CRUISE REPORT: I07N

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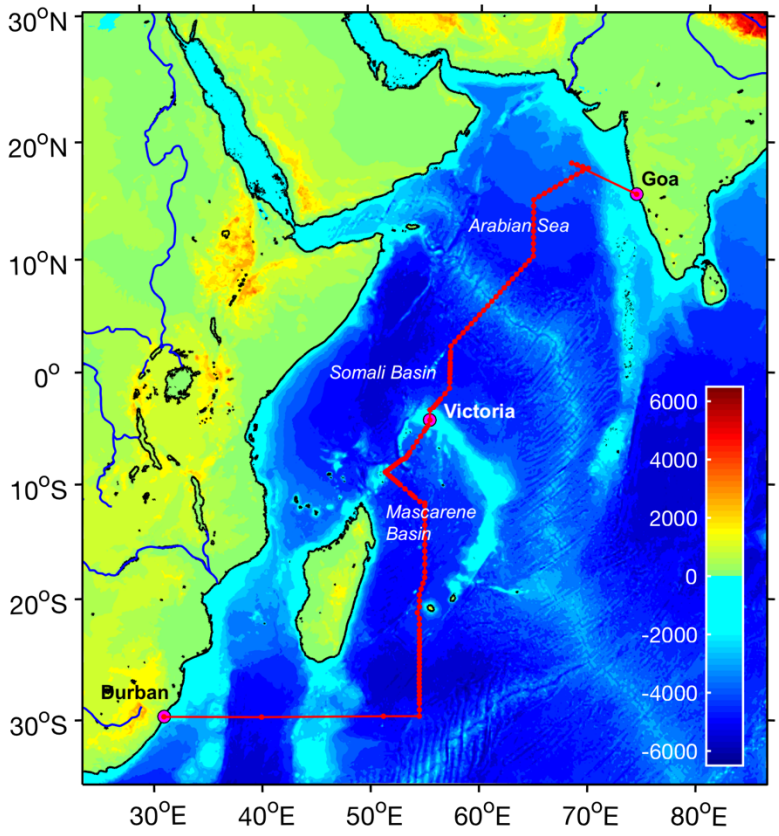

Cruise Summary Information

Section Designation	**I07N**
Expedition Designation (ExpoCode)	33RO20180423
Chief Scientist	Denis L. Volkov / AOML / CIMAS-UM
Dates	**23 April 2018 – 6 June 2018**
Ship	NOAA Ship *Ronald H. Brown*
Ports of Call	Durban, South Africa – Victoria, Seychelles – Mormugao, India
Geographic Boundaries	**18°N** **31°E** **73.8°E** **30°S**
Stations	128 (including 2 test stations)
Floats and Drifters Deployed	15 Argo floats and 10 SVP drifters
Moorings Deployed and Recovered	0

Contact Information

NOAA-AOML Miami, FL 33149

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Links to Selected Topics
Shaded sections are not relevant to this cruise or were not available when this report was compiled.

Cruise Report for the 2018 US GO-SHIP Reoccupation of I07N Section

(*Last edited 12 July 2018*)

Leg 1
NOAA Ship Ronald H Brown
23 April 2018 – 15 May 2018
Durban, South Africa – Victoria, Seychelles

Chief Scientist:
Dr. Denis L. Volkov
National Oceanic and Atmospheric Administration, AOML
Cooperative Institute for Marine and Atmospheric Studies,
University of Miami

Co-Chief Scientist:
Dr. Viviane Menezes
Woods Hole Oceanographic Institution

Leg 2
NOAA Ship Ronald H Brown
19 May 2018 – 6 June 2018
Victoria, Seychelles – Goa, India

Chief Scientist:
Dr. Denis L. Volkov
National Oceanic and Atmospheric Administration, AOML
Cooperative Institute for Marine and Atmospheric Studies,
University of Miami

Co-Chief Scientist:
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Woods Hole Oceanographic Institution

CTD Data Submitted by:
Kristene E. McTaggart
Pacific Marine Environmental Laboratory (PMEL)
National Oceanic and Atmospheric Administration (NOAA)
Seattle, WA

Preliminary Bottle Data Submitted by:
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Table of Contents

1. Introduction

Hydrographic measurements were carried out along the I07N section in the western Indian Ocean (Figure 1.1) in April-June 2018 under the auspices of the Global Ocean Ship-Based Hydrographic Investigation Program (GO-SHIP). The unique aspect of the 2018 I07N research cruise is that it was the first reoccupation of the I07N section since 1995. The section was not revisited for about 23 years because of the rise of piracy in the region. This cruise report details the cruise objectives, all science operations carried out during the cruise, as well as problems that were encountered.

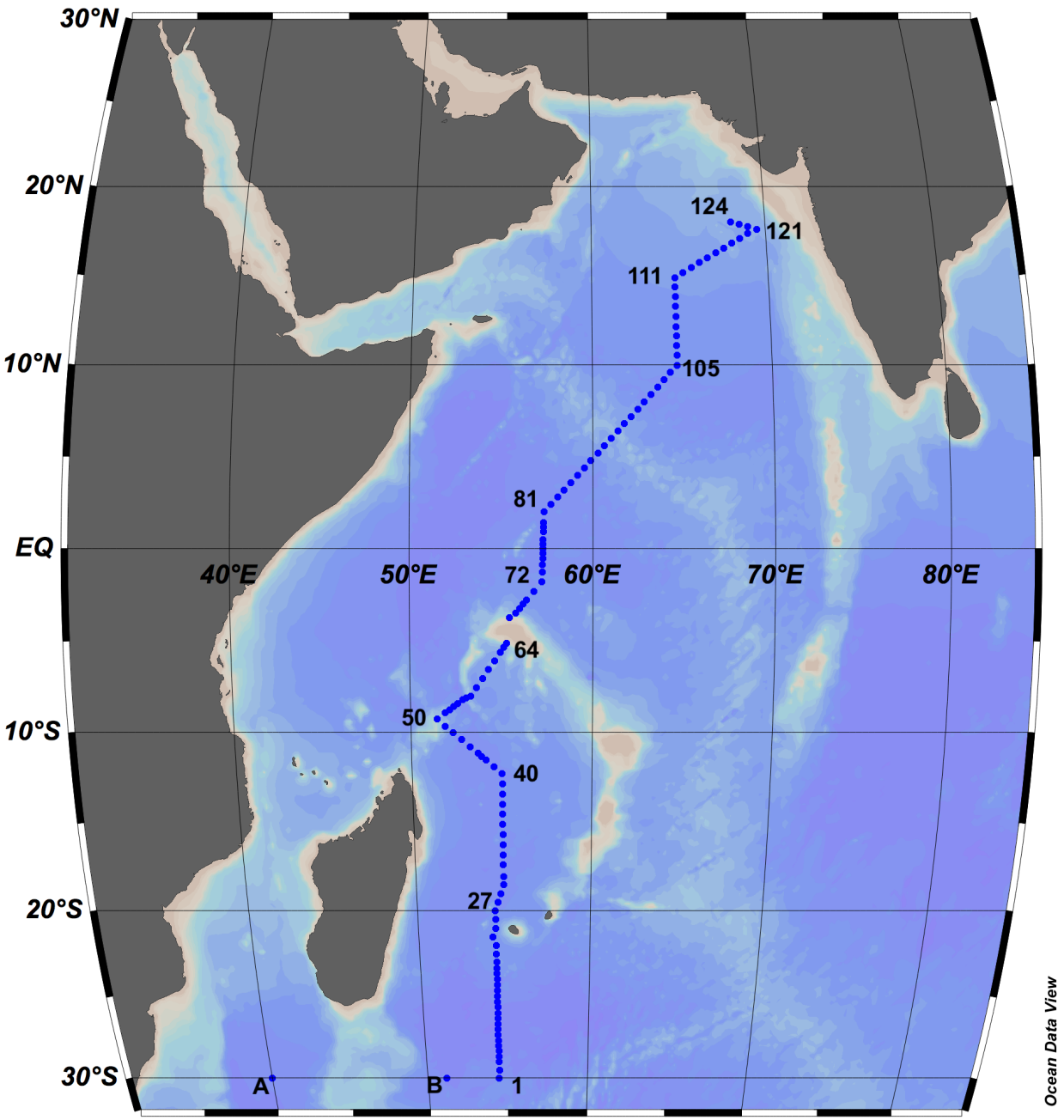

Fig. 1. I07N cruise track in Apr-Jun 2018

2. Participants

2.1. Participating Institutions

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Additional (alphabetical)

CCU	Coastal Carolina University
CIMAS	Cooperative Institute for Marine and Atmospheric Studies, University of Miami
JAMSTEC	Japan Agency for Marine-Earth Science and Technology
JISAO	Joint Institute for the Study of Atmosphere and Ocean, Univ. of Washington
LDEO	Lamont-Doherty Earth Observatory
PMEL	NOAA Pacific Marine Environmental Laboratory
PU	Princeton University
RSMAS	Rosenstiel School of Marine and Atmospheric Sciences, University of Miami
SCCWRP	Southern California Coastal Water Research Project
SIO	Scripps Institution of Oceanography
TAMU	Texas A&M University
UCI	University of California Irvine
UH	University of Hawaii
UMar	University of Maryland
UW	University of Washington
WHOI	Woods Hole Oceanographic Institution
WWU	Western Washington University

2.2. Programs and Principal Investigators

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	Scott D. Wankel		

2.3. Scientific Personnel (Legs 1 and 2)

	Duties	Name	Affiliation	Email
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3. Program and Project Overview

The I07N cruise is part of the decadal re-occupation of select NOAA hydrographic transects to determine natural and man-made changes in chemical and physical properties in the ocean as part of the USA component of the

international GO-SHIP program. This cruise is one of approximately 60 decadal repeated globally as part of this program with the goal of quantifying changes and variability in ocean heat content, chloro-fluorocarbons (CFCs) dissolved inorganic and organic carbon, oxygen, alkalinity, pH, nutrients, and other natural and man-made tracers of ocean circulation. The cruises also measure and infer variability in ocean currents and water mass distributions. Earlier programs under the Joint Global Ocean Flux Study (JGOFS), World Ocean Circulation Experiment (WOCE), and Climate Variability and predictability (CLIVAR) programs provided an approximately decadal set of observations on hydrographic lines, including the I07N line that GO-SHIP builds upon. Examples of critical findings made possible by decadal measurements include ongoing ocean uptake and subsurface storage of anthropogenic CO2 with consequent ocean acidification, ongoing warming and freshening of the deepest bottom waters, and accelerated overturning of intermediate depth water masses in the Southern Ocean. The repeat hydrography cruises are the only means to obtain climate quality data to study changes and impacts in the ocean, and they provide a robust observational framework to monitor these long-term changes.

The GO-SHIP program serves to address the following overlapping scientific objectives:

- Collect data for carbon system studies
- Study ocean circulation, heat and freshwater storage and fluxes
- Study deep and shallow water mass changes and their ventilation time scales
- Collect data for model calibration and validation, as well as for calibration of autonomous sensors

The I07N cruise started in Durban, South Africa on April 23rd 2018 and ended in Goa, India, on June 6th 2018. The cruise consisted of two legs with a mid-point port stop in Victoria (The Republic of Seychelles) from May 15th 2018 to May 19th 2018. Twenty-six scientists from 15 different institutions were engaged in surface and full-depth water column measurements, surface water measurements form the scientific seawater supply line, and deployment of profiling (Argo) floats and drifters en route. During the cruise 126 CTD casts (including 2 test casts) were carried out, and 15 Argo floats, 10 SVP drifters, and 3 wave buoys were deployed. The CTD/Rosette operations were carried out using 24, 12-L bottles.

The 2018 I07N research cruise was jointly funded by the USA agencies: National Oceanic and Atmospheric Administration (NOAA) and National Science Foundation (NSF). The cruise was led by NOAA Atlantic Oceanographic and Meteorological Laboratory and NOAA Pacific Marine Environmental Laboratory. Numerous US academic institutions as well as Japan Agency for Marine-Earth Science and Technology (JAMSTEC) took part in the cruise.

4. The I07N Section

The operating area was in the western Indian Ocean, with a schematic of the I07N-2018 cruise track shown in Figure 1. The I07N section runs across the Madagascar and Mascarene Basins in the south, crosses the Amirante Trench, and after the Seychelles Bank it crosses the Somalia Basin, Carslberg Ridge, and the Arabian Sea in the north. This section, if completed all the way to the coast and combined with the new I07S section, that will be occupied by Japanese oceanographers, would provide a constraint for estimates of the cross-basin fluxes. The final segment of the I07N line in the Arabian Sea is of particular interest because it crosses the Arabian Sea oxygen minimum zone (OMZ) and the local salinity maximum. The Arabian Sea OMZ is the thickest of the three oceanic OMZ and it is of global biogeochemical significance. The local salinity maximum just beneath the mixed layer is an indicator of the subduction processes of high-salinity surface water during the monsoon period.

The spacing between the stations along the I07N line varied from ~15 nm over the complicated topography and in the eddy-rich Madagascar Basin to ~30-34 nm in other regions. Measurements were made at each station for a variety of physical, chemical, and biological parameters. Underway sampling was conducted throughout the entire cruise, ceasing briefly at the boundary between the Mauritius and the Seychelles Exclusive Economic Zones (EEZs) due to a lapse in getting the EEZ clearance from the Seychelles. The underway systems were also turned off over the Seychelles Bank as the ship was sailing in the territorial waters and in the Indian EEZ.

The NOAA Ship “Ronald H. Brown” departed Durban, South Africa, on April 23, 2018 and headed strictly eastward along 30°S towards 54.5°E, where the I07N-2018 section started. While in transit to the first I07N station, two test stations (A and B in Fig. 1) were carried out. A segment of the I07N section between the first station (54.5°E and 30°S) and station 31 (~55°E and ~18°S) repeats stations along the eastern segment of I04 cruise conducted in 1995. Between stations 23 and 25, due to the French military exercises just southwest of La Reunion, we had to deviate from our route and do station 24 about 10 nm west off the line, but still keeping it at the same latitude (54.3°E and 21.5°S). Starting from station 31, the I07N-2018 cruise followed strictly the footsteps of the I07-1995 cruise except for the final segment in the Arabian Sea.

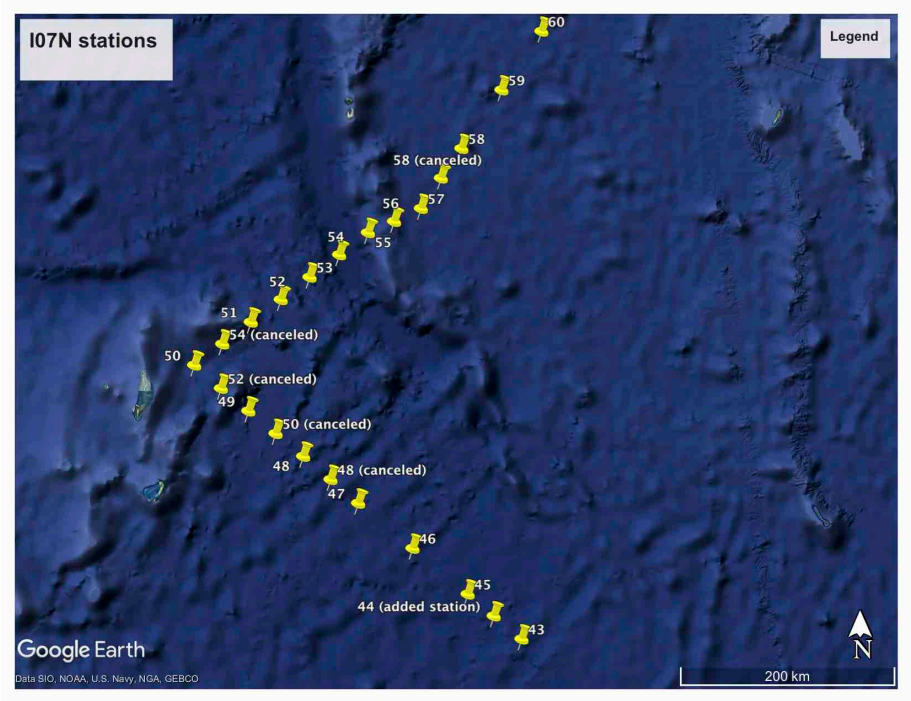


Figure 2. A map with stations near the Amirante Trench. Stations 48, 50, 52, 54, and 58 were canceled.

Near the Amirante Trench in the Mascarene Basin, due to a 1-day delay caused by waiting for the Seychelles Marine Scientific Research (MSR) clearance, we had to skip 4 stations south and 1 station just north of the Amirante Trench. A map of stations near the Amirante Trench, including those canceled, is displayed in Figure 2. Cancelling the stations increased the spacing between the stations along the corresponding segments from 17 to 34 nm. This was not critical along the more or less flat bottom topography. But we retained the short spacing between the stations over the Amirante Trench.

In the Arabian Sea, the original I07N-1995 section went all the way towards to the coast of Oman. Unfortunately, due to existing safety concerns in the region, we were not able to reoccupy the original line in the Arabian Sea. As a compromise plan A for this cruise was to reach 18°N and head straight towards the Indian continental slope (Figure 3). This plan depended on obtaining the MSR clearance to sample in the Indian EEZ. We also had an alternative plan B in case the Indian MSR clearance was not granted. According to this plan B, starting from the turning point at station 111 (~14.9°N) we would dogleg towards ~69.5°E and 17.6°N, which would bring us as close as possible to the continental slope, but still keep us outside the Indian EEZ (Figure 3). Unfortunately, we did not receive the Indian MSR, neither before reaching station 111 nor later, and decided to follow plan B. Station 121 was the last station on the segment between the turning point at station 111 and the Indian EEZ. Upon reaching station 121, we still had about 2 days available for doing more stations. As one of the wishes for our cruise was to get as deep into the Oxygen Minimum Zone (OMZ) as possible, we decided to head northwestward and do 3 more stations up to 18°N – this is the northernmost latitude the ship agreed to sail to due to safety concerns.

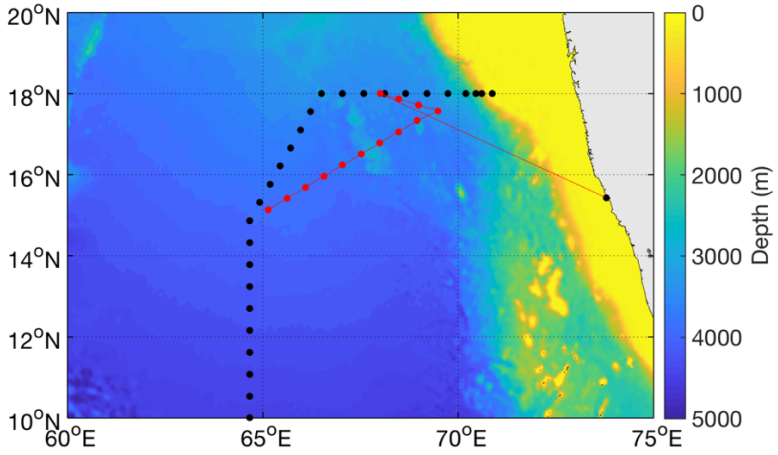


Figure 3. Plans A (black dots) and B (red dots).

5. Cruise Narrative

Detailed weekly descriptions of operations during the cruise are provided in Appendix 10.3. Here, we describe and categorize challenges that we had to deal with prior and during the cruise.

5.1. Start of the cruise

The I07N cruise was initially planned to start in February and end in March, 2018. However, prior to sailing from Charleston (USA) to Durban (South Africa) the ship discovered engine problems that had to be fixed in port. Due to lengthy repairs, the entire yearly schedule of "Ronald H. Brown" was shifted, and our new tentative departure was set on April 23, 2018. This eventually became our actual departure date, as after the repairs the ship made it to Durban without any additional delays. Most of our scientific gear, including 3 containers (PMEL CFC van, and AOML DIC and gear storage vans), was loaded on the Brown while the ship was in Charleston and during a port call in Fort Lauderdale. Only the LADCP gear and some additional sample bottles were shipped to Durban. This made the mobilization and loading in Durban relatively easy and fast. After clearing immigration and customs, the ship departed from Durban on April 23, 2018 at 2 pm local time.

5.2. Foreign clearances

The I07N-2018 cruise was crossing the EEZs of 5 coastal states: South Africa, France (La Reunion), Mauritius, Seychelles, and India. In addition, the cruise crossed the EEZ of Tromelin Island, which is a disputed territory between France and Mauritius. As the initial departure was scheduled for February 2018, all foreign clearance requests were submitted via NOAA to the Department of State in August 2017. Considering that the cruise was eventually delayed by about 2.5 months, there was more than enough time to process these requests in timely manner. By the beginning of the cruise we had received clearances from South Africa (for underway survey only) and from France for sampling in La Reunion and Tromelin EEZs. The French clearance, however, was for initial dates of the cruise (in February), so an appropriate amendment with updated dates of the cruise was also submitted.

When we left Durban, we had no other EEZ clearances besides from South Africa and France. As we were approaching the Mauritius EEZ, the situation was becoming nervous as we had no clearance to sample there. We were in contact we a person in charge at the US Embassy in Mauritius, but the situation did not resolve until we brought it to the attention of NOAA's Climate Program Office (CPO). Fortunately for the cruise, the CPO's International Coordinator Dr. Thurston knew a person in the Mauritius government, who also happened to be the one who issues MSR clearances for the Mauritius EEZ. To our surprise, this person did not hear anything about our cruise. However, he was very accommodating and graciously expedited the issuance of the MSR clearance for "Ronald Brown", which we received several hours before entering the Mauritius EEZ.

It was a temporary relief for us because our transit in the Mauritius EEZ lasted only 2 days and we still did not have clearance for the Seychelles EEZ. It was also the US Embassy in Mauritius that was in charge for handling our MSR clearance request for the Seychelles, but this time we did not have any acquaintances in the Seychelles government to approach them directly. On May 9 in the afternoon, we came to the boundary between the Mauritius and

Seychelles EEZs without clearance for the latter. Since we could not proceed, we decided to do an extra CTD cast at the boundary and just wait. The situation was complicated by the fact that the Mauritius clearance was expiring at midnight, which meant that we had to seize all operations and turn off the underway systems. As there was no certainty about the Seychelles clearance, we started to think about an alternative route around the Seychelles EEZ and sent a request to extend our clearance for the Mauritius EEZ for several more days. Fortunately, clearance for the Seychelles EEZ was eventually granted, but it costed us one full sea day, during which we stayed at the boundary without a possibility to do any research, and 5 canceled stations thereafter.

As opposed to the situation with Mauritius and the Seychelles, the person in charge of our clearance request for the Indian EEZ at the US Embassy was very proactive. And in the end, a conditional clearance was granted, but it contained the provisions that the ship's leadership found unacceptable. One of these provisions was a potential Naval inspection of the ship, which would undermine the sovereign status of "Ronald Brown". A request to waive unacceptable condition was submitted, but the Indian authorities were not willing to change anything in the formal document. Unfortunately for the entire science project, this resulted in a denial of our MSR request to sample in the Indian EEZ.

Lessons learned.

- Stay in a regular contact with the NOAA's Office of Marine and Aviation Operations and make sure they do their part by coordinating clearance requests with the Department of State in timely manner, including regular checks of the status of already submitted requests.
- If a research cruise involves transiting multiple EEZs that border each other, consider asking for more transit time than actually needed. If one of the clearances is not granted, there will be an option to go around that particular EEZ and continue sampling while on the way.
- Some reconsideration of NOAA policy with respect to the applicability of sovereign status of NOAA vessels is desired. The rules need to become more specific, and both the ship's leadership and the chief scientist need to be aware of how flexible the ship can be with regard to the requirements imposed by other states in their EEZs. There must be a general understanding that if a research vessel wants to measure in foreign waters, that foreign state has a right to impose certain requirements. In our particular situation with India, it appears that if we were a UNOLS vessel, there would not be a problem at all, and we would get the Indian clearance. It is also very unlikely that any Naval inspection, indicated in the formal document, would ever happen. If the scientists knew that a conditional clearance from India would not be accepted by the NOAA ship, it would be more reasonable to do this cruise on a UNOLS vessel, given such a rare opportunity to measure in the western Indian Ocean and in the Indian waters in particular. Unfortunately, in our case, science suffered from bureaucracy on both sides.

5.3. Issues with the aft winch

Problems with the aft winch on the Brown started well before our cruise. In fact, the ship left Charleston on a round-the-world trip knowing that the aft winch might not be operable. The aft winch was used during the first test CTD cast. The cast resulted in multiple modulo errors on the CTD, in particular during the upward cast. Tests indicated that the problem was not related to the termination of cable, but it was rather in the winch itself. There was nothing we could do with the aft winch during the cruise, and we decided to proceed with the forward winch. The forward winch was used during the second test CTD cast that went all the way to just above the bottom at 5240 m. The forward winch worked perfectly, and it was used for the remainder of the cruise.

Lessons learned.

- Because mechanical problems are inevitable during oceanographic cruises, it is very risky to start a long cruise with having only one operable winch, and such situations need to be avoided by all means possible. During our cruise, we were just lucky that nothing serious happened, although it could easily happen as described in the next section.

5.4. Attempt to find a PMEL mooring

One of the requests we had for the cruise was to attempt to find a mooring, the communication with which was lost 5 years ago. If the buoy were present, at the very least, we were asked to photograph it, and recover the mooring if the schedule allowed. We arrived at the mooring location in the dark, however, the weather was favorable, and the visibility was good enough. Being well equipped with the ship's radar, night vision device, and a searchlight we started the search. Our plan was to locate the buoy, proceed to the next station (#42), and then return to the mooring and recover it next day in the morning. However, the buoy was not present. After hovering around for about an hour, the transducer was lowered at the last reported position of the mooring and disable command was sent. Unfortunately, the mooring is lost.

5.5. CTD wire situation

After leaving Victoria (the Republic of Seychelles), we entered a very strong eastward current, possibly associated with the seasonal Wyrtki Jet, with surface velocities exceeding 1 m/s. A little further north, in addition to the strong eastward current near the surface there a was strong westward current between about 100 and 200 m depth. Probably because of this strong velocity shear we started to experience twists on the forward winch cable that were causing modulo errors on the CTD and caging of the wire. This situation was causing a lot of concern and worries, especially given the fact that we did not have a backup winch. The cable was re-terminated while the ship was in port in Victoria, but the visible degradation of the cable, while we were experiencing the strong current, made it necessary to re-terminate it 2 more times. A continued use of the forward winch with degrading cable was increasing the chances of losing the entire package, but the only solution we had was to closely monitor the state of the cable after each station and hope that the situation would improve once we exit the strong current. Fortunately, the situation did improve once we left the current. A few modulo errors on the CTD that we were getting after re-terminations were not critical, and overall, we were getting high quality data. We continued to keep a close eye on the state of the cable until the end of cruise, but no more re-terminations were required.

Lessons learned.

- CTD casts are routinely carried out in stronger currents than the one we experienced. Although we were sailing across the region of strong vertical velocity shear, we did not expect that the cable would start degrading so fast. It is likely that the cable was defective from the start and, therefore, the quality of the cable is one of the things that require close attention prior to starting a cruise.
- The state of the cable needs to be routinely monitored, in particular in the regions of strong currents.

5.6. Scientific staffing

The I07N science party consisted of 26 scientists. Because the cruise was crossing the High-Risk Area, the ship decided to increase the number of crew members to add additional security watches on the bridge. This was not clear how critical that was, but as a result, the science personnel had to be cut by 2 persons and 2 groups were understaffed. Namely, the Alkalinity/pH group was one person less than the usual four, and we had only 2 CTD watch-standers. We also did not have a dedicated data manager. The data management role was fulfilled by the chief and the co-chief scientists using the PMEL Bottle Data Management System software (PMEL-BDMS). Fortunately, participants from ancillary programs provided sufficient help for the understaffed groups. While the CTD was operated by the same persons and no help was necessary, much help was provided during sampling.

One berth was reserved for an Indian scientist who was supposed to join the cruise in the Seychelles. The first Indian scientist, who was cleared by NOAA to sail on the Brown, canceled his participation before the start of the cruise, and was substituted by another one. It took us some efforts to expedite the clearance process for the second scientist, however, he also canceled his participation several days prior to our arrival in Victoria. As a result, there was no Indian representation during the I07N cruise.

Lessons learned.

- Data management can be easily fulfilled by the chief and co-chief scientists, perhaps sometimes with some involvement of student helpers. The PMEL-BDMS is easy to learn and use.
- If understaffing is inevitable, it is important to make everybody aware what groups/people require help. Participants from some ancillary programs usually have some spare time to help others. During our cruise we had no problems with that at all. Help was always there when it was needed.

6. Underway Data Acquisition

Underway data collection included meteorological parameters, upper ocean current measurements from the shipboard ADCP, surface oceanographic (temperature, salinity, pCO2) from the ship's underway clean seawater intake, bathymetric data, and measurements of atmospheric CO2, CFCs, SF6 and ozone.

Navigation data were acquired at 1-second intervals from the ship’s Furuno Marine Touch Screen navigational radar from the start of the cruise. In addition, centerbeam depth data, with a correction for hull depth included in each data line, were acquired directly from the ship’s Multibeam/Kongsberg EM122 system. These data were used to determine the position and ocean depth information for each station and deployment. The centerbeam depths were also continuously displayed, and data were manually recorded at cast start/bottom/end on CTD Cast Logs.

6.1. Acoustic Doppler Current Profiler Measurements

PI’s: Eric Firing (UH) and Jules Hummon (UH)

The NOAA Ship "Ronald H. Brown" has a permanently mounted 75 kHz acoustic Doppler current profiler ("ADCP" Teledyne RDI) for measuring ocean velocity in the upper water column. The ADCP is a Phased Array instrument, capable of pinging in broadband mode (for higher resolution), narrowband mode (lower resolution, deeper penetration), or interleaved mode (alternating). On this cruise, data were collected with 8 m broadband pings and 16 m narrowband pings. The data were collected for the entire duration of I07N except when the ship was over the Seychelles Bank in the territorial waters of the Republic of Seychelles and in the Indian EEZ. The ADCP was also turned off along with all underway systems while the ship was waiting for the Seychelles MSR clearances at the boundary between the Mauritius and Seychelles EEZs.

The shipboard ADCP data are acquired and processed by specialized software developed at the University of Hawaii and installed on the Brown. The acquisition system ("UHDAS", University of Hawaii Data Acquisition System) acquires data from the ADCPs, gyro heading (for reliability), position and orientation systems for marine vessels (POSMV) headings (for increased accuracy), and GPS positions from various sensors. Single-ping ADCP data are automatically edited and combined with ancillary feeds, averaged, and disseminated via the ship's web, as regularly-updated figures on a web page and as Matlab and netCDF files. The automated at-sea product should be good enough for preliminary use, and the final dataset should be among the best to come from this ship.

6.2. Underway pCO_2 Analyses

PI's: Rik Wanninkhof (NOAA/AOML) and Denis Pierrot (UM/CIMAS)
Technicians: Charles Featherstone (NOAA/AOML) and Dana Greeley (NOAA/PMEL)

An automated underway pCO_2 system from AOML was installed in the Hydro Lab of the RV Ronald H. Brown. The design of the instrumental system is based on Wanninkhof and Thoning (1993) and Feely et al. (1998), while the details of the instrument and of the data processing are described in Pierrot, et.al. (2009).

The repeating cycle of the system included 4 gas standards, 5 ambient air samples, and 100 headspace samples from its equilibrator every 4.5 hours. The concentrations of the standards range from 280 to 550 ppm CO_2 in compressed air. These field standards were calibrated with primary standards that are directly traceable to the WMO scale. A gas cylinder of ultra-high purity air was used every 20 hours to set the zero of the analyzer.

The system included an equilibrator where approximately 0.6 liters of constantly refreshed surface seawater from the bow or mid-ship intake was equilibrated with 0.8 liters of gaseous headspace. The water flow rate through the equilibrator was 1.5 to 2.2 liters/min.

The equilibrator headspace was circulated through a non-dispersive infrared (IR) analyzer, a LI-COR™ 6262, at 50 to 120 ml/min and then returned to the equilibrator. When ambient air or standard gases were analyzed, the gas leaving the analyzer was vented to the lab. A KNF pump constantly pulled 6-8 liter/min of marine air through 100 m of 0.95 cm (= 3/8") OD Dekoron™ tubing from an intake on the bow mast. The intake had a rain guard and a filter of glass wool to prevent water and larger particles from contaminating the intake line and reaching the pump. The headspace gas and marine air were dried before flushing the IR analyzer.

A custom program developed using LabView™ controlled the system and graphically displayed the air and water results. The program recorded the output of the IR analyzer, the GPS position, water and gas flows, water and air temperatures, internal and external pressures, and a variety of other sensors. The program recorded all of these data for each analysis.

The automated pCO_2 analytical system had several issues during the cruise:

1. April 23, 2018 – Start of IO7N cruise system turned on at 12:25
2. April 26, 2018 – System shut down at 13:00 restarted computer and the system resumed normal operations
3. April 26, 2018 – Unplugged TSG and plugged back in at approx. 21:52
4. April 27, 2018 – Tried to dislodge air bubbles from SBE 45 at approx. 21:01
5. May 6, 2018 – System went into emergency shutdown mode at approx. 17:06
6. May 7, 2018 – System restarted normal functions at approx. 21:22

7. May 9, 2018 – TSG water flow turned off at approx. 11:05 because of entering the Mauritius EEZ while awaiting approval to sample in the Seychelles' EEZ. The water flow was off for approx. 24 hrs.

The system worked well for the remainder of the cruise.

Standard Gas Cylinders

Cylinder#	ppm CO_2
CA04957	280.55
CC05863	380.22
CB09696	453.04
CB09032	539.38

References

Pierrot, D.; Neill, C.; Sullivan, K.; Castle, R.; Wanninkhof, R.; Luger, H.; Johannessen, T.; Olsen, A.; Feely, R.A.; and Cosca, C.E. (2009). *Recommendations for autonomous underway pCO2 measuring systems and data-reduction routines*. Deep-Sea Res., II, v. 56, pp. 512-522.

Feely, R.A.; Wanninkhof, R.; Milburn, H.B.; Cosca, C.E.; Stapp, M.; and Murphy, P.P. (1998). *A new automated underway system for making high precision pCO2 measurements onboard research ships*. Analytica Chim. Acta, v. 377, pp. 185-191.

Wanninkhof, R., and Thoning, K. (1993). *Measurement of fugacity of CO2 in surface water using continuous and discrete sampling methods*. Mar. Chem., v. 44, no. 2-4, pp. 189-205.

7. Conductivity, Temperature, Depth (CTD) Stations

The CTD/rosette system was deployed off the starboard side. The ship's personnel were responsible for the deployment and recovery of the CTD/rosette with assistance of experienced scientific personnel. During recovery, the CTD/rosette package was lowered onto a cart and rail system, maintained by the ship, allowing the CTD/rosette package to be safely brought into the staging bay. One of two 24-position AOML rosette systems with 12 litter bottles was used for CTD/rosette casts. The second backup package was secured in a readily accessible area, but it was never required. An altimeter was mounted on the rosette system and used during casts to monitor distance from the bottom.

7.1. CTD data acquisition

The CTD data acquisition system consisted of the ship's SBE-11*plus* (V2) deck unit s/n 11P111660 and a networked Dell Optiplex 7040 Windows 10 workstation running SBE Seasave V7 version 7.26.7.107 software. NMEA GPS data were received through the deck unit. The workstation was used for data acquisition and to close bottles on the rosette. Raw data files were archived immediately after each cast on a USB drive as well as on Survey and PMEL networked PCs. No real-time data were lost during this cruise.

CTD deployments were initiated by Survey after the Bridge advised that the ship was on station. The transmissometer windows were uncapped, washed, and deployed wet. The computer console operator maintained a CTD Cast log recording position and depth information at the surface, depth, and end of each cast; a record of every attempt to close a bottle, and any pertinent comments.

After the underwater package entered the water, the winch operator lowered it to 20-30 meters and held position. After a 60-second startup delay, the pumps turned on. The console operator watched the CTD data for reasonable values, waited three minutes at the soak depth for sensors to stabilize, instructed the winch operator to bring the package to the surface, paused for 30 seconds, and began the descent to a target depth approximately 10 meters above the sea floor. The descent rate was nominally 30 m/min to 50 m, 45 m/min to 200 m, and 60 m/min deeper than 200 m. These rates could vary depending on sea cable tension and the sea state.

