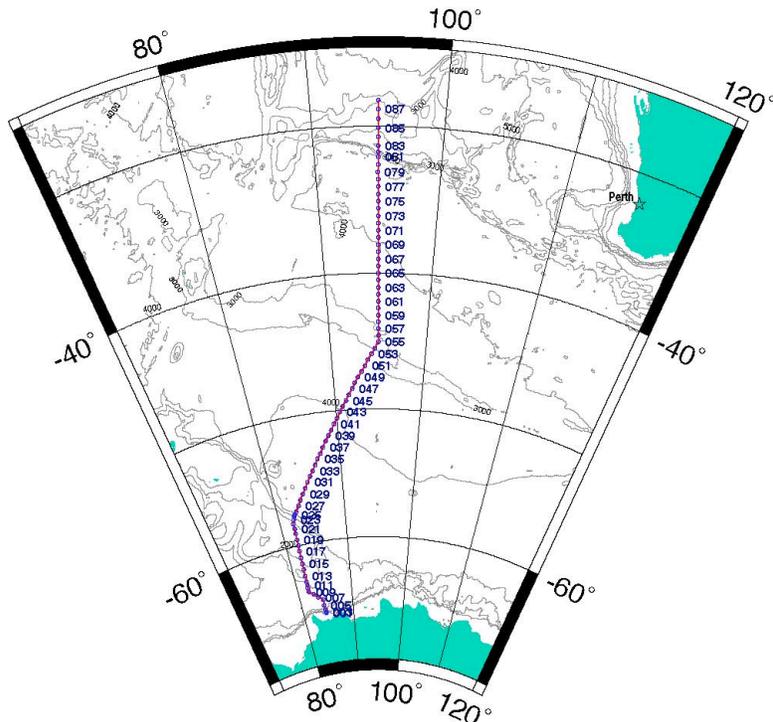


Cruise report: I08S_2007
(Updated MAY 2007)



A. Highlights

A.1. Cruise Summary Information

WOCE section designation	I08S_2007	
Expedition designation (ExpoCodes)	33RR20070204	
Chief Scientist	Dr. James H. Swift / SIO	
Co-chief Scientist	Dr. Annie Wong	
Dates	4 FEB 2007 - 17 MAR 2007	
Ship	<i>R/V Revelle</i>	
Ports of call	Dunedin, NewZealand - Fremantle, Australia	
Station geographic boundaries	84.5501	-28.318 95.0084 -65.8108
Stations	88	
Floats and drifters deployed	14 ARGO Floats Deployed	
Moorings deployed or recovered	0	

Chief Scientists:

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Cruise and Data Information

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

Cruise Summary Information	Hydrographic Measurements
Description of Scientific Program	CTD Data:
Geographic Boundaries	Acquisition
Cruise Track (Figure): PI CCHDO	Processing
Description of Stations	Calibration
Description of Parameters Sampled	Salinities
Bottle Depth Distributions (Figure)	Oxygens
Floats and Drifters Deployed	Bottle Data
Moorings Deployed or Recovered	Oxygen
Principal Investigators	Nutrients
Cruise Participants	Carbon System Parameters
Problems and Goals Not Achieved	Helium / Tritium
Other Incidents of Note	Radiocarbon
Underway Data Information	References
Navigation Bathymetry	
Acoustic Doppler Current Profiler (ADCP)	
Thermosalinograph	
XBT and/or XCTD	
Meteorological Observations	Acknowledgments
Atmospheric Chemistry Data	
Data Processing Notes	

Summary

A hydrographic survey consisting of LADCP/CTD/rosette sections, bio-optical casts, trace metals rosette sections, underway shipboard ADCP, float deployments in the southern Indian Ocean was carried out in February and March 2007. The R/V Revelle departed Dunedin, New Zealand on 4 February 2007. A total of 88 stations were occupied. 88 LADCP/CTD/Rosette casts, 39 Trace Metals Rosette casts, 25 bio-optical casts were made, and 14 ARGO floats were deployed from 15 February to 14 March. Water samples (up to 36) and CTD data were collected on each LADCP/CTD/rosette cast in most cases to within 10-20 meters of the bottom. Salinity, dissolved oxygen and nutrient samples were analyzed for up to 36 water samples from each cast of the principal LADCP/CTD/rosette program. Water samples were also measured for Total DIC, Total Alkalinity, CFCs and CDOM, and samples were collected for DOC, POC, Helium/Tritium, and C13. Underway surface pCO₂, temperature, conductivity, dissolved oxygen, fluorometer, meteorological and multibeam acoustical bathymetric measurements were made. The cruise ended in Fremantle, Australia on 17 March 2007.

