three others that had not yet been deployed (1573, 1604, 1605). Andy had 316SS washers as well as 4" zipties on hand and provided Jim with the OD and the thickness for the given washers. Jim was then able to provide remediation (see emails 18 April 2023) as follows:

Float Ballast Weight Correction Table

rfs1604	"Float 1604, add 3 x .25 washers externally with 1 (or 2) zip tie. The small ties are nearly neutral. Tie them off to the hydrophone protector but not in direct contact to it."
rfs1573	"Float 1573, add8 x .375 washers externally. Secure as above."
rfs1605	"1605 has an incorrect washer weight. It needs an additional 8.86g of internal (dry) weight. This is equivalent to 4 of your 3/8 washers external."

We corrected the floats as stated in Table above, photo documentation below.

All floats:		

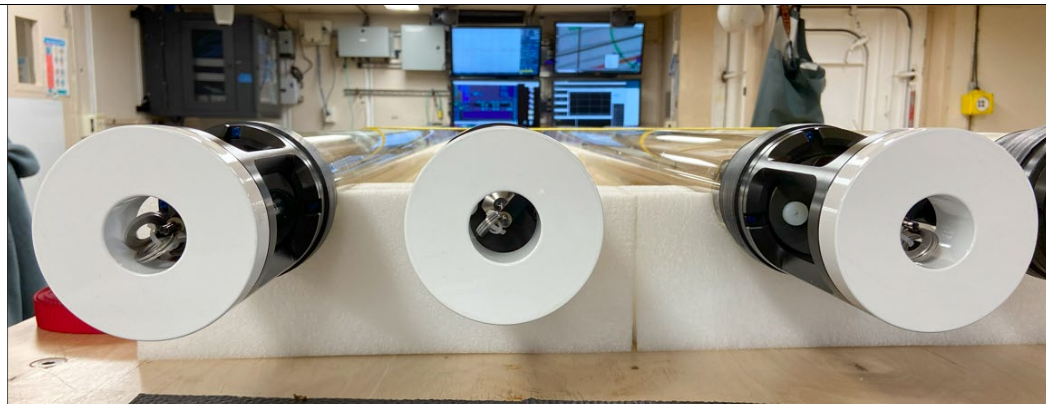
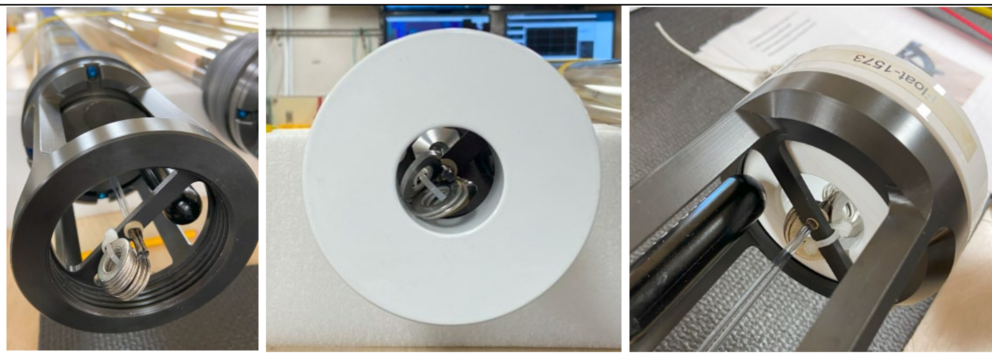
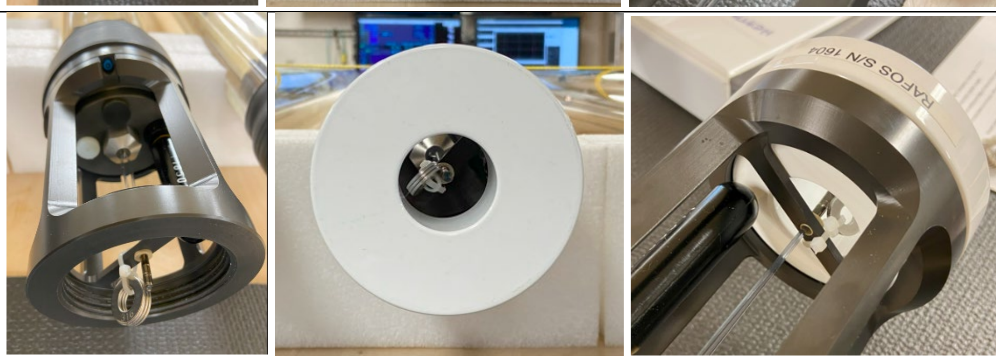
	
Float 1573	
1604	
1605	

Figure 4.3. Photos showing how each float had corrective weight (washers) attached to the float body.

4.4 EMC RAFOS Float Narrative

The isopycnal floats were all deployed on the same day, in an eddy that was on the northern flank of the South Indian Counter Current. Half the isopycnal floats were ballasted for $\sigma\theta = 26.2$ (about 300 dbar) and half for $\sigma\theta = 26.8$ (about 600 dbar). We deployed the EMC floats in 'stacks', where two floats and one surface drifter were deployed together, to assess circulation at the surface, ~300dbar, and ~600 dbar. Our original intent was to seed these stacks at five locations across the East Madagascar Current and collect CTD and LADCP data at each location. The departure delay (due to shipping container delay) meant that we lost the time needed to steam to the EMC and complete this mission. We knew we had further EMC deployment opportunities in the EMC using another vessel (Blue Observer's Iris), and we knew we had to deploy the isopycnal floats for testing. Therefore, we targeted two locations in the eddy north of the SICC, just inside the swirl velocity maximum and at the center, that were within reach considering the remaining shiptime. Two stacks were deployed inside but near the velocity maximum, and three stacks were deployed at the center of the eddy. The target location at the center of the eddy was off center by the time we arrived, but we decided to stick with the original target location due to time constraints. All deployments went smoothly using the float launch tube. Once the compressees were attached to the float there was noticeable strain on the lanyard attaching the dropweight/spacer to the floats. We tried to minimize the strain by making the float's time spent horizontal quick.

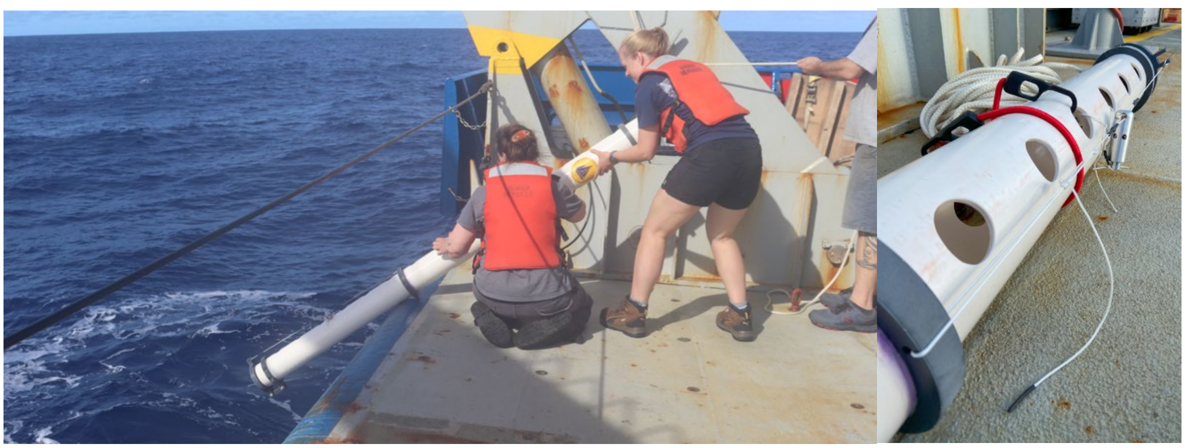


Figure 4.4. Photos showing method of deployment and launch tube rigging.

To determine the bailout (surface detect) temperature and pressure for the isopycnal floats, we considered the 26.2 σ^{θ} surface across the southwest Indian Ocean. This isopycnal surface outcrops, therefore, we decided to set the surface detect to values that would not be met. We wanted a float in active mission to stay in mission even if the isopycnal it was ballasted for outcropped. In this way the float would have a chance to resubmerge if it travelled into a location where the isopycnal deepened. We worked with Seascan (see emails 26 April 2023) to determine that 0 dbar was the minimum and also unsatisfiable criteria for pressure. Viviane determined that 32°C was a good temperature that she felt sure the floats would never measure.

Table 4.2. Nominal EMC Float Mission

```
      SCHEDULER TASK TABLE

Number of windows to acquire (<1000) = 330
Open window at =  00 00:00:00
 Offset  00 00:00:00   Listen Rcvr Duration 120
 Offset  00 02:01:00   GetCorr from Rcvr
 Offset  00 02:02:00   GetParam
 Offset  00 12:00:00   Listen Rcvr Duration 120
 Offset  00 14:01:00   GetCorr from Rcvr
 Offset  00 14:02:00   GetParam
 Offset  00 15:00:00   End of Window

R Sweep Length= 261 (Samples) Corr Sampling period= 30750 (x10 microS)
Number of correlations to retain= 6
Press Launch Threshold in dBars= 5
Surface assumed if T > 32000 and P < 0
Max_Depth= 1200
Forced_Start= 1440
*Initialized
```

One of the isopycnal floats, rfs1626, surfaced about three hours after deployment, and it was determined by Peter Jones at Seascan that this was due to 'overpressure', and possibly same failure mechanism as some deep DMB floats: over-ballasting.

4.5 Monitor RAFOS Float Narrative

Four floats were deployed as monitor floats. These floats were recycled from the CISESE DWDE and GOM programs in the Gulf of Mexico and ballasted for 1000 dbar. The floats were deployed to monitor the sound source array: to surface early and transmit information regarding the signal quality of all the sound sources, not to collect science data. Two monitors were deployed along the southerly line of DMB RAFOS deployments, and two monitors were deployed at the mooring M5 site.

RAFOS Float Deployment Table

Float entries with a ‡ are floats that surfaced unexpectedly shortly after launch, documented in narrative above.

Table 4.3. DMB Isobaric Floats Table

Float s/n	Mission Length (days)	Target Pressure (dbar)	CTD sta#	Launch Date yy-mm-dd	Time UTC	Latitude S		Longitude E	
1549‡	730	3000	2	23-04-16	17:11	28	23.842	49	25.554
1571	730	3000	20	23-04-23	14:58	31	12.306	47	12.281
1572‡	730	3000	3	23-04-16	22:42	28	23.475	49	45.919
1573	730	3000	19	23-04-23	09:50	31	12.245	47	33.237

1574‡	730	3000	20	23-04-23	15:05	31	12.306	47	12.281
1575	730	3000	4	23-04-17	05:05	28	23.369	50	5.766
1576	730	3000	4	23-04-17	04:59	28	23.380	50	5.828
1577	730	3000	19	23-04-23	10:01	31	12.027	47	33.756
1578	730	3000	19	23-04-23	09:55	31	12.042	47	33.025
1579	730	3000	2	23-04-16	16:56	28	23.557	49	23.560
1580	730	3000	2	23-04-16	17:03	28	23.695	49	25.712
1581	730	3000	20	23-04-23	14:53	31	12.105	47	12.095
1582	730	3000	20	23-04-23	14:47	31	12.042	47	12.039
1583	730	3000	2	23-04-16	16:47	28	23.390	49	25.983
1591	90	3000	3	23-04-16	22:48	28	23.560	49	45.832
1592	90	3000	4	23-04-17	04:53	28	23.396	50	5.992
1599	730	3000	3	23-04-16	22:53	28	23.652	49	45.732
1600	730	3000	3	23-04-16	23:00	28	23.706	49	45.596
1603	90	3000	18	23-04-23	04:31	31	12.266	47	55.567
1604	90	3000	19	23-04-23	09:45	31	12.263	47	33.510
1605	730	3000	18	23-04-23	04:16	31	12.266	47	55.567
1606	730	3000	18	23-04-23	04:22	31	12.266	47	55.567

Table 4.4. DMB/EMC 'Monitor' Isobaric Floats Table

Float s/n	Mission Length (days)	Target Pressure (dbar)	CTD sta#	Launch Date yy-mm-dd	Time UTC	Latitude S		Longitude E	
1216	30	1000	18	23-04-23	04:26	31	12.267	47	55.567
1456	30	1000	none	23-05-11	04:46	25	29.640	51	36.540
1479	330	1000	none	23-05-11	04:41	25	29.640	51	36.540
1529	330	1000	19	23-04-23	09:49	31	12.036	47	33.982

Table 4.5 EMC Isopycnal Floats Table

Float s/n	Mission Length (days)	Target Pressure (dbar)	CTD sta#	Launch Date yy-mm-dd	Time UTC	Latitude S		Longitude E	
1622	60	26.8	none	23-05-11	06:23	25	15.000	51	35.820
1623	60	26.8	none	23-05-11	06:16	25	15.000	51	35.940
1624	60	26.8	none	23-05-11	09:17	24	44.940	51	36.060
1625	60	26.2	none	23-05-11	09:22	24	44.940	51	36.120
1626‡	60	26.2	none	23-05-11	06:19	25	15.000	51	35.880
1627	60	26.2	none	23-05-11	06:28	25	14.940	51	35.700
1628	210	26.2	none	23-05-11	09:10	24	45.000	51	35.940
1629	210	26.8	none	23-05-11	09:13	24	45.000	51	36.000
1630	330	26.2	none	23-05-11	09:29	24	44.880	51	36.180
1631	330	26.8	none	23-05-11	09:26	24	44.880	51	36.120

Section 5. CTD and Rosette Setup

Research Technicians
Josh Manger (SIO STS)
Nick Mathews (RVTEC)

For DMB-2023 a SIO STS 24-place orange rosette and bottles were used. The rosette and bottles were newly built at SIO, with DMB-2023 among the first deployments of the package. 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 DMB-2023 weighs roughly 1200 lbs in air without water and 1700 lbs in air with water. The package used on DMB-2023 weighs roughly 850 lbs in water. In addition to the standard CTDO package, two WHOI LADCP were mounted on the rosette.

CTD and rosette performance is described in greater detail in the sections below.

5.1 Underwater Sampling Package

CTDO/Rosette/LADCP casts were performed with a package consisting of a 24-bottle rosette frame, a 24-place carousel, and 24 Bullister-style Niskin bottles with an absolute volume of 10.6 L.

Niskin bottles 11 and 12 were removed to accomodate the upward-facing LADCP. LADCP were deployed with the CTD/rosette package and their use is outlined in sections of this document specific to their titled analysis. One 150 KHz bi-directional Workhorse LADCP (RDI) unit was mounted vertically on the bottom side of the frame. Another 300 KHz bi-directional Workhorse LADCP (RDI) unit was mounted vertically on the top side of the frame. The LADCP battery pack was also mounted on the bottom of the frame. The LADCP and LADCP battery pack were mounted near (90°) each other at the beginning of the cruise.

CTD and cage were horizontally mounted at the bottom of the rosette frame, located below the carousel for all stations. The temperature, conductivity, dissolved oxygen, respective pumps and exhaust tubing was mounted to the CTD and cage housing as recommended by SBE. Underwater electronic components primarily consisted of a SeaBird Electronics housing unit with Paroscientific pressure sensor with dual plumbed lines where each line has a pump, temperature sensor, conductivity sensor, and exhaust line. A SeaBird Electronics membrane oxygen sensor (SBE43) was mounted on the “primary” line. The reference temperature sensor (SBE35) was mounted between the primary and secondary temperature sensors at the same level as the intakes for the pumped temperature sensors.

A reference thermometer, RINKO oxygen optode, WetLabs C-Star transmissometer, chlorophyll-a fluorometer, and Valeport altimeter were also mounted on the rosette. The transmissometer was mounted horizontally to the rosette frame and CTD cage with hose clamps, avoiding shiny metal inside that would introduce noise in the signal. The hose clamps for the transmissometer were covered in black electrical tape. The oxygen optode, fluorometer, and altimeter were mounted vertically inside the bottom ring of the rosette frames, with nothing obstructing their line of sight.

Table 5.1. CTD Components Table

Equipment	Model	S/N	Cal Date	Stations	Group
Rosette	24-place	Orange	–	900-77	STS/ODF
CTD	SBE9+	0569	–	900-77	STS/ODF
Pressure Sensor	Digiquartz	75672	Dec 7, 2021	900-77	STS/ODF
Primary Temperature	SBE3+	4907	Mar 14, 2023	900-77	STS/ODF
Primary Conductivity	SBE4C	44651	Jan 20, 2023	900-77	STS/ODF
Primary Pump	SBE5	53342	–	900-77	UCSD
Secondary Temperature	SBE3+	36142	Mar 14, 2023	900-64	STS/ODF
Secondary Temperature	SBE3+	34588	Oct 22, 2022	65-77	STS/ODF
Secondary Conductivity	SBE4C	44650	Dec 13, 2022	900-77	STS/ODF
Secondary Pump	SBE5	58689	–	900-77	UCSD
Transmissometer	Cstar	1873DR	Sep 29, 2022	900-77	STS/ODF
Fluorometer Chlorophyll	WetLabs ECO-FL-RTD	4334	Jan 7, 2022	900-77	STS/ODF
Dissolved Oxygen	SBE43	431071	Mar 8, 2023	900-29	STS/ODF
Dissolved Oxygen	SBE43	430614	Aug 12, 2022	30	STS/ODF
Dissolved Oxygen	SBE43	431508	Oct 7, 2022	31-77	STS/ODF
Oxygen Optode	JFE Advantech Rinko-III	0251	Aug 24, 2022	900	STS/ODF
Oxygen Optode	JFE Advantech Rinko-III	0297	Aug 22, 2022	1-77	STS/ODF
Reference Temperature	SBE35	0105	Mar 15, 2022	900-77	STS/ODF
Carousel	SBE32	0417	–	900-77	STS/ODF
Altimeter	Valeport 500	53821	–	900-77	UCSD

Winch and Deployment

The CAST6 winch and deployment system was used for all stations. The rosette system was suspended from a UNOLS standard three-conductor 0.322” electro-mechanical sea cable. The sea cable was terminated with a Guy Grip as the primary and secondary, and set of Crosby Clips as the tertiary.

The deck watch prepared the rosette 10-30 minutes prior to each cast. The bottles were cocked and all valves, vents, and lanyards were checked for proper orientation. Any biofouling noted was cleaned off the outside of the rosette before the next cast, and the inside of the bottles were checked for biofouling and sprayed down. LADCP technician would check for LADCP battery charge, prepare instrument for data acquisition, and disconnect cables. Once stopped on station, the Marine Technician would check the sea state prior to cast and decide if conditions were acceptable for deployment.

The rosette was moved from the sampling bay out to the deck using the Revelle’s pallet jack. Once on deck, sea cable slack was pulled up by the winch operator. CTD watch standers would then turn on the deckbox and begin data acquisition, and the cast would begin.

Recovering the package at the end of the deployment was the reverse of launching, placing the rosette on a wooden pallet. Once rolled back into the sampling bay, a technician secured the pallet to the deck using additional ratchet straps. The LADCP technician would plug in cables to recharge the battery and download the data from the cast. The carousel was rinsed and sensors were cleaned (as described below) after every cast, and then samplers were allowed to begin collecting water from Niskin bottles.

Figure 5.1. Photos of the CTD and rosette, showing the package sensor setup from all sides.

Figure 5.2. (left) Down-facing LADCP mounted behind the CTD package central on the rosette. (right) Up-facing LADCP mounted in place of Niskin bottles 11, 12 on the rosette frame.

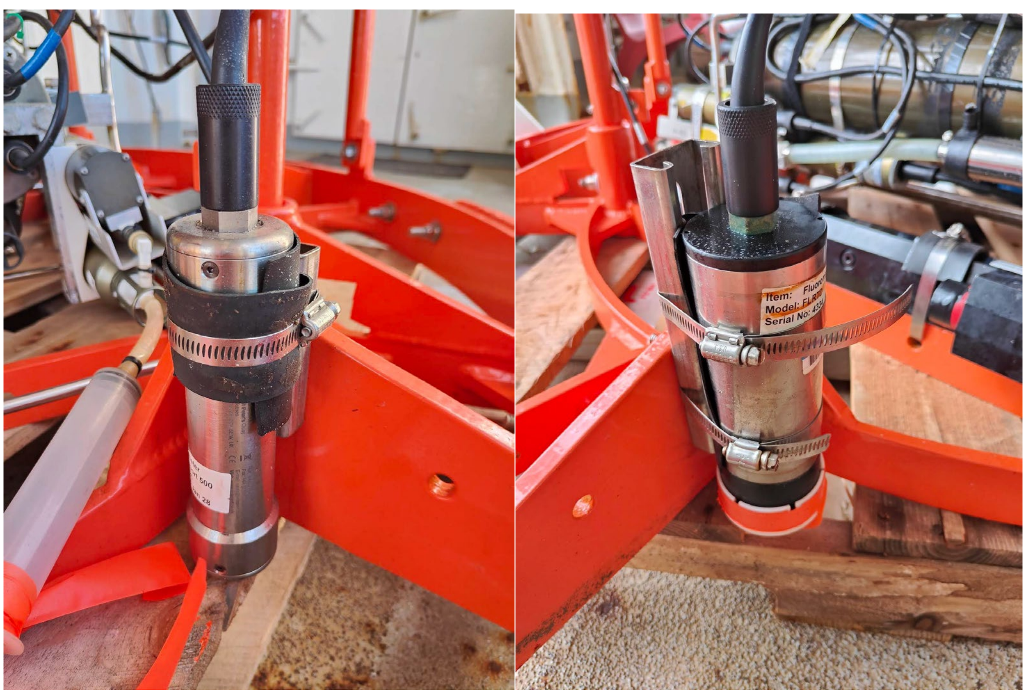


Figure 5.3. (left) Package auxiliary altimeter from east. (right) Package auxiliary fluorometer from north.

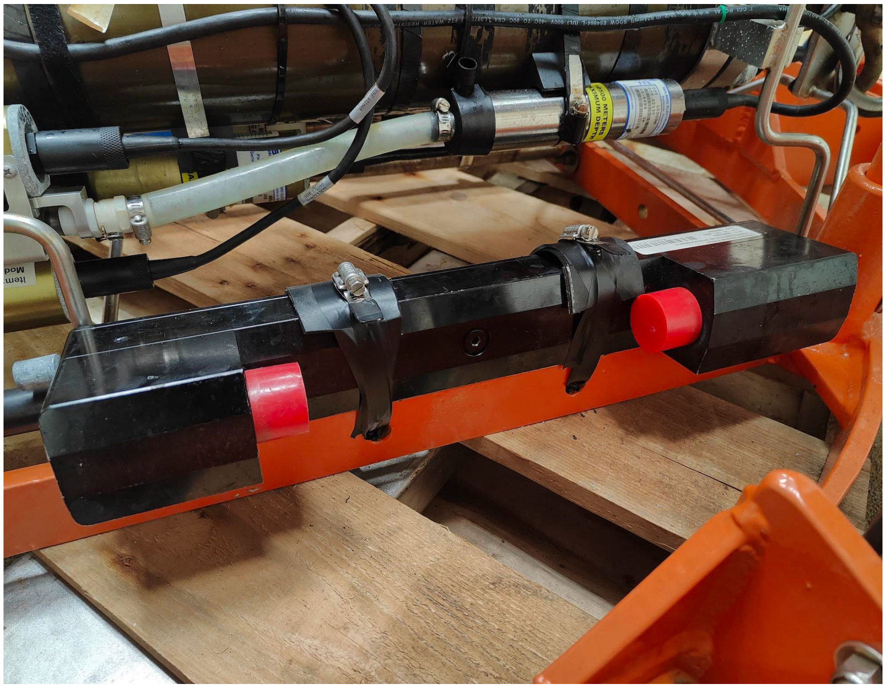


Figure 5.4. Package auxiliary transmissometer.

Figure 5.5. Package setup, top view, and auxiliary RINKO optode.

Maintenance and Calibrations

During DMB-2023 routine maintenance was done to the rosette to ensure quality of the science done. Prior to the first station, the transmissometer was calibrated with a light-dark test.

When the CTD was brought into the hangar of the Revelle following each cast, the CTD lines were flushed with fresh water and syringes were connected to the plumbed lines to allow them to soak between casts. Transmissometer lenses and the fluorometer faceplate were rinsed with fresh water. The transmissometer, fluorometer, and RINKO optode were capped prior to sampling. The carousel latch mechanism was rinsed thoroughly with fresh water prior to any sampling.

Care was taken not to rinse the spigots and other parts of the bottle that might be touched by samplers in order to not contaminate the samples. For casts where eDNA was sampled, the hangar was cleared of non-essential personnel and appropriate PPE was worn to avoid contamination. Spigots were sterilized prior to attaching eDNA sample tubing.