The console operator monitored the progress of the deployment and quality of the CTD data through interactive graphics and operational displays. The chief or co-chief scientist created a sample log for the cast that would be used to record the water samples taken from each Bullister bottle. The altimeter channel, CTD depth, wire-out, and

EM122 bathymetric depth were all monitored to determine the distance of the package from the bottom, allowing a safe approach to within 10 meters.

Bottles were closed on the up-cast through the software and were tripped 30 seconds after stopping at each bottle depth to allow the rosette wake to dissipate and the bottles to flush. The winch operator was instructed to proceed to the next bottle stop 15 seconds after closing bottles to ensure that stable CTD and reference temperature data were associated with the trip.

Near the surface, Survey directed the winch to stop the rosette just beneath the surface. After the surface bottle was closed, the package was recovered. Once on deck, the console operator terminated data acquisition, turned off the deck unit, and assisted with rosette sampling.

At the end of each cast, primary and secondary CTD/O_2 sensors were flushed with a solution of dilute Triton-X in de-ionized water using syringes fitted with tubing. The syringes were left attached to the temperature ducts between casts, with the temperature and conductivity sensors immersed in the rinsing solution to guard against airborne contaminants. The rosette carousel was rinsed with warm freshwater. The transmissometer windows were rinsed with DI water, dried, and capped after each cast.

Table 7.1. Package component and calibration data

Manufacturer / Model	Serial Number	Calibration Date	Stations Used
Sea-Bird 9plus CTD	1292	14-Sep-16	1-128
Sea-Bird 3Plus primary temperature	4569	22-Sep-17	1-128
Sea-Bird 4C primary conductivity	3068	22-Sep-17	1-128
Sea-Bird 43 primary oxygen	3419	10-Oct-17	1-128
Sea-Bird 5T primary pump	7265	n/a	1-89
Sea-Bird 5T primary pump	8774	n/a	90-128
Sea-Bird 3Plus secondary temperature	4193	21-Oct-17	1-128
Sea-Bird 4C secondary conductivity	2882	22-Sep-17	1-128
Sea-Bird 43 secondary oxygen	3420	10-Oct-17	1-128
Sea-Bird 5T secondary pump	7741	n/a	1-128
Sea-Bird 35 reference temperature	76	28-Oct-13	1-128
Sea-Bird 32 24-position carousel	500	n/a	1-128
Valeport VA500 altimeter	56634	16-Sep-16	1-128
WET Labs C-Star transmissomter	1636DR	04-Dec-17	1-128
WET Labs ECO chlorophyll fluorometer	FLRTD-2125	21-Dec-10	1-128

7.2. CTD data processing

The reduction of profile data began with a standard suite of processing modules using Sea-Bird Data Processing Version 7.23.2 software in the following order:

DATCNV converts raw data into engineering units and creates a ROS bottle file. Both down and up casts were processed for scan, elapsed time(s), pressure, t0, t1, c0, c1, oxvo1, oxvo2, ox1 and ox2. Optical sensor data were converted to voltages and also carried through the processing stream. MARKSCAN was used to skip over scans acquired on deck and while priming the system under water.

ALIGNCTD aligns temperature, conductivity, and oxygen measurements in time relative to pressure to ensure that derived parameters are made using measurements from the same parcel of water. Primary and secondary conductivity were automatically advanced in the V2 deck unit by 0.073 seconds. No further alignment was warranted. It was not necessary to align temperature or oxygen.

BOTTLESUM averages burst data over an 8-second interval (within ± 4 seconds of the confirm bit) and derives both primary and secondary salinity, potential temperature (θ), and potential density anomaly (σ_θ). Primary and secondary oxygen (in μmol/kg) were derived in DATCNV and averaged in BOTTLESUM, as recommended recently by Sea-Bird.

WILDEDIT makes two passes through the data in 100 scan bins. The first pass flags points greater than 2 standard deviations; the second pass removes points greater than 20 standard deviations from the mean with the flagged points excluded. Data were kept within 0.005 of the mean.

FILTER applies a low pass filter to pressure with a time constant of 0.15 seconds. In order to produce zero phase (no time shift) the filter is first run forward through the file and then run backwards through the file.

CELLTM uses a recursive filter to remove conductivity cell thermal mass effects from measured conductivity. In areas with steep temperature gradients the thermal mass correction is on the order of 0.005 PSS-78. In other areas the correction is negligible. Nominal values of 0.03 and 7.0 s were used for the thermal anomaly amplitude (α) and the thermal anomaly time constant (β^{-1}), respectively, as suggested by Sea-Bird.

LOOPEDIT removes scans associated with pressure slowdowns and reversals. If the CTD velocity is less than 0.25 m s^{-1} or the pressure is not greater than the previous maximum scan, the scan is omitted.

DERIVE uses 1-dbar averaged pressure, temperature, and conductivity to compute primary and secondary salinity, as well as more accurate oxygen values.

BINAVG averages the data into 1-dbar bins. Each bin is centered on an integer pressure value, e.g. the 1-dbar bin averages scans where pressure is between 0.5 dbar and 1.5 dbar. There is no surface bin. The number of points averaged in each bin is included in the data file.

STRIP removes oxygen that was derived in DATCNV.

TRANS converts the binary data file to ASCII format.

Package slowdowns and reversals owing to ship roll can move mixed water in tow to in front of the CTD sensors and create artificial density inversions and other artifacts. In addition to Seasoft module LOOPEDIT, MATLAB program deloop.m computes values of density locally referenced between every 1 dbar of pressure to compute the square of the buoyancy frequency, N^2, and linearly interpolates temperature, conductivity, and oxygen voltage over those records where N^2 is less than or equal to -1×10^{-5} s^{-2}. Some profiles failed the criteria near the surface. These data were retained and flagged as questionable in the final CCHDO formatted .CSV files.

Program calctd.m reads the delooped data files and applies calibrations to pressure, temperature, conductivity, and oxygen; and computes calibrated salinity.

7.3. Pressure calibration

An on-deck pressure offset of -0.5 dbar was entered into the instrument configuration file and applied during acquisition. On-deck pressure readings prior to each cast were examined at sea and their offsets remained within 0.5 dbar throughout the cruise. Differences between first and last submerged pressures for each cast were also examined and the residual pressure offsets were less than 0.6 dbar.

7.4. Temperature calibration

A viscous heating correction of -0.0006 °C was applied (as recommended by Sea-Bird) prior to preliminary temperature, conductivity, and oxygen calibrations; and to the preliminary data set at the end of the cruise.

SBE 35 reference temperature sensor data were used to correct SBE 3 temperature sensor data. SBE 35 s/n 76 was used for all stations. Primary SBE 3 temperature sensor s/n 4569 and secondary SBE 3 temperature sensor s/n 4193 was used for all stations. At sea, residuals between the reference data and those from the primary SBE 3 were minimized (giving the deeper values more weighting than the shallower ones in the fit) to determine a linearly station-dependent offset, and a linear pressure-dependent correction applied only to temperatures collected at pressures exceeding a value estimated by the minimization. The best fit for primary SBE 3 temperature sensor s/n 4569 applied a slope of 4.487824e-006, an offset of 0.000204 °C, and a pressure correction term of 2.50659e-007.

Temperature corrections were applied to profile data using program calctd.m and to burst data using calclo.m.

7.5. Conductivity calibration

Seasoft module BOTTLESUM creates a sample file for each cast. These files were appended using program sbecal.f. Program addsal.f matched sample salinities to CTD salinities by station/sample number.

Primary conductivity sensor s/n 3068 was used for all stations and calibrated as a single group. At sea, program calco2p1.m calculated a station-dependent slope, a single conductivity bias and quadratic term, and a single pressure correction term (pressure times measured conductivity) that best fit this sensor:

Stations: 1-124
number of points used: 2251
total number of points: 2744
% of points used in fit: 82.03
fit standard deviation: 0.002571
fit bias: 0.0072818444
fit co pressure fudge: -5.0916431e-007
min fit slope: 0.9996982
max fit slope: 0.99970231

Conductivity calibrations were applied to profile data using program calctd.m and to burst data using calclo.m.

7.6. Oxygen calibration

A hybrid of the Owens-Millard (1985) and Murphy-Larson (revised 2010) oxygen sensor modeling equations was used to calibrate the SBE-43 oxygen sensor data from this cruise. The equation has the form

Ox=Soc*(V+Voff+Tau*exp(DI*P+D2*T).*dV/dt).*Os.*exp(Tcor*T).*exp(Pcor*P./(273.15+T));

Where Ox is the CTD oxygen (in µmol/kg), V is the measured oxygen voltage (in volts), dV/dt is the temporal gradient of the oxygen voltage (in volts/s estimated by running linear fits made over 5 seconds), P is the CTD pressure (in dbar), T is the CTD temperature (in °C), and Os is the oxygen saturation computed from the CTD data following Garcia & Gordon (1992). Oxygen sensor hysteresis was improved by matching upcast bottle oxygen data to downcast CTD data by potential density anomalies referenced to the closest 1000-dbar interval using program match_sgn.m. We used the values provided by SBE for each sensor for the constants D1 (1.9263e-4) and D2 (-4.6480e-2) to model the pressure and temperature dependence of the response time for the sensor. For each group of stations fit we determined values of Soc (sometimes station dependent), Voff, Tau, Tcor, and Pcor by minimizing the residuals between the bottle oxygen and CTD oxygen. W represents fitting switches. If the switches are set to 0,0 the fit is a regular L2 (least squares) norm for the entire group. If the switches are set to 1,0 the fit is a regular L2 norm for the entire group but with a slope that is a linear function of station number. If the switches are set to 2,0 the program first fits the entire group, then goes back and fits a slope and bias to individual stations, keeping the other parameters at the group values. If the switches are set to 0,1 the fit is a regular L2 norm for the entire group, but it is weighted by the nominal oxygen bottle spacing, thus fitting the deep portion of the water column better.

At sea, program addsal.f matched bottle sample oxygen values to CTD oxygen values by station/sample number. Program run_oxygen_cal_ml.m was used to determine calibration coefficients by visual inspection for primary oxygen sensor s/n 3419 used for all stations.

Stns	Soc	Voff	Tau	Tcor	Pcor	Npts	%Used	StdDev	W
1-29	0.5101-0.5127	-0.4664	6.5938	0.0004	0.0399	677	88.6	0.6213	1,0
30-38	0.5144	-0.4761	6.3184	0.0004	0.0409	215	87.0	0.9457	0,0
39-49	0.5249	-0.4910	7.2989	-0.0002	0.0412	263	86.7	0.7751	0,0

50-58	0.5395	-0.4970	6.1816	-0.0032	0.0402	216	80.1	0.7658	0,1
59-81	0.5386	-0.4967	4.8043	-0.0030	0.0401	524	84.2	0.8331	0,1
82-112	0.5363	-0.4947	6.7710	-0.0011	0.0401	738	90.5	0.7504	0,1
113-124	0.5321	-0.4918	5.7279	-0.0010	0.0401	762	90.7	0.7590	0,1

Oxygen calibration coefficients were applied to profile data using program calctd.m, and to burst data using calclo.m.

7.7. Discrete Niskin sampling

Most rosette casts were lowered to just about 10 meters above the bottom, using an altimeter to determine distance above the bottom. Up to about 11.5°S a simple sampling scheme AB was utilized to stagger sample depths. Staggering sample depths was to avoid spatial aliasing with in this sample data set. Because with spacing between the stations of 17-30 nm the CFC group was able to sample every other station, so they were getting the same depths. In order to make their samples also staggered, we decided to follow an ABC scheme for all stations almost throughout the entire cruise. At station 112 in the Arabian Sea, to better resolve sharp vertical gradients, we modified the sampling scheme by firing more bottles in the near-surface layer of the ocean. However, we quickly realized that this modified scheme with fewer bottles at mid-depths was not optimal for all groups, and we went back to the original ABC scheme. The sampling depths used during the I07N-2018 cruise are shown in Figure 4.

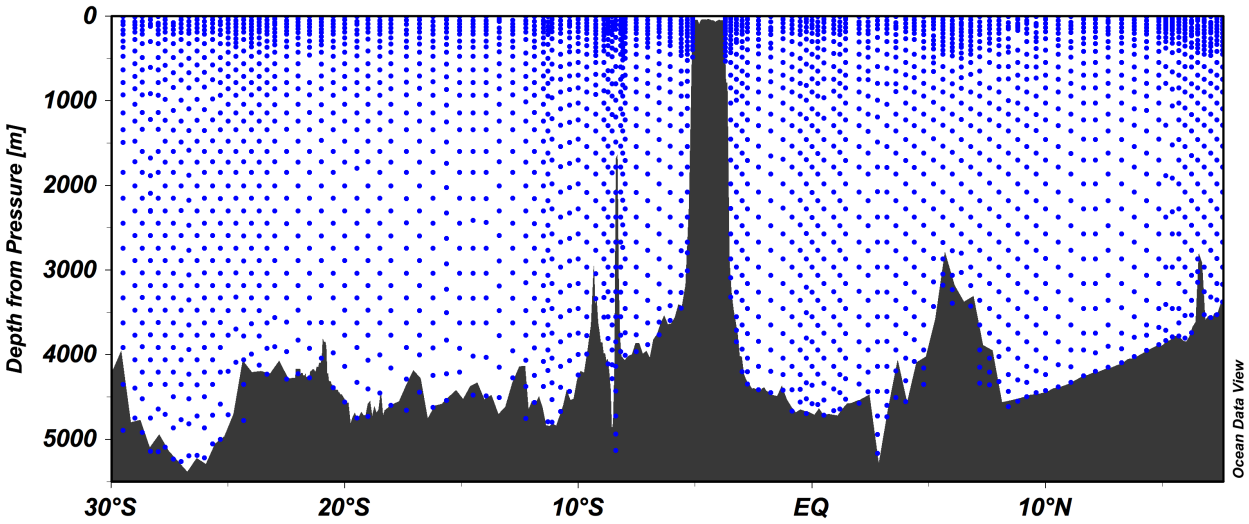


Figure 4. I07N-2018 bottle sample distribution

The 24-place SBE32 carousel had few bottle lanyard or mis-tripped bottle problems. Rosette maintenance was performed on a regular basis. O-rings were replaced, and lanyards repaired as necessary. Rosette bottle maintenance was performed each day to insure proper closure and sealing. Valves were inspected for leaks and repaired or replaced as needed. Periodic leaks were noted on sample logs. Log notes were cross-referenced with sample data values and quality coded. Log notes, mis-trips, bottle lanyard issues and associated quality codes can be found in the Appendix 10.3.

At the end of each rosette deployment water samples were drawn from the rosette bottles in the following order:

- Chlorofluorocarbons (CFCs) and SF6
- Dissolved oxygen (O_2)
- Dissolved Inorganic Carbon (DIC)
- pH
- Total Alkalinity
- DI^{14}C
- Dissolved Organic Carbon (DOC)

- Nutrients
- Salinity
- Biomarkers
- Black Carbon/ DO^{14}C / Walker Dissolved Organics
- Calcium
- Density
- Nitrate (NO_{3-})
- Genetic samples
- Particulate Organic Matter (POM)
- Biological samples

Properties measured during the cruise are also listed in Appendix 10.2.

7.8. Bottle data processing

Water properties that were analyzed from samples onboard during the cruise were managed centrally through a Fortran-based bottle data management system (BDMS) developed by Dr. John Bullister at PMEL. The system was set up on a Ubuntu Linux workstation with network access to the ship and shell scripts for pulling data and pushing summary HY1 files.

Once the rosette was sampled, sample quality flags (1 = sampled or 9 = not sampled) plus comments were recorded for every parameter from the sample logsheets. Approximately daily, the BDMS was updated, combining all available CTD bottle data and analytical data (with their associated quality flags). Quality flags follow the coding scheme developed for the World Ocean Circulation Experiment (WOCE) Hydrographic Programme (WHP, Table 6.4.3).

Various consistency checks and detailed examination of the data continued throughout the cruise. A summary of Cast Log and Sample Log comments, mis-trips, bottle lanyard issues and associated quality codes can be found in Appendix 10.3.

7.9. Collected samples

Samples analyzed onboard during the cruise	Samples collected (not analyzed at sea)
Chlorofluorocarbons(CFCs)/SF6	DI^{14}C
Dissolved O_2	DOC
Total CO_2 (DIC)	Black Carbon / Biomarkers / DO^{14}C
pH	Walker Dissolved Organics
Total Alkalinity	Density
Nutrients	Calcium
Salinity	NO_{3-}
Biological samples	Genetics / Particulate Organic Matter

8. Ship-Board Analysis Section

8.1. Temperature

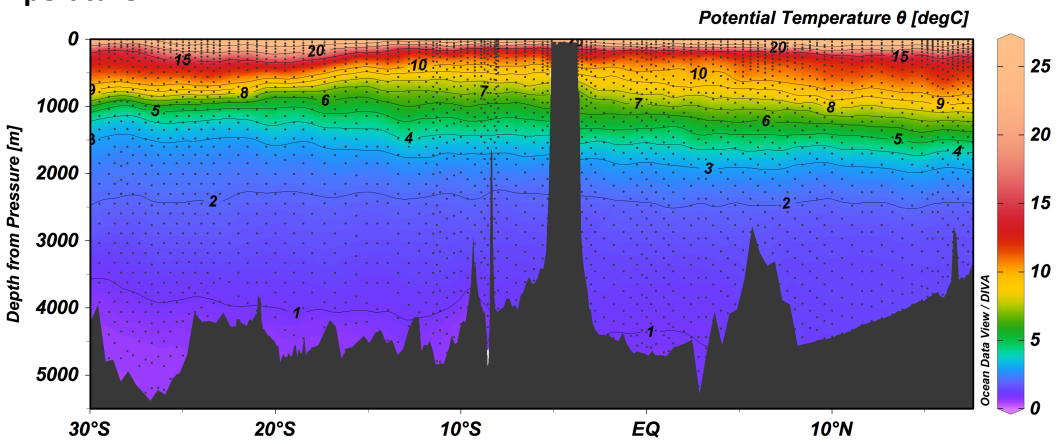


Figure 5. Potential temperature

8.2. Salinity

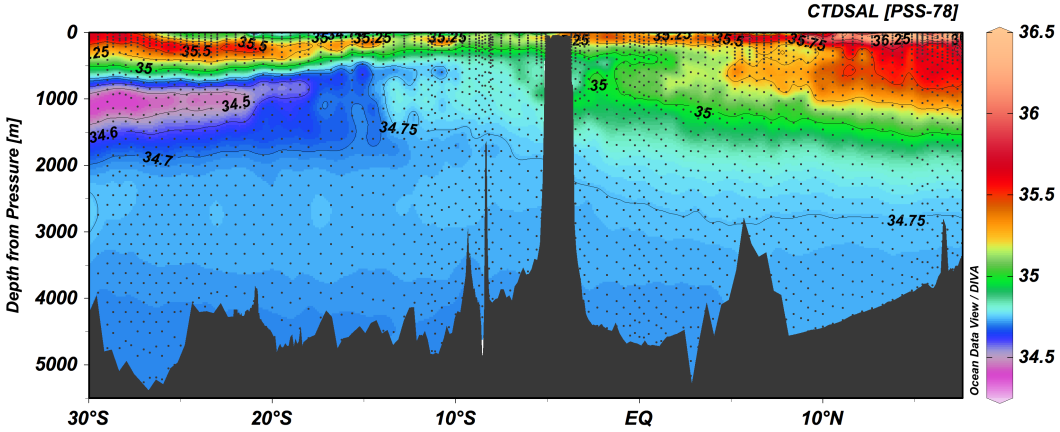


Figure 6. Salinity

8.3. Dissolved Oxygen

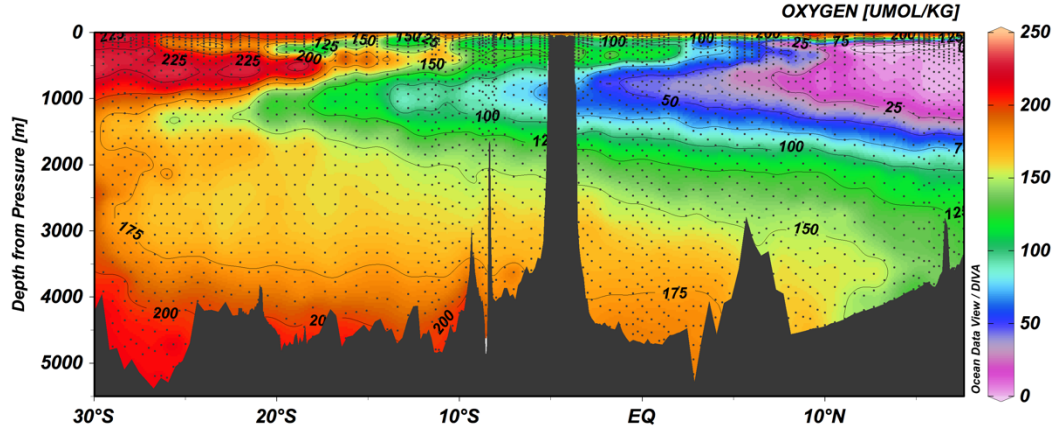


Figure 7. Dissolved oxygen

8.4. Total CO_2

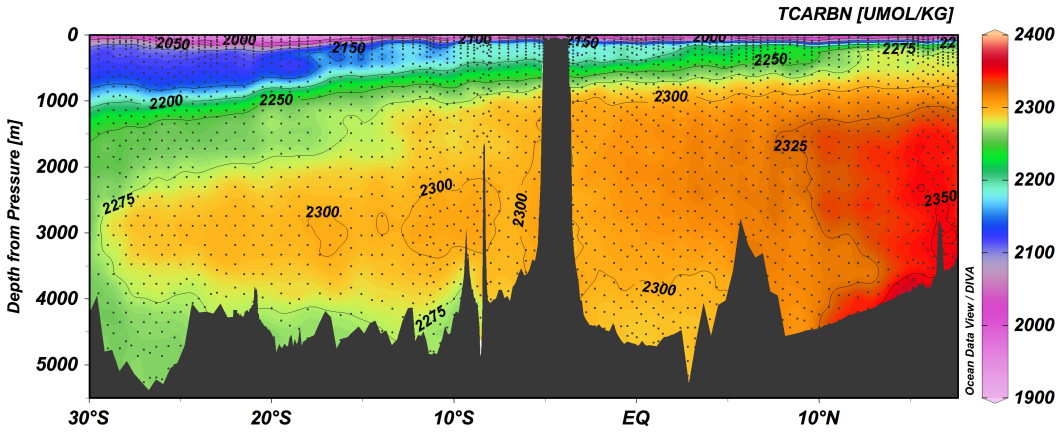


Figure 8. Total Carbon

8.5. Total Alkalinity / pH

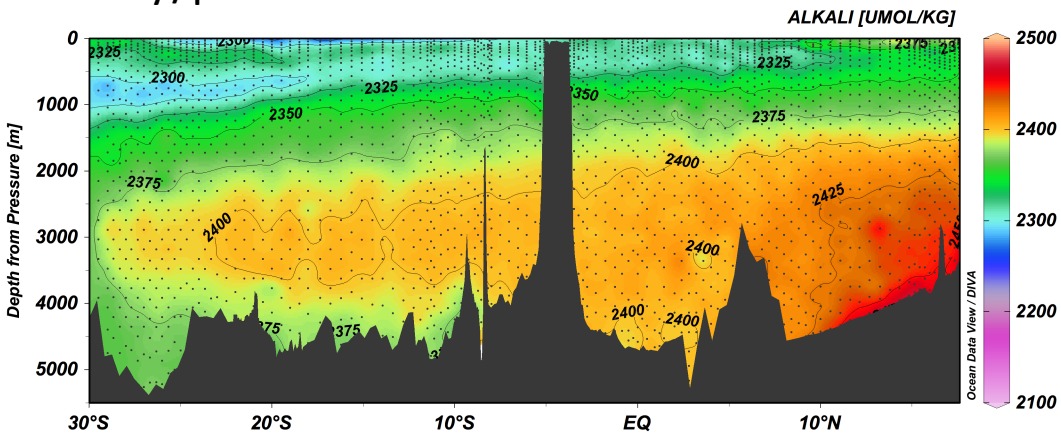


Figure 9. Total Alkalinity

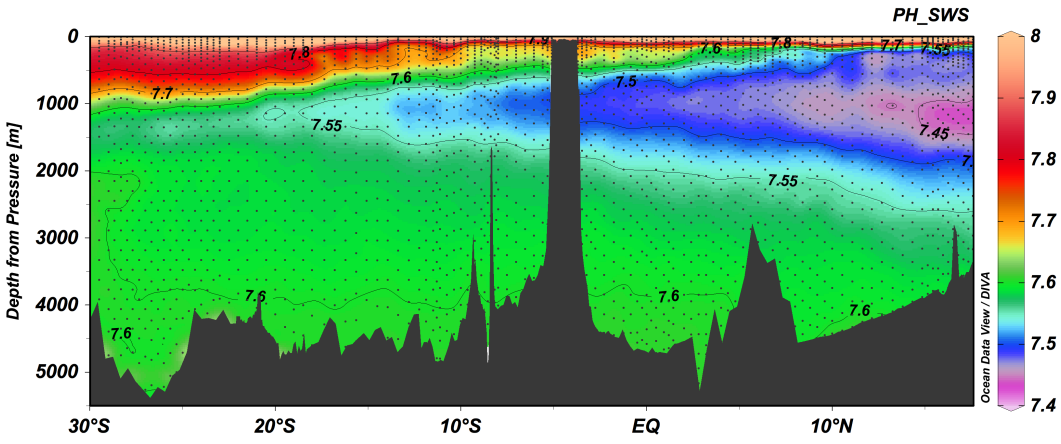


Figure 10. pH

8.6. Nutrients

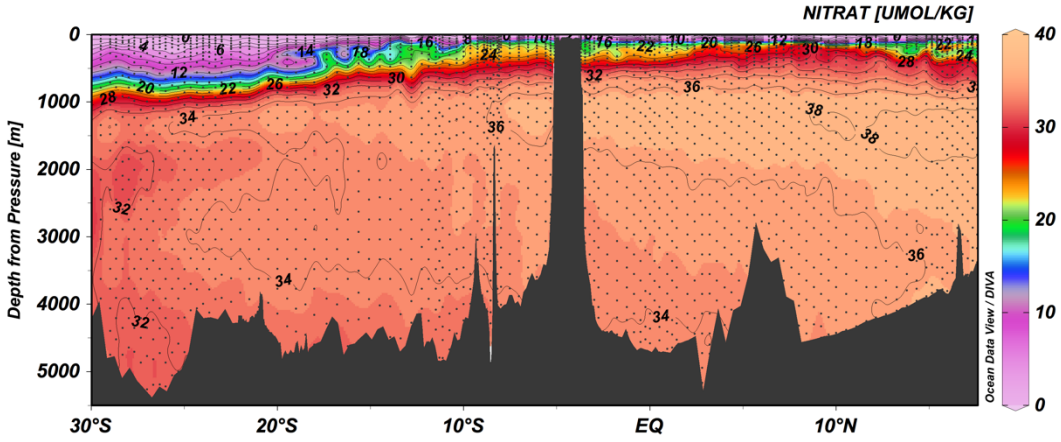


Figure 11. Nitrate

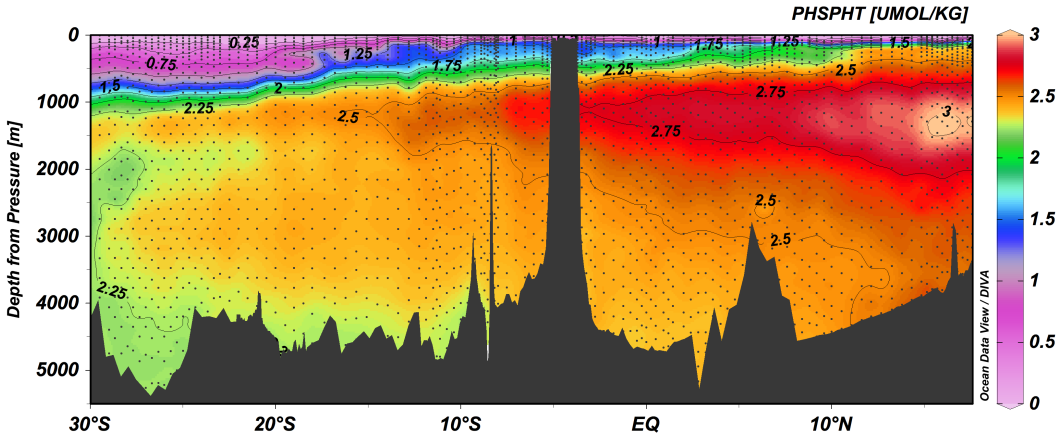


Figure 12. Phosphate

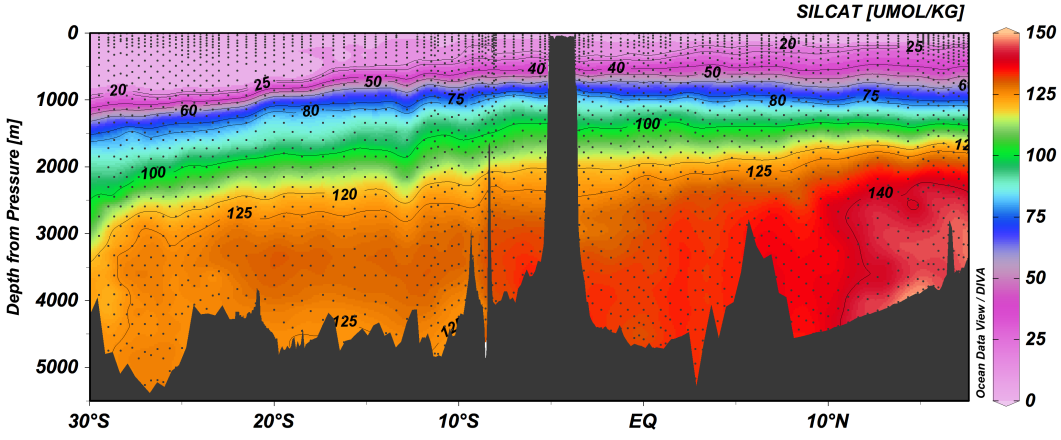


Figure 13. Silicate

8.7. Chlorofluorocarbons (CFCs) / SF_6

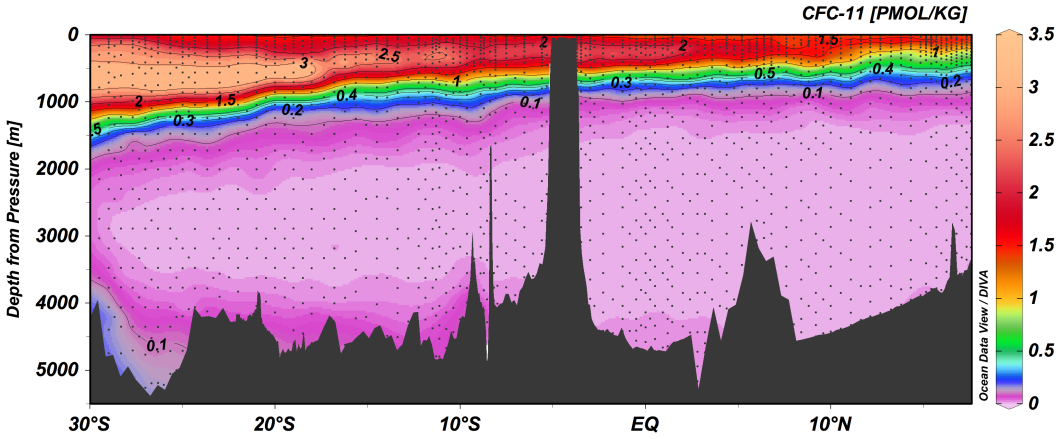


Figure 14. CFC-11

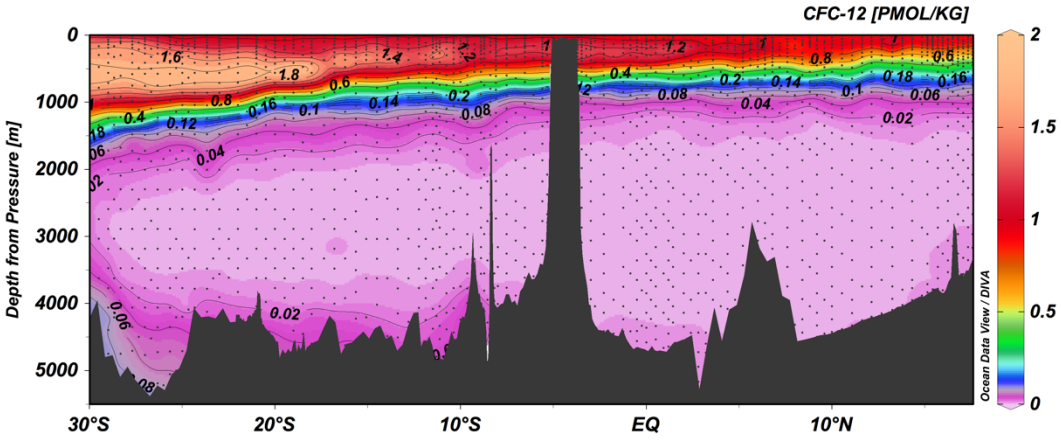


Figure 15. CFC-12

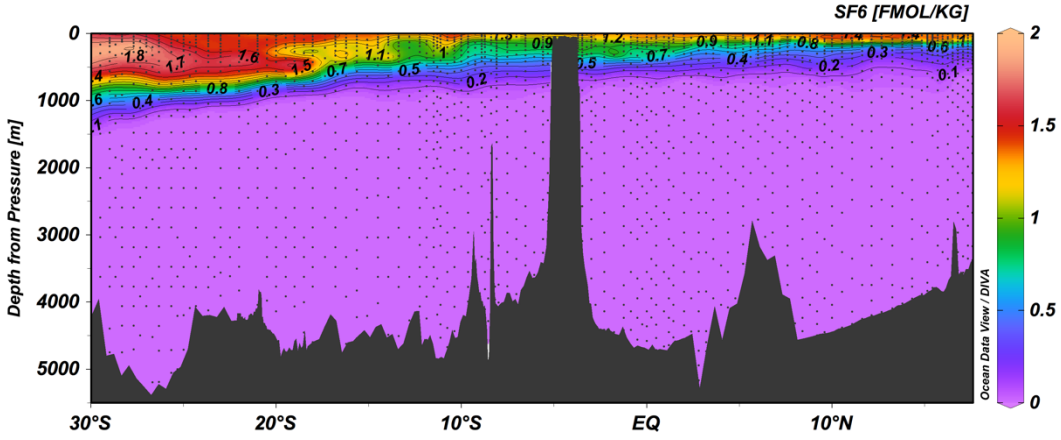


Figure 16. SF_6

9. Individual Sub-Project Reports

9.1. Deployments

During the I07N-2018 cruise we deployed 15 Argo floats (Table 9.1), 10 SVP drifters (Table 9.2), and 3 wave buoys (Table 9.3). The following sections contain tables that show the serial numbers of these autonomous devices, and the locations and times of their deployment. All assets were deployed from the starboard side of the stern and at the speed of around 1.5-2 knots. The Argo floats were carefully lowered in the water by three people using a rope. The drifters were thrown overboard by one person, and the wave buoys were carefully lowered in the water by one person holding the parachute of the buoy.