Chief and Co-Chief Scientist's Report

R/V Roger Revelle Expedition KNOX03RR
US CLIVAR I8S: 65° 48.6' S, 84° 33.0' E – 28° 19.1' S, 95° 0.05' E
4 February - 17 March 2007
Port Calls: Dunedin, New Zealand, to Fremantle, Australia

James H. Swift, chief scientist
Annie Wong, co-chief scientist

Officers and Crew

Name	Position
David Murline	Captain
Paul Mauricio	Chief Engineer
Robert Widdrington	1st Mate
Joe Ferris	2nd Mate
Favi Lochananonda	3rd Mate
Jack Healy	1st A/E
Michael Breen	2nd A/E
Ernie Juhasz	3rd A/E
Dax McTaggart	Senior Cook
Paul Porcincula	Cook
James Pearson	Boatswain
Mark Johnson	Electrician
Shon Bowden	A/B
Gary Curry	A/B
George Kennedy	A/B
Sean Mix	Oiler
Andrew Carter	Oiler
Phil Hogan	Oiler
Matthew Slater	Oiler
Buddy Carron	Wiper
Joe Martino	OS

Science Programs and Science Team Leaders

CTDO/rosette/S/O2/nutrients/data processing

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CO2 (DIC and underway pCO2)

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Robert Key, Princeton (key@Princeton.EDU)

CFCs

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He/Tr

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

ARGO floats

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Aerosols

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

Narrative

We carried out Leg 1 of the R/V Roger Revelle "KNOX03RR" expedition for the US Global Ocean Carbon and Repeat Hydrography Program (contributions to both CLIVAR and IOCCP). The leg, from Dunedin, New Zealand, to Fremantle, Australia, was a repeat of the WOCE line I8S, last carried out aboard R/V Knorr during December 1994.

Loading commenced in Dunedin, New Zealand, on 31 January 2007. The ship was left in fine condition by the previous science group. Loading went smoothly, and a good relationship between science team and crew was already building. We loaded three lab vans, cargo from three other containers, plus numerous other shipments. SIO Shipboard Technical Support gets special kudos for providing four Resident Technicians to assist during loading - all of whom were friendly and helpful, not to mention very busy. Chief Engineer Paul Mauricio and his team cheerfully set to work fixing the trace metal winch, which had been damaged in shipping. After a "happy hour" for all hands at the Speight's brew pub, on Saturday evening, the ship left the dock Sunday, 04 February 2007, at 1606 local time in good weather, Captain Dave Murline in command.

The plan was to complete the first occupation of Indian Ocean transects for the US Global Ocean Carbon and Repeat Hydrography program, which contributes to both the CLIVAR Repeat Hydrography project and the International Ocean Carbon Coordination Project via decadal reoccupations of selected high-priority WOCE Hydrographic Program transects. The science program followed or improved on the WOCE protocols, with enhanced measurements of ocean carbon parameters in particular, plus a trace metal sampling program. Sampling and analytical work for temperature, salinity, dissolved oxygen, nutrients, a host of carbon-related parameters, CFCs, helium, tritium, radiocarbon, trace metals, and velocity were planned from surface-to-bottom at ca. 50 km intervals along ca. 95°E from Antarctica to Bangladesh, along with acquisition of data from a number of underway sampling systems, plus deployment of Argo floats.

The cruise began with a long steam to the first station, located in one of the most remote reaches of the World Ocean, with the goal of carrying out the first station on the intended track as close to Antarctica as ice, weather, and the captain would permit. We headed southwest across the 40s and 50s, making most westward progress south of 60°S, south of the strongest headwinds, swell, and opposing currents. A further benefit was some westward currents and occasional following seas. Hence we arrived somewhat ahead of schedule in the region where we hoped to make our close approach to Antarctica. To approach the continental shelf break we required (1) working near the time of the local annual sea ice minimum (provided thanks to the ship schedulers), (2) useful satellite ice edge imagery and analyses (kindly provided for us real time by the Navy/NOAA Joint Ice Center), (3) navigational expertise (no problem with Captain Murline and his bridge staff in charge), and (4) a truly significant dose of good luck.