For all sampling, a CTD watchstander was designated as a “sample cop” to coordinate different sampling groups and record the sample status on a tangible log sheet.
When the hangar was cleared of all sampling, hose clamps and guide rings were inspected as needed such that lanyards had appropriate tension. The rosette was routinely examined for valve and o-ring leaks, which were maintained as needed. SBE35RT temperature data was routinely downloaded each day, with the deck unit and CTD powered up outside of sampling or operation hours.

<u>Chronic Rosette and CTD Problems</u>

***Bottle 1*:** Bottle 1 was fired at the bottom of each cast (unless otherwise misfired and noted below), though it often mistripped and closed much closer to the surface. Carousel SBE32 was inspected and there were no solenoids nor latches that appeared problematic. On the 3rd of May, the procedure was changed to also fire bottle 2 at the bottom of each cast in case of a mistrip on bottle 1.

***SBE43*:** SBE43 O2 was consistently noisy at depths of 4000 m or greater on all casts. This persisted even after changing sensors (new serial numbers) and CTD cables. This was not evident on the RINKO optode.

Logs

In port: Preparation of the CTD and rosette was minimal. The CTD’s primary and secondary sensors were changed out for sensors which were more recently calibrated. The LADCP arrived in Cape Town and was mounted after the CTD on the rosette, with Niskin bottles 11 and 12 removed to accomodate for the upward facing sensor.

April 14
90001 - Test station to 1716 m. Fired all 22 bottles. Removed RINKO SN 0251 because data appeared noisy. Mounted SN 0297 and inspected cables. Sensors were not plotting correctly in SeaSave, but there were no issues with either 0251 or 0297. Kept 0297 on the rosette.

April 16
00202 - Dedicated test cast for eDNA sampling. 20 bottles fired at bottom and surface.

00401 - Bottom end cap of Niskin #4 had the lanyard break off of the spring while cocking before 00401. Replaced lanyard and cap.

April 17
00601 - Bottom end cap of Niskin #14 appeared to be leaking slightly when air valve was open. Keeping under close observation.

April 20
00901 - Bottle 9 mistripped and closed closer to 2000 m than the intended 2900 m. Black electrical tape on transmissometer hose clamps was missing prior to deployment. Deployed without tape and data did not appear noisy or spiky.

April 21
01101 - A hydraulic line came undone during the recovery of 01101 on DMB-2023. Fluid contamination was not detected inside the Niskins when sampling was done during that cast. No hydraulic fluid was identified on the rosette after rinsing and after recovering on 01301.

April 22
01501 - Bottles 13, 19 leaking from bottom end caps following recovery. Marine Technician replaced bottom o-rings.
01601 - Bottle 3 mistripped, closing around 600 m rather than at 4400 m.
01701 - Bottle 1 mistripped, closing around 2700 m rather than 4477 m.

April 23
01901 - Bottles 5, 13 were leaking from the bottom end caps after 01901. Replaced Niskin 13 before 02001.
02001 - Due to inclement weather, the CTD did not return to the surface immediately after soaking on cast 02001.

April 24
02201 - Kinks were identified in the rosette wire following the recovery of 02201, whereafter the cable was mechanically reterminated and wrapped around the interior of the rosette.
02301 - Cable reterminated and run along the interior of the rosette. Checked lanyards to ensure they were not rubbing on the cable.

April 25
02401 - Bottle 5 leaking from bottom end cap. Replaced bottle before 02501.
02601 - There was an electrical issue in the engine room following the conclusion of cast 02501 and the CAST6 winch needed to be restarted.

April 26
02601, 02701, 02901 - Oxygen sensor SN 1071 data quality was bad. Replaced with SN 0614 after 02901.

April 27

03001 - Oxygen (SBE43) sensor SN 0614 data quality was bad. Replaced with SN 1508.
03101 - Bottle 1 mistripped. Lifted bottle before 03201 and it did not have problems. Tightened all top and guide hose clamps on bottles.

April 28
03401, 03501 - Bottle 1 was leaking during sampling. Replaced bottom cap of bottle 1 prior to cast 03501. Still leaking after 03501 using new cap and the O-ring was identified to be damaged. Replaced the O-ring.
03501 - Bottle 6 was fired, but the latch did not release. Deck tested before 03601 and the problem did not persist on 03601.

April 29
03901, 04101 - Bottles 10 and 13 were leaking while sampling. Replaced O-rings on bottom cap before station 04201.

April 30
04401 - Bottle 1 was misfired during the downcast at approximately 600 m. Cast was aborted at approximately 1400 m to recover CTD, assess niskin for any damage, and recock for redeployment on 04402. No damage was detected on bottle 1.

May 1
04801 - Bottle 1 mistripped after firing and appears to have finally closed at around 3000 m.

May 2
05001 - Rough weather created kink in the rosette wire. Coiled wire inside rosette frame and put a new mechanical termination on the wire before 05101.
05101 - At 1150 m on downcast, something was sucked into primary line. A small fish was identified on deck after flushing the lines before sampling. Rinsed the lines thoroughly with fresh water. Following sampling, the rosette cable was fully electrically reterminated.

May 3
05301, 05402 - Transmissometer C-Star 1873 was frequently spiking to 0 V. Inspected Y cable and pin 6 (+V) was corroded away. Identified residue on/in the transmissometer cable. Replaced Y and transmissometer cables from ship spares.
05401 - Bottle 1 was misfired at approximately 100 m during the downcast. It was quickly identified and the cast was aborted to redeploy on cast 05402.

May 4
05701, 05801 - Bottle 10 was leaking during sampling on 05701. Replaced bottom O-ring and shortened lanyard to tighten spring. The O-ring was not properly seated and leaked on 05801. Fixed seating before 05901.

May 5
05901 - Mechanically reterminated 0.322 wire above new kink, identified after the cast.
06201 - Raised bottle 1 after sampling to improve lanyard angle with rosette. Also moved guide ring to

left side of niskin to provide better angle.
06301, 06401 - Secondary temperature line was spiking to -34, 99 °C during cast 06301 at depths of >4000 m. History of sensor frequency errors suggest secondary line could have been problematic since 04101 on April 30th. Replaced sensor 6142 with 4588 on secondary line. Still spiking after sensor replacement on 06401. Replaced cable between SBE3 and SBE9, which resolved the problem on cast 06501.

May 6
06501 - Bottle 14 was leaking from the bottom cap during sampling. Replaced the bottom o-ring and shortened the lanyard.
06701 - Bottle 1 was lowered slightly after cast 06601 to adjust the lanyard angle in an attempt to improve closure performance.
06901 - Bottle 24's inner bottom lanyard broke while preparing for the cast. Inner lanyard was replaced and did not leak on 07001.

May 9
07601 - Swapped out the cable on the SBE43 to test if data noise persisted at depths >3000 m and the data quality did not change.

Section 6. CTDO and Hydrographic Analysis

Technicians
Aaron Mau (*SIO ODF*)

CTDO and Bottle Data Acquisition

The CTD data acquisition system consisted of an SBE-11+ (V2) deck unit and a networked generic PC workstation running Windows 10. SBE SeaSave7 v.7.26.7.121 software was used for data acquisition and to close bottles on the rosette.

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

Once the deck watch had deployed the rosette, the winch operator would lower it to 10 meters. The CTD sensor pumps were configured to start 10 seconds after the primary conductivity cell reports salt water in the cell. The CWO checked the CTD data for proper sensor operation, waited for sensors to stabilize, and instructed the winch operator to bring the package to the surface in good weather. Deck technicians would advise on resurfacing in inclement weather. The winch was then instructed to lower the package to the initial target wire-out at no more than 60 m/min after 100 m depending on depth, sea-cable tension, and the sea state.

The CWO monitored the progress of the deployment and quality of the CTD data through interactive graphics and operational displays. The altimeter channel, CTD pressure, wire-out and center multi-beam depth were all monitored to determine the distance of the package from the bottom. The winch was directed to slow decent rate to 30 m/min 100 m from the bottom, and 20 m/min 50 m from the bottom. The bottom of the CTD cast was usually to within 10-15 meters of the bottom determined by altimeter data. For each full upcast, the winch operator was directed to stop the winch at up to 22 predetermined wire lengths. During upcasts specific to eDNA sampling, the winch operator was directed to stop at up to fewer sampling lengths. The difference between sampling depth (CTD depth) and the winch wire out was recorded at every planned bottle closure. The CTD CWO waited 30 seconds prior to tripping sample bottles, to ensure package had shed its wake. This waiting time was reduced to 20 seconds following cast 01101. An additional 15 seconds elapsed before moving to the next consecutive trip depth, which allowed for the SBE35RT to record bottle trip temperature averaged from 13 samples. After the last bottle was closed, the CWO directed the winch operator to recover the rosette.

Once the rosette was out of the water and on deck, the CWO terminated the data acquisition, turned off the deck unit and assisted with rosette sampling. The CWOs filled out a console log for every deployment of the CTD to record depth metadata when bottles were fired. A sample log was filled out when the rosette returned on deck, recording the depths where bottles were fired and correspondence between analytical samples drawn. The bottles and rosette were examined before samples were drawn. The CTD sensors were rinsed after every cast using syringes of fresh water connected to Tygon tubing. The tubing was left on the CTD between casts, with the temperature and conductivity sensors immersed in fresh water.

Each bottle on the rosette had a unique serial number, independent of the bottle position on the rosette. If a Niskin bottle was replaced, the new bottle was tracked within a new rosette configuration.

Any abnormalities were noted on the sample log, stored in the cruise database and reported in the APPENDIX.

CTDO Data Processing

Shipboard CTD data processing was performed after deployment. SeaBird bin averages were made using SeaSave in 1 Hz, 1, dbar, 2 dbar for immediate use aboard the ship following the cast.

Raw CTD data were manually fit and quality controlled using *SIO ODF* CTD processing software "ctdcal" v. 0.1.4. CTD acquisition data were copied onto a OS X system and then processed. CTD data at bottle trips were extracted, and a 2-decibar downcast pressure series created. The pressure series data set was submitted for CTD data distribution after corrections outlined in the following sections were applied.

A total of 76 CTD stations were occupied including one test station. A total of 80 CTDO/Rosette/LADCP casts were completed.

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

Temperature, salinity and dissolved O2 comparisons were made between down and upcasts as well as between groups of adjacent deployments. Vertical sections of measured and derived properties from sensor data were checked for consistency.

A number of issues were encountered during DMB-2023 that directly impacted CTD analysis. Issues that directly impacted bottle closures, such as slipping guide rings, were detailed in the Underwater Sampling Package section of this report. Temperature, conductivity, and oxygen analytical sensor issues are detailed in the following respective sections.

For stations where ODF subsampling was not emphasized (eDNA, LADCP-only, aborted casts), fit coefficients were pulled and reused from recent casts.

Cast to fit to	Cast to reuse from	Notes
00202	00201	*eDNA* only
03301	03501	*LADCP* yo-yo
03401	03501	*eDNA* only
03601	03501	*LADCP* yo-yo
03701	03501	*eDNA* only
04401	04402	cast aborted due to misfired bottle
04701	04801	*eDNA* only
04901	04801	*LADCP* yo-yo
05101	05001	*eDNA* only
05401	05402	cast aborted due to misfired bottle
05501	05402	*eDNA* only
05901	05801	*eDNA* only
06601	06701	*eDNA* only

Pressure Analysis

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

The lab calibration coefficients provided on the calibration report were used to convert frequencies to pressure. Initial SIO pressure lab calibration slope and offsets coefficients were applied to cast data. A shipboard calibration offset was applied to the converted pressures during each cast. These offsets were determined by the pre- and post-cast on-deck pressure offsets. The pressure offsets were applied per cast.

CTD #0569:

	Start P (dbar)	End P (dbar)
Min	0.06	-0.41
Max	0.77	0.46
Average	0.47	0.18

On-deck pressure reading varied from 0.06 to 0.77 dbar before the casts, and -0.41 to 0.46 dbar after the casts. The pressure offset varied from -1.07 to 0.04, with a mean value of -0.27 dbar.

Temperature Analysis

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

The pre-cruise laboratory calibration coefficients were used to convert SBE3plus frequencies to ITS-90 temperature. Additional shipboard calibrations were performed to correct systematic sensor bias. Two independent metrics of calibration accuracy were used to determine sensor bias, with the exception of eDNA or yo-yo casts where bottles may not be closed. At each bottle closure, the primary and secondary temperature were compared with each other and with a SBE35RT reference temperature sensor.
The SBE35RT Digital Reversing Thermometer is an internally-recording temperature sensor that operates independently of the CTD. The SBE35RT was located equidistant between the two SBE3plus temperature sensors. The SBE35RT is triggered by the SBE32 carousel in response to a bottle closure. According to the manufacturer's specifications, the typical stability is 0.001 °C/year. The SBE35RT was set to internally average over 13 samples, approximately a 15 second period.

A functioning SBE3plus sensor typically exhibit a consistent predictable well-modeled response. The response model is second-order with respect to pressure and second-order with respect to temperature:

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

Fit coefficients are shown in the following tables.

Primary temperature (T1) coefficients.

Station		cp_2	cp_1	ct_2	ct_1	c_0
900-77		-1.0754e-11	6.5325e-8	0.e+0	0.e+0	-2.2716e-4

Secondary temperature (T2) coefficients.

Station	cp_2	cp_1	ct_2	ct_1	c_0
900-63	3.6080e-10	-2.6714e-6	0.e+0	0.e+0	4.9570e-3
63-77	5.8716e-11	-4.4800e-7	0.e+0	0.e+0	9.3089e-4

Corrected temperature differences are shown in the following figures.

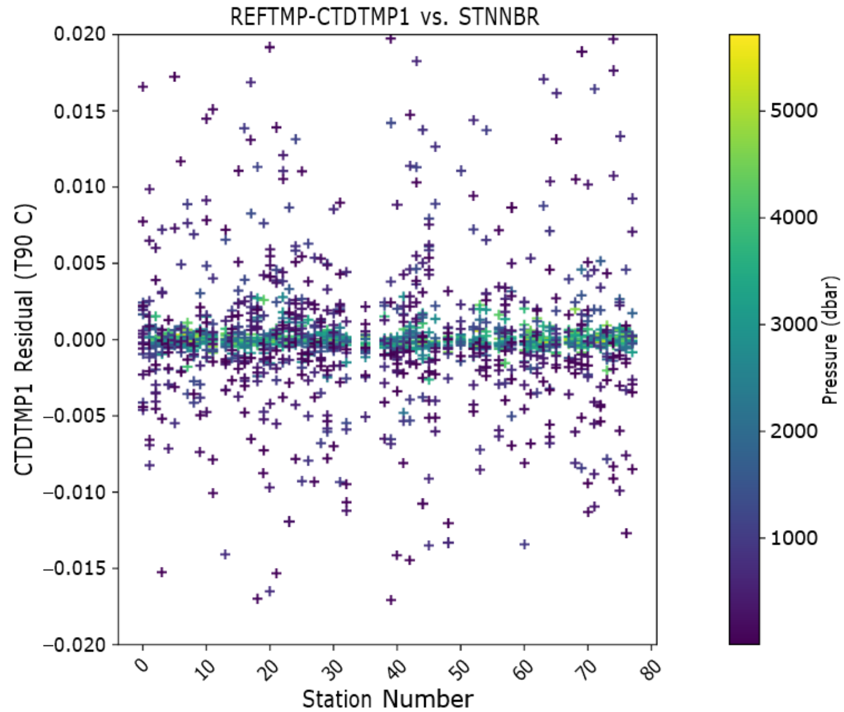


Figure 6.1. SBE35RT-T1 versus station.

The 95% confidence limits for the mean low-gradient (values -0.002 °C ≤ T1-T2 ≤ 0.002 °C) differences are ±0.00398°C for SBE35RT-T1, ±0.00440 °C for SBE35RT-T2 and ±0.00194 °C for T1-T2. The 95% confidence limits for the deep temperature residuals (where pressure ≥ 2000 dbar) are ±0.00097 °C for SBE35RT-T1, ±0.00165 °C for SBE35RT-T2 and ±0.00110 °C for T1-T2.

Problems arose during the DMB-2023 cruise, prompting CTD temperature sensors (SBE3) to be exchanged. At station 43, SN 6142 was returning erroneous frequencies, which converted to -34 and 99 ℃. The sensor was replaced with SN 4588, but the issue persisted on station 64. With the replacement of the SBE3 cable, the issue was not seen after station 65. Minor complications impacted the reference temperature sensor (SBE35) data. Internal memory overflowed following station 71, and 5 bottle closures from station 71 were not captured. During cast 00202 designated for eDNA, bottles were fired quickly (< 15 seconds) at the bottom and surface for SBE35 readings.

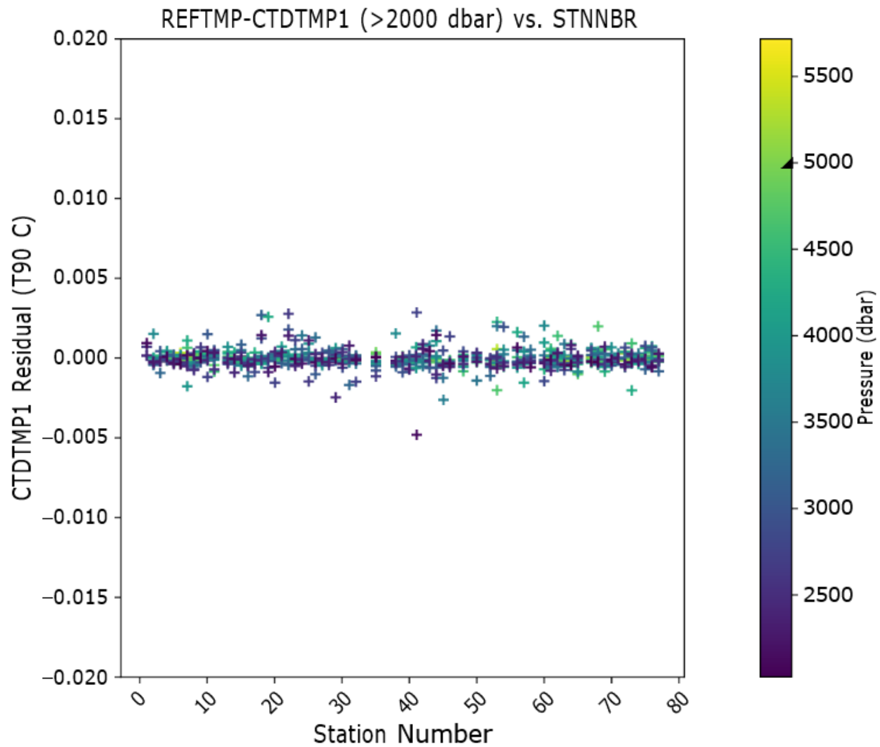


Figure 6.2. Deep SBE35RT-T1 by station (Pressure ≥ 2000dbar).

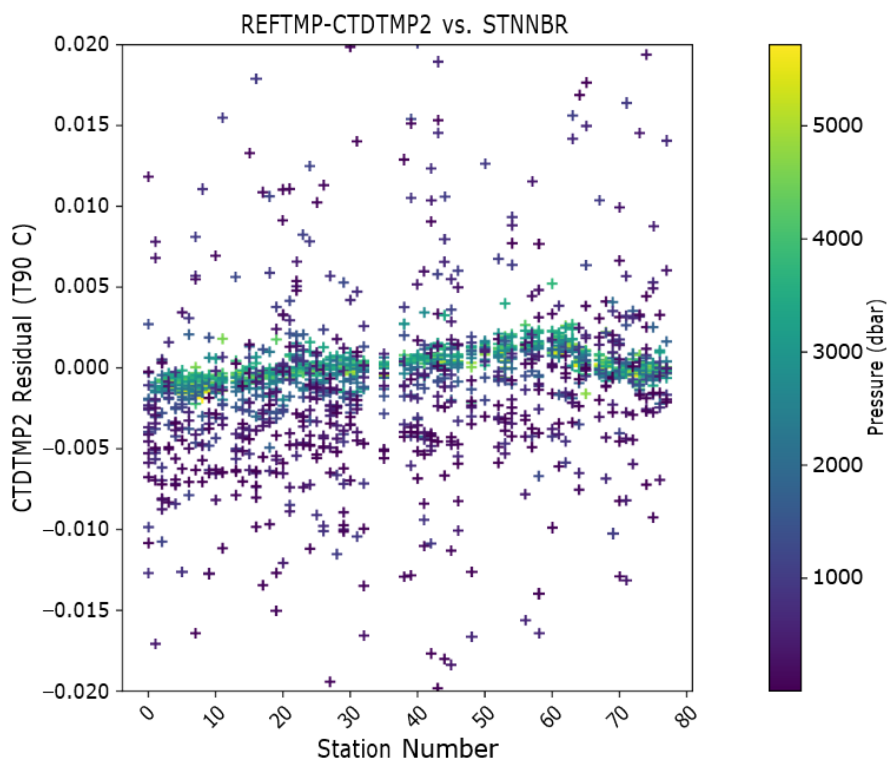


Figure 6.3. SBE35RT-T2 versus station.

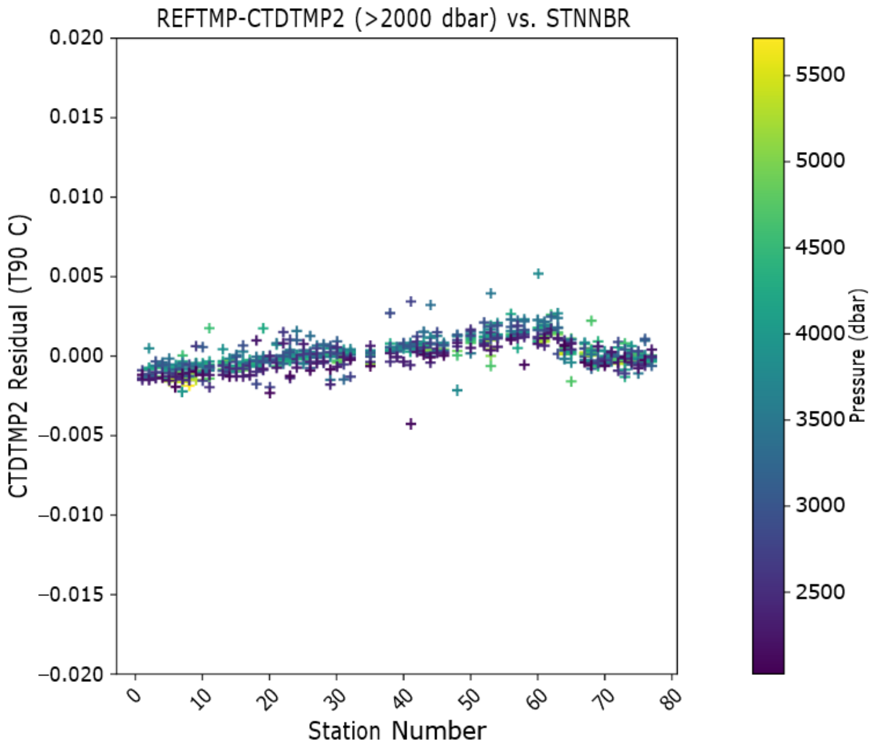


Figure 6.4. Deep SBE35RT-T2 by station (Pressure ≥ 2000dbar).

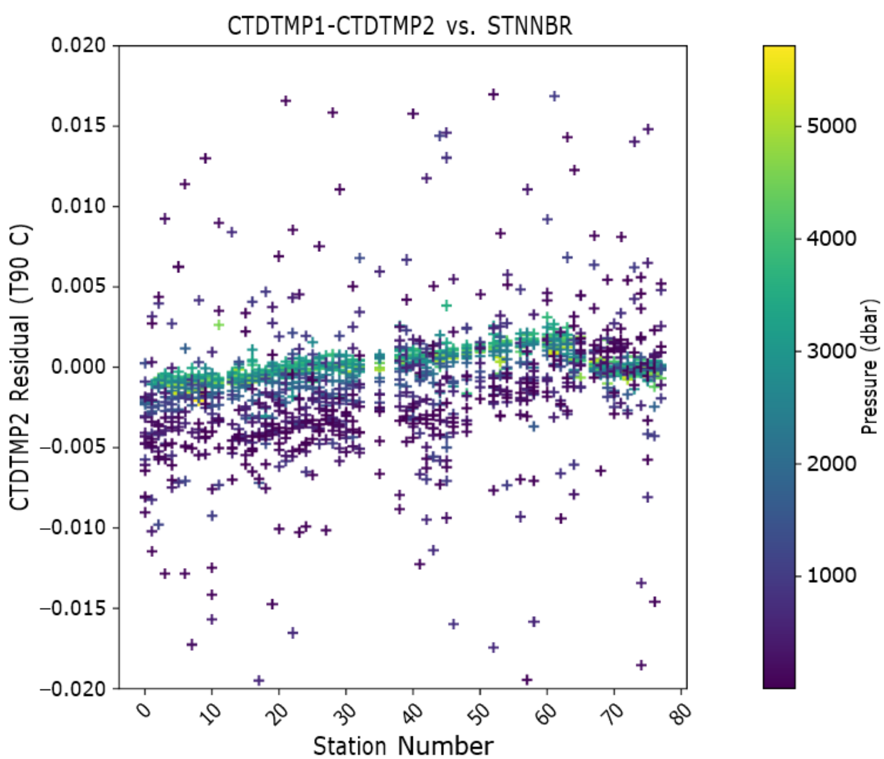


Figure 6.6. T1-T2 versus station.

