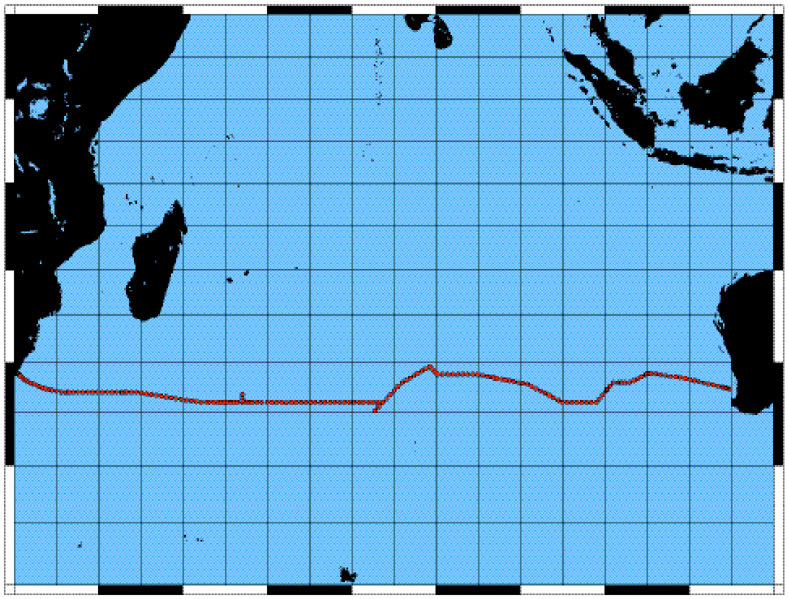
CRUISE REPORT: I05

(Updated JAN 2010)



A. HIGHLIGHTS

A.1. CRUISE SUMMARY INFORMATION

Section designation	**I05**
Expedition designation (ExpoCode)	**33RR20090320**
Chief Scientists	**James H. Swift / UCSD/SIO** **Gregory C. Johnson / NOAA/PMEL**
Dates	20 MAR 2009 to 15 MAY 2009
Ship	*R/V Roger Revelle*
Ports of call	Cape Town, South Africa, to Fremantle, Australia
Geographic boundaries	30° 22.8' S 30° 19.67' E 114° 50.72' E 34° 48.01' S
Stations	195 CTD/rosette stations
Floats and drifters deployed	19 Argo floats deployed
Moorings deployed or recovered	0

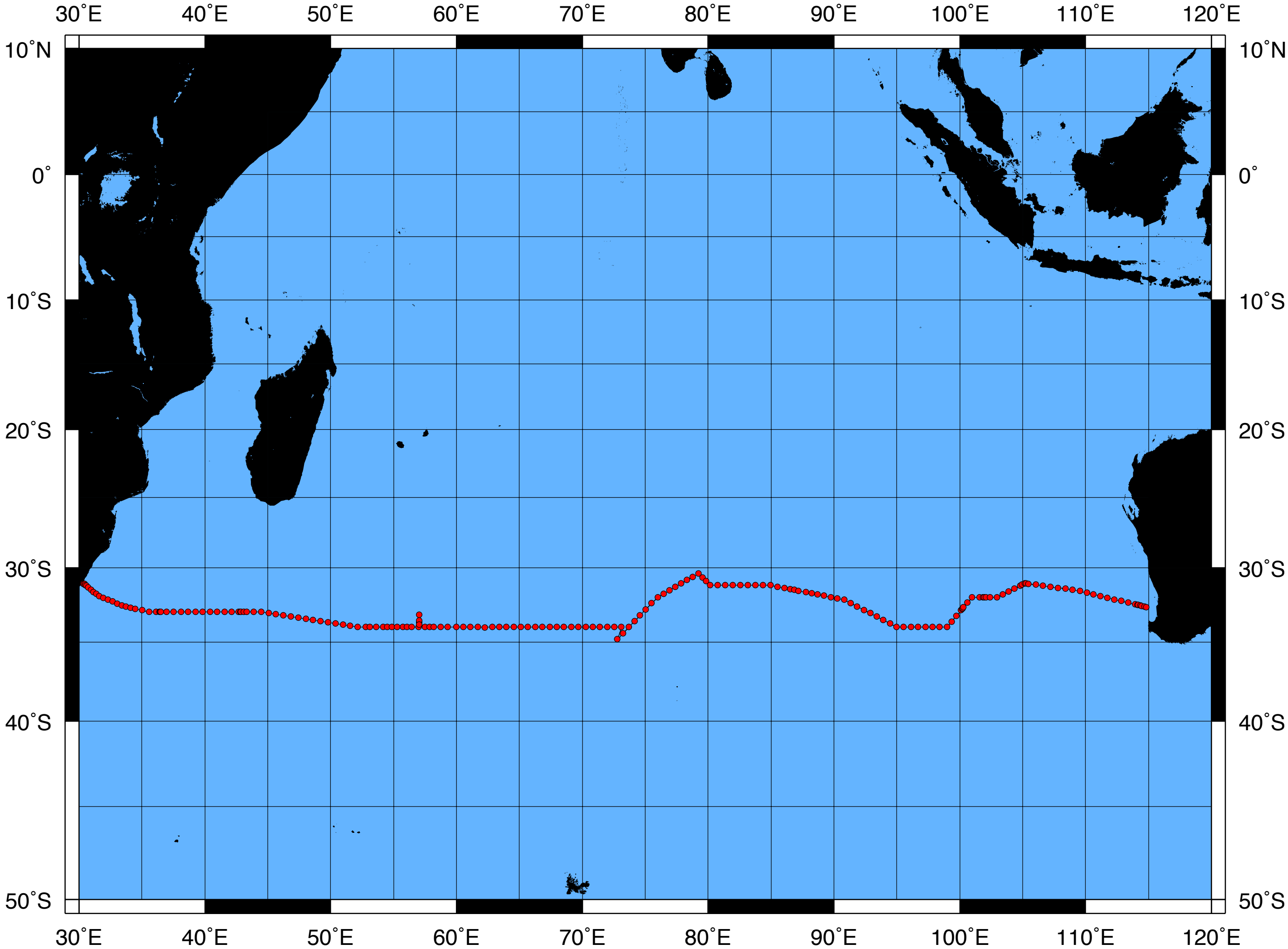
James H. Swift
University of California, San Diego • Scripps Institution of Oceanography
9500 Gilman Drive • MS 0214 • La Jolla CA 92093-0214
Tel: 858-534-3387 • Fax: 858-534-7383 • Email: jswift@ucsd.edu

Gregory C. Johnson
National Oceanic and Atmospheric Administration/Pacific Marine Environmental Laboratory
7600 Sand Point Way NE, Bldg. 3 • Seattle WA 98115-6349
Tel: 206-526-6806 • Fax: 206-526-6744 • Email: Gregory.C.Johnson@noaa.gov

LINKS TO TEXT LOCATIONS

Shaded sections are not relevant to this cruise or were not available when this report was compiled

I05 • 2009 • Swift/Johnson • R/V Revelle



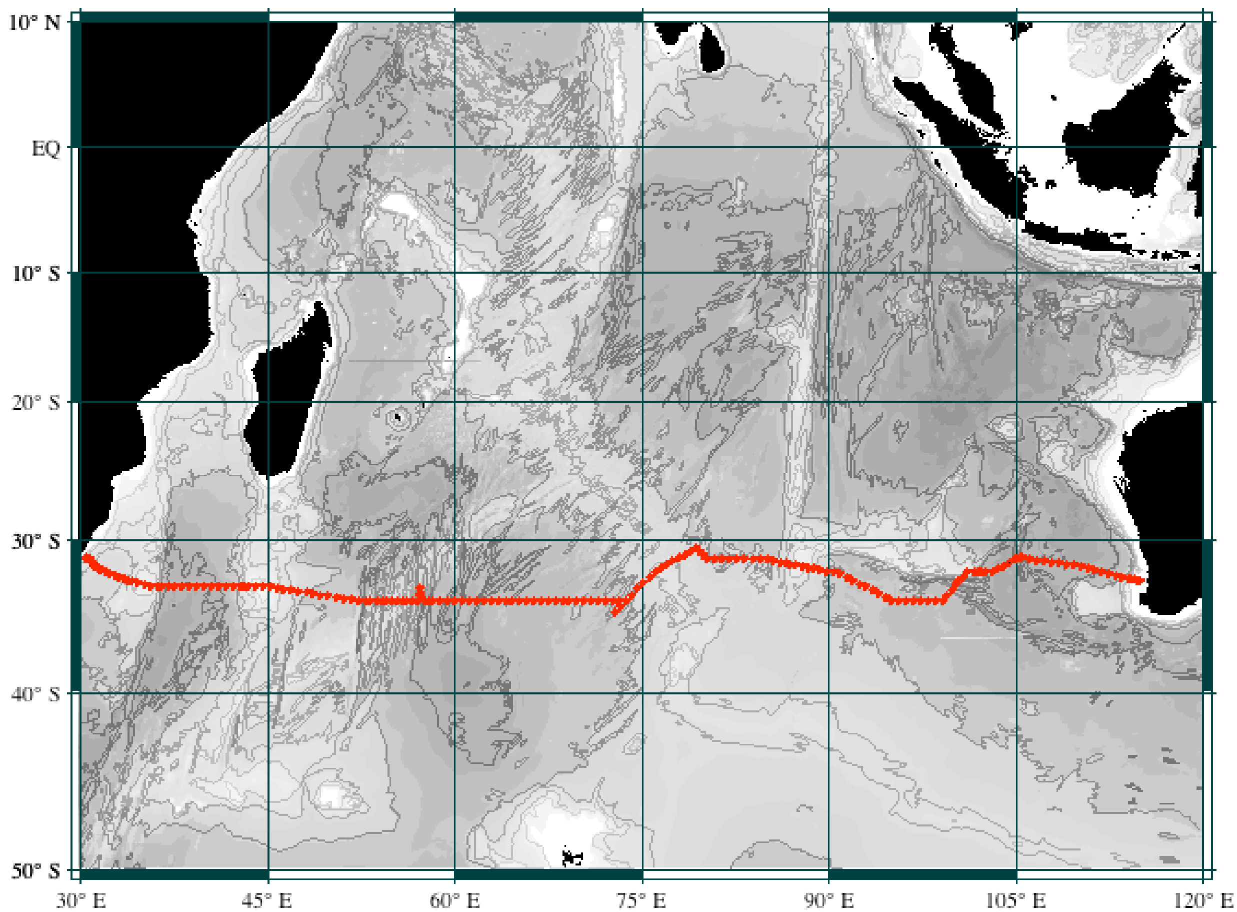
(Produced by CCHDO)

US Global Ocean Carbon and Repeat Hydrography Program Cruise I5

Cape Town, South Africa, to Fremantle, Australia
20 March - 15 May 2009
R/V Roger Revelle

Preliminary Cruise Report
James H. Swift and Gregory C. Johnson

195 CTD/rosette stations
6,724 levels sampled
87 trace metal casts
19 Argo floats deployed
55 days at sea (no port stops or landings)



Acknowledgements of Interagency cooperation and support

The U.S. Global Ocean Carbon and Repeat Hydrography Program (also known as the U.S. CLIVAR/CO2 Repeat Hydrography Program) has benefited from interagency, multi-institutional, and cross-disciplinary collaboration from its inception. Some of the ship time has been provided by NOAA on the NOAA Ship Ronald H. Brown, and some by NSF on UNOLS ships, such as this cruise on R/V Roger Revelle. The traditional close cooperation among NSF and NOAA funded partners on this very long single-leg cruise was particularly strong. As usual on these cruises, NOAA analysts measured dissolved inorganic carbon (DIC), while university teams measured pH and total alkalinity. While NSF-funded SIO-ODF took the lead on CTD/O2, bottle salinity, bottle oxygen, and nutrients data collection and processing, NOAA personnel assisted in each of those areas, allowing for methodological cross-training. Two NOAA CFC/SF6 analysts worked on NSF-funded equipment and with the able assistance of an NSF-funded graduate student. Finally, Jim Swift and Greg Johnson were the NSF-NOAA day-night chief-co-chief scientist tag-team using their complementary skills to lead the expedition. We are very grateful to NSF and NOAA, and our program managers, for the support, advice, and encouragement which continues to make this program a success.

Officers and Crew

Name	Position
Tom Desjardins	Captain
Paul Mauricio	Chief Engineer
Robert Widdrington	1st Mate
Joe Ferris	2nd Mate
Melissa Turner	3rd Mate
John Healy	1st A/E
Frank Oathout	2nd A/E
Matthew Peer	3rd A/E
Jay Erikson	1st Cook
Mark Smith	2nd Cook
Joe Evers	Boatswain
Antje Galbraith	Electrician
Robert Arthur	A/B
Gary Braden	A/B
Edmund Warren	A/B
Phil Hawkins	Oiler
Phil Hogan	Oiler
Malcolm Cobb	Oiler
William Brown, Jr.	Oiler
Jonathan Alvarez	Wiper
Kevin Moran	OS

Science Programs and Responsible Principal Investigators

CTDO/rosette/S/O2/nutrients/data processing
Jim Swift, Scripps (jswift@ucsd.edu; ph 858-534-3387; fx 858-534-7383)

Transmissometer
Wilf Gardner, Texas A&M U (wgardner@ocean.tamu.edu; ph 979-845-7211)

CDOM Fluorometer
Norm Nelson, UCSB (norm@icess.ucsb.edu)
Craig Carlson, UCSB (carlson@lifesci.ucsb.edu; 805-893-2541)

Research Technician Group
Carl Mattson, Scripps (cmattson@ucsd.edu or restech@ucsd.edu; ph 858-543-1632)

Shipboard Computer Group
Frank Delahoyde, Scripps (fdelahoyde@ucsd.edu; ph 858-534-2751)

CO2 (alkalinity and pH)
Andrew Dickson, Scripps (adickson@ucsd.edu; ph 858-534-2990)

CO2 (DIC and underway pCO2)
Rik Wannikhof, AOML/NOAA (Rik.Wanninkhof@noaa.gov; ph 305-361-4379)
Richard A. Feely, PMEL/NOAA (Richard.A.Feely@noaa.gov; ph 206-526-6214)

DOC/TDN
Dennis Hansel, RSMAS/Miami (dhansell@rsmas.miami.edu; ph 305-421-4078)

13C/14C
Ann McNichol, WHOI (amcnichol@whoi.edu; ph 508-289-3394)
Robert Key, Princeton (key@Princeton.EDU; ph 609-258-3595)

CFCs
John Bullister, PMEL/NOAA (John.L.Bullister@noaa.gov; ph 206-526-6741)
Mark Warner, University of Washington (mwarner@ocean.washington.edu; ph 206-543-0765)

He/Tr
Peter Schlosser, LDEO (peters@ldeo.columbia.edu; ph 845-365-8816)

ADCP/LADCP
Eric Firing, U Hawaii (efiring@soest.hawaii.edu; ph 808-956-7894)

Trace elements
Chris Measures, U Hawaii (chrism@soest.hawaii.edu; ph 808-956-8693)
Bill Landing, U Florida (landing@ocean.fsu.edu; ph 850-644-6037)

ARGO floats
Stephen Riser, U of Washington (riser@ocean.washington.edu; ph 206-543-1187)

Aerosols
Bill Landing, U Florida (landing@ocean.fsu.edu; ph 850-644-6037)

Narrative

The R/V Roger Revelle "I5" cruise for the NSF- and NOAA-funded US CLIVAR/CO_2 Repeat Hydrography program carried out a transect of boundary-to-boundary full-depth CTDO/LADCP/hydrographic/carbon/tracer stations along ca. 32°S from South Africa to Australia, 20 March - 13 May 2009. The full transect had been carried out twice before, in 1987 (November – December, 36 days, 108 stations) and 2002 (March – April, 46 days, 133 stations plus 13 on a different transect), and in 1995 the east (March-May) and west (June – July) portions were done well. But the remote central portion of the 32°S Indian Ocean transect had not yet been measured to the same standard we have measured the other oceans. Thus we planned a very long cruise (with no mid-cruise port stop): 57 days and 194 stations.

All 34 in the science team made it to the ship in Cape Town without undue difficulty. The ship had arrived slightly ahead of schedule after a transit from South America. All hands thoroughly enjoyed Cape Town. SIO arranged docking in the main waterfront tourist area, which was also just a short walk (by day) or cab ride (at night) to the city center. We had time for dinners at some of Cape Town's excellent restaurants, visits to busy pubs, and many of us enjoyed the excellent South African wines. Some toured the Cape Town region, visited wineries, went up Table Mountain (Cape Town's dramatic backdrop), or toured Robben Island (where South Africa kept some of its political prisoners up through 1991).

The scientific equipment and lab supplies had been shipped in advance from California, Washington, Hawaii, Massachusetts, New York, and Florida, much of it in three 20-foot lab vans and two 20-foot shipping containers. Over four days the science party, SIO research technicians, and crew loaded the cargo onto the ship, and craned aboard the lab and storage vans. The science team then outfitted the lab vans and the ship's four main labs, assembled and installed the rosette bottles onto the frame, along with the underwater electronics, and installed the deck equipment. Each measurement group was experienced and got its work done well. Only one item of scientific equipment never arrived: a new version of the lowered ADCP. The older spare downward-looking 150 KHz model was installed, and it worked well the entire cruise, probably better than the newer primary upward and downward-looking 300 KHz models would have. The ship also took on tons of food, including such a large amount of fresh stores that the science walk-in refrigerator was used for some of it for a brief time.

R/V Roger Revelle left port ca. 10:00 pm local time Friday, March 20th, after 6-hour delay to complete fueling (some bad fuel was found in the initial delivery that day). The southern tip of Africa is notorious for high seas, but although some choppy ship roll began as soon as we left the harbor, by morning the seas were easier. The weather was excellent.

From the very start the science team felt welcome and very well supported onboard the ship. This was the fourth cruise for the CLIVAR/CO_2 Repeat Hydrography Program on Revelle, and the fifth on an SIO ship. Thus we enjoyed the fortune of sailing with highly experienced officers and crew, many of whom had sailed on previous cruises for our program. The ship is spacious, well-maintained, and well-outfitted for long cruises such as I5, and makes a pleasant workplace and home at sea. Jay and Mark, the cooks, set the bar high from Day One and kept challenging waistlines and will-power without let-up. (They actually told us, "we try to make things as difficult as we can for you"!) [Seriously, on a voyage such as this, the cooks and the weather make all the difference. Jay and Mark baked bread or rolls nearly every day, served lettuce in the salad bar for 48 days (albeit increasingly mixed with cabbage toward the very end), provided fresh fruit at breakfast through the entire cruise, presented tasty choices for every meal, made caches of bread and treats for the night watch, did well by the vegetarians, and on and on. They made a significant contribution to the positive morale that pervaded this cruise.]

As the ship steamed northeast towards the first station, the course stayed over the continental shelf to avoid the strong southward Agulhas Current over the shelf break. The ship was in a designated northbound shipping lane from time to time, as evidenced by cargo ships and empty tankers. En route the science teams successfully carried out three training and familiarization casts, and the ship held safety drills. We reached the start of our 32°S transect early Tuesday morning, March 24th.

Our primary task was to carry out nearly 200 CTD/rosette stations. The CTD (deployed amidships from the starboard boom) and other electronics mounted on the rosette frame provided measurements of pressure, temperature, conductivity (salinity), and dissolved oxygen, plus there were light transmission and fluorometric sensors. The lowered Acoustic Doppler Current Profiler measured the velocity relative to the rosette, from which the absolute velocities can be derived. Water samples from the 36 10-liter bottles on the rosette were analyzed on board for salinity, dissolved oxygen, nutrients (nitrate, nitrite, phosphate, and silicate), CFCs (F11, F12), SF6, dissolved inorganic carbon, total alkalinity, and pH. Samples for shore analysis were collected for dissolved organic carbon, total dissolved nitrogen, the carbon isotopes 13C & 14C, tritium, dissolved helium, and helium-3. We also had with us a 5-person team measuring aluminum and iron (from separate "trace metal" casts with their own rosette and synthetic cable deployed on a Kevlar-coated cable using the stern A-frame) and aerosols. We ran a continuously-pumped surface seawater system that measured temperature, salinity, dissolved oxygen, fluorescence, and pCO2. Other measurements included velocity from the ship's Doppler current profilers, data from a suite of meteorological parameters, multibeam bathymetry, and navigation data. And we deployed 19 Argo floats at predetermined locations along the section for Dr. Stephen Riser, University of Washington.

The science program began with a crossing of the Agulhas Current (the western boundary current of the South Indian Ocean). The Agulhas is a strong current, which was of practical as well as scientific interest to participants on this expedition. During our sampling of the Agulhas, the near-surface currents measured by the shipboard ADCP reached speeds of over 2.0 m/s (about 3.7 kts) near the coast. This high velocity made stations challenging, but the officers and crew of the R/V Revelle overcame the impediment competently. On the continental slope, we were aiming to occupy a CTD station at every 500-m increase in bottom depth from the continental shelf break all the way down to the base of the continental rise. Since the current runs mostly parallel to isobaths, we would find our target depth, and then steam a few nm along that isobath upstream (roughly northeast) from the nominal station track. The officer on watch would then orient the ship properly with respect to winds, waves, and currents, after which we would begin our station, with the ship drifting southwest with the current during the station to minimize wire angle. By the time the CTD reached the bottom, the ship was usually close to our target position on the section, and then moved past it as the CTD was brought back to the surface. During these cruises we generally try to sample to within 10 m of the bottom. However, when drifting along at over 3 kt, with far more wire paid out than there was depth below the ship, and uncertain bathymetry ahead, we sometimes settled for a 20-m gap. One oceanographic consequence of this strong velocity is that, with the admittedly very crude (and likely erroneous) assumption of zero velocity at the deepest common level of each station pair, the preliminary data yield and estimated volume transport of the Agulhas across the section was roughly 85×10^6 m^3 s^{-1} to the southwest (typical of other similarly derived estimates).

Another interesting feature associated with the Agulhas is the northeastward flowing Agulhas Undercurrent, a reversal in flow that is usually found deeper than 800 m, adjacent to the continental slope, below the core of the Agulhas. Since we had Eric Firing's trusty (except for a sticky mercury switch used for sensing vertical orientation) old 150-KHz broadband lowered ADCP on the CTD frame, we were able to measure the expression of this current as we crossed the Agulhas starting from near Durban. On this cruise the Agulhas Undercurrent was remarkable by its absence. While our data were very closely spaced (every 500 m of bottom change, and from 2 to 25 km in distance), we did not find any velocity structure that would merit the designation of Undercurrent in the preliminary LADCP data.

Taking as much data as we did, it would be peculiar indeed if we did not find interesting and unexpected oceanographic features now and again. For example, Francois Ascani, who is working with PI Eric Firing on the ADCP and LADCP data, found a distinctive high vertical mode signal on the peak of the Madagascar Ridge on a station taken 10-20 km from Walter's Shoal. The signal was clearly captured by both the ship's hull-mounted Hydrographic Doppler Sonar System (an ADCP system unique to the Revelle thanks to SIO PI Robert Pinkel) and the lowered Acoustic Doppler Current Profiler on the rosette.

> From Francois Ascani: "During station 41 (44°E, 33°S), located just above the 800-m deep Madagascar Ridge, the Lowered Acoustic Doppler Current Profiler (LADCP) instrument

measured a profile in cross-ridge (east-west) velocity periodic in the vertical with a 200-m wavelength and an amplitude of 10 to 20 cm s^{-1}. This remarkable pattern was also observed by the Hydrographic Doppler Sonar System (HDSS) before, during and after station 41, over a distance reaching nearly 100 km. No apparent vertical propagation of the phase was observed during the 2-4 hours of observations, suggesting that the pattern corresponds to a standing wave in the vertical. This feature has sufficient peculiar characteristics to motivate future investigation. Possible causes are a ridge-trapped internal wave that resonates with the wind or an internal tide created at the ridge or at the nearby Walter's Shoal."

On Saturday-Sunday, 11-12 April, at about 34°S, 61°E, Tropical Cyclone Jade hit us directly. We were able to carry out CTD operations as the storm built because the wind and swell were from the same direction, making it possible for the mates to hold the ship remarkably steady during casts. But on station 077 during Saturday afternoon, as the storm built, we didn't count on winds rising as quickly as they did: When we put the CTD into the water for the 5525-meter deep cast, winds were a more or less manageable and fairly steady 35 knots. Four hours later, when we brought the CTD back on deck, average winds were 52 knots. Thanks to the considerable expertise of the Captain, mates, winch operator, and deck crew, the recovery went well, though it was challenging. While we sampled the rosette, winds continued rising into the upper 50s, roaring most impressively over a stormy ocean just feet away from the open hangar doors of the sampling room. During the night the wind shifted direction (and decreased to 40 knots or so), meaning that now swell built from other directions. As these new swells joined in, the high seas became ever more confused. It meant a rough ride, and a tough night for sleep for all but a lucky few. Winds finally dropped to the 25-knot range, the mixed-up seas smoothed to the point where we could resume CTD operations, with loss of about 26 hours to the storm. Aside from some relatively minor flooding in the vans and one entrance on the ship, there was no damage from the storm.

We were able to take time to occupy four CTD/LADCP stations just north of the I5 section, near 33.5°S, 57°E, roughly along the axis of the Atlantis II Fracture Zone, a major conduit for deep and bottom water flow northward from the Crozet Basin through the Southwest Indian Ridge into the Madagascar Basin. Data from the four stations plus one along the I5 section itself supported an earlier investigation with further evidence of heightened mixing along the passage. The LADCP data clearly captured the strong northward deep flow along the passage. In addition to the LADCP data, the transmissometer on the CTD revealed an increase in particulates, presumably resuspended by this strong flow, starting around 3500 db and increasing towards the bottom. In addition, the deep salinity maximum and CFC-12 minimum were both eroded in the station occupied furthest to the north in the fracture zone. The downstream erosion of these extrema could be a result the vertical mixing from above and below. In fact, the CFC-12 data strongly supported this assertion, since CFC-12 levels would be expected to decrease northward with decreasing salinity if the latter were simply a signature of increasing influence of older, fresher, and more CFC-poor North Indian Deep Water relative to the more recently ventilated, saltier, and more CFC-rich North Atlantic Deep Water. Instead the CFC-12 concentration at the minimum increased, quite probably a result of mixing with more CFC-12 rich waters above and below the minimum.

From Francois Ascani: "The flow below 2500 m across all Revelle stations along the SW Indian Ocean Ridge shows the dramatically strong northward intrusion through the Atlantis II Fracture Zone, and also some weaker intrusions in the next three fracture zones to the east. Interestingly, the northward intrusion in the fracture zone around 57.5E is blocked further north by the topography and should feed its neighboring fracture zones, in particular the Atlantis II one."

The weather was mostly subtropically good-to-excellent, with air temperatures beginning in the mid-upper 70s (degrees Fahrenheit), decreasing to the mid-60s. Winds were mostly moderate to light. We did experience swell from the south during much of the cruise, especially the first half, amplitude modulated on synoptic time-scales, generated by the big Southern Ocean storms that circle Antarctica.

The I5 cruise crossed its planned series of boundaries, basins, and ridges on plan and on schedule. Station spacing was nominally 55 km, but closed over steeper bathymetry so that in most cases there was not more than 750-1000 meters depth change between adjacent stations, and the track and spacing was adjusted with an eye to the most significant bathymetric and circulation features. The minimum time between cast starts for the most closely-spaced stations was determined by either the total sampling time for the previous station or the time to download the LADCP data. One might argue that overall, given the entire station plan, the time-limiting factor in carrying it out is the time required to analyze samples for the most time-consuming shipboard analyses, here the total carbon and the alkalinity analyses. (The trace metal casts thus assumed an important logistic role in providing an extra hour each for the sample analyses.) But another point of view is that the overall program has achieved a balance between station spacing, sampling density for the various parameters, ship speed, and the laboratory work that effectively and efficiently meets the science needs that drive the program.

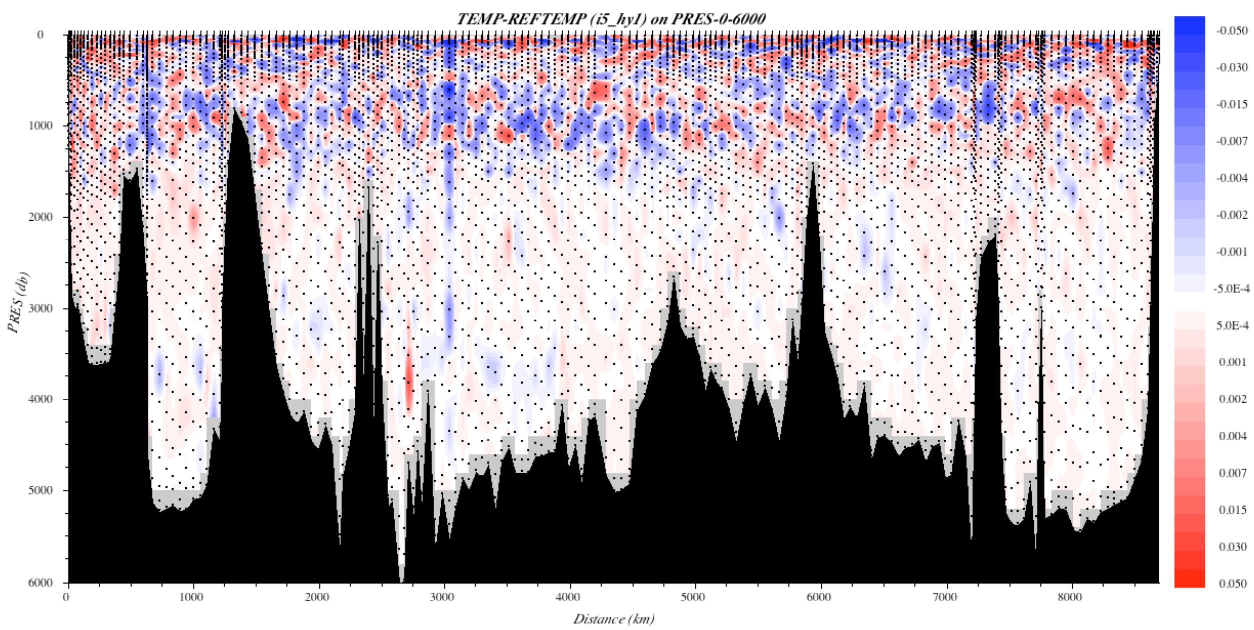
SIO Shipboard Technical Support had originally planed to carry out tests of the ship's multibeam system on the final day at sea, during which time the shipboard technicians would carry out laboratory analyses of the water samples from the final group of close-spaced stations. Because the multibeam tests were cancelled by SIO and since the last station was only ca. 5-6 hours from port, we chose to finish the work at the dock rather than at sea. Also, due to remarkably good weather and kind seas during the final month of the cruise, plus extraordinarily well working equipment (see below), we were about one day ahead of the maximum time we allotted for the station work. Hence we came to the dock at 0845 local time, 13 May 2009, after 55 UNOLS days at sea, rather than the planned 57. No one complained.

Data quality assessment (refers to preliminary shipboard data only)

The overall data quality from Level 1 parameters measured shipboard during I5 appears to be very good. There is no parameter whose overall quality of measurement does not appear to meet or exceed requirements and expectations.

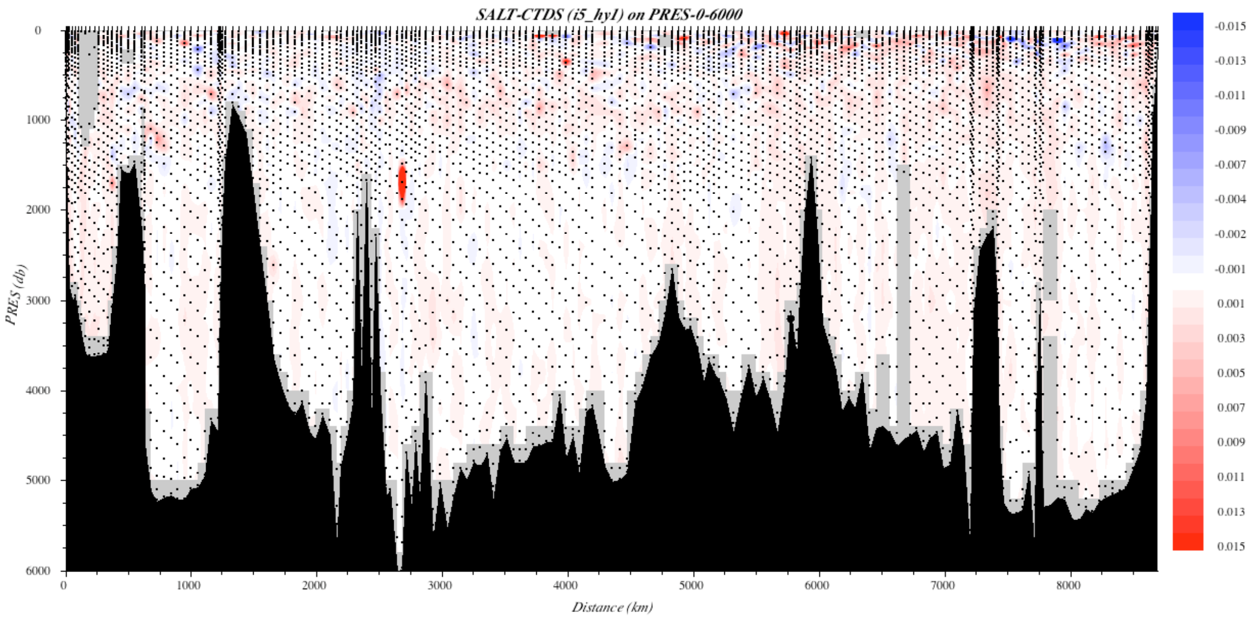
One SeaBird CTDO instrument, serial 796, was used throughout the cruise. The CTD team changed out the pump one time, replaced the SBE-43 dissolved oxygen sensor once, and replaced the secondary temperature sensor once. The instrument was remarkably stable, and its drifts were small and easily corrected.