9.1.1. Argo floats

PIs: Elizabeth Steffen (PMEL), Gregory Johnson (PMEL)
Shipboard personnel: Kristene McTaggart (PMEL), Denis Volkov (AOML/CIMAS), James Hooper (AOML/CIMAS), Andrew Stefanick (AOML)

Table 9.1. The list of Argo floats deployed during the I07N-2018 cruise

Device Type and Number	Deployment Location		Deployment Time (UTC)
	Latitude	Longitude	
Navis F0839	29° 59.976' S	42° 42.005' E	4/25/2018 18:28
Apex 7023	23° 59.278'	54° 30.534' E	05/02/2018 12:05
Apex 5599	21° 59.680' S	54° 31.122' E	05/03/2018 16:17
Navis F0837	18° 0.965' S	55° 0.087' E	05/05/2018 20:24
Navis F0836	15° 05.350' S	55° 00.256' E	05/07/2018 05:55
Apex 7024	3° 28.613' S	55° 48.374' E	05/20/2018 01:10
Navis F0835	2° 44.518'S	56° 25.870'E	05/20/2018 16:17
Apex 5600	1° 45.773'S	57° 13.435' E	05/20/2018 05:33
Navis F0825	0° 51.545'S	57° 15.395' E	05/21/2018 19:56
Apex 5601	0° 00.213'N	57° 16.443' E	05/22/2018 12:10
Navis F0840	1° 27.892'N	57° 18.558' E	05/23/2018 18:33
Navis F0841	5° 11.985' N	60° 15.657' E	05/26/2018 03:29
Apex 5023	7° 11.570' N	62° 05.422' E	05/27/2018 11:30
Navis F05602	13° 47.283' N	64° 39.935' E	05/31/2018 08:18
Apex F05024	16° 47.032' N	67° 59.598' E	06/02/2018 02:17

9.1.2. Surface Velocity Program (SVP) drifters

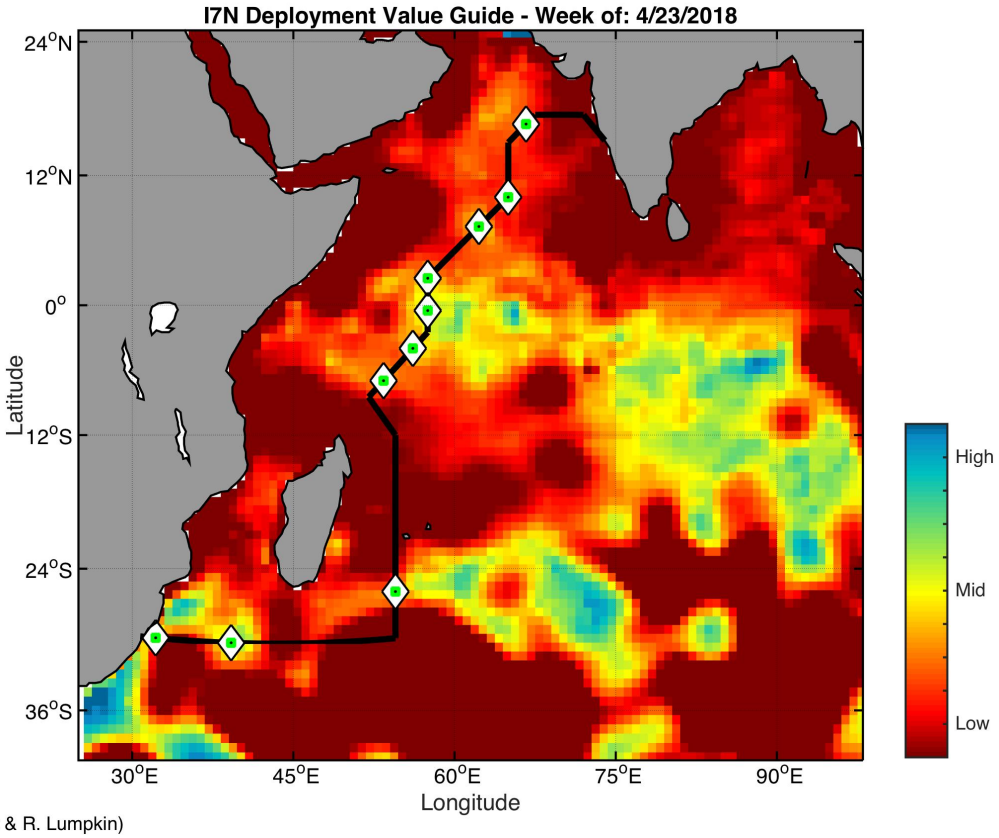
PIs: Rick Lumpkin (AOML), Shaun Dolk (AOML/CIMAS)
Shipboard personnel: Denis Volkov (AOML/CIMAS), James Hooper (AOML/CIMAS), Andrew Stefanick (AOML)

Table 9.2. The list of SVP drifters deployed during the I07N-2018 cruise

Drifter Number	Deployment Location		Deployment Time (UTC)
	Latitude	Longitude	

300234065701170	29° 50.950' S	32° 12.730' E	04/23/2018 18:11
300234065701160	29° 58.826' S	39° 00.040' E	04/25/2018 00:37
300234065701130	25° 59.939' S	54° 30.110' E	04/30/2018 01:40
300234065701120	7° 01.284' S	53° 58.247' E	05/13/2018 23:35
300234065701110	3° 13.912' S	56° 00.135' E	05/20/2018 05:52
300234065701020	2° 15.527' S	56° 49.452' E	05/20/2018 22:52
300234065700990	0° 00.400' N	57° 16.440' E	05/22/2018 12:15
300234065700950	3° 11.588' N	58° 25.983' E	05/24/2018 20:00
300234065700970	6° 47.436' N	61° 43.390' E	05/27/2018 05:10
300234065700980	7° 40.467' N	62° 32.011' E	05/27/2018 18:40

Most of SVP drifters were deployed according to the plan developed by the PIs Rick Lumpkin (AOML) and Shaun Dolk (AOML/CIMAS). A map in Figure 17 highlights the areas with drifter data gaps (colors from yellow to blew) that were selected for deployment. We deviated from this plan a little by deploying one drifter in a strong eastward current (Wyrtki Jet) at about 2°S just north of the Seychelles Bank. Due to a miscommunication between the day and night shifts, we mistakenly deployed two last drifters close to each other, at 6°47'N and at 7°40'N (see Table 9.2).



(S. Dolk & R. Lumpkin)

Figure 17. Drifter Deployment Value model, highlighting areas to fill data sparse regions, as well as to maximize drifter lifetimes. Red means low priority and blue means high priority for deployment.

9.1.3. Wave buoys

PI: Kerstin Paulsson (SIO)
Shipboard personnel: Denis Volkov (AOML/CIMAS), James Hooper (AOML/CIMAS), Andrew Stefanick (AOML)

During the I07N-2018 cruise we deployed 3 GPS-based wave sensing buoys (Table 9.3), part of a 72-buoy array deployed throughout a 3-year program, provided by the Scripps Institution of Oceanography. The buoys measure the u,v,w of the ocean surface, process for the first 5 moments of the directional wave height coefficients, and relays the information in near-real time back to SIO. A near-surface drogue allows the buoys to follow the upper O(1)m currents. The focus of the deployments is twofold: basin-scale observations of the surface wave field, and intensive sampling of the Somali Current and the resulting wave-current interactions. The buoy trajectories as well as the measured significant wave heights as of July 10 are shown in Figure 18.

Table 9.3. The list of wave buoys deployed during the I07N-2018 cruise

Drifter Number	Deployment Location		Deployment Time (UTC)
	Latitude	Longitude	
545	29° 59.957' S	45° 00.419' E	04/25/2018 03:45
548	13° 56.631' S	55° 00.343' E	05/07/2018 19:48
547	6° 03.299' S	54° 38.344' E	05/14/2018 12:13

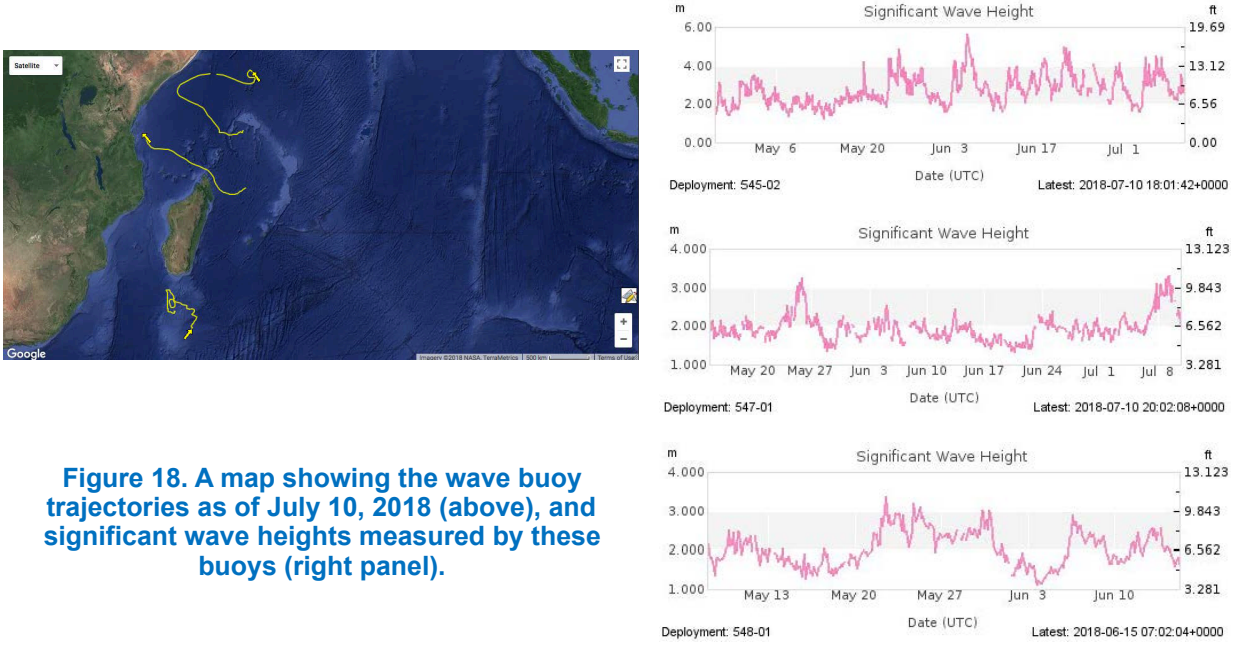


Figure 18. A map showing the wave buoy trajectories as of July 10, 2018 (above), and significant wave heights measured by these buoys (right panel).

9.2. Lowered Acoustic Doppler Current Profiler (ADCP)

PI: Andreas Thurnherr (LDEO)
Operator: Amanda Fay (LDEO)

Introduction

LADCP data were collected during the full-depth CTD cast at all stations. Preliminary processing and QC was performed onboard by Amanda Fay. Casts were sent to A. Thurnherr for shore-based processing as internet access allowed. A full QC will be carried out after the cruise by A. Thurnherr.

LADCP System Configuration

An AOML custom 48V lead acid rechargeable battery pack was used for all deployments. Instruments and battery pack were interfaced using a standard RDI star cable. Custom AOML deck leads were used for communications and charging between casts. The battery pack was periodically vented manually to prevent pressure build up. Battery power was periodically checked to ensure proper charge level of 52V was being maintained before deployments. Both the battery pack and the ADCP's were affixed to the CTD package using custom tabbed brackets aligned on horizontal cross-members of the package. The upward ADCP was positioned between niskin bottles 1 and 24 towards the outer ring, while the downward ADCP was affixed in the middle of the package about 4 inches from the bottom ring. The configuration is shown in Figure 19.

The power supply and data transfer were handled independently from any CTD connections. While on deck, a communications and power cable was connected to a cable in the staging bay that ran into the wet lab. This cable connected to a battery charger located in the wet lab for power supply and also to an acquisitions computer via USB connection for data download. The LADCP acquisitions computer clock was synced to the master clock in the computer lab via network.

Table 01: Instruments used on cruise. DL = downlooker UL = uplooker.

Model	Serial Number	Stations used
Teledyne RDI WHM300	150	1- 6, 11-44 (UL)
Teledyne RDI WHM300	24497	7- 10, 45- 124 (UL)
Teledyne RDI WHM150	24544	1-124 (DL)

Three different ADCP instruments were used during this cruise (table 01). Initial configuration consisted of the WHM15O #24544 as downlooker and the WHM300 #150 as uplooker. After perfect performance on the test casts, the downlooker reported a weak beam 1 on casts 1-3 and by cast 4 it appeared to have failed completely. We did not have a spare WHM150 onboard, so we did not replace the instrument. Around station 26 the beam came back as “weak” rather than “failed” and continued in this manner for the rest of the stations. The original UL, #150, was used for stations 1-6 before being swapped out for the alternate due to poor vertical velocities at depth due to the scattering environment. Unfortunately, the replacement UL (# 24497) did not improve the situation so at station 11 we went back to UL # 150. After recovering at station 11 however, the instrument came back reported that beam 3 was broken on the uplooker. We chose to maintain this setup regardless of the broken beam but kept a close eye on the data after each cast in case of another failure. At station 44 we noticed that beam 4 was cutting in-and-out at a depth around 1000 m. Before station 45 we installed the replacement UL (#24497) and continued with this setup throughout the rest of the stations without incident.

All ADCPs were set up to record velocity data with 8m pulses/bins and zero blanking. At station 69 we increased the number of bins for the DL because of improved acoustic scattering conditions. Staggered pinging was used to avoid previous ping interference, which is particularly important for 150kHz instruments.

Problems/Setup Changes

Test Station B, cast 1: Switched to aft winch. Maintained aft winch throughout cruise.
Station 4-25: Beam 1 of DL SN # 24544 reported failed
Station 7: Replaced UL from SN #150 to SN #24497
Station 11: Replaced UL from SN #24497 to SN #150
Station 25-124: Beam 1 of DL SN # 24544 reported as weak
Station 45: Replaced UL from SN #150 to SN #24497
Station 69, cast 1: MASTER.cmd changed from LN25 to LN30
Station 73, cast 1: Wire was trimmed and reterminated before this station.
Station 85, cast 1: Acquisition computer shut down between station 84 and 85. No issues once rebooted.

LADCP Operation

ADCP programming and data acquisition were carried out using the LDEO Acquire software running on a MacBook Pro laptop. Communications between the acquisitions computer and the ADCPs took place across two parallel RS232 connections via a Keyspan USA-49WG 4-port USB-to-RS232 adapter. No significant communications issues were encountered throughout the cruise. After sending the corresponding command files to the instruments prior to each cast, communication between the computer and the instrument was terminated, the deck cables were disconnected, and all connections were sealed with dummy plugs and secured. After the CTD was brought back on deck following a cast, the data and the power supply cable were reconnected to the computer and battery charger via the deck cables. Data acquisition was terminated and the data were downloaded using the Acquire software. The battery charger remained on from the time of data download until the time the instrument was prepared for the next cast. Log files were kept for each cast to ensure that all the steps were completed.

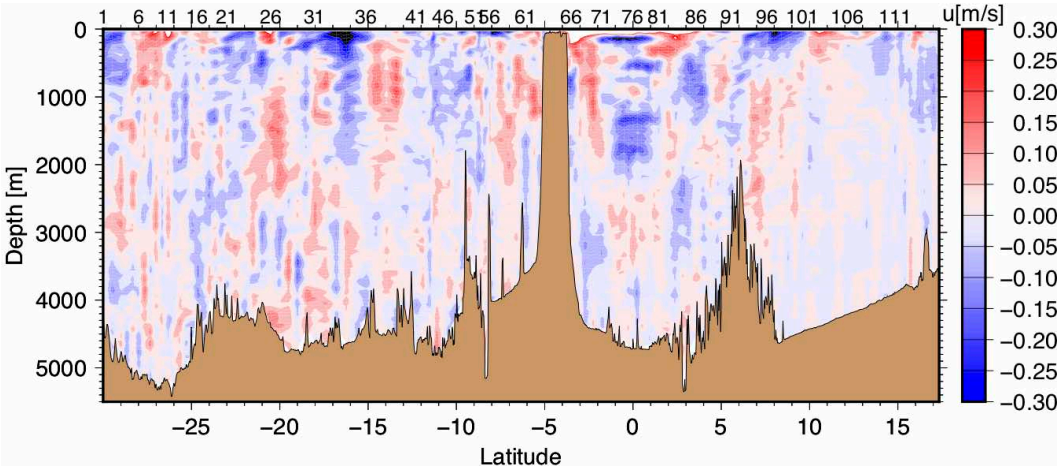
Data Processing and Quality Control

The LADCP data were processed by A. Fay at least once per day using the Matlab-based LDEO IX_10 processing software (1). Thurnherr also conducted additional processing in his lab on the data in batches of 2-4 stations. Processing warnings and diagnostic figures created during processing were reviewed for signs of anomalies, which included checking the realism of final profile values, checking for any biased shear, examining the agreement between aligned CTD/LADCP time series, and monitoring beam strength and range. Thurnherr was sent data and consulted when questionable profiles were observed.

The cruise-processed profiles of LADCP-derived horizontal velocity are shown in Figure 20. Comparison of the LADCP velocities in the upper ocean with the corresponding on-station SADCP velocities (Figure 21) indicates that the quality of these data is improved as we moved North due to improved scattering environment. Data quality will be assessed more quantitatively during additional post-cruise QC and re-processing by Thurnherr at LDEO.

(1) available for download at http ://www.ldeo.columbia.edu/LADCP

Figure 19. Instruments and battery pack on rosette. UVP is not mounted in this photo.



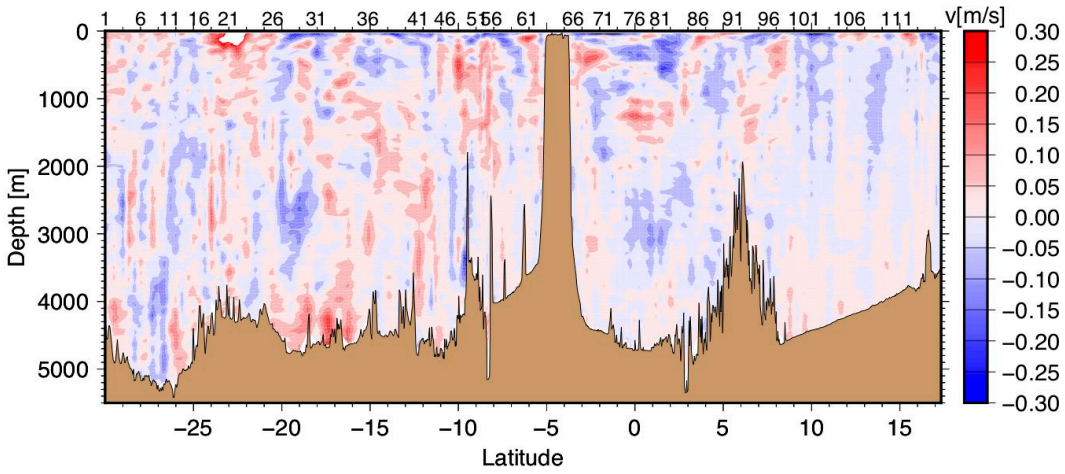


Figure 20. LADCP-derived velocities observed during I07N from preliminary processing. Upper panel: Zonal velocity component (u). Lower panel: Meridional velocity component (v).

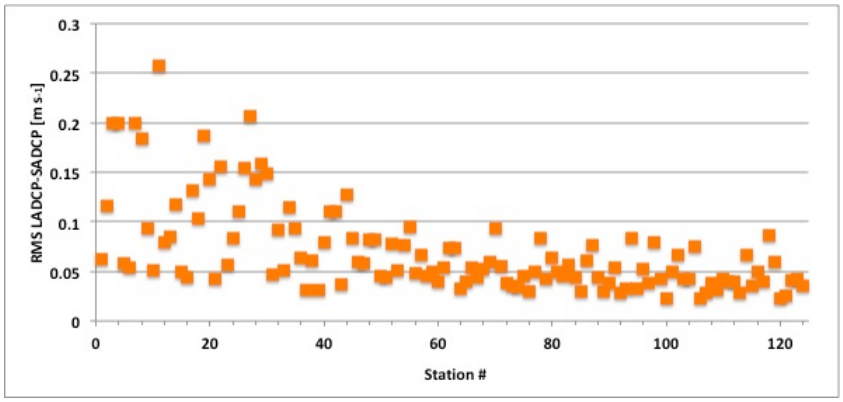


Figure 21. RMS difference between the SADCP and LADCP velocities, showing improved agreement as cruise progressed.

9.3. Discrete Salinity Sampling

PI: Molly Baringer (AOML)
Shipboard analysts: James Hooper (AOML/CIMAS), Andrew Stefanick (AOML)

A single Guildline Autosal, model 8400B salinometers (S/N 61664, nicknamed Miller Freeman), located in the salinity analysis room, was used for all salinity measurements. The autosals was calibrated on 9/2016. The salinometer readings were logged on a computer using Ocean Scientific International's logging hardware and software. The Autosal's water bath temperature was set to 24°C, which the Autosal is designed to automatically maintain. The laboratory's temperature was also set and maintained to just below 24°C, to help further stabilize reading values and improve accuracy. Salinity analyses were performed after samples had equilibrated to laboratory temperature at least 12 hours after collection and at least 18 hours in colder waters. The salinometer was standardized for each group of samples analyzed (usually 2 casts and up to 52 samples) using two bottles of standard seawater: one at the beginning and end of each set of measurements. The salinometer output was logged to a computer file. The software prompted the analyst to flush the instrument's cell and change samples when appropriate. Prior to each run a sub-standard flush, approximately 200 ml, of the conductivity cell was conducted to flush out the DI water used in between runs. For each calibration standard, the salinometer cell was initially flushed 6 times before a set of conductivity ratio reading was taken. For each sample, the salinometer cell was initially flushed at least 3 times before a set of conductivity ratio readings were taken. After each run the autosal conducitivity cell was flushed with approximately 200 ml of a triton-DI water solution and then rinsed and stored with DI water until the net run.

IAPSO Standard Seawater Batch P-160 was used to standardize all casts.

The salinity samples were collected in 200 ml Kimax high-alumina borosilicate bottles that had been rinsed at least three times with sample water prior to filling. The bottles were sealed with custom-made plastic insert thimbles and Nalgene screw caps. This assembly provides very low container dissolution and sample evaporation. Prior to sample collection, inserts were inspected for proper fit and loose inserts replaced to insure an airtight seal. PSS-78 salinity [UNES81] was calculated for each sample from the measured conductivity ratios. The offset between the initial standard seawater value and its reference value was applied to each sample. Then the difference (if any) between the initial and final vials of standard seawater was applied to each sample as a linear function of elapsed run time. The corrected salinity data was then incorporated into the cruise database. When duplicate measurements were deemed to have been collected and run properly, they were averaged and submitted with a quality flag of 6. On I07N, 2832 salinity measurements were taken, including 205 duplicates, and approximately 140 vials of standard seawater (SSW) were used. Up to two duplicate samples, one for shallow casts, were drawn from each cast to determine total analytical precision.

The standard calibration values and duplicates are below in Figure 22 and Figure 23. The duplicates taken during the cruise showed a median precision of -0.0002 +/- 0.004 psu.

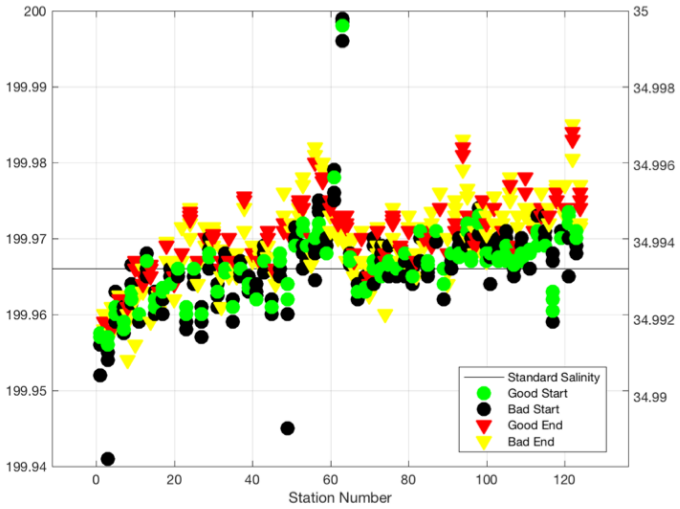


Figure 22. Standard vial calibrations throughout the cruise. The left vertical axis is 100 X the conductivity ration and the right axis is the corresponding salinity.

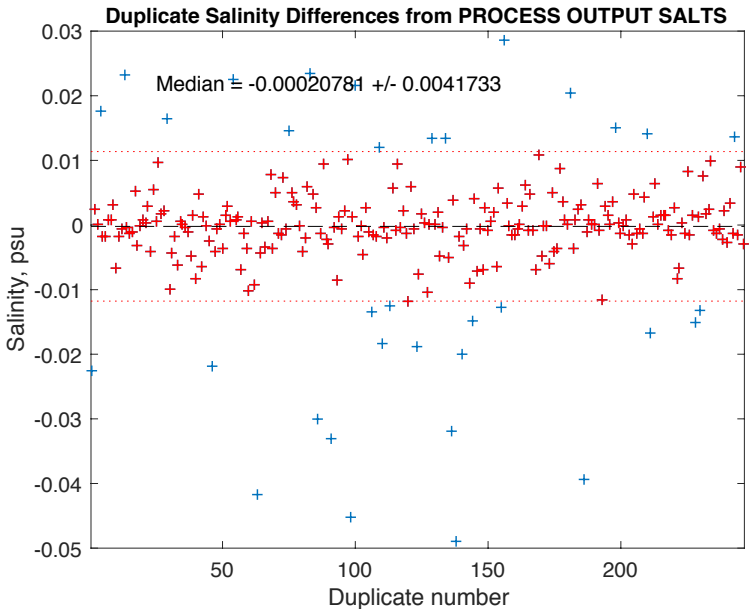


Figure 23: Duplicates throughout the cruise.

9.4. Dissolved Oxygen (discrete)

Analysts Leg1: Samantha Ladewig and Leah Chomiak
Analysts Leg2: Samantha Ladewig and Leah Chomiak
PIs: Chris Langdon, RSMAS, Molly Baringer, AOML

Equipment and Techniques

Dissolved oxygen analyses were performed with an automated titrator using amperometric end-point detection [Langdon, 2012]. Sample titration, data logging, and graphical display were performed with a PC running a LabView program written by Ulises Rivero of AOML. The temperature-corrected molarity of the thiosulfate titrant was determined as given by Dickson [1994]. Thiosulfate was dispensed by a 2 mL Gilmont syringe driven with a stepper motor controlled by the titrator. The whole-bottle titration technique of Carpenter [1965], with modifications by Culberson et al. [1991], was used. Three to four replicate 10 mL iodate standards were run every 3-4 days (SD<1 uL). The reagent blank was determined as the difference between V1 and V2, the volumes of thiosulfate required to titrate 1-mL aliquots of the iodate standard, was determined at the beginning and end of the cruise.

Sampling and Data Processing

Dissolved oxygen samples were drawn from Niskin bottles into calibrated 125-150 mL iodine titration flasks using silicon tubing to avoid contamination of DOC and radiocarbon samples. Samples were drawn by counting while the flask was allowed to fill at full flow from the Niskin. This count was then doubled and repeated thereby allowing the flask to be overflowed by two flask volumes. At this point the silicone tubing was pinched to reduce the flow to a trickle. This was continued until a stable draw temperature was obtained on the Oakton meter. These temperatures were used to calculate umol/kg concentrations and provide a diagnostic check of Niskin bottle integrity. 1 mL of MnCl2 and 1 mL of NaOH/NaI were added immediately after drawing the sample using a re-pipettor bottle-top dispenser. The flasks were then stoppered and shaken well. DI water was added to the neck of each flask to create a water seal. 24 samples plus two duplicates were drawn at each station. The total number of samples collected from the rosette was 3206.

The samples were stored in the lab in plastic totes at room temperature for 1-2 hours before analysis. The data were incorporated into the cruise database shortly after analysis.

Thiosulfate normality was calculated for each standardization and corrected to the laboratory temperature. This temperature ranged between 17.5 and 19.9 C.

A total of 11 standardizations were performed during legs 1 and 2 (mean=706.487, SD=1.26 uL). Reagent blanks were run at the beginning (1.8±1.4 uL) and end of the cruise (1.8±0.5 uL).

Volumetric Calibration

The dispenser used for the standard solution (SOCOREX Calibrex 520) and the burette used to dispense the thiosulfate titrant were calibrated gravimetrically just before the cruise. Oxygen flask volumes were determined gravimetrically with degassed deionized water at AOML. The correction for buoyancy was applied. Flask volumes were corrected to the draw temperature.

Duplicate Samples

Duplicate samples were drawn at two depths on every cast. The Niskins selected for the duplicates and hence the oxygen flasks were changed for each cast. A total of 247 sets of duplicates were run. The average standard deviation of all sets was 0.248 umol kg^{-1}.

Quality Coding

Based on preliminary quality control performed during the cruise the following quality flags were assigned.

Quality flag	Number Note	
2	2824	Good
3	66	Questionable - stopper loose, Niskin leak, bubble in flask
4	45	Bad - overshot endpoint, maxed out data points during titration
6	247	Duplicate
9	23	Not Sampled

Problems

Flask 181 had an incorrect volume value (typo) in the bottle volumes .txt file, resulting in an incorrect oxygen calculation. This was discovered after Station 36. The correct value of the flask was fixed in the .txt file and each calculation derived from flask 181 was recalculated with the proper volume for Stations 1-36; all calculations were updated in the logbook, final data file, and respective ABR files.

The re-pipettor bottle-top dispenser for the NaI reagent bottle was replaced at Station 5 after a crack in the neck occurred.

At Station 12, the electrode probe (SN8137155P) was replaced with a new probe (SN3129026P) due to erratic behavior.

At Station 23, the electrode was replaced again (SN6235027P) due to abnormal readings.

At Station 41, the electrode was replaced again (SN3350011P) due to erratic behavior.

At Station 105, upon entering the OMZ with recorded O2 values <5umol/kg, the titrator began having difficulties completing the titration script and calculating the final endpoint. The U=2 endpoint was recorded, and later the final endpoint was derived using the TRT script files to manually create a regression of the intercept between the current detector readings and uL titrant added. This regression endpoint was then used to manually calculate O2 in umol/L and umol/kg. The issue persisted from Station 105 through the last station, 124.

Cross-over comparisons

None this cruise.

References

Carpenter, J. H., "The Chesapeake Bay Institute technique for the Winkler dissolved oxygen method," Limnology and Oceanography, 10, pp. 141-143 (1965).

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Dickson, A. G., "Determination of dissolved oxygen in seawater by Winkler titration," WHP Operations and Methods (1994a).

Langdon, C. (2010). Determination of dissolved oxygen in seawater by Winkler titration using the amperometric technique. The GO-SHIP Repeat Hydrography Manual: A Collection of Expert Reports and Guidelines. E. M. Hood, C. L. Sabine and B. M. Sloyan, IOCCP Report Number 14, ICPO Publication Series Number 134.

9.5. Dissolved Inorganic Carbon (DIC)

PI's: Rik Wanninkhof (NOAA/AOML) and Richard A. Feely (NOAA/PMEL)
Technicians: Charles Featherstone (NOAA/AOML) and Dana Greeley (NOAA/PMEL)

Sample collection:

Samples for DIC measurements were drawn (according to procedures outlined in the PICES Publication, *Guide to Best Practices for Ocean CO2 Measurements*) from Niskin bottles into 294 ml borosilicate glass bottles using silicone tubing. The flasks were rinsed once and filled from the bottom with care not to entrain any bubbles, overflowing by at least one-half volume. The sample tube was pinched off and withdrawn, creating a 6 ml headspace, followed by 0.12 ml of saturated $HgCl_2$ solution which was added as a preservative. The sample bottles were then sealed with glass stoppers lightly covered with Apiezon-L grease and were stored at room temperature for a maximum of 12 hours.

Equipment:

The analysis was done by coulometry with two analytical systems (AOML 3 and AOML 4) used simultaneously on the cruise. Each system consisted of a coulometer (CM5015 UIC Inc) coupled with a Dissolved Inorganic Carbon Extractor (DICE). The DICE system was developed by Esa Peltola and Denis Pierrot of NOAA/AOML and Dana Greeley of NOAA/PMEL to modernize a carbon extractor called SOMMA (Johnson et al. 1985, 1987, 1993, and 1999; Johnson 1992).

The two DICE systems (AOML 3 and AOML 4) were set up in a seagoing container modified for use as a shipboard laboratory on the aft main working deck of the *R/V Ronald H. Brown.*

DIC Analysis:

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

DIC Calculation:

Calculation of the amount of CO_2 injected was according to the CO_2 handbook (DOE 1994). The concentration of CO_2 *($[CO_2]$)* in the samples was determined according to:

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

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

The instrument has a salinity sensor, but all DIC values were recalculated to a molar weight (µmol/kg) using density obtained from the CTD's salinity. The DIC values were corrected for dilution due to the addition of 0.120 ml of saturated HgCl2 used for sample preservation. The total water volume of the sample bottles was 294 ml (calibrated by Esa Peltola, AOML). The correction factor used for dilution was 1.00037. A correction was also applied for the offset from the CRM. This additive correction was applied for each cell using the CRM value obtained at the beginning of the cell. The average correction was 0.93 µmol/kg for AOML 3 and 1.8 µmol/kg for AOML 4.

The coulometer cell solution was replaced after 25 – 28 mg of carbon was titrated, typically after 9 – 12 hours of continuous use. Normally the blank is less than 30, but we were forced to run them with blanks in the 12 – 51 range.

Calibration, Accuracy, and Precision:

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

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

Each coulometer was calibrated by injecting aliquots of pure CO_2 (99.999%) by means of an 8-port valve (*Wilke et al., 1993*) outfitted with two calibrated sample loops of different sizes (~1ml and ~2ml). The instruments were each separately calibrated at the beginning of each cell with a minimum of two sets of these gas loop injections.

The accuracy of the DICE measurement is determined with the use of standards (Certified Reference Materials (CRMs), consisting of filtered and UV irradiated seawater) supplied by Dr. A. Dickson of Scripps Institution of Oceanography (SIO). The CRM accuracy is determined manometrically on land in San Diego and the DIC data reported to the data base have been corrected to this batch 169 CRM value. The CRM certified value for this batch is 2063.31 µmol/kg[1].

The precision of the two DICE systems can be demonstrated via the replicate samples. Approximately 7% of the niskins sampled were duplicates taken as a check of our precision. These replicate samples were interspersed throughout the station analysis for quality assurance and integrity of the coulometer cell solutions. The average absolute difference of these replicates is 1.68 (AOML 3) and 1.64 (AOML) µmol/kg - No major systematic differences between the replicates were observed[2].

The pipette volume was determined by taking aliquots of distilled water from volumes at known temperatures. The weights with the appropriate densities were used to determine the volume of the pipettes.

Calibration data during this cruise:

UNIT	Ave Gas Cal Factor	Pipette	Ave CRM	Std Dev	Ave Difference Dupes
AOML 3	1.00172	27.928 ml	2062.38, N= 63	1.91	1.68
AOML 4	1.00204	29.366 ml	2061.51, N = 61	2.44	1.64

Underway DIC Samples

Underway samples were collected from the flow thru system in the forward Main Lab during transit. Discrete DIC samples were collected approximately every 4 hours with duplicates every fifth sample. A total of 24 discrete DIC samples including duplicates were collected while underway. The average difference for replicates of underway DIC samples was 0.56 µmol/kg and the average STDEV was 0.33.

Summary

The overall performance of the analytical equipment was good during the cruise. No problems occurred with either of the systems during leg 1 and leg 2.

Including the duplicates, over 3047 samples were analyzed from 124 CTD casts for dissolved inorganic carbon (DIC) which means that there is a DIC value for approximately 96% of the niskins tripped. The DIC data reported to the database directly from the ship are to be considered preliminary until a more thorough quality assurance can be completed shore side.

References

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9.6. Discrete pH Analyses

PI's: Rik Wanninkhof (NOAA/AOML) and Frank Millero (UM/RSMAS)
Analysts: Carmen Rodriguez (UM/RSMAS), Annelise Hill (UM/RSMAS), Holly Westbrook (UM/RSMAS)

Sampling
Samples were collected in 125ml glass serum bottles, sealed with rubber stoppers and crimped aluminum caps. They were rinsed a minimum of 2 times and allowed to overflow 1.5 times the volume. Immediately after collection, 2.5ml of sample were withdrawn from the bottles and they were subsequently preserved with 25ul of concentrated mercury (II) chloride to prevent biological alterations of pH. Samples were thermostated to 25°C before analysis. Three duplicates were collected from each station. One sample per station was collected and analyzed with excess indicator in order to correct for pH perturbations due to the indicator addition. This correction has not been applied to the preliminary data. All data should be considered preliminary.