We had been out of satellite communications (including email) for a few days, partly due to not being able to aim the ship's antenna low enough on the horizon to see geostationary satellites, and partly because SIO had to put together, ashore and at sea, the technical and business pieces to effect a transfer to an Indian Ocean satellite as we left behind the footprint of the Pacific one. But just when we needed the connection to receive ice images, the satellite connection was reestablished, and updated ice images arrived. One of the SIO grad students along, JJ Becker, works with SIO's Dave Sandwell, an expert in teasing out ocean bathymetry from satellite data. JJ had along on his computer the latest bottom depth information. Combined with the ice edge information, plus our operational limits, this influenced our plan to approach along 84 degrees, 35 minutes east longitude, in the western Davis Sea. It turned out to be a good choice, and in hindsight perhaps was the only one which would have worked: As we proceeded south, the bottom beneath us rose, but meanwhile the ice was getting closer. Just when Captain Murline said "no further" the real-time bathymetry data showed that we'd reached our goal of the 500 meter isobath.

We lowered our instruments there for our first station, the late day sun illuminating the sea ice, with icebergs all about, in an embayment of open water, killer whales patrolling the ice edge for seals and penguins, seals on the ice not inclined to join them, soon into sunset with an aurora above. Through the cold 25°F night we completed our 500 meter station, then the 1200 meter station offshore of that, then the 2000 meter station, and so on, being chased north by encroaching ice, yet in the process completing a rare Antarctic shelf-slope-basin transect from a non-ice-strengthened ship.

We were not yet through our encounters with sea ice. The ice images showed a tongue of sea ice spreading eastward from an nearby ice shelf, nearly across our planned path out from the Davis Sea to the 1994 I8S line. Sure enough, on the way to station 7 and 8, sea ice provided an exciting moment, with parades of icebergs and myriad growlers about, causing a small detour.

Three LADCPs were brought on the cruise, two newer 300kHz "workhorse" models (usually used in pairs), and one older "broadband" 150kHz instrument. Testing uncovered problems with the originally intended LADCP pair, and there were also some data issues with the back-up unit. The 300kHz instruments typically only perform well in regions of high scattering (e.g. high latitudes, due to higher productivity overall) so the plan was to use the 300kHz instruments for most of the first leg, and switch to the 150kHz instrument when scattering levels dropped in the desert-like subtropical gyre. One of the 300kHz instruments was an experimental model with higher power and was to be field-tested during this cruise. That instrument was rendered moot until its bulkhead connector can be replaced (in Fremantle). The remaining (more typical) 300kHz instrument was used successfully until it started returning casts with incomplete data. The cause was unknown. We switched to the 150kHz instrument for the duration of the cruise. It was heavier than the 300kHz instrument, and its extra weight may have helped the rosette sink better, too.

During some CTD casts early in the cruise very slow descent rates were needed to 1000-1500m because wire tension was very low, even in moderate to low sea states. Since the rosette weighs ca. 1100 lbs. in air, the reluctance to sink was puzzling. Focus gradually centered on the Reville's new CTD cable, which seemed to have a propensity to develop kinks under roll and load conditions which seemed significantly less severe than experienced, with fewer problems, on some other similar cruises. Admittedly, we were working our way north through the 50s, a tough area to work with a large rosette. Still, our battle with cable kinks was perplexing because two years earlier we carried out a similar Southern Ocean transect (in the Pacific Ocean sector) from this ship with virtually the same equipment, and under occasionally trying sea conditions, but with few cable kink problems. A working solution was elusive. Finally we switched our rosette from the new CTD cable installed for this trip to the older CTD cable on the second winch, the cable used during the 2005 P16S cruise. After that switch, CTD casts were completed without problems. It thus seems plausible that the new cable had from its manufacture some intrinsic characteristic incompatible with our rosette operations in swell. We did not know this with certainty, of course.