The stability of the primary temperature sensor is exemplified by the excellent fit of CTD temperatures at bottle closures with the SBE-35 reference thermometer readings from each closure. See figure:

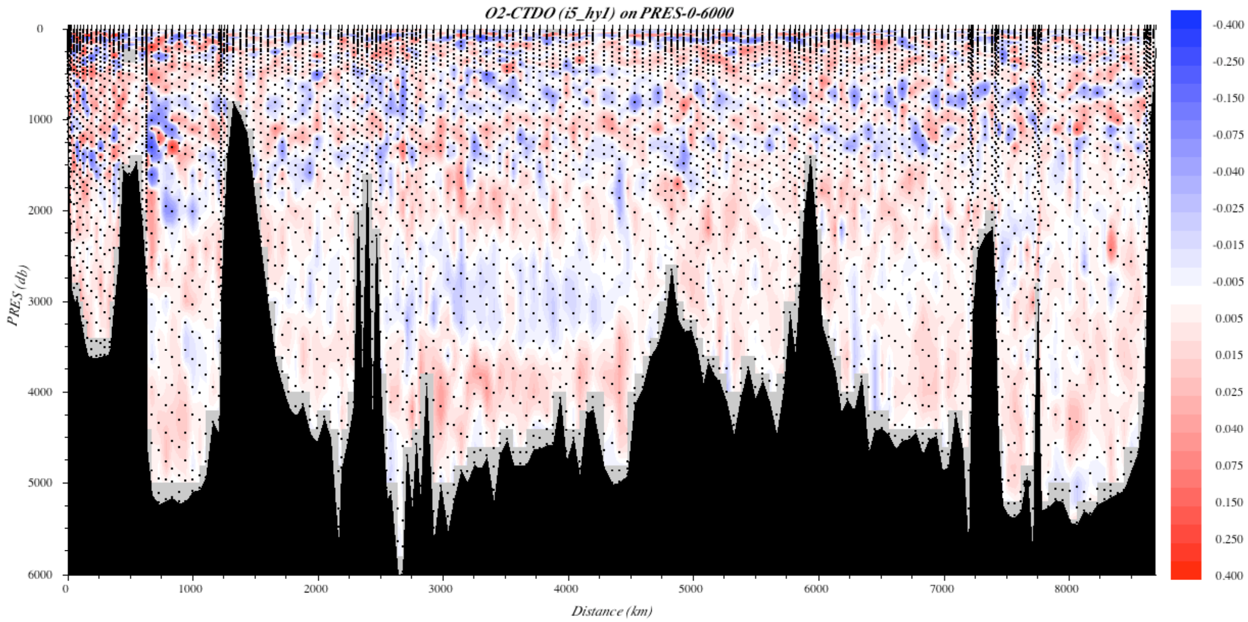


This figure is color-contoured at variable intervals which are very fine (smaller than one millidegree) near 0°C difference, and so the lack of color/contours in the low-temperature-gradient water column below ca. 1500 db is indicative of sub-millidegree agreement. It is nearly certain that no post-cruise adjustments greater than 0.001°C will be made to the preliminary shipboard CTD temperatures.

The preliminary CTD conductivity data fit to the water sample data (expressed in salinity) shows overall agreement below ca 1500 db better than 0.001 PSS-78, except for differences slightly greater than 0.001 at a few stations. Except for possibly those few stations, it is thus highly unlikely that any post-cruise adjustments greater than 0.001 will be made to the preliminary shipboard CTD salinities. In the figure below bad and questionable bottle salinity values have been purged from the data file before plotting:

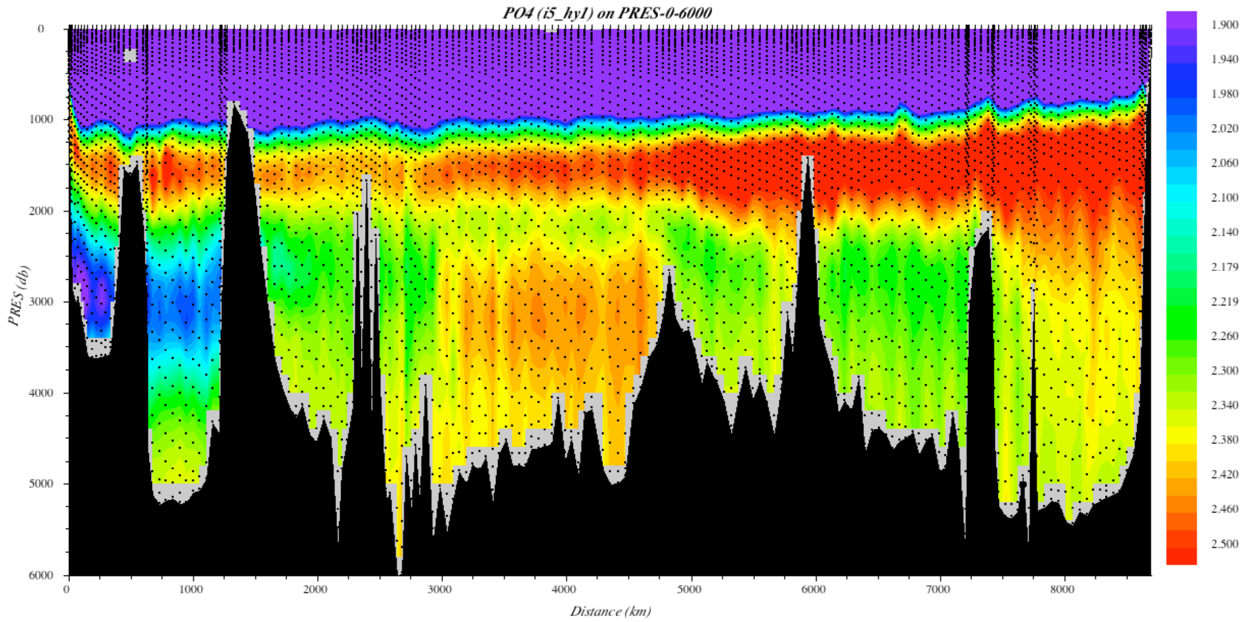


The preliminary fit of the SBE-43 CTD dissolved oxygen sensor data to the water samples is carried out between down-cast CTD oxygen values matched to up-cast water samples, usually on density surfaces. The overall fit is excellent with differences on the order of 0.5 μM kg^{-1}(see figure, below). What appears at first to be a small non-linear pressure-dependent error may actually be more nearly a small pressure offset: The shape of the dissolved oxygen profiles would likely generate a difference pattern such as this from a single-valued small vertical offset. A possible explanation would be that the frame/bottles are carrying water from deeper with them that is not quite flushed out by a 30-second bottle stop, or that the preliminary shipboard match of the down cast CTD oxygens onto the up cast bottle data is affected by a small pressure error. The dissolved oxygen data, though of very good quality, may change slightly during post-cruise examination and final processing.



The shipboard measurements for the bottle data parameters also appear to be of very high quality. For salinity and oxygen, the consistency of the measurements - i.e. the high degree of overall internal precision achieved during the cruise - is readily apparent both from the bottle-minus-CTD plots and from finely-contoured plots of the bottle salinities and oxygens (not shown). If for some reason future bulk adjustments are deemed necessary (for example for comparisons with salinities referenced to a different batch of standard seawater) the I5 data should be straightforward to adjust (e.g. via single offsets for each property). It is unlikely that any significant post-cruise changes to the bottle salinity or bottle oxygen data values will be made, though it is likely that some quality code changes will take place during final post-cruise data processing.

Much the same can be said about the nutrient data, which appear to be of very high quality, or at the very least, very high internal consistency. The silicate and nitrate data are clearly ready for scientific work, and no significant changes are expected in data values as a result of post-cruise data processing, although, as with any of the bottle data, quality code changes associated with some data values may change. The phosphate data have a different type of internal consistency in that a very regular, small (maximum range ca. 1.5% full scale) "daily" oscillation in phosphate values was observed nearly continuously throughout the cruise. It shows up clearly on finely-contoured (0.02 μM/l interval here) deep plots:



Contour interval 0.02 µM/l

Examinations at sea were unable to get to the root of this fluctuation. There were two nutrient operators - one might guess that each was consistent in the work, but that there was some small difference in technique (which we were unable to uncover) that produced the differences. *But noting that the differences are not abrupt, station to station, as would be the case for an operator-generated difference:* Another interpretation is that there was some activity that happened daily - whether directly part of the nutrient analyses or some other aspect of the shipboard environment - that influenced the chemical reactions or colorometric output in this fashion. With each run standardized to the same set of standards, and all procedures carefully cross-checked between both analysts, the second explanation appeals to Swift. As a result Swift began examining nutrient data from other SIO CO2/Repeat Hydrography cruises and found the same type of deep phosphate variation on most other cruises, though not as well defined. He observed that the I5 phosphate data are from a zonal transect, have a deep maximum that responds well (visually) to contouring, and are of such outstanding quality and consistency that this small effect was unambiguously observed here. More study will be carried out ashore.

CLIVAR I5

R/V Revelle, RR0903

20 March 2009 - 13 May 2009

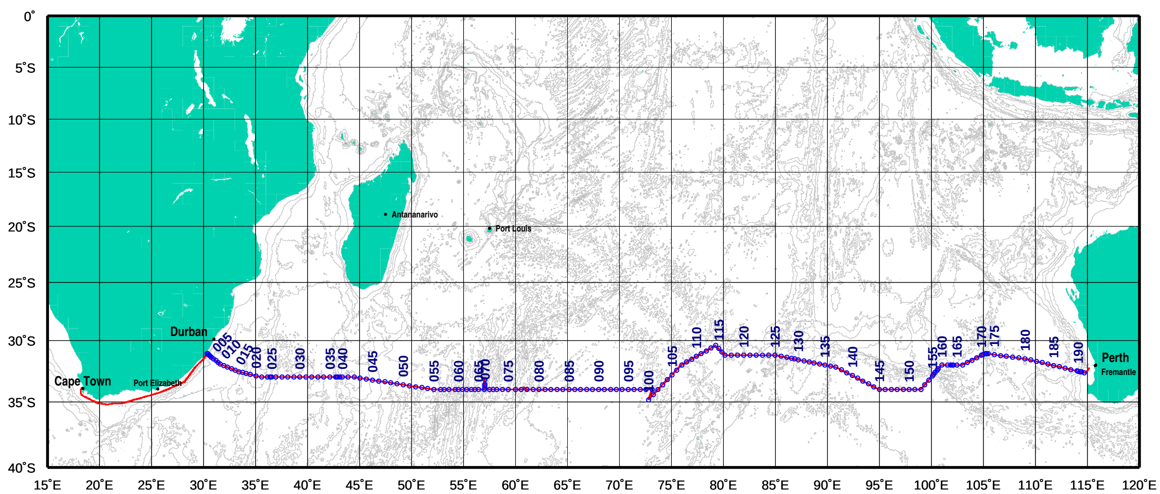
Cape Town, South Africa - Fremantle, Australia

Chief Scientist: Dr. James H. Swift

University of California, San Diego; Scripps Institution of Oceanography

Co-Chief Scientist: Dr. Gregory C. Johnson

NOAA/PMEL



Cruise Report
13 May 2009

Data Submitted by:

Oceanographic Data Facility, Computing Resources and Electronics Group
Shipboard Technical Support/Scripps Institution of Oceanography
La Jolla, CA 92093-0214

Summary

A hydrographic survey consisting of Rosette/CTD/LADCP sections, trace metals rosette sections, underway shipboard ADCP and float deployments in the southern Indian Ocean was carried out during early 2009. The R/V Revelle departed Cape Town, South Africa on 20 March 2009. A total of 195 stations were occupied. 195 Rosette/CTD/LADCP casts, and 87 Trace Metals Rosette casts were made, and 19 ARGO floats were deployed from 25 March to 12 May 2009. Water samples (up to 36) and CTD data were collected on each Rosette/CTD/LADCP cast, usually made to within 20 meters of the bottom. Salinity, dissolved oxygen and nutrient samples were analyzed for up to 36 water samples from each cast of the principal Rosette/CTD/LADCP program. Water samples were also measured for DIC, pH, Total Alkalinity, and CFCs and samples were collected for DOC/TDN, Helium/Tritium, and C13/C14. Underway surface pCO2, temperature, conductivity, dissolved oxygen, fluorometer, meteorological and acoustical bathymetric measurements were made. The cruise ended in Fremantle, Australia on 13 May 2009.

Introduction

A sea-going science team gathered from 8 oceanographic institutions participated on the cruise. The science team and their responsibilities are listed below.

Duties	Name	Affiliation	email
Chief Scientist	James H. Swift	UCSD/SIO	jswift@ucsd.edu
Co-Chief Scientist	Gregory C. Johnson	NOAA/PMEL	Gregory.C.Johnson@noaa.gov
Data	Kristin Sanborn	UCSD/SIO/STS	ksanborn@ucsd.edu
ET/Salinity/Deck Leader	Rob Palomares	UCSD/SIO/STS	rpalomares@ucsd.edu
Oxygen/Deck	Susan Becker	UCSD/SIO/STS	sbecker@ucsd.edu
CTD Data	Courtney Schatzman	UCSD/SIO/STS	cschatzman@ucsd.edu
Nutrients/Deck	Sue Reynolds	UCSD/SIO/STS	smreynold@ucsd.edu
Salinity/Deck/ET	Robert Thombley	UCSD/SIO/STS	rthomble@ucsd.edu
O2/Deck	Chuck Featherstone	NOAA/AOML	charles.featherstone@noaa.gov
Nutrients/Deck	Peter Proctor	NOAA/PMEL	peter.proctor@noaa.gov
CTD Watch	Kristene E. McTaggart	NOAA/PMEL	Kristene.E.McTaggart@noaa.gov
CTD Watch	Kelly Kearney	Princeton	kkearney@princeton.edu
CTD Watch/Argo	Alison Rogers	UW	alison@ocean.washington.edu
CTD Watch	Sarah Purkey	UW	purkeysg@u.washington.edu
CTD Watch	Caitlin Whalen	UCSD/SIO	caitlin.whalen@gmail.com
DIC/U-WpCO2	Dana Greeley	NOAA/PMEL	dana.greenley@noaa.gov
DIC/U-WpCO2	Robert Castle	NOAA/AOML	bob.castle@noaa.gov
PH	Brendan Rae Carter	UCSD/SIO	brcarter@ucsd.edu
PH	John Adam Radich	UCSD/SIO	jradich@ucsd.edu
TALK	George Cyril Anderson	UCSD/SIO	gcanderson@ucsd.edu
TALK	Jennale Peacock	UCSD/SIO	jlpeacock@ucsd.edu
C14, DOC/TDN	Wenhao Chen	UM/RSMAS	wenchen@rsmas.miami.edu
TM	Christopher Measures	UofHawaii	chrism@soest.hawaii.edu
TM	William M. Landing	FSU	wlanding@fsu.edu
TM	Kathleen Gosnell	FSU	kjg06c@fsu.edu
TM	Maxime Marcel Grand	UofHawaii	maxime@hawaii.edu
TM	Mariko Hatta	UofHawaii	mhatta@hawaii.edu
He/Tr	Anthony Dachille	LDEO	dachille@ldeo.columbia.edu
CFC	Dave Wisegarver	NOAA/PMEL	david.wisegarver@noaa.gov
CFC	Eric Wisegarver	NOAA/PMEL	eric.wisegaver@noaa.gov
CFC	Erin Shields	UCSD/SIO	erin@gaslab.ucsd.edu
ADCP/LADCP	Francois Ascani	UofHawaii	fascani@hawaii.edu
Computer Tech/CTD Data	Frank M. Delahoyde	UCSD/SIO/STS	scg@rv-revelle.ucsd.edu
Resident Tech	David Langner	UCSD/SIO/STS	restech@rv-revelle.ucsd.edu

Scientific Personnel I5

Description of Measurement Techniques

1. CTD/Hydrographic Measurements Program

A total of 195 Rosette/CTD/LADCP casts were made to within 28m of the bottom. Hydrographic measurements consisted of salinity, dissolved oxygen and nutrient water samples taken from each Rosette cast. Pressure, temperature, conductivity/salinity, dissolved oxygen, transmissometer and fluorometer data was recorded from CTD profiles. Current velocities were measured by the downward-facing LADCP. No major problems were encountered during the operation. The distribution of samples is shown in figure 1.0.

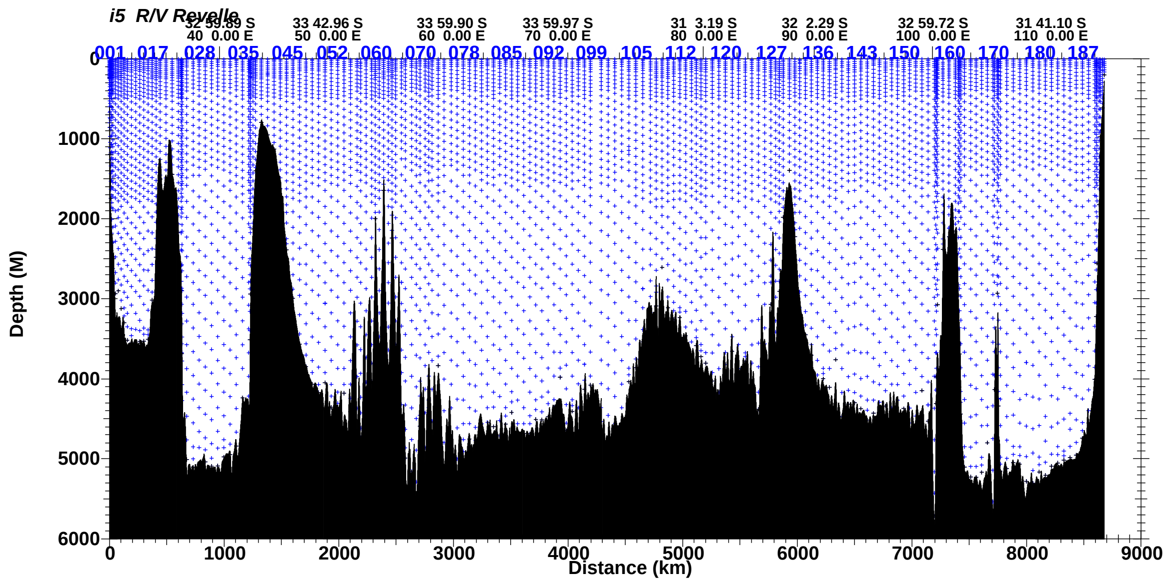


Figure 1.0 Sample distribution, stations 1-195.

1.1. Water Sampling Package

Rosette/CTD/LADCP casts were performed with a package consisting of a 36-bottle rosette frame (SIO/STS), a 36-place carousel (SBE32) and 36 10.0L Bullister bottles (SIO/STS) with an absolute volume of 10.4L. Underwater electronic components consisted of a Sea-Bird Electronics SBE9*plus* CTD (SIO/STS #796) with dual pumps, dual temperature (SBE3*plus*), dual conductivity (SBE4C), dissolved oxygen (SBE43), transmissometer (Wetlabs), fluorometer (Wetlabs CDOM), altimeter (Simrad) and LADCP (RDI).

The CTD was mounted vertically in an SBE CTD cage attached to the bottom of the rosette frame and located to one side of the carousel. The SBE4C conductivity, SBE3*plus* temperature and SBE43 Dissolved oxygen sensors and their respective pumps and tubing were mounted vertically as recommended by SBE on the CTD cage. Pump exhausts were attached to the sensor bracket on the side opposite from the sensors and directed downward. The transmissometer was mounted horizontally, and the fluorometer was mounted vertically along the bottom of the rosette frame. The altimeter was mounted on the inside of the bottom frame ring. The 150 Khz downward-looking Broadband LADCP (RDI) was mounted vertically on one side of the frame between the bottles and the CTD. Its battery pack was located on the opposite side of the frame, mounted on the bottom of the frame. Table 1.1.0 shows height of the sensor referenced to the bottom of the frame.

Instrument	Height in cm
Temperature sensors	14
SBE35	14
Altimeter	5
Transmissometer	9
CDOM Fluorometer	7
Pressure Sensor	21
Inner bottle midline	109
Outer bottle midline	116
BB LADCP XDCR Face midline	11
Zero tape	300

Table 1.1.0 Heights referenced to bottom of rosette frame

The rosette system was suspended from a UNOLS-standard three-conductor 0.322" electro-mechanical sea cable. The sea cable underwent an initial termination at the beginning of I5, a retermination was performed prior to station 13 and an additional mechanical retermination was performed prior to Station 102. The R/V Revelle's forward starboard-side Markey winch was used for all casts.

The deck watch prepared the rosette 10-30 minutes prior to each cast. The bottles were cocked and all valves, vents and lanyards were checked for proper orientation. Once stopped on station, the rosette was moved out from the aft hanger to the deployment location under the squirt boom block using an air-powered cart and tracks. The CTD was powered-up and the data acquisition system started from the computer lab when directed by the deck watch leader. The rosette was unstrapped from the air-powered cart. Tag lines were threaded through the rosette frame and syringes were removed from CTD intake ports. Winch operator was directed by the deck watch leader to raise the package. Squirt boom and rosette were extended outboard and the package was quickly lowered into the water. Tag lines were removed and the package was lowered to 10 meters, until the console operators determined that the sensor pumps had turned on. The winch operator was then directed to bring the package back to the surface (0 winch wireout) and to begin the descent.

Each rosette cast was lowered to within 7-28 meters of the bottom, using the altimeter, winch wireout, CTD depth and echosounder depth to determine the distance. On station 25, the oxygen sensor indicated that the bottom or side of the plateau was touched. One cast was lowered to 6000db, the pressure limit of some of the package instrumentation.

For each up cast, the winch operator was directed to stop the winch between 12-36 standard sampling depths. These standard depths were staggered every station using 3 sampling schemes. To insure package shed wake had dissipated, the CTD console operator waited 30 seconds prior to tripping sample bottles. Before moving to next consecutive trip depth, an additional 8 second pause was observed. Deck watch leader directed the package to the surface for the last bottle trip.

Recovering the package at the end of the deployment was essentially the reverse of launching, with the additional use of poles and snap-hooks to attach tag lines. The rosette was secured on the cart and moved into the aft hanger for sampling. The bottles and rosette were examined before samples were taken, and anything unusual noted on the sample log.

Each bottle on the rosette had a unique serial number. Bottle serial identification was considered independent of the bottle position on the rosette. Sample identification was outlined on sample logs sheet prior to cast recovery or at the time of collection.

Routine CTD maintenance included soaking the conductivity and oxygen sensors in fresh water between casts to maintain sensor stability and occasionally putting dilute Triton-X solution through the conductivity sensors to eliminate any accumulating biofilms. Rosette maintenance was performed on a regular basis. Valves and o-rings were inspected for leaks. No bottle repairs were necessary for this cruise.

1.2. Underwater Electronics Packages

CTD data was collected with a SBE9*plus* CTD (STS/ODF #796). This instrument provided pressure, dual temperature (SBE3), dual conductivity (SBE4), dissolved oxygen (SBE43), CDOM fluorometer (Wetlabs), transmissometer (Wetlabs) and altimeter (Simrad 807) channels. The CTD supplied a standard SBE-format data stream at a data rate of 24 frames/second.

Instrument	Serial Number	A/D Channel
Sea-Bird SBE32 36-place Carousel Water Sampler	3216715-0187	
Sea-Bird SBE9*plus* CTD	0796	
Paroscientific Digiquartz Pressure Sensor	98627	
Sea-Bird SBE11*plus* Deck Unit	11P41717-0727	
Sea-Bird SBE3*plus* Temperature Sensor	03P-4907 (Primary)	
Sea-Bird SBE3*plus* Temperature Sensor	03P-4532 (Secondary, 1-171)	
Sea-Bird SBE3*plus* Temperature Sensor	03P-4476 (Secondary, 172-195)	
Sea-Bird SBE4C Conductivity Sensor	04-3430 (Primary)	
Sea-Bird SBE4C Conductivity Sensor	04-3369 (Secondary)	
Sea-Bird SBE43 DO Sensor	43-0255	Aux 4, Channel 6
Sea-Bird SBE43 DO Sensor	43-0186 (71-195)	Aux 4, Channel 6
Sea-Bird SBE5 Pump	05-5124 (Primary)	
Sea-Bird SBE5 Pump	05-4160 (Primary, 77-195)	
Sea-Bird SBE5 Pump	05-5011 (Secondary)	
Sea-Bird SBE35 Reference Temperature Sensor	35-0035	
Wetlabs CDOM Fluorometer	FLCDRTD-428	Aux 1, Channel 0
Wetlabs CStar Transmissometer	CST-327DR	Aux 1, Channel 1
Simrad 807 Altimeter	9711091	Aux 3, Channel 4
RDI LADCP, UH BB 150	1546	

Table 1.2.0 CLIVAR I5 Rosette Underwater Electronics.

The CTD was outfitted with dual pumps. Primary temperature, conductivity and dissolved oxygen were plumbed into one pump circuit and secondary temperature and conductivity into the other. The sensors were deployed vertically. The primary temperature and conductivity sensors (#03P-4907 and #04-3430) were used for all reported CTD temperatures and conductivities. The secondary temperature and conductivity sensors were used as calibration checks. A SBE35RT reference temperature sensor was connected to the SBE32 carousel and recorded a temperature for each bottle closure. These temperatures were used as additional CTD calibration checks.

The SBE9*plus* CTD was connected to the SBE32 36-place carousel providing for single-conductor sea cable operation. The sea cable armor was used for ground (return). Power to the SBE9*plus* CTD (and sensors), SBE32 carousel and Simrad 807 altimeter was provided through the sea cable from the SBE11*plus* deck unit in the main lab.

1.3. Navigation and Bathymetry Data Acquisition

Navigation data was acquired at 1-second intervals from the ship's GP90 GPS receiver by a Linux system beginning March 22.

Bathymetric data were logged from the ship's Simrad EM120 multibeam echosounder for stations 1-104 and from the Knudsen 3.5KHz echosounder for stations 105-195.

The bottom depths reported in the data transmittal files were calculated with the depth of deepest CTD sampling point and adding the altimeter reading.

1.4. CTD Data Acquisition and Rosette Operation

The CTD data acquisition system consisted of an SBE-11*plus* (V2) deck unit and four networked generic PC workstations running CentOS-5.2 Linux. Each PC workstation was configured with a color graphics display, keyboard, trackball and DVD+RW drive. Two of the systems had a Comtrol Rocketport PCI multi-port serial controller providing 8 additional RS-232 ports. The systems were interconnected through the ship's network. These systems were available for real-time operational and CTD data displays, and provided for CTD and hydrographic data management.

One of the workstations was designated the CTD console and was connected to the CTD deck unit via RS-232. The CTD console provided an interface and operational displays for controlling and monitoring a CTD deployment and closing bottles on the rosette. Another of the workstations was designated the website and database server and maintained the hydrographic database for I5. Redundant backups were managed automatically.

CTD deployments were initiated by the console watch after the ship had stopped on station. The acquisition program was started and the deck unit turned on at least 5 minutes prior to package deployment. The watch maintained a console operations log containing a description of each deployment, a record of every attempt to close a bottle and any relevant comments. The deployment and acquisition software presented a short dialog instructing the operator to turn on the deck unit, to examine the on-screen CTD data displays and to notify the deck watch that this was accomplished.

Once the deck watch had deployed the rosette, the winch operator lowered it to 10 meters. The CTD sensor pumps were configured with an 8-second startup delay after detecting seawater conductivities. The console operator checked the CTD data for proper sensor operation, waited an additional 30 seconds for sensors to stabilize, then instructed the winch operator to bring the package to the surface and descend to a specified target depth (wire-out). The profiling rate was no more than 30m/min to 50m, no more than 45m/min to 200m and no more than 60m/min deeper than 200m, depending on sea cable tension and sea state.

The progress of the deployment and CTD data quality were monitored through interactive graphics and operational displays. Bottle trip locations were transcribed onto the console and sample logs. The sample log was used later as an inventory of samples drawn from the bottles. The altimeter channel, CTD depth, winch wire-out and bathymetric depth were all monitored to determine the distance of the package from the bottom, allowing a safe approach to 10 meters.

Bottles were closed on the up cast by operating an on-screen control. The winch operator was given a target wire-out for the bottle stop, proceeded to that depth and stopped. Bottles were tripped 30-40 seconds after stopping to allow the rosette wake to dissipate and the bottles to flush. The winch operator was instructed to proceed to the next bottle stop at least 8 seconds after closing bottles to ensure that stable CTD data were associated with the trip and to allow the SBE35RT tertiary temperature sensor to make a measurement.

After the last bottle was closed, the console operator directed the deck watch to bring the rosette on deck. Once the rosette was on deck, the console operator terminated the data acquisition, turned off the deck unit and assisted with rosette sampling.

1.5. CTD Data Processing

Shipboard CTD data processing was performed automatically during each Rosette/CTD/LADCP deployment, and at the end of each Trace Metals rosette deployment using SIO/ODF CTD processing software. The Trace Metals rosette contained its own CTD and carousel. These data were acquired using SBE SeaSave software, then copied to a Linux workstation for further processing. No shipboard calibration was done for Trace Metals rosette CTD data.

Processing was performed during data acquisition for Rosette/CTD/LADCP deployments. The raw CTD data were converted to engineering units, filtered, response-corrected, calibrated and decimated to a more manageable 0.5-second time series. The laboratory calibrations for pressure, temperature and conductivity were applied at this time. The 0.5-second time series data were used for real-time graphics during deployments, and were the source for CTD pressure and temperature associated with each rosette bottle. Both the raw 24 Hz data and the 0.5-second time series were stored for subsequent processing. During the deployment, the data were backed up to another Linux workstation.

At the completion of a deployment a sequence of processing steps were performed automatically. The 0.5-second time series data were checked for consistency, clean sensor response and calibration shifts. A 2-decibar pressure series was then generated from the down cast. Both the 2-decibar pressure series and 0.5-second time series data were made available for downloading, plotting and reporting on the shipboard cruise website.

Rosette/CTD/LADCP data were routinely examined for sensor problems, calibration shifts and deployment or operational problems. The primary and secondary temperature sensors (SBE3*plus*) were compared to each other and to the SBE35 temperature sensor. CTD conductivity sensors (SBE4C) were compared to each other, then calibrated by examining differences between CTD and check sample conductivity values. The CTD dissolved oxygen sensor data were calibrated to check sample data. Additional Salinity and O_2 comparisons were made with respect to isopycnal surfaces between down and up casts as well as with adjacent deployments. Vertical sections were made of the various properties derived from sensor data and checked for consistency.

Few CTD acquisition or data processing problems were encountered during I5. During the down cast on 102/02 a software problem required that the cast be restarted at 1200M. The up cast was used for the 2db pressure series in this one case.

A total of 195 casts were made using the 36-place CTD/LADCP rosette, and 87 casts using the 12-place Trace Metals rosette.

1.6. CTD Sensor Laboratory Calibrations

Laboratory calibrations of the CTD pressure, temperature, conductivity and dissolved oxygen sensors were performed prior to CLIVAR I5. The calibration dates are listed in table 1.6.0.

Sensor	S/N	Calibration Date	Calibration Facility
Paroscientific Digiquartz Pressure	98627	07-November-2008	SBE
Sea-Bird SBE3*plus* T1 Temperature	03P-4907	03 February 2009	ODF
Sea-Bird SBE3*plus* T2 Temperature	03P-4532	19 October 2008	SBE
Sea-Bird SBE3*plus* T2 Temperature	03P-4476	23 January 2009	SBE
Sea-Bird SBE4C C1 Conductivity	04-3430	28 October 2008	SBE
Sea-Bird SBE4C C2 Conductivity	04-3369	28 October 2008	SBE
Sea-Bird SBE43 Dissolved Oxygen	43-0255	15 November 2008	SBE
Sea-Bird SBE43 Dissolved Oxygen	43-0186	08 November 2008	SBE
Sea-Bird SBE35 Reference Temperature	0035	10 February 2009	SBE

Table 1.6.0 CLIVAR I5 CTD sensor laboratory calibrations.

1.7. CTD Shipboard Calibration Procedures

CTD #796 was used for all Rosette/CTD/LADCP casts during I5. The CTD was deployed with all sensors and pumps aligned vertically, as recommended by SBE. The primary temperature and conductivity sensors (T1 & C1) were used for all reported CTD data for casts 1-195, with the secondary sensors (T2, 03-4532 & C2, 04-3369) reported for casts 1-171. Prior to cast 172, the secondary temperature was replaced with 03-4476. The SBE35RT Digital Reversing Thermometer (S/N 3528706-0035) served as an independent calibration check for T1 and T2. *In-situ* salinity and dissolved O_2 check samples collected during each cast were used to calibrate the conductivity and dissolved O_2 sensors.

1.7.1. CTD Pressure

The Paroscientific Digiquartz pressure transducer (S/N 98627) was calibrated in November 2008 By SeaBird Electronics Calibration Facility. A calibration correction slope and offset was provided by the SBE calibration report and applied to raw pressures during each cast in addition to the calibration coefficients. Initial out of water pressure transducer offsets varied from -0.5 to +0.1db and final offsets from -0.1 to 0.4db during I5. Residual pressure offsets (the difference between the first and last submerged pressures) varied from -0.4 to +0.1db. No additional adjustments were made to the calculated pressures.

1.7.2. CTD Temperature

A single primary temperature sensor, S/N 03P-4907, was used for all casts and for all reported temperatures. Two secondary temperature sensors were used. T2, S/N 03P-4532, was used for casts 1/1-171/1, and T2, S/N 03P-4476, for casts 172/1-195/1. Calibration coefficients derived from the pre-cruise calibrations plus shipboard temperature corrections determined during the cruise were applied to raw primary and secondary sensor data during each cast.

A single SBE35RT was used as a tertiary temperature check. It was located equidistant between T1 and T2 with the sensing element aligned in a plane with the T1 and T2 sensing elements.

The SBE35RT Digital Reversing Thermometer is an internally-recording temperature sensor that operates independently of the CTD. It is triggered by the SBE32 carousel in response to a bottle closure. According to the Manufacturer's specifications the typical stability is 0.001°C/y ear. The SBE35RT on I5 was set to internally average over an 8 second period.

Two independent metrics of calibration accuracy were examined. At each bottle closure, the primary and secondary temperature were compared with each other and with the SBE35RT temperatures.

Very few temperature corrections were applied during I5. The primary and both of the secondary sensors exhibited a secondary pressure response compared to the SBE35. The first secondary (4532) also had a temperature slope. All corrections made to temperatures had the form:

$$T_{cor} = T + D_1P^2 + D_2P + D_3T^2 + D_4T + Offset$$

The final corrections for all three sensors used on I5 are summarized in table 1.7.2.0. Note that a temperature slope of 0.00024 was applied to all three sensors to convert from the ITS-90 calibration to IPTS-68. Reported sensor data have been converted to ITS-90.

Sensor	P^2	P	T^2	T	Offset
T1 4907	6.68781e-11	-5.10399e-07	0.0	0.00024	0.000621425
T2 4532	-2.17351e-11	-1.06497e-07	0.0	0.000303921	-0.000252577
T2 4476	3.91322e-11	-5.29884e-07	0.0	0.00024	0.000128564

Table 1.7.2.0 Shipboard temperature sensor corrections.

The residual differences after correction are shown in figures 1.7.2.0 and 1.7.2.1.