Analysis
pH (μmol/kg seawater) on the seawater scale was measured using an Agilent 8453 spectrophotometer according to the methods outlined by Clayton and Byrne (1993). An RTE10 water bath maintained spectrophotometric cell temperature at 25°C. A 10 cm micro-flow through cell (Sterna, Inc) was filled automatically using a Kloehn 6v syringe pump. The purified sulfonephthalein indicator m-cresol purple (mCP) was also injected automatically by the Kloehn 6v syringe pump into the spectrophotometric cells, and the absorbance of light was measured at four different wavelengths (434 nm, 578 nm, 730 nm, and 488 nm). The ratios of absorbances at the different wavelengths were used to calculate pH on the total and seawater scales using the equations of Liu et al (2011). The equations of Dickson and Millero (1987), Dickson and Riley (1979), and Dickson (1990) were used to convert pH from the total to seawater scale. The isobestic point (488nm) will be used for the indicator correction. Salinity data were obtained from the conductivity sensor on the CTD. These data were later corroborated by shipboard measurements. Temperature of the samples was measured immediately after spectrophotometric measurements using a Fluke Hart 1523 digital platinum resistance thermometer. Due to ship berthing limitations, only one technician was available to analyze pH samples. All samples were analyzed, however, within 12 hours of collection.

Reagents
The mCP indicator dye was a concentrated solution of ~2.0 mM. Purified indicator provided by Dr. Robert Byrne, University of South Florida.

Standardization
The precision of the data can be accessed from measurements of duplicate samples, certified reference material (CRM) Batch 169 (Dr. Andrew Dickson, UCSD) and TRIS buffers (Ramette et al. 1977). The measurement of CRM and TRIS was alternated at each station.

Data Processing
Addition of the indicator affects the pH of the sample, and the degree to which pH is affected is a function of the pH difference between the seawater and indicator. Therefore, a correction is applied for each batch of dye. One sample from each station was measured twice, once normally and a second time with double the amount of indicator. The change in the ratio is then plotted verses the change in the isobestic point to develop an empirical relationship for the

effect of the indicator on the pH. This correction has not yet been applied to the preliminary data. A summary of the preliminary quality control of the data is given in Table 1. Underway samples were collected approximately every 4 hours prior to the start of the first station, but are not included in Table 1.

Table 9.1. Preliminary Quality Control

Number of Samples	2846
Good (flag=2)	2470
Dup (flag=6)	357
questionable (flag = 3)	13
bad (flag=4)	5
lost (flag = 5)	1

Problems
No major problems occurred during the cruise.

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9.7. Total Alkalinity

PI's: Rik Wanninkhof (NOAA/AOML) and Frank Millero (UM/RSMAS)
Analysts: Carmen Rodriguez (UM/RSMAS), Annelise Hill (UM/RSMAS), Holly Westbrook (UM/RSMAS)

Sampling
At each station total alkalinity (TA) samples were drawn from Niskin bottles into 500 ml borosilicate bottles using silicone tubing that fit over the petcock. Bottles were rinsed with a small volume, then filled from the bottom and allowed to overflow 1.5 times the bottle volume. The sampler was careful not to entrain any bubbles during the filling procedure. Approximately 15 ml of water is withdrawn from the bottle by halting the sample flow and removing the sampling tube, thus creating a reproducible headspace for thermal expansion during thermal equilibration. The sample bottles were sealed at a ground glass joint with a glass stopper. The samples were then thermostated at 25°C before analysis. Three duplicates were collected at each station.

Analyzer Description
The sample TA was evaluated from the proton balance at the alkalinity equivalence point, pH ≈ 4.5 at 25°C and zero ionic strength using a closed cell HCl titration. This method utilizes a multi-point hydrochloric acid titration of seawater (Dickson 1981). The instrument program uses a Levenberg-Marquardt nonlinear least-squares algorithm to

calculate the TA and DIC from the potentiometric titration data. The program is patterned after those developed by Dickson (1981), Johansson and Wedborg (1982), and U.S. Department of Energy (DOE) (1994). The least-squares algorithm of the potentiometric titrations not only give values of TA but also those of DIC, initial pH as calculated from the initial EMF, the standard potential of the electrode system (E0), and the first dissociation constant of CO_2 at the given temperature and ionic strength (pK_1). Two titration systems, A and B were used for TA analysis. Each of them consists of a Metrohm 765 Dosimat titrator, an Orion 720A, or 720A+, pH meter and a custom designed plexiglass water-jacketed titration cell (Millero et al, 1993). The titration cell allows for the titration to be conducted in a closed system by incorporating a 5mL ground glass syringe to allow for increased volume with acid addition. The seawater samples were temperature equilibrated to a constant temperature of 25 ± 0.1°C with a water bath (Thermo, HAAKE A10). The electrodes used to measure the EMF of the sample during a titration were a ROSS glass pH electrode (Orion, model 810100) and a double junction Ag, AgCl reference electrode (Orion, model 900200). The water-jacketed cell is similar to the cells used by Bradshaw and Brewer (1988) except a larger volume (~200 ml) is employed to increase the precision. Each cell has a solenoid fill and drain valve which increases the reproducibility of the volume of sample contained in the cell. A typical titration records the stable solution EMF (deviation less than 0.09 mV) and adds enough acid to change the voltage a pre-assigned increment (~13 mV). A full titration (~25 points) takes about 20 minutes. A 6 port valve (VICI, Valco EMTCA-CE) allows 6 samples to be loaded into the instrument and successively measured.

Reagents

A single 50-L batch of ~0.25 m HCl acid was prepared in 0.45 m NaCl by dilution of concentrated HCl (AR Select, Mallinckrodt), to yield a total ionic strength similar to seawater of salinity 35.0 (I = 0.7 M). The acid is standardized with alkalinity titrations on seawater of known alkalinity (certified reference material, CRM, provided by Dr. Andrew Dickson, Marine Physical Laboratory, La Jolla, California). The calibrated normality of the acid used was 0.24494 ± 0.0001 N *HCl*. The acid is stored in 500-ml glass bottles sealed with Apiezon® M grease for use at sea.

Standardization

The reproducibility and precision of measurements are checked using low nutrient surface seawater collected from the ship's underway seawater system, used as a substandard, and Certified Reference Material (Dr. Andrew Dickson, Marine Physical Laboratory, La Jolla, California). The CRM was utilized to account for instrument drift over the duration of the cruise and to maintain measurement precision. At each station, the drift and precision of each system was monitored by alternate measurements of either a CRM or a low nutrient surface water sample. Duplicate analyses (2 samples taken from the same Niskin bottle) provided additional quality assurance. Three duplicates samples were collected at each station; one set is analyzed on system A, one on system B, and one split between systems A and B. This provided a measure of the precision on both the same system and between systems. Laboratory calibrations of the Dosimat burette system with water indicate the systems deliver 3.000 ml of acid (the approximate value for a titration of 200 ml of seawater) to a precision of ± 0.0004 ml, resulting in an error of ±0.3 μmol/kg in TA. All samples were analyzed less than 12 hours after collection.

Data Processing

Measurements were made on CRM batch 169. The difference between the measured and certified values will be used to correct the TA values produced on each system, however, no correction has been made on preliminary data at this time. Eighteen different batches of low nutrient surface water were used. They all had standard deviations of <3 μmol/kg, and were generally less than 2 μmol/kg. The preliminary quality control results are shown in table 1. Underway samples were collected every 4 hours prior to the first station, but the data and are not included in table 1.

Table 9.2. Preliminary quality control

Total Samples	2815
Good (flag=2)	2414
Duplicate (flag=6)	363
questionable (flag=3)	20
Bad (flag=4)	9
lost (flag=5)	9

Problems

No major problems occurred during the cruise.

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9.8. Nutrients

PI's: Jia-Zhong Zhang (NOAA/AOML) and Calvin Mordy (NOAA-PMEL)
Technicians: Eric Wisegarver (NOAA/PMEL) and Ian Smith (UM/CIMAS)

Equipment and Techniques

Dissolved nutrients (phosphate, silicate, nitrate and nitrite) were measured by using a Seal Analytical AA3 HR automated continuous flow analytical system with segmented flow and colormetric detection. Detailed methodologies are described by Gordon et al. (1992).

Silicic acid was analyzed using a modification of Armstrong et al. (1967). An acidic solution of ammonium molybdate was added to a seawater sample to produce silicomolybic acid. Oxalic acid was then added to inhibit a secondary reaction with phosphate. Finally, a reaction with ascorbic acid formed the blue compound silicomolybdous acid. The color formation was detected at 660 nm. The use of oxalic acid and ascorbic acid (instead of tartaric acid and stannous chloride by Gordon et al.) were employed to reduce the toxicity of our waste steam.

Nitrate and Nitrite analysis were also a modification of Armstrong et al. (1967). Nitrate was reduced to nitrite via a copperized cadmium column to form a red azo dye by complexing nitrite with sulfanilamide and N-1-naphthylethylenediamine (NED). Color formation was detected at 540 nm. The same technique was used to measure nitrite, (excluding the reduction step).

Phosphate analysis was based on a technique by Bernhart and Wilhelms (1967). An acidic solution of ammonium molybdate was added to the sample to produce phosphomolybdate acid. This was reduced to the blue compound phosphomolybdous acid following the addition of hydrazine sulfate. The color formation was detected at 820 nm.

Sampling and Standards

Nutrient samples were drawn in 50ml HDPE Nalgene sample bottles that had been stored in 10% HCl. The bottles are rinsed 3-4 times with sample prior to filling. A replicate was normally drawn from the deep Niskin bottle at each station for analysis to reduce carry over. Samples were then brought to room temperature prior to analysis. Fresh mixed working standards were prepared before each analysis. In addition to the samples, each analysis consisted of 3 replicate standards, 3 DIW blanks and 3 Matrix blanks placed at the beginning and then repeated at the end of each run. Also, one mixed working standard from the previous analytical run was used at the beginning of the new run to determine differences between the two standards. Samples are analyzed from deep water to the surface. Low Nutrient Seawater (LNSW) was used as a wash, base line carrier and medium for the working standards.

The working standard was made by the addition of 0.1ml of primary nitrite standard and 10.0 ml of a secondary mixed standard (containing silicic acid, nitrate, and phosphate) into a 250ml calibrated volumetric flask of LNSW. Working standards were prepared for each station.

Dry standards of a high purity were pre-weighed at PMEL. Nitrite standards were dissolved at sea. The secondary mixed standard was prepared by the addition of 30ml of a nitrate - phosphate primary standard to the silicic acid

standard. Lab temperatures were recorded for each analytical run. Nutrient concentrations were reported in micromoles per kilogram. All the pump tubing was replaced at least two times during the I07N cruise.

Approximately 2900 samples were analyzed.

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9.9. Chlorofluorocarbons (CFCs) and Sulfur Hexafluoride (SF6)

PI: John Bullister (NOAA/PMEL)
Lead Analyst: Bonnie Chang, NOAA/PMEL and UW (Leg 1 and Leg 2)
CFC analysts: Charles Kleinwort and Kathryn Williams (Leg 1 and Leg 2)

The PMEL analytical system (Bullister and Wisegarver, 2008) was used for CFC-11, CFC-12, sulfur hexafluoride (SF_6) and nitrous oxide (N_2O) analyses on the GOSHIP I07N expedition. Greater than 2300 samples of dissolved CFC-11, CFC-12 and SF_6 ('CFC/SF_6') were analyzed.

In general, the analytical system performed well for CFCs, SF_6 and N_2O during the cruise. Typical dissolved SF_6 concentrations in modern surface water are ~1-2 fmol kg^{-1} seawater (1 fmol= femtomole = 10^{-15} moles), approximately 1000 times lower than dissolved CFC-11 and CFC-12 concentrations. The limits of detection for SF_6 were approximately 0.04 fmol kg^{-1} on this cruise.

Water samples were collected in bottles designed with a modified end-cap to minimize the contact of the water sample with the end-cap O-rings after closing. Stainless steel springs covered with a nylon powder coat were substituted for the internal elastic tubing provided with standard Niskin bottles. When taken, water samples collected for dissolved CFC-11, CFC-12 and SF_6 analysis were the first samples drawn from the bottles. Care was taken to coordinate the sampling of CFC/SF_6 with other samples to minimize the time between the initial opening of each bottle and the completion of sample drawing. Samples easily impacted by gas exchange (dissolved oxygen, ^3He, DIC and pH) were collected within several minutes of the initial opening of each bottle. To minimize contact with air, the CFC/SF_6 samples were drawn directly through the stopcocks of the bottles into 250 ml precision glass syringes equipped with three-way plastic stopcocks. The syringes were immersed in a holding tank of clean surface seawater held at ~10°C until 20 minutes before being analyzed. At that time, the syringe was place in a bath of surface seawater heated to 32°C.

For atmospheric sampling, a 75 m length of 3/8" OD Dekaron tubing was run from the CFC van, located on the fantail, to the bow of the ship. A flow of air was drawn through this line into the main laboratory using an Air Cadet pump. The air was compressed in the pump, with the downstream pressure held at ~1.5 atm, using a backpressure regulator. A tee allowed a flow of ~100 ml min^{-1} of the compressed air to be directed to the gas sample valves of the CFC/SF_6 analytical systems, while the bulk flow of the air (>7 L min^{-1}) was vented through the back-pressure regulator. Air samples were analyzed only when the relative wind direction was within 60 degrees of the bow of the ship to reduce the possibility of shipboard contamination. Analysis of bow air was performed at ~12 locations along the cruise track. At each location, at least four air measurements were made to improve the precision of the measurements.

Concentrations of CFC-11, CFC-12 and SF_6 in air samples, seawater, and gas standards were measured by shipboard electron capture gas chromatography (EC-GC) using techniques modified from those described by Bullister and Weiss (1988) and Bullister and Wisegarver (2008), as outlined below. For seawater analyses, water was transferred from a glass syringe to a glass-sparging chamber (volume 200 ml). The dissolved gases in the seawater sample were extracted by passing a supply of CFC/SF_6-free N_2 through the sparging chamber for a period of 6 minutes at 150 ml

min^{-1}. Water vapor was removed from the purge gas during passage through a Nafion drier. Carbon dioxide was removed with an 18 cm long, 3/8" diameter glass tube packed with Ascarite and a small amount of magnesium perchlorate desiccant. The sample gases were concentrated on a cold-trap consisting of a 1/16" OD stainless steel tube with a 2.5 cm section packed tightly with Porapak Q, a 15 cm section packed with Carboxen 1000 and a 2.5 cm section packed with MS5A. A Neslab Cryocool CC-100 was used to cool the trap to -65°C. After 6 minutes of purging, the trap was isolated, and it was heated electrically to 170°C. The sample gases held in the trap were then injected onto a precolumn (~61 cm of 1/8" O.D. stainless steel tubing packed with 80-100 mesh Porasil B, held at 80°C) for the initial separation of CFC-12, CFC-11, SF_6 from later eluting peaks.

After the SF_6 and CFC-12 had passed from the pre-column and into the second pre-column (26 cm of 1/8" O.D. stainless steel tubing packed with MS5A, 160°C) and into the analytical column #1(174 cm of 1/8" OD stainless steel tubing packed with MS5A + 60 cm Porasil C held at 80°C), the outflow from the first pre-column was diverted to the second analytical column (180 cm 1/8" OD stainless steel tubing packed with Porasil B, 80-100 mesh, held at 80°C). The gases remaining after CFC- 11 had passed through the first pre-column, were backflushed from the precolumn and vented. After CFC-12 had passed through the second pre-column, a flow of Argon:Methane (95:5) was used to divert the N_2O to a third analytical column (30 cm of MS5A, 150°C). Column #3 and the second pre-column were held in a Shimadzu GC8AIE gas chromatograph with an electron capture detector (ECD) held at 330°C. Columns #1, and the first pre-column were in another Shimadzu GC8AIE gas chromatograph with ECD. The column #2 was also in a Shimadzu GC8AIE gas chromatograph with the ECD held at 330°C.

The analytical system was calibrated frequently using a standard gas of known CFC/SF_6 composition (PMEL-WRS-72611). Gas sample loops of known volume were thoroughly flushed with standard gas and injected into the system. The temperature and pressure was recorded so that the amount of gas injected could be calculated. The procedures used to transfer the standard gas to the trap, pre-columns, main chromatographic column, and ECD were similar to those used for analyzing water samples. Four sizes of gas sample loops were used. Multiple injections of these loop volumes could be made to allow the system to be calibrated over a relatively wide range of concentrations. Air samples and system blanks (injections of loops of CFC/SF_6 free gas) were injected and analyzed in a similar manner. The typical analysis time for seawater, air, standard or blank samples was ~12 minutes. Concentrations of the CFC-11 and CFC-12 in air, seawater samples, and gas standards are reported relative to the SIO98 calibration scale (Bullister and Tanhua, 2010). Concentrations of SF_6 in air, seawater samples, and gas standards are reported relative to the SIO-2005 calibration scale (Bullister and Tanhua, 2010). Concentrations in air and standard gas are reported in units of mole fraction CFC in dry gas and are typically in the parts per trillion (ppt) range. Dissolved CFC concentrations are given in units of picomoles per kilogram seawater (pmol kg^{-1}) and SF_6 concentrations in fmol kg^{-1}. CFC/SF_6 concentrations in air and seawater samples were determined by fitting their chromatographic peak areas to multi-point calibration curves, generated by injecting multiple sample loops of gas from a working standard (PMEL cylinder WRS72611) into the analytical instrument. The response of the detector to the range of moles of CFC/SF_6 passing through the detector remained relatively constant during the cruise. Full-range calibration curves were run at several times during the cruise and partial curves were run as frequently as possible, usually while sampling. Single injections of a fixed volume of standard gas at one atmosphere were run much more frequently (at intervals of 90 minutes) to monitor short-term changes in detector sensitivity.

The purging efficiency was estimated by re-purging a high-concentration water sample and measuring the residual signal. At a flow rate of 150 ml min^{-1} for 6 minutes, the purging efficiency for SF_6 and both CFC gases was > 99%. The efficiency for N_2O was typically about 96%.

On this expedition, based on the analysis of more than 180 pairs of duplicate samples, we estimate precisions (1 standard deviation) of about 0.5% or 0.003 pmol kg^{-1} (whichever is greater) for dissolved CFC-12 and 1% or 0.005 pmol kg^{-1} for CFC-11 measurements. The estimated precision for SF_6 was 3% or 0.04 fmol kg^{-1}, (whichever is greater). The estimated precision for N_2O was 3% or 0.2 nmol kg^{-1}, (whichever is greater). Overall accuracy of the measurements (a function of the absolute accuracy of the calibration gases, volumetric calibrations of the sample gas loops and purge chamber, errors in fits to the calibration curves and other factors) is estimated to be about 2% or 0.004 pmol kg' for CFC-11 and CFC-12 and 4% or 0.04 fmol kg^{-1} for SF_6.

A small number of water samples had anomalously high CFC-12 and/or SF_6 concentrations relative to adjacent samples. These samples occurred sporadically during the cruise and were not clearly associated with other features in the water column (e.g., anomalous dissolved oxygen, salinity, or temperature features). This suggests that these samples were probably contaminated with CFCs/SF_6 during the sampling or analysis processes.

Measured concentrations for these anomalous samples are included in the data file, but are given a quality flag value of either 3 (questionable measurement) or 4 (bad measurement). Less than 1% of samples were flagged as bad or

questionable during this voyage. A quality flag of 5 was assigned to samples which were drawn from the rosette but never analyzed due to a variety of reasons (e.g., leaking stopcock, plunger jammed in syringe barrel, etc).

Radio frequency interference (RFI) occasionally occurred and was manifested as negative excursions in the signal acquired from the CFC-11 channel. RFI was avoided by keeping hand-held radio transmissions on their low power setting (<0.5W) at a distance >15ft from the CFC lab van.

Some N_2O samples had elevated re-strip and stripper blank values which is due to biological growth on the glass frit or walls of the stripper. These were not used in the determination of the stripper efficiency corrections. During the purging process with nitrogen gas, the seawater samples and interior of the stripping chamber become anoxic, which may lead to in-situ production of N_2O in the stripping chamber. The stripping chamber remains anoxic during subsequent 12-minute stripper blank and re-strip analyses, and any in-situ N_2O production during this period would increase the N_2O values of the re-strip or stripper blank measurements. Washing the stripper frit and walls with 10% HCl immediately reduced the stripper blank and re-strip values. However, these values often significantly increased within a day or so after the acid rinses. During the cruise the stripper frit was washed with 10% HCl at 24-48hr intervals to maintain a stripper efficiency of approximately 96%.

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9.10. DOC and TDN Sampling

Objectives: Determine the distributions of dissolved organic carbon (DOC) and total dissolved nitrogen (TDN) along a meridional section of the western Atlantic Ocean. The ultimate goal is to understand the role of DOC in the ocean carbon cycle, while TDN provides an estimate of the concentrations of dissolved organic nitrogen (DON) in the ocean (DON = TDN – DIN, where DIN is the concentration of inorganic N). DON, in turn, serves as a nutrient source to photoautotrophs in meso- and oligotrophic surface ocean waters.

Sampling was done at alternating stations along the cruise track, such that sampling was done at about 1o latitude intervals. Full water column sampling was done, which returns 24 samples per station. Since the goal is to measure dissolved organic matter, samples from the upper 250 m of the w ater column are gravity filtered through in-line polycarbonate filter holders; the filters employed were 45 mm Whatman GF/F, precombusted at 400^{o}C before use. Water taken from >250 m are sampled unfiltered since the particulate organic matter concentrations are typically inconsequential at those depths.

Analyses are by high temperature combustion of 100 microliters of sample water injected into 680oC tube furnace. An oxygen carrier gas allows combustion to CO2 and NO, gaseous products that are assessed with IR and chemiluminescent detectors, respectively. DOC analysis is performed using a Shimadzu Model TOC-L. The system configuration and operating parameters are as follows: Ultra high purity O2 is used as a carrier gas, flowing through the system at 150 ml min^{-1}. 100 µl of sample is injected with automation through a Teflon/sliding injection port into a quartz combustion tube packed with Pt gauze and 5% Pt on alumina catalyst heated to 680°C. Samples are acidified with 37% HCl (15 µl per 10 ml of sample; 0.15%) and, immediately prior to injection, sparged with ultra-high purity, CO_2 free oxygen for 1.5 minutes to remove inorganic carbon. Samples are combusted in the furnace and the resulting gas passed through water traps and a final copper halide trap before entering the detector.
To minimize the system blank, conditioning of the combustion tube is required prior to analysis of samples. Conditioning is performed through repeated injections of Milli-Q water and/or seawater. After conditioning, the system blank is assessed with ampoulated low carbon reference water (LCW). Typical relative standard deviations

of replicate DOC analyses are 2%. The instrument response factor is determined with potassium hydrogen phthalate in Milli-Q (LCW) water (0, 40, 80, 160 mM C) and potassium nitrate in LCW (0, 5, 10, 20, 40 mM N). The instrument blank is measured every 4-6 samples using LCW water.

9.11. Genetics and Particulate Organic Matter

PI: Adam Martiny (UCI)
Samplers: Catherine Garcia and Jenna Lee (UCI)

Genetics

Genetics samples were collected approximately every half degree of latitude from the surface Niskin bottle ~5m deep. In total, 54 samples were collected from the surface niskin bottle. Water was also collected from the uncontaminated underway seawater system every four hours (04:00, 08:00, 12:00, 16:00, 20:00, and 24:00 local time) for each sampling day. Up to 4L of seawater was collected into a plastic cubitainer and filtered immediately after collection. Water was filtered through a Sterivex 0.22µm filter using a peristaltic pump at a low speed. Once all water is pumped through the Sterivex cartridge, one end is sealed with Crito-seal putty. 1620µL of sterile lysis buffer is pipetted into the filter cartridge and the other end is sealed with a luer-lok cap. The filter is placed in a Ziplok bag and preserved frozen at -20°C until shipment to the Adam Martiny lab at UC Irvine for further analysis. Final filtration volume was recorded for all samples. Gloves were worn during all steps.

Prior to the cruise, all silicone tubing, Omnifit caps and cubitainers were cleaned in soapy water, 10% HCL, and Milli-Q water. Weekly, the tubing and Omnifit caps were soaked in a 10% bleach solution overnight and rinsed with Milli-Q water. Between sample collections, the tubing and sample container were rinsed 2x with 0.7µm filtered seawater.

Problems: If the Sterivex filter was abnormally dark, the sample was noted as potential biofilm contamination from the sea water system. This was noticed to be a problem only when the underway valve was turned on at a high blast. Comparison samples of underway and station Niskin water were collected for potential contamination problems.

Particulate Organic Matter

Particulate organic matter (POM) samples were collected for particulate organic carbon (POC), nitrogen (PON), phosphorous (POP) and biological oxygen demand (BOD). The underway seawater system was chosen to increase water volumes and replication. In total, 749 underway stations were sampled. Each sample was pre-filtered through a 30µm nylon mesh and passed through a GF/F filter (nominal pore size 0.7µm). An aspirator pump was used to pull water through the filters at a vacuum setting of -0.06 to -0.08 MPa. South of 54°S an additional set of samples was collected without a pre-filter. Twelve carboys were filled with 6-8L of water (volume biomass-dependent) and designated as follows: 3x POP, 3x POC/PON, 3x BOD method 1, 3x BOD method 2. Single replicates were taken for POC/PON and POP every hour, with triplicate samples every day at noon. BOD samples were collected in triplicate on a two day on, one day off rotation. An additional BOD triplicate set was taken on silver filters to reduce particulate oxygen contamination every three days. Two triplicate sets of BOD were collected for method development and comparison. POP filters were rinsed with 5mL of 0.017M Na_2SO_4 to remove traces of dissolved organic phosphorous at the end of filtration. BOD filters were rinsed with MilliQ water to remove salt ions. Filters were folded and stored frozen at -20°C in pre-combusted foil squares.

All carboys were rinsed 1x with sample water before collection. GF/F filters and foil squares were pre-combusted at 500°C for 4.5 hours. Prior to the cruise, all silicone tubing, filter holders, and carboys were cleaned in soapy water, 10% HCL, and Milli-Q water. The 30µm nylon mesh was rinsed with filtered seawater between sample collections. All filters will be shipped frozen and analyzed by the Martiny lab at UC Irvine. Gloves were used for all steps mentioned above.

Problems: As stated above, contamination by a biofilm in the underway system was noted if the filters were abnormally dark. This was only an occurrence if the valve was opened too far. The silver BOD samples filtered far slower than the GF/F filters. To keep filtration times under two hours, the collection volume was halved (3-4L).

9.12. Dissolved Inorganic Carbon Isotopes in Seawater (DI^{14}C)

PIs: Robert Key (PU) and Ann McNichol (WHOI)
Sampler: Shinichiro Umeda (JAMSTEC)

Project Goals

In the upper water column, the goal is to adequately measure the distribution in order to estimate the penetration of bomb-produced ^{14}C and quantify the ^{13}C decrease due to the influx of anthropogenic CO_2. While the vast majority of bomb-^{14}C will be confined to the upper 1000m of the water column, we are also looking to document the presence of bomb-produced ^{14}C in bottom waters.

Sampling

Approximately 400 samples were collected from 19 stations along the I07N transect (Figure 24). Each of the major basins encountered was sampled with two or more profiles. Full water column profiles were mixed with profiles that focused on the upper water column down to approximately 1500m. A random duplicate was taken at some stations to provide a check of accuracy.

Samples were collected in 500 mL glass bottles. The first 50mL was used to rinse the tygon tubing. Then the flasks were rinsed 2 times with seawater from the specified Niskin. While keeping the tubing at the bottom of the flask, the flask was filled and flushed by allowing it to overflow 1.5 times its volume. Once the sample was taken, about 10 mL of water was removed to create a headspace and 120 µL of 50% saturated mercuric chloride solution was added to the sample. To minimize contamination, plastic bags were used to cover any surface where sampling or processing occurred.

After each sample was taken, the glass stoppers and ground glass joint were dried and Apiezon-M grease was applied to ensure an airtight seal. Stoppers were secured with a large rubber band wrapped around the entire bottle. Samples were secured in AMS crates inside an onboard walk-in cooler set at 10°C. Samples were shipped to WHOI for analysis.

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

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

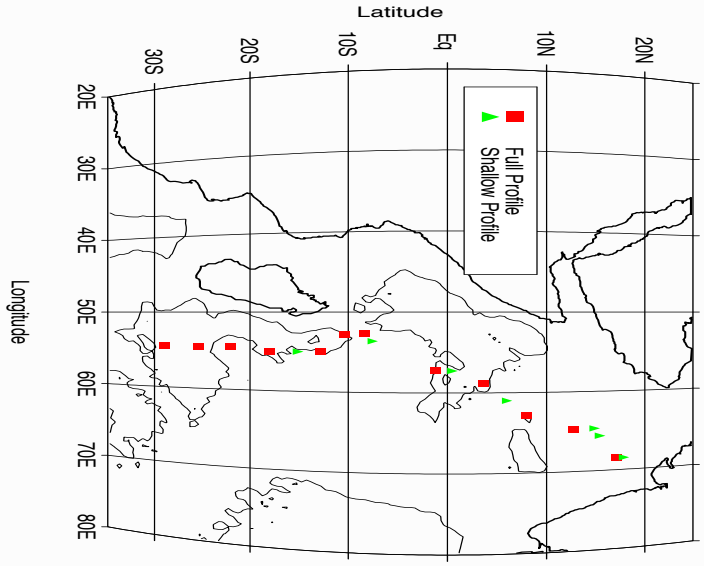


Figure 24. Station plot showing ^{14}C sampling along the I07N cruise. Red squares represent full profile casts, and green triangles represent stations where only the upper water column (1500-2000m) was sampled.

9.13. Dissolved organic matter ^{14}C, black carbon ^{14}C

PI: Ellen R.M. Druffel, Earth System Science, University of California, Irvine
Sample Collection: Christian Lewis, Earth System Science, University of California, Irvine

DOC is the largest pool of organic carbon in the ocean, comparable to the total carbon content in the atmosphere. Knowing the carbon isotopic signatures of DOC is important for understanding the biogeochemistry and dynamics of DOC cycling and is essential for the C cycle modeling community. This study addresses fundamental gaps in our knowledge of the global carbon cycle and the dynamic nature of DOC in the ocean. These results will provide much needed, quantitative information on the timescale of DOC cycling in the ocean. These results will also help to determine the amount of terrestrially-derived organic carbon (*e.g.*, black carbon, BC) in the open ocean. DOC may serve as a sink for excess carbon dioxide produced from fossil fuel and biomass burning. Most of this excess carbon will end up in the ocean, and it is critical to improve our understanding of the processes that are important for its long-term storage. Results of this research will be made available for use in models that assess present and future concentrations of atmospheric CO2.

The average radiocarbon (^{14}C) age of dissolved organic carbon (DOC) in the deep ocean ranges from 4000 – 6500 ^{14}C years. However, the data set used to estimate this range is based on only a few sites in the world ocean. The main objective of this research is to determine the ^{14}C signatures of DOC in seawater from the North Indian Ocean and Arabian Sea for which there is no data. High-precision $\Delta^{14}C$ measurements will be performed on samples using AMS (accelerator mass spectrometry) of DOC in water samples. Another objective is to isolate black carbon from DOC and determine the $\Delta^{14}C$ and $\delta^{13}C$ signatures of this recalcitrant DOC fraction. We are testing the following hypotheses:

(1) ^{14}C of bulk DOC in the Indian Ocean are similar to those in Pacific and Atlantic Oceans.

(2) Black carbon constitutes a significant amount of DOC in open ocean water, and its ^{14}C age is greater than 20,000 ^{14}C years in the deep ocean.

A summary of stations and number of depths sampled for DO^{14}C and Black Carbon on IO7 are provided in the table below.

Dissolved Organic Carbon-14 Sampling and Analysis

Dissolved organic carbon-14 (as $\Delta^{14}C$) samples were sampled in pre-combusted (540°C/2 hours) 1L borosilicate bottles (amber boston rounds). We collected 7x DOC samples below 1000m and 7x samples above 1000m at each station plus one duplicate. Samples above 900m depth were filtered using pre-combusted 70mm GF/F filters, acid cleaned silicone tubing and a stainless-steel filter manifold. Samples were immediately frozen after collection and stored at -20°C for analysis at UCI. Once in the lab, samples will be acidified and sparged of dissolved inorganic carbon, and CO2 will be produced from DOC via UV oxidation and vacuum line extraction. This CO2 will then be graphitized, and its radiocarbon content measured via AMS at the Keck Carbon Cycle AMS laboratory at UCI. DOC $\delta^{13}C$ will also be measured in a split of the CO2 from each sample using light isotope mass spectrometry.

Black Carbon-14 Sampling

Due to extremely low concentrations of Black carbon in seawater (~<5% of the DOC pool), 1x 4 gallon filtered surface (0-200m) samples and 1x8 gallon deep (~2000m) samples were collected. Surface samples were filtered using pre-combusted 150mm GF/F filters, acid-cleaned silicone tubing and a PVC filter manifold. The concentration and carbon isotopes (^{14}C and ^{13}C) of black carbon in these samples will be measured using the benzene polycarboxylic acid (BPCA) method. These data will be used to estimate the abundance and source of black carbon in oceanic DOC. Individual BPCAs will be isolated using a preparative capillary gas chromatograph (PCGC). These fractions will be combusted to CO2 gas, graphitized and radiocarbon content measured by AMS.

9.14. DOM Biomarkers and Molecular Composition

PI: Dr. Brett Walker, Earth System Science, University of California, Irvine
Co-PI: Dr. Karl Kaiser, Department of Marine Sciences and Oceanography, Texas A&M University Galveston Campus
Co-PI: Dr. Hussain Abdulla, Department of Physical & Environmental Sciences, Texas A&M University, Corpus Christi
Sample Collection: Christian Lewis, Earth System Science, University of California, Irvine

Dissolved organic matter (DOM) represents the largest reservoir of organic carbon in the ocean, comparable to the total carbon content in the atmosphere. Marine DOM fuels microbial food webs and has also been implicated to modulate transient warming events in Earth's history. Fundamental to the role of DOM in ocean biogeochemical cycles is its ability to control, store and release energy. Hence, fluxes of biologically labile DOM constituents between carbon reservoirs are arguably more important than net fluxes of total DOM. Thus, DOM cycling is largely

determined by selective source and removal mechanisms. This study addresses fundamental gaps in our knowledge of DOM sources, molecular structures and removal of DOM in several unique ocean environments. Coupled with radiocarbon dating of dissolved inorganic and dissolved organic carbon (DIC, DOC), knowledge of DOM sources and composition provide much needed, quantitative information on the timescale and magnitude of DOM cycling in the north Indian Ocean and Arabian Sea, where currently no data exists.

The main objectives of this research are 1) to investigate the formation of recalcitrant DOM by microbial processes, and 2) to identify mechanisms that remove recalcitrant DOM from the water column. Our approach relies on a comprehensive analysis of the chemical composition of DOM including organic biomarkers (carbohydrates, DL-amino acids, lignin phenols), Proton Nuclear Magnetic Resonance (1H-NMR) and Fourier Transform Ion Cyclotron Resonance Mass Spectrometry (FT-ICR-MS). These measurements will be integrated with existing GO-SHIP measurements (DOC and DIC $^{14}C/^{13}C$, Black Carbon, O2, Nutrients, CFCs, etc.) and will provide an unprecedented analysis of DOM chemical composition in a major ocean basin. In addition, our analysis of DOM composition will evaluate the biogeochemistry of OMZs, which are predicted to expand in a warming ocean.

We will test the following hypotheses:

(1) The combination of biomarker analysis with high-resolution spectroscopic techniques (NMR, FT-ICR-MS) will reveal origins, structures and removal mechanisms of recalcitrant DOM (RDOM) molecules in the deep ocean. RDOM dynamics will be compared with the radiocarbon age of DOM (determined by Druffel Group) and thus help constrain processes responsible for DOM cycling on millennial timescales. We hypothesize that both carboxyl-rich alicyclic molecules (CRAM) and a specific dissolved organic nitrogen (DON) component will accumulate in the deep ocean, and that D-amino acids will indicate this to be the result of microbial degradation processes.

(2) Distinct DOM molecular compositions will be observed in the ODZ in the ETP/ETSP reflecting intense microbial cycling of DOM. We expect to find high bacterial contributions to DOM due to the importance of bacterial chemoautotrophy, and likely differences that can be attributed to specific chemoautotrophic metabolism (i.e. denitrification vs. anaerobic ammonium oxidation).

A summary of stations and number of depths sampled for dissolved biomarkers and molecular-level composition on IO7 are provided in the Table 9.3 below.