Late in the cruise we dealt with odd behavior from both the primary and back-up transmissometers. This was finally tracked to a coincidence of faults in two cables, not the instruments.

The rosette used on this cruise utilized Niskin-type "Bullister" bottles which delivered 10.4 liters of samples, up from 9-liters with the previous generation of ODF "Bullister" bottles. We found that it was possible to sample nearly all samples from a single bottle, except for the occasional 4-liter POC samples.

In addition to the usual cast of officers, crew, researchers, and graduate students, we had a three-person public outreach team along. In delving into the grit of oceanographic fieldwork, they hoped to improve public understanding regarding how data that reflect the changing state of climate are collected. They plan to produce a website, several articles, and multimedia features. Their role on the ship was purposefully nebulous, something of a hybrid between research assistants and a media crew. We integrated them into the science team by assigning them tasks that were, in their words, "difficult to ruin".

Their project continues to evolve based on the materials they gather and the opportunities that arise. They shadowed the scientists and shipboard technicians on their daily rounds, and were busy turning interviews into short articles and film clips about our research. Captain Murline helped considerably regarding coordinating the part of their work that provides a sense of the foundational support needed to run a cruise.

We arrived dockside in Fremantle, Australia, the morning of 17 March, having completed not only all of the I8S line, with extension to the Antarctic continental shelf break, but also a few of the next leg's stations on the northern end. The plan was for the ship to stay in Fremantle for about five days, then head back out to 95°E to resume northward on Leg 2 (called "I9N"), with Dr. Janet Sprintall (SIO) as chief scientist. A handful of hardy souls in the I8S science team stayed on for Leg 2, and of course most of the mariners of R/V Roger Revelle remained aboard. The I8S team enjoyed the satisfaction of a job Very Well Done. Officers, crew, science team - it was as strong and harmonious a ship's company one can ever experience.