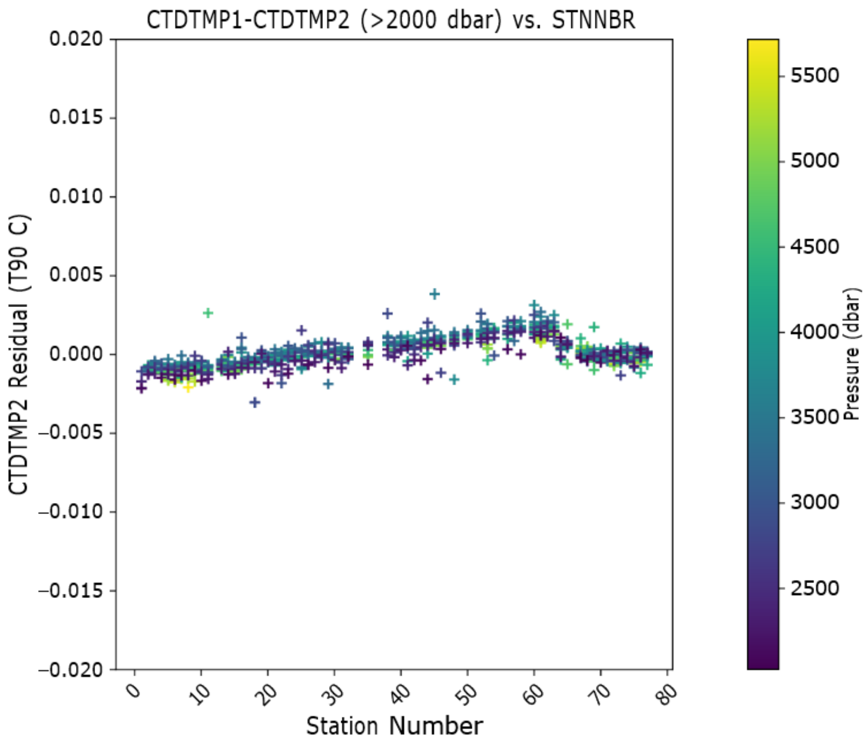


Figure 6.7. Deep T1-T2 versus station (Pressure ≥ 2000dbar).

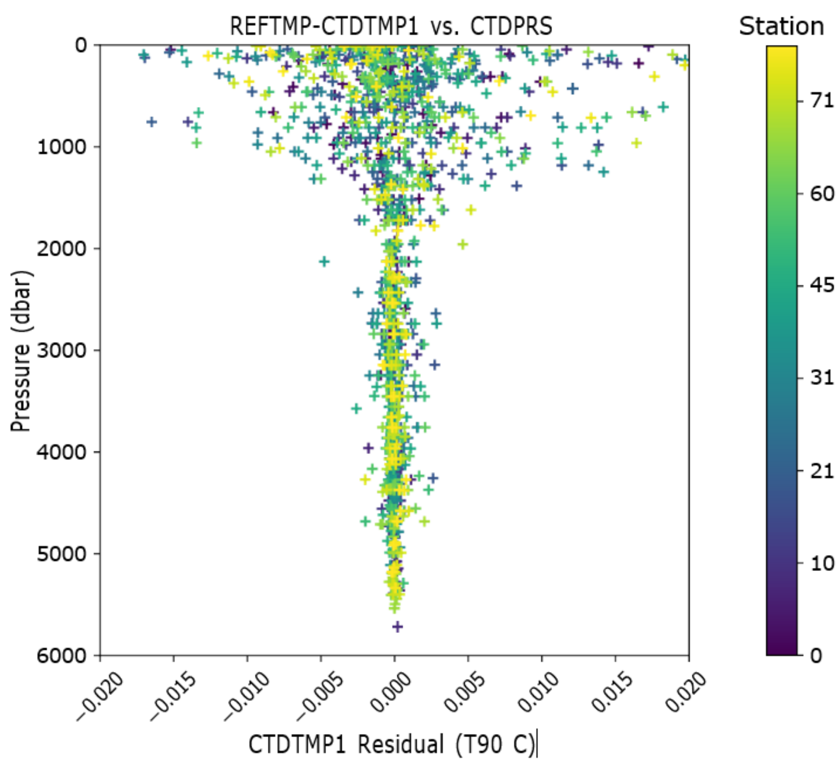


Figure 6.8. SBE35RT-T1 versus pressure.

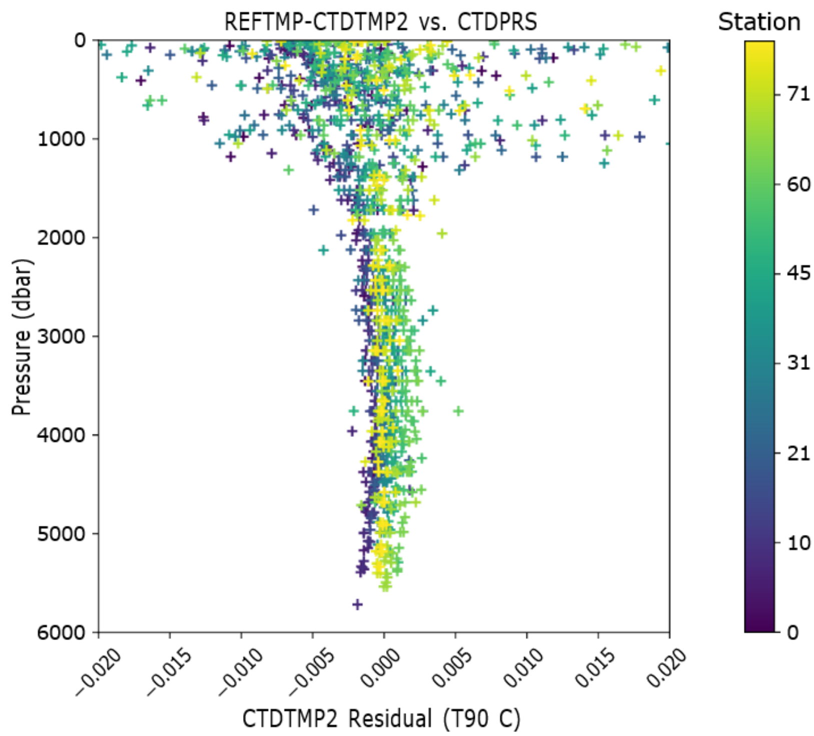


Figure 6.9. SBE35RT-T2 versus pressure.

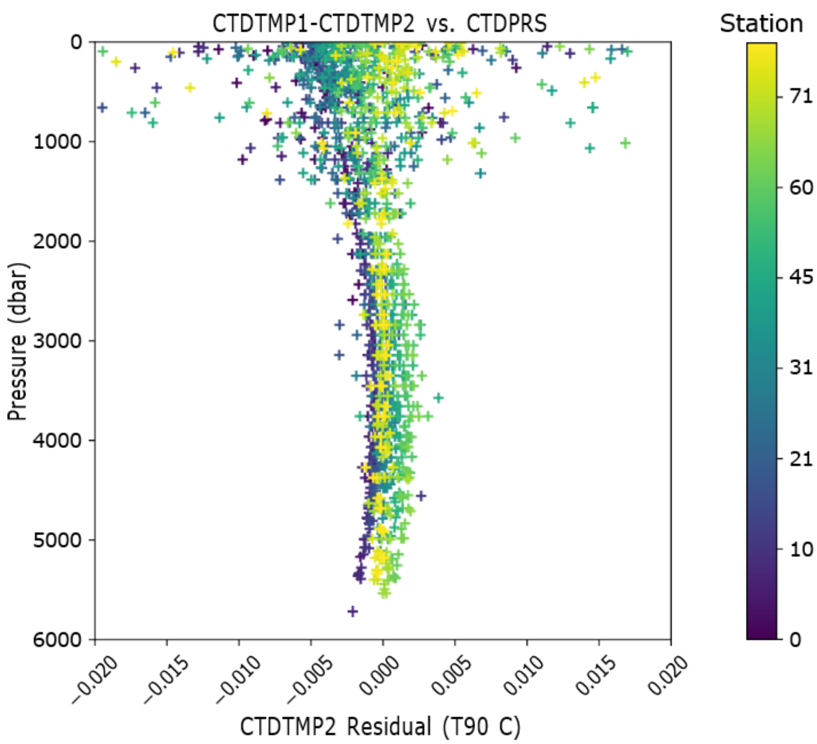


Figure 6.10. T1-T2 versus pressure.

A similar issue, bottle 1 frequently mistripped during the cruise, prompting the decision to fire bottle 2 at the same depth. Bottle 2 was occasionally fired too quickly for a reading. The resulting affected sections of data have been coded and documented in the quality code APPENDIX.

Conductivity Analysis

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

The pre-cruise laboratory calibration coefficients were used to convert SBE4C frequencies to mS/cm conductivity values. Additional shipboard calibrations were performed to correct sensor bias. Corrections for both pressure and temperature sensors were finalized before analyzing conductivity differences. Two independent metrics of calibration accuracy were examined. At each bottle closure, the primary and secondary conductivity were compared with each other. Each sensor was also compared to conductivity calculated from check sample salinities using CTD pressure and temperature.

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

A functioning SBE4C sensor typically exhibit a predictable modeled response. Offsets for each C sensor were determined using CBottle - CCTD 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:

$$C_{cor} = C + cp_2 P^2 + cp_1 P + ct_2 T^2 + ct_1 T + cc_2 C^2 + cc_1 C + \text{Offset}$$

Fit coefficients are shown in the following tables.

Primary conductivity (C1) coefficients.

Station	cp_2	cp_1	ct_2	ct_1	cc_2	cc_1	c_0
900-77	2.3506e-10	-1.8777e-6	0.e+0	0.e+0	0.e+0	0.e+0	3.5958e-3

Secondary conductivity (C2) coefficients.

Station	cp_2	cp_1	ct_2	ct_1	cc_2	cc_1	c_0
900-77	1.5433e-10	-1.3161e-6	0.e+0	0.e+0	0.e+0	0.e+0	4.3239e-3

Salinity residuals after applying shipboard P/T/C corrections are summarized in the following figures. Only CTD and bottle salinity data with “acceptable” (WOCE = 2) quality codes are included in the differences. Quality codes and comments are published in the APPENDIX of this report.

The 95% confidence limits for the mean low-gradient (values -0.002 °C ≤ T1-T2 ≤ 0.002 °C) differences are ±0.00299 mPSU for salinity-C1SAL, ±0.00376 mPSU for salinity-C2SAL and ±0.00300 mPSU for C1SAL-C2SAL. The 95% confidence limits for the deep salinity residuals (where pressure ≥ 2000 dbar) are ±0.00174 mPSU for salinity-C1SAL,±0.00159 mPSU for salinity-C2SAL and ±0.00165 mPSU for C1SAL-C2SAL.

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

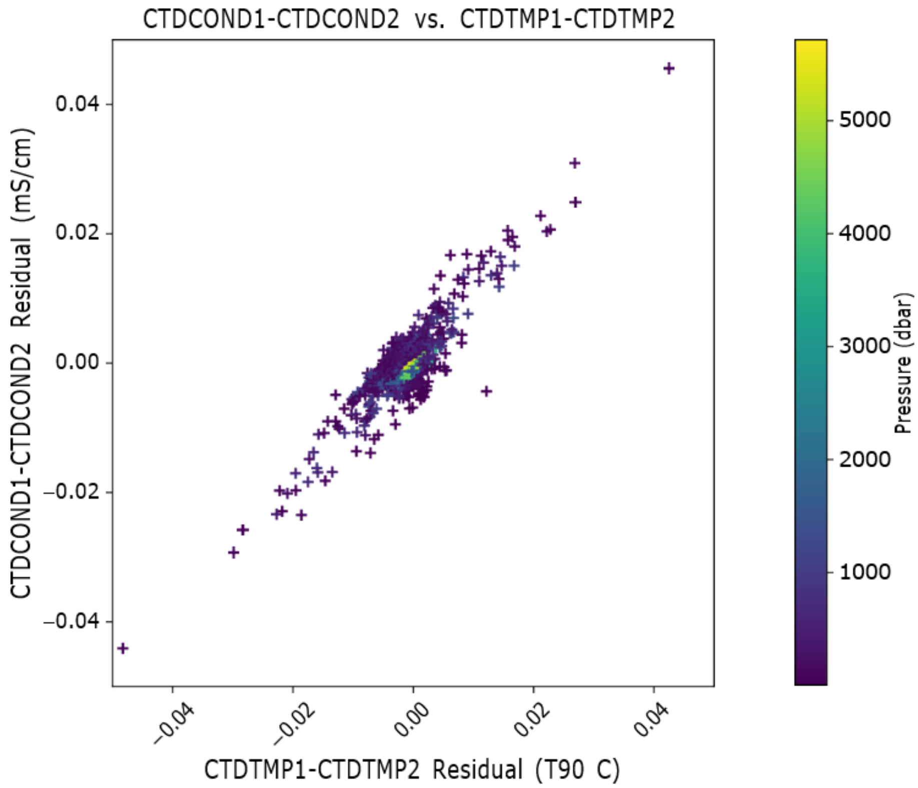


Figure 6.11. Coherence of conductivity differences as a function of temperature differences.

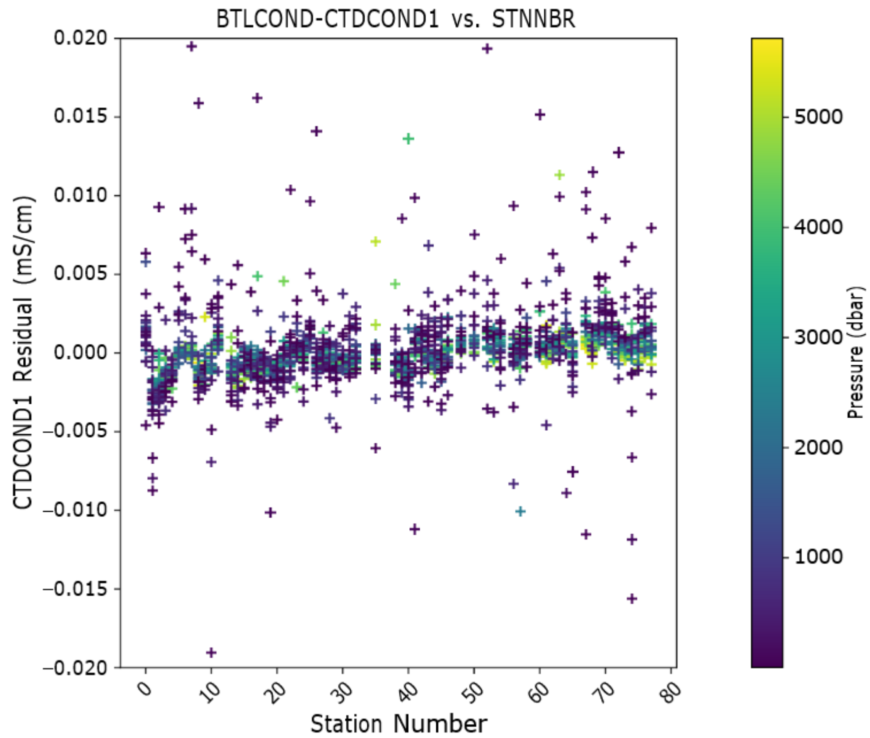


Figure 6.12. Corrected C_{Bottle} - C1 versus station.

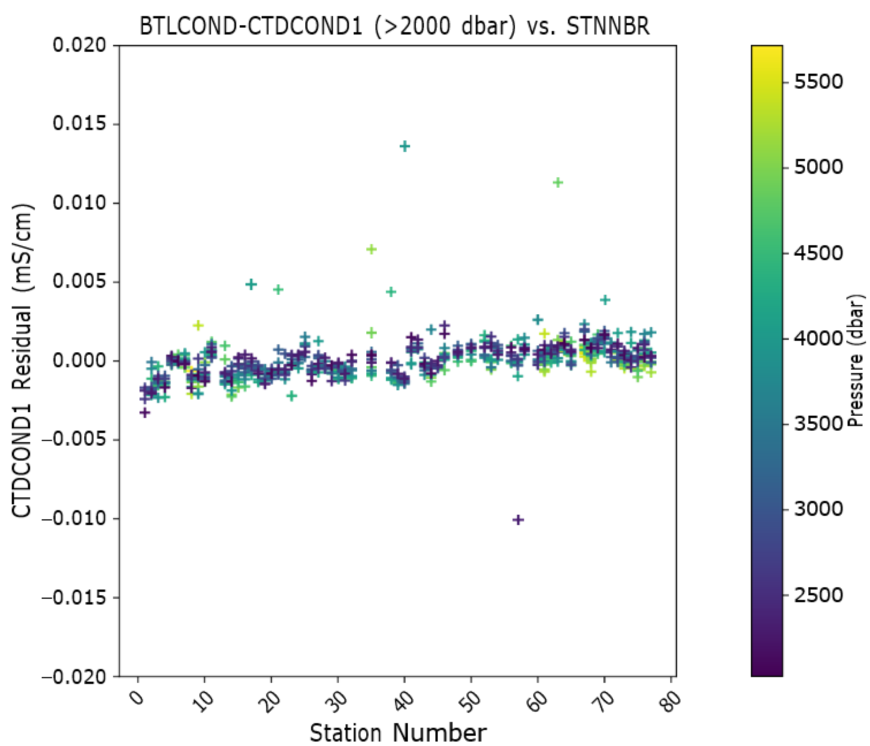


Figure 6.13. Deep Corrected C_{Bottle} - C1 versus station (Pressure >= 2000dbar).

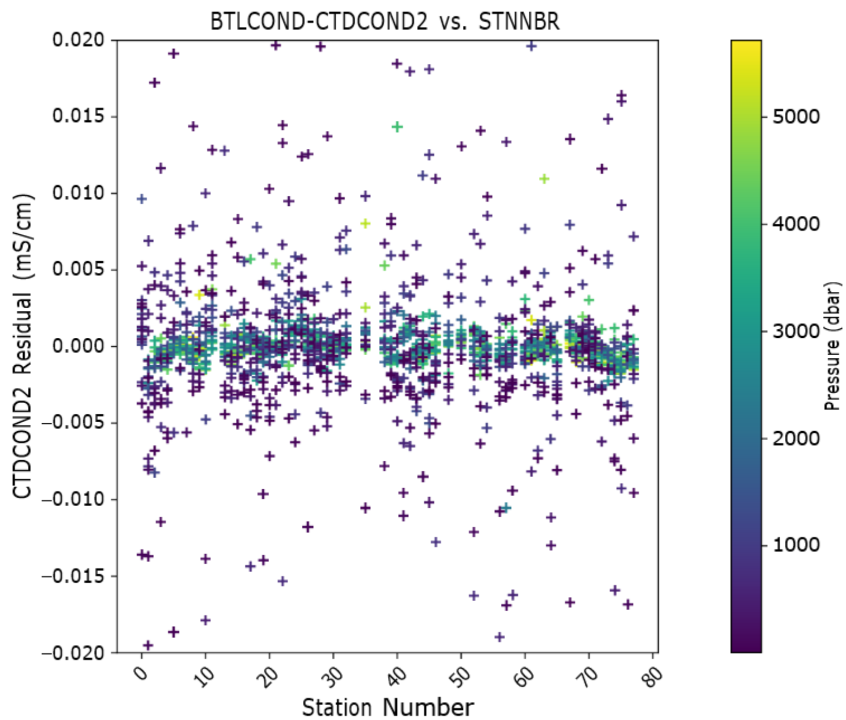


Figure 6.14. Corrected C_{Bottle} - C2 versus station.

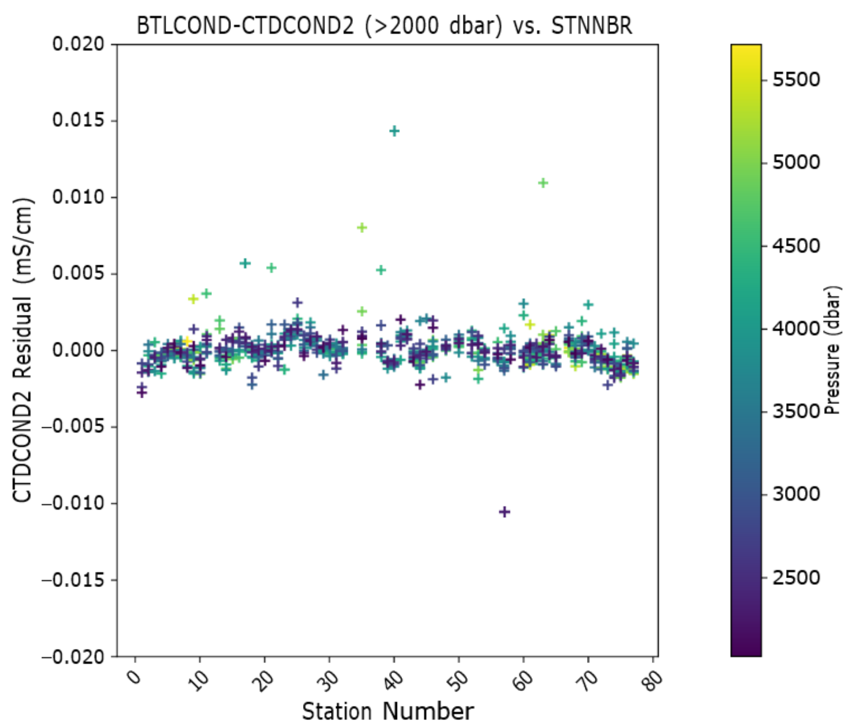


Figure 6.15. Deep Corrected C_{Bottle} - C2 versus station (Pressure >= 2000dbar).

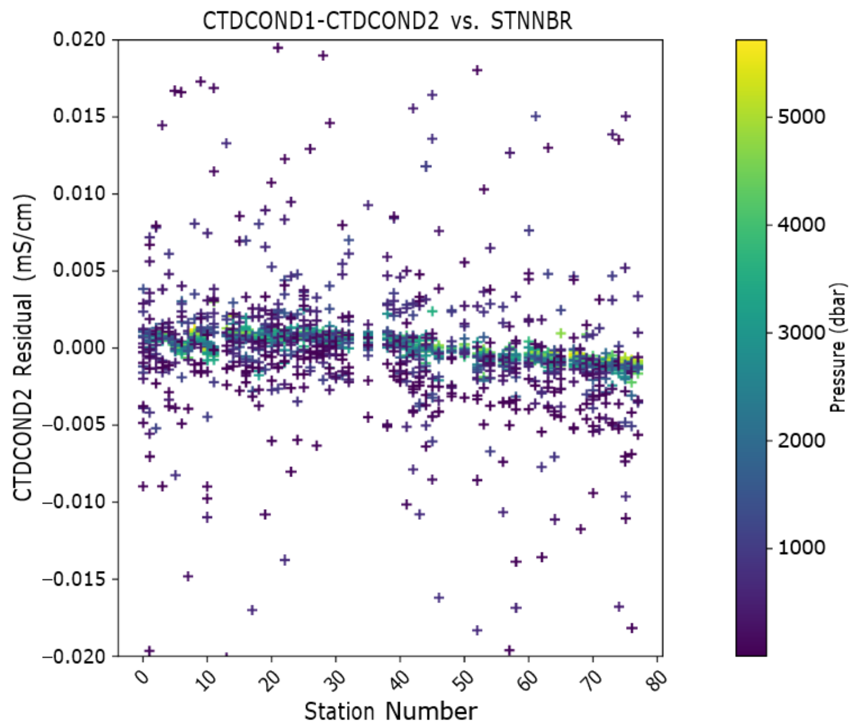


Figure 6.16. Corrected C1-C2 versus station.