Dissolved Organic Matter Biomarker Sampling and Analysis:

Dissolved organic matter (DOM) biomarker samples were collected into 60 mL acid-soaked (10% HCl) and rinsed (18.2 MΩ Milli-Q water) high density polyethylene (HDPE) bottles. Sample depths shallower than 400m were filtered through a pre-combusted (540°C/2hr) GF/F filter and clean stainless-steel manifold. On biomarker stations (Table 9.3), all Niskins were sampled. All samples were frozen immediately at -20°C and will be stored frozen until they can be shipped overnight and analyzed at Texas A&M Galveston (Co-PI Kaiser). Biomarker samples will be analyzed for many individual biomolecules including a suite of: total dissolved amino acids (including D-enantiomeric forms), amino sugars and neutral sugars. These will be measured via high performance liquid chromatography and ion chromatography by PI Kaiser at Texas A&M Galveston.

Dissolved Organic Matter Molecular Composition Sampling and Analysis:

Samples were taken for characterization of DOM composition at molecular level. As per all sample types, depths shallower than 400m were filtered through pre-combusted (540°C/2hrs) GF/F filter manifolds. We collected 6x DOC samples below 1000m and 8x samples above 1000m at each station and often one duplicate. First, samples were collected into pre-combusted (540°C/2hrs) 10 mL glass ampoules in triplicate, and subsequently poisoned with 1 drop saturated mercuric chloride (HgCl2) or 1 drop 12N hydrochloric acid. These ampoules were flame sealed and will be stored at room temperature in the dark until analysis via Proton Nuclear Magnetic Resonance Spectroscopy (1H-NMR) at the University of California, Irvine (PI Walker). This analysis will allow for the "bulk" molecular characterization of DOM at the functional group level. In addition, 1000 mL samples were collected into acid-soaked (10% HCl) and rinsed (18.2 MΩ Milli-Q water) polycarbonate bottles. These samples were immediately frozen at -20°Cand stored until further sample processing at Texas A&M Corpus Christi (Co-PI Abdulla). At Texas A&M, 1L samples be split for biomarker analysis (Texas A&M, Galveston) and the remaining 600ml of DOM isolated by solid phase extraction (SPE) and analyzed via either an Orbit Trap MS (Texas A&M Corpus Christi), or via Fourier Transform Ion Cyclotron Resonance Mass Spectrometry (FT-ICR-MS). These latter two analyses will allow for the characterization of several thousand individual DOM molecules and fragments.

Table 9.3. Summary of stations sampled for PI Walker and Druffel parameters on GO-SHIP I07N. (*n*) indicates the number of Niskin bottles sampled from each station depth profile for each measurement parameter.

I07N Station #	Latitude	Longitude	Biomarker + Molecular	WDO	DO14C	DBC
2	-29.499	54.496				11
3	-28.974	54.4988		11	14	
7	-27.660	54.4955	24			
14	-25.330	54.5048	24			
19	-23.656	54.5153	24			
22	-22.495	54.5003				10
23	-21.995	54.507		11	14	
24	-21.499	54.5				
28	-19.489	54.6705	24			
35	-15.652	55.0007	24			
43	-11.499	54.1085	24			
45	-10.752	53.211				11
46	-10.383	52.7675		11	14	
71	-1.770	57.2205				11
72	-1.229	57.2372		11	14	
73	-0.865	57.2473				
76	-0.001	57.2693	24			
80	1.194	57.2995		11		
83	2.399	57.6923	24			
86	3.591	58.7945	24			
89	4.796	59.8912		11		
93	6.394	61.3570	24			
96	7.594	62.4597				11
97	7.994	62.8283		11	14	
98	8.396	63.1947				
101	9.598	64.2978	24			
104	11.075	64.6652	24			
107	12.703	64.6672		11		
111	14.866	64.6673	24			
114	16.211	65.4435	24			
118	16.785	67.9927				11
119	17.059	68.470		11	14	
123	17.865	68.48	24		6	

9.15. Dissolved Calcium

PI: Akihiko Murata (JAMSTEC)-not onboard
Sampler: Shinichiro Umeda (JAMSTEC)

Objectives

According to the recent IPCC report, concentrations of CO2 in the atmosphere have increased by 40% since pre-industrial times, primarily by fossil fuel burning and secondarily by net land use change. The ocean is said to absorb about 30% of the emitted anthropogenic CO_2, accordingly moderating progression of global warming. However, the ocean suffers from ocean acidification by the uptake of anthropogenic CO2. Ocean acidification is characterized by an increase of H^+ (i.e., a decrease of pH) and a concurrent decrease of carbonate ion concentration (CO_3^{2-}). The decrease of CO_3^{2-} is unfavorable to marine calcifying organisms, which utilize CO_3^{2-}, together with Ca^{2+}, to produce their calcium carbonate ($CaCO_3$) shells and skeletons. To evaluate dissolution and precipitation of calcium carbonate, we measure concentration of calcium in water colums in the western part of the Indian Ocean.

Sampling

The samples were collected into 60 mL of HDPE bottles from Niskin bottles attached to the CTD system. The sampling was made at 11 stations, with a few replicates at individual stations (see Figure 25). In total, 265 samples were collected during the cruise. The samples will be stored at room temperature for 3-4 months until shipped back to onshore laboratory for analysis.

Analytical method

The measurement will be made in a laboratory on land. The method is based on a photometry proposed by Culkin and Cox (1966). We use a modified Dissolved Oxygen Titrator DOT-01 (Kimoto Electronic Co. Ltd.), which bandpass filter is replaced to f0=620nm. The titrant is calibrated by 1000 mg/l Ca standard solution (produced by Wako Pure Chemical Industries, Ltd.).

Results

Results will be publicly available within 2 years of measurements.

References

Culkin, F. and Cox, R.A. (1966). Sodium, potassium, magnesium, calcium and strontium in seawater. Deep Sea Research 13: 789-804.

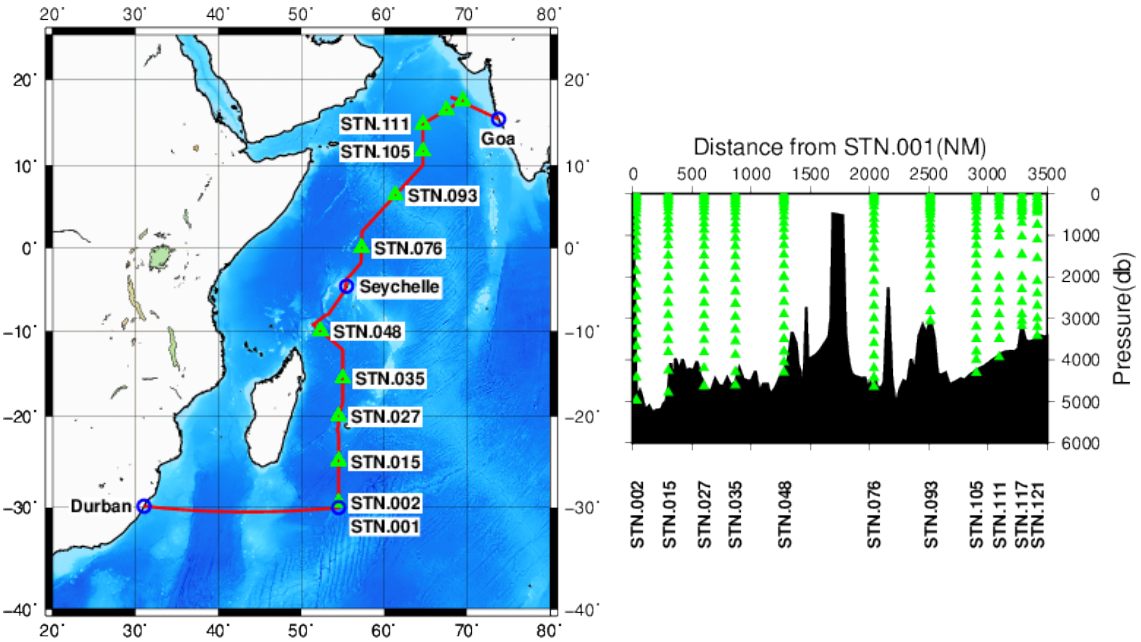


Figure 25. Map of cruise track (red) and collected stations (green) are shown on the left panel. Sampling layers are shown on the right panel.

9.16. Density (JAMSTEC)

PI: Akihiko Murata (JAMSTEC)-not onboard
Sampler: Shinichiro Umeda (JAMSTEC)

Objectives
The aim of this study is to evaluate and update the algorithm for estimating Absolute Salinity adopted in TEOS-10 (the International Thermodynamic Equation of Seawater 2010. IOC et al., 2010) by accumulating accurate seawater density data, especially for the Arabian Sea in which density of seawater have not yet measured directly.

Materials and methods
The water samples for seawater densities were collected in 100-mL aluminum bottles (Mini Bottle Can, Daiwa Can Company, Japan) at a number of stations shown in Figure 26. The bottles are stored at room temperature (~23 ºC) upside down for 3-4 months until shipped back to onshore laboratory. Total 240 bottles from 10 stations were collected (shown in figure). Seawater densities will be measured at 20 ºC by using an oscillation-type density meter (DMA 5000M, Anton-Paar GmbH, Graz, Austria) with a sample changer (Xsample 122, Anton-Paar GmbH) to load samples automatically from up to ninetysix 12-mL glass vials, in accordance with a method described in Uchida et al. (2011). Density salinity can be back calculated from measured density and temperature (20 ºC) with TEOS-10, and will be submitted as a dataset.

Results
Results will be publicly available within 2 years of measurements.

References

IOC, SCOR and IAPSO (2010): The international thermodynamic equation of seawater – 2010: Calculation and use of thermodynamic properties. Intergovernmental Oceanographic Commission, Manuals and Guides No. 56, United Nations Educational, Scientific and Cultural Organization (English), 196 pp.

Uchida, H., T. Kawano, M. Aoyama and A. Murata (2011): Absolute salinity measurements of standard seawaters for conductivity and nutrients. La mer, 49, 237-244.

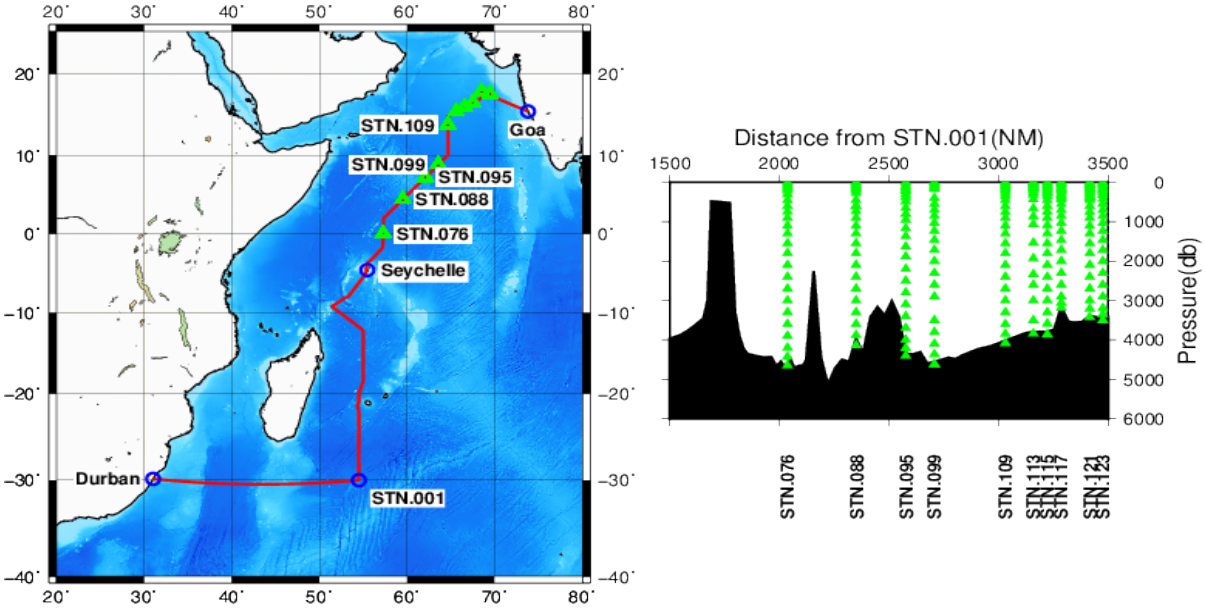


Figure 26. Map of cruise track (red) and collected stations (green) are shown on the left panel. Sampling layers are shown on the right panel.

9.17. Density (UM/RSMAS)

PI Frank Millero (UM/RSMAS)
Analyst: Carmen Rodriguez (UM/RSMAS)

Density samples were collected at eleven stations during the cruise. The full cast was sampled on 10 stations (Stations 29, 76, 88, 95, 99, 109, 113, 115, 117 & 121). A partial cast was sampled on Station 123 (from four niskin bottles).

The samples were drawn into 125 mL HDPE bottles rinsing three times before filling. These samples will be analyzed for density using an Anton-Parr vibrating densitometer and re-analyzed for salinity (to account for any evaporation) back in Miami.

9.18.Transmissometer Measurements

PIs: Wilford Gardner[1], Mary Jo Richardson[1], Alexey Mishonov[2]
[1]Texas A&M University, [2]University of Maryland - CICS

Our WetLabs C-STAR 1636DR (650 nm LED) was factory calibrated in particle-free water. A WetLabs algorithm corrected for instrument internal temperature hysteresis during the cast. The voltage was corrected for temporal drift in the instrument during the cruise by using factory and field air and blocked beam readings:

Tr = ((VSig -VBlock) / (VFac - VBlock))*(VFacAir /VFieldAir),

where - VSig –is the measured output voltage,
VBlock is the output voltage with the beam blocked during calibration,
VFac – is the factory clean-water value,
VFacAir – is the factory measured voltage output in air,
VFieldAir – is the field measured voltage output in air.

Transmissometer windows were cleaned prior to each cast and air calibrations through the CTD were made every 20 casts. Without in situ particle samples we employed the common method of using the cruise minimum voltage or a cruise-average minimum on each cast because particle concentrations are very low in mid-ocean depths.

The transmissometer measures in volts (0-5 volts (V)) the transmission (T) of light across a path of known length (r = 0.25 m). Voltage is then converted to beam attenuation of light (c) by the equation:

$V/5 = T = e^{-cr}$,

which can be rewritten as

$c = -(1/r) * ln(T)$

Internal firmware subtracts attenuation due to water (c_w) from the output data stream leaving c_p, the attenuation due to particles. Processing of the data includes data averaging (1 or 2 db binning), and examination and removal of transient spikes.

c_p is linearly correlated with particle concentration (PM or POC). Thus, either regressing particle concentrations from filtered water samples from the cast with c_p, or using c_p/PM correlations from other studies, we are able to quantify the particle concentration throughout the water column. Particle concentration can be correlated with other parameters measured from the CTD (e.g. particle backscatter, particle size distribution, acoustic backscatter from the ADCP, chlorophyll fluorescence, temperature, oxygen) to study sources and sinks of particulate matter. We will also compare particle distributions in 2018 with those obtained in 1995. For an example, see Gardner, W.D., A.V. Mishonov, M.J. Richardson, 2018. Decadal Comparisons of Particulate Matter in Repeat Transects in the Atlantic, Pacific, and Indian Ocean Basins, Geophysical Research Letters https://doi.org/10.1002/2017GL076571.

9.19.Biological Underway Measurements

PIs: Victoria Coles[1], Raleigh Hood[1], Joaquim Goes[2]
Cruise Participants: Victoria Coles[1], Hannah Morrissette[1]
[1] University of Maryland Center for Environmental Science, Horn Point Laboratory
[2] Columbia University, Lamont Doherty Earth Observatory

Scientific Goals: The goal of the underway measurements collected as part of the IO7 line were to collect observations of the plankton size structure and community composition as well as physiological status of the phytoplankton community in order to improve and validate remote sensing observations of surface chlorophyll and primary productivity, and to better understand how local variability in physics and biogeochemistry contributes to the variability in plankton community structure.

To meet these goals, two underway instruments were deployed in the flow through uncontaminated seawater system in the Biological Lab.

The benchtop FlowCAM system version 3.4 (Fluid Imaging Technologies, Inc. www.fluidimaging.com) was operated primarily in flow through mode, with 10ml samples drawn at 30 minute intervals. Particles were imaged at an 0.9ml/minute flow rate, resulting in a sample processing period of 11 minutes. Sample was debubbled, then drawn into the imaging chamber by a pump. With a laser in triggering mode, images were captured at 18 frames per second with a 4x optical magnifier. Pixels that are identified as particles are segmented out of the image, and stored for further analysis. A pre-filter removed images of particles less than 5 microns as recommended for the 4x objective for most of the cruise, though other sizer were tested due to particles sticking on the glass of the flow cell. The system produces images of the plankton community as well as measures of particle size and other quantities (Area, Area (filled), Aspet ration, Average blue, Average green, Average red, Capture x, Capture y, Circle fit, Circularity, Circularity hu, Compactness, Convex perimeter, Convexity, D (ABD), D (ESD), Diameter (ESD), Diameter (ABD), Diameter (FD), Edge gradient, Elapsed time, Elongation, Fiber curl, Fiber straightness, Geodesic aspect ratio, Geodesic length, Geodesic thickness, Image Height, Image width, Intensity, Length, Particles per chain, Perimeter, Ratio Blue/Green, Ratio Red/Blue, Ratio Red/Green, Roughness, Sigma Intensity, Sum intensity, Symmetry, Transparency, Volume (ABD), Volume (ESD), Width). No classification has been performed on the images, though daily plankton samples were collected for deriving a classification library.

The instrument arrived functioning well, however the flow cell was highly clogged with particles stuck to the cell glass and attempts to clean the flow cell were initially unsuccessful resulting in very high numbers of spurious particles identified. High levels of pruning were required to remove these spurious particles, and as a result real particles with similar characteristics were certainly lost. An automated filter that removed particles less than 9 microns was employed to reduce manual pruning required.

As of 5/4/2018, when a new detergent (dawn dishwashing liquid) was employed, the flow cell conditions improved, and the initial filter was relaxed back to 5 microns.

After the port stop in the Seychelles, 5/19/2018, discrete sampling at the upper 4 Niskin bottles in the productivity cast was initiated each morning. Not all samples have been analyzed yet.

The mini-FIRe system (Miniaturized fluorescence induction and relaxation) was also deployed in flow through mode. Samples were collected at 36 second intervals for 20 minutes. Then a 5-minute light profile with increasing actinic light was performed on a sample, and this pattern was repeated. The machine was developed to measure photosynthetic and physiological characteristics of photosynthetic organisms (Gorbunov and Falkowski 2005), including photochemistry in photosystem II, and photosynthetic electron transport down to fixation of carbon. Blanks were collected twice and run for removal of the dissolved water fluorescence signal.

After the port stop in the Seychelles when a cuvette was procured, discrete samples were also collected for both the underway and the actinic light source protocols at primary production stations in the upper four Niskin bottle samples when water was available.

Preliminary assessment indicates that the instrument was functioning well, however all the data have not yet been assessed, and the light profiles have not been analyzed.

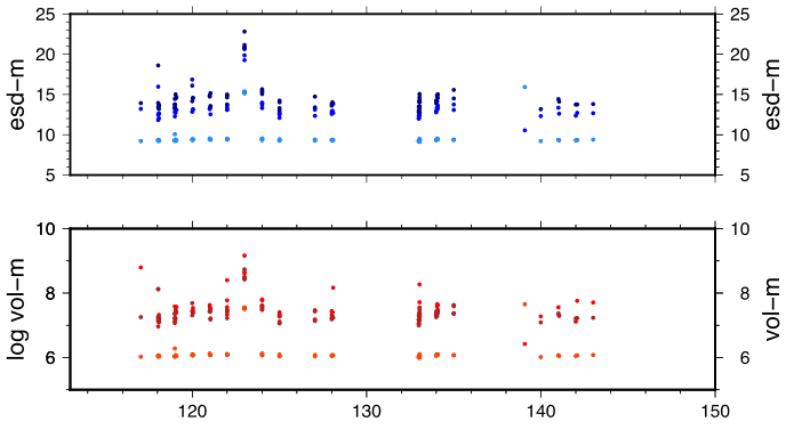


Figure 27. 25th, 50th, and 75th percentile equivalent spherical diameter and volume for samples along the cruise track by Julian day.

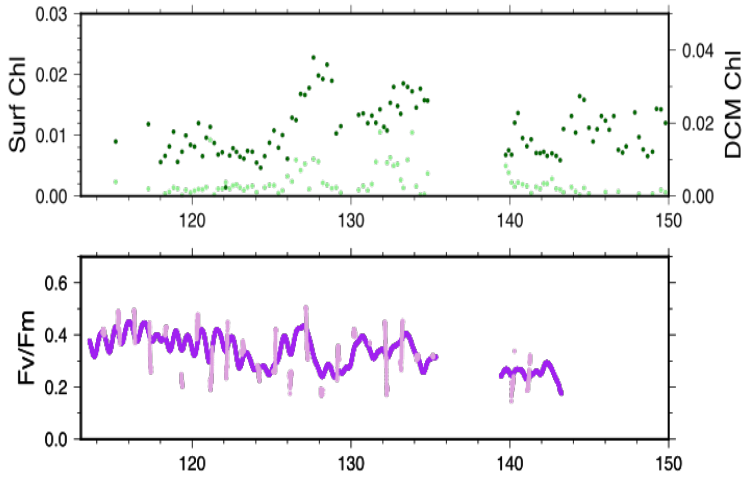


Figure 28. Surface CTD fluorescence voltage (uncalibrated) in light green, and at the depth of the fluorescence maximum in dark green. Photosynthetic yield during high ambient light periods in light purple and averaged over a daylong period in dark purple.

9.20.Biological Samples from Niskin Bottles

PIs: Joaquim Goes[2], Victoria Coles[1], Raleigh Hood[1]
Cruise Participants: Victoria Coles[1], Hannah Morrissette[1]

[1] University of Maryland Center for Environmental Science, Horn Point Laboratory
[2] Columbia University, Lamont Doherty Earth Observatory

Scientific Goals: The goal of the oxygen based primary productivity incubation measurements was to relate net community production to local environmental conditions and community composition, and to validate remote sensing estimates of primary productivity.

Oxygen based primary productivity measurements were performed daily with 24 hour on-deck incubations at the surface from bucket samples and at the depth of the deep chlorophyll maximum as determined by the CTD fluorometer. Samples were collected into oxygen flasks at the local time of the CTD cast closest to dawn. Samples were analyzed using Winkler oxygen reagents [Carpenter, 1965] for oxygen determination on an automated titrator using amperometric end point detection [Langdon, 2012]. (See CTD oxygen measurements. Standards were drawn four times during the cruise using the standard KIO_3 of the oxygen titration group.) The temperature of the water samples was not measured, and corrections were not made for this difference. However, the temperatures of the surface and DCM waters rarely diverged by more than 5 degrees C. Note that due to limitations in water budgets, the productivity water samples were not collected following typical oxygen measurement procedures. Instead, simultaneity for collection of all samples was emphasized to ensure that the difference in oxygen concentration between the initial and incubated samples would remain constant.

Surface triplicate oxygen samples (9 total) were simultaneously submerged in a bucket water sample, removed, bubbles clinging to the flask walls were tapped out manually, then all samples were closed as quickly as possible and the initial samples were pickled. Dark bottles (3) were covered to remove light, and incubated on deck in a clear incubator with ship's flow through seawater running continuously. Light bottles (3) were also incubated. The incubator was screened to reduce the surface light intensity slightly to mimic in water conditions. Samples from the deep chlorophyll maximum were collected into a 4l polycarbonate bottle, then poured into oxygen flasks. They were then treated identically to the surface bucket derived samples. After 24 hours, samples were recovered from the incubator and pickled with oxygen reagents. The samples were equilibrated to the laboratory temperature (with DIW in the bottle necks) for no less than 5 hours. Samples were then analyzed.

The difference between the initial oxygen concentration and the final concentrations incubated for 24 hours either in

the dark (Respiration) or the light (Net Community Production; both phytoplankton production and bacterial respiration) provide a measure of the community metabolism. The difference between net community production and respiration is assumed to be the gross primary production under the assumption that light and dark respiration are equivalent.

Over the course of the cruise, precision in the initial time zero samples (triplicate) improved markedly, illustrating that sampling procedures are key to accurate measurements. Sampling improvements included: tapping out bubbles clinging to the oxygen flask sides, using manual pipettes that were wiped with a kimwipe prior to each sample pickling, wetting the oxygen flask necks with DIW prior to measurement, careful thiosulfate reagent purging prior to sample analysis and careful attention to cleaning the electrode between samples.

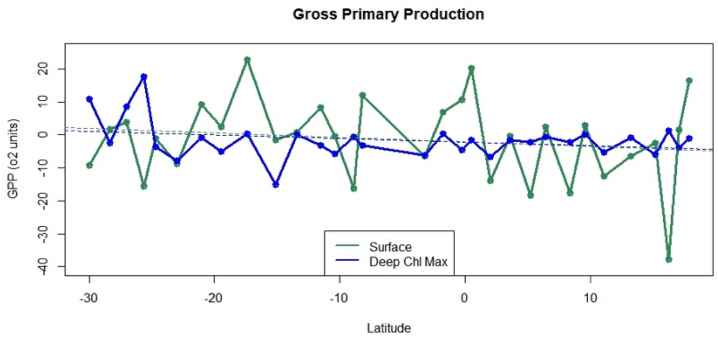


Figure 29. Gross primary productivity values (umol/kg) are shown as colored circles (scale to right).

Standard deviation between triplicate initial samples varied, but decreased from initial average values of 2.4 standard deviation to later values of 0.65.

References

Carpenter JH (1965) The accuracy of the Winkler method for dissolved oxygen analysis. Limnol Oceanogr 10:135−140

Langdon, C. (2010). Determination of dissolved oxygen in seawater by Winkler titration using the amperometric technique. The GO-SHIP Repeat Hydrography Manual: A Collection of Expert Reports and Guidelines. E. M. Hood, C. L. Sabine and B. M. Sloyan, IOCCP Report Number 14, ICPO Publication Series Number 134.

9.21. Biological Filtration Measurements

PIs: Victoria Coles[1], Raleigh Hood[1], Greg Silsbe[1]
Cruise Participants: Victoria Coles[1], Hannah Morrissette[1]
[1] University of Maryland Center for Environmental Science, Horn Point Laboratory

Scientific Goals: Then goal of the HPLC, absorption, chlorophyll-a, and CDOM measurements was to characterize the different factors that combined determine ocean color for satellites.

Filtered samples for determination of HPLC, chlorophyll-a, absorption, and CDOM were collected at each primary production station and also at net tow stations. Samples were collected from the surface bucket sample and the upper 4 Niskin bottles and filtered using a vacuum pump through Whatman GF/F 25mm filters. Filters were stored folded in half in histoprep capsules (or flat for absorption) in liquid nitrogen for further analysis at NASA GSFC (HPLC) and HPL (Chlorophyll, CDOM, Absorption). CDOM samples were filtered through a 0.2 micron filter into pre-combusted amber glass vials with pre-combusted tin foil shielding the sample from the lids and stored in the refrigerator. One liter was filtered for chlorophyll and absorption samples, 2-4 liters were filtered for HPLC. Small volume samples were collected and stored with lugols iodine for phytoplankton taxonomic enumeration.

Sample Type	Total

High Performance Liquid Chromatography (HPLC)	51
Absorption	50
Chlorophyll α	230
Colored Dissolved Organic Matter (CDOM)	45
Preserved phytoplankton sample for microscopy	45
Sun Photometer	460

9.22. Net Tows

PIs: Nina Bednarsek[1], Victoria Coles[2], James Pierson[2]
Cruise Participants: Victoria Coles[2], Hannah Morrissette[2], Catherine Garcia[3]
[1] Southern California Coastal Water Research Project
[2] University of Maryland Center for Environmental Science, Horn Point Laboratory
[3] University of California, Irvine

Scientific Goals: Net tows were conducted through the upper 80m of the watercolumn at night. The goal was to examine the skeletons of organisms with aragonite shells such as pteropods for evidence of stress or dissolution associated with changing pH levels in the ocean due to increasing carbon dioxide levels in the atmosphere. Tows were also stored for taxonomic analysis and potential genetic analysis.

Net tows were conducted at 14 stations throughout the cruise. A .32m radius, 200 micron mesh ring net with a self-draining cod end was used. The net was towed off the aft CTD winch except for stations with heavy current when the net tow was at risk of exacerbating concerns about twisting the CTD wire. These exceptions are detailed below. Net tows took place between 10pm and 3am local time in the dark. The net was lowered with a 60-80 pound weight and a modest underway speed to maintain a 45 degree wire angle measured with a clinometer. 125m of wire were released at 20m/minute, then the net was gradually raised to the surface while maintaining the 45 degree wire angle at 6-7m/minute speed. The distance towed was computed from the start and end time using the ship underway GPS measurements. On deck, the net was rinsed with seawater, and the sample returned to the Bio laboratory. Wet volume of the sample was measured in a graduated cylinder before and after filtering with 200micron mesh. The sample was photographed, and stored in 190 proof ethanol. After 24-48 hours, the ethanol was replaced fresh.

Date (GMT)	Station	Zooplankton wet volume (ml)	Total net distance (m)	Volume cleared m3
4/29/2018	7	21	1388.726339	1.39E+03
5/3/2018	23	17	979.2020705	9.77E+02
5/4/2018	27	26	1326.747508	1.32E+03
5/7/2018	38	31	932.8277148	9.30E+02
5/9/2018	44	46	1853.209033	1.85E+03
5/19/2018	65	48	1653.164587	1.65E+03

5/22/2018	77	35	598.3642288	5.97E+02
5/24/2018	86	29	915.6759636	9.13E+02
5/26/2018	93	24	997.6232758	9.95E+02
5/28/2018	100	33	1648.371472	1.64E+03
5/29/2018	104	29	1190.714023	1.19E+03
5/30/2018	107	31	1172.336773	1.17E+03
5/31/2018	111	46	1042.752852	1.04E+03
6/4/2018	122	63	1341.914122	1.34E+03
total tows: 14				

The samples will be analyzed to evaluate stress on pteropod shell formation resulting from ocean acidification. Remaining samples will be shipped to Horn Point Laboratory for microscope counting.

5/22/2018, 5/24/2018: the net was towed off the starboard side on the crane with Kevlar line. Wire out was estimated from 10m increment markings on the Kevlar line. Wire angle was measured with the clinometer, and depth was inferred.

Figure 30. Some animals captured in the net tows.

9.23. Isotopic Composition of Nitrate

PIs: Chawalit "Net" Charoenpong and Scott D. Wankel (WHOI)
Samplers: Viviane Menezes, Amanda Fay and Cathy Garcia

Nitrate (NO_3-) is the dominant dissolved inorganic nitrogen ions. Like other nutrients, it is depleted in the surface due to biological consumption and abundant in the ocean interior due to remineralization. Natural abundance isotopic composition is a powerful tool to elucidate the sources and the processes that affect the nitrate concentrations. For example, denitrification which consumes NO_3^- during its reaction should be prevalent in the low-oxygen region of the Arabian Sea and impart isotopic signature on the remaining NO_3^-.

Samples from Niskin bottles were taken for analyses of isotopic composition of nitrate (NO_3^-), $\delta^{15}N$-NO_3^- and $\delta^{18}O$-NO_3^-. Samples for NO_3^- isotopic analysis (storeed in 30ml LDPE bottles) were preserved by mild acidification with hydrochloric and sulfuric acid to pH 2 to 3. These steps are in place to ensure the retention of the $\delta^{15}N$ and $\delta^{18}O$ signatures and remove any nitrite in the sample (Granger and Sigman, 2009). Samples bottles were stored at room temperature until analysis. No onboard analysis was carried out and all samples will be analyzed back in the Wankel lab for stable isotope biogeochemistry at WHOI with the denitrifier method (Casciotti et al., 2002; Sigman et al., 2001) which quantitatively convert NO_3^- to N_2O before being extracted and purified (as in McIlvin and Casciotti, 2010) before being analyzed by the IRMS.

References

Casciotti, K. L., D. M. Sigman, M. G. Hastings, J. K. Böhlke, and A. Hilkert (2002), Measurement of the oxygen isotopic composition of nitrate in seawater and freshwater using the denitrifier method, *Anal. Chem.*, 74(19), 4905–4912, doi:10.1021/ac020113w.

Granger, J., & Sigman, D. M. (2009). Removal of nitrite with sulfamic acid for nitrate N and O isotope analysis with the denitrifier method. *Rapid Communications in Mass Spectrometry*, *23*(23), 3753-3762.

McIlvin M. R., Casciotti K. L. (2010). Fully automated system for stable isotopic analyses of dissolved nitrous oxide at natural abundance levels. *Limnology and Oceanography: Methods* 8, 54-66, doi: 10.4319/lom.2010.8.54

Sigman, D. M., K. L. Casciotti, M. Andreani, C. Barford, M. Galanter, and J. K. Böhlke (2001). A bacterial method for the nitrogen isotopic analysis of nitrate in seawater and freshwater, *Anal. Chem.*, 73(17), 4145–4153, doi: 10.1021/ ac010088e.

9.24 Density; Post-Cruise Processing (JAMSTEC)

28 November 2018

PI: Hiroshi Uchida (JAMSTEC)-not onboard
Sampler: Shinichiro Umeda (JAMSTEC)

Objectives

The aim of this study is to evaluate and update the algorithm for estimating Absolute Salinity adopted in TEOS-10 (the International Thermodynamic Equation of Seawater 2010. IOC et al., 2010) by accumulating accurate seawater density data, especially for the Arabian Sea in which density of seawater have not yet measured directly.

Materials and methods

The water samples for seawater densities were collected in 100-mL aluminum bottles (Mini Bottle Can, Daiwa Can Company, Japan) at 10 stations shown in Fig. 1. The bottles are stored upside down in a marine container on-deck of the ship for about 6 months until shipped back from Miami, USA to JAMSTEC, Japan. A total of 240 bottles were collected (shown in Fig. 1). Seawater densities were measured at 20 ºC by using two oscillation-type density meters (DMA 5000M, S/N 80570578 [No. 1] and S/N 81661961 [No. 2], Anton-Paar GmbH, Graz, Austria) with sample changers (Xsample 122, Anton-Paar GmbH) to load samples automatically from up to forty-eight (for No. 2) or ninety-six (for No. 1) 12-mL glass vials, in accordance with a method described in Uchida et al. (2011) with slight modification. Density salinity can be back calculated from measured density and temperature (20 ºC) with TEOS-10. Offset and time drift of the density meters were corrected with measurements of the Reference Material for Oceanic O2 and CO2 Measurements (lot Pre18, S/N 147, 168, and 269, Kanso Technos Co., Ltd., Osaka, Japan). Properties of the reference material at the production are listed in Table 1. Density of the Pre18 were periodically measured at about every 20 measurements (10 bottles of samples) (Fig. 2). Density of the Pre18 S/N 269 was increased about 0.003 kg/m3 due to leakage of seawater. Density samples for stations 76, 95, 109, 115, and 121 were measured by the No. 1 density meter and that for station 88, 99, 113, 117, and 123 were measured by the No. 2 density meter. To check the offset correction, IAPSO Standard Seawater (lot P160, Ocean Scientific International Ltd., Havant, Hampshire, United Kingdom) was measured. Density of P160 at 20 ºC is expected to be 1024.7609 kg/m3, and the measured densities was 1024.7590 kg/m3 and 1024.7600 kg/m3 for No. 1 and No. 2 density meter, respectively.

Practical Salinities for the rest of the density samples were also measured at 24 ºC by using a salinometer (AUTOSAL 8400B, S/N 60132, Guildline Instruments Ltd., Ontario, Canada) within 24 hours after the density measurements. Practical Salinity data measured on-board are usually used to estimated Absolute Salinity anomalies for the density samples. However, Practical Salinities for the rest of the density samples were measured to estimated Absolute Salinity anomalies from the density measurements, since the Practical Salinity data measured on-board were noisy.

Results

Practical Salinities measured for the rest of the density samples are compared with the CTD salinity and bottle sampled salinity measured on-board (Fig. 3). The Practical Salinity measured for the density samples well agreed with the CTD salinity and bottle sampled salinity for depths below 2000 dbar. However, the Practical Salinity measured for the density samples is slightly (about 0.002 in salinity) smaller than the CTD salinity for depths above 2000 dbar. The CTD salinity data for depths above 2000 dbar might be affected by largely (positively) deviated bottle sampled salinity data there in the in situ calibration using the bottle sampled salinity data.

Absolute Salinity anomalies estimated from the density and practical salinity measurements are compared with the calculated Absolute Salinity anomalies (Fig. 4). The measured Absolute Salinities well agreed with calculated Absolute Salinities for latitude south of 8ºN. However, for latitude north of 8ºN, both of the Absolute Salinities measured by the two density meters tend to be larger than the calculated Absolute Salinities (Fig. 5).