CLIVAR I08S

R/V Revelle, KNOX03RR

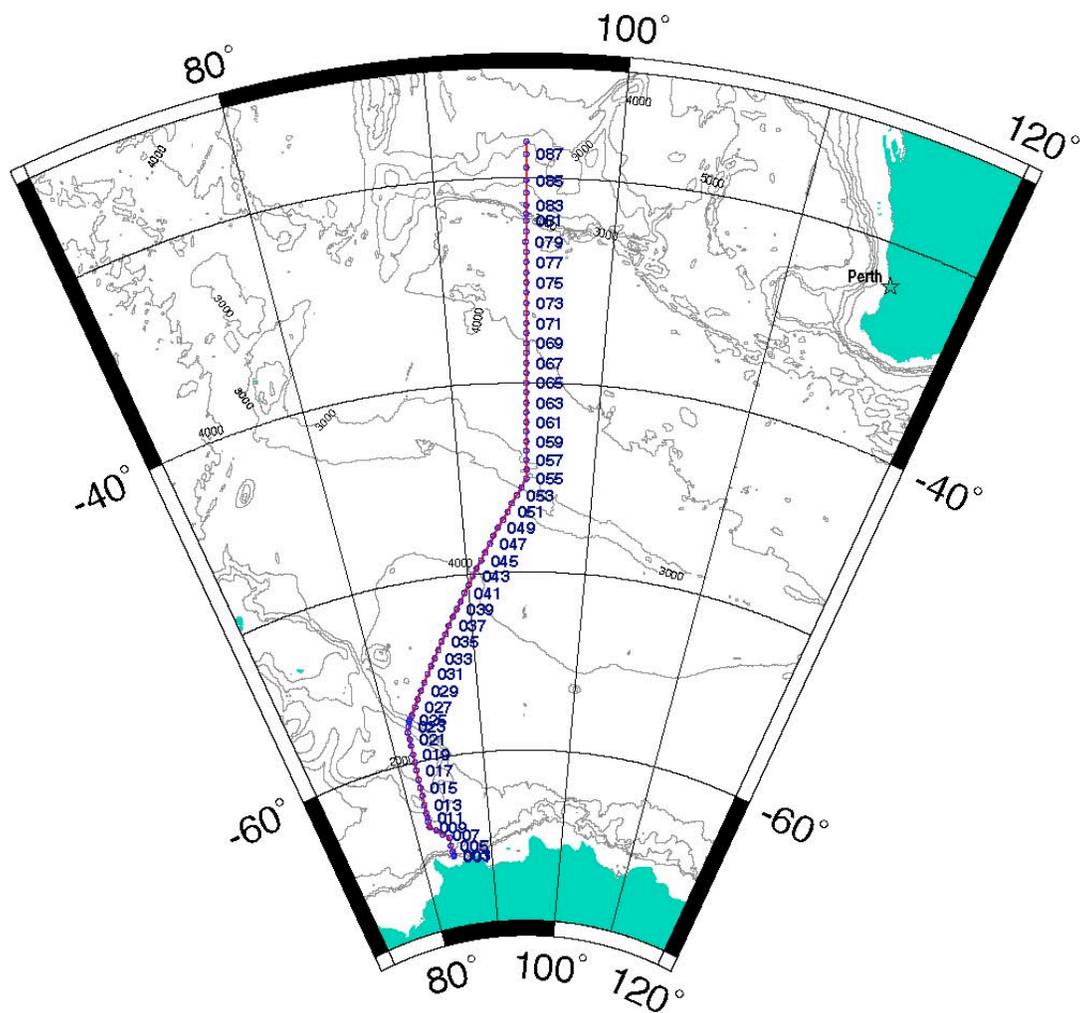
4 February 2007 - 17 March 2007

Dunedin, New Zealand - Fremantle, Australia

Chief Scientist: Dr. James H. Swift

University of California, San Diego, Scripps Institution of Oceanography

Co-Chief Scientist: Dr. Annie Wong



Preliminary Cruise Report 15 March 2007

Data Submitted by:

Shipboard Technical Support/Oceanographic Data Facility
Scripps Institution of Oceanography
La Jolla, Ca. 92093-0214

Introduction

A sea-going science team gathered from 8 oceanographic institutions participated on the cruise. Several other science programs were supported with no dedicated cruise participant. 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	Annie Wong	UW	awong@ocean.washington.edu
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Salinity/Deck	Chad Klinesteker	USCG for UCSD/SIO/STS	cklinesteker@uscg.mil
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CTD Watchstander	David Ullman	U of Wisconsin	ullman@wisc.edu
CTD/LADCP Watchstander	Lora VanUffelen	UCSD	lvanuffe@ucsd.edu
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CFC	Eric Wisegarver	NOAA/PMEL	Eric.Wisegarver@noaa.gov
CFC	David Cooper	NOAA/PMEL and LDEO	fееce@critter.net
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CDOM	Dave Menzies	UCSB	davem@icess.ucsd.edu
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PCO2	Robert Castle	NOAA/PMEL	Robert.Castle.noaa.gov
TALK	George Anderson	UCSD/SIO	ganderson@ucsd.edu
TALK	Susan Alford	UCSD/SIO	sealford@ucsd.edu
TM	Chris Measures	UH	chrism@soest.hawaii.edu
TM	Amir Hamidian	Otago	ahamidian@chemistry.otago.ac.nz
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TM	Cliff Buck	FSU	cbuck@ocean.fsu.edu
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Resident Tech	Gene Pillard	UCSD/SIO/STS	restech@rv-revelle.ucsd.edu
Outreach	Pien Huang	Outreach	pien.huang@gmail.com
Outreach	Cassandra Lopez	RSMAS	CassandraSLopez@gmail.com
Outreach	Daniel Park	Outreach	park.dan@gmail.com

Scientific Personnel I8S

Description of Measurement Techniques

1. CTD/Hydrographic Measurements Program

The basic CTD/hydrographic measurements consisted of salinity, dissolved oxygen and nutrient measurements made from water samples taken on LADCP/CTD/rosette casts, plus pressure, temperature, salinity, dissolved oxygen, transmissometer and fluorometer from CTD profiles. A total of 88 LADCP/CTD/rosette casts were made, usually to within 10-20m of the bottom. No major problems were encountered during the operation. The distribution of samples is illustrated in figures 1.0 and 1.1.