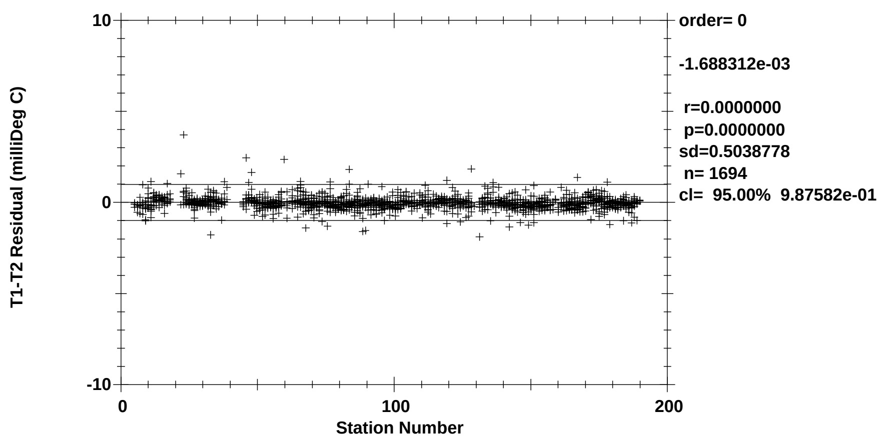


Figure 1.7.2.0 T1-T2 by station ($P \geq 2000$db).

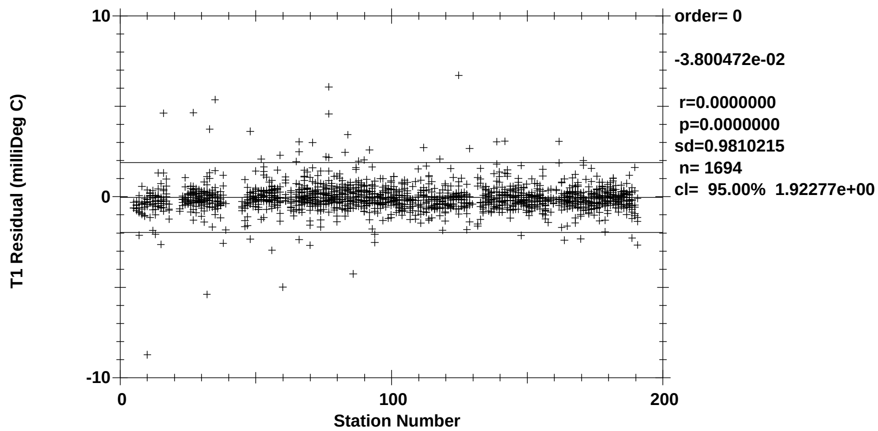


Figure 1.7.2.1 SBE35RT-T1 by station ($P \geq 2000$db).

The 95% confidence limits for the mean low-gradient differences are ±0.0010°C for T1-T2, and ±0.0019°C for SBE35RT-T1.

1.7.3. CTD Conductivity

A single primary conductivity sensor, C1 S/N 04-3430, was used for all casts and for all reported conductivities. A single secondary conductivity sensor, C2 S/N 04-3369, was used. Calibration coefficients derived from the pre-cruise calibrations plus shipboard conductivity corrections determined during the cruise were applied to raw primary and secondary sensor data during each cast.

Two independent metrics of calibration accuracy were examined. At each bottle closure, the primary and secondary conductivity were compared with each other. Each sensor was also compared to conductivity calculated from check sample salinities.

The differences between primary and secondary temperature sensors were used as filtering criteria to reduce the contamination of conductivity comparisons by package wake. The coherence of this relationship is shown in figure 1.7.3.0.

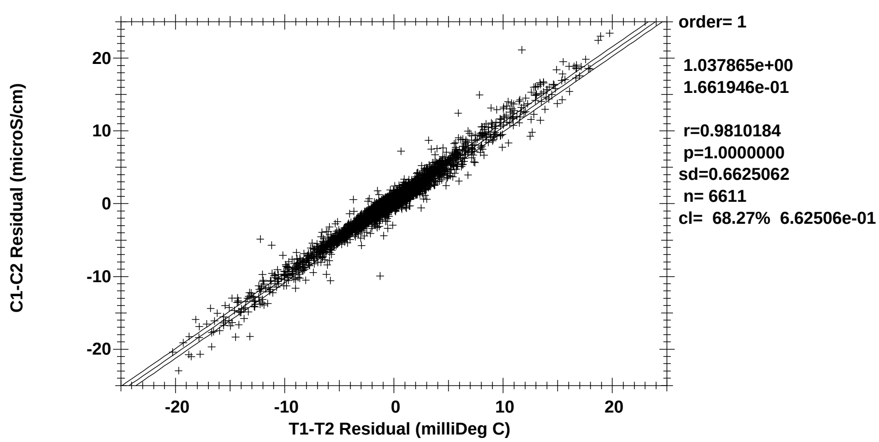


Figure 1.7.3.0 Coherence of conductivity differences as a function of temperature differences.

The uncorrected conductivity comparisons are shown in figures 1.7.3.1 through 1.7.3.3.

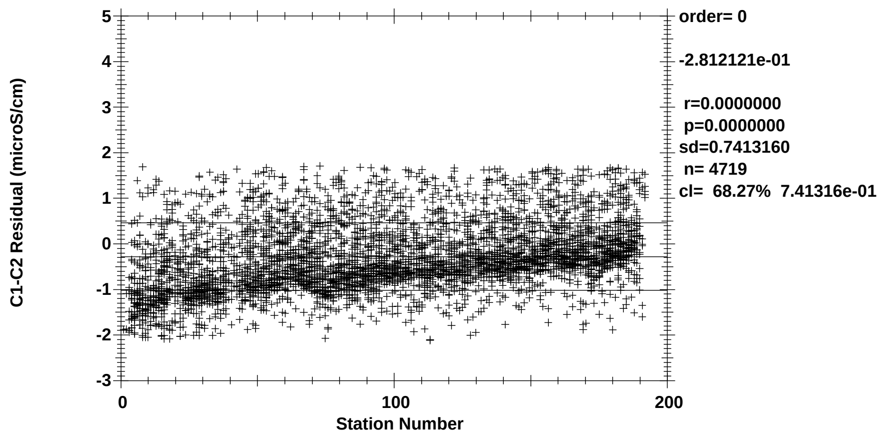


Figure 1.7.3.1 Uncorrected $C1 - C2$ by station (-0.002°C ≤T1-T2≤0.002°C).

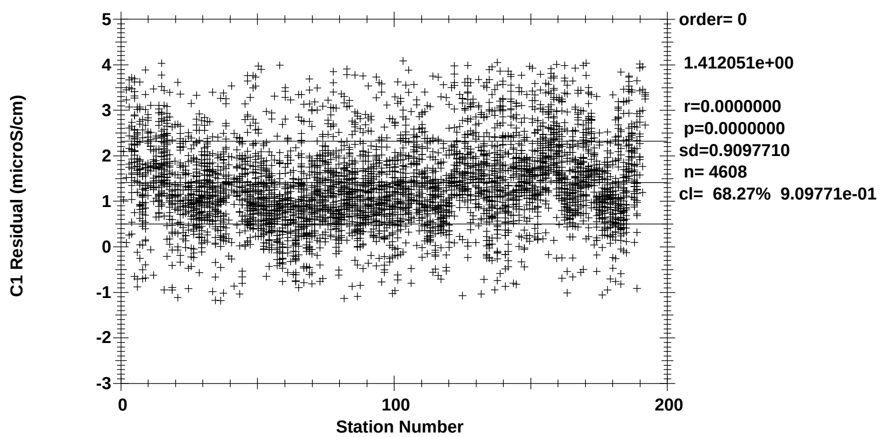


Figure 1.7.3.2 Uncorrected $C_{Bottle} - C1$ by station (-0.002°C ≤T1-T2≤0.002°C).

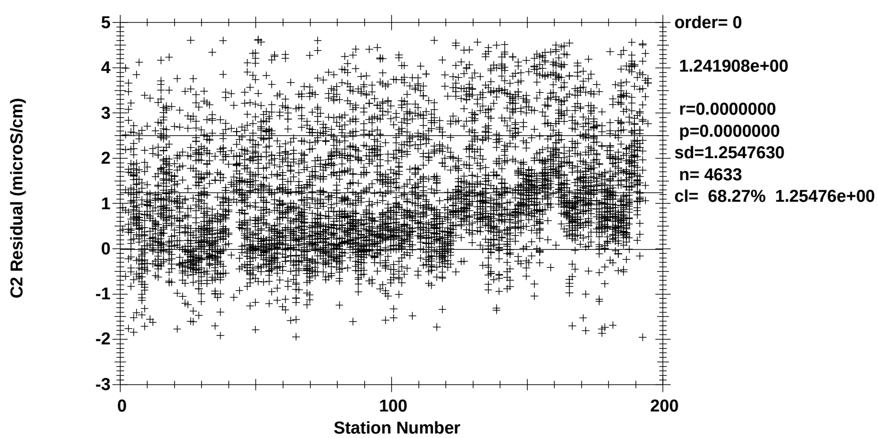


Figure 1.7.3.3 Uncorrected $C_{Bottle} - C2$ by station (-0.002°C ≤T1-T2≤0.002°C).

Based on C1-C2, two first-order time-dependent drift corrections (changing conductivity offset with time) were applied to C2: one for stations 1-71 and another for stations 72-195.

Both conductivity sensors exhibited secondary pressure responses as well as second-order conductivity responses.

The residual differences after correction are shown in figures 1.7.3.4 through 1.7.3.9.

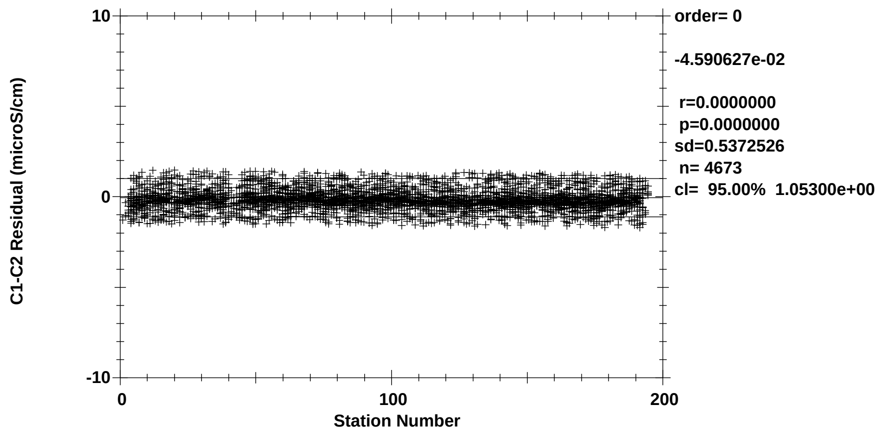


Figure 1.7.3.4 Corrected $C1-C2$ by station (-0.002°C ≤T1-T2≤0.002°C).

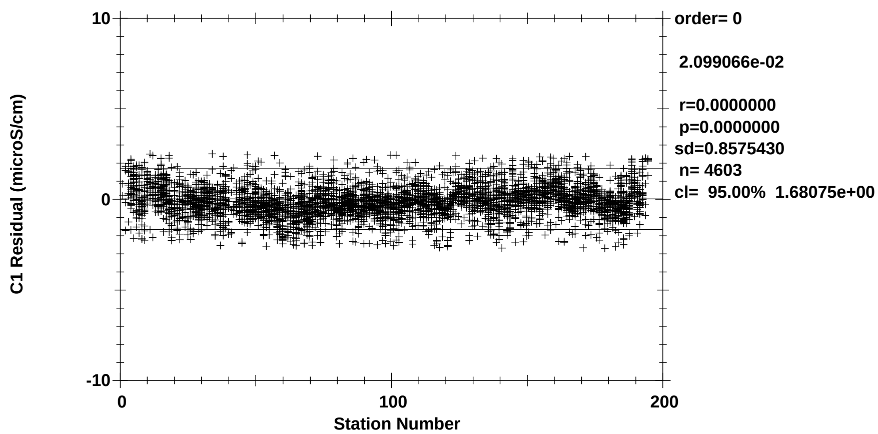


Figure 1.7.3.5 Corrected $C_{Bottle}-C1$ by station (-0.002°C ≤T1-T2≤0.002°C).

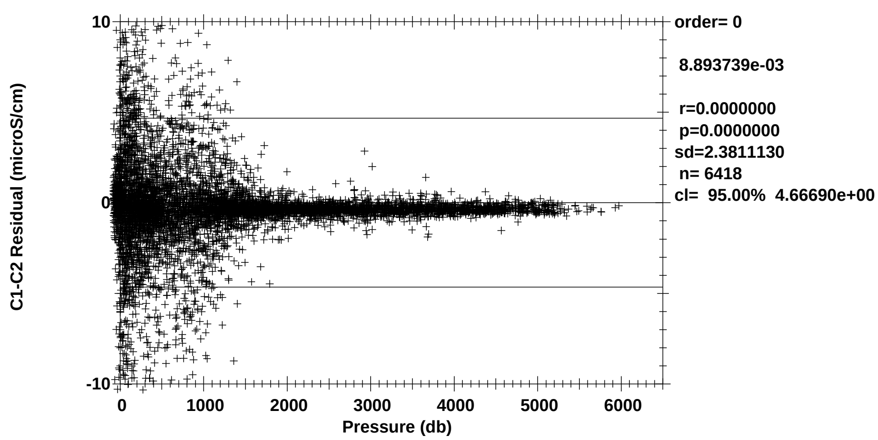


Figure 1.7.3.6 Corrected $C1-C2$ by pressure (-0.01°C ≤T1-T2≤0.01°C).

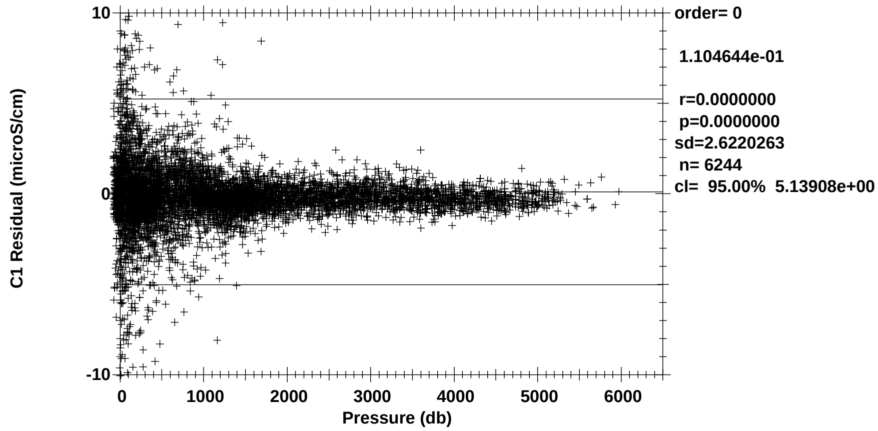


Figure 1.7.3.7 Corrected $C_{Bottle} - C1$ by pressure (-0.01°C ≤T1-T2≤0.01°C).

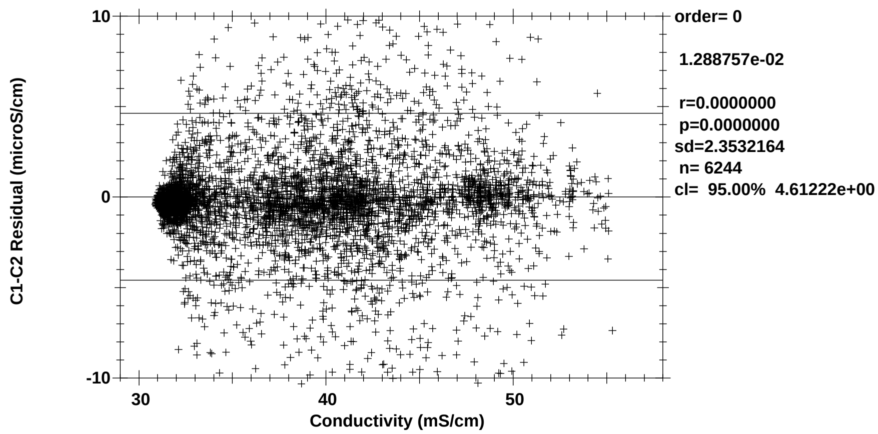


Figure 1.7.3.8 Corrected $C1 - C2$ by conductivity (-0.01°C ≤T1-T2≤0.01°C).

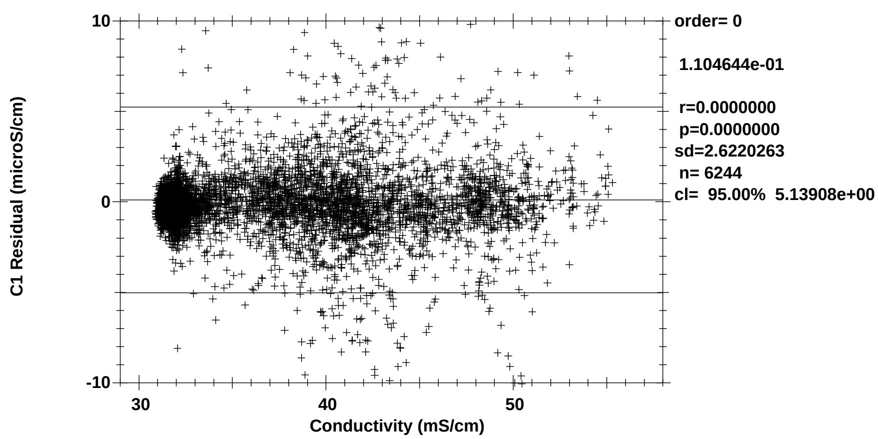


Figure 1.7.3.9 Corrected $C_{Bottle} - C1$ by conductivity (-0.01°C ≤T1-T2≤0.01°C).

All corrections made to conductivity had the form:

$$C_{cor} = C + D_1 P^2 + D_2 P + D_3 C^2 + D_4 C + Offset$$

The final corrections for both sensors used on I5 are summarized in table 1.7.3.0.

Sensor	P^2	P	T^2	T	Offset
C1 3430	5.60178e-11	-4.13345e-07	-7.08965e-06	0.000542455	-0.00823852
C2 3369	5.57295e-11	-4.90364e-07	-1.01074e-05	0.000822047	Varies

Table 1.7.3.0 Shipboard conductivity sensor corrections.

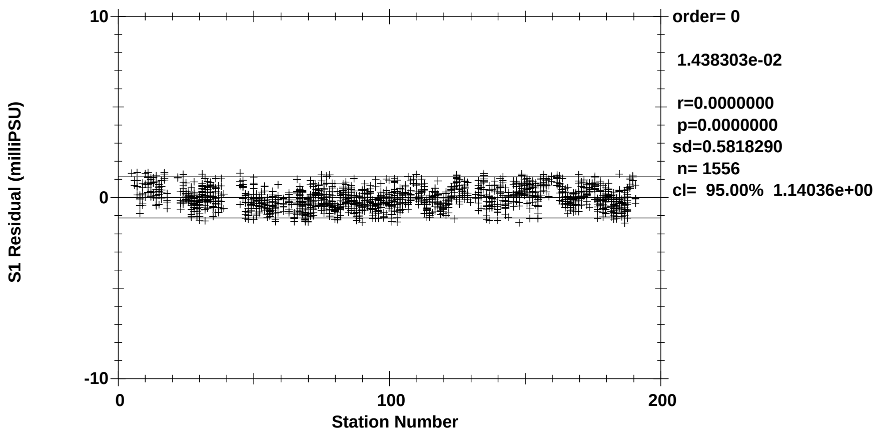


Figure 1.7.3.10 Salinity residuals by station (Pressure>2000db)

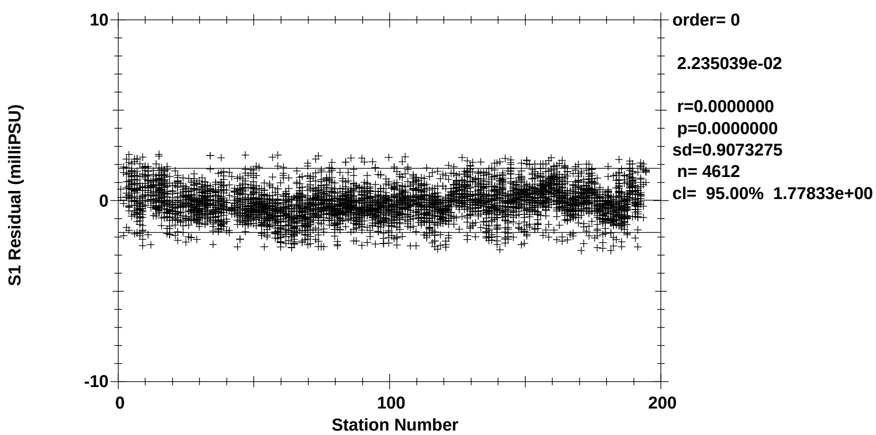


Figure 1.7.3.11 Salinity residuals by station (-0.002°C ≤T1-T2≤0.002°C).

Figures 1.7.3.10 and 1.7.3.11 represent estimates of the deep salinity accuracy of CLIVAR I5. The 95% confidence limits are ±0.0011 PSU relative to the bottle salinities for deep salinities, and ±0.0017 PSU relative to the bottle salinities for all salinities.

1.7.4. CTD Dissolved Oxygen

Two SBE43 dissolved O_2 (DO) sensors were used during this cruise. Sensor S/N 43-0255 was used on Stations 1-70 and 43-0186 was used for 71-195. The sensors were plumbed into the primary T1/C1 pump circuit after C1.

The DO sensors were calibrated to dissolved O_2 check samples taken at bottle stops by matching the down cast CTD data to the up cast trip locations on isopycnal surfaces, then calculating CTD dissolved O_2 using a DO sensor response model and minimizing the residual differences from the check samples. A non-linear least-squares fitting procedure was used to minimize the residuals and to determine sensor model coefficients, and was accomplished in three stages. The time constants for the lagged terms in the model were first determined for each sensor. These time constants are sensor-specific but applicable to an entire cruise. Next, casts were fit individually to check sample data. The resulting calibration coefficients were then smoothed and held constant during a refit to determine sensor slope and offset.

Standard and blank values for check sample oxygen titration data were smoothed and the oxygen recalculated prior to the final fitting of CTD oxygen.

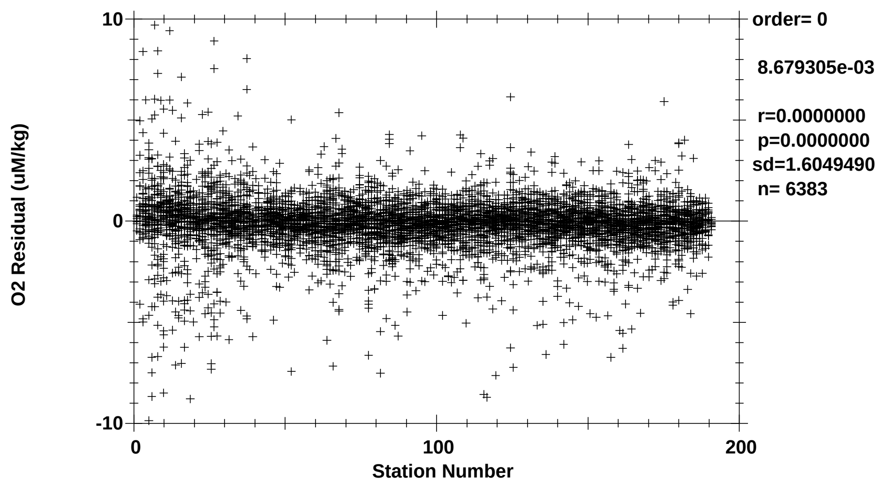


Figure 1.7.4.0 O_2 residuals by station (-0.01°C ≤T1-T2≤0.01°C).

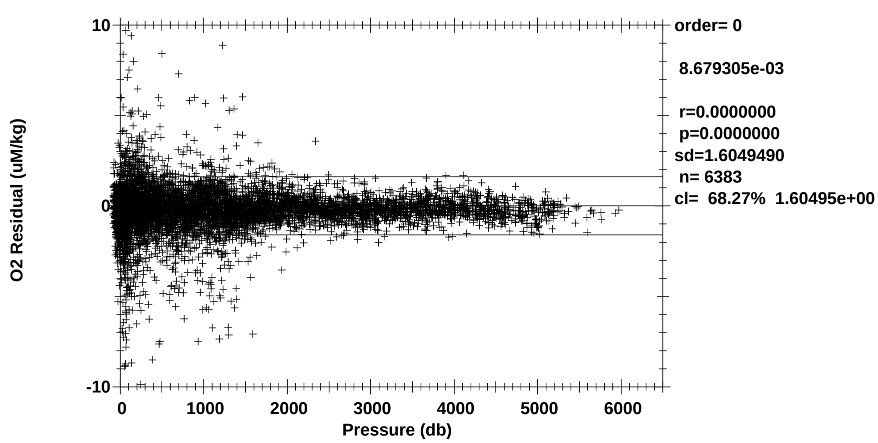


Figure 1.7.4.1 O_2 residuals by pressure (-0.01°C ≤T1-T2≤0.01°C).

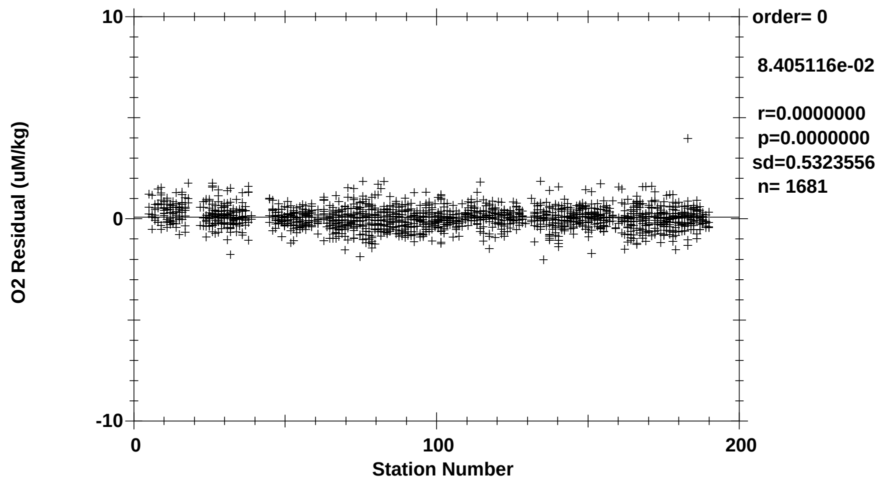


Figure 1.7.4.2 O_2 residuals by station (Pressure>2000db).

The standard deviations of 1.605 μmol/kg for all oxygens and 0.532 μmol/kg for deep oxygens are only presented as general indicators of goodness of fit. ODF makes no claims regarding the precision or accuracy of CTD dissolved O_2 data.

The general form of the ODF DO sensor response model equation for Clark cells follows Brown and Morrison [Brow78], and Millard [Mill82], [Owen85]. ODF models DO sensor secondary responses with lagged CTD data. *In-situ* pressure and temperature are filtered to match the sensor responses. Time constants for the pressure response τ_p, a slow (τ_{Tf}) and fast (τ_{Ts}) thermal response, package velocity (τ_{dP}), thermal diffusion (τ_{dT}) and pressure hysteresis (τ_h) are fitting parameters. Once determined for a given sensor, these time constants typically remain constant for a cruise. The thermal diffusion term is derived by low-pass filtering the difference between the fast response (T_s) and slow response (T_l) temperatures. This term is intended to correct non-linearities in sensor response introduced by inappropriate analog thermal compensation. Package velocity is approximated by low-pass filtering 1st-order pressure differences, and is intended to correct flow-dependent response. Dissolved O_2 concentration is then calculated:

$$O_2ml/l = [C_1V_{DO}e^{(C_2\frac{P_h}{5000})} + C_3] \cdot f_{sat}(T,P) \cdot e^{(C_4T_l + C_5T_s + C_6P_l + C_7\frac{dP}{dt} + C_8dT)} \qquad (1.7.4.0)$$

where:

O_2ml/l	Dissolved O_2 concentration in ml/l;
V_{DO}	Raw sensor output;
C_1	Sensor slope
C_2	Hysteresis response coefficient
C_3	Sensor offset
$f_{sat}(T,P)$	O_2 saturation at T,P (ml/l);
T	*insitu* temperature (°C);
P	*insitu* pressure (decibars);
P_h	Low-pass filtered hysteresis pressure (decibars);
P_l	Low-pass filtered pressure (decibars);
T_l	Long-response low-pass filtered temperature (°C);
T_s	Short-response low-pass filtered temperature (°C);
$\frac{dP}{dt}$	Filtered package velocity (db/sec);
dT	low-pass filtered thermal diffusion estimate (T_f - T_s).
$C_4 - C_8$	Response coefficients.

1.8. Bottle Sampling

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

- CFC-11,CFC-12, SF6
- ^{3}He
- O_2
- Dissolved Inorganic Carbon (DIC)
- pH
- Total Alkalinity
- ^{13}C and ^{14}C
- Dissolved Organic Carbon (DOC) and Total Dissolved Nitrogen (TDN)
- Nutrients
- Tritium
- Salinity

The correspondence between individual sample containers and the rosette bottle position (1-36) from which the sample was drawn was recorded on the sample log for the cast. This log also included any comments or anomalous conditions noted about the rosette and bottles. One member of the sampling team was designated the *sample cop*, whose sole responsibility was to maintain this log and insure that sampling progressed in the proper drawing order.

Normal sampling practice included opening the drain valve and then the air vent on the bottle, indicating an air leak if water escaped. This observation together with other diagnostic comments (e.g., "lanyard caught in lid", "valve left open") that might later prove useful in determining sample integrity were routinely noted on the sample log. Drawing oxygen samples also involved taking the sample draw temperature from the bottle. The temperature was noted on the sample log and was sometimes useful in determining leaking or mis-tripped bottles.

Once individual samples had been drawn and properly prepared, they were distributed for analysis. Oxygen, nutrient and salinity analyses were performed on computer-assisted (PC) analytical equipment networked to the data processing computer for centralized data management.

1.9. Bottle Data Processing

Water samples collected and properties analyzed shipboard were centrally managed in a relational database (PostgreSQL 8.1.11) running on a Linux system. A web service (OpenACS 5.3.2 and AOLServer 4.5.0) front-end provided ship-wide access to CTD and water sample data. Web-based facilities included on-demand arbitrary property-property plots and vertical sections as well as data uploads and downloads.

The sample log (and any diagnostic comments) was entered into the database once sampling was completed. Quality flags associated with sampled properties were set to indicate that the property had been sampled, and sample container identifications were noted where applicable (e.g., oxygen flask number).

Analytical results were provided on a regular basis by the various analytical groups and incorporated into the database. These results included a quality code associated with each measured value and followed the coding scheme developed for the World Ocean Circulation Experiment Hydrographic Programme (WHP) [Joyc94].

Table 1.9.0 shows the number of samples drawn and the number of times each WHP sample quality flag was assigned for each basic hydrographic property:

Rosette Samples Stations 1- 195								
	Reported levels	WHP Quality Codes 1	2	3	4	5	7	9
Bottle	6724	0	6715	2	5	0	0	2
CTD Salt	6724	0	6693	0	31	0	0	0
CTD Oxy	6699	0	6699	0	0	22	0	3
Salinity	6598	0	6540	41	17	4	0	122
Oxygen	6700	0	6689	2	9	6	0	18
Silicate	6710	0	6704	1	5	1	0	13
Nitrate	6710	0	6703	2	5	1	0	13
Nitrite	6710	0	6704	1	5	1	0	13
Phosphate	6710	0	6702	1	7	1	0	13

Table 1.9.0 Frequency of WHP quality flag assignments.

Additionally, all WHP water bottle/sample quality code comments are presented in Appendix A.

Various consistency checks and detailed examination of the data continued throughout the cruise.

1.10. Salinity

Equipment and Techniques

A single Guildline Autosal 8400B salinometer (S/N 69-180) located in Revelle's hydro lab, was used for all salinity measurements. This salinometer had been modified to include a communication interface for computer-aided measurement, a higher capacity pump and three temperature sensors. Two of these sensors were used to measure air and bath temperatures. The third was used to check sample bottle temperature.

Samples were analyzed after they had equilibrated to laboratory temperature, usually within 16-20 hours after collection. The salinometer was standardized for each group of analyses (usually 1-2 casts, up to ~48 samples) using at least two fresh vials of standard seawater per group.

Salinometer measurements were aided by computer using software developed by SIO/STS. The software maintained A log of each salinometer run which included salinometer settings and air and bath temperatures. It also guided the operator through the standardization procedure and making sample measurements. The analyst was prompted to change samples and flush the cells between readings.

Special standardization procedures included flushing the cell at least 4 times with a fresh vial of Standard Seawater (SSW), setting the flow rate as low as possible during the last fill, and monitoring the STD dial setting. If the STD dial changed by 10 units or more since the last salinometer run (or during standardization), another vial of SSW was opened and the standardization procedure repeated to verify the setting.

Samples were run using 3 flushes before the final fill. The computer determined the stability of a measurement and prompted for additional readings if there appeared to be drift. The operator could annotate the salinometer log, and would routinely add comments about cracked sample bottles, loose thimbles, salt crystals or anything unusual in the amount of sample in the bottle.

A system of fans and heaters set up to expedite equilibrating salinity samples usually worked.

Sampling and Data Processing

A total of 6598 salinity measurements were made (1016 for Trace Metals) and approximately 210 vials of standard seawater (IAPSO SSW) were used.

Salinity samples were drawn into 200 ml Kimax high-alumina borosilicate bottles, which were rinsed three times with the sample prior to filling. The bottles were sealed with custom-made plastic insert thimbles and kept closed with 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. The draw and equilibration times were logged for all casts. Laboratory temperatures were logged at the beginning and end of each run.

PSS-78 salinity [UNES81] was calculated for each sample from the measured conductivity ratios. The difference (usually none) between the initial vial of standard water and the next one run as an unknown was applied as a linear function of elapsed run time to the measured ratios. The corrected salinity data were then incorporated into the cruise database.

Data processing included double checking that the station, sample and box number had been correctly assigned, and reviewing the data and log files for operator comments. The salinity data were compared to CTD salinities and were used for shipboard sensor calibration.

Laboratory Temperature

The salinometer water bath temperature was maintained slightly higher than ambient laboratory air temperature. It was set to 27 °C for the first 3 stations and to 24 °C for the rest of the cruise. The ambient air temperature varied from 21 to 27°C during the cruise, and from -1.5 to 4.3 °C during any particular run.