References

IOC, SCOR and IAPSO (2010): The international thermodynamic equation of seawater – 2010: Calculation and use of thermodynamic properties. Intergovernmental Oceanographic Commission, Manuals and Guides No. 56, United Nations Educational, Scientific and Cultural Organization (English), 196 pp.

Pawlowicz, R., D.G. Wright and F.J. Millero (2011): The effects of biogeochemical processes on ocean conductivity/salinity/density relationships and the characterization of real seawater. Ocean Science, 7, 363-387.

Uchida, H., T. Kawano, M. Aoyama and A. Murata (2011): Absolute salinity measurements of standard seawaters for conductivity and nutrients. La mer, 49, 237-244.

Table 9.4. Properties of Pre18 at the production (18 December 2013).

Parameter	Initial value	Unit/Scale	Contribution to the Density anomaly (kg/m^3)
Practical Salinity	34.2797	PSS-78	
Dissolved Inorganic Carbon	2213.14	umol/kg	0.0005
Total Alkalinity	2310.85	umol/kg	0.0004
Silicate	67.26	umol/kg	0.0026
Nitrate	30.30	umol/kg	0.0009
Dissolved Organic Carbon	75.0	umol/kg	0.0010
Estimated density	1024.2223	kg/m^3 @ 20 ºC	

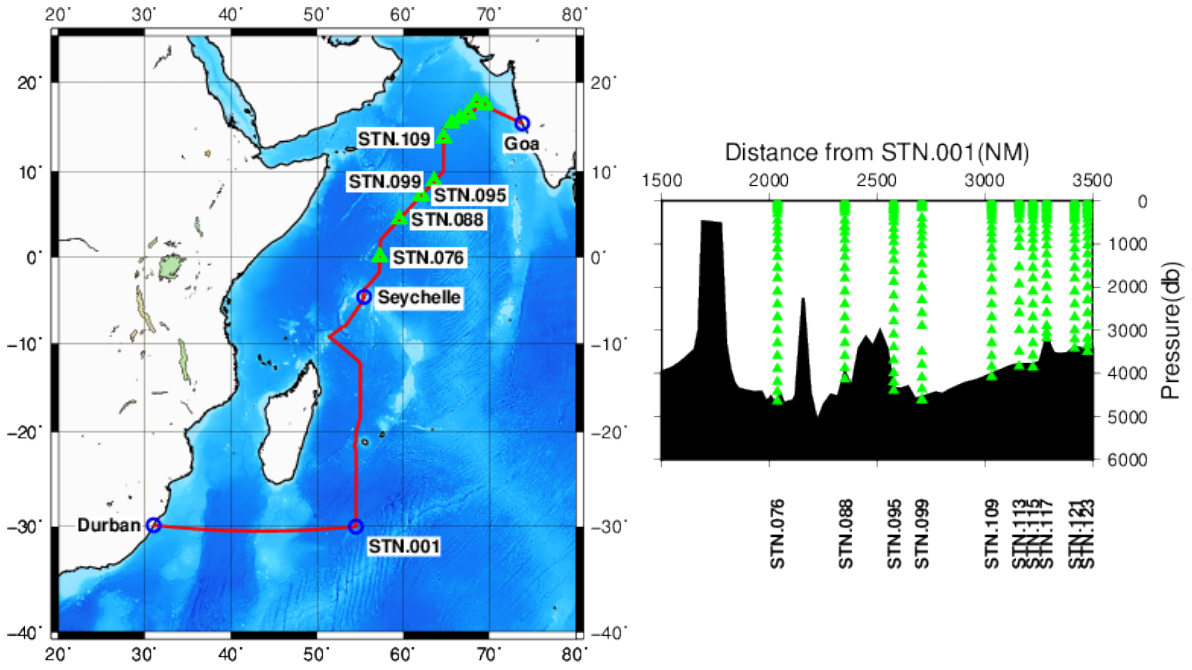


Figure 31. Map of cruise track (red) and collected stations (green) are shown on the left panel. Sampling layers are shown on the right panel.

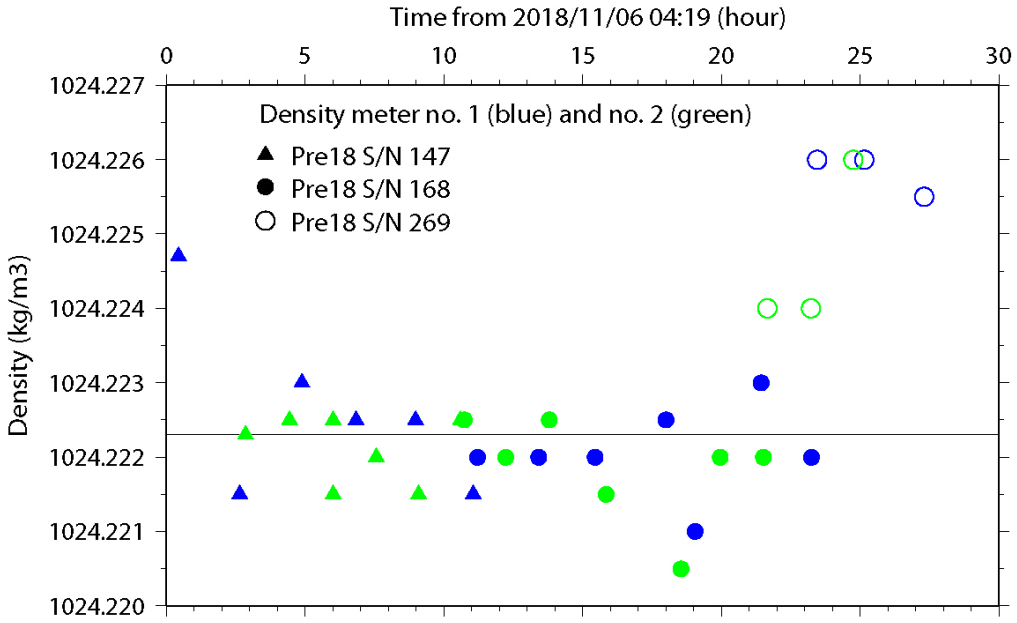


Figure 32. Time series of the density for the reference material Pre18 measured during the density measurements.

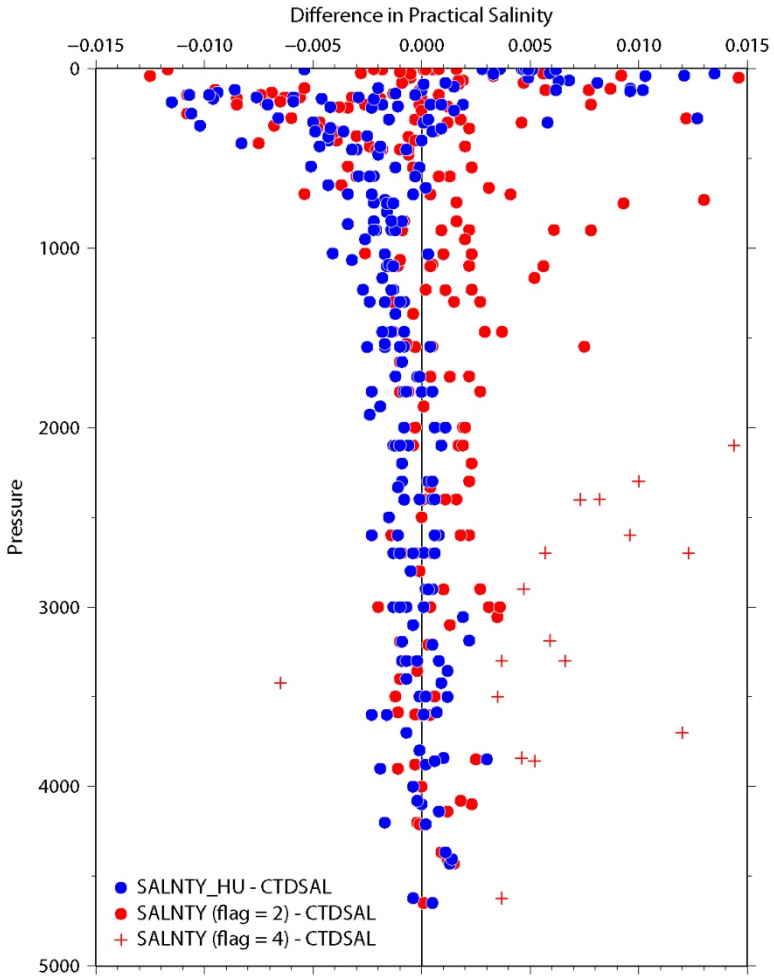


Figure 33. Vertical profiles of difference in Practical Salinity between CTD salinity and salinity measured for the density samples (blue dots). Difference between CTD salinity and bottle sampled salinity measured on-board are also shown (red dots and red crosses).

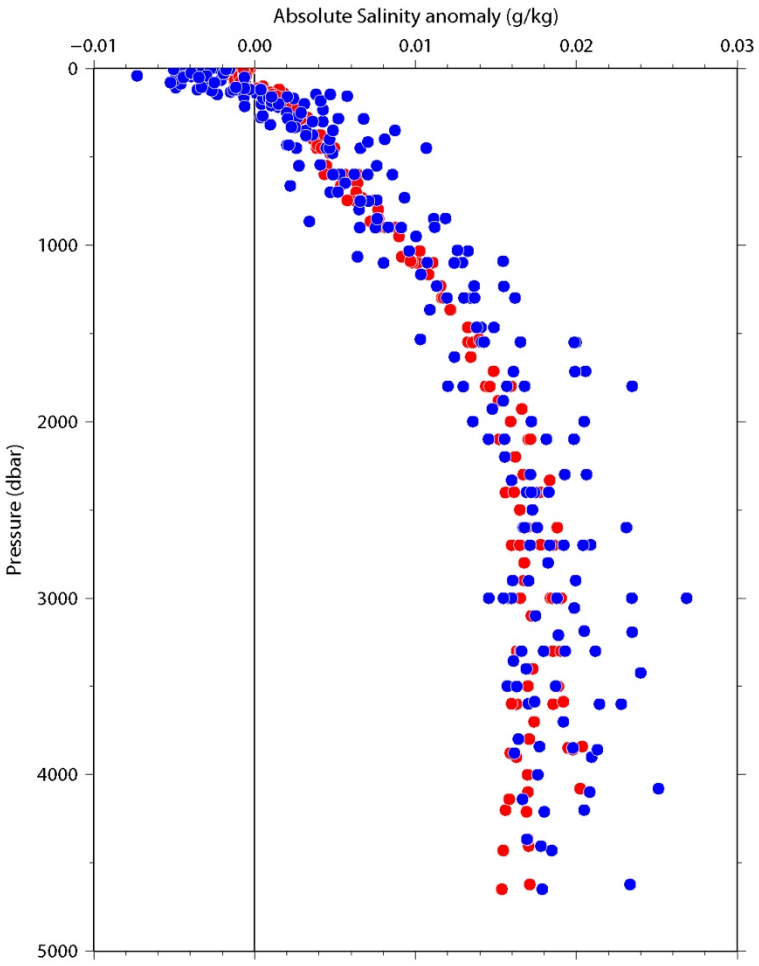


Figure 34. Vertical profiles of Absolute Salinity anomalies. Blue dots show results from the density measurements. Red dots show estimates from nutrients and carbonate system parameter data by an equation of Pawlowicz et al. (2011).

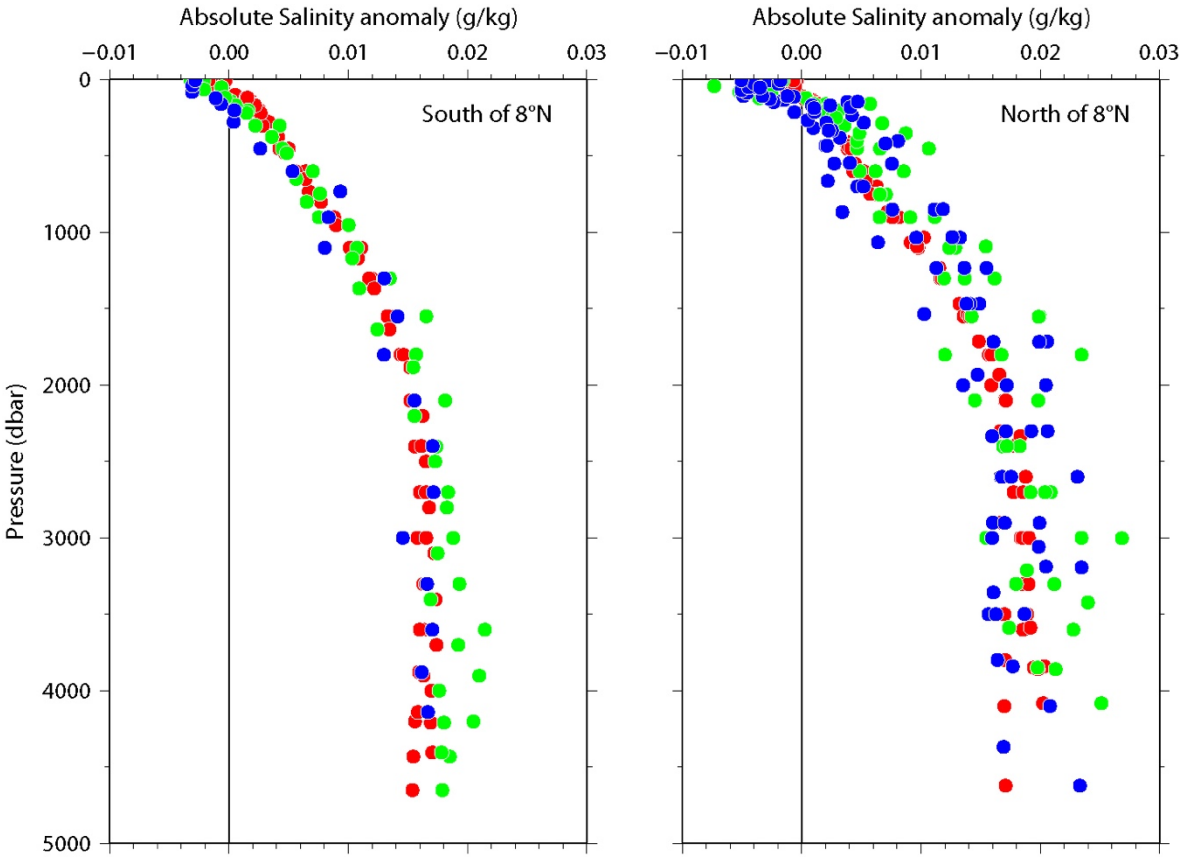


Figure 35. Vertical profiles of Absolute Salinity anomalies. Blue and green dots show results from the density measurements by No. 1 and No. 2 density meter, respectively. Red dots show estimates from nutrients and carbonate system parameter data by an equation of Pawlowicz et al. (2011).

9.25 Dissolved Calcium; Post-Cruise Processing (JAMSTEC)

2019/03/12)

PI: Akihiko Murata (JAMSTEC)-not onboard
Sampler: Shinichiro Umeda (JAMSTEC)

Objectives

According to the recent IPCC report, concentrations of CO_2 in the atmosphere have increased by 40% since pre-industrial times, primarily by fossil fuel burning and secondarily by net land use change. The ocean is said to absorb about 30% of the emitted anthropogenic CO_2, accordingly moderating progression of global warming. However, the ocean suffers from ocean acidification by the uptake of anthropogenic CO_2. Ocean acidification is characterized by an increase of H^+ (i.e., a decrease of pH) and a concurrent decrease of carbonate ion concentration (CO_3^{2-}). The decrease of CO_3^{2-} is unfavorable to marine calcifying organisms, which utilize CO_3^{2-}, together with Ca^{2+}, to produce their calcium carbonate ($CaCO_3$) shells and skeletons. To evaluate dissolution and precipitation of calcium carbonate, we measure the concentration of calcium in water columns in the western part of the Indian Ocean.

Sampling

The samples were collected into 60 mL of HDPE bottles from Niskin bottles attached to the CTD system. The sampling was made at 11 stations, with a few replicates at individual stations (see Figure 25a). In total, 265 samples were collected during the cruise. The samples were stored for 5 months until shipped back to the onshore laboratory for analysis.

Analytical method

The measurement was made in a laboratory on land. The method was based on photometry proposed by Culkin and Cox (1966). We used a modified Dissolved Oxygen Titrator DOT-01 (Kimoto Electronic Co. Ltd.), which bandpass filter is replaced to f0=620nm. Approximately 20 mM of EGTA (Ethylene Glycol Tetraacetic Acid) solution was used as a titrant. The titrant was calibrated several times by in-house Ca-standard solution whose Ca-source was pure $CaCO_3$ produced by NMIJ (CRM 3013-a).

Results

Results of calibrations are shown in Table 25 and Figure 25b with the concentrations of the titrant. The total number of the replicate sample pairs in good measurement (flagged 2) was 9, and its standard deviation was 0.0177 mmol/kg calculated by a procedure (SOP23) in DOE (1994). For 6 samples, Practical Salinities for the rest of the calcium samples were also measured at 24 ºC by using a salinometer (AUTOSAL 8400B, S/N 60132, Guildline Instruments Ltd., Ontario, Canada) after the calcium measurements. Averaged anomalies from Practical Salinity data measured onboard was +0.03% (+0.0097 +/- 0.0041 psu (standard deviation)), regarded as an effect of evaporation during the shipment to the laboratory. A previous work (Culkin and Cox, 1966) points out that magnesium (Mg) and strontium (Sr) cause positive bias to the titrated volume of Ca because of their interference with the reaction between EGTA and Ca; the bias caused by Mg was 0.729% and by Sr was 0.388%. No correction for the evaporation and interference was given to the data.

References

Culkin, F. and Cox, R.A. (1966). Sodium, potassium, magnesium, calcium and strontium in seawater. Deep Sea Research 13: 789-804.

DOE (1994) Handbook of methods for the analysis of the various parameters of the carbon dioxide system in sea water; version 2. A.G. Dickson and C. Goyet (eds), ORNL/CDIAC-74.

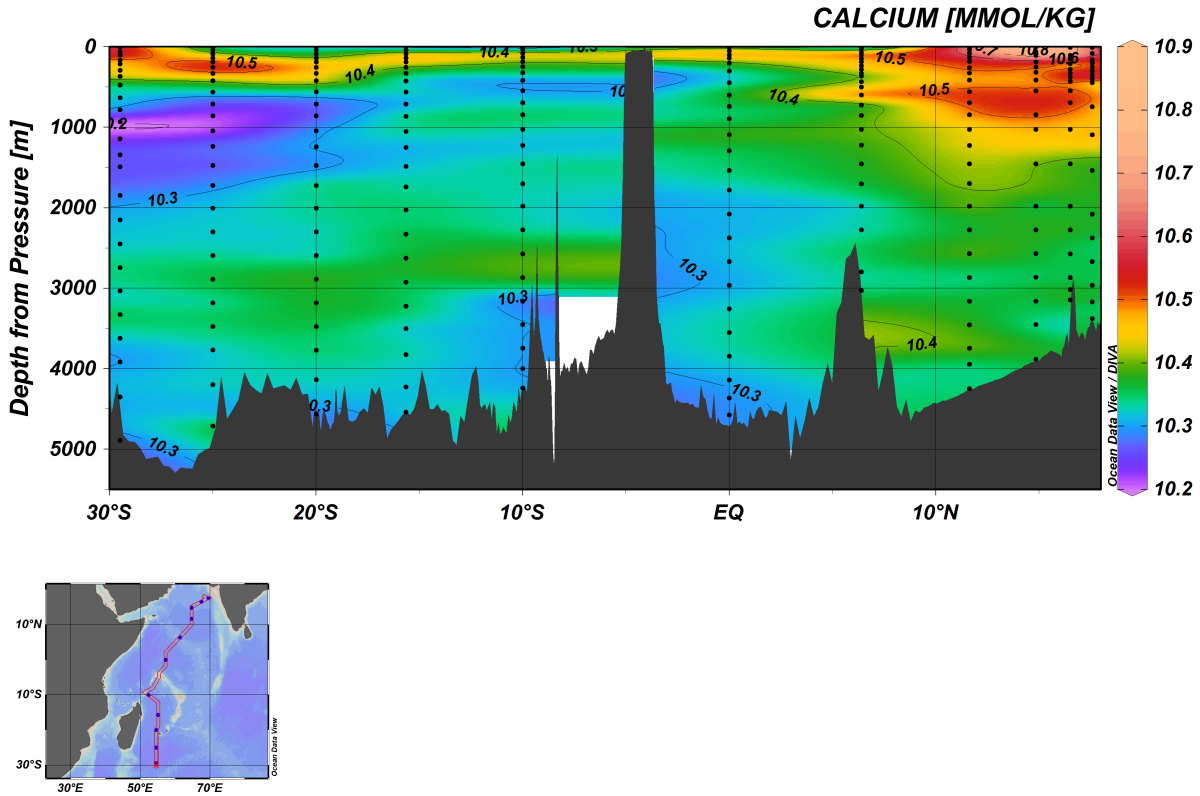


Figure 36a. Section plot of dissolved calcium and sampling layers (top panel). Map of collected stations (bottom panel).

Table 9.5. Results of the calibrations during the analysis. %CV means coefficient of variation for the calibrations (S.D. / Average).

EGTA No.	Dates	Average (mM)	S.D. (mM)	N	%CV	Stations
2	2018/11/06-08	19.9220	0.0067	11	0.03	117, 121
3	2018/11/08-12	19.3451	0.0164	8	0.08	105, 111
4	2018/11/13	19.6633	0.0351	5	0.18	76, 93
5	2018/11/14-22	19.7043	0.0252	20	0.13	2, 15, 27, 35, 48

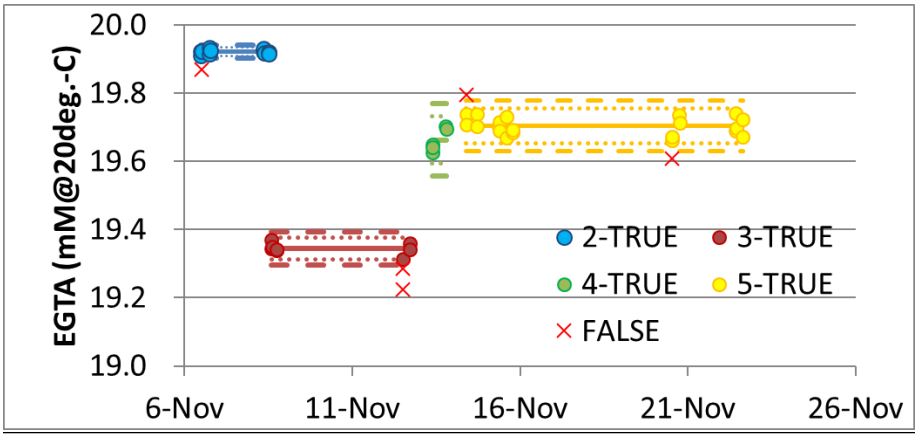


Figure 36b. Results of the calibrations during the analysis. Each result is shown with the average concentration (solid line) with error bar of +/- 2sigma (dotted line), +/- 3sigma (broken line).

10.Appendix

10.1.Station Plan

Table A1. I07N-2018 Station Plan

Station Number	Lat (dec)		Lon (dec)		dist (nm)	depth (m)	Arrival Time (LT)	Depart Time (LT)
Durban	-29.86	S	31.02	E	0.00		23-Apr 14:00	23-Apr 14:00
Test cast A	-30	S	40	E	466.9	3000	25-Apr 5:24	25-Apr 8:08
First Argo	-30.00	S	42.70	E	140.3		25-Apr 20:20	25-Apr 20:35
Test cast B	-30	S	50	E	379.3	5000	27-Apr 9:15	27-Apr 13:06
1	-30	S	54.5	E	233.8	4315	28-Apr 3:23	28-Apr 6:52
2	-29.494	S	54.4975	E	30.4	4910	28-Apr 9:45	28-Apr 13:34
3	-28.9747	S	54.4988	E	31.2	4799	28-Apr 16:32	28-Apr 20:17
4	-28.6643	S	54.4992	E	18.6	5062	28-Apr 22:03	29-Apr 2:57
5	-28.3243	S	54.4967	E	20.4	5144	29-Apr 4:53	29-Apr 9:50
6	-27.9927	S	54.4958	E	19.9	5131	29-Apr 11:43	29-Apr 15:39
7	-27.6605	S	54.4955	E	19.9	5149	29-Apr 17:33	29-Apr 21:29
8	-27.3302	S	54.4848	E	19.8	5199	29-Apr 23:58	30-Apr 4:56
9	-27.0028	S	54.4863	E	19.6	5269	30-Apr 6:48	30-Apr 10:49
10	-26.6698	S	54.4883	E	20.0	5265	30-Apr 12:43	30-Apr 16:43
11	-26.3257	S	54.503	E	20.7	5258	30-Apr 18:41	30-Apr 22:41
12	-25.9997	S	54.5015	E	19.6	5250	1-May 0:33	1-May 5:33
13	-25.6608	S	54.5037	E	20.3	4996	1-May 7:29	1-May 11:38
14	-25.3308	S	54.5048	E	19.8	5048	1-May 13:32	1-May 17:25
15	-24.9965	S	54.4997	E	20.1	4856	1-May 19:19	1-May 23:06
16	-24.6613	S	54.502	E	20.1	4663	2-May 1:01	2-May 4:41
17	-24.3355	S	54.5198	E	19.6	4805	2-May 6:23	2-May 10:08
18	-23.9925	S	54.5107	E	20.6	4423	2-May 11:56	2-May 15:43
19	-23.6563	S	54.5153	E	20.2	4062	2-May 17:28	2-May 20:48
20	-23.3332	S	54.5027	E	19.4	4199	2-May 22:29	3-May 1:54
21	-22.9938	S	54.5037	E	20.4	3911	3-May 3:40	3-May 6:56
22	-22.495	S	54.5003	E	29.9	4294	3-May 9:32	3-May 13:00
23	-21.9957	S	54.507	E	30.0	4237	3-May 15:36	3-May 19:17
24	-21.499	S	54.5	E	29.8	4160	3-May 22:27	4-May 1:50

25	-21.0012	S	54.5083	E	29.9	4051	4-May 4:52	4-May 8:11
26	-20.4973	S	54.5095	E	30.2	4334	4-May 11:04	4-May 14:33
27	-19.9972	S	54.4963	E	30.0	4599	4-May 17:25	4-May 21:03
28	-19.4893	S	54.6705	E	32.0	4769	5-May 0:06	5-May 3:50
29	-19.0028	S	54.8292	E	30.5	4749	5-May 7:39	5-May 11:22
30	-18.5032	S	54.9898	E	31.3	4225	5-May 14:21	5-May 17:47
31	-18.0208	S	55.0017	E	29.0	4571	5-May 20:32	6-May 0:24
32	-17.3653	S	54.9973	E	39.3	4594	6-May 4:09	6-May 7:47
33	-16.7958	S	54.9997	E	34.2	4319	6-May 10:47	6-May 14:15
34	-16.2275	S	54.997	E	34.1	4605	6-May 17:06	6-May 20:56
35	-15.652	S	55.0007	E	34.5	4579	6-May 23:49	7-May 3:26
36	-15.0912	S	55.001	E	33.6	4195	7-May 6:39	7-May 9:45
37	-14.5183	S	55.0042	E	34.4	4144	7-May 12:53	7-May 16:16
38	-13.9545	S	54.9988	E	33.8	4486	7-May 20:29	8-May 0:04
39	-13.3905	S	54.9938	E	33.8	4437	8-May 3:00	8-May 6:33
40	-12.8193	S	54.9997	E	34.3	4284	8-May 9:32	8-May 12:59
41	-12.244	S	54.994	E	34.5	4664	8-May 15:59	8-May 19:40
PMEL mooring	-12	S	55	E	14.6		8-May 20:53	8-May 21:05
42	-11.8757	S	54.5507	E	27.4	4606	8-May 23:22	9-May 3:00
43	-11.4995	S	54.1085	E	34.4	4453	9-May 5:52	9-May 9:26
44	-11.3085	S	53.8792	E	17.7	4810	9-May 12:46	10-May 14:07
45	-11.128	S	53.6645	E	16.6	4837	10-May 15:30	10-May 19:23
46	-10.7523	S	53.2110	E	35.0	4640	10-May 22:18	11-May 1:57
47	-10.3837	S	52.7675	E	34.3	4315	11-May 4:49	11-May 8:17
48	-10.1902	S	52.5425	E	17.6	4422	11-May 9:58	11-May 13:30
48	-10.0013	S	52.3187	E	35.1	4257	11-May 11:13	11-May 14:39
50	-9.8157	S	52.0942	E	17.3	4205	11-May 16:49	11-May 20:14
49	-9.632	S	51.8723	E	34.5	4071	11-May 17:32	11-May 20:52
52	-9.4473	S	51.6482	E	17.3	2862	11-May 22:31	12-May 1:11
50	-9.2572	S	51.4292	E	34.5	3714	11-May 23:45	12-May 2:53
54	-9.0887	S	51.6630	E	17.1	3722	12-May 4:31	12-May 7:40
51	-8.9137	S	51.8988	E	34.6	3308	12-May 5:47	12-May 8:42
52	-8.7343	S	52.1455	E	18.2	4148	12-May 10:25	12-May 13:48
53	-8.5548	S	52.3827	E	17.7	4264	12-May 15:30	12-May 18:57
54	-8.3755	S	52.6263	E	18.0	5130	12-May 20:40	13-May 0:35

55	-8.198	S	52.8623	E	17.6	3579	13-May 2:16	13-May 5:20
56	-8.1088	S	53.0750	E	13.7	2773	13-May 6:38	13-May 9:27
57	-8.0047	S	53.2950	E	14.5	4039	13-May 10:50	13-May 14:17
58	-7.7588	S	53.4590	E	17.7	4047	13-May 15:58	13-May 19:17
58	-7.518	S	53.6290	E	35.3	3961	13-May 17:38	13-May 20:55
59	-7.0385	S	53.9592	E	34.8	3890	14-May 0:05	14-May 3:20
60	-6.5525	S	54.2903	E	35.2	3756	14-May 6:32	14-May 9:42
61	-6.0688	S	54.6257	E	35.2	3516	14-May 12:54	14-May 15:56
62	-5.5885	S	54.9570	E	35.0	3489	14-May 19:07	14-May 22:08
63	-5.3452	S	55.1177	E	17.5	3031	14-May 23:43	15-May 2:29
64	-5.105	S	55.2842	E	17.5	898	15-May 4:04	15-May 5:29
Victoria	-4.6254	S	55.4627	E	30.7		15-May 8:16	19-May 16:30
65	-3.7119	S	55.4607	E	54.8	540	19-May 21:28	19-May 22:41
66	-3.4822	S	55.7865	E	23.9	3261	20-May 0:45	20-May 3:39
67	-3.2358	S	55.9963	E	19.4	3854	20-May 5:20	20-May 8:33
68	-2.996	S	56.1943	E	18.6	4229	20-May 10:11	20-May 13:36
69	-2.7423	S	56.4045	E	19.8	4373	20-May 15:24	20-May 19:10
70	-2.2587	S	56.8150	E	38.0	4423	20-May 22:37	21-May 2:10
71	-1.7707	S	57.2205	E	38.1	4445	21-May 5:37	21-May 9:25
72	-1.2292	S	57.2372	E	32.5	4470	21-May 12:22	21-May 15:56
73	-0.8653	S	57.2473	E	21.8	4671	21-May 20:18	22-May 0:14
74	-0.502	S	57.2568	E	21.8	4644	22-May 2:25	22-May 6:04
75	-0.2507	S	57.2645	E	15.1	4769	22-May 7:57	22-May 11:41
76	-0.0012	S	57.2693	E	15.0	4686	22-May 13:11	22-May 17:07
77	0.2482	N	57.2787	E	15.0	4715	22-May 18:37	22-May 22:19
78	0.4995	N	57.2788	E	15.1	4764	22-May 23:49	23-May 3:33
79	0.9295	N	57.2958	E	25.8	4333	23-May 6:08	23-May 9:37
80	1.1943	N	57.2995	E	15.9	4438	23-May 11:13	23-May 14:45
81	1.461	N	57.3095	E	16.0	4645	23-May 16:21	23-May 20:16
82	2.004	N	57.3285	E	32.6	4583	23-May 23:32	24-May 3:09
83	2.3995	N	57.6923	E	32.2	4587	24-May 6:23	24-May 10:00
84	2.7998	N	58.0615	E	32.7	4730	24-May 13:38	24-May 17:20
85	3.1943	N	58.4270	E	32.2	4619	24-May 20:16	24-May 23:55
86	3.5913	N	58.7945	E	32.4	4440	25-May 3:10	25-May 6:42
87	3.9982	N	59.1555	E	32.6	4633	25-May 9:58	25-May 13:37
88	4.39	N	59.5233	E	32.2	4082	25-May 16:33	25-May 19:54

89	4.7962	N	59.8912	E	32.8	3914	25-May 23:11	26-May 2:26
90	5.1963	N	60.2593	E	32.6	3380	26-May 5:41	26-May 8:54
91	5.594	N	60.6242	E	32.3	3156	26-May 12:08	26-May 14:58
92	5.9937	N	60.9907	E	32.5	3419	26-May 18:13	26-May 21:11
93	6.3948	N	61.3570	E	32.5	3019	27-May 0:26	27-May 3:12
94	6.7917	N	61.7237	E	32.3	3551	27-May 6:26	27-May 9:29
95	7.1922	N	62.0882	E	32.4	4065	27-May 12:34	27-May 16:09
96	7.5947	N	62.4597	E	32.7	4070	27-May 19:26	27-May 22:46
97	7.9943	N	62.8283	E	32.5	4344	28-May 2:01	28-May 5:31
98	8.3963	N	63.1947	E	32.5	4673	28-May 8:46	28-May 12:26
99	8.7948	N	63.5632	E	32.4	4564	28-May 15:40	28-May 19:17
100	9.1963	N	63.9295	E	32.4	4506	28-May 22:32	29-May 2:07
101	9.5985	N	64.2978	E	32.5	4464	29-May 5:22	29-May 8:56
102	9.992	N	64.6687	E	32.2	4423	29-May 11:51	29-May 15:24
103	10.5407	N	64.6662	E	32.9	4384	29-May 18:08	29-May 21:39
104	11.0757	N	64.6652	E	32.1	4314	30-May 0:20	30-May 3:48
105	11.6222	N	64.6673	E	32.8	4249	30-May 6:32	30-May 9:59
106	12.1607	N	64.6680	E	32.3	4209	30-May 12:40	30-May 16:05
107	12.7032	N	64.6672	E	32.6	4158	30-May 18:48	30-May 22:11
108	13.2435	N	64.6673	E	32.4	4091	31-May 2:15	31-May 5:36
109	13.7855	N	64.6662	E	32.5	4055	31-May 8:51	31-May 12:26
110	14.3258	N	64.6673	E	32.4	3946	31-May 15:40	31-May 18:57
111	14.8667	N	64.6673	E	32.5	3927	31-May 22:11	1-Jun 1:27
112	15.1408	N	65.1405	E	32.0	3854	1-Jun 4:39	1-Jun 8:52
113	15.4149	N	65.6143	E	32.0	3795	1-Jun 12:04	1-Jun 16:15
114	15.689	N	66.0888	E	32.0	3800	1-Jun 18:55	1-Jun 23:07
115	15.9631	N	66.5639	E	32.0	3830	2-Jun 1:47	2-Jun 4:59
116	16.2372	N	67.0397	E	32.0	3649	2-Jun 7:39	2-Jun 11:33
117	16.5112	N	67.5161	E	32.0	3127	2-Jun 14:13	2-Jun 17:02
118	16.7853	N	67.9932	E	32.0	3528	2-Jun 19:57	2-Jun 23:59
119	17.0593	N	68.4710	E	32.0	3594	3-Jun 2:54	3-Jun 7:28
120	17.3334	N	68.9496	E	32.0	3479	3-Jun 10:23	3-Jun 14:23
121	17.575	N	69.4833	E	33.8	3385	3-Jun 17:28	3-Jun 21:25
122	17.7202	N	68.9816	E	30.0	3494	4-Jun 0:09	4-Jun 3:10
123	17.8654	N	68.4795	E	30.0	3458	4-Jun 5:54	4-Jun 8:54
124	18	N	68.0000	E	28.5	3426	4-Jun 11:29	4-Jun 14:28

Goa	15.43	N	73.7900	E	366.7	0	6-Jun 7:00	6-Jun 7:00

10.2. Properties Measured During I07N

Property Name	Description	Units	Principal Investigator	Responsible Party Onborad
ctdprs	CTD Pressure	dbars	Molly Baringer / Gregory Johnson	Kristene McTaggart
ctdtmp	CTD Temperature	ITS-90	ditto	ditto
ctdsal	CTD Salinity	PSS78	ditto	ditto
ctdoxy	CTD Oxygen	umol/kg	ditto	ditto
LADCP	N/S velocity	m/s	A. Thurnherr	Amanda Fay
LADCP	E/W velocity	m/s	ditto	ditto
LADCP	Vertical velocity	m/s	ditto	ditto
btlsal	Bottle salinity	PSS78	Molly Baringer	Andrew Stefanick
oxygen	Bottle dissolved oxygen	umol/kg	Chris Langdon	Emma Pontes / Samantha Ladewig
silcat	silicate	umol/kg	Jia-Zhong Zhang / Calvin Mordy	Ian Smith /Eric Wisegarver
phspht	phosphate	umol/kg	ditto	
nitrat	nitrate	umol/kg	ditto	
nitrit	nitrite	umol/kg	ditto	
	amonnia	umol/kg	ditto	
tcarbn	dissolved inorganic carbon	umol/kg	Rik Wanninkhof (AOML)	Chuck Featherstone & Dana Greeley
underway pco2	surface water pCO2	uatm	ditto	ditto
cfc11	CFC-11	pmol/kg	John Bullister	Bonnie Chang
cfc12	CFC-12	pmol/kg	ditto	ditto
sf6	sulfur hexafluoride	fmol/kg	ditto	ditto
ph	pH	1	Rik Wanninkhof (AOML) / Frank Millero (RSMAS)	Ryan Woosley
alkali	total alkalinity	umol/kg	ditto	Ryan Woosley
doc	dissolved organic carbon	umol/kg	Dennis Hansell	Shinichiro Umeda

tdn	total dissolved nitrogen	umol/kg	ditto	ditto
di14c	dissolved inorganic 14C	Δ14C	14C: A. McNichol/R. Key/A. Gagnon	Shinichiro Umeda
POC	Particulate Organic Carbon	umol/L	A. Martiny	Catherine Garcia
PON	Particulate Organic Nitrogen	umol/L	ditto	ditto
POP	Particulate Organic Phosphorus	umol/L	ditto	ditto
TBD	DNA metagenomic analysis	none	ditto	ditto
DNSSAL	Density salinity	g/kg	Hiroshi Uchida	Shinichiro Umeda
CALCIUM	Calcium	mmol/kg	Akihiko Murata / Shinichiro Umeda	Shinichiro Umeda
DOC14	DOC 14C	Δ14C	Druffel/Walker	Christian Lewis
Black Carbon	Black Carbon 14C	Δ14C	Druffel/Walker/Lewis	Christian Lewis
WDO	Walker dissolved organics		Walker/Abdulla	Christian Lewis
Biomarkers	Dissolved amino acids	nanomole/ kg	Walker/Kaiser	Christian Lewis
CTDBEAMCP	Beam c	/meter	Wilford Gardner/Mary Jo Richardson	Kristene McTaggart
Density	Density	g/kg	Frank Millero (RSMAS)/Ryan Woosley (MIT)	Fen Huang
Pteropods	Bongo net sampling		Nina Bednarsek (SCCWRP)	Catherine Garcia, Victoria Coles

10.3.Sampling Notes

Note: #x = Niskin x (where x = position 1-24, not serial number)

Station 1, Cast 1:
#1 sampled without gloves.
#2 sampled without gloves.
#10 did not fire.