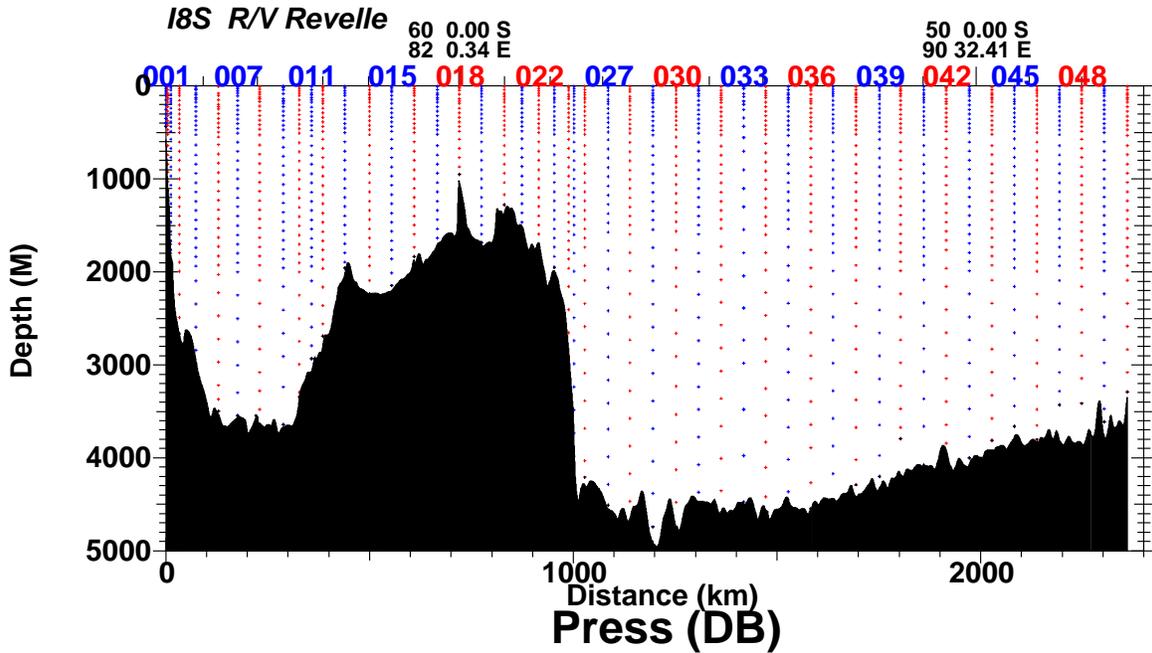


Figure 1.0 Sample distribution, stations 1-50.