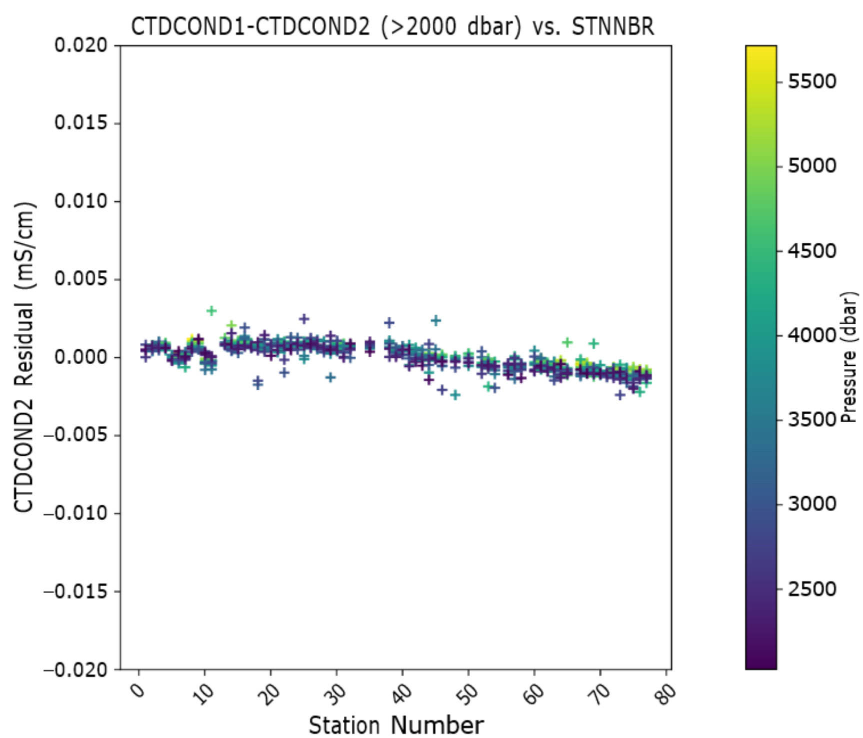


Figure 6.17. Deep Corrected C1-C2 versus station (Pressure >= 2000dbar).

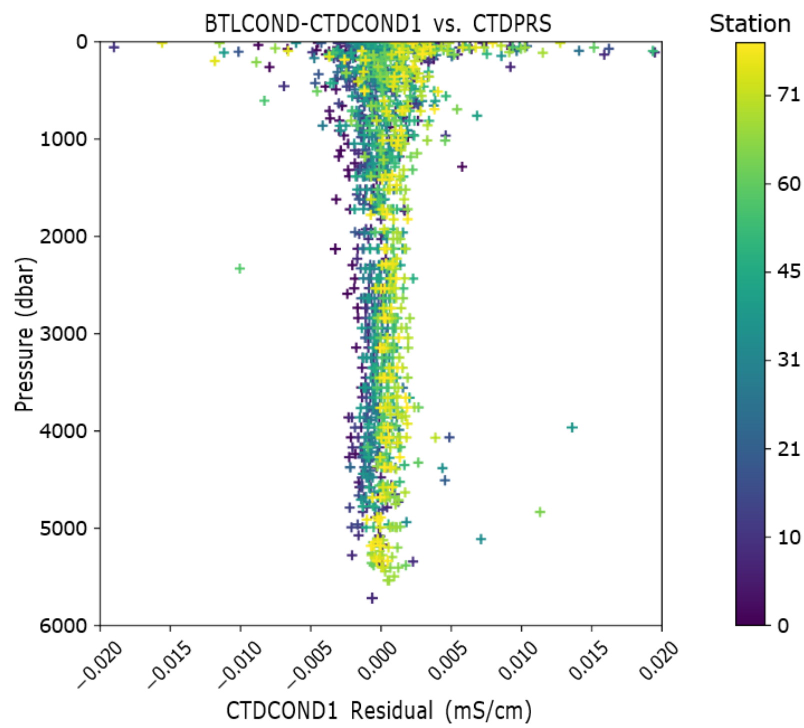


Figure 6.18 Corrected C_{Bottle} - C1 versus pressure.

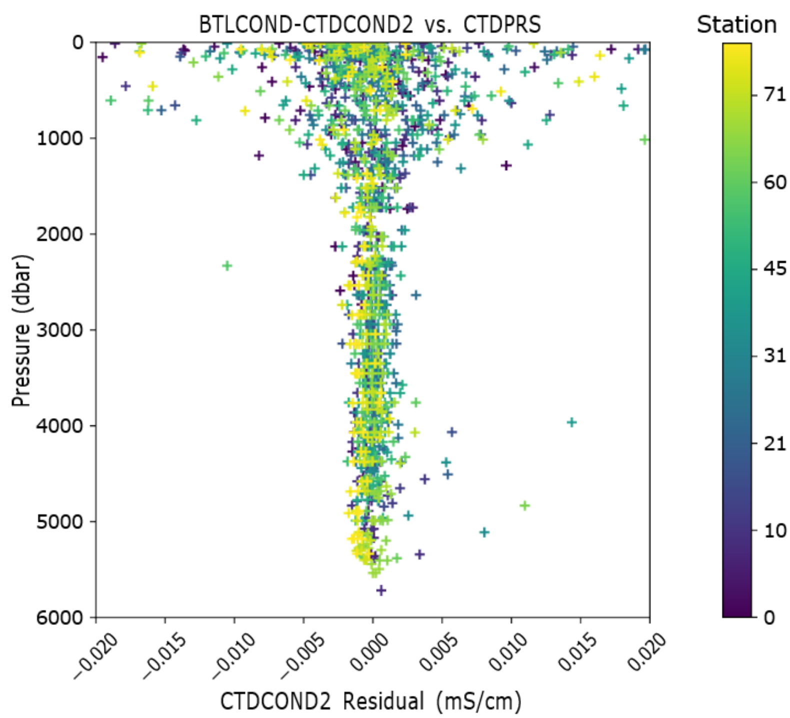


Figure 6.19. Corrected C_{Bottle} - C2 versus pressure.

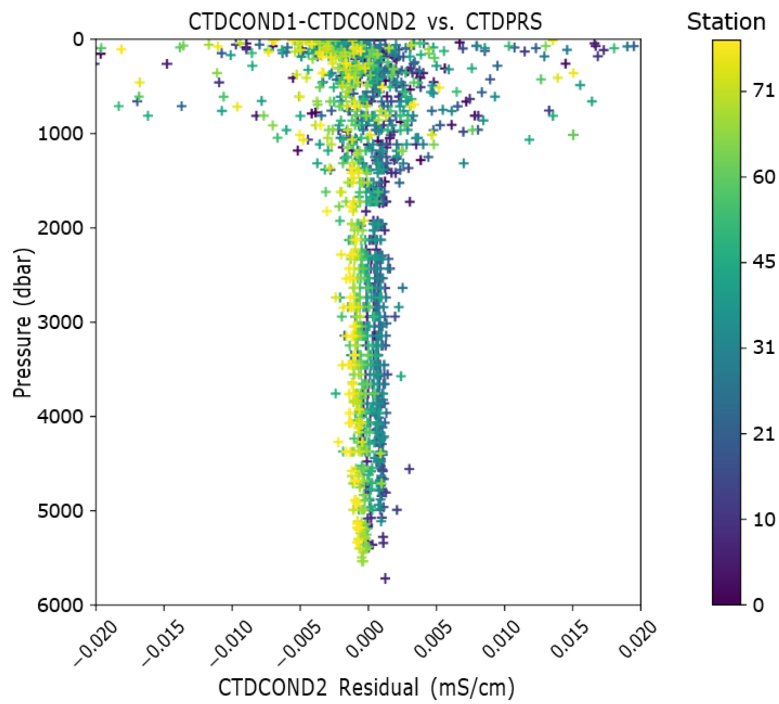


Figure 6.20. Corrected C1-C2 versus pressure.

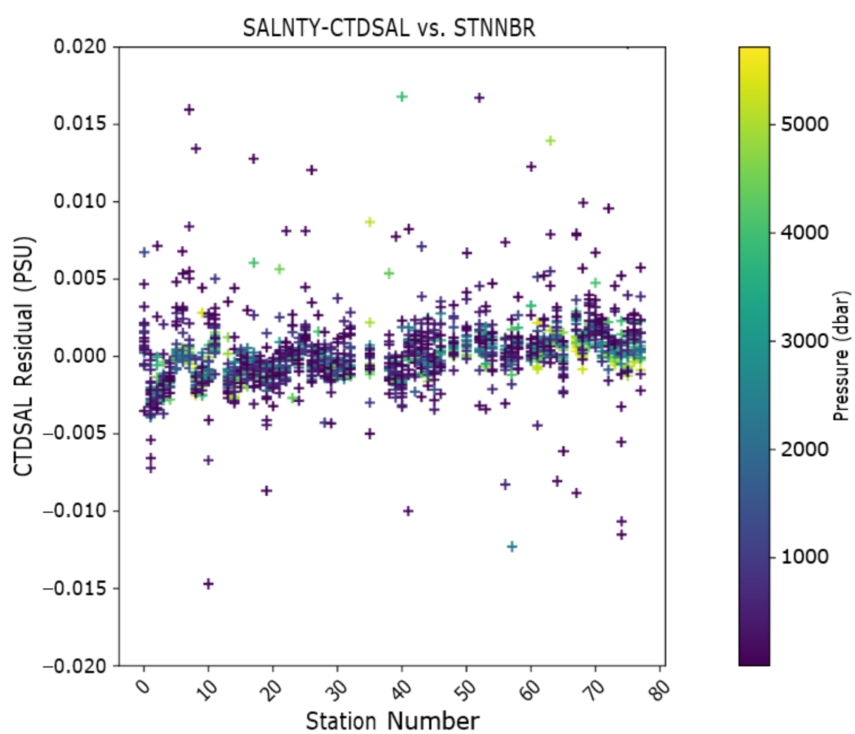


Figure 6.21. Salinity residuals versus station.

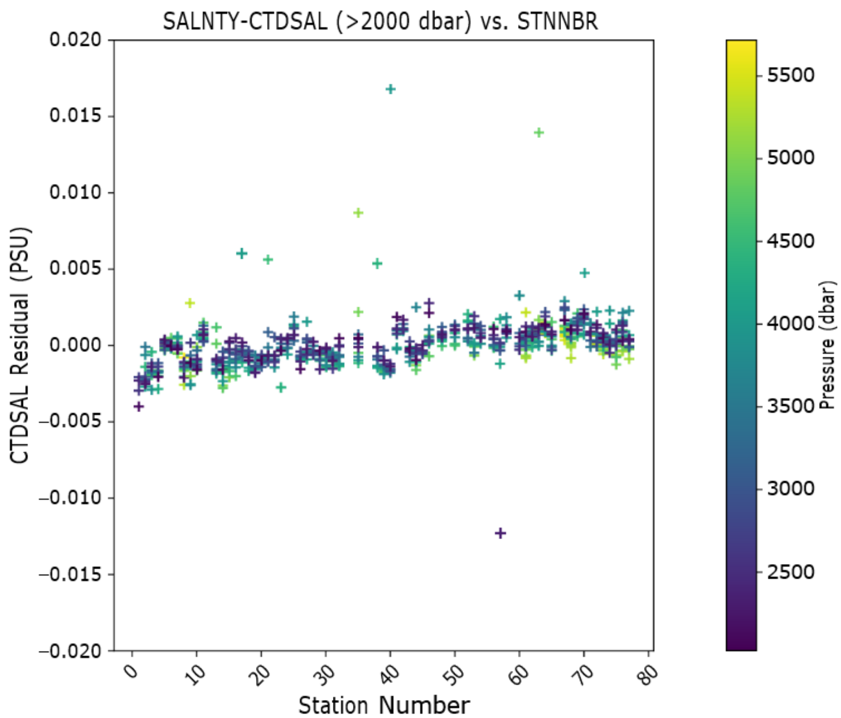


Figure 6.22. Deep Salinity residuals versus station (Pressure >= 2000dbar).

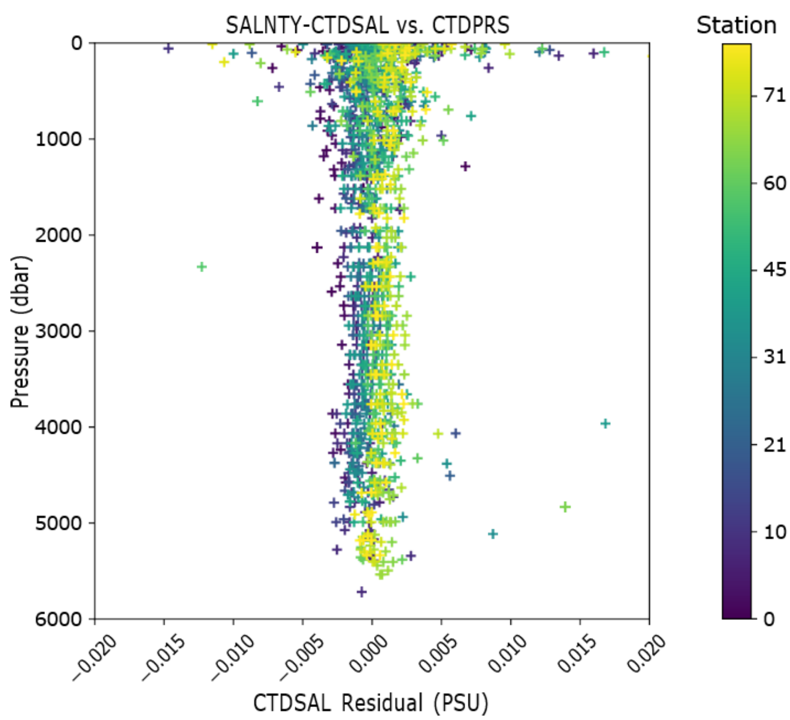


Figure 6.23. Salinity residuals versus pressure.

CTD Dissolved Oxygen (SBE43)

Laboratory calibrations of the dissolved oxygen sensors were performed prior to the cruise at the SBE calibration facility. Dates of laboratory calibration are recorded on the underway sampling package table and calibration documents are provided in the APPENDIX. The pre-cruise laboratory calibration coefficients were used to convert SBE43 frequencies to µmol/kg oxygen values for acquisition only. Additional shipboard fitting were performed to correct for the sensors non-linear response. Corrections for pressure, temperature, and conductivity sensors were finalized before analyzing dissolved oxygen data. Corrections for hysteresis are applied following Sea-Bird Application Note 64-3. The SBE43 sensor data were compared to dissolved O2 check samples taken at bottle stops by matching the downcast CTD data to the upcast trip locations along isopycnal surfaces. CTD dissolved O2 was then calculated using Clark Cell MPOD O2 sensor response model for Beckman/SensorMedics and SBE43 dissolved O2 sensors. The residual differences of bottle check value versus CTD dissolved O2 values are minimized by optimizing the PMEL DO sensor response model coefficients using the BFGS non-linear least-squares fitting procedure.

The general form of the PMEL DO sensor response model equation for Clark cells follows Brown and Morrison [Mill82] and Owens [Owen85]. Dissolved O2 concentration is then calculated:

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

where:

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

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

Table 6.5: SBE43 group fit coefficients. Coefficients were further refined station-by-station.

Station	S_{oc}	V_{off}	tau_{20}	T_{cor}	E
900-77	3.1219e-1	1.3301e-1	1.4551e+0	1.6453e-2	2.7136e-2

CTD dissolved O2 residuals are shown in the following figures SBE43 O2 residuals versus station. through Deep SBE43 O2 residuals versus station (Pressure >= 2000dbar).

The 95% confidence limits of 1.66 (µmol/kg) for all acceptable (flag 2) dissolved oxygen bottle data values and 1.44 (µmol/kg) for deep dissolved oxygen values are only presented as general indicators of the goodness of fit.

Issues arose with the acquisition and processing of CTD dissolved oxygen data.
In stations leading up to 02901, sensor SN 1071 had frequent noise at pressures exceeding 1500 dbar. SN

1071 was replaced with SN 0641 on 03001, but the data quality was noisy by over 60 µmol/kg. SN 0641 was replaced with SN 1508 on 03101, and no issues were observed thereafter.

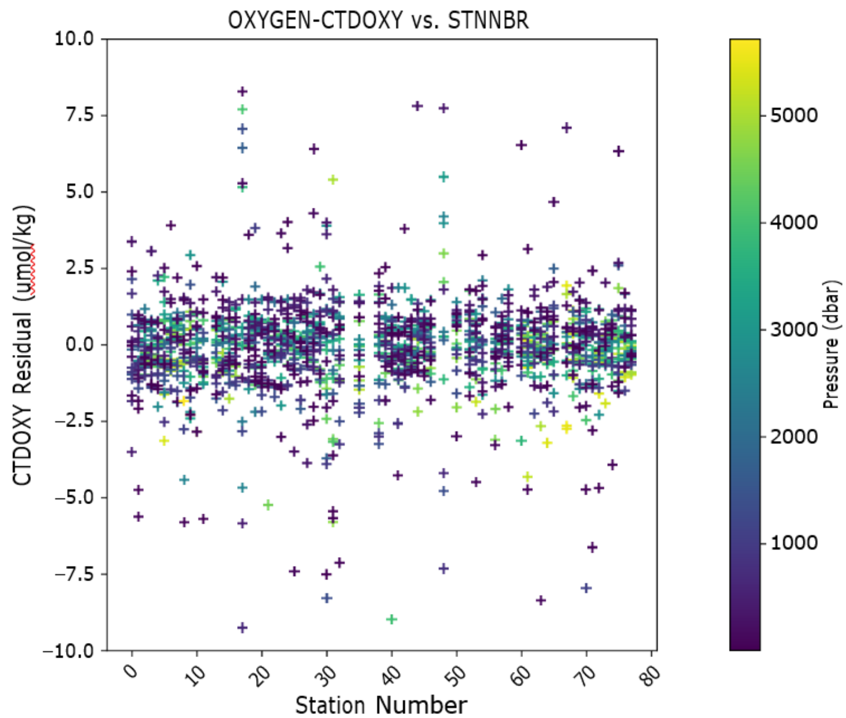


Figure 6.24. SBE43 O_2 residuals versus station.

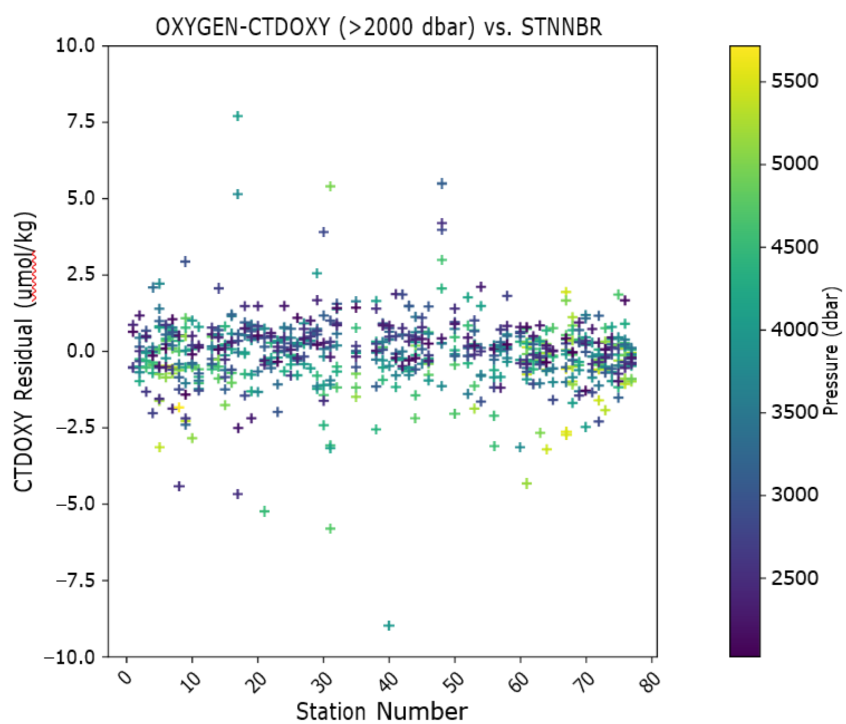


Figure 6.25. Deep SBE43 O_2 residuals versus station (Pressure >= 2000dbar).

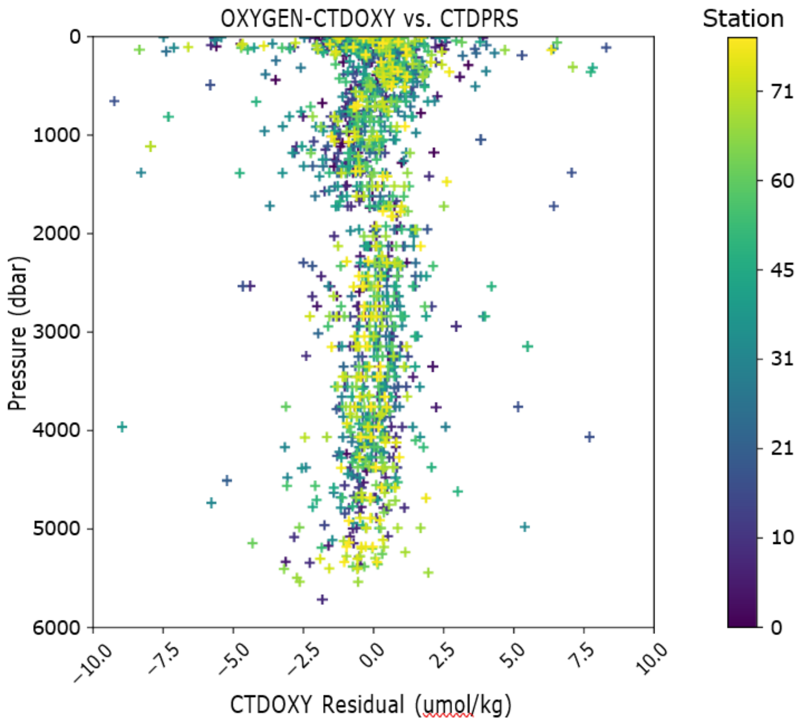


Figure 6.26. SBE43 O_2 residuals versus pressure.

CTD Dissolved Oxygen (RINKO)

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

Rinko temperature (factory coefficients) was used for pre-cruise calibration. Generally, the Rinko III sensor appears to have performed as expected with no major problems or sharp drift throughout the deployment. An SBE 43 dissolved oxygen sensor was deployed simultaneously. Both oxygen sensor data sets were analyzed and quality controlled with Winkler bottle oxygen data. RinkoIII data used as primary oxygen for all stations (900-77).

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

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

$K_{sv} = c_0 + c_1T + c_2T^2, \quad V_0 = 1 + d_0T, \quad V_c = d_1 + d_2V_r$

where:

T is temperature (°C)
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:

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

where:

P is pressure (dbar)
c_p is pressure compensation coefficient

Lastly, salinity corrections are applied [GarciaGordon1992]:

$$[O_2]_{sc} = [O_2]_c \exp[S(B_0 + B_1T_S + B_2T^2 + B_3T^3) + C_0S^2]$$

where:

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

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

Table 6.6: Rinko group fit coefficients. Coefficients were further refined station-by-station.

Station	c_0	c_1	c_2	d_0	d_1	d_2	c_p
900	1.8510e+0	9.1647e-2	1.729e-3	2.4064e-2	-1.8366e-1	3.1019e-1	1.3642e-3
1-77	1.8759e+0	7.1561e-2	1.3416e-3	1.1291e-2	-2.2967e-1	3.2231e-1	7.8759e-2

CTD dissolved O2 residuals are shown in the following figures.

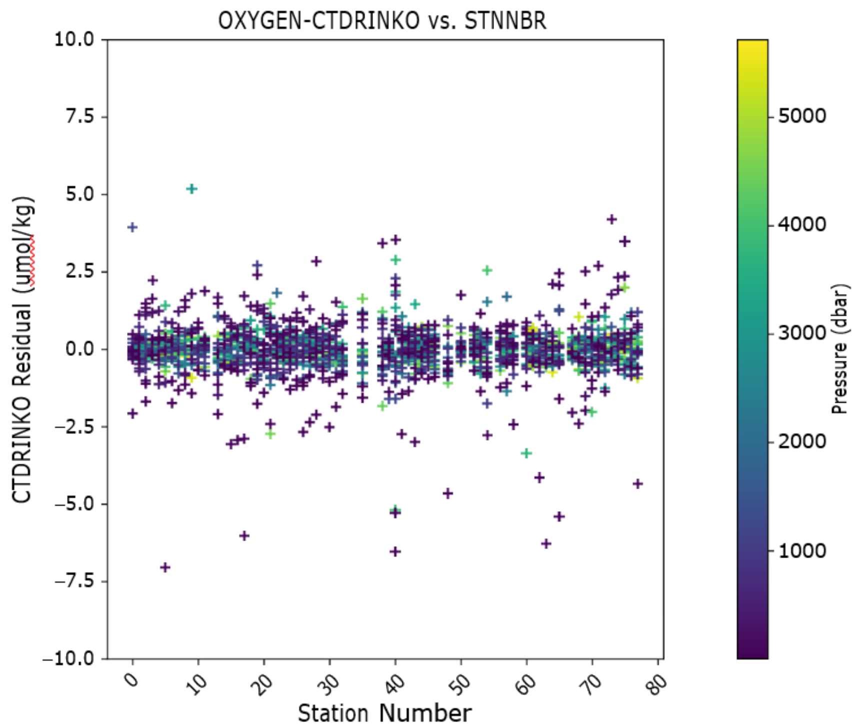


Figure 6.27. RINKO O_2 residuals versus station.