Station 2, Cast 1:
#13 leaking from the bottom cap.

Station 3, Cast 1:
Gloves required.
#13 small leak from the bottom cap.

Station 4, Cast 1:
#24 replaced valve on 278 CFC syringe

Station 5, Cast 1:
Gloves required
#10-12 No sampling on these bottles because of there was a problem to fire them
#13 small leak

Station 6, Cast 1:
#7 small leak at the bottom.

Station 7, Cast 1:
Gloves required

Station 8, Cast 1:
#24 was not fired (operators mistake).
#18 valve is hard to close

Station 9, Cast 1:
Gloves required

Station 10, Cast 1: [no comments]

Station 11, Cast 1:
Gloves required
02 flask #173 was dropped with the cap closed. no visible damage.

Station 12, Cast 1:
#11 endcap closed over the lanyard when tripped. Oxygen draw temperature seems to be an outlier.

Station 13, Cast 1:
Add sample flags for Chl on Niskins 21-24

Station 14, Cast 1:
Gloves required

Station 15, Cast 1:
Gloves required

Station 16, Cast 1:
#06 broken peacock. No samples, except for nuts and salt
#12 valve was open

Station 17, Cast 1
#06 broken peacock. No samples, except for nuts and salt

Station 18, Cast 1: [no comments]

Station 19, Cast 1: [no comments]
Gloves required

Station 20, Cast 2: [no comments]

Station 21, Cast 1:

Gloves required
#10 broken peacock, but it has been fixed before CFC sampling

Station 22, Cast 1: [no comments]

Station 23, Cast 1:
Gloves required
#6 needs new o-ring
#22 probably misfired.

Station 24, Cast 1: [no comments]

Station 25, Cast 1:
Gloves required
#7 small leak at the bottom.

Station 26, Cast 1: [no comments]

Station 27, Cast 1:
Gloves required

Station 28, Cast 1:
Gloves required

Station 29, Cast 1:
Gloves required
#21 is leaking from the bottom cap

Station 30, Cast 1: [no comments]

Station 31, Cast 1:
Gloves required

Station 32, Cast 1:
Acquired as station 31 cast 2, renamed afterward

Station 33, Cast 1:
Gloves required
#2 bottle was fired at a wrong depth (4060 instead of 4163)

Station 34, Cast 1: [no comments]

Station 35, Cast 1:
Gloves required

Station 36, Cast 1:
Gloves required

Station 37, Cast 1:
#15 heavy leaking. no sampling.

Station 38, Cast 1:
Gloves required

Station 39, Cast 1:
#11 small leak from bottom

Station 40, Cast 1:

Gloves required
#22 closed at 130 instead of 90 dbar
#23 closed at 90 instead of 49 dbar
#24 closed at 49 instead of surface (no surface sample)

Station 41, Cast 1: [no comments]

Station 42, Cast 1:
Gloves required
#18 peacock broken. Only CFC has been sampled.

Station 43, Cast 1:
#11 small leak from bottom cap
#18 peacock broken but all samples were collected.

Station 44, Cast 1:
This is an added station (not initially planned), because the ship had to wait for the MSR clearance for the Seychelles
Gloves required
#2 and #3 same depth
#18 o-ring fell off
#23 cracks on o-ring

Station 45, Cast 1: [no comments]

Station 46, Cast 1:
Gloves required
#12 vent was open

Station 47, Cast 1:
Gloves required
#11 and #16 run out water. No salts, DOC14 and WDO samples.
#24 runs out water. no genetic and chl-a sample

Station 48, Cast 1:
Gloves required

Station 49, Cast 1: [no comments]

Station 50, Cast 1:
Gloves required

Station 51, Cast 1:
#5 peacok broken but all parameters were sampled
#24 ctd cames out during the firing due to a rogue wave

Station 52, Cast 1:
Gloves required

Station 53, Cast 1:
Gloves required because of biomarkers
O-ring broke on #5, repared by Dana
O2 temperature was not recorded on #5

Station 54, Cast 1:
Gloves required

Station 55, Cast 1: [no comments]

Station 56, Cast 1:
Gloves required
#17 o-ring broken before cfc sampling. it was replaced by a new ones. all samples have been taken
#24 small bottom leaking

Station 57, Cast 1:

Station 58, Cast 1:

Station 59, Cast 1:
#2 tripped on surface
#7 heavy leak from bottom
#11 leak from bottom
#24 leak from bottom

Station 60, Cast 1:
Gloves required
#7 heavy leak from bottom
#11 small leak from bottom

Station 61, Cast 1:
#16 dripping from the nipple reported, but then stopped
#20 small drip from the bottom cap

Station 62, Cast 1:
Gloves required

Station 63, Cast 1:
#20 small leak

Station 64, Cast 1:
Gloves required

Station 65, Cast 1:
Gloves required
#14 extra bottle fired at Chl-maximum

Station 66, Cast 1:
#18 broken during CFC. fixed.

Station 67, Cast 1:
Gloves required
#23 leaked out

Station 68, Cast 1:
#16 o-ring was replaced
#18 o-ring went off but not damaged

Station 69, Cast 1:
Gloves required
#17 ph was sampled after #20

Station 70, Cast 1:
#1 leaking from bottom but it was fixed during the CFC sampling

Station 71, Cast 1:
Gloves required

#23 and #24 software error, but bottles have been fired

Station 72, Cast 1:
Gloves required
#6 vent was open
#22 leaked from the bottom cap
#23 didnt close well. no sampling.

Station 73, Cast 1: [no comments]

Station 74, Cast 1:
Gloves required
Oxygen #6 was sampled after #7

Station 75, Cast 1:
#6 was leaking from bottom when came out

Station 76, Cast 1:
Gloves required
#1 was leaking from bottom

Station 77, Cast 1:
#1 did not fire

Station 78, Cast 1:
Gloves required
#15 leaked out. No sampling.

Station 79, Cast 1:
air may have entered bottle #18 during CFC sampling

Station 80, Cast 1:
bottle #1 leaking out the back o-ring
bottle #15 broke, no sampling from it

Station 81, Cast 1:
Gloves required

Station 82, Cast 1:
#1 had a small leak
#15 and #18 broken before CFC, but they have been fixed
#22 giving air bubbles CFC sampling

Station 83, Cast 1:
it took time to sample bottle #3 for O2
o-ring on bottle #11 broke
o-ring on bottle #18 went off, but was put back with no damages

Station 84, Cast 1:
#23 strong leak from the bottom, no sampling

Station 85, Cast 1:
Gloves required

Station 86, Cast 1:
Gloves required
#2 is probably contaminated by surface waters. Oxygen was off.

Station 87, Cast 1:
#1 o-ring has little cracks
#9 pull ring was in, but vent was closed, no leak seen

Station 88, Cast 1:
Gloves required
#15 and #16 fired at the same depth (600 m)

Station 89, Cast 1: [no comments]

Station 90, Cast 1:
Gloves required
#22 vent was open
bottles specifically fired at #12 (02 minimum), #13 (subsurface salinity max), #14 oxycline and #22 (DCM)

Station 91, Cast 1: [no comments]

Station 92, Cast 1:
Gloves required
#15 leaked from the bottom cap. No sampling.
#20 02 flask 256- chemical may not been pushed all the way to the bottom.

Station 93, Cast 1:
Gloves required
line #3 got caugth by bottom 2
#1 small leak
#3 leaked bad. No CFC, O2, DIC, ph, alkalinity, calcium, salt samples. Nuts and biomarkes samples were taken.

Station 94, Cast 1: [no comments]

Station 95, Cast 1:
Gloves required

Station 96, Cast 1:
Gloves required
#16 was supposed to be fired at 700m, but this depth was missed, fired at 550m instead

Station 97, Cast 1:
Gloves required
#20 intermittent little leak

Station 98, Cast 1:
#20 had a small leak from the bottom endcap
#23 no duplicates

Station 99, Cast 1:
Gloves required
#6 lanyard caught in bottom endcap, badly leaking, not sampled
#20 Niskin will be replaced prior to station 100

Station 100, Cast 1:[no comments]

Station 101, Cast 1:
Gloves required
#13 and #20 small leaking

Station 102, Cast 1:

Station 103, Cast 1: [no comments]

Station 104, Cast 1:
Gloves required

Station 105, Cast 1:
Gloves required
#20 leaking peacock after close

Station 106, Cast 1:
Gloves required
#22 depth changed to capture fluorescence maximum

Station 107, Cast 1: [no comments]

Station 108, Cast 1:
#15 o-ring came out twice, but fixed
#23 water was coming out of the niki bottle even with closed vent. Only nuts, salt and chrolophyll samples have been taken

Station 109, Cast 1:
Gloves required

Station 110, Cast 1: [no comments]

Station 111, Cast 1:
Gloves required
#20 o-ring broken, but fixed

Station 112, Cast 1:
#13 small leaking bottle cap

Station 113, Cast 1:

Station 114, Cast 1:

Station 115, Cast 1:
Gloves required

Station 116, Cast 1:
#7 o-ring broken

Station 117, Cast 1:
Temperature for O2 on #14 looks suspicious. The two temperature probes used were showing different temperatures on #24.
When taken indores for inspection, they were back to normal. Suspec sensitivity to hot weather and humidity.

Station 118, Cast 1:
Gloves required
#13 small leaking from bottom

Station 119, Cast 1:
Gloves required
#22, #23, and #24 run out water. Bio group only sample #23 for DCM

Station 120, Cast 1: [no comments]

Station 121, Cast 1:

Gloves required
vent on bottle #23 was not closed

Station 122, Cast 1: [no comments]

Station 123, Cast 1:
Gloves required
#2 oxygen was sampled after #4

Station 124, Cast 1: [no comments]

10.4. Weekly Reports

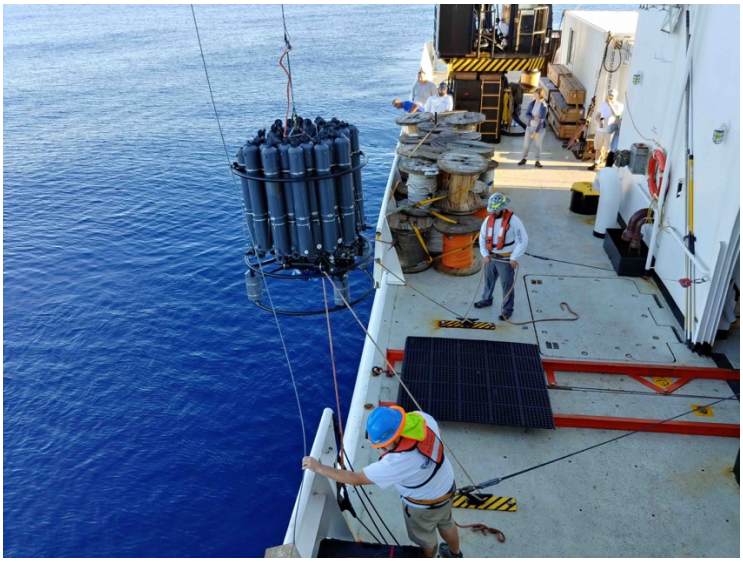
10.4.1. Week 0

Departed Durban (South Africa) on April 23, 2018, headed for I07N

The I07N cruise was initially planned to start in February, however, due to the ship's engine problems all cruises onboard the R/V Ronald Brown scheduled this year were postponed. Our departure date was shifted to April 23. Most of our scientific gear was loaded on the Brown while the ship was in Charleston and during a port call in Fort Lauderdale. Only the LADCP gear and some additional sample bottles were shipped to Durban. This made the mobilization in Durban relatively easy. All I07N scientist safely made it to Durban without delays. Half of the group came to the ship on April 20 and started setting up their lab spaces and equipment, and all scientists moved onboard on April 22, our official staging day. On this day, we also had our first All-Hands meeting, when all participants introduced themselves to the rest of the group, the chief scientist talked about the station plan and schedule for the first 2 weeks, and both the operations and the security officers did a 'welcome onboard' briefing. After clearing customs and immigration, we departed at 2 pm local time on April 23. So far everything is going smoothly and according to the schedule. Our next report will cover our transit towards the first station of I07N at 30°S and 54.5°E, during which we will do two test casts, deploy an Argo float, a wave buoy, and drifters.

10.4.2.Week 1 (Apr. 23-29)

Departed Durban (South Africa) on April 23, 2018, headed for I07N



The rosette is being lowered at the I07N first test station.

We departed from Durban on April 23 at 2 pm local time. During the first day and night the ocean was a little rough, but everybody onboard could cope with it reasonably well. On the first day of the cruise we deployed the first SVP drifter in the Agulhas Current. On the second day, we did the "fire" and "abandon the ship" drills. Later we also had an "Egress" drill when everybody had to find the way out being blindfolded (that was a lot of fun!). The crew is paying significant attention to safety, and everybody understands that safety is our top priority.

The second SVP drifter was deployed on April 25. On the same day we reached the first test station and did a CTD cast down to 3000 m firing all Niskin bottles. Two bottles were fired at the same depth (80 m) as was requested by our oxygen group. Because the ship had issues with the aft winch during previous cruises, we decided to test this winch once again using it for the first test cast. The first cast showed that the issue remains, and it is reflected in modulo error, in particular during the upward cast. Tests indicate that the problem is unlikely to be related to the cable or termination, but it's rather in the winch itself. Unfortunately, there is nothing that can be done onboard to fix the problem. We will proceed using the forward winch instead, which worked flawlessly during the previous cruises. The first test cast was mostly dedicated to teaching students, so not all groups were involved, and not all depths were sampled. On April 25, we also deployed the first (NAVIS type) Argo float from NOAA-PMEL. The ship slowed down to 1.5 knots, and the float was released from the port side of the stern. On April 26 we deployed the first (out of four) wave buoy from Scripps Institution of Oceanography. We decided to move the location of the second test station a little further east than we initially planned, because we wanted to do a cast deeper than 5000 m and past a sea mountain on our way, so eventually we did the second test cast down to just above the bottom at 5240 m. This time we used the forward winch and it worked very well. After about 14 hours of steaming from the second test station, we reached the first station of the I07N line in time according to our schedule, and the I07N survey officially began. By the end of the week, we have completed 7 stations. On station 7 we did the first net tow, and our biologists seem to be satisfied with the catch.

We have not had major issues overall. The forward winch has worked very well. Among the minor issues, we have occasional leakages from the bottom caps of Niskin bottles that are easily fixed between the stations.

One of the minor concerns so far is timing. The distance between the stations south of 22.5 S (stations 4 to 21) is only 20 miles, which takes less than 2 hours of steaming. When all groups are sampling, sometimes we are not able to complete sampling before we arrive at the next station. Upon the arrival at the next station, the ship is just waiting for sampling to be completed and then the rosette goes in the water right away. Because of this, we are currently running about 4 hours behind the schedule. The most time consuming was sampling for black carbon on stations 2-4. We will not do black carbon until station 22, so we are hoping that our sampling time will improve, and we will

be able to make some time to return on schedule. When the distance between the stations increases to 30 nm, the ship will be able to steam at a higher speed, which will also bring us closer to the schedule.

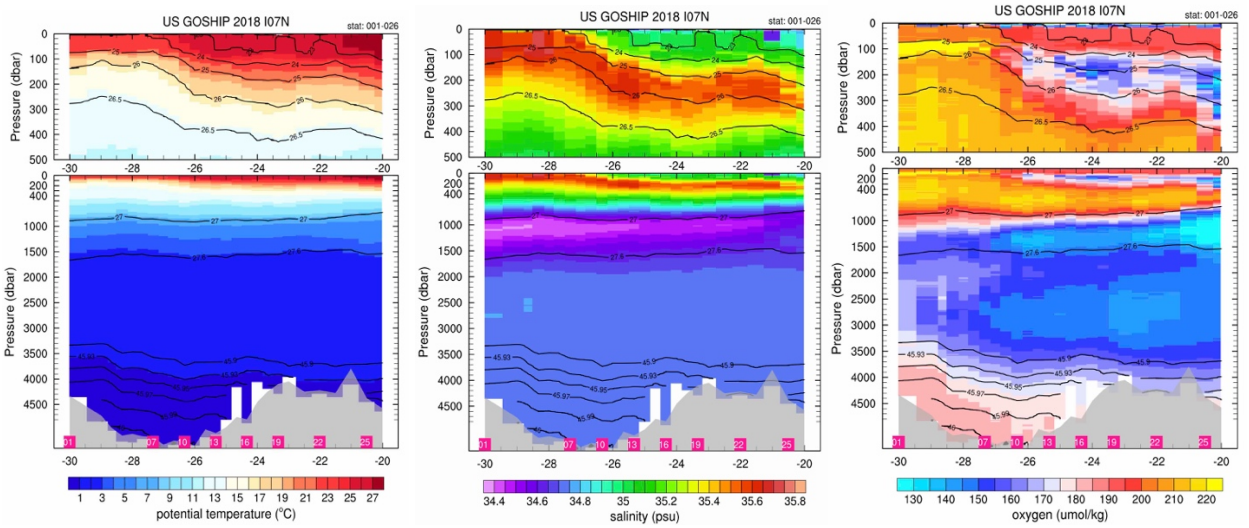
The ship's leadership and the entire crew has been very professional and attentive to our needs. The galley is keeping us well fed, including those with dietary restrictions. We have been enjoying calm seas and everybody onboard is doing well.

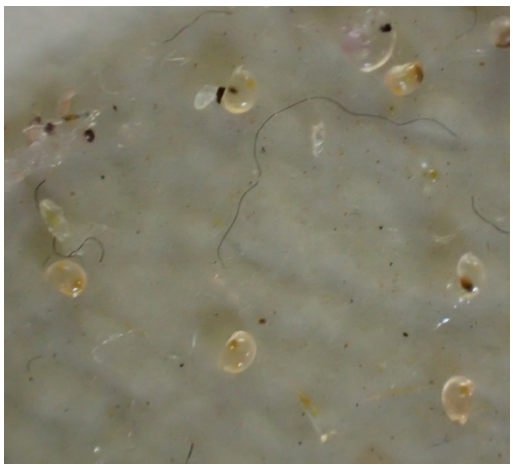
10.4.3. Week 2 (Apr 30 - May 6)

On the second week of the cruise the science team is very well adjusted to the daily routine: shifts, CTD casts, sampling, data and sample analysis, meals, sleep, etc.. The beginning of the week was rather dense, because the distance between the stations was ~20 nm, but at the end of the week the distance increased to ~30 nm, which took off some stress and let us return on schedule by steaming faster during transits. The weather has been relatively good. Occasionally we have some wind and swell, but nothing major yet that would impact operations. Hopefully, we will have the same weather all the way to Goa. As we go north, when the sky is clear, which is almost every day, we enjoy watching the sunset on the port side of the ship followed by a spectacular moonrise on the starboard (as shown by photographs above).

By the afternoon of May 6, we have completed 33 stations (25 stations last week), so exactly a quarter of all planned stations on the I07N line. We deployed a drifter and 3 Argo floats. Everything worked well, and we experienced no major issues. On station #24, close to the Reunion Island, we had to deviate a little from our route, because the French were conducting military exercises offshore the island, and our station was in the "no sail" area. Because of this, we decided to move station #24 10 nm westward, but still keeping it on the same latitude. As we were approaching the Exclusive Economic Zone (EEZ) of Tromelin Island, which is a disputed territory between France and Mauritius, we were getting more and more anxious about not having the Marine Scientific Research clearance from Mauritius. We finally received it when we were only a day away from entering the Tromelin EEZ. That was a big relief! Now we are still waiting for clearances from the Seychelles and India…

As a quarter of the I07N stations is already behind the stern, we are starting to look at the data we have collected. Displayed in the left figure below is the potential temperature for the first 26 stations if I07N obtained by CTD (this is raw data without corrections). Stations 1-26 run along the 54.5 E meridian. The top panel shows the upper layer and bottom panel the whole water column. Black curves in the top panels are sigma-0 density; in the bottom panels they are sigma-0 (above 200 m) and sigma-4 (below 3000 m) densities. The volume between 27 and 27.6 is occupied by the AAIW (Antarctic Intermediate Water). Below 3000 m, the cold waters (< 3^{o}C) represent the AABW (Antarctic Bottom Water). The AAIW, trapped in the 27-27.6 density layer, is clearly seen in the middle plot that shows the salinity profile. Near the surface at ~28S, there is a signature of the subduction of the saltier subtropical water. The vertical profile of oxygen (the right plot) shows an increased oxygen concentration near the bottom, indicating recent ventilation, which is a clear AABW signature.





Our biologists have been busy too. By the end of the second week of the cruise, they have completed 3 net tows. One of the reasons for towing the net is to collect samples for studying whether the skeletons of pteropods are gradually dissolving because of the increase in acidity of the oceans due to increasing CO2. Victoria Coles and Hannah Morrissette caught a bunch of them on their filters the other night (see photo on the left). Pteropod's shells are aragonite and are sensitive to the pH of the ocean. Just like a soda, adding CO2 to the ocean makes it more acid.

We are making 12 knots towards our next station #34, which should be completed by the end of May 6. Next week we will be crossing the Mascarene Basin, and we will attempt to find and (if found) to recover a PMEL mooring, the communication with which was lost 5 years ago. Stay tuned!

10.4.4.Week 3 (May 7 - May 13)

This week was relatively rich for events. It started as usual with routine operations at stations. An Argo float and a mini wave buoy were deployed on the first day of the week. The weather was good as in previous weeks, and all operations were going smoothly. On the second day we entered the Mauritius EEZ, and by the end of the day we reached the location of a PMEL mooring, communication with which was lost 5 years ago. We were asked to attempt to find the mooring and, if the buoy is present, to recover the mooring or at least to make pictures of the buoy if we are off the schedule. We arrived at the mooring location in the dark, however, the weather was favorable, and the visibility was good enough. Being well equipped with the ship's radar, night vision device, and a searchlight we started the search. Our plan was to locate the buoy, proceed to the next station (#42), and then return to the mooring and recover it next day in the morning. However, the buoy was not present. After hovering around for about an hour, the transducer was lowered at the last reported position of the mooring and disable command was sent. Unfortunately, the mooring is lost.

Although we did not have to spend much time for the recovery and proceeded to the next station right away, our anxiety was growing because we still did not have the Marine Scientific Research (MSR) clearance from the Seychelles. And by the time we reached the boundary between the Mauritius and Seychelles Exclusive Economic Zones (EEZs), the clearance was not issued. Whatever the bureaucratic reasons were involved, we were just stranded. Apparently, up to this moment the cruise was going too smooth, so something had to happen. And it happened. The situation was complicated by the fact that our Mauritius clearance was expiring at midnight on the

day we arrived at the boundary. Therefore, there was not much we could do inside the Mauritius EEZ. We did a full-depth CTD cast just 3 nm off the Seychelles EEZ boundary, which became our new station 44. Then we did a net tow at around 10 pm. But at midnight all science operations were ceased, and all underway systems were turned off. We decided to wait for the clearance at station 44 and not to proceed to the next station. This would allow us to have continuous in space underway data once the clearance is issued. On the next day by noon, we still did not have clearance, so we started to prepare for the worst. We sent a request to the person who issued clearance for Mauritius asking him for an extension, which would let us return to a turning point at station 40 and head northeastward around the Seychelles EEZ. We had identified possible locations for 10 new stations inside the Mauritius EEZ. Fortunately, the Seychelles clearance came at around 2 pm, and we immediately rushed to the next I07N station.

The delay with clearance costed us one full day at sea, but at least we did not have to change the route. As a result, we had to cancel 5 stations to return on schedule. We decided to cancel stations 48, 50, 58, located over relatively flat bottom topography, and stations 52 and 54, located over the slopes of sea mountains. Cancelling the stations increased the spacing between the stations along the corresponding segments from 17 to 34 nm. But we still retained the short spacing between the stations over the Amirante Trench. A map of stations near the Amirante Trench, including those canceled, is displayed in fig. 1. We are still a little behind the schedule as the sea state does not permit seaming faster than 10 knots. Postponing the last station on leg 1 to leg 2 is not a desirable option, however, because it would take about half a day from the leg 2 schedule just for steaming given the large area of the Seychelles bank we will have to cross. But we will do that if necessary as there'll be no more cancellations on the leg 1.

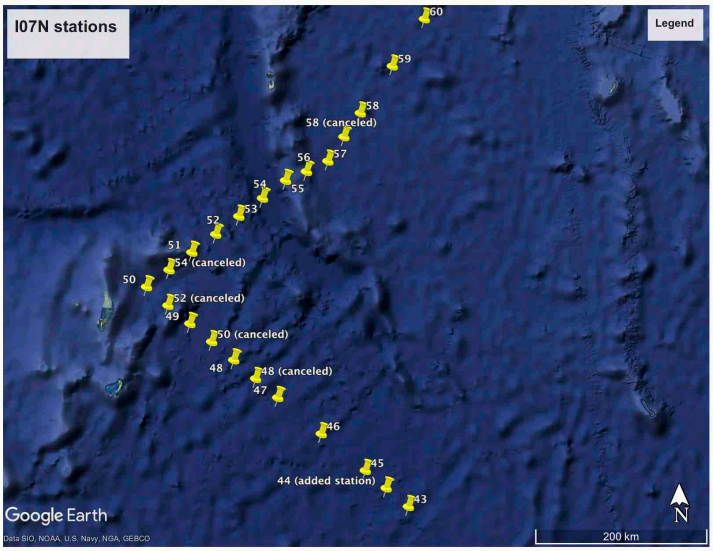


Figure 1. *A map with stations near the Amirante Trench. Stations 48, 50, 52, 54, and 58 were canceled.*

As we are completing the first leg of the cruise, some interesting scientific findings are starting to emerge. Below are the profiles of temperature, salinity, and oxygen from station 1 at 30°S to station 57 at about 8°S (fig. 1). We have passed a warm pool bounded by the eastward South Indian Countercurrent in the south and the westward South Equatorial Current in the north. We have observed the saltier subtropical water that subducts under the warm and less saline near-surface water. This subtropical water was still seen at our last CTD cast. The Antarctic Intermediate Water (AAIW) is not observed beyond station 38 (~14°S). The increased oxygen concentrations near the bottom associated with the Antarctic Bottom Water (AABW) are observed everywhere along the first leg of the cruise. What we find particularly interesting with regard to AABW is the observed concentrations of CFC in comparison to those observed in 1995 (see fig. 2). As you can see, in 2018 we have observed substantially higher concentrations of CFC in the AABW layer, which means that new AABW was formed over the last 23 years and advected all the way to the tropical latitudes of the Indian Ocean.

We are just one day away from our port stop in Victoria. Besides the issues with clearances and the necessity to cancel 5 stations on the first leg, everything else has been going well. The instruments are working great, no problems with the forward winch. The next report will cover only 3 days at sea during the fourth week as the other 4 days we will spend on shore.

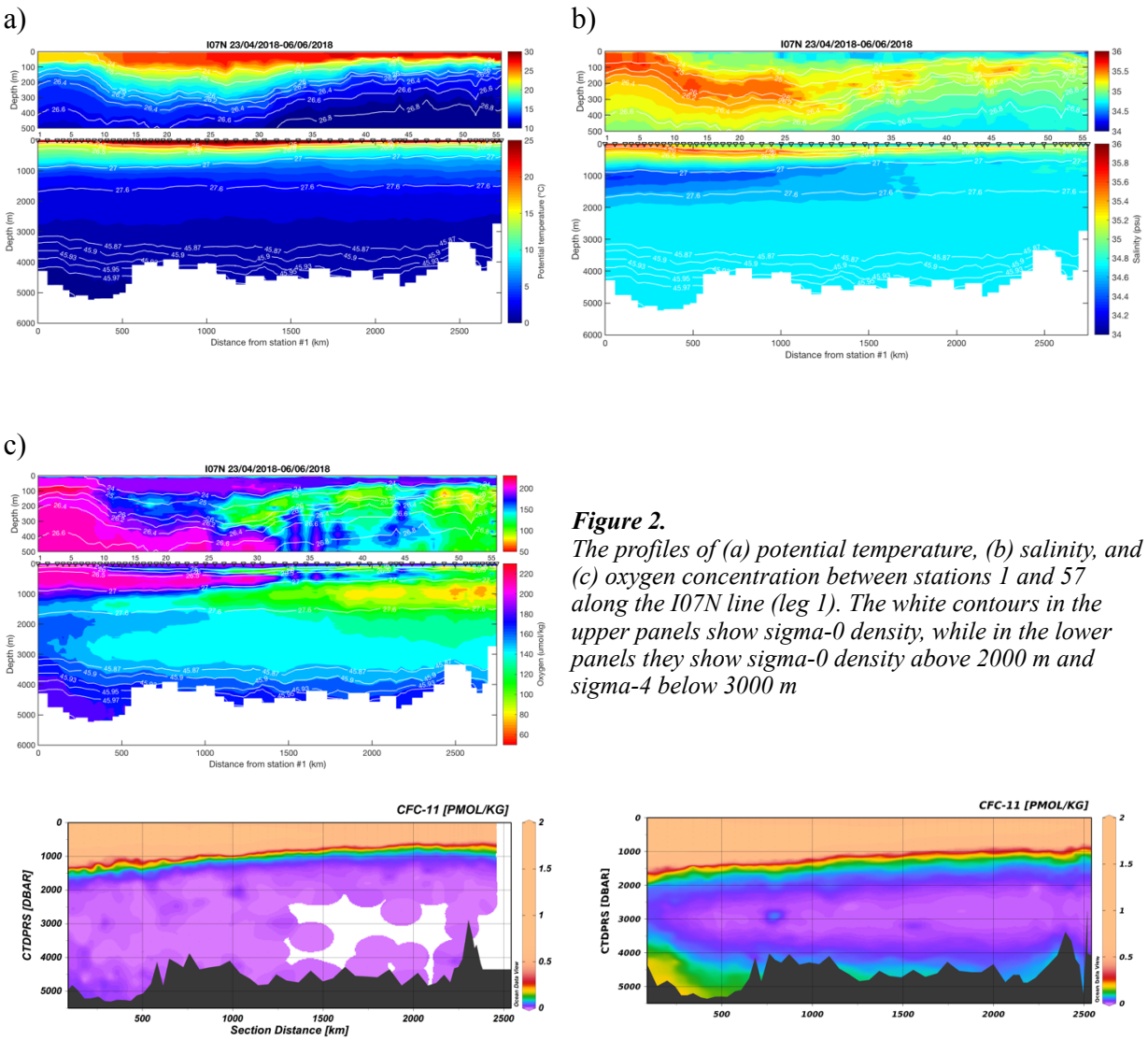


Figure 2.
The profiles of (a) potential temperature, (b) salinity, and (c) oxygen concentration between stations 1 and 57 along the I07N line (leg 1). The white contours in the upper panels show sigma-0 density, while in the lower panels they show sigma-0 density above 2000 m and sigma-4 below 3000 m

Figure 2. *CFC concentrations along the I07N line (left panel) in 1995 and (right panel) in 2018.*

10.4.5.Week 4 (May 14 - May 20)

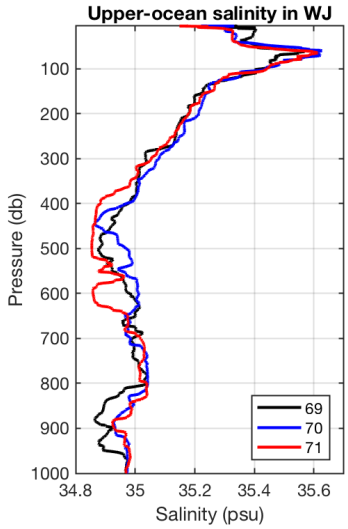
Leg 2: Departed Victoria on May 19, headed to Goa (India)

And here, we would probably end the past week's report … ☺️

… if the port call in the Seychelles lasted the whole week. But science operations ended on Tuesday morning and re-started after our departure from Victoria on Saturday afternoon. On Monday and Tuesday, we did stations 59-64 (6 CDT casts with depths ranging from about 900 to 3800 m) with no cancelations like during the previous week. We deployed a drifter at 7°S and a wave buoy at 6°S. Upon completing the last station of leg 1, we steamed to Victoria and anchored off shore. After clearing customs and being briefed by an NCIS agent, we disembarked and enjoyed the solid ground and the beauty of the island… Overall, the port stop worked very well, in particular for the moral onboard, because in the end people returned back safe, well-rested, and enthusiastic about the second leg of the cruise. So, we are all grateful for that. A photograph below shows some scientists onboard the Brown after their return. Yes, only some, 18 out of 26…

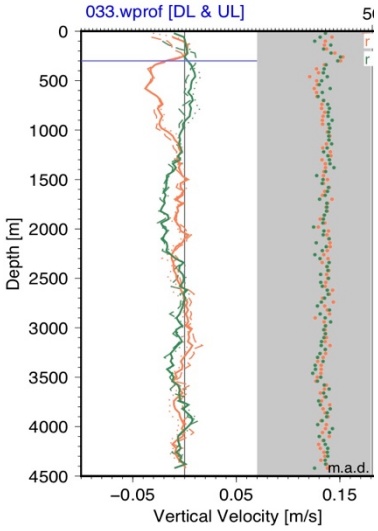
But do not worry. Nobody decided to stay or was left behind in the Seychelles! ☺️ One person was taking the picture and the rest were either helping or watching Andy Stefanick and Jay Hooper to wire the rosette. We will definitely make another group picture after we complete all stations of the cruise. In Victoria, we were expecting an Indian scientist to board the ship and join the cruise. Unfortunately, the Indian participant did not arrive as his participation was eventually not approved by his institution. This, however, has no impact on our science operations, and we will continue as we did during the leg 1. The entire science team is working together very well, everybody is very professional and responsible, knows the needs of each other, so help is always there when required.