Standards

IAPSO Standard Seawater Batch P-149 was used to standardize all casts. It was noticed that some of the vials did not have uniform volumes of standard, labels were not put on the vial straight and many of the crimp seals did not release properly, the tab breaking away instead of pulling the sealed section away. These observations raise quality control questions about this batch of Standard Seawater. The recent batch to batch comparison conducted by Dr. Kawano [Kawa09] claims in a draft that P-149 has an offset of 0.8 $^{*10^{-3}}$.

Analytical Problems

A few of the analyses had sample temperature issues. Stations 166 through 168 required adjusting the analytical temperature to match the sample temperatures which hadn't equilibrated. The resulting agreement with adjacent cast data stresses the importance of sample temperature to the accuracy of the salinity measurement.

Minimal sampling was done for stations 10-13, concentrating on the deep profile to insure the availability of sample bottles for future casts.

Results

The estimated accuracy of bottle salinities run at sea is usually better than ±0.002 PSU relative to the particular standard seawater batch used. The 95% confidence limit for residual differences between the bottle salinities and calibrated CTD salinity relative to SSW batch P-149 was ±0.0017 PSU for all salinities, and ±0.00011 PSU for salinities deeper than 2000db.

1.11. Oxygen Analysis

Equipment and Techniques

Dissolved oxygen analyses were performed with an SIO/ODF-designed automated oxygen titrator using photometric end-point detection based on the absorption of 365nm wavelength ultra-violet light. The titration of the samples and the data logging were controlled by PC LabView software. Thiosulfate was dispensed by a Dosimat 665 buret driver fitted with a 1.0 mL buret. ODF used a whole-bottle modified-Winkler titration following the technique of Carpenter [Carp65] with modifications by Culberson *et al.* [Culb91], but with higher concentrations of potassium iodate standard (~0.012N) and thiosulfate solution (~55 gm/l). Pre-made liquid potassium iodate standards were run daily (approximately every 2-4 stations), unless changes were made to the system or reagents. Reagent/distilled water blanks were also determined daily or more often if a change in reagents required it to account for presence of oxidizing or reducing agents.

Sampling and Data Processing

6700 oxygen measurements were made. Samples were collected for dissolved oxygen analyses soon after the rosette was brought on board. Four different cases of 36 flasks each were rotated by station to minimize flask calibration issues, if any. Using a Tygon and silicone drawing tube, nominal 125ml volume-calibrated iodine flasks were rinsed 3 times with minimal agitation, then filled and allowed to overflow for at least 3 flask volumes. The sample drawing temperatures were measured with an electronic resistance temperature detector (RTD) embedded in the drawing tube. These temperatures were used to calculate umol/kg concentrations, and as a diagnostic check of bottle integrity. Reagents ($MnCl_2$ then NaI/NaOH) were added to fix the oxygen before stoppering. The flasks were shaken twice (10-12 inversions each time) to assure thorough dispersion of the precipitate, once immediately after drawing, and then again after about 20 minutes.

The samples were analyzed within 1-4 hours of collection, and the data incorporated into the cruise database.

Thiosulfate normalities were calculated from each standardization and corrected to 20°C. The thiosulfate normalities and blanks were monitored for possible drifting or possible problems when new reagents were used. There was no indication of drifting blanks or thiosulfate normalities over the course of the cruise. The blanks and thiosulfate normalities for each batch of thiosulfate were smoothed (averaged) in two groups during the cruise and the oxygen values recalculated. The difference between the original and "smoothed" data was less than 0.1%.

Bottle oxygens data was reviewed insuring proper station, cast, bottle number, flask, and draw temperature were entered properly. Any comments made during analysis was also reviewed making certain that any anomalous actions were investigated and resolved. Occasionally, an incorrect end point was encountered. The analyst has the provisions available through the software to check the raw data and have the program recalculated a correct end point. This happened very few times on this data set. The occurrence is usually attributed to debris in the water bath.

After the data is uploaded to the database, oxygen is graphically compared with CTD oxygen and adjoining stations. Any erroneous looking points are reviewed and comments are made regarding the final outcome of the investigation. These investigations and final data coding are reported in Appendix A.

Volumetric Calibration

Oxygen flask volumes were determined gravimetrically with degassed deionized water to determine flask volumes at ODF's chemistry laboratory. This was done once before using flasks for the first time and periodically thereafter when a suspect volume is detected. The volumetric flasks used in preparing standards were volume-calibrated by the same method, as was the 10 ml Dosimat buret used to dispense standard iodate solution.

Standards

Liquid potassium iodate standards were prepared in 6 liter batches and bottled in sterile glass bottles at ODF's chemistry laboratory prior to the expedition. The normality of the liquid standard was determined by calculation from weight. The standard was supplied by Alfa Aesar (lot B05N35) and has a reported purity of 99.4-100.4%. All other reagents were "reagent grade" and were tested for levels of oxidizing and reducing impurities prior to use.

1.12. Nutrient Analysis

Equipment and Techniques

Nutrient analyses (phosphate, silicate, nitrate plus nitrite, and nitrite) were performed on an SIO/STS/ODF-modified 4 channel Technicon AutoAnalyzer II. Modifications to the system include STS/ODF developed data acquisition and processing software using the LabView utility and an interface from the detectors to the computer.
The analytical methods used are described by Gordon *et al.* [Gord92] Hager *et al.* [Hage68] and Atlas *et al.* [Atla71]

Silicate

Silicate was analyzed using the technique of Armstrong *et al.* [Arms67]. An acidic solution of ammonium molybdate was added to a seawater sample to produce silicomolybdic acid which was then reduced to silicomolybdous acid (a blue compound) following the addition of stannous chloride. Tartaric acid was also added to impede PO_4 color development. The sample was passed through a 15mm flowcell and the absorbance measured at 660nm.

Reagents

Tartaric Acid (ACS Reagent Grade)

200g tartaric acid dissolved in DW and diluted to 1 liter volume. Stored at room temperature in a polypropylene bottle.

Ammonium Molybdate

10.8g Ammonium Molybdate Tetrahydrate dissolved in 1000ml dilute H_2SO_4*.

*(Dilute H_2SO_4 = 2.8ml conc H_2SO_4 to a liter DW). Added 3 drops 15% ultra pure SDS per liter of solution.

Stannous Chloride (ACS Reagent Grade)

Stock solution:

40g of stannous chloride dissolved in 100 ml 5N HCl. Refrigerated in a polypropylene bottle.

Working solution:

5 ml of stannous chloride stock diluted to 200 ml final volume with 1.2N HCl. Made up daily and stored at room temperature when not in use in a dark polypropylene bottle.

NOTE: Oxygen introduction was minimized by swirling rather than shaking the stock solution.

Nitrate + Nitrate

A modification of the Armstrong *et al.* [Arms67] procedure was used for the analysis of nitrate and nitrite. For the nitrate analysis, the seawater sample was passed through a cadmium reduction column where nitrate was quantitatively reduced to nitrite. Sulfanilamide was introduced to the sample stream followed by N-(1-naphthyl)ethylenediamine dihydrochloride which coupled to form a red azo dye. The stream was then passed through a 15mm flowcell and the absorbance measured at 540nm. The same technique was employed for nitrite analysis, except the cadmium column was not present, and a 50mm flowcell was used for measurement.

Reagents

Sulfanilamide (ACS Reagent Grade)

10g sulfanilamide dissolved in 1.2N HCl and brought to 1 liter volume. Added 5 drops of 40% surfynol 465/485 surfactant. Stored at room temperature in a dark polypropylene bottle.

N-(1-Naphthyl)-ethylenediamine dihydrochloride (N-1-N) (ACS Reagent Grade)

1g N-1-N in DIW, dissolved in DW and brought to 1 liter volume. Added 2 drops 40% surfynol 465/485 surfactant. Stored at room temperature in a dark polypropylene bottle. Discarded if the solution turned dark reddish brown.

Imidazole Buffer (ACS Reagent Grade)

13.6g imidazole dissolved in ~3.8 liters DIW. Stirred for at least 30 minutes until completely dissolved. Added 60 ml of CuSO4 + NH4Cl mix (see below). Added 4 drops 40% Surfynol 465/485 surfactant. Using a calibrated pH meter, adjusted to pH of 7.83-7.85 with 10% (1.2N)HCl(about 20-30ml of acid, depending on exact strength). Final solution brought to 4L with DIW. Stored at room temperature.

NH_4Cl **+** $CuSO_4$ **mix**:

2g cupric sulfate dissolved in DIW, brought to 100 ml volume (2%) 250g ammonium chloride dissolved in DIW, brought to 1 liter volume. Added 5ml of 2% $CuSO_4$ solution to the NH_4Cl stock.

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

Prepared solution at least one day before use to stabilize.

Phosphate

Phosphate was analyzed using a modification of the Bernhardt and Wilhelms [Bern67] technique. An acidic solution of ammonium molybdate was added to the sample to produce phosphomolybdic acid, then reduced to phosphomolybdous acid (a blue compound) following the addition of dihydrazine sulfate. The reaction product was heated to ~55°C to enhance color development, then passed through a 50mm flowcell and the absorbance measured at 820nm.

Reagents

Ammonium Molybdate (ACS Reagent Grade)

H_2SO_4 solution:

420 ml of DIW poured into a 2 liter Ehrlenmeyer flask or beaker, this flask or beaker was placed into an ice bath. SLOWLY added 330 ml of conc H_2SO_4. This solution gets VERY HOT!!

27g ammonium molybdate dissolved in 250ml of DIW. Brought to 1 liter volume with the cooled sulfuric acid solution. Added 5 drops of 15% ultra pure SDS surfactant. Stored in a dark polypropylene bottle.

Dihydrazine Sulfate (ACS Reagent Grade)

6.4g dihydazine sulfate dissolved in DIW, brought to 1 liter volume and refrigerated.

Sampling and Data Processing

6710 nutrient samples were analyzed and 1016 were analyzed for Trace Metal casts. Duplicates for 24 stations were drawn and analyzed on the Technicon AA3 system. The cruise started with new pump tubes and then they were changed five times during the cruise, after Stations 025, 068, 099, 141 and 180. Ten Beer’s Law calibration checks were run throughout the cruise. Six sets of Primary/Secondary standard were made up over the course of the cruise. Primary and secondary standards were compared to the "old" standard before they were used to insure continuity between standards. The cadmium column efficiency was check periodically. Initially column efficiencies were 93%, however, after replacing the original column, efficiencies were 100% for the remainder of the cruise.

Nutrient samples were drawn into 40 ml polypropylene screw-capped centrifuge tubes. The tubes and caps were cleaned with 10% HCl and rinsed once with de-ionized water and 2-3 times with sample before filling. Samples were analyzed within two hours after sample collection, allowing sufficient time for all samples to reach room temperature. The centrifuge tubes fit directly onto the sampler.

The analog outputs from each of the channels were digitized and logged automatically by computer (PC) at 2-second intervals. After each group of samples was analyzed, the raw data file was processed to produce another file of response factors, baseline values, and absorbances. Computer-produced absorbance readings were checked for accuracy against values taken from a strip chart recording which is produced simultaneously with the computer. Refractive Index blanks were determined periodically by measuring the absorbance of low nutrients seawater with one reagent from each of the chemistries offline. The difference between the distilled water baseline and the seawater absorbance was recorded. Sample concentrations were then calculated, refractive index blanks and any non-linear corrections applied, and data merged with other hydrographic measurements. Carryover was minimized by running the samples from low to high concentration. Nutrients, reported in micromoles per kilogram, were converted from micromoles per liter by dividing by sample density calculated at 1 atm pressure (0 db), in-situ salinity, and the lab temperature measured when individual samples were drawn into the AA.

Standards and Glassware

Standardizations were performed at the beginning and end of each group of analyses with an intermediate concentration mixed nutrient standard prepared prior to each run from a secondary standard in a low-nutrient seawater matrix. A group usually consisted of one station/cast or two trace metal stations/casts (up to 36 samples). The secondary standards were prepared aboard ship by dilution from the pre-weighed primary standards. A set of 7 different standard concentrations, Table 1.12.0, were analyzed periodically to determine the deviation from linearity, if any, as a function of absorbance for each nutrient. Residuals were determined and fit to a 3rd order polynomial, which was then used to calculate the non-linear corrections applied to the nutrient concentrations. An aliquot from a large volume of stable deep seawater was also run with each set of samples as a substandard and as an additional check.

std	N+N	PO4	SiO3	NO2
1)	0.0	0.0	0.0	0.0
2)	7.75	0.6	30	0.25
3)	15.50	1.2	60	0.50
4)	23.25	1.8	90	0.75
5)	31.00	2.4	120	1.00
6)	38.75	3.0	150	1.25
7)	46.50	3.6	180	1.50

Table 1.12.0 CLIVAR I5 Standard Concentrations

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

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

Working standards were made up in low nutrient seawater (LNSW). The first 40L carboy of water used was collected off shore of coastal California and treated in the lab. The water was first filtered through a 0.45 micron filter then re-circulated for ~8 hours through a 0.2 micron filter, passed a UV lamp and through a second 0.2 micron filter. Subsequent LNSW used was collected at various stations in clean 40L carboys from the ship's underway system, which provided uncontaminated low nutrient surface water. The actual concentration of nutrients in this water was empirically determined during the calculation of the non-linear corrections that were applied to the nutrient concentrations.

The Nitrate (KNO_3 lot# 042263) and Phosphate (KH_2PO_4 lot# 991608) primary standards were obtained from Fisher Scientific with reported purities of 100% and 99.8%, respectively. The Silicate standards were from both Alfa Aesar (Na_2SiF_6 lot# J25E26) and Fluka (Na_2SiF_6 lot# 449247/1) with reported purities of >98%. Nitrite standards were obtained from Alfa Aesar ($NaNO_2$ lot# K19D12 and lot# B065013) with reported purities of 97%.

Quality Control

As is standard ODF practice, a deep calibration *check* sample was run with each set of sample. Table 1.12.1 is a summary of those calibration check samples.

Parameter	AAII concentration
NO3	30.54 uM ±0.27
PO4	2.17 uM ±0.02
SIL	71.6 uM ±0.69
NO2	0.01 uM ±0.005

Table 1.12.1 Calibration *check* samples

Analytical problems

The pump for the Silicate channel was changed out after station 028 due to mechanical problems causing it to stop pumping periodically. The Nitrite SCIC was changed out after station 077 which improved the stability of the baseline. The standard cal was adjusted for Nitrate after station 010, and all Beer's Law checks run after this could only be used for smoothing the final Nitrate data after this station. Two of the ten Beer's Law check runs were not acceptable and thus not used in the nutrient calculations. There were observed small Phosphate variations in the deep water, however, these variations are close to or at the limits of the methods for both sample collection and sample analysis. The temperature of the laboratory used for the analyses ranged from 23.0°C to 24.5°C.

During the nutrient analysis of Station 141 cast 1, the air-conditioning unit was switched off and the lab temperature increase. This caused a drift in nitrate values at the end of the analysis. However, a correction was applied to the nitrate raw data, it was reprocessed and is acceptable.

Nutrient instrument comparison

Duplicate samples were drawn from 25 stations for comparison with results of the AAII, the current equipment, with the AA3. Data will be reviewed in the office and sent to the CLIVAR community for review and comments before incorporating the autoanalyzer into the STS/ODF CLIVAR time-series data.

1.13. Historical Comparison

James Swift, Chief Scientist and $CTDO_2$/rosette/S/O2/nutrients/data processing PI

The I5 cruise track crossed the 2007 I8S cruise track at about 34°S, 95°E. The bottle cast data for I5 stations 144-146 were compared with those from I8S stations 76-78. The comparisons indicated close cruise-to-cruise agreement between temperature, salinity, dissolved oxygen, silicate, CFC-12, and total carbon, except for variations which appeared likely to be due more to oceanography than standardization. Possible small cruise-to-cruise offsets (standardization differences) were observed for nitrate, phosphate, and alkalinity.

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Chlorofluorocarbon and Sulfur Hexafluoride Measurements

PIs: John Bullister
Mark Warner

Analysts: David Wisegarver
Eric Wisegarver
Erin Shields

Approximately 3500 samples were analyzed for two dissolved chlorofluorocarbons (CFC-11 and CFC-12) and for sulfur hexafluoride (SF_6) on the CLIVAR I5 expedition, using methods described by Bullister and Wisegarver (2008).In general the analytical system performed well on the cruise.

Routine measurements of dissolved SF6 in seawater remain extremely challenging. 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 on CLIVAR I5 were approximately 0.02 fmol kg^{-1}. SF_6. Improvements in the analytical sensitivity to this compound at low concentrations are essential to make these measurements more routine on future CLIVAR cruises.

Water samples on CLIVAR I5 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 ('CFC/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 most easily impacted by gas exchange (dissolved oxygen, ^{3}He, 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^{O}C until ~20 minutes before being analyzed. At that time, the syringe was place in a bath of surface seawater heated to ~30^{o}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 14 locations along the cruise track. At each location, at least five air measurements were made to increase the precision of the measurements. Air measurements are listed at the end of this report.

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 purge gas 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 an 18 cm long, 3/8" diameter glass tube packed with the desiccant magnesium perchlorate. The sample gases were concentrated on a cold-trap consisting of a 1/16" OD stainless steel tube with a 5 cm section packed tightly with Porapak Q (60-80 mesh) and a 22 cm section packed with Carboxen 1000. A Neslab Cryocool CC-100 was used to cool the trap to ~-70°C. After 6 minutes of purging, the trap was isolated, and it was heated electrically to ~200°C. The sample gases held in the trap were then injected onto a precolumn (~60 cm of 1/8" O.D. stainless steel tubing packed with 80-100 mesh Porasil B, held at 80°C) for the initial separation of CFC-12, CFC-11, SF_6 and CCl_4 from later eluting peaks.

After the SF_6 and CFC-12 had passed from the pre-column and into the second precolumn (5 cm of 1/8" O.D. stainless steel tubing packed with MS5A, 80°C) and into the analytical column #1 (240 cm of 1/8" OD stainless steel tubing packed with MS5A and held at 80°C), the outflow from the first precolumn was diverted to the second analytical column (150 cm 1/8" OD stainless steel tubing packed with Carbograph 1AC, 80-100 mesh, held at 80°C). After CFC-11 had passed through the first pre-column, the flow was diverted to a third analytical column (1.7 m of Carbograph 1AC, 80°C). The gases remaining after CCl_4 had passed through the first pre-column, were backflushed from the pre column and vented. Column #1 and the second pre-column were held in a Shimadzu GC8 gas chromatograph with an electron capture detector (ECD) held at 340^{o}C. Column #2 and the first precolumn were in another Shimadzu GC8 gas chromatograph with ECD. Column #3 was held in a Shimadzu Mini2 gas chromatograph (90 C) with the ECD held at 250^{o}C.

The analytical system was calibrated frequently using a standard gas of known CFC/SF_6 composition. Gas sample loops of known volume were thoroughly flushed with standard gas and injected into the system. The temperature and pressure was recorded so that the amount of gas injected could be calculated. The procedures used to transfer the standard gas to the trap, precolumn, main chromatographic column, and 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 ~11 minutes. Concentrations of the CFC-11 and CFC-12 in air, seawater samples, and gas standards are reported relative to the SIO98 calibration scale (Cunnold et al., 2000). Concentrations of SF_6 in air, seawater samples, and gas standards are reported relative to the SIO-05 calibration scale. 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 45174) 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 intervals of 4-5 days during the cruise. Single injections of a fixed volume of standard gas at approximately one atm pressure 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 this residual signal. At a flow rate of 150 cc min^{-1} for 6 minutes, the purging efficiency for all 3 gases was >99%.

On this expedition, based on the analysis of ~250 pairs of duplicate samples, we estimate precisions (1 standard deviation) of about 1% or 0.002 pmol kg^{-1} (whichever is greater) for both dissolved CFC-11 and CFC-12 measurements. The estimated precision for SF_6 was 2% or 0.02 fmol 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^{-1} for CFC11 and CFC-12 and 4% or 0.04 fmol kg^{-1} for SF_6).

A small number of water samples had anomalously high CFC/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 2% of samples were flagged as bad or questionable during this voyage. A quality flag of 5 was assigned to water samples which were drawn from the rosette but lost during storage or due to errors in the multi-step analytical process.

Air Measurements on I05_2009

Concentrations are in pats-per-trillion (PPT)

Date YYMMDD	**Time** HHMM	**CFC12** PPT	**CFC11** PPT	**SF6** PPT
090321	2335	532.7	239.3	6.39
090321	2342	534.0		
090321	2349	532.0	240.2	6.49
090321	2356	531.8	241.9	6.45
090322	0003	531.3	244.2	6.52
090322	0010	531.7	243.5	6.55
090322	1412		238.4	6.52
090322	1419	532.3	237.2	6.49
090322	1426	536.4	237.3	6.45
090322	1433	536.1	237.8	6.37
090322	1440	534.1	238.0	6.37
090326	1003	536.4	240.6	
090326	1010	536.2	240.5	
090326	1017	532.3	240.0	
090326	1024	532.8	240.5	
090326	1031	533.2	241.2	
090330	0135	535.6	240.8	6.70
090330	0145	530.5	240.4	6.77
090330	0155	531.5	239.9	6.69
090330	0205	529.1	240.1	6.69
090330	0215	532.2	239.9	6.56
090330	0225	532.0	240.4	6.70
090331	0706	528.6	239.5	6.34
090331	0713	525.2	239.5	6.37
090331	0720	535.7	240.2	6.61
090331	0727	528.1	239.9	6.52
090331	0734	530.9	240.6	6.50
090331	0741	534.1	239.8	6.51
090406	0050	532.2	240.6	6.46
090406	0057	530.8	240.2	6.43
090406	0104	531.6	240.9	6.51
090406	0111	531.1	240.2	6.67
090406	0118	534.2	240.5	6.63
090406	0125	535.4	240.3	6.53
090409	1825	531.0	240.3	6.63
090409	1835	531.7	239.3	6.53
090409	1845	535.2	239.4	6.59
090409	1855	530.1	239.7	6.64
090409	1905	532.2	239.7	6.68
090409	1915		240.2	6.64
090414	2145	532.6	239.9	6.45
090414	2155	533.5	239.0	6.72
090414	2205	534.7	240.0	6.67
090414	2215	531.8	238.7	6.58
090414	2225	531.8	239.5	6.68
090414	2235	532.4	239.2	6.67
090418	0524	529.2	237.0	6.56
090418	0534	529.8	235.3	6.65
090418	0544	531.5	233.9	6.72
090418	0554	533.5	232.0	6.72
090418	0604	529.3	231.0	6.75
090422	1143	533.8	244.3	6.43
090422	1153	535.2	245.4	6.40
090422	1203	534.4	244.8	6.44
090422	1213	535.0	245.2	6.51
090423	2057	533.5	242.3	
090423	2107	534.5	242.7	6.38
090423	2117	532.5	243.3	6.34
090423	2127	533.6	244.2	6.38
090427	0335	531.6	240.1	6.81
090427	0346	533.2	238.7	6.74
090427	0357	527.7	239.0	6.66
090427	0408	530.9	239.0	6.51
090427	0419	531.4	241.4	6.39
090504	0450	539.0	238.7	6.46
090504	0501	537.7	236.0	6.65
090504	0512	537.3	236.6	6.61
090504	0523	539.3	238.1	6.68
090504	0534	543.4	239.1	6.72
090507	0559	532.4	240.1	6.69
090507	0611	530.4	240.4	6.76
090507	0623	529.9	239.9	6.71
090507	0635	532.1	241.2	6.68
090507	0647	532.2	239.5	6.70
Mean	532.8	239.8	6.57	
STDEV	2.9	2.5	0.13	
%STDEV	0.5	1.1	1.9	

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Total Dissolved Carbon

(Dana Greeley)

"A total of over 500 pure (99.995%) CO2 gas calibrations were run on both SOMMA systems during I5. The precision and accuracy obtained from these calibrations can be described as follows;

1. The precision is displayed by the greater than 450 replicate samples drawn. The absolute average difference from the mean of these replicates are less than 0.85 μmol/kg. No significant systematic differences were noted.

2. The accuracy can be described by the greater than 250 Certified Reference Materials (batch 94) that were analyzed. The average difference from the certified value for these is 0.65 μmol/kg with a standard deviation of 1.5 μmol/kg.

The overall accuracy and precision as described above, though excellent for the Somma systems, does not mean there will not be small corrections to the data made shore side after a more thorough examination and post cruise calibrations are performed. These final corrections may change the data by as much as 2-3 μmol/kg but in the majority the correction will be less than 1 μmol/kg. In addition, it is likely there will be a few changes made to the quality control flags.

Alkalinity

(George C. Anderson and Jennale Peacock, laboratory of Andrew G. Dickson, Marine Physical Laboratory, Scripps Institution of Oceanography)

As part of the overall sampling program, alkalinity sampling was included. Samples were taken from all Niskin bottles on every other stations; intermediate stations were partially sampled with as few as one and as many as 24 of the levels being sampled. During the 195 stations approximately 5000 samples were collected and analyzed.

After thorough rinsing, samples were collected in 250 ml pyrex serum bottles. Approximately 0.06 milliliters of a saturated mercuric chloride solution were added to each sample. Samples were analyzed using an open beaker titration procedure using two thermostated beakers, one sample being titrated while the second was being prepared and equilibrating to the system temperature of 20 degrees C. After an initial aliquot of approximately 1.3 mls of standardized hydrochloric acid (~0.1Molar HCl in ~0.6M NaCl solution) was added, the sample was stirred for approximately 5 minutes to remove liberated carbon dioxide. The stir time has been minimized by bubbling carbon dioxide free air into the sample. After the ~5 minute equilibration time, 19 aliquots of ~0.02 mls were added. The data within the pH range of 3.5 to 3.0 were processed using a non-linear least squares fit from which the alkalinity value of the sample was calculated (Dickson, et.al., editors, 2007). A sample volume of 50 mls was titrated. Sample temperatures were measured using a calibrated YSI thermister thermometer accurate to 0.05 degrees Celsius.

Dickson laboratory Certified Reference Materials (CRM) Batch B94 was used to determine the accuracy of the analysis.

On a 36 bottle cast 3 duplicate samples were collected typically from Niskins 1 (the bottom of the cast), 18 (mid depth of the cast) and 36 (the surface bottle). Over the course of the cruise, approximately 450 duplicates were analyzed. The pooled standard deviation was approximately 1 micromole-per-kilogram.

The data should be considered preliminary since the correction to be applied for the difference between the CRMs stated and measured values has yet to be finalized and applied. Also the correction for the mercuric chloride addition has yet to be applied. As part of the data evaluation, a determination was made for the possible contribution of the mercuric chloride to the alkalinity. The data indicate no contribution, either positive or negative, from the mercuric chloride.

Reference:

Dickson, Andrew G., Chris Sabine and James R. Christian, editors, "Guide to Best Practices for Ocean CO2 Measurements", Pices Special Publication 3, IOCCP Report No. 8, October 2007, SOP 3b, "Determination of total alkalinity in sea water using an open-cell titration"

14C Sampling

14C samples were taken at ~ every 5 stations. 880 samples were taken in total. Bottles were cleaned at WHOI before the cruise. Samples were taken and sealed for storage according to the instructions provided by WHOI (1). Samples will be shipped back to WHOI for 13C and C14 analyses.

(1) Measuring 14C in seawater total CO2 by accelerator mass spectrometry, WHP Operation and Methods, July, 2003.

DOC sampling

DOC samples were taken from every Niskin bottles at every other station. 3350 samples were taken from 52 stations in total, including duplicate sets from 5 stations. Samples from up 250 m were filtered through GF/F filters using in-line filtration. Samples from deeper depths were not filtered. High density polyethylene 60 ml sample bottles were 10% HCl cleaned and Mili-Q water rinsed. Filters were combusted at 450 C for overnight. Filter holders were 10% HCl cleaned and Mili-Q water rinsed. Samples were introduced into the sample bottles by a pre-cleaned silicone tubing. Bottles were rinsed by sample for 3 times before filling. 40-50 ml of water were taken for each sample. Samples were kept frozen in the ship's freezer room. Frozen samples will be shipped back by express shipping to RSMAS for DOC analysis.

pH

(Brendan Carter and Adam Radich)

On this CLIVAR leg, over 7500 measurements of pH were made on water sampled from rosette casts at 195 regular stations, 2 test stations, and 1 reoccupation of a station from the I6S line. Analyses were made with an Agilent 8453 spectrophotometer equipped with a 10 cm jacketted flow cell using m-cresol purple indicator dye. Results are reported on the total hydrogen ion scale. Sample introduction to the cell and dye addition were automated with a Kloehn V6 Syringe Pump.

The plan for water sampling included coverage of every bottle sampled for alkalinity or total carbon for a complete characterization of the carbon system. This scheme typically alternated between full and partial coverage of tripped bottles. Samples were obtained from rosette bottles into 300 mL Pyrex glass serum bottles. Serum bottles were rinsed three times and allowed to overflow by one additional bottle volume. The bottles were poisoned with 0.02% saturated $HgCl_2$ solution and capped with a rubber stopper without allowing for headspace. Analyses were completed within three hours of sampling. Prior to measurement, samples were brought to 20 °C by partially submerging the serum bottles in a temperature bath for 16 minutes.

Data precision was evaluated by analysis of duplicate samples (multiple samples from the same bottle on the rosette). The pooled standard deviation of the ~650 duplicate analyses is 0.0004 pH units.

Accuracy of spectrophotometric pH measurements is difficult to constrain with no agreed upon calibration procedure. For this cruise two approaches were made. First, since the same bottles that were sampled for alkalinity and total carbon were sampled for pH, an independent estimate of pH can be obtained from equilibrium equations. Second, pH analyses of Certified Reference Materials (currently only certified for DIC and alkalinity) were performed. A review of the accuracy of the pH measurements is underway, and large changes (~0.01) in the final reported values are likely. Confidence in the precision of the measurements remains high, and likely changes would be a simple offset or an offset that is a simple function of reported pH.

No correction for $HgCl_2$ addition has been made for the reported preliminary pH values. Testing aboard ship suggested that a very small correction (~0.0003 pH unit increase) might be appropriate for all measured values.

Reference:

Dickson, A.G., Sabine, C.L. and Christian, J.R. (Eds.), (2007): Guide to Best Practices for Ocean C O2 Measurements.

I5 (2009) crossover with I8S (2007)

The I5 cruise track crossed the 2007 I8S cruise track at about 34°S, 95°E. The bottle cast data for I5 stations 144-146 were compared with those from I8S stations 76-78. The comparisons indicated:

temperature versus pressure - slightly warmer in 2009 above 400 db; slightly colder in 2009 500-1000 db; nearly the same 1100-3200 db; possibly very slightly warmer in 2009 below 3400 db.
salinity versus pressure - salinity differences 600-1600 db look very much like salinity minimum was a bit shallower and maybe slightly saltier in 2009; very good agreement below 1800 db;
d*issolved oxygen versus pressure* - slightly lower in 2009 200-1500 db; agrees well below 1600 db.
dissolved oxygen versus sigma-0 - nearly the same from sigma-0 26.85-27.20; slightly lower in 2009 sigma-0 27.20- 27.55; nearly the same for sigma-0 > 27.55.
silicate versus pressure - slightly higher in 2009 700-1800 db; nearly the same 1800-2500 db; slightly higher in 2009 2500-3100 db; nearly the same > 3200 db.
s*ilicate versus sigma-0* - nearly the same for sigma-0 < 27.20 or maybe < 27.40; slightly higher in 2009 sigma-0 27.45-27.60; nearly the same for sigma-0 > 27.60.
nitrate versus pressure - slightly lower in 2009 above 400 db; a small amount higher in 2009 400-1500 db; nearly the same 1500-2500 db; slightly higher in 2009 from 2500-3500 db; and very nearly the same below 3500 db.
nitrate versus sigma-0 - NO3 slightly higher in 2009 for all sigma-0 > 27.10; this suggests a small NO3 offset between the cruises.
phosphate versus pressure - PO4 slightly higher in 2009 for most pressures > 500 db.
phosphate versus sigma-0 - PO4 higher in 2009 (by. ca. 0.06-0.07 µMol/kg) for all sigma-0 > 27.10.
nitrate versus phosphate - agrees very well for NO3 < 26 µMol/kg and PO4 < 1.8 µMol/kg; for NO3 26-36 µMol/kg PO4 is a little higher for a given NO3 concentration.
CFC-12 versus pressure - deep values (below 1500 db) nearly the same except that 2009 is slightly higher 2000-2800 db.
total carbon versus pressure - higher in 2009 from 400-1600 db, nearly the same below 1800 db.
alkalinity versus pressure - in general values are higher in 2009 at all pressures, though nearly the same near 2000 db and only slightly higher below 4000 db.

These cruise-to-cruise crossover comparisons suggest that standardization for most parameters may have been about the same in 2007 and 2009. Of the parameters examined, the case for possible small cruise-to-cruise offsets was strongest for nitrate, phosphate and alkalinity.

Problems and time lost

The cruise went exceptionally well. For example, there was only need for one CTD electrical retermination, to solve a problem in the early going. The fault occurred on landing the rosette and so we lost no data and little time in the process. At other times the techs also performed one CTD mechanical retermination as preventative maintenance near the cruise midpoint, and carried out maintenance on the winch slip rings.

There were few problems or delays with CTD cast operations: Station 14 was delayed 2.5 hours for the CTD retermination noted above; on station 36 there was a firmware glitch in the deck unit; a winch problem on station 44 caused a 2 hour delay (see below); on station 77 all bottles were closed on the fly due to storm sea conditions associated with Tropical Cyclone Jade; at station 102 the winch stopped at 158 meters on the down cast for a problem and the data acquisition system froze at 1112 db for total loss of abut 25 minutes; on stations 138 and 180 (and maybe one other time) the cast start was delayed ca. 20-25 minutes each due to data acquisition system problems; wire payout speed was slowed at some stations, especially during approximately the second quarter of the cruise, due to low-tensions during ship roll; haul-in was slowed to 30 m/min on the deepest portions (generally below 5000-5300 meters) of the deepest casts to keep wire tension from exceeding maximum limits; and there were short coming-to-station delays for some stations where specific depths were being sought. The cruise was planned to allow for such events, and no adjustments to the station plan were necessary to compensate for these.

The only significant weather event was the passage of Tropical Cyclone Jade (see above), which resulted in the loss of slightly more than one day of ship time.

During CTD/rosette recovery on station 44, just as the package was being raised out of the water, a retaining spring on the winch failed, resulting in loss of control. The winch operator alertly hit the emergency stop, at which point the wire started free-wheeling, with the package falling toward the ocean floor. However, the operator quickly engaged the emergency brake, stopping the package after only 18 meters of descent. His quick and professional actions impressively averted disaster. The chief engineer and his team were able to diagnose and fix the unusual equipment failure in less than two hours, competently minimizing loss of time to the program.