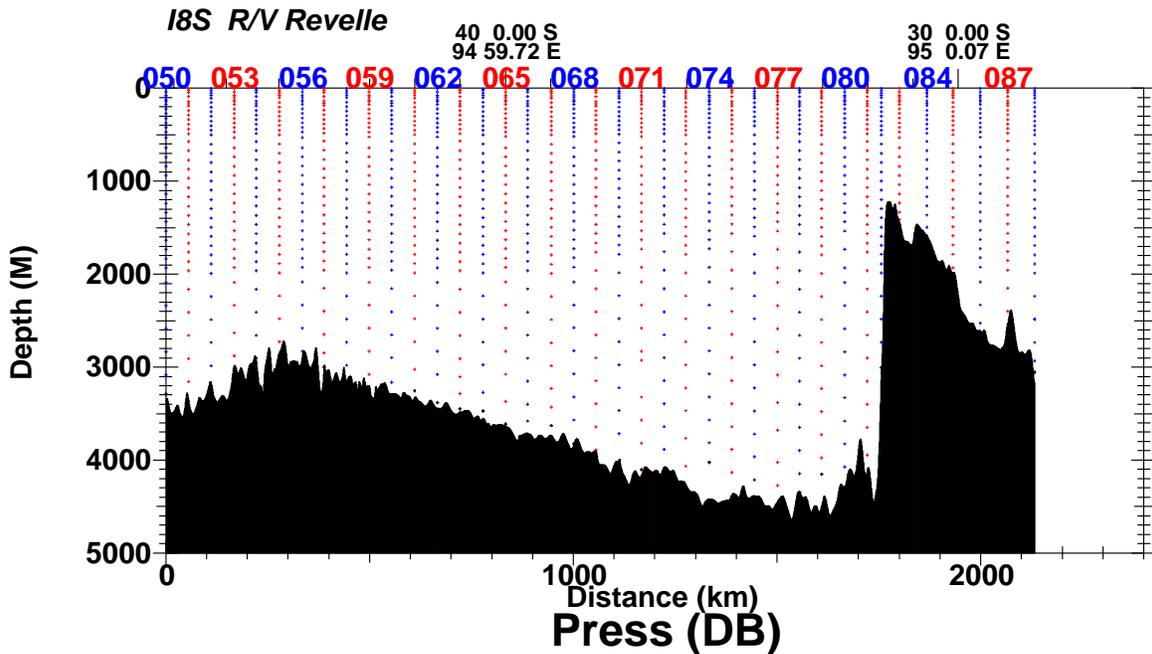


Figure 1.1 Sample distribution, stations 50-88.

1.1. Water Sampling Package

CTD/rosette casts were performed with a package consisting of a 36-bottle rosette frame (SIO/STS), a 36-place carousel (SBE32) and 36 10.5L Bullister bottles (SIO/STS). Underwater electronic components consisted of a Sea-Bird Electronics SBE9plus CTD (SIO/STS #381) with dual pumps, dual temperature (SBE3plus), dual conductivity (SBE4), dissolved oxygen (SBE43), transmissometer (Wetlabs),

fluorometer, 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 SBE4 conductivity, SBE3*plus* temperature and SBE43 Dissolved oxygen sensors and their respective pumps and tubing were mounted vertically as recommended by SBE on a bracket adjacent to the CTD cage. Pump exhausts were attached to the sensor bracket on the side opposite from the sensors and directed downward. The transmissometer and fluorometer were mounted horizontally along the bottom of the rosette frame. The altimeter was mounted on the inside of the bottom frame ring. The RDI LADCP 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.

The rosette system was suspended from a UNOLS-standard three-conductor 0.322" electro-mechanical sea cable. Three sea cable reterminations were made during I8S after casts 31/1, 32/1 and 33/2.

The R/V *Revelle's* aft starboard-side Markey winch was used for casts 1/1-33/2. The forward starboard-side Markey winch was used for all subsequent casts (34/2-88/3). The decision was made to move from the aft Markey winch to the forward one after noticing irregularities in the construction of the aft winch seacable. The forward winch slings were changed after cast 43/1.

The deck watch prepared the rosette 10-15 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 in the computer lab started when directed by the deck watch leader. The rosette was unstrapped from its tiedown location on the cart. Tag lines were threaded through the rosette frame and syringes were removed from the CTD intake ports. The winch operator was directed by the deck watch leader to raise the package, the squirt boom and rosette were extended outboard and the package quickly lowered into the water. The tag lines were removed and the package was lowered to 10 meters, by which time 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 10-20 meters of the bottom, using the altimeter, winch wireout, CTD depth and echosounder depth to determine the distance.

During the up cast the winch operator was directed to stop the winch at each bottle trip depth. The CTD console operator waited 30 seconds before tripping a bottle to insure the package wake had dissipated and the bottles were flushed, then an additional 10 seconds after each bottle closure to insure that stable CTD comparison data had been acquired. Once a bottle had been closed, the deck watch leader was directed to haul in the package to the next bottle stop.

Standard sampling depths were used throughout CLIVAR I8S. These standard depths were staggered every station using 3 sampling schemes.

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. This bottle identification was maintained independently of the bottle position on the rosette, which was used for sample identification. Three bottles were replaced on this leg and various parts of bottles were occasionally changed or repaired.

Routine CTD maintenance included soaking the conductivity and DO 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. O-rings were changed and lanyards repaired as necessary. Bottle maintenance was performed each day to insure proper closure and sealing. Valves were inspected for leaks and repaired or replaced as needed.

1.2. Underwater Electronics Packages

CTD data were collected with a SBE9*plus* CTD (STS/ODF #381). 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.