The 95% confidence limits of 1.13 (µmol/kg) for all acceptable (flag 2) dissolved oxygen bottle data values and 0.86 (µmol/kg) for deep dissolved oxygen values are only presented as general indicators of the goodness of fit.

There were no issues with the RINKO during DMB-2023.

RINKO SN 0251 was replaced with SN 0297 after the test station (900) and deck tested, after misreading the voltages in SeaSave. SN 0297 was used on all other casts.

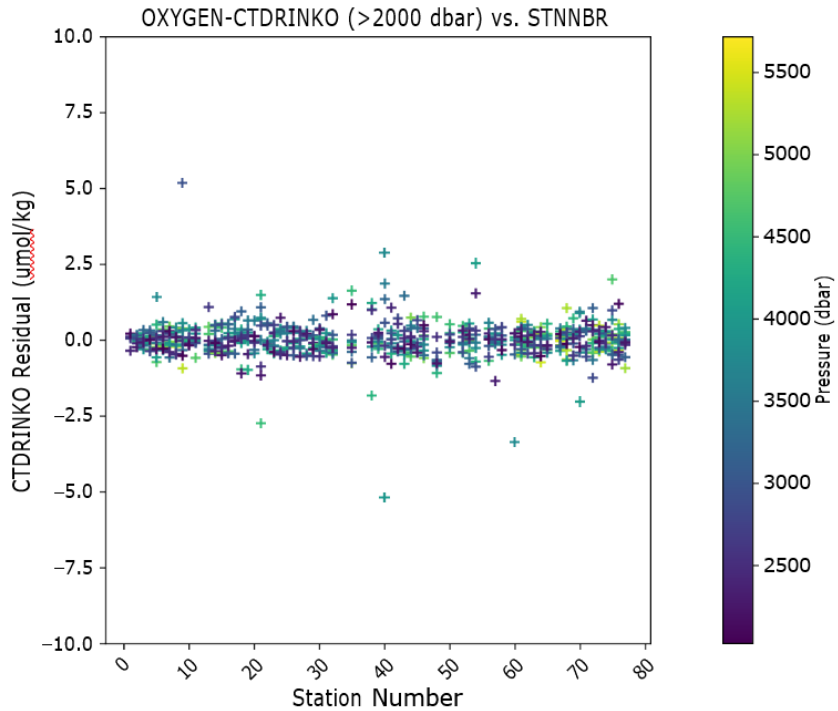


Figure 6.28. Deep RINKO O2 residuals versus station (Pressure >= 2000dbar).

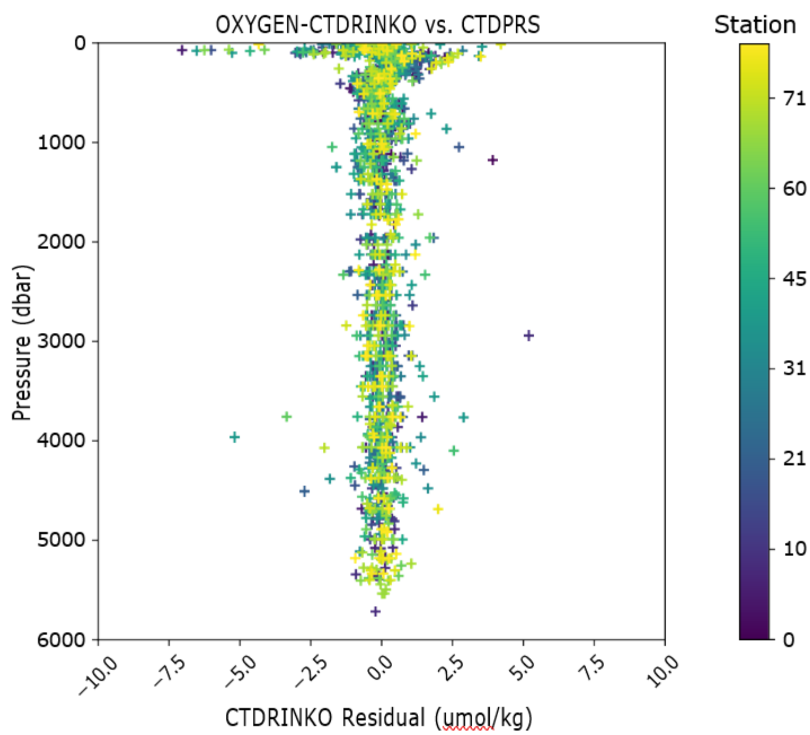


Figure 6.29. RINKO O2 residuals versus pressure.

Section 7. Salinity

Technician
Nick Mathews (RVTEC)

Equipment and Techniques

Two Guildline Autosals were on board and operational, SIO-owned 8400A S/N 57-526 and 57-654. S/N 57-526 was used for all salinity measurements during DMB-2023. 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 21 and 25 degrees Celcius around 3 times each hour, with an average (based on measuring temperatures of items in the chamber) of about 23°C.

IAPSO Standard Seawater Batch P-165 was used for all calibrations: K15 = 0.99986, salinity 34.994, expiration 2024- 04-15. A LabView program developed by Carl Mattson (UCSD ODF) was used for monitoring temperatures, logging data and prompting the operator. Salinity analyses were performed after samples had equilibrated to laboratory temperature of 23°C, usually 8 hours or more after collection. Samples were placed under fans to speed their acclimatization to the set room temperature.

The salinometer was standardized for each group of samples analyzed (1 to 3 casts, up to 66 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.

Sampling and Data Processing

The salinity samples were collected in 200 ml Kimax high-alumina borosilicate bottles that had been rinsed at least three times with sample water prior to filling. The bottles were sealed with plastic insert thimbles and Nalgene screw caps. This assembly provides very low container dissolution and sample evaporation. Prior to sample collection, inserts were inspected for proper fit and loose inserts replaced to 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.

Narrative

1466 salinity samples were taken during DMB-2023, including 20 samples from test cast 90001.

Salt sample bottle #1 was broken while sampling during cast 00701. Replaced with a spare to resume sampling. Due to difficulties standardizing during casts 00501, 00601, 00701, and 01001 and 01101, the standardization dial was adjusted significantly. This was resolved after cast 01101 by inverting the standard more rigorously and flushing the conductivity cell more prior to a standardization. Sample Bottle #34 in box O's threaded lip where cap goes was found to be cracked slightly. The bottle was removed from circulation after station 15.

The climate chamber had two instances where temperature rose outside of acceptable tolerances. Following the recovery of cast 02001, the chamber's climate control stopped cooling and rose to approximately 29 °C. The issue was resolved by the shipboard electrician and the chamber returned to 22 °C within 6 hours of identifying the problem. Prior to the deployment of cast 07101, the chamber rose to approximately 28 °C. The chief engineer was able to resolve the issue and the chamber returned to 22 °C within 3 hours of identifying the problem. Samples were allowed to equilibrate for another 8 hours after the room returned to normal.

Section 8. Oxygen Analysis

Technicians

Andrew Barna (SIO)

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.

Sampling and Data Processing

A total of 1463 oxygen measurements were made, all of which were niskin samples. Niskin samples were collected soon after the rosette was secured on deck, either from fresh niskins or immediately following CFC sampling.

Nominal 125 mL volume-calibrated biological oxygen demand (BOD) flasks were rinsed 3 times with minimal agitation using a silicone draw tube, then filled and allowed to overflow for at least 3 flask volumes, ensuring no bubbles remained. Pickling reagents $MnCl_2$ 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 analyzed within 2-24 hours of collection, and the data incorporated into the cruise database.

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

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.

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.

Narrative

The ODF oxygen rig was setup in the main lab of the R/V Roger Revelle while in Cape Town, ZA. About 600ml of each oxygen reagent were left over from the previous cruise and utilized for the first few stations. Additional reagents were made after the ship left port and the DI water systems were running again. A single batch of ODF oxygen standard was used (2022A.A 14Oct2022mjr) for the entire cruise.

No analytical issues were encountered.

Section 9. Nutrient Analysis

Technicians
Kelcey Chung (SIO)
Megan Roadman (SIO)

Summary of Analysis

- 1534 samples from 81 stations (this includes 20 samples from test station), four stations did not include a CTD, and ten CTD stations were not sampled for nutrients.
- The cruise started with new pump tubes, and they were changed once, before station 03.8
- 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 96%-100%.

Equipment and Techniques

Nutrient analyses (phosphate, silicate, nitrate+nitrite, and nitrite) were performed on a Seal Analytical continuous-flow AutoAnalyzer 3 (AA3). The methods used are described by Gordon et al [Gordon1992] Hager et al. [Hager1972], and Atlas et al. [Atlas1971]. Details of modification of analytical methods used in this cruise are also compatible with the methods described in the nutrient section of the updated GO-SHIP repeat hydrography manual (Becker et al., 2019, [Becker2019]).

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 30% Brij 35 surfactant. Store at room temperature in a dark poly bottle.

N-(1-Naphthyl)-ethylenediamine dihydrochloride (N-1-N) Dissolve 1g N-1-N in DIW, bring to 1 liter volume. Add 2 drops of 30% Brij 35 surfactant. Store at room temperature in a dark poly bottle. Discard if the solution turns dark reddish brown.

Imidazole Buffer Dissolve 13.6g imidazole in ~3.8 liters DIW. Stir for at least 30 minutes to completely dissolve. Add 60 ml of CuSO4 + NH4Cl mix (see below). 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% CuSO4 solution to this NH4Cl stock. This should last many months.

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 H2SO4. This solution gets VERY HOT!! Cool in the ice bath. Make up as much as necessary in the above proportions. Dissolve 27g ammonium molybdate in 250ml of DIW. Bring to 1 liter volume with the cooled sulfuric acid sol'n. Add 3 drops of 15% DDS surfactant. Store in a dark poly bottle.

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

Silicate Analysis

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

Reagents

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

Ammonium Molybdate Dissolve 10.8g Ammonium Molybdate Tetrahydrate in 1000ml dilute H_2SO_4. (Dilute H_2SO_4= 2.8ml conc H_2SO_4 or 6.4ml of H_2SO_4 diluted for PO_4 moly per liter DW) (dissolve powder, then add H_2SO_4) Add 3-5 drops 15% SDS surfactant per liter of solution.

Stannous Chloride stock: (as needed)

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

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

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

Sampling

Nutrient samples were drawn into 30 ml polypropylene screw-capped centrifuge tubes. The tubes and caps were cleaned with 10% HCl and rinsed 2-3 times with sample before filling. Samples were analyzed within 1 hours after sample collection. Prior to analysis, the samples were left on counter for 30-60 minutes to reach room temperature. The tubes were put directly onto the sampler.

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 concen- trations (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.

Another program was used to convert micro moles/liter to micro moles/kilogram, using the lab temperature and salinity from the CTD.

Standards and Glassware Calibration

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

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

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

Standardizations were performed at the beginning of each group of analyses with working standards prepared every 12-16 hours from a secondary. Working standards were made up in low nutrient seawater (LNSW). Three batches of LNSW were used on the cruise. Two batches of LNSW were treated in the lab, and one was collected on station 9. The water that was treated in the lab was re-circulated for ~8 hours through a 0.2 micron filter, passed a UV lamp and through a second 0.2 micron filter. The actual concentration of nutrients in this water was empirically determined during the standardization calculations.

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

	N+N µmol/L	PO_4 µmol/L	SIL µmol/L	NO_2 µmol/L
0	0.0	0.0	0.0	0.0
3	15.50	1.20	60	0.50
5	31.00	2.40	120	1.00
7	46.50	3.60	180	1.50

Quality Control

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

NO_3	0.05 µM (micro moles/Liter)
PO_4	0.004 µM
SIL	2-4 µM
NO_2	0.05 µM

The deep check sample (99) was collected on the first station and was analyzed on every station.
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. [Becker 2019]. RMNS batch CM was used on this cruise, with each bottle being used for four runs before being discarded and a new one opened.

Data are tabulated below.

Parameter	Concentration	stddev	assigned conc
-	(µmol/kg)	-	(µmol/kg)
NO_3	33.2	0.3	33.2
PO_4	2.38	0.03	2.38
Sil	100.5	0.5	100.5
NO_2	0.018	0.006	0.0018

Analytical Problems

There were some issues with the intersample bubble causing the phosphate baseline not to be stable during a run, it did not effect the samples or the data produced. After the pump tubes were changes, more of this bubble went to the N+N channel and it was even less of an issue.

The values of the reference material were used to in addition to the periodic column efficiency checks to monitor data quality. Adjustments based on the values obtained for the reference material were made as necessary.

Section 10. CFC-11, CFC-12, SF_6

Lead Technician
Jim Happell (RSMAS)

Technicians
Abby Tinari (RSMAS)
Anne Cruz (WHOI/NOSAMS)

Sample Collection

All water samples were collected from the 10.4 liter Niskin bottles on the 24 bottle ODF rosette. Only 22 bottles were used because 7wo were removed for an ADCP. A water sample was collected from the Niskin bottle petcock using silcone tubing to fill a 300 ml BOD bottle. The tubing was flushed of air bubbles. The BOD bottle was placed into a plastic overflow container. Water was allowed to fill BOD bottle from the bottom into the overflow container. The stopper was held in the overflow container to be rinsed. Once water started to flow out of the overflow container the overflow container/BOD bottle was moved down so the tubing came out and the bottle was stoppered under water while still in the overflow container. Additional surface water samples were also collected from the ships underway system. Air samples, pumped into the system using an Air Cadet pump from a polyethylene air intake hose mounted high on the foremast were also run Air measurements are used as a check on accuracy.

Equipment and Technique

Chlorofluorocarbons CFC-11, CFC-12, and SF6 were measured on 62 stations for a total of ~ 1400 samples. Stations 68 through 71 were not sampled due to instrument issues. These instrument issues caused the SF6 values to be no good from stations 72 to 77. Analyses were performed on a custom-built purge and trap gas chromatograph (GC) equipped with an electron capture detector (ECD). This system had recently been rebuilt, with a new gas chromatograph, new values actuators, and new instrument control and data acquisition software. Modifications were also made to measure N2O, along with the other three parameters. The samples were stored at room temperature and analyzed within 12 hours of collection. Every 6 to 12 samples were followed by an instrument blank and a standard. A subset of samples were held after measurement and was sent through the process again in order to "restrip" it to determine the efficiency of the purging process.

Calibration

A gas phase standards, 426505, was used for calibration. The concentrations of the compounds in this standard are reported on the SIO 1998 absolute calibration scale. Calibration curves were run over the course of the cruise. Estimated accuracy is +/- 2%. Precision for CFC-12, CFC-11, and SF6 was less than 2%. The estimated limit of detection is 1 fmol/kg for CFC-11, 3 fmol/kg for CFC-12 and 0.05 fmol/kg for SF6.

Section 11. LADCP

Shore Support, Oversight, pre-cruise port setup
Dan Torres (WHOI)
Lead Technician
Frank Bahr (WHOI)
ECRs
Lois Baker (ICL)
Nick Reynard (ICL)

Instrumentation and setup

Full ocean depth velocity profiles were collected by outfitting the CTD rosette with two Acoustic Doppler Current Profilers (ADCPs). The upward facing unit was a TRDI WH300 (serial number 10417), while the downward facing unit was a lower frequency TRDI WH150 (#13656) for extended range. A 48V battery from Deep Sea Power and Light completed the instrumentation. A so-called star cable with five leads connected both ADCPs to the battery and provided two leads for communications with the data acquisition computer situated in the wet lab. Between casts, two deck cables were attached to those leads to program the ADCPs for deployment, and to download the internally recorded data after the rosette's return on deck. The battery could be charged through either of these two deck cables. Prior to launch, the deck cables were disconnected and dummied up.

The hardware to install of the WH150 onto the rosette shown below was newly designed for this cruise. Due to time constraints, only a mock-up of the setup could be tested prior to the cruise by Dan Torres before the rosette was shipped out from San Diego to Cape Town. While Dan did not participate in the cruise, he traveled to Cape Town to ensure that the system could be properly assembled with the newly fabricated bracketry.

While the WH300 brackets were similar to those used on previous cruises, we included a picture of its attachment to the rosette here as well.

The ADCPs were programmed via the python script "wh_dnup.py" that started two terminal windows with menus to send standard TRDI commands for uploading ADCP command files, downloading data, and other tasks. It ran on a linux computer that was connected to the ship's time sever to ensure accurate system and ADCP time in UTC.


Data collection and initial processing

Following a cast, the data were downloaded from the two ADCPs to the linux computer and backed up on local USB drive as well as to the ship's network "cruise share" drive. It was copied from there to a PC for initial processing in matlab. Utilizing the Visbeck/Thurnherr LADCP LDEO _IX software package with additional inputs from a CTD 1Hz time series as well as the Revelle's shipboard ADCP, preliminary estimates of zonal and meridional water velocity as well as a series of quality plots were generated to assess system performance. A simple website provided access to a series of figures for each station (see the example included below). Final processing will be performed at WHOI by Dan Torres following the cruise.

System performance

Following station 4, intermittent data drop-outs occurred during the data download from the upward looking WH300. After some trouble-shooting, the issue was traced to a faulty star cable. In hindsight, the last portion of the cable leading to the WH300 connector had not been adequately protected from strumming during CTD profiling. The issue disappeared after the star cable was replaced and the lead to the WH300 re-routed and stiffened.

An error by the python script "wh_dnup.py" was observed later in the cruise that did not appear to affect operations but was disturbing nonetheless. With no other changes to the system, it seemed that it might have related to the recently started linux screensaver. The error disappeared when the screensaver was turned off again. It remains unclear how the screensaver could have triggered the script error, but we were satisfied with the disappearance of the problem and did not investigate further.

Figures

General oceanographic understanding of the deep ocean suggests that water velocities there are small, as was observed here in most LADCP profiles. However, a few casts around the canyons included remarkable water speeds. The example shown below is from station 56.

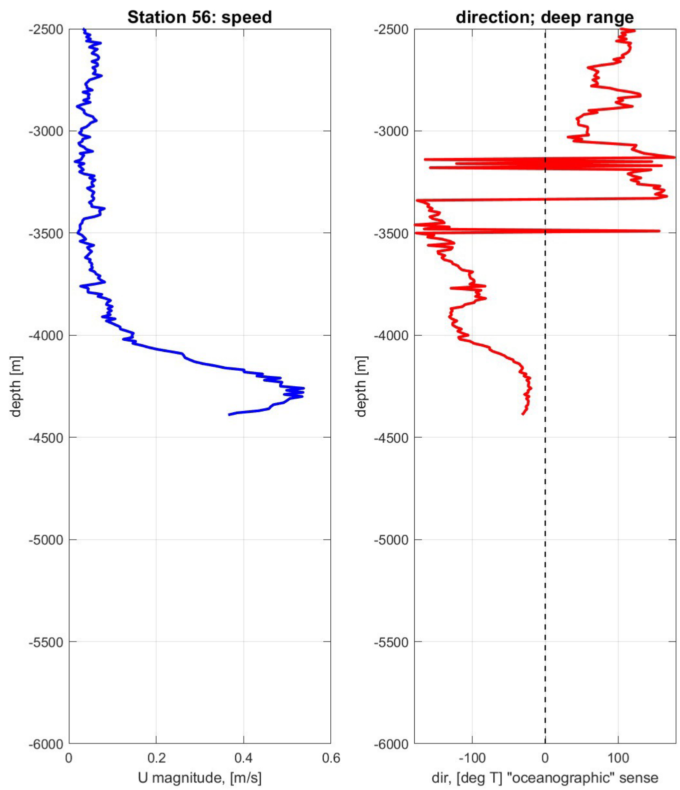


Figure 11.1. LADCP measured at Station 56, in the Novara Fracture Zone.

Section 12. SADCP

Technician

Frank Bahr (*WHOI*)

Instrumentation

Shipboard Acoustic Doppler Current Profiler (ADCP) measurements were collected by a TRDI 150 KHz Ocean Surveyor transducer. Conversion from ship-relative to earth coordinates (eastward, northward positive) utilized ship's GPS position from a Seapath unit and heading from the ship's gyro compass. Small time-dependent errors of the gyro compass were corrected with a secondary heading dataset, in this case also coming from the Seapath. Derived from inertial navigation aided by differential GPS, this additional heading device has traditionally been considered less reliable than the gyro heading and is therefore applied as a correction rather than selected as the original heading feed. However, we did not observe drop-outs of Seapath heading during this voyage.

Unfortunately, the ship's second TRDI ADCP, an OS75 KHz, was not available during our cruise due to hardware prob- lems of the transducer. However, the R/V Revelle also operates the Hydrographic Sonar System (HDSS) supported by Scripps' Multiscale Ocean Dynamics (MOD) group. A two-frequency system, it is capable of measuring ocean currents down to 1000m, more than twice the range of the OS150. The HDSS data still require specialized processing by the MOD group, but may become available to us at a later time.

Data collection and initial processing

OS150 data were collected throughout the cruise by the University of Hawaii's UHDAS acquisition software (https://currents.soest.hawaii.edu/index.html). It was configured to collect 5-minute ensemble averages with 8m vertical res- olution in narrowband mode only. With surface blanking set to 8m, the first vertical bin was centered at 22m. High quality data were collected down to about 300m in the DMB23 operations area; the ADCP briefly reached down to 450m shortly after departing Cape Town during acoustically more favorable conditions.

While ADCP system performance was very closely monitored by the *UH* group, we opted to collect bottom track (BT) data over the continental shelf off Cape Town to confirm the calibration. The results shown below confirm the expected excellent alignment ("phase") of the transducer.

During the cruise, the collected data were visually inspected using the CODAS program "dataviewer.py -e" (CODAS is an ADCP data processing package also developed at *UH*). It revealed a remarkably clean dataset that required very little manual editing. Aside from a short stretch of bottom interference during our brief stop off Mussel Bay, the only issue that required manual editing was occasional "underway bias" affecting the top bins, usually only the first one. It was observed during times of high ship speed (>12 knots) and/or poor weather conditions, likely triggered by bubbles getting swept under the hull.

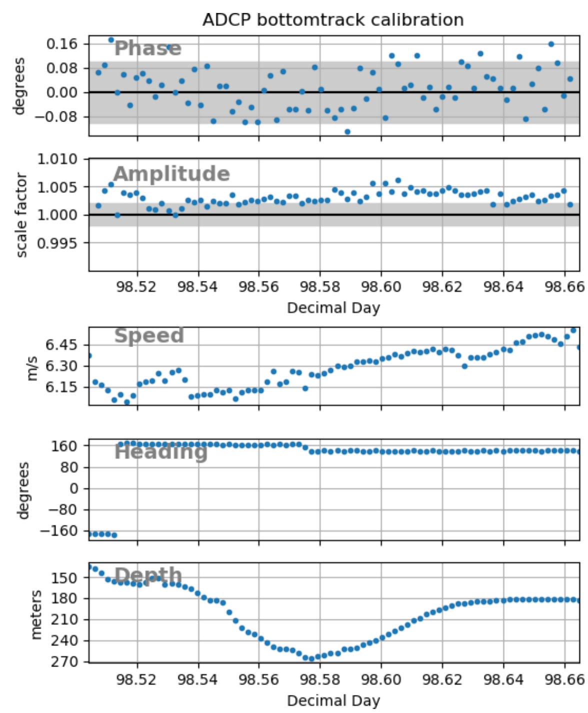


Figure 12.1. Daily plots of ADCP vector maps and velocity contour plots provided a first impression of the data during the cruise, with an example shown below. The data will be run through one final "sanity check" back at *WHOI* following the cruise but are close to finally processed at this point.

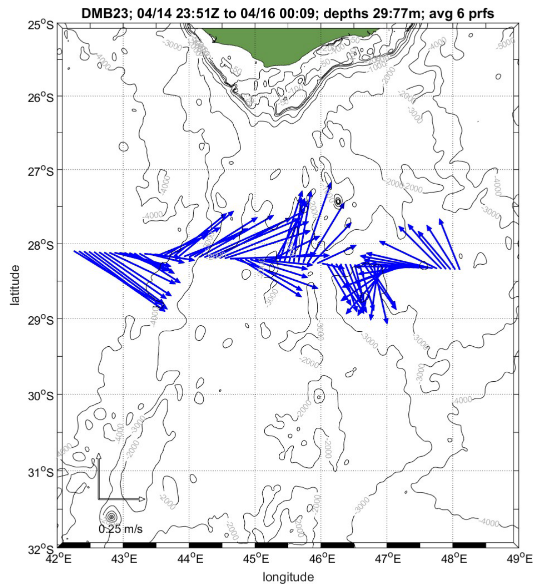


Figure 12.2. Daily map of ADCP velocity vertically averaged over 50m centered at about 50m from April 15 UTC. Depth contours from ETOPO1.