The Revelle's multibeam sonar failed (for the remainder of the cruise) on 17 April. The multibeam sonar is an ancillary instrument for the I5 science program; the multibeam data are not processed. But the loss of real-time use of the multbeam sonar to guide station placement near bathymetric features and for stations being occupied at specified bottom depths was felt from time to time, though without significant harm to the measurement program or loss of time.

Algal blooms were noted in some of the salinity sample bottles in late April, and so all salinity sample bottles were thoroughly scrubbed and rinsed by the science team on 26-27 April. The salinometers were also cleaned at this time.

The performance of key portions of the helium extraction system progressively worsened during the expedition. It finally became unsatisfactory for further work and so the final two planned helium profiles were cancelled as a result.

There were no significant injuries or illnesses suffered during the cruise. A gastro-intestinal virus (perhaps akin to a norovirus) made it's way through many of the officers, crew, and science team in the early going, but caused no problem other than being highly unpleasant for its victims.

Argo floats
(Alison Rogers)

During the CLIVAR/CO_2 2009 repeat of I05, 19 autonomous CTD profiling floats were deployed along the cruise track in waters deeper than 3000 db. These floats are part of the Argo Program (www.argo.ucsd.edu) and were provided by Dr. Steve Riser from the University of Washington. All floats were deployed at CTD stations after all casts were completed, from the starboard stern of the ship, with the ship moving forward at about 1 knot. Depending on the sea conditions, deployment was carried out by either lowering the float on a line or by releasing the float manually. All 19 floats successfully self-activated via pressure activation and began executing their programmed mission. Data from all Argo floats are publicly available in real-time via the two global servers at www.usgodae.org and www.coriolis.eu.org. The following are the approximate positions where the 19 floats were deployed.

Float ID	Latitude	Longitude
6280	31 10.76' S	30 37.85' E
6383	32 32.57' S	33 24.11' E
0067	32 59.78' S	36 57.33' E
6099	32 59.86' S	39 15.40' E
6285	32 59.83' S	42 08.46' E
6279	33 18.44' S	46 50.20' E
6222	33 41.44' S	49 47.48' E
5409	34 20.04' S	52 09.96' E
6300	33 59.86' S	54 53.14' E
6299	33 59.82' S	56 59.19' E
6219	33 59.89' S	59 19.24' E
6220	34 00.00' S	61 41.68' E
5183	33 59.79' S	63 58.95' E
6278	34 00.05' S	66 50.26' E
6286	34 00.12' S	69 07.49' E
6223	34 00.14' S	71 24.78' E
6224	33 36.58' S	74 09.08' E
6212	31 59.89' S	76 00.04' E
6218	30 50.43' S	78 19.73' E

Shipboard Acoustic Doppler Current Profiler

(Julia Hummon/University of Hawaii)

The Revelle has three Doppler sonars for measuring ocean velocity. One of these, a commercial 150kHz narrowband instrument "NB150" (made by Teledyne R.D. Instruments), is considered to be the primary shipboard current profiler for CLIVAR cruises. The other two "High-resolution Doppler Sonar System" (HDSS, 50kHz and 140kHz) were designed at Scripps Institute of Oceanography specifically for installation on the Revelle. Their design characteristics were optimized for high-quality ocean shear measurements, and the ability to provide high-quality ocean velocity is under evaluation. The HDSS instruments are not considered part of the CLIVAR sonar velocity data.

The acquisition system used on the NB150 ("UHDAS", University of Hawaii Data Acquisition System) is an Open Sources suite, written in C and Python; processing software is in C, Python, and Matlab. UHDAS acquires data from the OS75NB150 instrument, gyro heading (for reliability), Ashtech heading (for increased accuracy), and GPS positions. Single-ping data are converted from beam to earth coordinates using known transducer angles and gyro heading, and are corrected by the average ashtech-gyro difference over the duration of the 5-minute profile.

Groups of single-ping ocean velocity estimates must be averaged to decrease measurement noise. These groups commonly comprise 5 minutes. Bad pings must be edited out prior to averaging. This is done by UHDAS using a collection of criteria tailored to the instrument type and frequency, and to the specific installation.

UHDAS uses a CODAS (Common Oceanographic Data Access System) database for storage and retrieval of averaged data. Various post-processing steps can be administered to the database after a cruise is over, but the at-sea data should be acceptable for preliminary work. Documentation is available at http://currents.soest.hawaii.edu.

UHDAS provides access to regularly-updated figures and data over the ship's network via samba share and nfs export, as well as through the web interface. The web site has regularly-updated figures showing the last 5-minute ocean velocity profile with signal return strength, and hourly contour and vector plots of the last 3 days of ocean velocity.

The Clivar Shipboard Ocean Velocity Component

Data quality

This instrument's range was typically about 200-250m in the western part of the cruise, deepening slightly as the cruise continued east. Diurnal migration accounted for about 50 of range (better range during the local daylight when the scatterers migrated down for safety). Data were lost during one heavy weather event, but aside from that, the instrument acquired high quality data for the entire cruise. The Ashtech, critical for accurate heading, had only a few short dropouts. Undoubtedly the vigilence of the CTD watchstanders contributed to the brevity of Ashtech data gaps.

Data Access:

The data have been released to the NODC Joint Archive for Shipboard ADCP (http://ilikai.soest.hawaii.edu/sadcp). A graphical summary of the data is available at:

http://currents.soest.hawaii.edu/clivar_co2/I5S/index.html

Lowered Acoustic Doppler Current Profiler

A single RD Instruments Broadband 150-kHz (BB-150) Lowered Acoustic Doppler Current Profiler (LADCP) was used throughout the cruise. A new 300-kHz Workhorse (WH-300) LADCP was lost in transit until after the ship's departure. The only instrument problem occurred at the beginning of the cruise. The first test casts showed that vertical orientation sensor was stuck in the wrong position. Fortunately, thanks to the *savoir-faire* of the resident technicians, the LADCP was fixed before the first regular station.

LADCP instrument setup and data downloading were done on a notebook computer running Linux, using graphical user interface software from the University of Hawaii (UH). The instrument was configured with 16-m pulse length, 8-m depth cell size, and a 16-m blanking interval. Data were recorded in beam coordinates for each ping. The command file is given in Table 1.

Command file
CR1
RA
RS
WV330
WN32
EZ0011101
EC1500
EX00100
WP1
WF1600
WS800
WT1600
WM1
WB1
WC056
BP0
CP255
CL0
TP 00:00:00
TE 00:00:01.00
TB 00:00:02.60
TC 2
CF11101

Table 1: *Command file use for the 150-kHz LADCP.*

The data were processed using two independent software packages: the older UH package calculates the vertical integral of the vertical shear and uses the ship's displacement to determine the constant of integration (Fisher and Visbeck, 1993), while the newer Lamont-Doherty Earth Observatory (LDEO) package, originally written by Martin Visbeck and now maintained by Andreas Thurnherr, uses an inverse method to include additional constraints such as the shipboard ADCP data and bottom tracking from the LADCP (Visbeck, 2002). The two methods typically agree to within a few cm/s, but the inverse method is expected to have lower rms error, and will be used for final processing to yield the official data set. With both software packages, LADCP depth is derived from the CTD data.

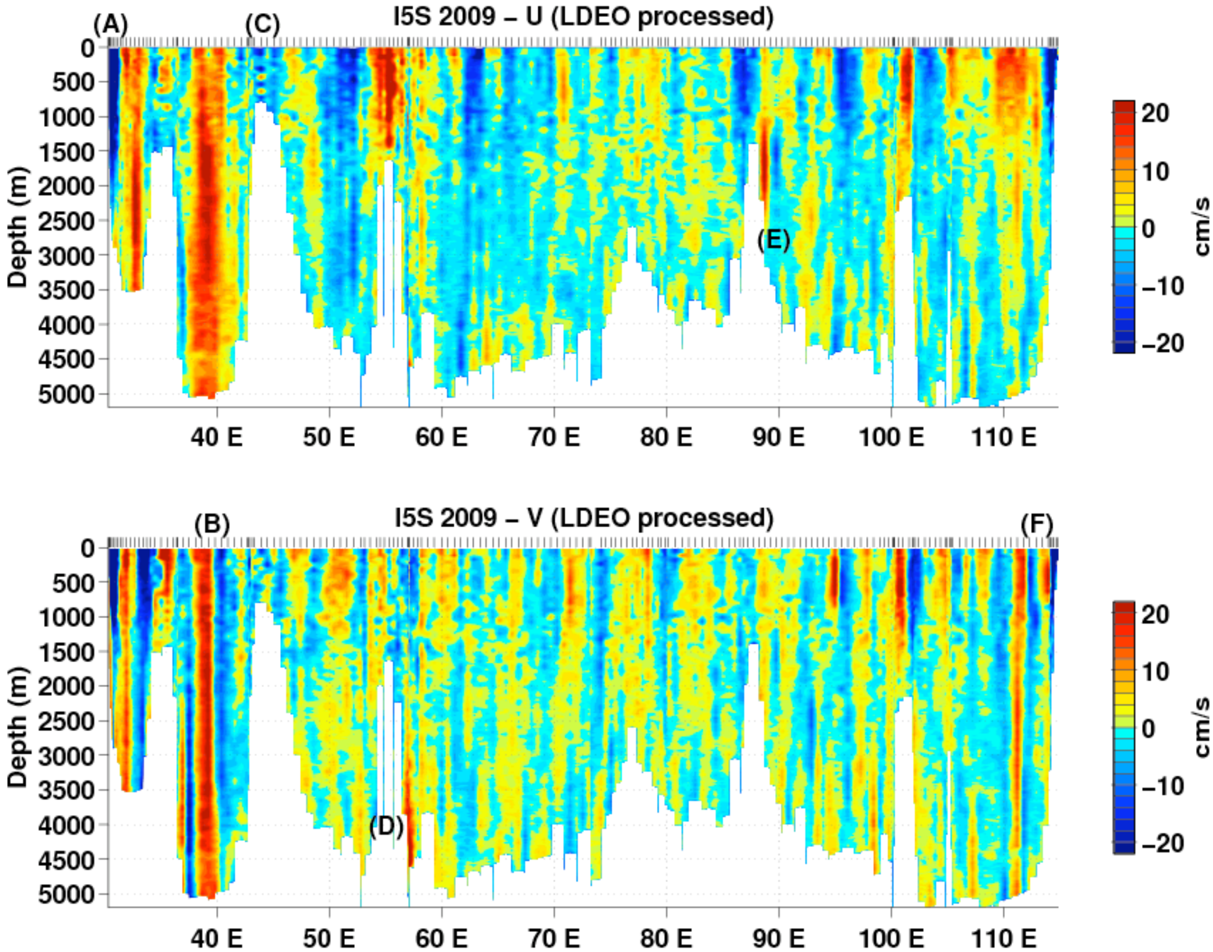


Figure 1: *Zonal (U) and meridional (V) velocity depth-longitudinal section. Letters mark features highlighted in the text: (A) the Agulhas Current; (B) deep eddies in the Mozambique Basin; (C) high-vertical-wavenumber oscillation over the Madagascar Ridge; (D) northward intrusion of deep and bottom water in the Atlantis II Fracture Zone; (E) subsurface eddies near the Ninety-east Ridge, and (F) deep eddies and the Leeuwin Current near the eastern boundary.*

Sections of velocity shown in Fig. 1 are from the LDEO processing. Several interesting features are apparent. First, the strong southwestward Agulhas current was observed along the African coast (shown by letter A in Fig. 1). The Mozambique Basin centered at 40°E was filled with energetic large-vertical-scale motions (B in Fig. 1); in some profiles, horizontal velocities were largest in the middle of the water column with speed up to 30 cm/s and decreasing only down to 20 cm/s near the 5000-m ocean bottom.

At the top of the meridionally-oriented Madagascar ridge (C in Fig. 1), a motion highly periodic with depth with a vertical wavelength of about 200 m was observed mostly in zonal velocity. The signal was shallow enough (less than 800 m deep) to be also captured by the Hydrographic Doppler Sonar System (HDSS) during the 2-hour-long cast. Preliminary analysis suggests that the motion has a period of about 22-hour, close to the local inertial period; the excess of zonal over meridional amplitude, however, is inconsistent with a single vertically-propagating near-inertial plane wave.

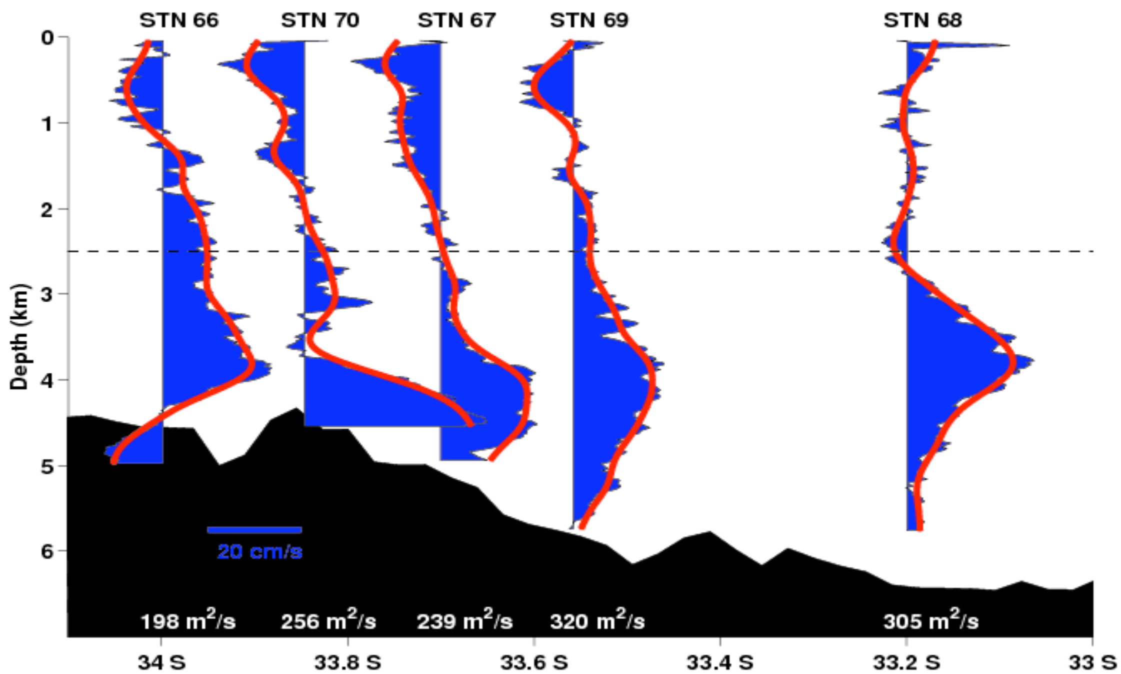


Figure 2: *Profiles of meridional velocity (blue; smoothed in red) observed at the 5 stations covering the southern entry of the Atlantis II Fracture Zone. The topography is that of the lowest level across the fracture zone from Smith and Sandwell's (1997) topographic dataset. The transport per unit width below 2500 m is shown in white below each profile.*

Another important feature was the northward intrusion of deep and bottom water from the Crozet to the Madagascar basins through the Atlantis II Fracture Zone (D in Fig. 1, Fig. 2). Northward velocities up to 30 cm/s with a core near 4000 m depth were observed across all 5 stations; the associated transport was comparable to previous observations (MacKinnon *et al.* 2008). High values from the CTD transmissometer from 3500 m to the bottom suggest large amounts of particulates are being resuspended by this strong flow. Salinity and CFC-12 observations are also consistent with intense vertical mixing at these locations. Northward intrusions in neighboring fracture zones were also observed (not shown). Hard work of students, crew and PIs, efficiency of acquisition and processing of LADCP data as well as sufficient internet bandwidth enabled an outside investigator in the USA to present the data on the Atlantis II Fracture Zone during the cruise.

Further east, one subsurface feature located near 1500 m depth was observed at the eastern edge of the Ninety-east Ridge (E in Fig. 1); although the motion was the most energetic in the direction parallel to the cruise course, the perpendicular motion appeared to be consistent with a geostrophic eddy. Finally, the cruise finished in the eastern basin with its energetic large-vertical-scale eddies and southward intense Leeuwin current along the eastern boundary (F in Fig. 1).

References:

Fisher, J. and M. Visbeck, 1993: Deep velocity profiling with self-contained ADCPs, *J. Atmos. and Oceanic Tech.*, **10**, 764-773.

MacKinnon, J. A., T. M. S. Johnston and R. Pinkel, 2008: Strong transport and mixing of deep water through the Southwest Indian Ridge, *Nature Geo.*, **1**, 755-758.

Smith, W. H. F., and D. T. Sandwell, 1997: Global seafloor topography from satellite altimetry and ship depth soundings, *Science*, **277**, 1957-1962.

Visbeck, M., 2002: Deep velocity profiling using lowered acoustic Doppler current profilers: bottom track and inverse solution, *J. Atmos. and Oceanic Tech.*, **19**, 795-807.

Appendix A

Bottle Quality Comments

Comments from the Sample Logs and the results of STS/ODF’s data investigations are included in this report. Units stated in these comments are degrees Celsius for temperature, Unless otherwise noted, milliliters per liter for oxygen and micromoles per liter for Silicate, Nitrate, Nitrite, and Phosphate. The sample number is the cast number times 100 plus the bottle number. Investigation of data may include comparison of bottle salinity and oxygen data with CTD data, review of data plots of the station profile and adjoining stations, and re-reading of charts (i.e. nutrients).

Station /Cast	Sample No.	Quality Property	Code	Comment
1/1	105	bottle	4	Water pouring out at bottom end cap, bottle reseated, only alkalinity drawn.
1/1	105	CTDOXY	5	CTDO sample lost, no bottle oxygen.
2/1	109	ctds	4	Variation in CTD trace at bottle trip, CTD spiky. Code CTD salinity bad.
2/1	109	salt	2	Bottle salinity is high compared with CTD, agrees with adjoining stations. Much variation at the bottle stop, water following the CTD. Salinity as well as oxygen and nutrients are acceptable.
2/1	117	no3	2	Nitrate value appears to be 5 units too low on profile. However, there is a similar drop in value for both silicate and phosphate. The peak is real and no analytical problems noted.
2/1	117	o2	2	High oxygen and salinity, low nutrients. Salinity and oxygen agree with CTD data. Data is acceptable.
3/2	201	salt	2	Lab temperature changing, analyst halted salinity analysis after this run until temperature stabilized.
3/2	214	po4	4	PO4 high compared with station profile and adjoining stations. Nutrient analyst rechecked and found no analytical errors. Code PO4 bad.
3/2	218	salt	2	Bottle 18 top chipped, removed bottle from service. First time this bottle was used. Salinity as well as oxygen and nutrients are acceptable.
4/1	101	salt	2	Lab temperature changing prior to this run, analyst halted salinity analysis before this run until temperature stabilized.
4/1	127	bottle	2	Bottles 28-34 were not tripped per sampling schedule.
5/2	223	bottle	2	Feature seen in salinity, low oxygen and high nutrients. Salinity agrees with CTD up cast. Data are acceptable.
5/2	231	bottle	2	Bottles 32-34 were not tripped per sampling schedule.
6/1	108	CTDOXY	5	CTDO sample lost, no bottle oxygen.
6/1	108	o2	5	Oxygen sample lost during analysis, aborted.
6/1	110	bottle	2	Ran out of water, no salinity sample, minimal sampling, 4 liters. Salinity as well as nutrients are acceptable. Although minimal sampling, suspect that analysts did not watch water budget.
6/1	110	sio3	2	SiO3 appears a little high. Analyst: "Silicate value appears high on the profile. However, adjacent stations exhibit similar spikes in silicate around the same depth. The peak is real and no analytical problems were noted."
7/1	101	sio3	2	SiO3 8 units high. Analyst: "Silicate value appears to be 8 units too high. However, adjoining stations have a similar bottom silicate increase. The peak is real and no analytical problems were noted." SiO3 as well as other nutrients, salinity and oxygen.

Station /Cast	Sample No.	Quality Property	Code	Comment
8/1	110	o2	2	Ran o2check put in new titer value. Oxygen as well as salinity and nutrients are acceptable.
8/1	118	o2	2	Sample was overtitrated and backtitrated. Oxygen as well as salinity and nutrients are acceptable.
8/1	132	salt	2	Feature seen in salinity and oxygen which corresponds to CTD up trace. Salinity as well as oxygen and nutrients are acceptable.
9/2	201	salt	2	Bottle salinity is high compared with CTD and lo2 compared with adjoining stations. Salinity is within specifications and acceptable as are oxygen and nutrients.
9/2	202	salt	2	Bottle salinity is high compared with CTD, low compared with adjoining stations. Salinity is within specifications and acceptable as are oxygen and nutrients.
9/2	204	salt	2	Salinity thimble popped off when cap was removed. Salinity as well as oxygen and nutrients are acceptable.
9/2	207	salt	2	Bottle salinity is high compared with CTD. Salinity is within specifications and acceptable as are oxygen and nutrients.
9/2	209	salt	2	Salinity thimble popped off when cap was removed. Salinity as well as oxygen and nutrients are acceptable.
9/2	224	o2	2	Sample was overtitrated and backtitrated. Oxygen as well as salinity and nutrients are acceptable.
9/2	231	salt	2	Bottle salinity is low compared with CTD. Salinity thimble popped off when cap was removed. Salinity agrees with adjoining stations. Salinity as well as oxygen and nutrients are acceptable.
10/1	109	salt	3	Bottle salinity is low compared with CTD and adjoining stations. No analytical problems noted. Code salinity questionable, oxygen and nutrients acceptable.
10/1	117	bottle	2	Lanyard was snagged during recovery. Oxygen as well as salinity and nutrients are acceptable.
11/1	106	salt	2	Bottle salinity thimble popped off when opened. Salinity as well as oxygen and nutrients are acceptable.
11/1	110	salt	2	Bottle salinity thimble popped off when opened. Salinity as well as oxygen and nutrients are acceptable.
11/1	134	bottle	2	Leaking at air vent when spigot opened. Oxygen as well as salinity and nutrients are acceptable.
12/1	103	salt	2	Bottle salinity thimble popped when opened. Salinity as well as oxygen and nutrients are acceptable.
12/1	109	salt	2	Bottle salinity thimble popped when opened. Salinity as well as oxygen and nutrients are acceptable.
12/1	128	o2	2	Ran o2check changed endpoint titer. Oxygen as well as salinity and nutrients are acceptable.
12/1	132	no3	3	NO3 2 units high. Analyst: "Nitrate value appears to be 2 units too high. However, this feature is also seen in both phosphate and silicate, and in the upper profile of adjoining stations. The peak is real and no analytical problems were noted." JHS: This is the only data value so far this cruise at this location on the NO3 vs PO4 diagram. NO3 is at least 2 units high for NO3 vs PO4. Code NO3 questionable.
13/2	225	salt	2	Sampled and analyzed-not on sample log sheet. Sample was from Station 5 and had been analyzed. No salinity sample drawn.

Station /Cast	Sample No.	Quality Property	Code	Comment
14/1	101	salt	2	Salinity standard seawater high at end of run. Ran three SSW at end all read the same high value took last bottle. Suspect initial SSW may have been low. Processor: "Salinity differences with CTD and comparison with adjoining station acceptable."
15/1	111	salt	2	3 attempts for a good salinity reading. Salinity as well as oxygen and nutrients are acceptable.
15/1	112	salt	2	Bottle salinity thimble came off in cap. Salinity as well as oxygen and nutrients are acceptable
15/1	119	salt	2	Bottle salinity thimble popped when cap removed. Bottle salinity is within specifications. Salinity as well as oxygen and nutrients are acceptable
15/1	131	salt	2	4 attempts for a good salinity reading. Salinity as well as oxygen and nutrients are acceptable.
15/1	135	ctds	4	Variations in CTD salinity at bottle trip, CTD spiky. Code CTD salinity bad.
15/1	135	salt	2	Bottle salinity is low compared with CTD; appears as entrained water. Salinity as well as oxygen and nutrients are acceptable.
16/1	121	salt	2	3 attempts for a good salinity reading. Salinity as well as oxygen and nutrients are acceptable.
16/1	127	salt	2	Bottle salinity thimble came off in the cap. Salinity as well as oxygen and nutrients are acceptable.
17/1	118	salt	5	Salinity computer froze, suspect it needed to be rebooted. Salinity sample lost.
18/1	101	CTDOXY	5	CTDO sample lost, no bottle oxygen.
18/1	101	o2	5	Oxygen sample lost, aborted sample.
18/1	106	sio3	2	SiO3 ˜3um/l high compared with adjoining stations. Corresponding low oxygen and high Po4 and NO3 and salinity. Analyst: "There were no analytical problems and the peaks look great." Data are acceptable.
18/1	121	salt	2	Salinity thimble came out with cap. Salinity as well as oxygen and nutrients are acceptable.
18/1	136	o2	2	Forgot to put tip in the oxygen flask, retitrated and data appears acceptable. Oxygen as well as salinity and nutrients are acceptable.
19/2	208	salt	2	Salinity bottle has minor chip on rim. Does not affect seal. Salinity as well as oxygen and nutrients are acceptable.
19/2	217	o2	2	Sample may be bad, endpoint different. Black particles seen mixing with the sample. Oxygen as well as salinity and nutrients are acceptable.
19/2	221	o2	2	Sample was overtitrated and backtitrated. Ran over-titrate find endpoint. Sample may be bad. Oxygen as well as salinity and nutrients are acceptable.
19/2	223	CTDOXY	5	CTDO sample lost, no bottle oxygen.
19/2	223	o2	5	Ran over-titrate but did not change still formed exact straight line to determine the endpoint. Oxygen sample lost.
19/2	224	o2	2	Thio volume added underestimated, had to restart the sample. Sample may be bad. Oxygen as well as salinity and nutrients are acceptable.
20/1	115	o2	2	Oxygen appears high compared to adjoining stations. Oxygen follows CTD trace and there is a feature in the nutrients. Oxygen as well as salinity and nutrients are acceptable.
20/1	116	bottle	9	Bottom end cap open, lanyard caught on hose clamp, no water samples.
20/1	116	CTDOXY	5	CTDO sample lost, no bottle oxygen.
20/1	117	bottle	3	Appears to have closed late.
20/1	117	no2	3	

Station /Cast	Sample No.	Quality Property	Code	Comment
20/1	117	no3	3	16 had a lanyard hangup, bottle 17 may have been effected. Salinity for 17 is a little high as is oxygen. JHS: "It does appear to be a late closing bottle, closed slightly higher in the water column, between that of 19 or 20. The bottle salt and oxygen fit that idea fairly well, and the nutrients are close to working that way. Neither NO3 versus PO4 nor SIO3 versus O2 support the idea that this is a unique water mass." Code bottle and samples 3.
20/1	117	o2	3	
20/1	117	po4	3	
20/1	117	salt	3	
20/1	117	sio3	3	
20/1	124	salt	2	3 attempts for a good salinity reading. Salinity as well as oxygen and nutrients are acceptable.
22/1	104	salt	2	Salinity thimble popped off when cap was removed. Salinity as well as oxygen and nutrients are acceptable.
22/1	112	salt	2	3 attempts for a good salinity reading. Salinity as well as oxygen and nutrients are acceptable.
22/1	131	bottle	2	Bottles 32-34 were not tripped per sampling schedule.
23/2	202	o2	2	Redraw on oxygen, NaOH dispenser changed. Oxygen as well as salinity and nutrients are acceptable.
23/2	212	o2	2	Oxygen low does not compare to adjoining stations. Feature seen in SiO3. Oxygen up and down shows this feature. Oxygen, salinity and nutrients are acceptable.
23/2	212	sio3	2	SiO3 high ˜4 units. Analyst: "Silicate value appears to be approx. 4 units too high. However, adjoining stations have a similar silicate spike around the same depth. The peak is real and no analytical problems were noted."
24/1	110	salt	4	Bottle salinity is high compared with CTD and adjoining stations. No analytical problem noted, could be drawing error, left over from Station 16. Code salinity bad, oxygen and nutrients acceptable.
24/1	127	salt	2	Salinity insert came off when cap was removed. Salinity as well as oxygen and nutrients are acceptable.
24/1	128	salt	2	Low initial salinity sample fill. Salinity as well as oxygen and nutrients are acceptable.
25/1	101	bottle	2	Hit bottom.
25/1	101	salt	3	0.003PSU low. Does not agree with adjacent casts.
25/1	106	salt	2	Salinity bottle chip on outer rim, does not affect seal. Bad sampling technique. Salinity agrees with CTD and adjoining stations and is acceptable as are oxygen and nutrients.
25/1	113	salt	2	Salinity bottle thimble came off with cap. Salinity agrees with CTD and adjoining stations and is acceptable as are oxygen and nutrients.
25/1	117	salt	2	Bottle salinity is high compared with CTD. There is a lot of structure in the CTD up/down trace. Salinity as well as oxygen and nutrients are acceptable.
25/1	132	salt	2	Salinity bottle thimble came off with cap. Salinity agrees with CTD and adjoining stations and is acceptable as are oxygen and nutrients.
26/1	118	salt	2	Bottle salinity is low compared with CTD agrees with adjoining stations. Salinity as well as oxygen and nutrients are acceptable.
26/1	119	salt	2	Bottle salinity is high compared with CTD agrees with adjoining stations. Salinity as well as oxygen and nutrients are acceptable.
26/1	130	o2	2	Oxygen appears high compared with CTD up/down trace. No analytical problems noted. Salinity and nutrients do not show this feature. Analyst: "No analytical problem, endpoint/titration looks good."

Station /Cast	Sample No.	Quality Property	Code	Comment
27/1	101	o2	2	Oxygen appears low compared with CTD up/down trace. SiO3 a little high compared with adjoining stations. Oxygen as well as salinity and nutrients are acceptable.
27/1	105	o2	2	Oxygen appears high compared with CTD up/down trace and adjoining stations. SiO3 also a little high compared with adjoining stations. Oxygen as well as salinity and nutrients are acceptable.
27/1	111	salt	2	Bottle salinity is low compared with CTD. Different features seen in CTD up/dn trace. Salinity as well as oxygen and nutrients are acceptable.
27/1	118	salt	2	Bottle salinity is high compared with CTD. 3 attempts for a good salinity reading. Gradient, other reading do not resolve difference. Salinity as well as oxygen and nutrients are acceptable.
27/1	134	bottle	2	Vent open, only nutrients and salinity drawn. Salinity and nutrients are acceptable.
27/1	134	CTDOXY	5	CTDO sample lost, no bottle oxygen.
28/1	104	salt	2	Salinity thimble came off when cap was removed. Salinity as well as oxygen and nutrients are acceptable.
28/1	109	salt	2	Salinity bottle rim chipped, seal not affected, bad sampling technique. Salinity as well as oxygen and nutrients are acceptable.
28/1	111	sio3	2	SiO3 ˜2um/l high compared with adjoining stations. Analyst: "No analytical problems. Adjoining stations do appear to exhibit a similar profile around the same depth."
28/1	117	salt	2	Bottle salinity is high compared with CTD. Salinity as well as oxygen and nutrients are acceptable.
28/1	124	salt	2	Salinity bottle rim chipped, seal not affected, bad sampling technique. Salinity as well as oxygen and nutrients are acceptable.
29/1	111	salt	2	Bottle salinity is low compared with CTD, gradient. Salinity as well as oxygen and nutrients are acceptable.
29/1	117	o2	2	Oxygen 4um/kg high compare with CTD down cast, agrees with up cast and adjoining stations.
30/1	108	salt	2	Salinity thimble popped off when cap was removed. Salinity as well as oxygen and nutrients are acceptable.
30/1	118	salt	2	3 attempts for a good salinity reading.
30/1	136	salt	2	Salinity thimble came off in the cap. Salinity as well as oxygen and nutrients are acceptable.
31/1	107	o2	2	Oxygen appears high compared with adjoining stations, CTD trace shows higher oxygen. NO3, PO4, SiO3 have a lower signal and salinity a little higher. Oxygen as well as salinity and nutrients are acceptable.
31/1	108	bottle	2	Vent open. Oxygen may be a little high, but is acceptable as are salinity and nutrients.
31/1	108	o2	2	Oxygen appears high compared with adjoining stations, CTD trace shows higher oxygen. NO3, PO4, SiO3 have a lower signal and salinity a little higher. Oxygen as well as salinity and nutrients are acceptable.
31/1	109	sio3	2	SiO3 ˜9 units high. Analyst: "Silicate values appear to be approx. 9 units too high. However, values fit the profile and are similar to adjoining stations. The peaks are real and no analytical problems were noted."
31/1	110	sio3	2	SiO3 ˜9 units high. Analyst: "Silicate values appear to be approx. 9 units too high. However, values fit the profile and are similar to adjoining stations. The peaks are real and no analytical problems were noted."
31/1	111	sio3	2	SiO3 ˜9 units high. Analyst: "Silicate values appear to be approx. 9 units too high. However, values fit the profile and are similar to adjoining stations. The peaks are real and no analytical problems were noted."