Since our departure from Victoria, we have completed 7 stations, which makes the total of 71 stations from the beginning of the I07N cruise. The first station after Victoria (#65) was done about 5 nm westward from the location occupied in 1995. The reason for that is that the original station 65 is located within the territorial waters of Seychelles (within 12 nm zone of Denis Island), and we did not have MSR clearance to sample in the territorial waters. Since the beginning of the leg 2 we have already deployed 3 Argo floats, 2 drifters, and did 1 net tow. At station 69 we experienced a very strong surface current, because of which the ship drifted about 1 nm eastward while doing a CTD cast. The ship's 75KHz "Ocean Surveyor" ADCP showed the eastward component of the current with a strength of up to 1 m/s (see figure below on the left). We think this current is related to the strong eastward Wyrtki Jets (WJ), forced directly by the equatorial westerlies.



The WJ occur during the monsoon transition periods of spring and fall, so our cruise happened to be at the right time to observe it. The WJ are associated with increased salinity, which is clearly seen in CTD casts at stations 69-70 (see the right figure on the left). Within the area of the WJ, in addition to CTD casts and underway measurements, we deployed 2 Argo floats at stations 69 and 71 and one drifter at station 70. The drifter deployment at this location was not pre-planned, so it is a "bonus" deployment that we decided to do while transiting this interesting oceanic feature.

Since we started talking about currents, and because the past work week was short, we thought it would also be interesting to bring everybody's attention to a very strong vertical flow we observed during the first leg of the cruise at station 33 (16.8°S). The vertical velocity (w) is derived from LADCP data using a technique developed by Andreas Thurnherr from Lamont-Doherty Earth Observatory, University of Columbia (Amanda Fay is our onboard LADCP operator, but Andreas is the PI of LADCP measurements on GO-SHIP cruises). As displayed in the figure on the right, there was an instantaneous w of up to 4 cm/s between about 300-1000 m depth. Our initial guess was that we saw a signature of an internal wave, which was later confirmed by Andreas. Because the buoyancy period, which is the shortest possible period for w in the internal-wave field, is not long compared to the sampling time of a CTD/LADCP profile, the down- and up-cast data are processed separately. The figure shows that the amplitude of w is similar during the downcast (orange) and upcast (green).



Our research cruise continues and by the end of week 5 we expect to cross the Carlsberg Ridge and enter the Arabian Sea. Stay tuned!

10.4.6.Week 5 (May 21 - May 27)

Leg 2: Departed Victoria on May 19, headed to Goa (India)

In the week 4 report, we told you about the observation of a strong eastward current north of the Seychelles Bank, which we associated with the seasonal Wyrtki Jet. The strong surface eastward flow with velocities ranging from 0.4 to above 1 m/s was observed over about 7° latitudinal band (fig. 1). Because of this current, starting from station 69 (~2.75°S) we started to have twists on the forward winch cable that were causing modulo errors on the CTD. The biggest unloading of twists and caging occurred during recovery of cast 71 (~1.75°S), when the ship's ADCP recorded a strong vertical shear of the flow in the upper 200 m: there was a strong eastward flow in the upper 100 m and a strong westward flow between 100-200 m (fig. 1).

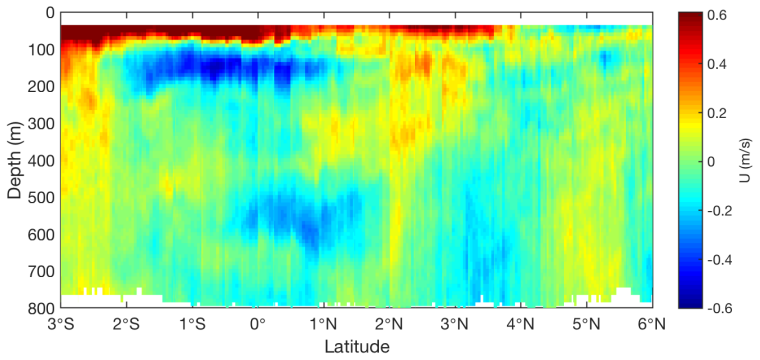


Figure 1. *Zonal velocity measured by the ship's ADCP along the I07N transect north of the Seychelles Bank.*

We had no evidence of caging after cast 72 (~1.2°S), but there was a severe twist near the mechanical termination and several static bends that warranted a re-termination of the cable. The re-termination helped, because we did not have modulo errors at station 73. But when the package was lifted onboard there was a wire twist again. This situation was causing a lot of concern, because we do not have a backup winch to use. As we mentioned in the week 1 report, the aft winch is not usable, because it makes unacceptable amount of modulo errors on the CTD, and all attempts to fix the winch had failed. A continued use of the forward winch with degrading cable would increase the chances of losing the entire package. However, the only solution we had is to keep an eye out for the cable and hope that the situation will improve once we exit the strong current. The cable was re-terminated again after station 77 and between 250-300 m of wire were cut. Fortunately, as the current was getting weaker on our way northward, the cable situation improved considerably. There are no more twists, and most of the time there are no modulo errors on the CTD. We continue to pay attention at the cable and hope that everything goes smoothly for the remainder of the cruise.

By the end of May 27th, we have completed 96 stations. During the past week, we completed 26 stations, deployed 6 Argo floats, 4 drifters, and 1 wave buoy, and did 4 net tows. We still have 32 stations ahead assuming we obtain the MSR clearance from India. If clearance is not obtained until the end of cast 111, we will change the route and follow our plan B, which will bring us as close as possible to the Indian continental slope, but still keeping us outside the Indian Exclusive Economic Zone.

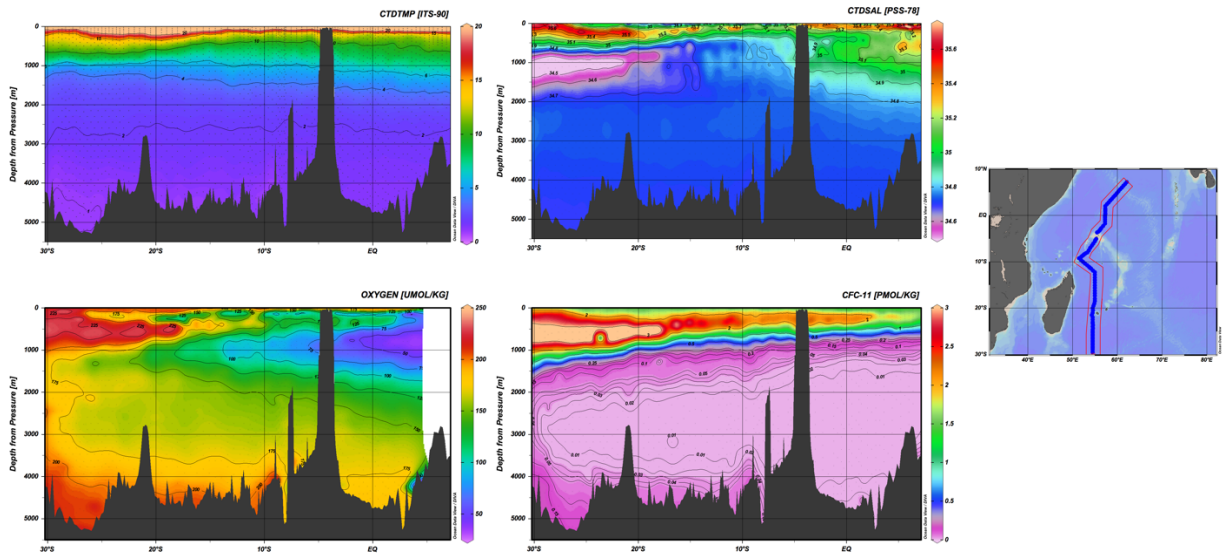


Figure 2. *Profiles of potential temperature, salinity, oxygen and CFC concentrations along the I07N transect in Apr-May 2018.*

As can be seen in Figure 2, after passing the Seychelles Bank (4-5°S) and entering the Somali Basin, we started to observe considerable increase of salinity and decrease of oxygen concentration in the upper ocean – the first signs of approaching the oxygen minimum and salinity maximum zones in the Arabian Sea. During the first leg of the cruise we reported on increased concentrations of CFCs in the Antarctic Bottom Water that were not observed during the previous occupation of the I07N section in 1995. In the Somali Basin, we observe only slightly elevated CFC concentrations near the bottom.

Although the monsoon season has started in the Arabian Sea, the weather has been very favorable to us so far. In fig. 3, you can see the weather forecast for May 27-28 with our track shown by the broken line with circles. It is amazing to see that our track lies right in the middle of the white swath of calm seas. We are tending to think that since we are a NOAA cruise, the NOAA's National Weather Service is taking a special care of us ☺️.

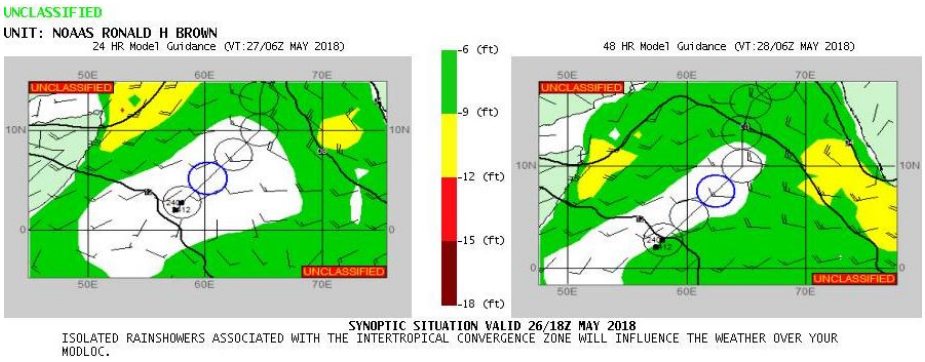


Figure 3. *Weather maps for May 27-28.*

10.4.7. Week 6+ (May 28 – June 5)

Leg 2: Departed Victoria (Seychelles) on May 19, arriving in Goa (India) on June 6.

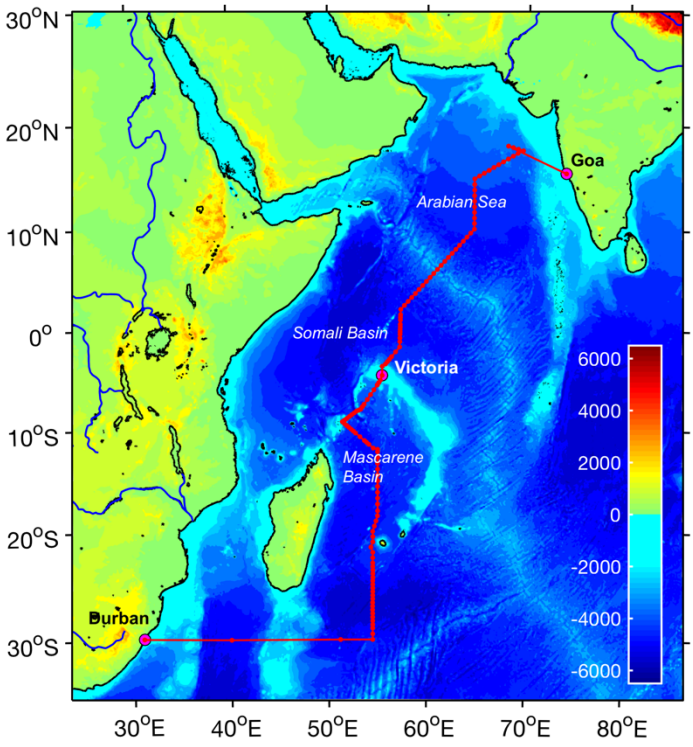


Figure 1 I07N 2018

This is our last weekly report for the GO-SHIP I07N cruise. And here, we are reporting on the last 9 days of the cruise. We just completed station 124, and we expect to arrive in Goa at 8 am on Wednesday, June 6. Overall, the cruise was a success, because we almost completely reoccupied the I07N transect for the first time since 1995. We had some issues with the winch cable (see our previous week 5 cruise report), but after taking some extra care of the cable, the problem was mitigated. During the last 9 days we were keeping a close eye on the state of the cable after each cast. We had to do one more re-termination after getting several modulo errors on the CTD. However, thanks to the extra measures we undertook, the cable situation had no impact on the quality of the data.

At the end of the previous report we left you somewhere over the Carlsberg Ridge. Upon crossing the ridge, we entered the Arabian Sea. Station 111 (~14.9N) was our decision point, from which we would either follow our initial plan A (black dots) or an alternative plan B (red dots) depending on the situation with the Indian Marine Scientific Research (MSR) clearance. Unfortunately, we did not receive the Indian MSR, neither before reaching station 111 nor later. As a result, we decided to follow plan B, which took us as close as possible to the continental slope, but still staying outside the Indian Exclusive Economic Zone (EEZ). Station 121 was the last station on the segment between the turning point at station 111 and the EEZ. Upon reaching station 121, we still had about 2 days available for doing more stations. As one of the wishes for our cruise was to get as deep into the Oxygen Minimum Zone (OMZ) as possible, we decided to head northwestward and reach the 18N latitude – this is the northernmost latitude the ship agreed to sail to due to safety concerns.

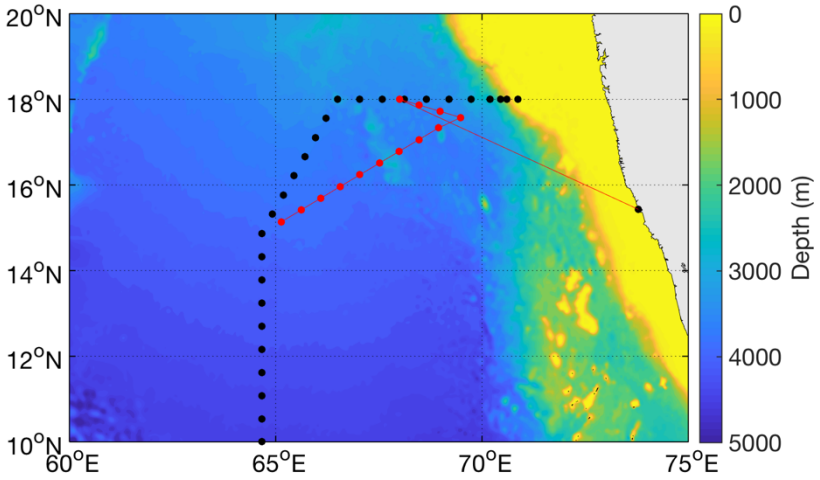


Figure 2 Plans A (black dots) and B (red dots)

Entering the OMZ was a unique experience for the CTD watchstanders and other members of the science party, observing in real-time the oxygen sharply dropping to zero (Figure 3).

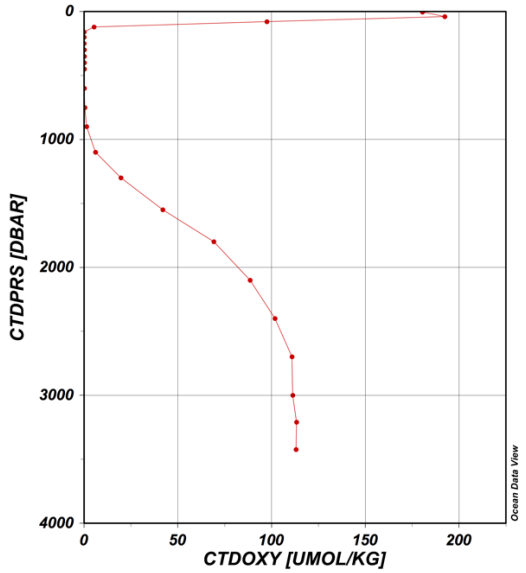


Figure 3 Oxygen Profile at station 121 (17.53° N; 64.48° E). Observe the thick layer of very low oxygen between 160 and 900 m. Red dots indicate the depths that the bottles have been fired.

To better resolve the Arabian Sea sharp features, we changed our sampling scheme at station 112, firing more bottles at the surface layer. We quickly learned that the new scheme was not optimal for all groups since several samples into the deep ocean are also needed. Thus, after only one station, we decided to go back to the previous scheme that was the best possible solution for all of us. We found that even under the old scheme, the OMZ is well defined, occupying a thick layer between 150 and 1000 m as can be seen in Figure 4. Unfortunately, because the final segment of the I07N cruise in 2018 does not follow the same track as the I07N cruise in 1995, we cannot compare the newest data with the previous ones. In 1995, the I07N path headed to Oman in the western Arabian Sea, but due to safety concerns, we couldn't follow their footsteps.

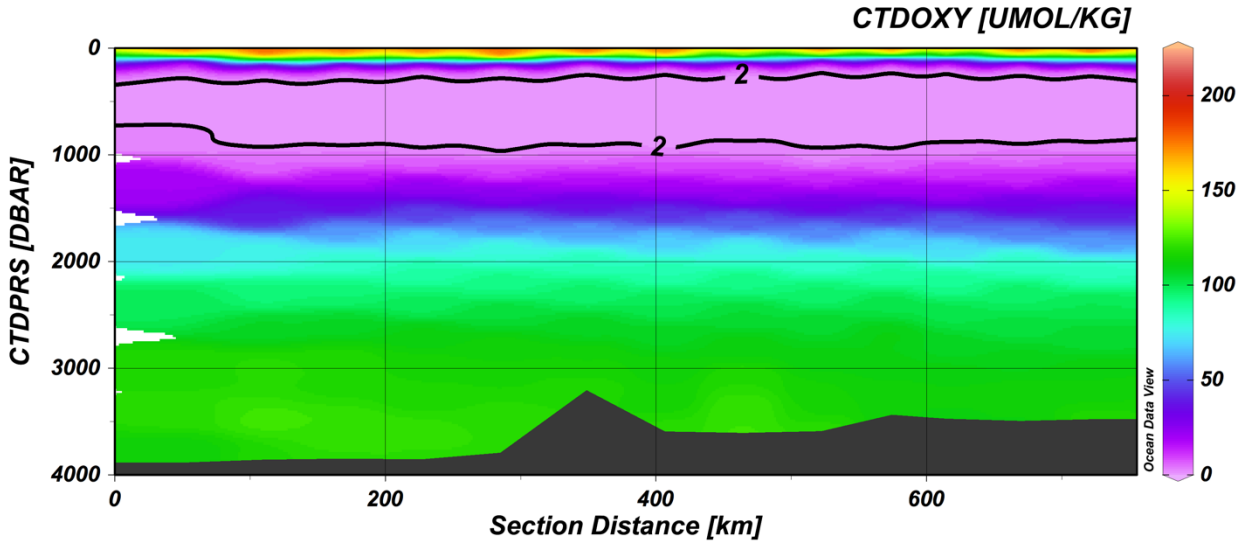


Figure 4 Oxygen concentration between stations 111 and 124 (Plan B in Figure 2)

Another feature of oxygen that caught our attention and let us intrigued was the lower oxygen near the bottom (Figure 5). This feature started around station 104, reached minimum oxygen concentration at station 111 (our inflection point to plan B in Figure 2) and persisted until station 114. A quick look at the 1995 data indicated that this feature was not prominent in that year. Several hypotheses have been discussed onboard from biological to physical mechanisms, but we couldn't decide the best ones without performing a more extensive investigation.

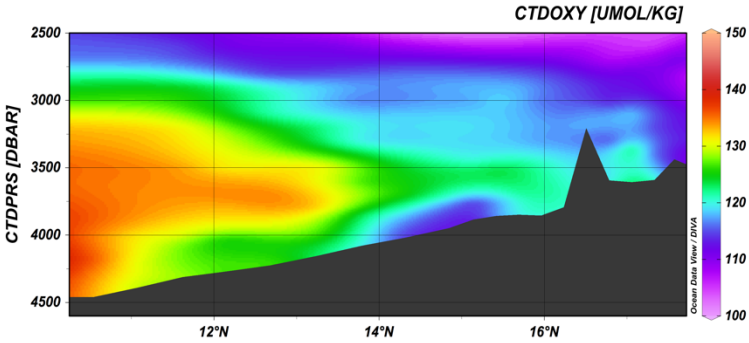
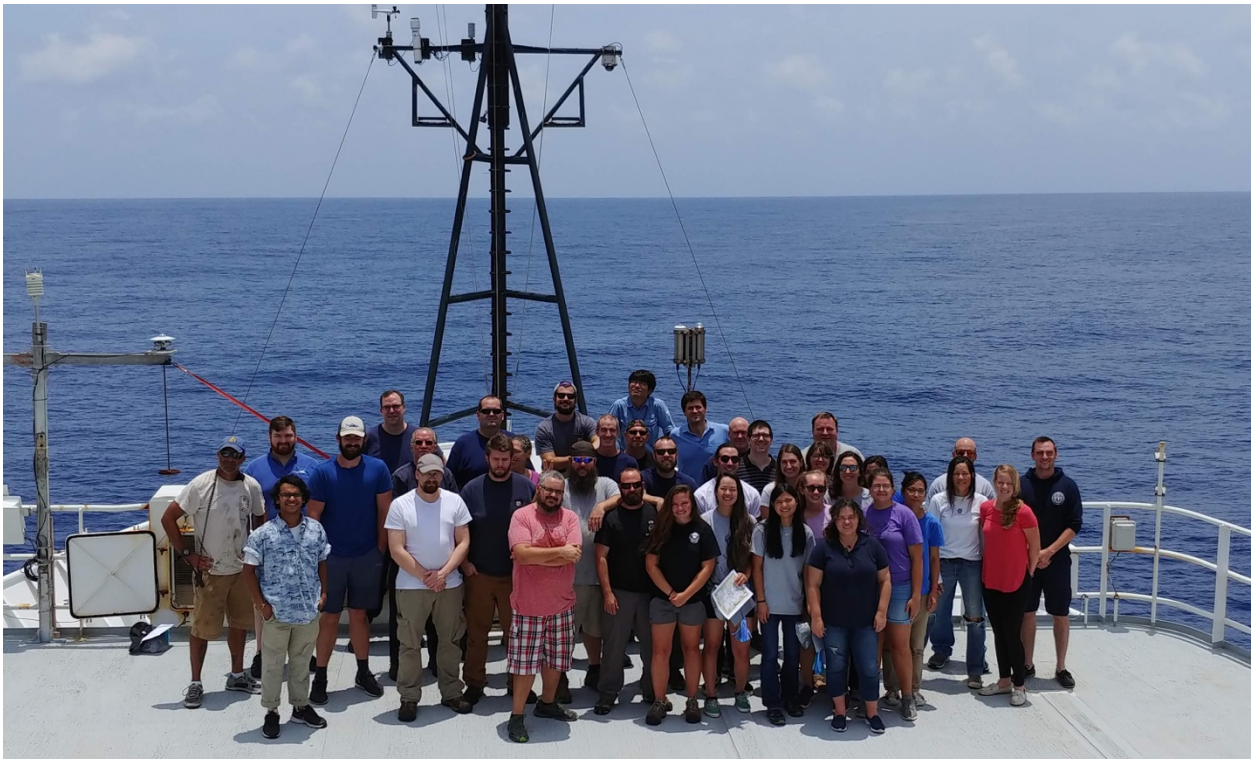


Figure 5 Oxygen below 200m between stations 102 and 122

After spending almost 40 days at sea (excluding 4 days of the port stop in Victoria), covering about 5200 nautical miles, completing 126 CTD casts (including 2 test casts at the beginning of the cruise), collecting and analyzing over 36000 liters of water from depths ranging from 5 to about 5500 m (excluding underway water intake) everybody is looking forward to return home. We have worked hard, had great and productive time onboard, met new people and made good friends. Now it is the time to analyze the data we have collected, and we know that we have observed many interesting features that still need to be investigated in detail and explained.

Although our cruise is ending, the GO-SHIP program continues. Therefore, see you next time!



CCHDO Data Processing Notes

- **File Online Carolina Berys**

cruise_report_calcium_post.docx (download) #aefd9
Date: 2019-04-16
Current Status: unprocessed

- **File Online Carolina Berys**

cruise_report_densitysalinity_post.doc (download) #dccb3
Date: 2019-04-16
Current Status: unprocessed

- **File Online Carolina Berys**

33RO20180423.exc.csv.JAM_add.20190312.csv (download) #e077b
Date: 2019-04-16
Current Status: unprocessed

- **File Submission Shinichiro Umeda**

33RO20180423.exc.csv.JAM_add.20190312.csv (download) #e077b
Date: 2019-03-12
Current Status: unprocessed
Notes
```
This file contains final values and flags for the following parameters
measured at the onshore laboratory in JAMSTEC.
-DNSSAL / DNSSAL2 (Density)
-SALNTY_HU / SALNTY_HU2 (Practical Salinities for the density samples)
-CALCIUM(Dissolved Calcium)
Supplemental documents for these data are also attached.
```

- **File Submission Shinichiro Umeda**

cruise_report_densitysalinity_post.doc (download) #dccb3
Date: 2019-03-12
Current Status: unprocessed
Notes
```
This file contains final values and flags for the following parameters
measured at the onshore laboratory in JAMSTEC.
-DNSSAL / DNSSAL2 (Density)
-SALNTY_HU / SALNTY_HU2 (Practical Salinities for the density samples)
-CALCIUM(Dissolved Calcium)
Supplemental documents for these data are also attached.
```

- **File Submission Shinichiro Umeda**

cruise_report_calcium_post.docx (download) #aefd9
Date: 2019-03-12

Current Status: unprocessed
Notes
```
This file contains final values and flags for the following parameters
measured at the onshore laboratory in JAMSTEC.
-DNSSAL / DNSSAL2 (Density)
-SALNTY_HU / SALNTY_HU2 (Practical Salinities for the density samples)
-CALCIUM(Dissolved Calcium)
Supplemental documents for these data are also attached.
```

- **File Online Carolina Berys**

Final winkler quality flags 05Mar19.csv (download) #20918
Date: 2019-03-11
Current Status: unprocessed

- **File Submission Chris Langdon**

Final winkler quality flags 05Mar19.csv (download) #20918
Date: 2019-03-05
Current Status: unprocessed
Notes
```
Final Winkler quality flags for 33RO20180423 IO7N cruise.
```

- **File Online Carolina Berys**

33RO20180423.exc.csv (download) #ad0bb
Date: 2019-01-28
Current Status: unprocessed

- **File Submission Robert Key**

33RO20180423.exc.csv (download) #ad0bb
Date: 2019-01-24
Current Status: unprocessed
Notes
```
This file now contains final values for TCARBN, PHSWS and ALKALI.
Values have been QC'ed.
Do NOT take vanilla values from this file.
NOTE there are a few bottle numbers equal to -9 in this file and probably in
other versions. Needs to be fixed but I don't know correction.
bob
```

- **File Online Carolina Berys**

33RO20180423.exc.csv (download) #d4957
Date: 2019-01-11
Current Status: unprocessed

- **File Merge Carolina Berys**

I7n_2018_hy1.csv (download) #96b54
Date: 2019-01-08
Current Status: merged

- **File Merge Carolina Berys**

33RO20180423_IO7N_DIC_Data_Final.csv (download) #e21de
Date: 2019-01-08
Current Status: merged

- **File Merge Carolina Berys**

33RO20180423.exc.csv (download) #d4957
Date: 2019-01-08
Current Status: unprocessed

- **Bottle file online, includes TCARBN update Carolina Berys**

Date: 2019-01-08
Data Type: Bottle
Action: Website Update
Note:

```
IO7N 2018 33RO20180423 processing - BTL/merge - processing, TCARBN

2019-01-08

C Berys

Submission

filename                                submitted by          date       id
-------------------------------------------------------------------------------
I7n_2018_hy1.csv                        Denis Volkov          2016-01-13 14083
33RO20180423_IO7N_DIC_Data_Final.csv  Charles Featherstone  2016-01-13 14242
33RO20180423.exc.csv                    Bob Key               2016-01-13 14253

Changes

* fMOL to FMOL for SF6
* PH_TEMP to PH_TMP
* N2O_FLAG to N2O_FLAG_W
* fill value for OXYGEN from -999.9900 to -999.0000

Merge

Merged 33RO20180423_IO7N_DIC_Data_Final.csv into I7n_2018_hy1.csv using hydro
0.8.2-48-g594e1cb. Renamed 33RO20180423_hy1.csv.

merged parameters: TCARBN, TCARBN_FLAG_W

All comment lines from original file copied back in following merge.
33RO20180423_hy1.csv opened in JOA with no apparent problems.

Conversion
----------
```

```
file                    converted from       software
-------------------------------------------------------------------------
33RO20180423_nc_hyd.zip 33RO20180423_hy1.zip hydro 0.8.2-48-g594e1cb
33RO20180423hy.txt      33RO20180423_hy1.csv hydro 0.8.2-48-g594e1cb

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

file                    stamp
-----------------------------------------
33RO20180423_hy1.csv    20190108CCHSIOCBG
33RO20180423_nc_hyd.zip 20190108CCHSIOCBG
33RO20180423hy.txt
```

- **File Online Carolina Berys**

33RO20180423.exc.csv (download) #d4957
Date: 2018-12-14
Current Status: unprocessed

- **File Submission Robert Key**

33RO20180423.exc.csv (download) #d4957
Date: 2018-12-12
Current Status: unprocessed
Notes
```
Merged DIC from file "33RO20180423_IO7N_DIC_Data_Final.csv" then QC.
Additional QC on nuts and O2, but this will likely be overwritten once final
values are uploaded. (and ok)
```

- **File Online Carolina Berys**

33RO20180423_IO7N_DIC_Data_Final.csv (download) #e21de
Date: 2018-12-04
Current Status: merged

- **File Submission Charles Featherstone**

33RO20180423_IO7N_DIC_Data_Final.csv (download) #e21de
Date: 2018-11-29
Current Status: merged
Notes
```
DIC Data for the IO7N cruise, expocode-33RO20180423
```

- **File Merge CCHSIO**

i07n_prelim_ct1.zip (download) #50b3f
Date: 2018-10-25
Current Status: merged

- **File Merge CCHSIO**

i07n_final_kem.zip (download) #b4065
Date: 2018-10-25
Current Status: merged

- **File Merge CCHSIO**

i07n_fixed_lon_ct1.zip (download) #23e1b
Date: 2018-10-25
Current Status: merged

- **update data from As Received to Data Set CCHSIO**

Date: 2018-10-25
Data Type: CTD
Action: Website Update
Note:

```
    2018 33RO20180423 processing - CTD/merge -
CTDPRS,CTDTMP,CTDSAL,CTDOXY,CTDNOBS,CTDXMISS,CTDFLUOR

2018-10-25

CCHSIO

Submission

filename                submitted by     date       id
----------------------- ---------------- ---------- -----
i07n_prelim_ct1.zip     Kristy McTaggart 2018-07-17 14090
i07n_final_kem.zip      Kristy McTaggart 2018-09-10 14162
i07n_fixed_lon_ct1.zip Kristy McTaggart 2018-09-12 14169

Changes
-------
i07n_prelim_ct1.zip
        - moved to  Data History, not used
i07n_final_kem.zip
        - moved to  Data History, not used

i07n_fixed_lon_ct1.zip
        - Renamed files to match EXCHANGE standard. Put original file name in
file as a comment.
        - No flags submitted for parameters CTDNOBS, CTDXMISS (0-5VDC),
CTDFLUOR(0-5VDC)
        - STNNBR: removed leading 0s from number
        - added cruise and header information as comments

Conversion
----------
file                     converted from       software
------------------------ -------------------- ----------------------
33RO20180423_nc_ctd.zip 33RO20180423_ct1.zip hydro 0.8.2-48-g594e1cb


Updated Files Manifest
----------------------
```

```
file                    stamp
----------------------- --------------
33RO20180423_ct1.zip    20181025CCHSIO
33RO20180423_nc_ctd.zip 20181025CCHSIO

:Updated parameters: CTDPRS,CTDTMP,CTDSAL,CTDOXY,CTDNOBS,CTDXMISS,CTDFLUOR

opened in JOA 5.2.1 with no apparent problems:
     33RO20180423_ct1.zip
     33RO20180423_nc_ctd.zip

opened in ODV with no apparent problems:
     33RO20180423_ct1.zip
```

- **File Online Carolina Berys**

i07n_fixed_lon_ct1.zip (download) #23e1b
Date: 2018-09-27
Current Status: merged

- **File Submission Kristy McTaggart**

i07n_fixed_lon_ct1.zip (download) #23e1b
Date: 2018-09-12
Current Status: merged
Notes
```
These are final CTDO data (profiles only) resubmitted with corrected
longitudes in all file headers from GO-SHIP cruise I07N (33RO20180423).
```

- **File Online Carolina Berys**

i07n_final_kem.zip (download) #b4065
Date: 2018-09-10
Current Status: merged

- **File Submission Kristy McTaggart**

i07n_final_kem.zip (download) #b4065
Date: 2018-09-10
Current Status: merged
Notes
```
These are final CTDO data (profiles and discrete) and documentation from GO-
SHIP cruise I07N (33RO20180423).
```

- **File Merge Jerry Kappa**

33RO20180423_do.txt (download) #ca4dc
Date: 2018-08-14
Current Status: dataset

- **File Submission Jerry Kappa**

33RO20180423_do.txt (download) #ca4dc
Date: 2018-08-09
Current Status: dataset
Notes
The text version of i07n_2018's cruise report is ready to be added to the CCHDO Dataset. It includes all of the PI-provided data reports and CCHDO summary and Data Processing Notes.

- **File Merge Carolina Berys**

I07N_CruiseReport.docx (download) #a2ecb
Date: 2018-08-06
Current Status: merged

- **File Merge Carolina Berys**

I07N_CruiseReport.pdf (download) #e7e31
Date: 2018-08-06
Current Status: merged

- **File Merge Jerry Kappa**

33RO20180423_do.pdf (download) #957e9
Date: 2018-08-06
Current Status: dataset

- **File Submission Jerry Kappa**

33RO20180423_do.pdf (download) #957e9
Date: 2018-07-31
Current Status: dataset
Notes
The pdf version of i07n_2018's cruise report is ready to be added to the dataset. It contains all of the PI-provided data reports as well as CCHDO summary pages and Data Processing Notes.

- **File Online Carolina Berys**

i07n_prelim_ct1.zip (download) #50b3f
Date: 2018-07-26
Current Status: merged

- **File Submission Kristy McTaggart**

i07n_prelim_ct1.zip (download) #50b3f
Date: 2018-07-17
Current Status: merged
Notes
These are preliminary CTDO data from GO-SHIP cruise I07N (33RO20180423). Preliminary calibrations were applied at sea and all data flags default as

'2'. Any near-surface instabilities flagged as '9' will be added back and flagged as '3' later.

- **File Online** **Carolina Berys**

I07N_CruiseReport.docx (download) #a2ecb
Date: 2018-07-14
Current Status: merged

- **File Submission** **Denis Volkov**

I07N_CruiseReport.docx (download) #a2ecb
Date: 2018-07-13
Current Status: merged
Notes
I07N cruise, Apr 23 - Jun 6, 2018

- **File Online** **Carolina Berys**

I07N_CruiseReport.pdf (download) #e7e31
Date: 2018-07-13
Current Status: merged

- **File Online** **Carolina Berys**

I7n_2018_hy1.csv (download) #96b54
Date: 2018-07-13
Current Status: merged

- **File Submission** **Denis Volkov**

I07N_CruiseReport.pdf (download) #e7e31
Date: 2018-07-12
Current Status: merged
Notes
NOAA Ship "Ronald H. Brown", I07N cruise, April 23 - June 6, 2018

- **File Submission** **Denis Volkov**

I7n_2018_hy1.csv (download) #96b54
Date: 2018-07-12
Current Status: merged
Notes
NOAA Ship "Ronald H. Brown", I07N cruise, April 23 - June 6, 2018