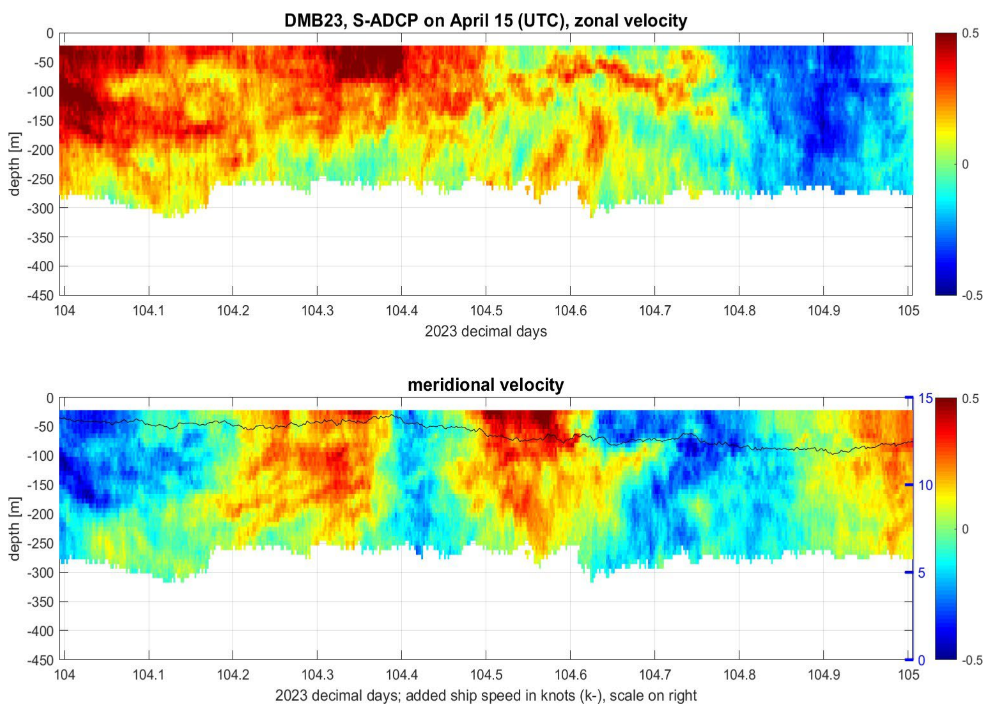


Figure 12.3. Velocity color contours from the same time period, April 15 UTC, with panels for zonal (top, eastward positive) and meridional (bottom, northward positive) velocity components. The lower panel includes ship speed in knots is superimposed as thin black line, with a speed scale on the right.

Section 13. Piggyback: $\delta^{15}N$, $\delta^{18}O$ Isotopes

Technician

Liisa Shangheta (UCT)

This piggy-back project was initiated by UCT researchers Tanya Marshall and Sarah Fawcett. At sea, Liisa Shangheta was the person carrying out the work.

Summary of Sampling Collection

Samples were collected for $\delta 15N$ and $\delta 18O$ of nitrate (NO3) and dissolved organic nitrogen (DON) following the conclusion of specific casts. The sampling technician wore latex gloves and collected samples following volatile gas sampling. Samples were collected in 50 mL Nalgene bottles which were labeled and sorted prior to the recovery of the cast. Sample bottles and lids were rinsed with Niskin water before the final sample was collected.

Samples were stored in refrigerators aboard the Revelle at -20 °C prior to shipping for further analyses at UCT . $\delta 15N$ and $\delta 18O$ of NO3 will be measured following the conclusion of the cruise in the University of Cape Town's Marine Biogeochemistry Lab (UCT-MBL). $\delta 15N$ of the sample's total dissolved nitrogen (TDN) will be measured to acquire the $\delta 15N$ of DON . All units are in per mille (‰).

Station	Note
900	Test station
1	
9	Center of Deep Madagascar Basin
13	Changed from 12
20	
27	
31	
38	Gallieni fracture; originally 37
40	
43	Duplicate sampling stops
46	
50	Atlantis II fracture
52	
58	Novara fracture; originally 59
62	
65	
71	Melville fracture
74	
77	

Section 14. Student Statements

Amália Andrade Adauto
UFC
As an oceanography undergraduate student who is currently working in geology on a geohabitats project, but has a strong interest in the physical interactions of the oceans, I am extremely grateful for the opportunity to participate in the DMB23 scientific cruise in the Indian Ocean to acquire new technical knowledge and to participate in the productive scientific discussions that took place through the expedition.

During the 35-days work experience on the RV Roger Revelle, together with another student, I participated on the night shift in the organization and observation of the CTD, where I was one of the responsibles for preparing the equipment before the ship arrived at the scheduled station, monitoring the data collected in the water column when the equipment was already deployed, firing the Niskin bottles at determined depth in order to later analyze the current patterns at each cast and supervising the collection of samples. In addition, I also participated in the launching of floats such as RAFOS and Deep ARGO. Moreover, of the eDNA sampling performed by the student and researcher Océane Desbonnes.

As a woman and a Latin American, I know how challenging it can be to get opportunities to develop in the scientific environment, whether it be professionally or even to get opportunities to participate in extracurricular activities. So, to be able to see two intelligent and inspiring women as chief scientists on this expedition, in addition to the other women students present was really encouraging for me. Also, having the opportunity to better understand the physical oceanographic processes instigated me to want to better understand this area of research and contribute to the knowledge that is available on this subject.

In short, this experience gave me a new perspective on marine science, with respect to the processes and techniques used in scientific research, in addition to personal development, by being in contact with people from different cultures and different conceptions of life. I will never forget the importance of this experience. I thank everyone involved, from the ship's crew members to the participants of the scientific party, but especially the chief scientist Viviane Menezes who provided me with this opportunity.

Gésica Canivete
MPDC
When I expressed my interest in participating in the oceanographic research cruise in the Madagascar basin, I was already extremely excited, some time later I learned that I had been selected and that made me even more excited to know that I would have the opportunity to "learn marine sciences with experienced people" convinced that this is the best way to start my journey to become a good professional.

I am Gésica Canivete, from Mozambique. Graduated in Physical Oceanography, currently working as a hydrographic researcher for the largest port in my country. As a student of Physical Oceanography I had the opportunity and privilege to work with hydrodynamic issues of the estuary, in order to determine the scope of saline intrusion in relation to the times of the year. I have also developed work in the area of environmental oceanography with communities that live close to coastal ecosystems in my country.

Opportunities like these to participate in Oceanographic expeditions in Mozambique unfortunately are still rare, I am grateful to have had this opportunity that allowed me to know, but also to experience what it is like to be a researcher in the area of Physical Oceanography. I had the opportunity to meet new instruments, interact, operate and above all learn about the various instruments for measuring the physical properties of the sea, their working principle, learn about how we collect data, take samples for laboratory analysis and also analyse the consistency of the data collected. But I am thankful to know that I was part of the team that did the first data collection in this region. I hope it will be the first of many research cruises in this region.

Well, a short time ago I started on a path to discover my life purpose, and there is nothing better than working in what I love most - marine sciences - and having the opportunity to participate in the cruise made me live each day one step closer to my cause, which is directly linked to ods 14 Conservation and sustainable use of the oceans, seas, and marine resources for sustainable development.

Being part of a team that is contributing to the achievement of target 14a of SDG 14 makes me excited to contribute to increasing scientific knowledge about the oceans, to stimulate the development of research skills in young people to improve ocean health, and to increase the contribution of marine biodiversity to the development of countries, especially developing countries, such as most countries bordering the Indian Ocean.

Among the many lessons learned from this experience, I would like to share two that I will carry with me for the rest of my life:
". . . No matter how much you are walking to the same place, everyone has their own journey in this and their own responsibility to make sure we get there, respecting the process is very good, but enjoying and living the process is much better, this is not about the end, it is about the journey."
" We can always learn something new every day even though we do the same thing every day"

I will end by saying "thank you very much, Kanimambo, Thank you very Much, Merci Beaucoup ,Ngiyabonga kakhulu, Misaotra betsaka, hartelijk dank, Baie dankie. This goes to show that there are no language barriers when we share the same ocean. The ocean is global and so we are united by the ocean and science.

Océane Desbonnes
ARBRE
I am an early career scientist currently working at the Biodiversity Research Agency of La Réunion (ARBRE). I am currently working on an inventory of rays and sharks in the Mascarene archipelago (Reunion, Mauritius, Rodrigues), by using underwater cameras, scuba dives and environmental DNA. I have a Master's degree in ecology and biology I and work on marine biology programs, so I did not know anything about oceanography before coming onboard. This cruise was a great opportunity for me to learn more about this field of studies, and also to lead my research.

Indeed, my role onboard was to make environmental DNA (eDNA) samplings. To do that, I collected water from the rosette's Niskin bottles in capsules containing a filter. The water flows through the capsule, and the DNA molecules get trapped on the filter. Then, I added in the capsule a liquid solution to preserve the DNA and avoid its degradation. These capsules were stored in a fridge to increase DNA preservation. After the cruise, they will be sent to a laboratory in France where PCR and barcoding analysis will be made, in order to match the DNA molecules from the sample with references species sequences. So, we will be able to know which species were present in the water when we collected it. Any kind of species can be found out, as for example plants, bacteria, plankton, fishes, sharks, marine mammals.

eDNA comes from plants or animals' secretions (mucus, dejections, pieces of skin), and can stay a few days in the water before being destroyed by UV, temperature, current or different kinds of enzymes.

To avoid contamination by human DNA, we had to wear gloves, masks, and caps. I was always helped by other students (thank you so much to them!). We collected water from the 3 deepest bottles in one filter, and from the 3 shallowest bottles in another filter, for 42 stations (84 filters in total). So, we will be able to compare the species from the bottom and from the surface, all along the South Indian Ocean Rift.

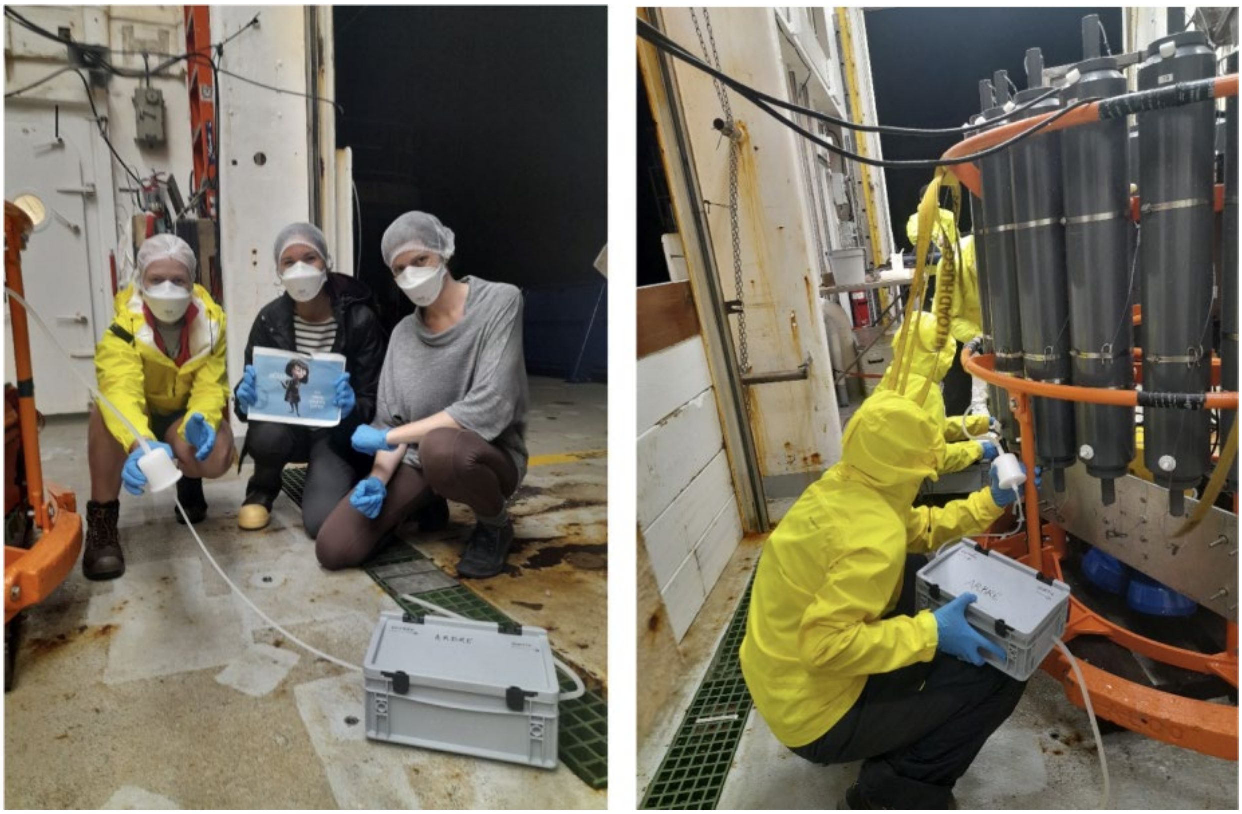


Figure 12.1. eDNA sampling installation, with the capsule filter and the pump.

Sometimes, I also participated in other tasks as CTD watch and floats deployment. I learnt a lot about oceanography studies, samplings, floats, and moorings. It was very interesting to see everyone's work onboard. I really appreciated that all the scientists were very happy to explain to us their study and allow students to get involved, and I was fascinated to discover all of this! Moreover, I liked to talk with crew members about the work and life onboard, and visit the bridge and the engineer room.

As my samplings occurred at different times in the day and the night, I was not part of a shift, I tried to sleep between my samplings. I really enjoyed the life onboard in the middle of the ocean, staying at the bow to see the waves, watching sunsets, sunrises, stars, birds around the ship, clouds. The weather was sometimes very rough, but it was an interesting experience to work and live in these "moving conditions".

To conclude, this cruise was a really great and amazing experience for me, both for the science and the life at sea. Thank you for having allowed me to come onboard and make eDNA sample where nobody did before! I am grateful to all the people onboard that shared their research, their knowledge, and their life experiences, and for the nice moments we spent together. I hope I will have the chance to participate in more research cruises.

Figure 12.2. Pouring preservation solution into the capsule filter

Alexis Mullen

Bowdoin College

I am writing this as we just finished launching the last few drifters and RAFOS floats for this cruise! It feels odd to be nearing the end of this adventure, but after my first time at sea I feel keenly aware that time can warp in mysterious ways.

I've been lucky to be here both as a student and as a WHOI employee under Chief Scientist Viviane's mentorship. I was invited to participate in the cruise following my summer student fellowship in the Physical Oceanography department at WHOI, where I researched intermediate circulation in the Indian Ocean with Viviane as my mentor. I made the decision to take off what would've been my final semester of undergrad at Bowdoin College to participate in this cruise, and I will return to school in the fall to finish out my degree in Earth and Oceanographic Science.

I came in with the intention of seeing what observational oceanography was really like, and now I understand the unpredictability of being at sea, and of being at the mercy of waves, weather, port logistics, and equipment. I've learned hands-on how to prep and monitor the CTD/rosette, and how to deploy drifters and a variety of different floats.

Experiencing this and talking with many on board about their jobs and life experiences has been incredibly informative as I decide whether to pursue graduate school in oceanography.

I'm grateful to have made friends from all over the world who have taught me much about language and life. Here, I have experienced the magic of the sky and sea. Never before in my life have I seen such beautiful stars, clouds, and waves. Scorpio and the Southern Cross have been friends throughout this trip and I feel in tune with the cycles of the moon. I'm leaving this ship knowing that I would like to learn how to navigate by the stars, and how to read the weather and clouds. It was a joy to be held and rocked by the ocean each day and night. I will cherish all of the sunrises, sunsets, and warm sunny days chilling out on the back deck for the rest of my life.

Figure 12.3. Rainbow off the bow. Photo credits to Frank Bahr

Nick Reynard
ICL
In my day-to-day PhD work, I focus on modelling large-scale ocean circulation based on observational data. Scaling down an entire ocean basin to the size of a computer screen can make you lose appreciation for the vastness of the actual ocean and how we often infer information from sets of singular vertical profiles the width of a CTD rosette. Being part of the DMB cruise brings back the appreciation of how much effort goes into collecting data at sea and I'd say every oceanographer, computational or observational, should jump at the opportunity if given the chance!

At the start of this DMB cruise the prospect of 5 weeks at sea was pretty daunting but I soon realised that some of the crew were going to be away for over 4 months so it was going to be no problem at all. I soon got into my own routine of 11.30pm alarms, multiple breakfasts, beautiful sunrises and great company to work with through my shift. I primarily worked as a LADCP watchstander under the knowledgeable Frank Bahr and I want to thank him for entrusting me to run his instruments. Lastly, thank you Viviane for allowing me to join this cruise and I'll look forward to seeing the work that comes from the data we collected on this cruise.

Anna Liisa Penelao Tulimevava Shangheta
UCT
What a great opportunity to meet amazing people and learn from world-renowned scientists. One thing that particularly stood out for me was the leadership style employed by our chief scientists, Viviane Menezes and Heather Furey. Their stellar example of soft leadership has impressed me beyond words, and I hope to emulate it in my future endeavours. Furthermore, this cruise was more hands-on than other cruises, which I really liked. Lovely discussions were had! I will always remember our enthusiasm as the CTD graphs showed the Antarctic Bottom Water signature characteristics. Science is really cool! I also enjoyed seeing MARPOL stickers and posters around the ship as I was writing a paper on the legal regime governing vessel-soured marine pollution.

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Appendix A: Abbreviations

A/B Able-bodied seaman
ADCP Acoustic Doppler Current Profiler
A/E Assistant engineer
ARBRE Agence de Recherche pour la Biodiversité à La Réunion
BGC Biogeochemical
CFCs Chlorofluorocarbons
CPUT Cape Peninsula University of Technology
CTDO Conductivity Temperature Depth Oxygen
DON Dissolved Organic Nitrogen
eDNA Environmental DNA
GO-BGC Global Ocean Biogeochemistry Array
HPLC High-Performance Liquid Chromatography
ICL Imperial College London
IHSM Institut Halieutique et des Sciences Marines
LADCP Lowered Accoustic Doppler Current Profiler
MET Meteorological sensor
MPDC Maputo Port Development Company
NO2 Nitrite
NO3 Nitrate
NOSAMS The National Ocean Sciences Accelerator Mass Spectrometry Facility - WHOI
NSF National Science Foundation
ODF Oceanographic Data Facility - SIO
O/S Ordinary seaman
OSNAP Overturning in the Subpolar North Atlantic Program
PO4 Phosphate
POC Particulate Organic Carbon
PON Particulate Organic Nitrogen

Appendix B: Bottle Quality Documents

During eDNA casts, bottle numbers were fired on the fly and the SBE35 reference thermometer did not have time to equilibrate. A list of eDNA casts is provided in the CTDO section.

Station	Cast	Bottle	Param	Code	Comment
8	1	4	SALNTY	3	salty, may be early closure
9	1	9	NUTS; SALNTY; OXY; CFC	4	Nutrient; salinity; oxygen; and CFC data indicate this bottle closed a higher depth than intended
16	1	3	NUTS; SALNTY; OXY; CFC	4	Nutrient; salinity; and oxygen data indicate this bottle closed a higher depth than intended
17	1	1	NUTS; SALNTY; OXY; CFC	4	Nutrient; salinity; and oxygen data indicate this bottle closed a higher depth than intended
21	1	1	SALNTY	3	salty may be, late closure
30	1	1	BOTTLE	4	Bottle did not close
31	1	1	SALNTY; OXY	4	Bottle was warm; salinity and oxygen indicates closure to surface
35	1	1	SALNTY	3	salty, may be late closure
35	1	6	BOTTLE	4	Bottle did not close
38	1	1	SALNTY; OXY	4	Oxy temp and salinity indicates bottle to have closed at the same level as bottle 4
40	1	1	SALNTY; OXY	4	Oxy temp and salinity indicates bottle to have closed at the same level as bottle 5
42	1	1	BOTTLE	4	Bottle did not close
46	1	10	SALNTY	3	salty, may be early closure
48	1	1	SALNTY; OXY	4	Oxy temp and salinity indicates bottle to have closed at the same level as bottle 8
50	1	20-24	REFTMP	3	Bottles fired on the fly
53	1	1	SALNTY; OXY	4	Oxy temp high, salinity salty
54	2	2	OXY	3	Oxygen value high
57	1	9	SALNTY	3	fresh, may be late closure
58	1	10	BOTTLE	4	Bottle leaking profusely and was not sampled
60	1	1	SALNTY	3	salty, may be late closure
64	1	9	SALNTY	3	salty, may be late closure
64	1	14	OXY; CFC	3	Low oxy temp; bottle leaky
64	1	23	SALNTY	3	fresh, may be early closure
66	1	1	BOTTLE	4	Bottle did not close
67	1	10	SALNTY	3	salty, may be early closure
74	1	23	SALNTY	3	fresh, may be early closure
77	1	23	SALNTY	3	fresh, may be early closure

Appendix C: Calibration Documents

Pressure Calibration Report
STS Calibration Facility

SENSOR SERIAL NUMBER: 0569
CALIBRATION DATE: 07-DEC-2021
Mfg: SEABIRD Model: 09P CTD Prs s/n: 75672

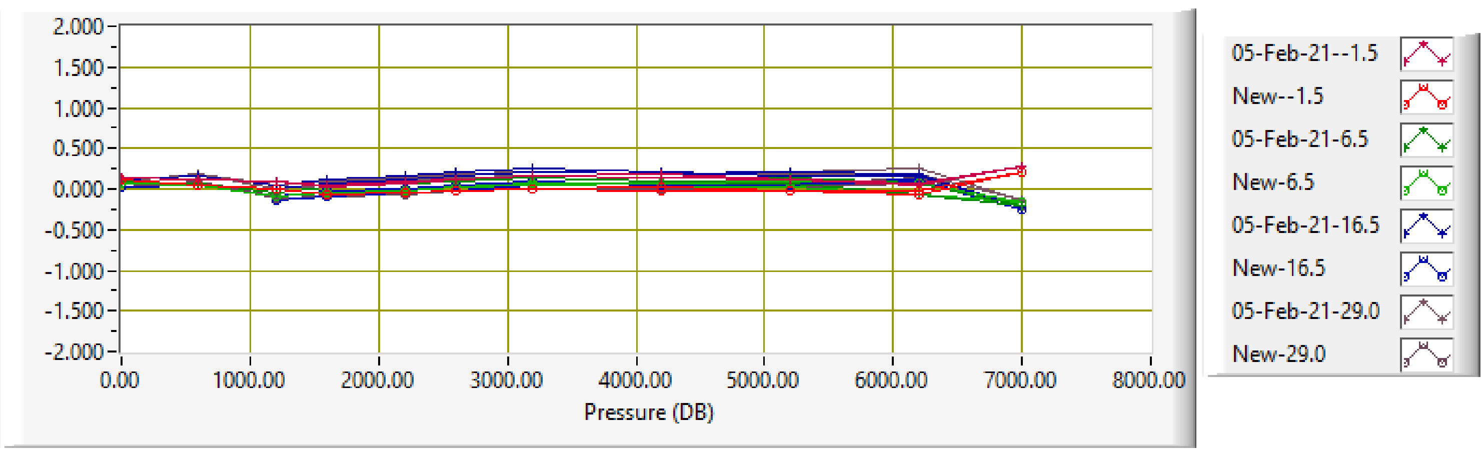
C1= -4.261473E+4
C2= -1.007365E-1
C3= 7.514018E-3
D1= 3.786680E-2
D2= 0.000000E+0
T1= 3.044517E+1
T2= -4.160351E-4
T3= 4.704882E-6
T4= -1.557303E-8
T5= 0.000000E+0
AD590M= 1.28617E-2
AD590B= -8.28826E+0
Slope = 1.00000000E+0
Offset = 0.00000000E+0

Calibration Standard: Mfg: FLUKE Model: P3125 s/n: 70856
t0=t1+t2*td+t3*td*td+t4*td*td*td
w = 1-t0*t0*f*f
Pressure = (0.6894759*((c1+c2*td+c3*td*td)*w*(1-(d1+d2*td)*w)-14.7)

Sensor Output	DWT	Sensor New_Coefs	DWT-Sensor Prev_Coefs	DWT-Sensor NEW_Coefs	PT-DegC	Bath_Temp
32851.539	0.27	0.16	0.13	0.11	-0.33	-1.522
33184.957	600.32	600.27	0.11	0.05	-0.31	-1.523
33514.522	1200.35	1200.34	0.10	0.01	-0.31	-1.523
33732.191	1600.37	1600.43	0.05	-0.06	-0.31	-1.523
34055.605	2200.40	2200.44	0.10	-0.04	-0.31	-1.523
34269.244	2600.41	2600.44	0.12	-0.02	-0.31	-1.523
34586.849	3200.48	3200.48	0.15	-0.00	-0.31	-1.523
35108.738	4200.53	4200.51	0.18	0.02	-0.30	-1.523
35621.723	5200.59	5200.61	0.12	-0.02	-0.31	-1.523
36126.138	6200.60	6200.63	0.07	-0.03	-0.30	-1.523
36523.627	7000.60	7000.39	0.27	0.21	-0.30	-1.522
36126.137	6200.57	6200.64	0.04	-0.07	-0.31	-1.522
35621.712	5200.56	5200.59	0.11	-0.03	-0.31	-1.522
35108.748	4200.53	4200.54	0.14	-0.01	-0.32	-1.522
34586.852	3200.49	3200.49	0.16	0.00	-0.31	-1.522
34269.262	2600.45	2600.48	0.11	-0.03	-0.33	-1.522
34055.619	2200.42	2200.47	0.08	-0.05	-0.33	-1.522
33732.202	1600.38	1600.46	0.03	-0.08	-0.33	-1.522