Station /Cast	Sample No.	Quality Property	Code	Comment
31/1	112	sio3	2	SiO3 ˜9 units high. Analyst: "Silicate values appear to be approx. 9 units too high. However, values fit the profile and are similar to adjoining stations. The peaks are real and no analytical problems were noted."
31/1	117	salt	2	Salinity thimble popped off in the cap when removed. Salinity as well as oxygen and nutrients are acceptable.
31/1	131	salt	2	Bottle salinity is high compared with CTD, bottle salinity agrees with adjoining stations. Both the CTD up and down trace agree with each other, CTD is not spiky at bottle trip. Salinity as well as oxygen and nutrients are acceptable.
31/1	132	bottle	2	Vent open. Oxygen as well as salinity and nutrients are acceptable.
32/1	112	o2	4	Oxygen 0.2 ml/l high compared with CTD and adjoining stations. No analytical problems noted, appears that the sample was drawn from bottle 11. Code oxygen bad, salinity and nutrients acceptable.
33/1	106	po4	2	PO4 is slightly high without obvious oceanographic causes. Analyst: "No analytical problems noted." PO4 is acceptable.
33/1	107	po4	2	PO4 is slightly high without obvious oceanographic causes. Analyst: "No analytical problems noted." PO4 is acceptable.
33/1	108	po4	2	PO4 is slightly high without obvious oceanographic causes. Analyst: "No analytical problems noted." PO4 is acceptable.
33/1	109	po4	2	PO4 is slightly high without obvious oceanographic causes. Analyst: "No analytical problems noted." PO4 is acceptable.
33/1	109	salt	2	Salinity bottle had a chipped rim; replace with spare bottles after running sample. Salinity as well as oxygen and nutrients are acceptable.
33/1	110	po4	2	PO4 is slightly high without obvious oceanographic causes. Analyst: "No analytical problems noted." PO4 is acceptable.
33/1	117	salt	2	Salinity thimble popped off when cap was removed. Salinity as well as oxygen and nutrients are acceptable.
33/1	130	salt	2	Bottle salinity is low compared with CTD. Salinity agrees with adjoining stations and is acceptable as are oxygen and nutrients.
34/2	217	salt	2	Salinity bottle rim chipped, seal not affected. Bad sampling technique. Salinity as well as oxygen and nutrients are acceptable.
34/2	219	o2	2	Oxygen appears low compared with adjoining stations. Corresponding feature not seen in nutrients or salinity. Analyst: "No analytical problem, endpoint/titration looks good."
35/1	109	salt	2	Salinity thimble popped off when cap was removed. Salinity as well as oxygen and nutrients are acceptable.
35/1	121	salt	2	Bottle salinity is high compared with CTD. Salinity agrees with adjoining stations, and is acceptable as are oxygen and nutrients.
36/1	110	salt	2	Salinities bottles 10 & 11 were reversed in box. Last used on Station 31 and that station data is acceptable.
36/1	127	bottle	4	Bottle appears to have mistripped and then leaked on the way up. Code bottle, did not trip as scheduled, and samples bad.
36/1	127	no2	4	
36/1	127	no3	4	
36/1	127	o2	4	Oxygen appears reasonable, but the draw temperature is 1.4-2.3 degrees lower than adjoining bottles. DIC analyst reports data also shows an anomaly.
36/1	127	po4	4	Nutrients look high as though they came from deeper in the water column. Oxygen looks reasonable, but the draw temperature is 1.4-2.3 degrees lower than adjoining bottles. DIC analyst reports data also shows an anomaly.
36/1	127	sio3	4	

Station /Cast	Sample No.	Quality Property	Code	Comment
37/1	104	salt	2	Salinity thimble came out with the cap. Salinity as well as oxygen and nutrients are acceptable.
39/1	127	o2	4	Left tip out, stopped titration, started over. Oxygen does not agree with adjoining stations or CTD. Code oxygen bad.
40/1	117	o2	2	Began to form curve at voltage made a straight line at end of titration. Oxygen is acceptable.
41/1	111	salt	2	3 attempts for a good salinity reading. Salinity thimble came off with cap. Salinity as well as oxygen and nutrients are acceptable.
41/1	113	salt	2	3 attempts for a good salinity reading. Salinity thimble came off with cap. Salinity as well as oxygen and nutrients are acceptable.
42/1	104	salt	2	Salinity thimble came off when cap was removed. Salinity, although a little low compared with CTD, is acceptable as well as oxygen and nutrients.
42/1	119	bottle	2	Bottles 20-35 were not tripped per sampling schedule.
43/2	222	bottle	2	Bottles 23-35 were not tripped per sampling schedule.
44/1	101	bottle	2	Winch problems delayed recovery nearly two hours. Package held at 18 meters while winch repair was performed. Oxygen and well as salinity and nutrients are acceptable.
44/1	109	salt	2	3 attempts for a good salinity reading. Salinity as well as oxygen and nutrients are acceptable.
44/1	118	no2	5	
44/1	118	no3	5	
44/1	118	po4	5	Nutrient tube was found empty, sampling error.
44/1	118	sio3	5	
47/1	106	salt	2	3 attempts for a good salinity reading. Used first reading which made salinity agree with CTD and adjoining stations. Salinity as well as oxygen and nutrients are acceptable.
47/1	127	po4	2	N:P ratio low, suspect PO4 is high. Analyst: "no analytical problems noted, Analyst: "No analytical problems noted." JHS: "No problems on sections of PO4 on PRES, NO3/PO4 on PRES, or NO/PO on PRES. Data are acceptable."
49/1	101	bottle	2	DOC sampled 1-8 after salinity.
49/1	103	bottle	2	Bottom endcap wrapped by recovery line, likely okay. Oxygen as well as salinity and nutrients are acceptable.
49/1	107	sio3	2	SiO3 appears low in relation to Oxygen. Features seen in adjoining stations. No analytical problems noted. Nutrients as well as salinity and oxygen are acceptable.
49/1	112	salt	4	Salinity low appears to have been drawn from bottle 11. Oxygen and nutrients do not show a feature. Code salinity bad, oxygen and nutrients acceptable.
49/1	117	bottle	2	Bottom lanyard caught on recovery hook, leaker. Oxygen as well as salinity and nutrients are acceptable.
49/1	129	CTDOXY	5	CTDO sample lost, no bottle oxygen.
49/1	129	o2	5	Oxygen may have skipped 29, 30 or 31. On bottle 32 when discovery of missed sample was made. Appears that sample 29 was missed.
49/1	130	o2	2	Oxygen may have skipped 29, 30 or 31. On bottle 32 when discovery of missed sample was made.
49/1	131	o2	2	Oxygen may have skipped 29, 30 or 31. On bottle 32 when discovery of missed sample was made.
50/1	113	salt	2	3 attempts for a good salinity reading. First reading results in better value, may have had a salt crystal for the third reading. Salinity as well as oxygen and nutrients are acceptable.

Station /Cast	Sample No.	Quality Property	Code	Comment
50/1	134	ctds	4	Spike in CTD up trace at bottle trip. Code CTD salinity bad.
50/1	134	salt	2	Bottle salinity is high compared with CTD. Feature seen in both the down and up trace, spike in CTD up trace. Salinity as well as oxygen and nutrients are acceptable.
51/2	201	o2	2	Oxygen NaI/NaOH dispenser not primed before fixing, proper amount possibly not added, result maybe no good. Oxygen as well as salinity and nutrients are acceptable.
51/2	206	bottle	2	Special bottle tripped with 5 for CFC ingrowth/incubation experiment.
51/2	220	salt	4	Bottle salinity is high compared with CTD and adjoining stations. Salinity appears to be a drawing error and sample is from last time salt was drawn from this box. Code salinity bad, oxygen and nutrients acceptable.
51/2	231	bottle	2	End cap was bumped during recovery and a little water leaked out. Oxygen as well as salinity and nutrients are acceptable.
51/2	235	CTDOXY	5	CTDO sample lost, no bottle oxygen.
51/2	235	o2	5	Oxygen flask 1365 broke in box in the lab.
52/1	123	no3	2	Nutrient samples appear to be switched. Evidence in oxygen lower at 490db and higher at 571 which agrees with CTD. Changed the sample number and the data is acceptable.
52/1	123	po4	2	Nutrient samples appear to be switched. Evidence in oxygen lower at 490db and higher at 571 which agrees with CTD. Changed the sample number and the data is acceptable.
52/1	124	no3	2	Nutrient samples appear to be switched. Evidence in oxygen lower at 490db and higher at 571 which agrees with CTD. Changed the sample number and the data is acceptable.
52/1	124	po4	2	Nutrient samples appear to be switched. Evidence in oxygen lower at 490db and higher at 571 which agrees with CTD. Changed the sample number and the data is acceptable.
53/2	226	o2	2	CHECK: Oxygen appears high compared with adjoining stations and CTD.
53/2	234	bottle	3	Bottle leaking, vent not fully closed. Oxygen not drawn, salinity and nutrients are acceptable.
53/2	234	CTDOXY	5	CTDO sample lost, no bottle oxygen.
54/1	105	salt	2	Bottle salinity is high compared with CTD and adjoining stations. 3 attempts for a good salinity reading. First reading gave good agreement with CTD and station profile. Salinity as well as oxygen and nutrients are acceptable.
54/1	116	no2	4	
54/1	116	no3	4	
54/1	116	o2	4	
54/1	116	po4	4	
54/1	116	salt	4	
54/1	116	sio3	4	
55/2	204	o2	2	Oxygen appears low compared with adjoining stations and in relationship with SiO3, agrees with CTD, some spiking in CTDO. No analytical problems. Oxygen as well as salinity and nutrients are acceptable.
55/2	209	salt	2	Bottle salinity is low compared with CTD, gradient. Salinity as well as oxygen and nutrients are acceptable.
56/1	135	ctds	4	CTD was responding to changes while the CTD was equilibrating at the bottle trip. Code CTD salinity bad.
56/1	135	salt	2	Bottle salinity is low compared with CTD. CTD was responding to changes while the CTD was equilibrating at the bottle trip. Salinity as well as oxygen and nutrients are acceptable.

Station /Cast	Sample No.	Quality Property	Code	Comment
57/2	201	o2	2	Oxygen appears low compared with CTDO. Nutrients are slightly low compared with adjoining stations and salinity a little high. No analytical problems found. Oxygen as well as salinity and nutrients are acceptable.
57/2	201	salt	2	Bottle salinity is high compared with CTD and adjoining stations. 4 attempts for a good salinity reading. Insert came off in cap when opened for analysis. First reading resolved initial salinity discrepancy, suspect salinity crystal for additional readings. Salinity as well as oxygen and nutrients are acceptable.
57/2	236	salt	2	Salinity thimble popped off when cap was removed. Salinity as well as oxygen and nutrients are acceptable. 4 attempts for a good salinity reading. First reading resolved initial salinity discrepancy, suspect salinity crystal for additional readings. Salinity as well as oxygen and nutrients are acceptable.
58/1	134	bottle	2	Bottle leaks from spigot when vent opened. Checked o-rings and bottle after the cast, refilled the bottle, could not find a problem. Oxygen as well as salinity and nutrients are acceptable.
59/1	127	salt	2	Salinity bottle rim chip, seal compromised. Salinity as well as oxygen and nutrients are acceptable.
60/1	101	salt	2	Bottle salinity is low compared with CTD and adjoining stations. No analytical problem noted, and does not appear to be a rinsing issue. Within accuracy of the measurement, salinity, oxygen and nutrients are acceptable. JHS: "This station is on top of a ridge so may be expected to be a bit different."
60/1	113	bottle	2	Bottle was knocked on recovery, may have leaked.Oxygen as well as salinity and nutrients are acceptable.
62/2	203	salt	2	3 attempts for a good salinity reading. First reading did not resolve low salinity value. Salinity is within accuracy of the measurement, oxygen and nutrients are also acceptable.
62/2	206	CTDOXY	5	CTDO sample lost, no bottle oxygen.
62/2	226	bottle	2	Vent open - not sampled for oxygen.
63/1	104	salt	2	Salinity thimble popped off when cap was removed. Salinity is a little low, within accuracy of the measurement. Salinity as well as oxygen and nutrients are acceptable.
63/1	126	o2	2	Oxygen appears low compared with adjoining stations. PO4 has a little high feature, do not see corresponding feature in other properties. No analytical problem noted. Oxygen as well as salinity and nutrients are acceptable.
64/1	114	salt	5	Salinity bottle split open when placed on autosal-sample lost.
64/1	122	o2	2	Oxygen appears high compared with CTDO, agrees reasonably well with adjoining stations. Oxygen as well as salinity and nutrients are acceptable.
66/1	110	bottle	2	Special bottle tripped with 11 for CFC ingrowth/incubation experiment.
66/1	110	CTDOXY	5	CTDO sample lost, no bottle oxygen.
66/1	133	o2	2	Sample was overtitrated and backtitrated. Oxygen as well as salinity and nutrients are acceptable.
68/1	114	salt	2	Bottle salinity is high compared with CTD and adjoining stations. 4 attempts for a good salinity reading. First reading resolved salinity discrepancy, must have been a salinity crystal. Salinity as well as oxygen and nutrients are acceptable
68/1	121	salt	2	Bottle salinity is high compared with CTD and adjoining stations. 4 attempts for a good salinity reading. First reading resolved salinity discrepancy, must have been a salinity crystal. Salinity as well as oxygen and nutrients are acceptable
68/1	123	salt	2	Bottle salinity is high compared with CTD. Variation in CTD salinity at the bottle trip. Salinity as well as oxygen and nutrients are acceptable.

Station /Cast	Sample No.	Quality Property	Code	Comment
68/1	134	salt	2	Bottle salinity is high compared with CTD down trace and adjoining stations as are 35 and 36, but agree with the CTD up trace. Salinity as well as oxygen and nutrients are acceptable.
69/1	104	salt	2	Duplicate draw, originally reported as bottle 5. Salinity with reassignment of sample numbers are acceptable.
69/1	115	salt	5	Salinity samples 105-115 actually from 104-114, sample 15 not lost. Salinity with reassignment of sample numbers are acceptable.
70/1	101	po4	2	PO4 appears low, could be oceanography. Analyst: "Rechecked analytical data and could find no problems."
70/1	102	po4	2	PO4 appears low, could be oceanography. Analyst: "Rechecked analytical data and could find no problems."
70/1	103	po4	2	PO4 appears low, could be oceanography. Analyst: "Rechecked analytical data and could find no problems."
70/1	104	po4	2	PO4 appears low, could be oceanography. Analyst: "Rechecked analytical data and could find no problems."
70/1	104	salt	2	3 attempts for a good salinity reading. Thimble came out with cap. Readings kept increasing- took first reading only. Salinity is within accuracy of measurement. Salinity, oxygen and nutrients are acceptable.
70/1	105	po4	2	PO4 appears low, could be oceanography. Analyst: "Rechecked analytical data and could find no problems."
70/1	109	po4	2	PO4 appears low, could be oceanography. Analyst: "Rechecked analytical data and could find no problems."
70/1	110	po4	2	PO4 appears low, could be oceanography. Analyst: "Rechecked analytical data and could find no problems."
70/1	111	po4	2	PO4 appears low, could be oceanography. Analyst: "Rechecked analytical data and could find no problems."
70/1	112	po4	2	PO4 appears low, could be oceanography. Analyst: "Rechecked analytical data and could find no problems."
70/1	118	bottle	2	Vent open - not sampled for oxygen. Salinity and nutrients are acceptable.
70/1	118	CTDOXY	5	CTDO sample lost, no bottle oxygen.
70/1	126	bottle	2	Vent open - not sampled for oxygen. Salinity and nutrients are acceptable.
70/1	126	CTDOXY	5	CTDO sample lost, no bottle oxygen.
71/2	202	salt	2	3 attempts for a good salinity reading. First reading did not resolve small salinity discrepancy, within specifications of the measurement. Salinity as well as oxygen and nutrients are acceptable.
71/2	236	salt	2	5 attempts for a good salinity reading. First reading resolved salinity discrepancy. Salinity as well as oxygen and nutrients are acceptable.
73/2	231	o2	2	Oxygen had bad endpoint; new titer entered. Oxygen as well as salinity and nutrients are acceptable.
74/1	117	bottle	9	Bottle did not trip. Lanyard caught on hose clamp. Not sampled.
74/1	117	CTDOXY	5	CTDO sample lost, no bottle oxygen.
77/1	101	bottle	2	Bottles were tripped on-the-fly for the entire cast.
77/1	101	salt	2	Bottle salinity is high compared with CTD and with Station 75, within accuracy of measurement. Bottles tripped on-the-fly, salinity as well as oxygen and nutrients are acceptable.
77/1	102	salt	2	Bottle salinity is high compared with CTD and with Station 75, within accuracy of measurement. Bottles tripped on-the-fly, salinity as well as oxygen and nutrients are acceptable.
77/1	103	salt	4	Bottle salinity is high compared with CTD and Station 75. Bottle salinity thimble came out with cap. Bottles tripped on-the-fly, code salinity bad, oxygen and nutrients are acceptable.

Station /Cast	Sample No.	Quality Property	Code	Comment
77/1	112	salt	3	Bottle salinity is high compared with CTD and adjoining stations. PO4 and NO3 are appropriately low oxygen a little higher, SiO3 does not show this feature. Bottles were tripped on-the-fly, salinity appears to show the water from lower in the water column.
78/1	108	sio3	2	SiO3 appears 3uM/kg low. No analytical problems noted. JHS: O2 vs. SiO3 relationship is good. Signal is oceanographic and acceptable.
78/1	114	o2	2	Endpoint curve started at 2.1 and ended at 2.3 making a straight line. Oxygen low compared with CTDO and adjoining stations. Rechecked endpoint, resolved issue. Oxygen as well as salinity and nutrients are acceptable.
78/1	136	bottle	2	Bottle was tripped on-the-fly.
79/1	112	salt	2	Salinity thimble came out with cap. Salinity a little high, within accuracy of measurement. Salinity as well as oxygen and nutrients are acceptable.
79/1	124	salt	4	Salinity appears to have been drawn from bottles 29. Code salinity bad, oxygen and nutrients acceptable.
79/1	132	o2	2	Oxygen appears high compared with the CTDO down trace, agrees with the up trace and the adjoining stations. Oxygen as well as salinity and nutrients are acceptable. Analyst: "No analytical problem, endpoint/titration looks good."
79/1	133	o2	2	Oxygen appears high compared with the CTDO down trace, agrees with the up trace and the adjoining stations. Oxygen as well as salinity and nutrients are acceptable. Analyst: "No analytical problem, endpoint/titration looks good."
80/1	102	salt	2	3 attempts for a good salinity reading. Salinity as well as oxygen and nutrients are acceptable.
80/1	122	salt	2	3 attempts for a good salinity reading. Salinity as well as oxygen and nutrients are acceptable.
80/1	133	o2	2	Bad endpoint on oxygen, recalculated and entered new titer. Oxygen as well as salinity and nutrients are acceptable.
82/1	105	o2	2	Oxygen slightly high compared with CTDO, agrees with adjoining stations. Oxygen as well as salinity and nutrients are acceptable. Analyst: "No analytical problem, endpoint/titration looks good."
82/1	113	bottle	2	Bottle tripped without the 30 second wait. Salinity, oxygen and nutrients are acceptable.
82/1	123	salt	2	3 attempts for a good salinity reading. First reading resolved salinity discrepancy. Salinity as well as oxygen and nutrients are acceptable.
82/1	132	no3	2	PO4 and NO3 look high compared with adjoining stations, low feature in oxygen. No corresponding feature seen in salinity or silicate. Analyst: "The peaks are great, there were no analytical problems." Nutrients as well as salinity and oxygen are acceptable.
84/1	105	sio3	2	SiO3 high, no corresponding feature in NO3, PO4, O2 or salinity. Analyst: "Checked SiO3 peaks, no analytical problems found."
84/1	106	sio3	2	SiO3 high, no corresponding feature in NO3, PO4, O2 or salinity. Analyst: "Checked SiO3 peaks, no analytical problems found."
84/1	125	salt	2	3 attempts for a good salinity reading. First treading resolved salinity discrepancy. Salinity as well as oxygen and nutrients are acceptable.
85/2	213	salt	2	3 attempts for a good salinity reading. First reading resolved salinity discrepancy. Salinity as well as oxygen and nutrients are acceptable.
85/2	221	salt	2	3 attempts for a good salinity reading. First reading resolved salinity discrepancy. Salinity as well as oxygen and nutrients are acceptable.

Station /Cast	Sample No.	Quality Property	Code	Comment
85/2	225	salt	2	3 attempts for a good salinity reading. First reading resolved salinity discrepancy. Salinity as well as oxygen and nutrients are acceptable.
85/2	229	salt	2	3 attempts for a good salinity reading. First reading did not completely resolve salinity discrepancy, within accuracy of measurement. Salinity as well as oxygen and nutrients are acceptable.
85/2	231	salt	2	4 attempts for a good salinity reading. First reading resolved salinity discrepancy. Salinity as well as oxygen and nutrients are acceptable.
85/2	235	salt	2	4 attempts for a good salinity reading. First reading resolved salinity discrepancy. Salinity as well as oxygen and nutrients are acceptable.
86/1	126	salt	2	Salinity thimble came out when cap was removed. Salinity as well as oxygen and nutrients are acceptable.
87/2	201	o2	2	Oxygen appears low compared with CTDO, agrees with adjoining stations. Oxygen as well as salinity and nutrients are acceptable. Analyst: "Re-checked end points, no analytical problems found."
88/1	102	o2	2	Oxygen appears high compared with adjoining stations, 0.02ml/l. No corresponding feature seen in salinity or nutrients. Analyst: "No analytical problem, endpoint/titration looks good."
88/1	119	o2	2	Oxygen appears high compared with adjoining stations, and O2 vs. SiO3 relationship, but agrees with CTDO. No corresponding feature seen in salinity or nutrients. Analyst: "No analytical problem, endpoint/titration looks good."
88/1	121	o2	4	Oxygen flask 1377 was used with stopper from Flask 1601 O2 value may be incorrect. Code oxygen bad.
91/2	201	salt	2	Bottle salinity is high compared with CTD and adjoining stations. 3 attempts for a good salinity reading. First reading resolved salinity discrepancy. Salinity as well as oxygen and nutrients are acceptable
91/2	202	salt	2	Bottle salinity is high compared with CTD and adjoining stations. 3 attempts for a good salinity reading. First reading resolved salinity discrepancy. Salinity as well as oxygen and nutrients are acceptable
91/2	209	po4	4	PO4 ˜0.04um/l high compared with adjoining stations. Salinity, oxygen and other nutrients are acceptable. Analyst: "Checked PO4 peak, peak manually read due to bubble, possibly too high, code data as bad."
91/2	215	salt	2	Bottle salinity is high compared with CTD. Salinity as well as oxygen and nutrients are acceptable.
91/2	221	salt	2	Bottle salinity is high compared with CTD. Gradient, salinity as well as oxygen and nutrients are acceptable.
91/2	232	salt	2	Bottle salinity is low compared with CTD. Variation in CTD, salinity as well as oxygen and nutrients are acceptable.
91/2	233	salt	2	Bottle salinity is high compared with CTD, does appear slightly higher than station 90 salinity, but acceptable. Variation in CTD, but still not "in-line" with bottle salinity, leave as is. Salinity as well as oxygen and nutrients are acceptable.
93/1	134	salt	2	Bottle salinity is high compared with CTD, agrees reasonably well with adjoining stations. Salinity, oxygen and nutrients are acceptable.
93/1	136	no2	4	
93/1	136	no3	4	
93/1	136	o2	4	
93/1	136	po4	4	
93/1	136	salt	4	
93/1	136	sio3	4	
94/1	101	bottle	2	Special bottle tripped with 2 for CFC ingrowth/incubation experiment.

Station /Cast	Sample No.	Quality Property	Code	Comment
94/1	101	CTDOXY	5	CTDO sample lost, no bottle oxygen.
94/1	108	salt	4	Bottle salinity is high compared with CTD and adjoining stations. 4 attempts for a good salinity reading. Could not resolve salinity discrepancy. Code salinity bad, oxygen and nutrients are acceptable.
94/1	133	o2	2	Oxygen bad endpoint, recalculated new titer. Oxygen as well as salinity and nutrients are acceptable.
95/2	210	salt	4	Bottle salinity is low compared with CTD and adjoining stations. Appears to have been drawn from bottle 12, is not a bottle problem. Code salinity bad, oxygen and nutrients are acceptable.
95/2	211	po4	2	Nutrients as well as salinity and oxygen are acceptable.
95/2	233	salt	2	Bottle salinity is low compared with CTD, agrees with adjoining stations. Spike in CTD trace at bottle trip. Salinity as well as oxygen and nutrients are acceptable.
96/1	101	salt	2	Bottle salinity is high compared with CTD and adjoining stations. 4 attempts for a good salinity reading. First reading resolved salinity discrepancy within accuracy of measurement. PO4 and SiO3 appeared a little low, but within accuracy of the measurement. Salinity, oxygen and nutrients are acceptable.
96/1	115	salt	2	Bottle salinity is high compared with CTD. No analytical problems noted, gradient area. Salinity as well as oxygen and nutrients are acceptable.
96/1	134	ctds	4	CTD spike at trip. Code CTD salinity bad.
96/1	134	salt	2	Bottle salinity is low compared with CTD. CTD spike at trip. Salinity, oxygen and nutrients are acceptable.
97/1	121	o2	2	Oxygen bad end point, recalculated new titer. Oxygen as well as salinity and nutrients are acceptable.
97/1	125	o2	2	Oxygen bad end point, recalculated new titer. Oxygen as well as salinity and nutrients are acceptable.
98/1	103	bottle	2	Special bottle tripped with 4 for CFC ingrowth/incubation experiment.
98/1	103	CTDOXY	5	CTDO sample lost, no bottle oxygen.
99/2	230	salt	2	3 attempts for a good salinity reading. First reading resolved the salinity discrepancy within accuracy of the measurement. Salinity as well as oxygen and nutrients are acceptable.
101/1	110	salt	2	Bottle salinity is high compared with CTD and adjoining stations. 4 attempts for a good salinity reading. First reading resolved salinity discrepancy. Salinity as well as oxygen and nutrients are acceptable.
102/2	202	salt	2	Bottle salinity is high compared with CTD and adjoining stations. 4 attempts for a good salinity reading. First reading resolved salinity discrepancy. Salinity as well as oxygen and nutrients are acceptable.
102/2	217	salt	2	Bottle salinity is high compared with CTD, agrees with adjoining stations. Salinity as well as oxygen and nutrients are acceptable.
103/1	103	salt	2	Salinity bottle 1 and 3 were reversed in the sampling crate. Salinity for bottle 3 does appear slightly high, but certainly not from bottle 1. Salinity within measurement accuracy. Salinity as well as oxygen and nutrients are acceptable.
103/1	104	o2	2	Oxygen appears high compared with CTDO, but agrees with Station 102. SiO3 relationship also acceptable. Oxygen as well as salinity and nutrients are acceptable.
103/1	104	salt	2	Bottle salinity is high compared with CTD and adjoining stations. 4 attempts for a good salinity reading. First reading resolved salinity discrepancy. Salinity as well as oxygen and nutrients are acceptable.
103/1	107	o2	2	Oxygen appears high compared with CTDO, but agrees with Station 102. Oxygen as well as salinity and nutrients are acceptable.

Station /Cast	Sample No.	Quality Property	Code	Comment
103/1	109	salt	2	Bottle salinity is high compared with CTD and adjoining stations. 4 attempts for a good salinity reading. First reading resolved salinity discrepancy. Salinity as well as oxygen and nutrients are acceptable.
103/1	117	salt	2	Bottle salinity is high compared with CTD agrees with adjoining stations. Salinity as well as oxygen and nutrients are acceptable.
103/1	130	salt	2	4 attempts for a good salinity reading. First reading resolved salinity discrepancy. Salinity as well as oxygen and nutrients are acceptable.
104/1	101	bottle	2	Only equilibrated the sensor for 18 seconds, bottom was changing rapidly per altimeter.
104/1	109	o2	2	Oxygen drawn twice, first flask 1136 broke. Oxygen as well as salinity and nutrients are acceptable.
104/1	136	salt	2	3 attempts for a good salinity reading. Thimble came out with cap. Liquid appeared to run back down inside bottle. First reading resolved salinity discrepancy. Salinity as well as oxygen and nutrients are acceptable.
105/1	112	salt	2	3 attempts for a good salinity reading. Thimble came out with cap. Readings increased in the classic contamination fashion. Took first reading only. Salinity as well as oxygen and nutrients are acceptable.
105/1	123	bottle	2	Bottle loose on frame. Salinity, oxygen and nutrients are acceptable.
106/2	205	bottle	2	Special bottle tripped with 4 for CFC ingrowth/incubation experiment.
106/2	205	CTDOXY	5	CTDO sample lost, no bottle oxygen.
107/1	101	salt	2	Bottle salinity is high compared with CTD and adjoining stations. 4 attempts for a good salinity reading. First reading resolved most of the discrepancy, still appears slightly high, within accuracy of measurement. Salinity as well as oxygen and nutrients are acceptable.
107/1	123	salt	2	4 attempts for a good salinity reading. First reading resolved salinity discrepancy. Salinity as well as oxygen and nutrients are acceptable.
107/1	127	salt	2	4 attempts for a good salinity reading. First reading resolved salinity discrepancy. Salinity as well as oxygen and nutrients are acceptable.
107/1	133	ctds	4	CTD is spiky at bottle trip. Code CTD salinity bad.
107/1	133	salt	2	Bottle salinity is low compared with CTD. CTD is spiky at bottle trip. Salinity as well as oxygen and nutrients are acceptable.
108/1	130	ctds	4	CTD spiky at trip. Code CTD salinity bad.
108/1	130	salt	2	Bottle salinity is high compared with CTD. CTD spiky at trip. Salinity as well as oxygen and nutrients are acceptable.
108/1	131	ctds	4	CTD spiky at trip. Code CTD salinity bad.
108/1	131	salt	2	Bottle salinity is high compared with CTD. CTD spiky at trip. Salinity as well as oxygen and nutrients are acceptable.
108/1	132	ctds	4	CTD spiky at trip. Code CTD salinity bad.
108/1	132	salt	2	Bottle salinity is low compared with CTD. CTD spiky at trip. Salinity as well as oxygen and nutrients are acceptable.
108/1	133	ctds	4	CTD spiky at trip. Code CTD salinity bad.
108/1	133	salt	2	Bottle salinity is high compared with CTD. CTD spiky at trip. Salinity as well as oxygen and nutrients are acceptable.
109/1	114	o2	4	Overshot oxygen endpoint over titrate did not work, lost sample. Code oxygen bad.
109/1	118	bottle	4	Anomalous features in oxygen and nutrients, could be real, will wait for salinity to be analyzed before making a determination. Bottle mistripped, code bottle 4, salinity, oxygen and nutrients bad.
109/1	118	no2	4	
109/1	118	no3	4	
109/1	118	o2	4	

Station /Cast	Sample No.	Quality Property	Code	Comment
109/1	118	po4	4	
109/1	118	salt	4	
109/1	118	sio3	4	
109/1	133	o2	2	Bad O2 endpoint, recalculated new titer. Oxygen as well as salinity and nutrients are acceptable.
110/2	201	bottle	2	Bottom endcap knocked on recovery, small amount of water leaked. Salinity is high, but within accuracy of the measurement. Salinity, oxygen and nutrients are acceptable.
110/2	203	salt	2	Bottle salinity is high compared with CTD and adjoining stations. 3 attempts for a good salinity reading. First reading resolved salinity discrepancy. Salinity as well as oxygen and nutrients are acceptable.
110/2	225	salt	2	4 attempts for a good salinity reading. First reading resolved salinity discrepancy. Salinity as well as oxygen and nutrients are acceptable.
111/1	107	no2	4	
111/1	107	no3	4	
111/1	107	po4	4	PO4 and NO3 high, SiO3 low compared with adjoining stations. No corresponding feature seen in salinity and oxygen. Looks like a drawing error. Analyst: "No analytical problems." Code nutrients bad, oxygen and salinity acceptable.
111/1	107	sio3	4	
111/1	115	salt	2	8 attempts for a good salinity reading. Salinity agrees with CTD and adjoining stations. First reading results in a high reading as much as last readings were low. Salinity agrees with CTD and adjoining stations within accuracy of the measurement. Salinity as well as oxygen and nutrients are acceptable.
111/1	119	o2	2	Oxygen titration curve for choosing and endpoint was not reasonable, value may not be good. Oxygen high compared with CTDO, but agrees with Station 110. Analyst: "Recalculated and updated titer."
111/1	121	salt	2	4 attempts for a good salinity reading. Salinity agrees with CTD and adjoining stations. Salinity as well as oxygen and nutrients are acceptable.
111/1	125	salt	2	3 attempts for a good salinity reading. First reading would result in a low reading as much as the second and third reading was high. Salinity agrees with CTD and adjoining stations and within accuracy of the measurement. Salinity as well as oxygen and nutrients are acceptable.
111/1	133	salt	2	Bottle salinity is high compared with CTD, agrees with adjoining stations, full sampling station. Variation at bottle trip, but none of the sampling points are with the bottle. The CTD up and down agree fairly well. Salinity as well as oxygen and nutrients are acceptable.
112/1	101	salt	2	Salinity ending SSW gave a large drift, suspect initial standard was low. Salinity values agree with adjoining stations and CTD, lab temperature was almost 1 degree lower than 4 hours early. Salinity is acceptable.
113/1	119	salt	2	5 attempts for a good salinity reading. Additional readings do not resolve the salinity discrepancy. Gradient, salinity agrees with adjoining stations. Salinity as well as oxygen and nutrients are acceptable.
113/1	127	salt	2	3 attempts for a good salinity reading. Additional readings do not resolve the slight salinity discrepancy. Salinity agrees with adjoining stations. Salinity as well as oxygen and nutrients are acceptable.
114/2	201	salt	2	Bottle salinity is high compared with CTD and adjoining stations. 3 attempts for a good salinity reading. First reading resolved salinity discrepancy. Salinity as well as oxygen and nutrients are acceptable.

Station /Cast	Sample No.	Quality Property	Code	Comment
114/2	214	salt	2	Bottle salinity is high compared with CTD and adjoining stations. 5 attempts for a good salinity reading. First reading resolved salinity discrepancy. Salinity as well as oxygen and nutrients are acceptable.
114/2	217	salt	2	Bottle salinity is high compared with CTD and adjoining stations. 5 attempts for a good salinity reading. First reading resolved salinity discrepancy. Salinity as well as oxygen and nutrients are acceptable.
114/2	218	salt	2	Bottle salinity is high compared with CTD and adjoining stations. 4 attempts for a good salinity reading. First reading resolved salinity discrepancy. Salinity as well as oxygen and nutrients are acceptable.
114/2	231	salt	2	4 attempts for a good salinity reading. First reading resolved salinity discrepancy. Salinity as well as oxygen and nutrients are acceptable.
114/2	232	ctds	4	CTD spiky at bottle trip. Code CTD salinity bad.
114/2	232	salt	2	Bottle salinity is low compared with CTD. CTD spiky at bottle trip. Salinity as well as oxygen and nutrients are acceptable.
114/2	236	salt	2	3 attempts for a good salinity reading. First reading resolved salinity discrepancy. Salinity as well as oxygen and nutrients are acceptable.
115/1	104	salt	2	Bottle salinity is high compared with CTD and adjoining stations. Salinity operator error, removed the sample bottle too early and starting analyzing 5, corrected error. Salinity as well as oxygen and nutrients are acceptable.
115/1	115	salt	2	Bottle salinity is high compared with CTD and adjoining stations. 4 attempts for a good salinity reading. First reading resolved salinity discrepancy. Salinity as well as oxygen and nutrients are acceptable.
115/1	126	salt	2	3 attempts for a good salinity reading. Additional readings did not make a significant difference in salinity value. Salinity as well as oxygen and nutrients are acceptable.
115/1	130	salt	2	3 attempts for a good salinity reading. First reading resolved salinity discrepancy. Salinity as well as oxygen and nutrients are acceptable.
115/1	133	ctds	4	CTD spiky at bottle trip. Code CTD salinity bad.
115/1	133	salt	2	Bottle salinity is low compared with CTD and adjoining stations. CTD spiky at bottle trip. Salinity as well as oxygen and nutrients are acceptable.
116/1	110	sio3	2	SiO3 high, does not agree with adjoining stations or station profile and high in relationship to oxygen. Station 114 and 115 did exhibit a higher SiO3 at this density level. JHS: This may be a boundary between two water masses, with all SiO3 data good in this depth range at these stations, 114-119.
117/1	129	salt	2	3 attempts for a good salinity reading. First salinity reading resolve discrepancy. Salinity as well as oxygen and nutrients are acceptable.
118/2	201	salt	2	Bottle salinity is high compared with CTD and adjoining stations. 4 attempts for a good salinity reading. First reading resolved salinity discrepancy. Salinity, oxygen and nutrients are acceptable.
118/2	202	salt	2	Bottle salinity is high compared with CTD and adjoining stations. 3 attempts for a good salinity reading. First reading resolved salinity discrepancy. Although still a little high, it is within the accuracy of the measurement. Salinity, oxygen and nutrients are acceptable.
118/2	230	salt	2	3 attempts for a good salinity reading. First reading was a little realistic, within accuracy of measurement. Salinity, oxygen and nutrients are acceptable.
118/2	232	salt	2	3 attempts for a good salinity reading. First reading resolved salinity discrepancy. Salinity, oxygen and nutrients are acceptable.
118/2	236	salt	2	3 attempts for a good salinity reading. First reading resolved salinity discrepancy. Salinity, oxygen and nutrients are acceptable.
119/1	136	bottle	2	Surface bottle was tripped at 12m, console operator asked to bring up to 5 meters instead of the surface.