Sensor Output	DWT	Sensor New_Coefs	DWT-Sensor Prev_Coefs	DWT-Sensor NEW_Coefs	PT-DegC	Bath_Temp
33514.522	1200.35	1200.35	0.10	0.01	-0.33	-1.523
33184.953	600.32	600.27	0.11	0.05	-0.33	-1.523
32854.870	0.27	0.19	0.08	0.08	7.71	6.485
33188.304	600.32	600.28	0.07	0.04	7.71	6.485
33517.954	1200.35	1200.45	-0.04	-0.09	7.71	6.485
33735.574	1600.37	1600.41	0.03	-0.04	7.71	6.485
34059.018	2200.41	2200.42	0.07	-0.02	7.71	6.484
34272.668	2600.42	2600.41	0.10	0.01	7.71	6.484
34590.279	3200.45	3200.40	0.13	0.04	7.71	6.484
35112.215	4200.46	4200.44	0.10	0.02	7.71	6.484
35625.206	5200.46	5200.45	0.06	0.01	7.71	6.484
36129.706	6200.48	6200.55	-0.07	-0.07	7.72	6.484
36527.416	7000.51	7000.68	-0.21	-0.16	7.72	6.484
36129.681	6200.57	6200.51	0.06	0.06	7.71	6.485
35625.231	5200.59	5200.50	0.15	0.09	7.71	6.485
35112.246	4200.57	4200.50	0.15	0.07	7.71	6.485
34590.300	3200.51	3200.44	0.16	0.07	7.71	6.485
34272.691	2600.46	2600.45	0.10	0.01	7.71	6.485
34059.034	2200.44	2200.45	0.07	-0.02	7.71	6.485
33735.589	1600.39	1600.44	0.02	-0.05	7.71	6.485
33517.961	1200.36	1200.46	-0.04	-0.10	7.71	6.485
33188.297	600.32	600.27	0.09	0.05	7.71	6.485
32858.199	0.27	0.23	0.12	0.03	17.77	16.491
33191.648	600.33	600.28	0.16	0.05	17.78	16.493
33521.344	1200.36	1200.46	0.05	-0.09	17.78	16.492
33738.990	1600.39	1600.42	0.12	-0.03	17.78	16.492
34062.469	2200.43	2200.42	0.17	0.00	17.78	16.492
34276.146	2600.44	2600.40	0.21	0.04	17.79	16.492
34593.787	3200.47	3200.38	0.26	0.09	17.79	16.491
35115.795	4200.48	4200.43	0.21	0.05	17.80	16.491
35628.853	5200.49	5200.45	0.17	0.04	17.80	16.491
36133.354	6200.53	6200.44	0.17	0.09	17.80	16.491
36531.228	7000.54	7000.80	-0.23	-0.26	17.80	16.491
36133.363	6200.57	6200.46	0.19	0.11	17.79	16.491
35628.873	5200.57	5200.50	0.20	0.07	17.78	16.492
35115.829	4200.52	4200.51	0.18	0.02	17.78	16.492
34593.819	3200.49	3200.45	0.21	0.04	17.78	16.492
34276.176	2600.45	2600.47	0.15	-0.02	17.77	16.492
34062.493	2200.42	2200.47	0.12	-0.05	17.78	16.492
33739.012	1600.38	1600.47	0.07	-0.09	17.77	16.491
33521.359	1200.35	1200.49	0.00	-0.14	17.77	16.491
33191.647	600.32	600.28	0.16	0.04	17.77	16.491
32861.152	0.27	0.23	0.08	0.03	30.36	29.003
33194.625	600.33	600.22	0.19	0.10	30.37	29.002
33524.401	1200.36	1200.45	0.03	-0.08	30.37	29.002
33742.094	1600.39	1600.43	0.09	-0.04	30.37	29.002

Sensor Output	DWT	Sensor New_Coefs	DWT-Sensor Prev_Coefs	DWT-Sensor NEW_Coefs	PT-DegC	Bath_Temp
34065.628	2200.43	2200.43	0.15	-0.01	30.37	29.002
34279.342	2600.44	2600.42	0.18	0.02	30.37	29.002
34597.053	3200.48	3200.44	0.20	0.04	30.37	29.002
35119.131	4200.49	4200.47	0.19	0.02	30.37	29.002
35632.257	5200.48	5200.46	0.18	0.03	30.37	29.001
36136.828	6200.49	6200.43	0.17	0.06	30.37	29.000
36534.721	7000.49	7000.69	-0.13	-0.20	30.37	29.001
36136.810	6200.52	6200.39	0.24	0.13	30.37	29.001
35632.277	5200.55	5200.50	0.20	0.05	30.37	29.002
35119.158	4200.53	4200.52	0.18	0.01	30.37	29.003
34597.082	3200.49	3200.50	0.16	-0.01	30.36	29.002
34279.371	2600.45	2600.48	0.13	-0.03	30.36	29.002
34065.652	2200.42	2200.48	0.09	-0.06	30.37	29.001
33742.113	1600.38	1600.47	0.04	-0.09	30.36	29.001
33524.416	1200.35	1200.48	-0.01	-0.12	30.36	29.002
33194.627	600.32	600.23	0.18	0.09	30.36	29.001
32861.142	0.27	0.22	0.10	0.05	30.36	29.000



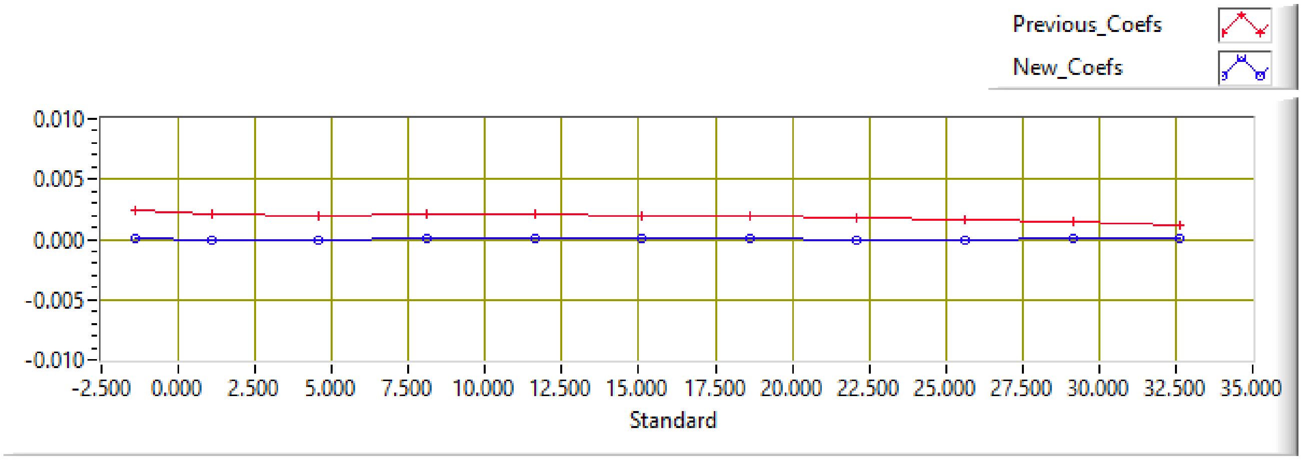
Temperature Calibration Report
STS Calibration Facility

SENSOR SERIAL NUMBER: 4588
CALIBRATION DATE: 25-Oct-2022
Mfg: SEABIRD   Model: 03
Previous cal: 17-Mar-22
Calibration Tech: AJM

ITS-90_COEFFICIENTS	IPTS-68_COEFFICIENTS ITS-T90	
g = 4.35572628E-3	a = 4.35592400E-3	
h = 6.38624856E-4	b = 6.38834399E-4	
i = 2.13547865E-5	c = 2.13865524E-5	
j = 1.86164699E-6	d = 1.86307120E-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
2985.8111	-1.4306	-1.4307	0.00245	0.00011
3158.5513	1.0741	1.0743	0.00207	-0.00013
3412.3253	4.5806	4.5807	0.00198	-0.00009
3680.5454	8.0887	8.0886	0.00208	0.00008
3963.6652	11.5986	11.5985	0.00204	0.00008
4261.1457	15.0997	15.0996	0.00194	0.00001
4575.1015	18.6123	18.6123	0.00192	0.00003
4904.6723	22.1220	22.1221	0.00171	-0.00010
5250.6178	25.6337	25.6337	0.00167	-0.00000
5612.7902	29.1421	29.1421	0.00148	0.00002
5992.2150	32.6542	32.6542	0.00114	0.00001



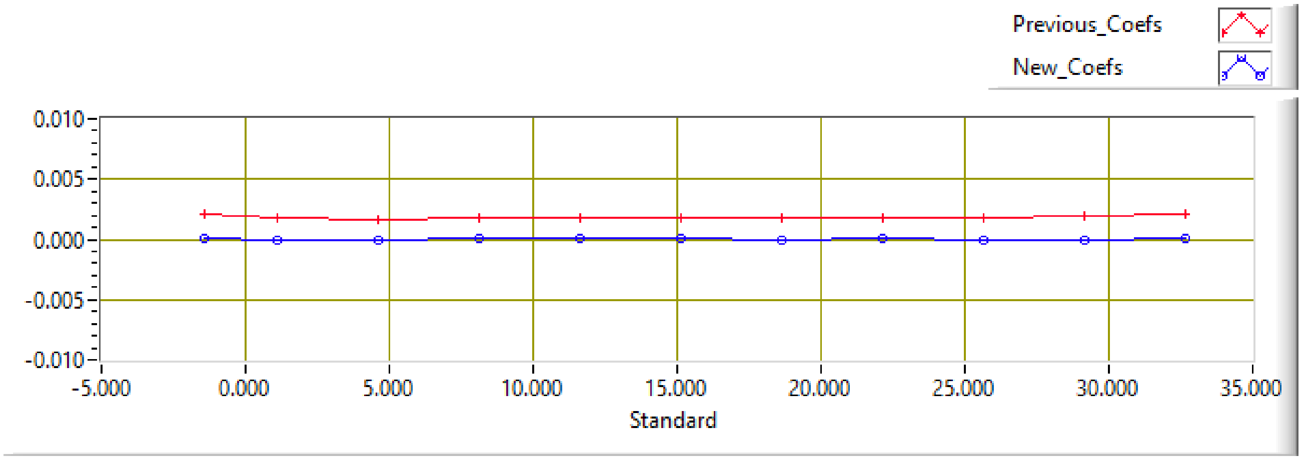
Temperature Calibration Report
STS Calibration Facility

SENSOR SERIAL NUMBER: 4907
CALIBRATION DATE: 14-Mar-2023
Mfg: SEABIRD   Model: 03
Previous cal: 20-Sep-22
Calibration Tech: AJM

ITS-90_COEFFICIENTS	IPTS-68_COEFFICIENTS ITS-T90	
g = 4.37064294E-3	a = 4.37084565E-3	
h = 6.30044752E-4	b = 6.30252852E-4	
i = 2.01947730E-5	c = 2.02257123E-5	
j = 1.55488611E-6	d = 1.55622822E-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
3106.1270	-1.4286	-1.4288	0.00208	0.00011
3288.3980	1.0756	1.0757	0.00174	-0.00012
3556.5123	4.5823	4.5824	0.00167	-0.00008
3840.1779	8.0902	8.0902	0.00171	0.00001
4139.9325	11.6001	11.6000	0.00175	0.00007
4455.3013	15.1016	15.1016	0.00175	0.00005
4788.4461	18.6140	18.6140	0.00175	0.00000
5138.5839	22.1241	22.1241	0.00185	0.00003
5506.6026	25.6364	25.6365	0.00183	-0.00007
5892.2716	29.1453	29.1454	0.00194	-0.00006
6296.6475	32.6571	32.6570	0.00216	0.00006



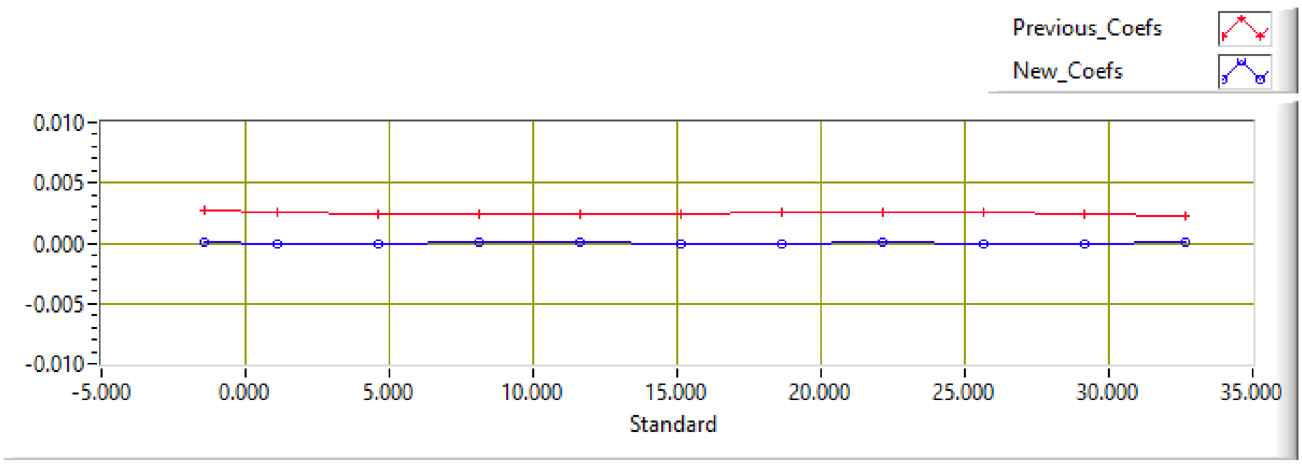
Temperature Calibration Report
STS Calibration Facility

SENSOR SERIAL NUMBER: 6142
CALIBRATION DATE: 14-Mar-2023
Mfg: SEABIRD   Model: 03
Previous cal: 15-Nov-22
Calibration Tech: AJM

ITS-90_COEFFICIENTS	IPTS-68_COEFFICIENTS ITS-T90	
g = 4.36897228E-3	a = 4.36917427E-3	
h = 6.38513742E-4	b = 6.38724030E-4	
i = 2.24170538E-5	c = 2.24488871E-5	
j = 2.10171782E-6	d = 2.10317999E-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
3058.5002	-1.4286	-1.4287	0.00279	0.00005
3236.1090	1.0756	1.0756	0.00250	-0.00006
3497.2026	4.5823	4.5823	0.00238	-0.00003
3773.2236	8.0902	8.0902	0.00240	0.00003
4064.6679	11.6001	11.6000	0.00242	0.00002
4371.0368	15.1016	15.1016	0.00246	-0.00000
4694.3988	18.6140	18.6140	0.00252	-0.00001
5033.9665	22.1241	22.1240	0.00261	0.00004
5390.5619	25.6364	25.6364	0.00254	-0.00002
5763.9350	29.1453	29.1454	0.00242	-0.00005
6155.0645	32.6571	32.6571	0.00230	0.00003



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SENSOR SERIAL NUMBER: 4650
CALIBRATION DATE: 13-Dec-22

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

COEFFICIENTS:
g = -1.01379684e+001
h = 1.34686637e+000
i = -6.91604213e-005
j = 6.87979907e-005

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

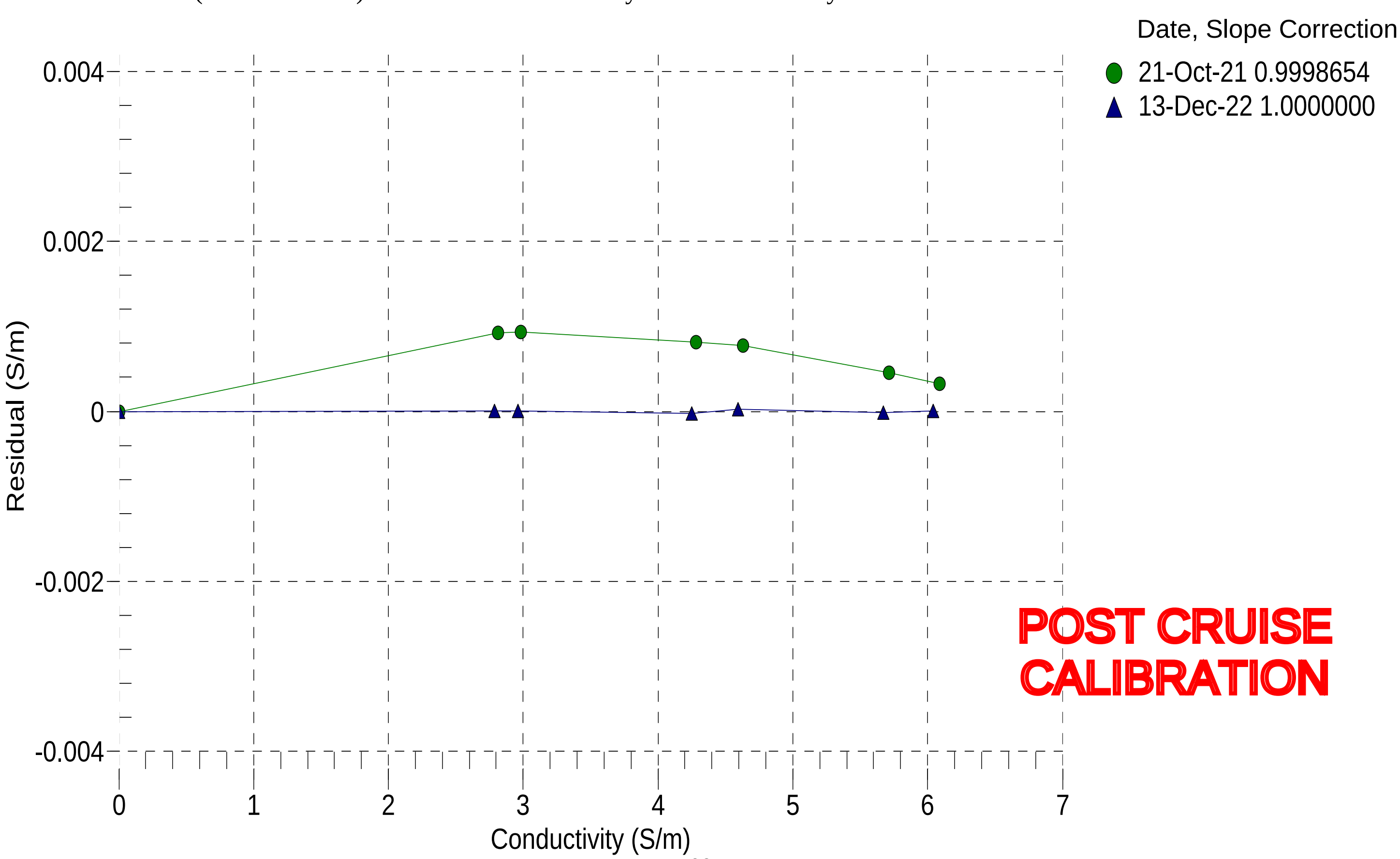
BATH TEMP (° C)	BATH SAL (PSU)	BATH COND (S/m)	INSTRUMENT OUTPUT (kHz)	INSTRUMENT COND (S/m)	RESIDUAL (S/m)
0.0000	0.0000	0.00000	2.74322	0.00000	0.00000
-1.0000	34.6046	2.78911	5.31058	2.78911	0.00000
1.0000	34.6046	2.95959	5.42816	2.95959	0.00000
15.0000	34.6034	4.24825	6.24540	4.24823	-0.00002
18.4999	34.6013	4.59291	6.44636	4.59293	0.00003
28.9999	34.5945	5.67005	7.03717	5.67004	-0.00001
32.4998	34.5787	6.03920	7.22847	6.03921	0.00001

f = Instrument Output (kHz)

t = temperature (°C); p = pressure (decibars); δ = CTcor; ε = CPcor;

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

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



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SENSOR SERIAL NUMBER: 4651
CALIBRATION DATE: 20-Jan-23

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

COEFFICIENTS:

```
g =  -1.01436909e+001
h =   1.37958024e+000
i =  -1.99313797e-005
j =   6.35228858e-005
```

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

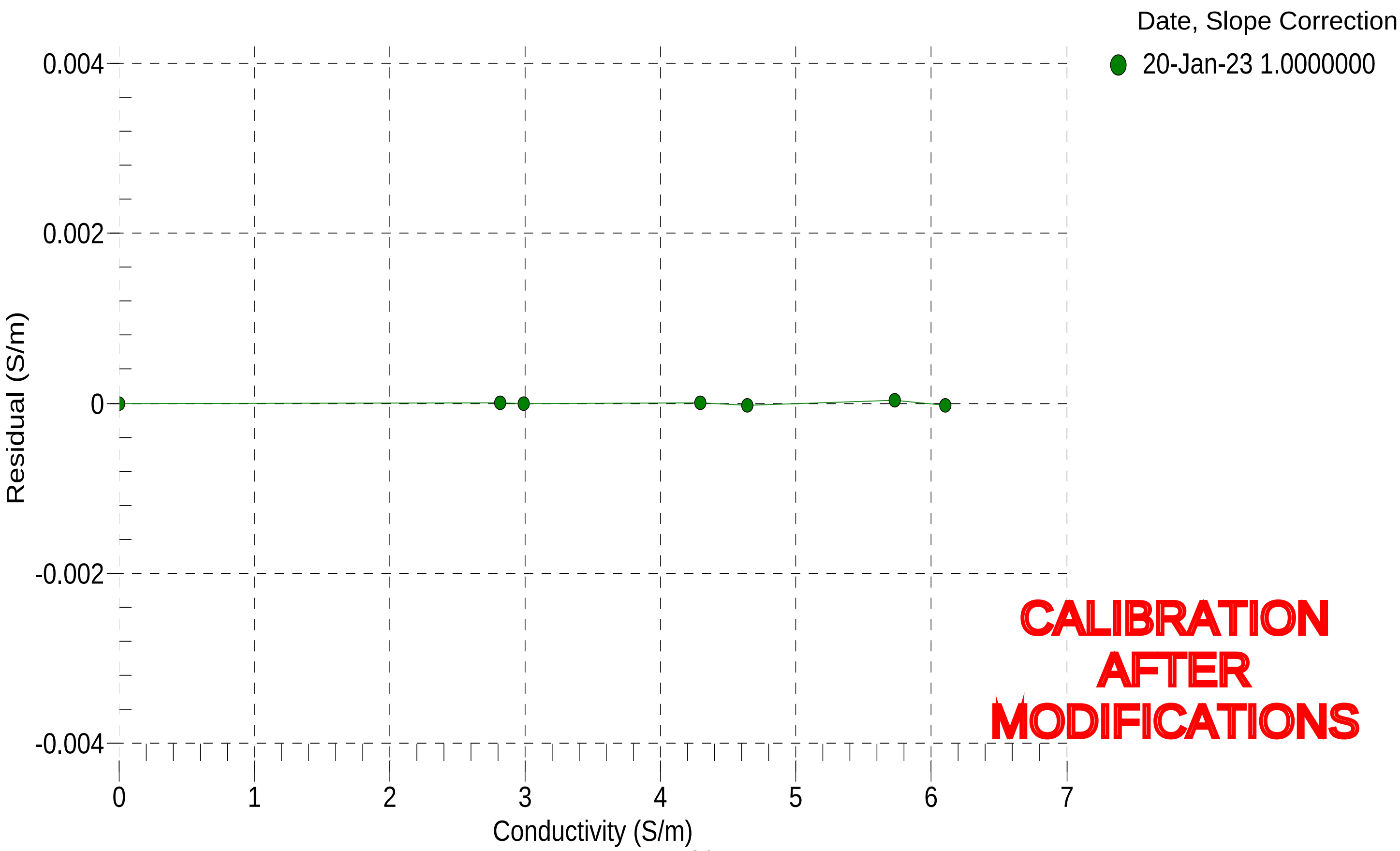
BATH TEMP (° C)	BATH SAL (PSU)	BATH COND (S/m)	INSTRUMENT OUTPUT (kHz)	INSTRUMENT COND (S/m)	RESIDUAL (S/m)
0.0000	0.0000	0.00000	2.71119	0.00000	0.00000
-1.0000	35.0061	2.81843	5.26774	2.81844	0.00001
1.0000	35.0064	2.99066	5.38464	2.99065	-0.00000
14.9999	35.0054	4.29234	6.19703	4.29234	0.00001
18.5000	35.0048	4.64067	6.39684	4.64064	-0.00003
29.0000	34.9983	5.72876	6.98410	5.72880	0.00004
32.4999	34.9843	6.10195	7.17433	6.10192	-0.00002

f = Instrument Output (kHz)

t = temperature (°C); p = pressure (decibars); δ = CTcor; ε = CPcor;

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

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



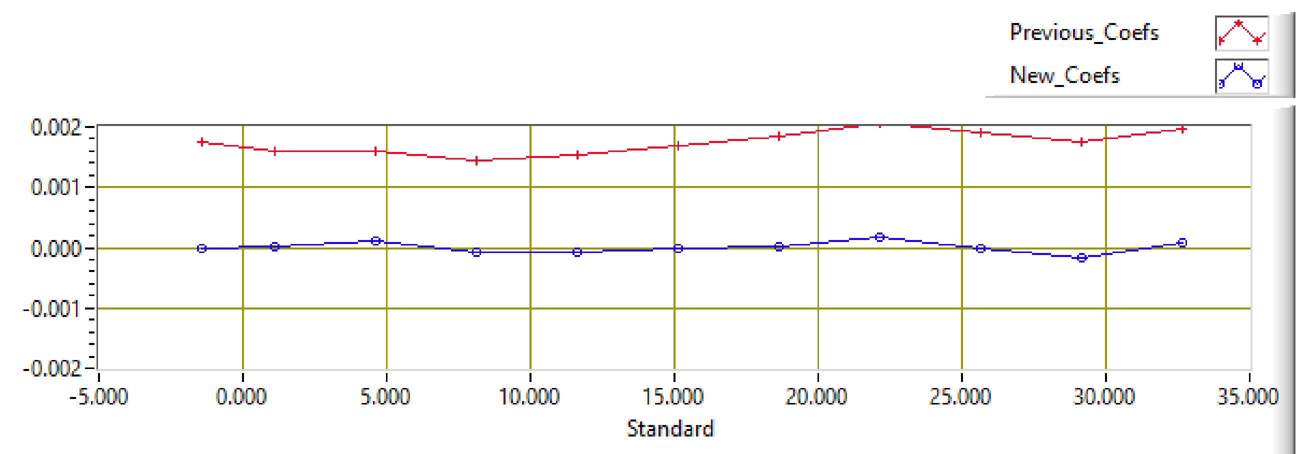
Temperature Calibration Report
STS Calibration Facility

SENSOR SERIAL NUMBER: 0105
CALIBRATION DATE: 02-Mar-2023
Mfg: SEABIRD   Model: 35
Previous cal: 15-Mar-22
Calibration Tech: AJM

ITS-90_COEFFICIENTS
a0 = 6.105468274E-3
a1 = -1.717194279E-3
a2 = 2.413985500E-4
a3 = -1.318564245E-5
a4 = 2.749867025E-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
921255.8794	-1.4298	-1.4298	0.00175	-0.00003
823821.3256	1.0743	1.0743	0.00159	0.00001
706012.6149	4.5808	4.5807	0.00159	0.00012
606582.5585	8.0891	8.0891	0.00143	-0.00008
522509.8750	11.5986	11.5987	0.00153	-0.00007
451438.2022	15.1002	15.1003	0.00170	-0.00002
390892.7079	18.6127	18.6127	0.00184	0.00001
339398.8755	22.1227	22.1226	0.00207	0.00017
295430.3968	25.6350	25.6350	0.00191	-0.00002
257858.4925	29.1437	29.1439	0.00176	-0.00016
225609.0673	32.6559	32.6558	0.00196	0.00007



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SENSOR SERIAL NUMBER: 0614
CALIBRATION DATE: 12-Aug-22

SBE 43 OXYGEN CALIBRATION DATA

COEFFICIENTS:
Soc = 0.4923
Voffset = -0.5039
Tau20 = 1.26

A = -5.2002e-003
B = 1.5701e-004
C = -1.7220e-006
E nominal = 0.036

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

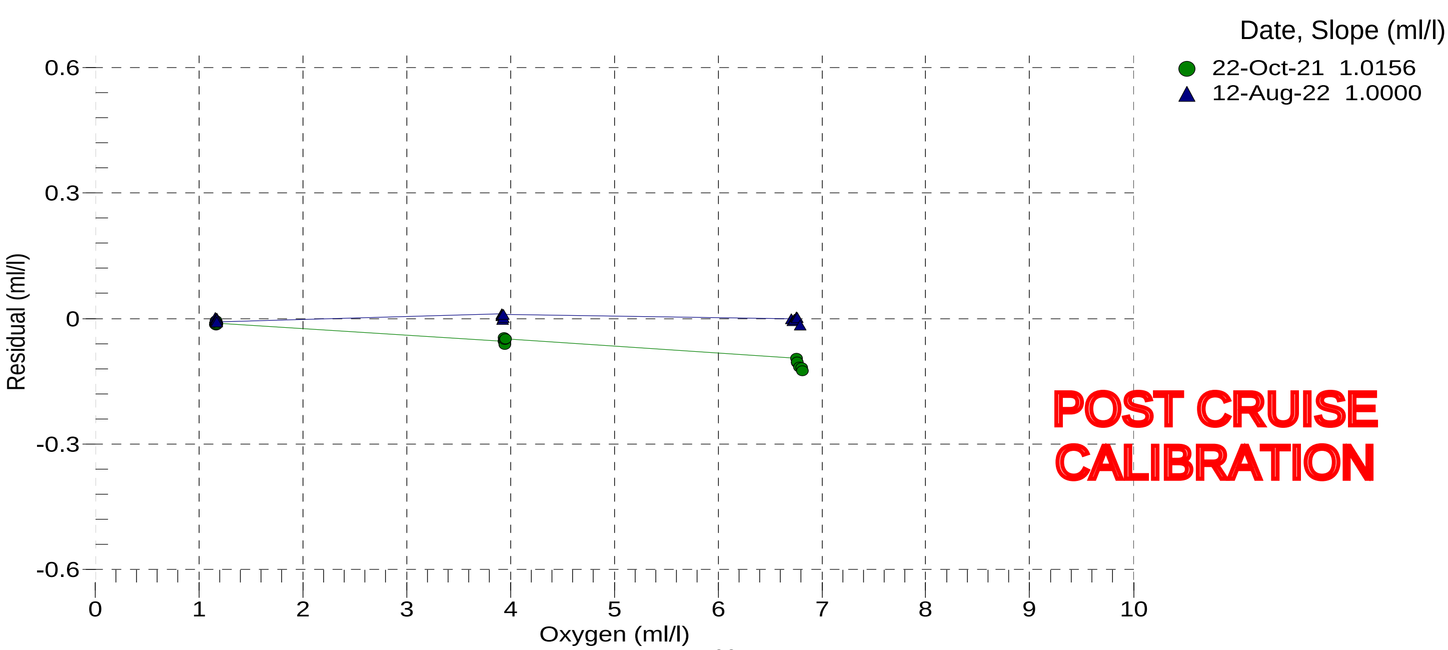
BATH OXYGEN (ml/l)	BATH TEMPERATURE (° C)	BATH SALINITY (PSU)	INSTRUMENT OUTPUT (volts)	INSTRUMENT OXYGEN (ml/l)	RESIDUAL (ml/l)
1.16	20.00	0.00	0.897	1.16	0.00
1.17	12.00	0.00	0.832	1.17	-0.00
1.17	6.00	0.00	0.782	1.16	-0.01
1.17	26.00	0.00	0.950	1.17	0.00
1.17	30.00	0.00	0.984	1.17	-0.00
1.18	2.00	0.00	0.751	1.17	-0.01
3.92	20.00	0.00	1.831	3.93	0.01
3.92	26.00	0.00	1.996	3.92	0.01
3.92	12.00	0.00	1.610	3.93	0.01
3.93	6.00	0.00	1.443	3.92	-0.00
3.93	30.00	0.00	2.114	3.93	0.00
3.94	2.00	0.00	1.340	3.95	0.01
6.70	2.00	0.00	1.925	6.70	-0.00
6.72	6.00	0.00	2.112	6.72	-0.01
6.73	12.00	0.00	2.398	6.73	-0.00
6.76	30.00	0.00	3.269	6.76	0.00
6.76	20.00	0.00	2.788	6.76	0.00
6.79	26.00	0.00	3.080	6.77	-0.02

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

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

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

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



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SENSOR SERIAL NUMBER: 1071
CALIBRATION DATE: 08-Mar-23

SBE 43 OXYGEN CALIBRATION DATA

COEFFICIENTS:
Soc = 0.5211
Voffset = -0.5125
Tau20 = 1.46

A = -3.9409e-003
B = 1.8373e-004
C = -3.3053e-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

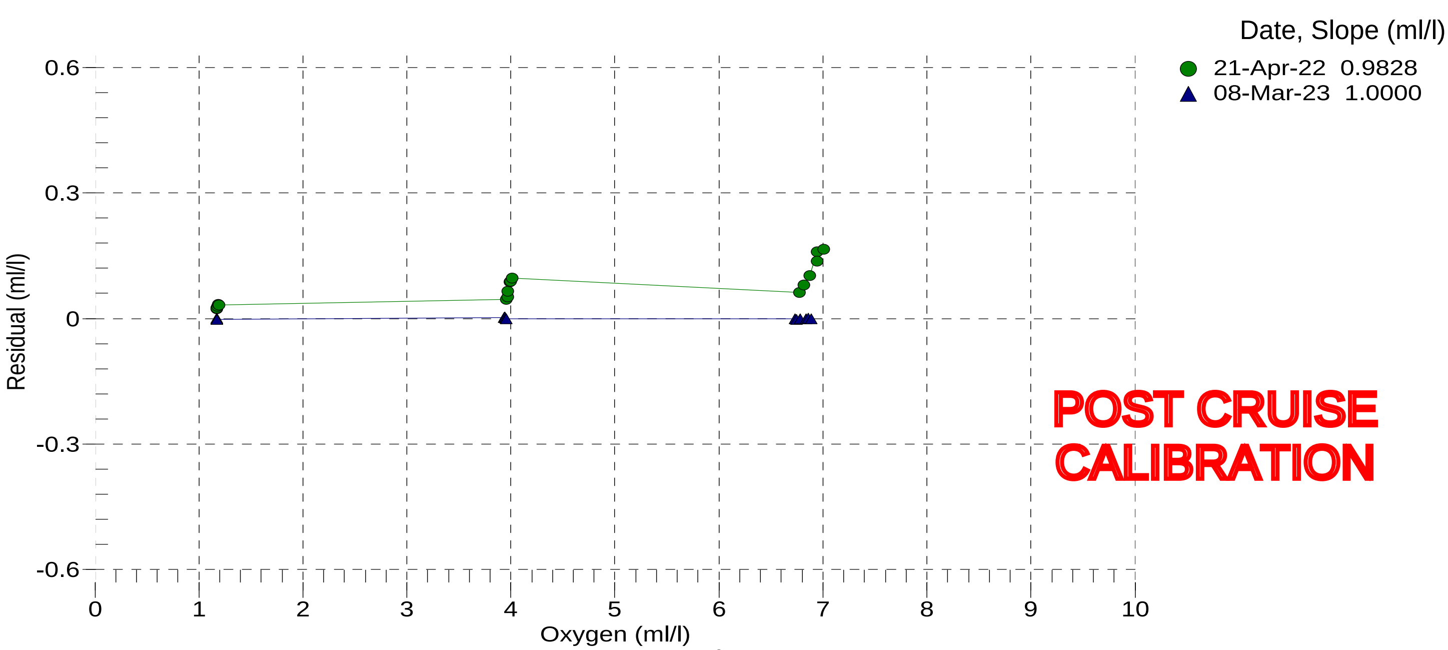
BATH OXYGEN (ml/l)	BATH TEMPERATURE (° C)	BATH SALINITY (PSU)	INSTRUMENT OUTPUT (volts)	INSTRUMENT OXYGEN (ml/l)	RESIDUAL (ml/l)
1.17	12.00	0.00	0.818	1.17	-0.00
1.17	26.00	0.00	0.923	1.17	-0.00
1.17	20.00	0.00	0.876	1.17	-0.00
1.17	6.00	0.00	0.775	1.17	-0.00
1.17	2.00	0.00	0.747	1.18	0.00
1.17	30.00	0.00	0.957	1.17	-0.00
3.94	2.00	0.00	1.299	3.94	0.00
3.94	26.00	0.00	1.895	3.94	0.00
3.94	6.00	0.00	1.397	3.94	0.00
3.95	12.00	0.00	1.545	3.95	0.00
3.95	30.00	0.00	2.010	3.95	0.00
3.96	20.00	0.00	1.745	3.96	-0.00
6.73	30.00	0.00	3.062	6.73	-0.00
6.74	2.00	0.00	1.859	6.74	-0.00
6.78	6.00	0.00	2.033	6.78	-0.00
6.84	12.00	0.00	2.299	6.84	-0.00
6.86	26.00	0.00	2.917	6.86	0.00
6.89	20.00	0.00	2.658	6.89	-0.00

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

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

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

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



POST CRUISE CALIBRATION

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SENSOR SERIAL NUMBER: 1508
CALIBRATION DATE: 07-Oct-22

SBE 43 OXYGEN CALIBRATION DATA

COEFFICIENTS:
Soc = 0.5639
Voffset = -0.4943
Tau20 = 0.94

A = -4.1583e-003
B = 1.7078e-004
C = -2.5988e-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

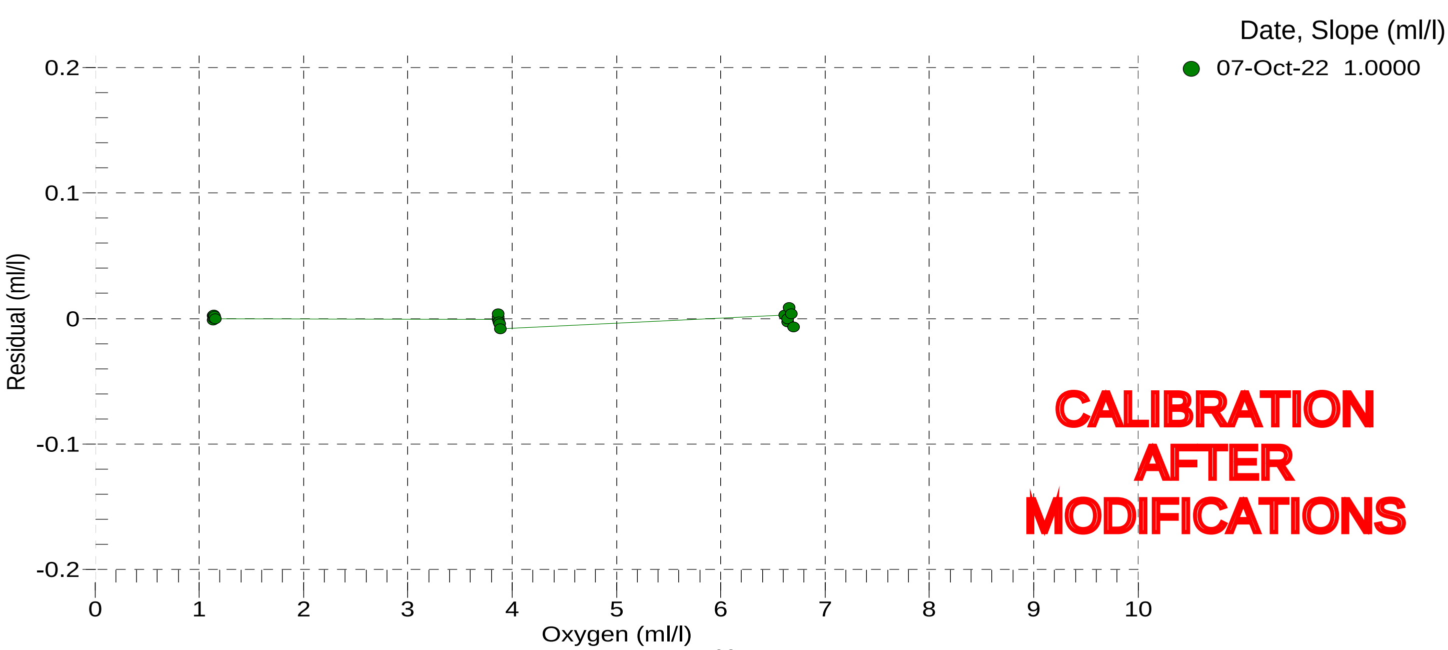
BATH OXYGEN (ml/l)	BATH TEMPERATURE (° C)	BATH SALINITY (PSU)	INSTRUMENT OUTPUT (volts)	INSTRUMENT OXYGEN (ml/l)	RESIDUAL (ml/l)
1.13	6.00	0.00	0.729	1.13	-0.00
1.13	12.00	0.00	0.770	1.14	0.00
1.14	2.00	0.00	0.705	1.14	0.00
1.14	20.00	0.00	0.825	1.14	0.00
1.15	26.00	0.00	0.867	1.15	0.00
1.15	30.00	0.00	0.897	1.15	-0.00
3.86	2.00	0.00	1.208	3.86	-0.00
3.87	12.00	0.00	1.432	3.87	0.00
3.87	20.00	0.00	1.613	3.87	0.00
3.87	6.00	0.00	1.297	3.87	-0.00
3.88	26.00	0.00	1.753	3.87	-0.00
3.88	30.00	0.00	1.850	3.88	-0.01
6.62	2.00	0.00	1.716	6.62	0.00
6.64	6.00	0.00	1.873	6.64	-0.00
6.64	12.00	0.00	2.105	6.64	-0.00
6.65	30.00	0.00	2.824	6.66	0.01
6.68	20.00	0.00	2.425	6.68	0.00
6.70	26.00	0.00	2.668	6.69	-0.01

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

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

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

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



CALIBRATION CERTIFICATE

NAME	:	RINKO Ⅲ
MODEL	:	ARO-CAV
SERIAL No.	:	0251
Parameter	:	Temperature Dissolved Oxygen

JFE Advantech Co., Ltd.

Temperature Calibration Certificate

Model	:	ARO-CAV
Serial No.	:	0251
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 × V+C × V^2+D × V^3 V: Instrument voltage[V]

2. Coefficients

A = −5.247409e+00

B = +1.665327e+01

C = −2.143417e+00

D = +4.600467e−01

3. Calibration results

Reference temperature [℃]	Instrument voltage [V]	Instrument temperature [℃]	Residual error [℃]	Acceptance [℃]	OK/NG
2.890	0.51953	2.890	0.000	±0.020	OK
9.657	0.99512	9.655	−0.002	±0.020	OK
16.613	1.51147	16.615	0.002	±0.020	OK
23.419	2.01849	23.418	−0.001	±0.020	OK
31.188	2.56897	31.188	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
20.741	20.745	0.004	±0.020	Passed

Examined M. Akiyama

Approved M. Ujiinaki

JFE Advantech Co., Ltd.

Dissolved Oxygen Calibration Certificate

Model	:	ARO-CAV
Serial No.	:	0251
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 =	−4.433937e+01	E =	+4.300000e−03
B =	+1.375743e+02	F =	+6.810000e−05
C =	−3.175331e−01	G =	+0.000000e+00
D =	+1.044300e−02	H =	+1.000000e+00

3. Verification

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

Acceptance: ±0.5% of full scale

Test for DO 0 %

	Test condition		Instrument DO [%]	Residual error [%]	Acceptance [%]	Judgement
	Atm. pressure [hPa]	Reference DO [%]				
1st	1004.0	0.00	0.05	0.05	±1.00	Passed
2nd	1004.0	0.00	0.04	0.04	±1.00	Passed
3rd	1004.1	0.00	0.04	0.04	±1.00	Passed

Test for DO 100 %

	Test condition			Instrument DO [%]	Residual error [%]	Acceptance [%]	Judgement
	Water T. [℃]	Atm. pressure [hPa]	Reference DO [%]				
1st	25.1	1003.5	99.01	99.05	0.04	±1.00	Passed
2nd	25.1	1003.5	99.01	98.94	−0.07	±1.00	Passed
3rd	25.1	1003.4	99.00	98.88	−0.12	±1.00	Passed

Examined M. FUJITA

Approved M. Ujinaki

JFE Advantech Co., Ltd.

CALIBRATION CERTIFICATE

NAME	:	RINKO Ⅲ
MODEL	:	ARO-CAV
SERIAL No.	:	0297
Parameter	:	Temperature Dissolved Oxygen

JFE Advantech Co., Ltd.

Temperature Calibration Certificate

Model	:	ARO-CAV
Serial No.	:	0297
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 = −5.282776e+00
B = +1.671875e+01
C = −2.186949e+00
D = +4.688863e−01

3. Calibration results

Reference temperature [℃]	Instrument voltage [V]	Instrument temperature [℃]	Residual error [℃]	Acceptance [℃]	OK/NG
2.819	0.51556	2.820	0.001	±0.020	OK
9.859	1.01007	9.856	−0.003	±0.020	OK
16.798	1.52588	16.802	0.004	±0.020	OK
23.737	2.04230	23.734	−0.003	±0.020	OK
30.871	2.54779	30.872	0.001	±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
20.688	20.698	0.010	±0.020	Passed

Examined H. Shimotsu

Approved M. Ujinaki

JFE Advantech Co., Ltd.

Dissolved Oxygen Calibration Certificate

Model	:	ARO-CAV
Serial No.	:	0297
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 =	−4.367428e+01	E =	+4.300000e−03
B =	+1.376636e+02	F =	+6.810000e−05
C =	−3.647983e−01	G =	+0.000000e+00
D =	+1.044300e−02	H =	+1.000000e+00

3. Verification

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

Acceptance: ±0.5% of full scale

Test for DO 0 %

	Test condition		Instrument DO [%]	Residual error [%]	Acceptance [%]	Judgement
	Atm. pressure [hPa]	Reference DO [%]				
1st	1003.9	0.00	−0.05	−0.05	±1.00	Passed
2nd	1003.8	0.00	−0.06	−0.06	±1.00	Passed
3rd	1003.7	0.00	−0.06	−0.06	±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	99.09	0.08	±1.00	Passed
2nd	25.1	1003.5	99.01	99.04	0.03	±1.00	Passed
3rd	25.1	1003.4	99.00	98.95	−0.05	±1.00	Passed

Examined M. FUJITA

Approved M. Ujinaki

JFE Advantech Co., Ltd.

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C-Star Calibration

Date September 9, 2022 S/N# CST-1874DR Pathlength 25cm

	Analog output	Digital output
V_d	0.007 V	0 counts
V_{air}	4.824 V	15811 counts
V_{ref}	4.700 V	15408 counts

Temperature of calibration water	21.5	°C
Ambient temperature during calibration	21.0	°C

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

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

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

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

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WET Labs

ECO Chlorophyll Fluorometer Characterization Sheet

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

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

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

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

Ambient temperature during characterization 21.0 °C

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

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

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

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

Resolution: Standard deviation of 1 minute of collected data.

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

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

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

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

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T: +44 (0) 1803 869292 | F: +44 (0) 1803 869293

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

Stage 1

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

To inhibit spurious readings set using: #226;40

	Pass/Fail
Bench Test Min Range <0.1m	Pass

Stage 2

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

Enter the SOS	1481.712

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

Stage 3

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

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

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

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

Stage 6: Reset the SOS
#830;1500

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

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

ltimeter Build and Calibration Record

© Valeport Limited

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

Calibration History:	Certificate	Date
	43900	28/01/2016

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

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16. Abstract (Limit: 200 words)

The DMB-2023 cruise, aboard the UNOLS vessel R/V Roger Revelle, took place from April 9 to May 13, 2023, as a key component of the "Deep Madagascar Basin (DMB) Experiment – A Quest to Find the Abyssal Water Pathways in the Southwest Indian Ocean", a project funded by the National Science Foundation. The DMB Experiment aims to understand the still largely unknown abyssal circulation of the Madagascar Basin in the Southwest Indian Ocean, how abyssal temperature varies within the basin interior, and how the complex seafloor topography shapes the abyssal circulation patterns there. The primary objective is to determine the pathway(s) by which younger abyssal water of southern origin, entering the basin through deep fracture zones on the Southwest Indian Ridge, spreads northward across the basin. This knowledge is essential for characterizing the Indian Ocean Meridional Overturning Circulation and its variability. The DMB Experiment includes a fieldwork component, which this report details, along with a state-of-the art modeling component, both of which

17. Document Analysis

a. Descriptors
Southwest Indian Ridge,
fracture zone,
Indian Ocean Meridional Overturning Circulation

b. Identifiers/
Open-Ended Terms

c. COSATI Field/
Group

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