Station /Cast	Sample No.	Quality Property	Code	Comment
119/1	136	salt	2	3 attempts for a good salinity reading. Additional readings did not resolve salinity discrepancy, salinity within accuracy of the measurement. Salinity, oxygen and nutrients are acceptable.
120/1	121	salt	2	3 attempts for a good salinity reading. Thimble came out with cap. First reading resolved salinity discrepancy. Salinity as well as oxygen and nutrients.
120/1	130	ctds	4	CTD spiky at trip. Code CTD salinity bad.
120/1	130	salt	2	Salinity thimble came out with cap. Salinity agrees with adjoining stations, CTD spiky at trip. Salinity as well as oxygen and nutrients are acceptable.
120/1	131	salt	2	3 attempts for a good salinity reading. Additional reading did not resolve salinity discrepancy, within accuracy of the measurement. CTD spiky at trip. Salinity as well as oxygen and nutrients are acceptable.
121/1	118	salt	2	3 attempts for a good salinity reading. Operator error, removed bottle before finished analyzing second set of readings, corrected. Salinity as well as oxygen and nutrients are acceptable.
121/1	132	salt	2	4 attempts for a good salinity reading. First reading resolved salinity discrepancy. Salinity as well as oxygen and nutrients are acceptable.
121/1	134	ctds	4	CTD spiky at trip. Code CTD salinity bad.
121/1	134	salt	2	Bottle salinity is high compared with CTD. CTD spiky at trip. Salinity as well as oxygen and nutrients are acceptable.
123/1	131	salt	2	3 attempts for a good salinity reading. May have not flushed well before starting the readings, second reading gives better results. Salinity as well as oxygen and nutrients are acceptable.
123/1	132	ctds	4	CTD is spiky at bottle trip. Code CTD salinity bad.
123/1	132	salt	2	Bottle salinity is high compared with CTD. CTD is spiky at bottle trip. Salinity as well as oxygen and nutrients are acceptable.
124/1	105	salt	4	Bottle salinity is high compared with CTD, agrees with Station 123. 3 attempts for a good salinity reading, could not resolve salinity discrepancy with additional readings. Code salinity bad, oxygen and nutrients are acceptable.
124/1	107	sio3	2	SiO3 appears low on the station profile. Agrees with Station 123 and oxygen has a higher feature. PO4 and NO3 also exhibit lower feature. Salinity, oxygen and nutrients are acceptable.
124/1	130	ctds	4	Bottle salinity is low compared with CTD. CTD spiky at bottle trip. Salinity, oxygen and nutrients are acceptable.
124/1	130	salt	2	Bottle salinity is low compared with CTD. CTD spiky at bottle trip. Salinity, oxygen and nutrients are acceptable.
125/1	132	salt	2	3 attempts for a good salinity reading. First reading resolved salinity discrepancy. Salinity as well as oxygen and nutrients are acceptable.
125/1	136	salt	2	4 attempts for a good salinity reading. First reading resolved salinity discrepancy. Salinity as well as oxygen and nutrients are acceptable.
126/2	207	salt	2	Bottle salinity is high compared with CTD and adjoining stations. 4 attempts for a good salinity reading. Salinity as well as oxygen and nutrients are acceptable.
126/2	234	salt	2	Bottle salinity is high compared with CTD. Variation also seen in the up and down trace. Salinity as well as oxygen and nutrients are acceptable.
126/2	235	salt	2	Bottle salinity is high compared with CTD. Variation also seen in the up and down trace. Salinity as well as oxygen and nutrients are acceptable.
127/1	101	bottle	2	CFC and Helium sample 1-7 then waited ˜10 minutes for oxygen to start.
127/1	108	salt	2	Salinity thimble popped off when cap was removed. Salinity as well as oxygen and nutrients are acceptable.

Station /Cast	Sample No.	Quality Property	Code	Comment
127/1	119	salt	2	3 attempts for a good salinity reading. First reading resolved small salinity discrepancy. Salinity as well as oxygen and nutrients are acceptable.
127/1	126	salt	2	3 attempts for a good salinity reading. Thimble jarred loose by cap - liquid almost certainly ran inside bottle. Took first reading only. Salinity as well as oxygen and nutrients are acceptable.
127/1	129	ctds	4	CTD spiky at bottle trip. Code CTD salinity bad.
127/1	129	salt	2	Bottle salinity is low compared with CTD. CTD spiky at bottle trip. Salinity as well as oxygen and nutrients are acceptable.
128/1	134	bottle	2	Vent was open. Oxygen is a little high compared with CTD, agrees with adjoining stations. Oxygen, salinity and nutrients are acceptable.
129/1	104	salt	2	Bottle salinity is high compared with CTD and adjoining stations. 3 attempts for a good salinity reading. First reading resolved salinity discrepancy. Salinity as well as oxygen and nutrients are acceptable.
129/1	110	salt	2	Bottle salinity is high compared with CTD and adjoining stations. 4 attempts for a good salinity reading. First reading resolved salinity discrepancy. Salinity as well as oxygen and nutrients are acceptable.
129/1	114	salt	2	3 attempts for a good salinity reading. First reading resolved salinity discrepancy. Salinity as well as oxygen and nutrients are acceptable.
129/1	115	salt	2	Bottle salinity is high compared with CTD and adjoining stations. 3 attempts for a good salinity reading. First reading resolved salinity discrepancy. Salinity as well as oxygen and nutrients are acceptable.
129/1	122	salt	2	3 attempts for a good salinity reading. First reading resolved salinity discrepancy. Salinity as well as oxygen and nutrients are acceptable.
129/1	125	salt	2	4 attempts for a good salinity reading. First reading resolved salinity discrepancy. Salinity as well as oxygen and nutrients are acceptable.
130/1	101	salt	2	Bottle salinity is high compared with CTD and adjoining stations. 5 attempts for a good salinity reading. First reading resoled salinity discrepancy. Salinity as well as oxygen and nutrients are acceptable.
130/1	102	salt	2	3 attempts for a good salinity reading. First reading resoled salinity discrepancy. Salinity as well as oxygen and nutrients are acceptable.
130/1	103	salt	2	4 attempts for a good salinity reading. First reading resoled salinity discrepancy. Salinity as well as oxygen and nutrients are acceptable.
130/1	104	salt	2	Bottle salinity is high compared with CTD and adjoining stations. 3 attempts for a good salinity reading. Salinity as well as oxygen and nutrients are acceptable.
130/1	105	salt	2	Bottle salinity is high compared with CTD and adjoining stations. 4 attempts for a good salinity reading. First reading resolved salinity discrepancy. Salinity as well as oxygen and nutrients are acceptable.
130/1	109	salt	2	3 attempts for a good salinity reading. First reading resolved salinity discrepancy. Salinity as well as oxygen and nutrients are acceptable.
130/1	113	salt	2	4 attempts for a good salinity reading. First reading resolved salinity discrepancy. Salinity as well as oxygen and nutrients are acceptable.
130/1	114	salt	2	3 attempts for a good salinity reading. First reading resolved salinity discrepancy. Salinity as well as oxygen and nutrients are acceptable.
130/1	119	salt	2	3 attempts for a good salinity reading. First reading resolved salinity discrepancy. Salinity as well as oxygen and nutrients are acceptable.
130/1	120	salt	2	4 attempts for a good salinity reading. First reading resolved salinity discrepancy. Salinity as well as oxygen and nutrients are acceptable.
130/1	123	salt	2	3 attempts for a good salinity reading. First reading resolved salinity discrepancy. Salinity as well as oxygen and nutrients are acceptable.

Station /Cast	Sample No.	Quality Property	Code	Comment
130/1	125	salt	2	3 attempts for a good salinity reading. Additional reading did not resolve discrepancy, leave as is. Salinity as well as oxygen and nutrients are acceptable.
130/1	128	salt	2	4 attempts for a good salinity reading. Additional reading did not resolve discrepancy, leave as is. Salinity as well as oxygen and nutrients are acceptable.
130/1	130	bottle	2	Bottles 31-35 were not tripped per sampling schedule.
131/2	222	salt	2	3 attempts for a good salinity reading. First reading would result in a higher salinity, second and third are reasonable. Salinity as well as oxygen and nutrients are acceptable.
131/2	224	ctds	4	CTD spiky at bottle trip. Code CTD salinity bad.
131/2	224	salt	2	Bottle salinity is low compared with CTD and adjoining stations, but CTD trace shows lower salinity. CTD spiky at bottle trip. Salinity as well as oxygen and nutrients are acceptable.
132/1	102	salt	4	Bottle salinity is high compared with CTD on station profile. 3 attempts for a good salinity reading. Second reading did not resolve salinity discrepancy, contamination. Code salinity bad, oxygen and nutrients are acceptable.
132/1	103	bottle	2	Special bottle tripped with 4 for pH only.
132/1	103	CTDOXY	5	CTDO sample lost, no bottle oxygen.
132/1	124	salt	2	3 attempts for a good salinity reading. Salinity as well as oxygen and nutrients are acceptable.
132/1	129	salt	2	Bottle salinity is high compared with CTD and adjoining stations. Spiky CTD at bottle trip. Salinity as well as oxygen and nutrients are acceptable.
133/1	103	salt	2	Bottle salinity is high compared with CTD, agrees with adjoining stations. Bottle 2 appears low compared with adjoining stations, although the agreement with the CTD was better. Salinity, oxygen and nutrients are acceptable.
133/1	106	salt	2	3 attempts for a good salinity reading. First reading resolved salinity discrepancy. Salinity as well as oxygen and nutrients are acceptable.
133/1	116	salt	2	3 attempts for a good salinity reading. First reading resolved salinity discrepancy. Salinity as well as oxygen and nutrients are acceptable.
134/1	102	salt	2	Bottle salinity is high compared with CTD and adjoining stations. 5 attempts for a good salinity reading. Rim chip, does not affect sample. First reading resolved salinity discrepancy. Salinity as well as oxygen and nutrients are acceptable.
134/1	105	salt	2	Bottle salinity is high compared with CTD and adjoining stations. 4 attempts for a good salinity reading. First reading resolved salinity discrepancy. Salinity as well as oxygen and nutrients are acceptable.
134/1	125	salt	2	4 attempts for a good salinity reading. First reading resolved salinity discrepancy. Salinity as well as oxygen and nutrients are acceptable.
135/2	201	salt	2	Bottle salinity is high compared with CTD and adjoining stations. 3 attempts for a good salinity reading. First reading resolved salinity discrepancy. Salinity, oxygen and nutrients are acceptable.
135/2	210	salt	2	Bottle salinity is high compared with CTD and adjoining stations. 3 attempts for a good salinity reading. First reading resolved salinity discrepancy. Salinity, oxygen and nutrients are acceptable.
135/2	211	salt	2	Bottle salinity is high compared with CTD and adjoining stations. 3 attempts for a good salinity reading. First reading resolved salinity discrepancy. Salinity, oxygen and nutrients are acceptable.

Station /Cast	Sample No.	Quality Property	Code	Comment
135/2	222	salt	2	3 attempts for a good salinity reading. First reading did not resolve small salinity discrepancy, but reasonable value. Salinity, oxygen and nutrients are acceptable.
135/2	234	ctds	4	Variation in CTD at bottle trip, CTD spiky. Code CTD salinity bad.
135/2	234	salt	2	Bottle salinity is high compared with CTD. Variation in CTD at bottle trip, CTD spiky. Salinity, oxygen and nutrients are acceptable.
136/1	101	salt	2	Salinity bottles were cleaned prior to this cast.
136/1	103	salt	2	Bottle salinity is high compared with CTD and adjoining stations. 3 attempts for a good salinity reading. First reading resolved salinity discrepancy. Thimble came out with cap. Salinity as well as oxygen and nutrients are acceptable.
136/1	124	salt	3	Salinity Thimble came out with cap. Salinity although a high compared to CTD is acceptable as are oxygen and nutrients.
138/1	101	salt	2	Room temperature increased 4.3 degrees in one hour. Analyst had been away from the salinometer for that long, samples 1-8 had been run. A new salinity run was started one hour later, the room temperature decreased 3.4 degrees. Salinity agreement with adjoining stations and CTD seems reasonable.
138/1	119	salt	2	3 attempts for a good salinity reading. First reading resolved salinity discrepancy. Salinity, oxygen and nutrients are acceptable.
138/1	120	o2	2	Oxygen bad endpoint, recalculated, entered new titer. Oxygen agrees with CTD and adjoining stations. Salinity, oxygen and nutrients are acceptable.
138/1	123	salt	2	4 attempts for a good salinity reading. First reading resolved salinity discrepancy. Salinity, oxygen and nutrients are acceptable.
138/1	134	ctds	4	Large CTD spike at bottle trip, code CTD salinity bad.
138/1	134	salt	2	Bottle salinity is low compared with CTD. Large CTD spike at bottle trip. Salinity, oxygen and nutrients are acceptable.
139/2	201	salt	2	Bottle salinity is high compared with CTD and adjoining stations. 5 attempts for a good salinity reading. Salinity as well as oxygen and nutrients are acceptable.
139/2	206	salt	2	Bottle salinity is high compared with CTD and adjoining stations. 4 attempts for a good salinity reading. Salinity as well as oxygen and nutrients are acceptable.
139/2	207	salt	2	Bottle salinity is high compared with CTD and adjoining stations. 4 attempts for a good salinity reading. Salinity as well as oxygen and nutrients are acceptable.
139/2	208	salt	2	Bottle salinity is high compared with CTD and adjoining stations. 3 attempts for a good salinity reading. Salinity as well as oxygen and nutrients are acceptable.
139/2	212	salt	2	Bottle salinity is high compared with CTD and adjoining stations. 4 attempts for a good salinity reading. Salinity as well as oxygen and nutrients are acceptable.
139/2	216	salt	5	Sampling error, salinity not collected.
139/2	233	ctds	4	Variation in CTD trace, CTD spiky. Code CTD salinity bad.
139/2	233	salt	2	Bottle salinity is high compared with CTD. Variation in CTD trace, CTD spiky. Salinity as well as oxygen and nutrients are acceptable.
139/2	234	ctds	4	Variation in CTD trace, CTD spiky. Code CTD salinity bad.
140/1	109	salt	2	3 attempts for a good salinity reading. Second reading resolved salinity discrepancy. Salinity as well as oxygen and nutrients are acceptable.
140/1	110	salt	2	Salinity thimble came out with cap. Salinity is a little low compared with CTD. Salinity as well as oxygen and nutrients are acceptable.

Station /Cast	Sample No.	Quality Property	Code	Comment
140/1	112	sio3	2	SiO3 looks high, fits well with stations >140, SiO3 is acceptable.. Analyst: "Peak slightly higher than 11, looks valid."
140/1	120	salt	2	Salinity severe rim chip, seal affected, bottle discarded. Salinity agreement with CTD is acceptable. Salinity as well as oxygen and nutrients are acceptable.
140/1	127	salt	2	3 attempts for a good salinity reading. Cap jarred thimble loose, apparent contamination. Took first reading only. Salinity as well as oxygen and nutrients are acceptable.
141/1	101	salt	3	Bottle salinity is high compared with CTD and adjoining stations, appears to have been a drawing error with bottle 2. Code salinity questionable, oxygen and nutrients are acceptable.
141/1	124	o2	2	Oxygen bad endpoint, recalculated and entered new titer. Oxygen appears slightly high compared with adjoining stations, but is acceptable as are salinity and nutrients.
141/1	134	ctds	4	Variation in CTD at bottle trip, CTD spiky. Code CTD salinity bad.
141/1	134	salt	2	Bottle salinity is low compared with CTD. Variation in CTD at bottle trip, CTD spiky. Salinity as well as oxygen and nutrients are acceptable.
142/1	101	salt	3	Bottle salinity is high compared with CTD and adjoining stations. 5 attempts for a good salinity reading.Additional readings did not resolve salinity discrepancy. Lab temperature change, suspect that salinity was affected. Code salinity questionable, oxygen and nutrients acceptable.
142/1	102	salt	3	Bottle salinity is high compared with CTD agrees with 141 and ˜0.001 higher than 140, both 141 and 142 are higher than 143. Lab temperature change, suspect that salinity was affected. Code salinity questionable, oxygen and nutrients acceptable.
142/1	103	salt	3	Bottle salinity is high compared with CTD agrees with 141 and ˜0.001 higher than 140, both 141 and 142 are higher than 143. Lab temperature change, suspect that salinity was affected. Code salinity questionable, oxygen and nutrients acceptable.
142/1	107	salt	3	Bottle salinity is high compared with CTD and adjoining stations. No analytical problem noted. Code salinity questionable, oxygen is acceptable.
142/1	110	salt	2	Bottle salinity is high compared with CTD and adjoining stations. 4 attempts for a good salinity reading. First reading resolved salinity discrepancy. Salinity as well as oxygen are acceptable.
142/1	116	salt	2	3 attempts for a good salinity reading. First reading resolved salinity discrepancy. Salinity as well as oxygen are acceptable.
142/1	130	sio3	2	SiO3 low ˜1 unit. Oxygen slightly higher on the station profile, do not see the feature in salinity, PO4 or NO3.
142/1	134	ctds	4	Variation in CTD traces, CTD spiky at bottle trip. Code CTD salinity bad.
142/1	134	o2	2	Oxygen bad endpoint, recalculated and entered new titer. Oxygen as well as salinity and nutrients are acceptable.
142/1	134	salt	2	Bottle salinity is high compared with CTD. Variation in CTD traces, CTD spiky at bottle trip. Salinity as well as oxygen are acceptable.
143/2	210	salt	2	Bottle salinity is low compared with CTD and adjoining stations. 3 attempts for a good salinity reading. Thimble came out with cap. Classic contamination pattern. Took first reading only. Second reading resolved salinity discrepancy. Salinity as well as oxygen and nutrients are acceptable.
143/2	224	salt	2	Salinity thimble came out with cap. Salinity appears a little high compared with CTD, agrees with adjoining stations. Salinity as well as oxygen and nutrients are acceptable.
143/2	234	ctds	4	Variation in CTD trace at bottle trip, CTD spiky. Code CTD salinity bad.

Station /Cast	Sample No.	Quality Property	Code	Comment
143/2	234	salt	2	Bottle salinity is high compared with CTD. Variation in CTD trace at bottle trip, CTD spiky. Salinity as well as oxygen and nutrients are acceptable.
144/1	104	salt	2	m
145/2	201	salt	3	Bottle salinity is high compared with CTD and adjoining stations. There was a air temperature difference for some samples of 0.03, bath temperature went a little higher 0.01 on one of these samples, but could not find any reason why the higher salinities. Code salinity questionable, oxygen and nutrients are acceptable.
145/2	202	salt	3	Bottle salinity is high compared with CTD and adjoining stations. There was a air temperature difference for some samples of 0.03, bath temperature went a little higher 0.01 on one of these samples, but could not find any reason why the higher salinities. Code salinity questionable, oxygen and nutrients are acceptable.
145/2	203	salt	3	Bottle salinity is high compared with CTD and adjoining stations. There was a air temperature difference for some samples of 0.03, bath temperature went a little higher 0.01 on one of these samples, but could not find any reason why the higher salinities. Code salinity questionable, oxygen and nutrients are acceptable.
145/2	204	salt	3	Bottle salinity is high compared with CTD and adjoining stations. There was a air temperature difference for some samples of 0.03, bath temperature went a little higher 0.01 on one of these samples, but could not find any reason why the higher salinities. Code salinity questionable, oxygen and nutrients are acceptable.
145/2	205	salt	3	Bottle salinity is high compared with CTD and adjoining stations. There was a air temperature difference for some samples of 0.03, bath temperature went a little higher 0.01 on one of these samples, but could not find any reason why the higher salinities. Code salinity questionable, oxygen and nutrients are acceptable.
145/2	206	salt	3	Bottle salinity is high compared with CTD and adjoining stations. There was a air temperature difference for some samples of 0.03, bath temperature went a little higher 0.01 on one of these samples, but could not find any reason why the higher salinities. Code salinity questionable, oxygen and nutrients are acceptable.
145/2	207	salt	3	Bottle salinity is high compared with CTD and adjoining stations. There was a air temperature difference for some samples of 0.03, bath temperature went a little higher 0.01 on one of these samples, but could not find any reason why the higher salinities. Code salinity questionable, oxygen and nutrients are acceptable.
145/2	208	salt	3	Bottle salinity is high compared with CTD and adjoining stations. There was a air temperature difference for some samples of 0.03, bath temperature went a little higher 0.01 on one of these samples, but could not find any reason why the higher salinities. Code salinity questionable, oxygen and nutrients are acceptable.
145/2	209	salt	3	Bottle salinity is high compared with CTD and adjoining stations. There was a air temperature difference for some samples of 0.03, bath temperature went a little higher 0.01 on one of these samples, but could not find any reason why the higher salinities. Code salinity questionable, oxygen and nutrients are acceptable.

Station /Cast	Sample No.	Quality Property	Code	Comment
145/2	210	salt	3	Bottle salinity is high compared with CTD and adjoining stations. There was a air temperature difference for some samples of 0.03, bath temperature went a little higher 0.01 on one of these samples, but could not find any reason why the higher salinities. Code salinity questionable, oxygen and nutrients are acceptable.
145/2	211	salt	3	Bottle salinity is high compared with CTD and adjoining stations. There was a air temperature difference for some samples of 0.03, bath temperature went a little higher 0.01 on one of these samples, but could not find any reason why the higher salinities. Code salinity questionable, oxygen and nutrients are acceptable.
145/2	212	salt	3	Bottle salinity is high compared with CTD and adjoining stations. There was a air temperature difference for some samples of 0.03, bath temperature went a little higher 0.01 on one of these samples, but could not find any reason why the higher salinities. Code salinity questionable, oxygen and nutrients are acceptable.
146/1	102	salt	2	Bottle salinity is high compared with CTD and adjoining stations. 6 attempts for a good salinity reading. First reading resolved salinity discrepancy. Salinity as well as oxygen and nutrients are acceptable.
146/1	103	salt	2	Bottle salinity is high compared with CTD and adjoining stations. 3 attempts for a good salinity reading. First reading resolved salinity discrepancy. Salinity as well as oxygen and nutrients are acceptable.
146/1	112	salt	2	3 attempts for a good salinity reading. First reading resolved salinity discrepancy. Salinity as well as oxygen and nutrients are acceptable.
147/2	216	o2	5	Oxygen sampling 16-22 were off by one bottle. Sample 16 was drawn from 17 and 22 was sampled twice. Salinity and nutrients are acceptable.
148/1	115	salt	4	Bottle salinity is high compared with CTD and adjoining stations. Initial sample fill low. Code salinity bad, oxygen and nutrients are acceptable.
148/1	133	ctds	4	
148/1	133	salt	2	Bottle salinity is high compared with CTD. Variation in CTD salinity at bottle trip, CTD spiky. Code CTD salinity bad, salinity, oxygen and nutrients are acceptable.
150/1	110	sio3	2	SiO3 high compared with adjoining stations and in relationship to oxygen. Analyst: "The peak is real and good, there were no analytical problems noted and the dpcal value is good. Adjoining stations have a similar spike in SiO3 around the same depth."
151/1	135	salt	2	Bottle salinity is high compared with CTD. Variation at trip, CTD as well as bottle salinity are reasonable. Salinity as well as oxygen and nutrients are acceptable.
152/1	111	sio3	2	SiO3 high, there is also a high SiO3 for Station 150. The signal is not seen in other nutrients or oxygen.
154/1	102	bottle	2	Special bottle tripped with 3 for CFC ingrowth/incubation experiment.
154/1	102	CTDOXY	5	CTDO sample lost, no bottle oxygen.
155/1	101	salt	2	Bottle salinity is high compared with CTD and on station profile. Salinity appears 0.001 high on the station profile and almost 0.003 compared with the CTD, within accuracy of the measurement. Salinity as well as oxygen and nutrients are acceptable.
156/1	101	salt	2	Bottle salinity is high compared with CTD reasonable agreement with adjoining stations. Oxygen and NO3 are low, SiO and PO4 are high. Salinity as well as oxygen and nutrients are acceptable.
156/1	106	salt	2	Bottle salinity is high compared with CTD. Salinity as well as oxygen and nutrients are acceptable.

Station /Cast	Sample No.	Quality Property	Code	Comment
156/1	127	salt	2	Salinity thimble came off with cap. Salinity agrees with adjoining stations and within accuracy with the CTD considering the size of the package. Some water entrainment noticeable in the CTD up cast at bottle trip. Salinity as well as oxygen and nutrients are acceptable.
156/1	131	ctds	4	Variation at the bottle trip from entrained water, code CTD salinity bad.
156/1	131	salt	2	Bottle salinity is high compared with CTD. Variation at the bottle trip, bottle salinity is acceptable as are oxygen and nutrients.
156/1	133	ctds	4	Variation at the bottle trip from entrained water, code CTD salinity bad.
157/1	102	salt	3	Bottle salinity is high compared with CTD and adjoining stations. Suspect that salinity was too warm for the bath temperature, most deep samples 1-5 are just outside of the accuracy of the measurement. Code salinity as questionable 1-5, oxygen and nutrients are acceptable.
158/1	131	ctds	4	Variation at bottle trip, code CTD salinity bad.
158/1	131	salt	2	Bottle salinity is high compared with CTD. Variation in CTD at bottle trip, code CTD salinity bad. Salinity as well as oxygen and nutrients are acceptable.
160/1	101	salt	2	Required 2 SSW at end of run-first read high, had higher than normal fill level before opening.
160/1	103	bottle	2	Special bottle tripped with 2 for pH.
160/1	103	CTDOXY	5	CTDO sample lost, no bottle oxygen.
160/1	117	salt	2	Bottle salinity is high compared with CTD, agrees with adjoining stations. Variation in CTD at bottle trip could have caused a larger difference. Salinity as well as oxygen and nutrients are acceptable.
160/1	124	salt	2	Salinity thimble came out with cap. Salinity high compared with CTD, agrees with adjoining stations.
161/1	101	salt	2	Bottle salinity is high compared with CTD, agrees with adjoining stations. Salinity as well as oxygen and nutrients are acceptable.
161/1	113	bottle	2	Endcap knocked open during recovery. Salinity, oxygen and nutrients are acceptable.
161/1	132	bottle	2	Bottles 33-35 were not tripped per sampling schedule.
162/1	133	ctds	4	Variation in CTD up trace at bottle trip, code CTD salinity bad.
162/1	133	salt	2	Bottle salinity is high compared with CTD, agrees with adjoining stations. Variation in CTD up trace at bottle trip, code CTD salinity bad. Salinity, oxygen and nutrients are acceptable.
163/2	201	salt	3	Bottle salinity is high compared with CTD and adjoining stations. No analytical problems noted may not have been flushed after the beginning SSW. Code salinity questionable, oxygen and nutrients are acceptable.
164/1	133	salt	2	Bottle salinity is high compared with CTD. Variations in CTD up trace at bottle trip. Code CTD salinity bad. Salinity as well as oxygen and nutrients are acceptable.
165/1	101	salt	4	Bottle salinity is high compared with CTD and adjoining stations. Suspect cells in salinometer were not flushed adequately after SSW. Code salinity bad, oxygen and nutrients are acceptable.
166/1	110	salt	2	Bottle salinity is low compared with CTD, agrees with adjoining stations in the gradient. Salinity as well as oxygen and nutrients are acceptable.
166/1	132	salt	2	Bottle salinity is low compared with CTD. Variations in the CTD up trace responding to less saline water from below. Code CTD salinity questionable. Salinity, oxygen and nutrients are acceptable.
167/1	127	o2	2	Oxygen appears high compared with adjoining stations, agrees with CTD up trace. Nutrients do not show this same feature. Salinity is a little high compared with CTD and acceptable. Salinity, oxygen and nutrients are acceptable.

Station /Cast	Sample No.	Quality Property	Code	Comment
168/1	119	salt	4	3 attempts for a good salinity reading. Slightly low compared with CTD. Operator pulled 19 early. Took first reading and keyboard entered it for reading 3, reading 2 is from sample 20. Code salinity bad, oxygen and nutrients are acceptable.
170/2	201	salt	3	Bottle salinity is high compared with CTD. Station 168 is the deepest adjoining station and is within accuracy of measurement. Suspect cells on salinometer were not flushed enough after the higher SSW. Code salinity questionable, oxygen and nutrients acceptable.
170/2	209	bottle	2	Vent was open. Oxygen looks reasonable. There was minimal sampling on this bottle, salinity, oxygen and nutrients. Salinity, oxygen and nutrients are acceptable.
170/2	234	bottle	2	Vent was open. Oxygen a little high compared with CTD, but higher features on adjoining stations. There was minimal sampling on this bottle, salinity, oxygen and nutrients. Salinity, oxygen and nutrients are acceptable.
171/1	112	bottle	2	Bottle fired with 13, missed firing the bottle depth of 1635, operator error. Does not effect the samples, bottle was properly equilibrated when tripped.
171/1	128	salt	2	Bottle salinity is low compared with CTD. Appears to be the difference in physical location of the CTD versus the bottle. Salinity as well as oxygen and nutrients are acceptable.
171/1	131	salt	2	Bottle salinity is low compared with CTD, agrees with Station 170 and 173. Appears to be the difference in physical location of the CTD versus the bottle. Salinity as well as oxygen and nutrients are acceptable.
173/1	131	salt	2	Bottle salinity is low compared with CTD, agrees with adjoining stations. CTD has a spike at the bottle trip, code CTD salinity bad. Salinity, oxygen and nutrients are acceptable.
174/1	102	salt	3	Bottle salinity is high compared with CTD and adjoining stations. At the salinity run for Station 176, the analyst found that the heater lamp had burnt out. Salinities on this station are all a little high with this sample being out of measurement accuracy. The lab temperature, although it did not change but by a few tenths, was also a degree lower than 5 hours before this run. SiO3 is high on the station profile, agrees with adjoining stations. Code salinity questionable, oxygen and nutrients are acceptable.
175/2	201	salt	3	The heater lamp was reported as malfunctioning on Station 176. It appears that it malfunctioned on Stations 174-175 also. There was also a large drift on the run. Code salinities questionable, oxygen and nutrients are acceptable.
175/2	202	salt	3	The heater lamp was reported as malfunctioning on Station 176. It appears that it malfunctioned on Stations 174-175 also. There was also a large drift on the run. Code salinities questionable, oxygen and nutrients are acceptable.
175/2	203	salt	3	The heater lamp was reported as malfunctioning on Station 176. It appears that it malfunctioned on Stations 174-175 also. There was also a large drift on the run. Code salinities questionable, oxygen and nutrients are acceptable.
175/2	204	salt	3	The heater lamp was reported as malfunctioning on Station 176. It appears that it malfunctioned on Stations 174-175 also. There was also a large drift on the run. Code salinities questionable, oxygen and nutrients are acceptable.

Station /Cast	Sample No.	Quality Property	Code	Comment
175/2	205	salt	3	The heater lamp was reported as malfunctioning on Station 176. It appears that it malfunctioned on Stations 174-175 also. There was also a large drift on the run. Code salinities questionable, oxygen and nutrients are acceptable.
175/2	206	salt	3	The heater lamp was reported as malfunctioning on Station 176. It appears that it malfunctioned on Stations 174-175 also. There was also a large drift on the run. Code salinities questionable, oxygen and nutrients are acceptable.
175/2	208	salt	3	The heater lamp was reported as malfunctioning on Station 176. It appears that it malfunctioned on Stations 174-175 also. There was also a large drift on the run. Code salinities questionable, oxygen and nutrients are acceptable.
175/2	210	salt	3	The heater lamp was reported as malfunctioning on Station 176. It appears that it malfunctioned on Stations 174-175 also. There was also a large drift on the run. Code salinities questionable, oxygen and nutrients are acceptable.
175/2	211	salt	3	The heater lamp was reported as malfunctioning on Station 176. It appears that it malfunctioned on Stations 174-175 also. There was also a large drift on the run. Code salinities questionable, oxygen and nutrients are acceptable.
175/2	225	o2	2	Oxygen temp sensor malfunction. Oxygen draw temp estimated from bottles above and below. Oxygen um/kg appears reasonable.
176/1	101	salt	3	Bottle salinity is high compared with CTD and adjoining stations. The heater lamp was reported as malfunctioning. It appears that it malfunctioned on Stations 174-175 also. There was also a large drift on the run. Code salinities questionable, oxygen and nutrients are acceptable.
176/1	103	salt	2	Bottle salinity is high compared with CTD and adjoining stations. The heater lamp was reported as malfunctioning. It appears that it malfunctioned on Stations 174-175 also. There was also a large drift on the run. Code salinities bad, oxygen and nutrients are acceptable.
176/1	132	salt	2	Bottle salinity is low compared with CTD. CTD is spiky at bottle trip. Code CTD salinity bad. Salinity, oxygen and nutrients are acceptable.
178/1	101	salt	3	Bottle salinity is high compared with CTD and adjoining stations. Suspect salinometer cell not properly flushed after higher SSW. Code salinity questionable, oxygen and nutrients are acceptable.
178/1	106	bottle	2	Special bottle tripped with 5 for CFC ingrowth/incubation experiment.
178/1	106	CTDOXY	5	CTDO sample lost, no bottle oxygen.
178/1	125	salt	2	3 attempts for a good salinity reading. Second and third reading resolved slight salinity discrepancy. Salinity as well as oxygen and nutrients are acceptable.
178/1	129	ctds	4	CTD spiky from water entrainment.
178/1	129	salt	2	Bottle salinity is low compared with CTD and adjoining stations. CTD spiky from water entrainment below, code CTD salinity bad. Salinity, oxygen and nutrients are acceptable.
179/2	222	salt	4	Bottle salinity is low compared with CTD and adjoining stations. Salinity appears to have drawn from 21. Code salinity bad, oxygen and nutrients are acceptable.
180/1	102	salt	2	Bottle salinity is high compared with CTD and adjoining stations. 4 attempts for a good salinity reading. First reading resolved salinity discrepancy. Salinity as well as oxygen and nutrients are acceptable.
182/1	108	bottle	2	Special bottle tripped with 7 for CFC ingrowth/incubation experiment.

Station /Cast	Sample No.	Quality Property	Code	Comment
182/1	108	CTDOXY	5	CTDO sample lost, no bottle oxygen.
182/1	133	salt	2	Bottle salinity is high compared with CTD. Variation in CTD at bottle trip. Salinity as well as oxygen and nutrients are acceptable.
183/2	218	salt	2	Bottle salinity is low compared with CTD. Feature in CTD up trace. Salinity as well as oxygen and nutrients are acceptable.
184/1	114	salt	2	3 attempts for a good salinity reading. Thimble came out with cap; suspect some contamination. Additional readings did not resolve the small salinity difference, within accuracy of the measurement. Salinity, oxygen and nutrients are acceptable.
186/1	103	salt	2	Salinity 3 and 4 were in the wrong spots in the case. Salinity, oxygen and nutrients are acceptable.
186/1	104	salt	2	Salinity 3 and 4 were in the wrong spots in the case. Salinity, oxygen and nutrients are acceptable.
186/1	105	salt	3	Bottle salinity high compared with CTD, and adjoining stations. No analytical problems noted. Code salinity questionable, oxygen and nutrients are acceptable.
186/1	118	o2	3	Oxygen sample was cloudy added additional acid to get it to clear and finish titrating. Slightly high compared with adjoining stations and CTDO. Code oxygen questionable, salinity and nutrients acceptable.
187/1	101	o2	4	Black particles in the sample which may have resulted in a bad endpoint and result. End point reviewed and recalculated, did not resolve oxygen discrepancy. Code oxygen bad.
187/1	128	salt	2	3 attempts for a good salinity reading. First reading resolved salinity discrepancy. Salinity as well as oxygen and nutrients are acceptable.
188/1	110	salt	2	4 attempts for a good salinity reading. Second reading resolved salinity discrepancy. salinity as well as oxygen and nutrients are acceptable.
189/2	216	salt	2	Bottle salinity is high compared with CTD, agrees with adjoining stations, gradient. Oxygen shows a low feature, nutrients higher. Salinity, oxygen and nutrients are acceptable.
190/1	118	salt	2	3 attempts for a good salinity reading. Additional readings did not resolve small salinity discrepancy. Salinity as well as oxygen and nutrients are acceptable.
190/1	122	salt	2	5 attempts for a good salinity reading. Additional readings did not resolve small salinity discrepancy. Salinity as well as oxygen and nutrients are acceptable.
192/1	110	salt	3	3 attempts for a good salinity reading. Additional reading did not resolve salinity difference. Code salinity questionable, oxygen and nutrients are acceptable.
194/1	103	salt	3	3 attempts for a good salinity reading. Additional readings did not resolve salinity discrepancy. Code salinity questionable, oxygen and nutrients are acceptable.
194/1	114	salt	3	3 attempts for a good salinity reading. Additional readings did not resolve salinity discrepancy. Code salinity questionable, oxygen and nutrients are acceptable.

Appendix B

Bottle Depth Schemes

The bottle depths followed the 3-scheme plan originally developed by Paul Robbins, adapted and refined by Greg Johnson for this cruise. The I5 version was more easily adjusted for bottom depth than the versions used in the past cruises for the program. Stations rotated through the three schemes, so samples collected principally on alternate stations received the same pattern, but every six stations. The tables show the three schemes used during I5.

Scheme 1:

1	5	5	5	5	5	5	5	5	5	5	5	5	5	5
2	20	20	20	20	20	20	20	20	20	20	20	20	20	20
3	40	40	40	40	40	40	40	40	40	40	40	40	40	40
4	65	65	65	65	65	65	65	65	65	65	65	65	65	65
5	90	90	90	90	90	90	90	90	90	90	90	90	90	90
6	135	135	135	135	135	135	115	115	115	115	115	115	115	115
7	185	185	185	185	185	185	140	140	140	140	140	140	140	140
8	235	235	235	235	235	235	185	185	185	185	185	165	165	165
9	285	285	285	285	285	285	235	235	235	235	235	190	190	190
10	335	335	335	335	335	335	285	285	285	285	285	235	215	215
11	385	385	385	385	385	385	335	335	335	335	335	285	240	240
12	465	465	465	465	465	435	385	385	385	385	385	335	285	285
13	565	565	565	565	565	485	435	435	435	435	435	385	335	335
14	665	665	665	665	665	565	485	485	485	485	485	435	385	385
15	765	765	765	765	765	665	565	565	565	565	565	485	435	435
16	865	865	865	865	865	765	665	665	665	665	665	565	485	485
17	965	965	965	965	965	865	765	765	765	765	765	665	565	565
18	1065	1065	1065	1065	1065	965	865	865	865	865	865	765	665	665
19	1165	1165	1165	1165	1165	1065	965	965	965	965	965	865	765	765
20	1265	1265	1265	1265	1265	1165	1065	1065	1065	1065	1065	965	865	865
21	1365	1365	1365	1365	1365	1265	1165	1165	1165	1165	1165	1065	965	965
22	1535	1535	1535	1535	1465	1365	1265	1265	1265	1265	1265	1165	1065	1065
23	1735	1735	1735	1735	1565	1465	1365	1365	1365	1365	1365	1265	1165	1165
24	1935	1935	1935	1935	1735	1565	1465	1465	1465	1465	1465	1365	1265	1265
25	2165	2165	2165	2165	1935	1735	1565	1565	1565	1565	1565	1465	1365	1365
26	2415	2415	2415	2415	2165	1935	1735	1665	1665	1665	1665	1565	1465	1465
27	2665	2665	2665	2665	2415	2165	1935	1765	1765	1765	1765	1665	1565	1565
28	2915	2915	2915	2915	2665	2415	2165	1935	1935	1935	1935	1765	1665	1665
29	3200	3200	3200	3200	2915	2665	2415	2165	2165	2135	2135	1935	1765	1765
30	3500	3500	3500	3500	3200	2915	2665	2415	2415	2335	2335	2135	1935	1865
31	3865	3800	3800	3800	3500	3200	2915	2665	2665	2535	2535	2335	2135	1965
32	4265	4165	4100	4100	3800	3500	3200	2915	2915	2735	2735	2535	2335	2135
33	4665	4565	4400	4400	4100	3800	3500	3200	3165	2935	2935	2735	2535	2335
34	5065	4965	4765	4700	4400	4100	3800	3500	3415	3200	3135	2935	2735	2535
35	split spacing with bottle above													
36	8 to 10 meters above the bottom													

Scheme 2:

1	5	5	5	5	5	5	5	5	5	5	5	5	5	5
2	25	25	25	25	25	25	25	25	25	25	25	25	25	25
3	50	50	50	50	50	50	50	50	50	50	50	50	50	50
4	75	75	75	75	75	75	75	75	75	75	75	75	75	75
5	100	100	100	100	100	100	100	100	100	100	100	100	100	100
6	150	150	150	150	150	150	125	125	125	125	125	125	125	125
7	200	200	200	200	200	200	150	150	150	150	150	150	150	150
8	250	250	250	250	250	250	200	200	200	200	200	175	175	175
9	300	300	300	300	300	300	250	250	250	250	250	200	200	200
10	350	350	350	350	350	350	300	300	300	300	300	250	225	225
11	400	400	400	400	400	400	350	350	350	350	350	300	250	250
12	500	500	500	500	500	450	400	400	400	400	400	350	300	300
13	600	600	600	600	600	500	450	450	450	450	450	400	350	350
14	700	700	700	700	700	600	500	500	500	500	500	450	400	400
15	800	800	800	800	800	700	600	600	600	600	600	500	450	450
16	900	900	900	900	900	800	700	700	700	700	700	600	500	500
17	1000	1000	1000	1000	1000	900	800	800	800	800	800	700	600	600
18	1100	1100	1100	1100	1100	1000	900	900	900	900	900	800	700	700
19	1200	1200	1200	1200	1200	1100	1000	1000	1000	1000	1000	900	800	800
20	1300	1300	1300	1300	1300	1200	1100	1100	1100	1100	1100	1000	900	900
21	1400	1400	1400	1400	1400	1300	1200	1200	1200	1200	1200	1100	1000	1000
22	1600	1600	1600	1600	1500	1400	1300	1300	1300	1300	1300	1200	1100	1100
23	1800	1800	1800	1800	1600	1500	1400	1400	1400	1400	1400	1300	1200	1200
24	2000	2000	2000	2000	1800	1600	1500	1500	1500	1500	1500	1400	1300	1300
25	2250	2250	2250	2250	2000	1800	1600	1600	1600	1600	1600	1500	1400	1400
26	2500	2500	2500	2500	2250	2000	1800	1700	1700	1700	1700	1600	1500	1500
27	2750	2750	2750	2750	2500	2250	2000	1800	1800	1800	1800	1700	1600	1600
28	3000	3000	3000	3000	2750	2500	2250	2000	2000	2000	2000	1800	1700	1700
29	3300	3300	3300	3300	3000	2750	2500	2250	2250	2200	2200	2000	1800	1800
30	3600	3600	3600	3600	3300	3000	2750	2500	2500	2400	2400	2200	2000	1900
31	4000	3900	3900	3900	3600	3300	3000	2750	2750	2600	2600	2400	2200	2000
32	4400	4300	4200	4200	3900	3600	3300	3000	3000	2800	2800	2600	2400	2200
33	4800	4700	4500	4500	4200	3900	3600	3300	3250	3000	3000	2800	2600	2400
34	5200	5100	4900	4800	4500	4200	3900	3600	3500	3300	3200	3000	2800	2600
35	split spacing with bottle above													
36	8 to 10 meters above the bottom													

Scheme 3:

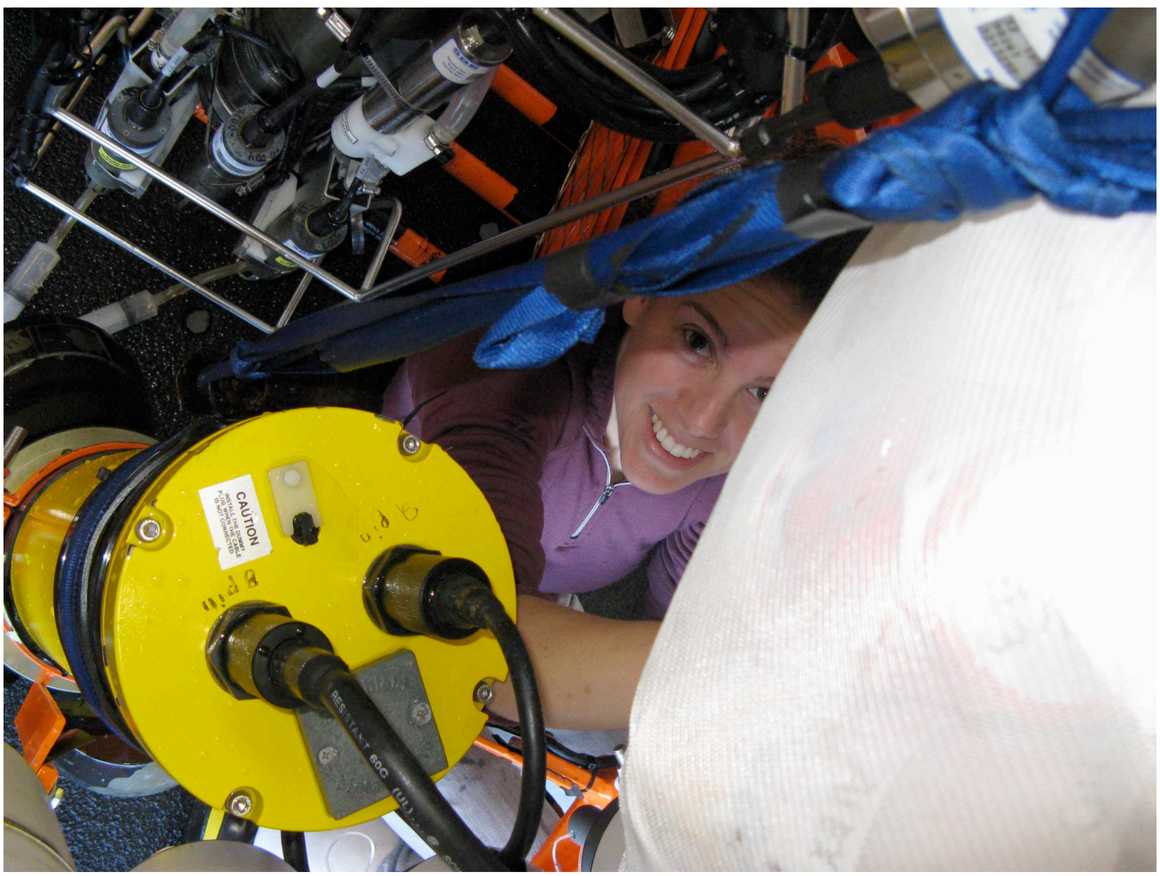
1	5	5	5	5	5	5	5	5	5	5	5	5	5	5
2	35	35	35	35	35	35	35	35	35	35	35	35	35	35
3	60	60	60	60	60	60	60	60	60	60	60	60	60	60
4	85	85	85	85	85	85	85	85	85	85	85	85	85	85
5	115	115	115	115	115	115	110	110	110	110	110	110	110	110
6	165	165	165	165	165	165	135	135	135	135	135	135	135	135
7	215	215	215	215	215	215	165	165	165	165	165	160	160	160
8	265	265	265	265	265	265	215	215	215	215	215	185	185	185
9	315	315	315	315	315	315	265	265	265	265	265	215	210	210
10	365	365	365	365	365	365	315	315	315	315	315	265	235	235
11	435	435	435	435	435	415	365	365	365	365	365	315	265	265
12	535	535	535	535	535	465	415	415	415	415	415	365	315	315
13	635	635	635	635	635	535	465	465	465	465	465	415	365	365
14	735	735	735	735	735	635	535	535	535	535	535	465	415	415
15	835	835	835	835	835	735	635	635	635	635	635	535	465	465
16	935	935	935	935	935	835	735	735	735	735	735	635	535	535
17	1035	1035	1035	1035	1035	935	835	835	835	835	835	735	635	635
18	1135	1135	1135	1135	1135	1035	935	935	935	935	935	835	735	735
19	1235	1235	1235	1235	1235	1135	1035	1035	1035	1035	1035	935	835	835
20	1335	1335	1335	1335	1335	1235	1135	1135	1135	1135	1135	1035	935	935
21	1465	1465	1465	1465	1435	1335	1235	1235	1235	1235	1235	1135	1035	1035
22	1665	1665	1665	1665	1535	1435	1335	1335	1335	1335	1335	1235	1135	1135
23	1865	1865	1865	1865	1665	1535	1435	1435	1435	1435	1435	1335	1235	1235
24	2085	2085	2085	2085	1865	1665	1535	1535	1535	1535	1535	1435	1335	1335
25	2335	2335	2335	2335	2085	1865	1665	1635	1635	1635	1635	1535	1435	1435
26	2585	2585	2585	2585	2335	2085	1865	1735	1735	1735	1735	1635	1535	1535
27	2835	2835	2835	2835	2585	2335	2085	1865	1865	1865	1865	1735	1635	1635
28	3100	3100	3100	3100	2835	2585	2335	2085	2085	2065	2065	1865	1735	1735
29	3400	3400	3400	3400	3100	2835	2585	2335	2335	2265	2265	2065	1865	1835
30	3735	3700	3700	3700	3400	3100	2835	2585	2585	2465	2465	2265	2065	1935
31	4135	4035	4000	4000	3700	3400	3100	2835	2835	2665	2665	2465	2265	2065
32	4535	4435	4300	4300	4000	3700	3400	3100	3085	2865	2865	2665	2465	2265
33	4935	4835	4635	4600	4300	4000	3700	3400	3335	3100	3065	2865	2665	2465
34	5335	5235	5035	4900	4600	4300	4000	3700	3585	3400	3265	3065	2865	2665
35	split spacing with bottle above													
36	8 to 10 meters above the bottom													

Graduate Student Experience at Sea

The National Science Foundation grant which supports the chief scientist's and co-chief scientist's participation also includes support for graduate students to participate at sea. At least two students work on the physical oceanography team on each cruise, and any savings from other program expenses are used to support up to two additional students, berths and other considerations allowing. Plus one graduate student is supported to work with the CFC group at sea. We had five students from this program on the I5 cruise. Below are short statements and a photo from each.

Sarah Purkey, University of Washington:

"Going to sea is always an enjoyable and educational experience for me, and I5 has been no exception. It is more satisfying to work with data that you helped to collect. In my graduate studies, I have worked primarily with data from CLIVAR/CO2 repeats of WOCE section, and the data collected on this trip will certainly be an important contribution to my future research. I have enjoyed comparing the water properties of this cruise to previous occupations of I5 as we made our way across the Indian Ocean. My area of research is temperature changes in the abyss, so seeing basin wide temperature trends compared to those of previous occupations was particularly exciting. While this wasn't my first cruise, it



was my first cruise in the subtropics and my first cruise on the Revelle. I quickly learned the perks of not being in the Southern Ocean and took full advantage of the seemingly endless good weather. The crew of the Revelle, especially the cooks, have also made this trip especially easy. One of my favorite parts of going to sea is meeting new people, and it is an excellent opportunity to get to know faculty and other students outside of the classroom environment."

Kelly Kearney

My current research focuses on modeling oceanic food webs, so I have spent my three years as a graduate student in front of a computer. However, I missed the hands-on experience of going to sea (I had several months worth of sea time from a previous job with the Navy), and was curious about the methods used to collect the biogeochemical data I use in my models, so I applied to work on one of the CLIVAR cruises.

Overall, I've had a great time on this cruise. As part of the CTD team, I helped with launching and recovering the CTD out on deck, monitoring the decent and ascent of the CTD in the lab, and sampling the nutrients and salts. Although tedious, there's a feeling of accomplishment that comes with the repetitive process, knowing how valuable well-measured datasets like this one can be to countless researchers. I also had a chance to step outside my area of expertise and do some research with the co-chief scientist, Greg Johnson, based on the CTD data we were collecting, analyzing some of the changes in temperature and salinity and their contribution to density compared to previous cruises in the same area. This short project allowed me to learn a bit more about the water mass properties of the Indian Ocean and brush up my physical oceanography. We have written a draft of the analysis that will be submitted for publication shortly; it was pretty rewarding to see work move so quickly from data gathering to an article draft. Finally, I enjoyed getting to know the other members of both the scientific party and the crew; it was a very diverse group, both in research focus and personality, and I hope I will run into many of them at conferences and such in the future.

Alison Rogers (University of Washington)

My participation in the I05 cruise has been one of the highlights of my graduate education thus far. Although, at 55 days at sea, this cruise was quite long, it served as a wonderful introduction to the fieldwork side of oceanography. As a CTD watchstander, I was involved in all aspects of the CTD casts, including cocking the 36 Niskin bottles, helping on deck to deploy and recover the rosette, operating the computer console and tripping the bottles, drawing nutrient and salt samples, and monitoring the sampling as "sample cop". I also helped to deploy a number of autonomous profiling floats that are part of the Argo program.

This experience has been beneficial in several ways. I have gained in-depth knowledge of how high-quality hydrographic data are collected. Since I use these datasets in my research, it is very helpful to have an understanding of the practical aspects involved in their generation, as well as the time and effort that are required. My research primarily involves data collected by the Argo global array of floats, and thus deploying some of these instruments has been a valuable experience. After 195 stations across the southern Indian Ocean, I have learned about the water properties and currents of this part of the ocean, knowledge which will serve me well as I extend my research to this region. Lastly, I have benefited immensely from my experiences working at sea as a part of a team and from my interactions with all of the scientists on board.

Caitlin Whalen (headed to UCSD/SIO)

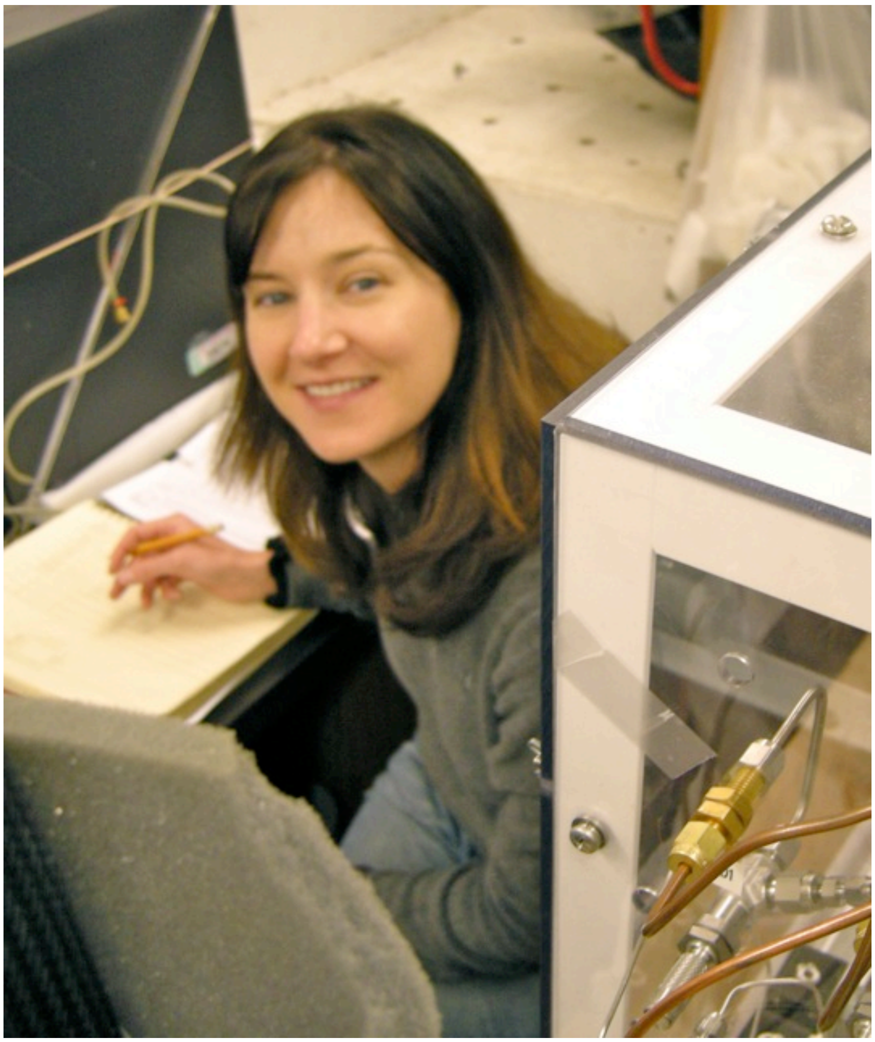
Shock was the typical response whenever I mentioned my participation on the I5 cruise with 57 days of scheduled time at sea. "57 days!" I would often hear, "you know that's quite a long time, right?" The accumulation of shocked looks, however, failed to deter me from participation, and I shortly found myself at sea as a CTD watchstander.

I thankfully did not encounter anything during the duration of the cruise that would merit the these reactions. While the monotonous work most certainly breeds boredom, I found that this ailment is easily mitigated by a healthy dose of creativity. This simple cure was triggered argo float boxes to morph into zombie coffins, and picket lines to materialize around the rosette during sampling.

I originally hoped to not just to survive being at sea for 57 days, but for a hands-on introduction to oceanography since I have not yet begun my graduate studies. This goal was certainly realized. I assisted with watch-standing, sampling, and rosette work while learning basic oceanography concepts. I also worked on a data analysis project considering changes in temperature and salinity using the data we were collecting combined with historical data. Additionally I was able to observe how each water sample is dealt with by an army of chemical analysts. What I didn't predict was the benefit of being introduced to these facets of oceanography in parallel. I will enter my first year of graduate study, not traumatized from my 57 days, but with an appreciation for the larger picture.

Erin Shields (UCSD/SIO)

Before setting off on this cruise, I didn't know if I would end up with a lifelong addiction or never want to see a ship again. I'm happy to report that, even after a maiden voyage of a mere 54 days, I would be all too happy to sail again. The hours are long and the work can feel repetitive,
but I was never bored. There was such a variety of people to get to know, wildlife to see, sunrises and meteor showers to enjoy, that no two days were truly the same. I have been incredibly impressed with the quality (and sheer quantity) of data we managed to collect, and with the amazing attitude of everyone aboard.



My job was to help with CFC sampling, and our lab space was in a van strapped to the fantail. I found myself really enjoying the van on my night shift, because I was just a few steps away from stargazing and sunrises whenever I had a moment. Drawing water samples from the rosette was always entertaining, as we all clustered around 'Rosy' and teased each other about anything and everything. And our cooks have been amazing, which was a huge bonus. I don't think the trip would have been nearly as enjoyable without good food and plentiful snacks.

All in all, it has been an amazing experience. I'm very grateful for the opportunity to participate, and I hope I was able to make a meaningful contribution. It left me inspired, excited, and proud to be a part of this field.

CCHDO Data Processing Notes

Event Date	Person	Date Type	Summary
2009-05-19	Swift, Jim	CTD/BTL/SUM	Data are Public
	Action: Place Online Notes: Data DVD contents from J. Swift on May 19, 2009. These are *most* of the data files from the i05_33RR20090320 cruise except for WOCE formatted CTD files and of course, NetCDF. This tarball contains: 1 Alkalinity Report for Clivar Cruise I.doc 2 I05_1_Hydrographic_DRAFT.pdf 3 I05_3_CFC.pdf 4 I05_6_pH.pdf 5 I05_CTDO_SON_DRAFT.pdf 6 I5_CTD_001_195_ct1.zip 7 I5_cruise_summary.doc 8 i5.sea.txt 9 i5.sum.txt 10 i5_hy1.csv		
2009-05-29	Swift, Jim	CTD/BTL/SUM	PRELIMINARY data online
	Changes will be forthcoming: (1) the WHP-Exchange bottle data file will soon be updated to include the PI contact and data citation information, and (2) the preliminary documentation file is currently being modified to more closely fit the CCHDO standard. The CTDO, salinity, oxygen, and nutrient data are very close to final form and are likely suitable as is for research purposes. As is always the case, the shipboard ocean carbon parameter data (TCARBN, TALK, pH) now on line must be considered strictly preliminary. These data will be examined by Alex Kozyr at CDIAC, and he and the carbon PIs will later (6-12 months from now?) provide an updated file to the CCHDO to replace the present ocean carbon parameter data. It is very strongly urged that any research use of the shipboard ocean carbon parameters include close collaboration with the data originators (Feely, Wanninkhof, and Dickson). The present CFC (F-11 and F-12) and SF6 data are preliminary and subject to update (within a year?), and should be used for research purposes only in close collaboration with the data originators (Bullister and Warner).		
2009-06-01	Schatzman,	CTD	NetCDF format resubmission
	Name: schatzman Institute: odf Country: usa Expo: 33RR20090320 Line: i5 Date: 2009-03-20 Action: Place Online Notes: resubmit NetCDF data		
2009-06-01	Diggs, Steve	Cruise Report	PDF doc current, more complete
	Action: new PDF documentation file from J. Kappa		
2009-06-01	Diggs, Steve	CTD/BTL	Data Citations in Exchange files added
	Action: data citations added to hy1 and ct1.zip files		

CCHDO Data Processing Notes

Event Date	Person	Date Type	Summary
2009-05-19	Swift, Jim	CTD/BTL/SUM	Data are Public

Action: Place Online

Notes: Data DVD contents from J. Swift on May 19, 2009. These are *most* of the data files from the i05_33RR20090320 cruise except for WOCE formatted CTD files and of course, NetCDF.

This tarball contains:

1 Alkalinity Report for Clivar Cruise I.doc
2 I05_1_Hydrographic_DRAFT.pdf
3 I05_3_CFC.pdf
4 I05_6_pH.pdf
5 I05_CTDO_SON_DRAFT.pdf
6 I5_CTD_001_195_ct1.zip
7 I5_cruise_summary.doc
8 i5.sea.txt
9 i5.sum.txt
10 i5_hy1.csv

Event Date	Person	Date Type	Summary
2009-05-29	Swift, Jim	CTD/BTL/SUM	PRELIMINARY data online

Changes will be forthcoming:

(1) the WHP-Exchange bottle data file will soon be updated to include the PI contact and data citation information, and

(2) the preliminary documentation file is currently being modified to more closely fit the CCHDO standard.

The CTDO, salinity, oxygen, and nutrient data are very close to final form and are likely suitable as is for research purposes.

As is always the case, the shipboard ocean carbon parameter data (TCARBN, TALK, pH) now on line must be considered strictly preliminary. These data will be examined by Alex Kozyr at CDIAC, and he and the carbon PIs will later (6-12 months from now?) provide an updated file to the CCHDO to replace the present ocean carbon parameter data. It is very strongly urged that any research use of the shipboard ocean carbon parameters include close collaboration with the data originators (Feely, Wanninkhof, and Dickson).

The present CFC (F-11 and F-12) and SF6 data are preliminary and subject to update (within a year?), and should be used for research purposes only in close collaboration with the data originators (Bullister and Warner).

Event Date	Person	Date Type	Summary
2009-06-01	Schatzman	CTD	NetCDF format resubmission

Name: schatzman
Institute: odf
Country: usa
Expo: 33RR20090320 Line: i5
Date: 2009-03-20
Action: Place Online
Notes: resubmit NetCDF data

Event Date	Person	Date Type	Summary
2009-06-01	Diggs, Steve	Cruise Report	PDF doc current, more complete

Action: new PDF documentation file from J. Kappa

Event Date	Person	Date Type	Summary
2009-06-01	Diggs, Steve	CTD/BTL	Data Citations in Exchange files added

Action: data citations added to hy1 and ct1.zip files

CCHDO Data Processing Notes

<table>
<tr><th>Event Date</th><th>Person</th><th>Date Type</th><th>Summary</th></tr>
<tr><td>2009-06-12</td><td>Kappa, Jerry</td><td>Cruise Report</td><td>Website Updated; text file online</td></tr>
<tr><td></td><td colspan="3">Both the PDF and text versions of the complete cruise report are now online.</td></tr>
<tr><td>2009-06-17</td><td>Kappa, Jerry</td><td>Cruise Report</td><td>Website Updated; Added ADCP report</td></tr>
<tr><td>2009-07-12</td><td>Talley, Dr. Lynne</td><td>NUTs</td><td>Update Needed; Stns. 193-195 missing NUTs</td></tr>
<tr><td></td><td colspan="3">Looking at the version of the I5 bottle data that is online at the WHPO, there are no nutrient data for stations 193, 194, 195. Based on the sum file, this is accurate for 195, but the sum file indicates that there should be nutrient data for 193 and 194, also CFC, carbon, etc etc. It looks like only salts and oxygens were merged for those stations.</td></tr>
<tr><td>2009-07-16</td><td>Schatzman,</td><td>CTD</td><td>Submitted; Quality code updates</td></tr>
<tr><td></td><td colspan="3">Quality code updates made to station 102 cast 02.</td></tr>
<tr><td>2009-07-27</td><td>Schatzman</td><td>BTL</td><td>Submitted; Ready to go online</td></tr>
<tr><td></td><td colspan="3">Place Online. Previous submissions from J.Swift did not have the complete bottle data set which included end of cruise data set.</td></tr>
<tr><td>2009-07-29</td><td>Schatzman</td><td>CTD</td><td>Submitted; updated quality coding</td></tr>
<tr><td></td><td colspan="3">Place Online. CTD WHP exchange data in the WOSE format. This data has updated quality coding.</td></tr>
<tr><td>2009-08-10</td><td>Schatzman</td><td>BTL</td><td>Submitted; updates depths & alk data</td></tr>
<tr><td></td><td colspan="3">This file should replace existing hy1 file with missing depths and alkalinity data.</td></tr>
<tr><td>2009-11-03</td><td>Schatzman</td><td>CTD</td><td>Submitted; Data Updates</td></tr>
<tr><td></td><td colspan="3">Updated transmissometer and fluorometer quality codes for all CTD station casts.</td></tr>
<tr><td>2009-11-03</td><td>Schatzma</td><td>O2/NUTs/Thio</td><td>Submitted; Data Updates</td></tr>
<tr><td></td><td colspan="3">Updates made to the following bottle data:

O2, Thio normality smoothing applied to stations 166-195.
Additional evaluations applied to the following nutrient sample stations.
Comments in third column.
4401 1 ??? Sta 45 instead
6901 2 "new pump tubes, sw-dw low, correct end po4 baseline for jump at end of run"
7001 1 "sw-dw low, adjust baselines down and recalc"
7102 "adjust N+N, po4 end baselines for jumps after reagents added, adjust po4 baselines for low sw-dw"
7201 1 ??? Not seen sta 07102?
7401 2 "std-sw values possibly low, reprocess with avg factors from the previous run"
7701 2 reprocess ignoring last dw
7801 1 end std-dw high use beginning factor for begin and end
7901 1 reprocess ignoring 3rd std at end
8001 2 std-sw low use avg factor from 08102
10001 1 std-sw possibly too high/new pump tubes reprocess using avg factor from 10101
10501 2 reprocessed ignore last dw
13701 1 end std-sw high use beginning factor
14502 2 std-sw low use avg factor from 14401
14601 2 beginning std-sw low use end factor
15101 1 use beginning factor
15901 1 std-sw high use avg factor from 15801
16601 2 ignore 2nd sw at end of run
16801 1 ignore 2nd std at end of run</td></tr>
</table>

CCHDO Data Processing Notes

Event Date	Person	Date Type	Summary
2009-12-10	*Bullister, John*	CFCs	Submitted; To replace older data set
	Please replace all shipboard CFC-11, CFC-12 and SF6 data values and flags with these data		
2010-01-05	*Kozyr, Alex*	DOC/TDN	Submitted To go Online
	Action: Merge Data, Place Online Notes: The final and public DOC and TDN data from Dennis Hansell/RSMAS.		