Sea-Bird SBE32 36-place Carousel Water Sampler	
Sea-Bird SBE9 <i>plus</i> CTD	0381
Paroscientific Digiquartz Pressure Sensor	S/N 58952
Sea-Bird SBE11 <i>plus</i> Deck Unit	
Sea-Bird SBE3 <i>plus</i> Temperature Sensor	S/N 03P-4588 (Primary)
Sea-Bird SBE3 <i>plus</i> Temperature Sensor	S/N 03P-4226 (Secondary)
Sea-Bird SBE4C Conductivity Sensor	S/N 04-3176 (Primary)
Sea-Bird SBE4C Conductivity Sensor	S/N 04-3058 (Secondary)
Sea-Bird SBE43 DO Sensor	S/N 43-1129
Sea-Bird SBE5 Pump	S/N 05-4160 (Primary)
Sea-Bird SBE5 Pump	S/N 05-4377 (Secondary)
Sea-Bird SBE35 Reference Temperature Sensor	S/N 35-0035
Wetlabs CDOM Fluorometer	S/N FLCDRTD-428
Wetlabs CStar Transmissometer	S/N CST-327DR
Wetlabs CStar Transmissometer	S/N CST-490DR
Simrad 807 Altimeter	S/N 4051
RDI LADCPs	

Table 1.2.0 CLIVAR I8S 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 (T1 #03P-4588 and C1 #04-3176) were used for reported CTD temperatures and conductivities on all casts except 50/2, where biofouling had rendered parts of the primary sensor record unusable. The secondary temperature and conductivity sensors were used as calibration checks for all other casts. 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 were acquired at 1-second intervals from the ship's GP90 GPS receiver by a Linux system beginning February 13.

Bathymetric data were logged from the Ship's Simrad EM120 multibeam echosounder system and merged with the navigation time series. These depths were corrected using sound velocity profiles derived from CTD casts.

1.4. CTD Data Acquisition and Rosette Operation

The CTD data acquisition system consisted of an SBE-11*plus* (V2) deck unit and three networked generic PC workstations running CentOS-4.4 Linux. Each PC workstation was configured with a color graphics display, keyboard, trackball and DVD+RW drive. One of the systems also had 8 additional RS-232 ports via a Control Rocketport PCI serial controller. The systems were interconnected through a 1000BaseTX ethernet switch which was also connected to the ship's network. These systems were available for real-time operational and CTD data displays, and provided for CTD and hydrographic data management and backup.

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 I8S. All three systems were used to maintain redundant backups of the data.

CTD deployments were initiated by the console watch after the ship had stopped on station. The watch maintained a console operations log containing a description of each deployment, a record of every attempt to close a bottle and any pertinent comments. The deployment and acquisition software presented a short dialog instructing the operator to turn on the deck unit, 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 would lower it to 10 meters. The CTD sensor pumps were configured with an 8 second startup delay, and were usually on by this time. The console operator checked the CTD data for proper sensor operation, waited an additional 60 seconds for sensors to stabilize, then instructed the winch operator to bring the package to the surface and descend to a 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 the 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 would later be used 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, usually allowing a safe approach to within 10-20 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 at least 30 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 10 seconds after closing bottles to insure that stable CTD data were associated with the trip and to allow the SBE35RT tertiary temperature sensor time to make a measurement.

After the last bottle was closed, the console operator directed the deck watch to bring the rosette on deck. Once 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 LADCP/CTD/Rosette 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 LADCP/CTD/Rosette 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 24hz 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.

Processing was performed after data acquisition for Trace Metals rosette deployments. The raw CTD data and bottle trips acquired by SBE SeaSave on the Windows XP workstation were copied onto the Linux database and web server workstation, then processed to a 0.5 second time series and bottle trip values extracted.

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.

LADCP/CTD/Rosette CTD data were routinely examined for sensor problems, calibration shifts and deployment or operational problems. The primary and secondary temperature sensors (SBE 3) were compared to each other and to the SBE35 temperature sensor. CTD conductivity sensors (SBE 4) were compared and calibrated by examining differences between CTD and check-sample conductivity values. The CTD dissolved oxygen sensor data were calibrated to check-sample data. Additional TS and theta-O₂ comparisons were made 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 and processing problems were encountered during I8S. A clogged bleeder valve in the primary pump circuit led to aborting cast 29/1 at 100M, then redeploying after cleaning the valve. The cast was not renamed. Wire problems (resulting in reterminations) were apparent in the downcasts of 31/1, 32/1 and 33/2 and were filtered out. Slipping problems on 43/1 were evident on the upcast and were filtered out. Biofilm artifacts contaminated the downcasts on 29/1 and 50/2. 29/1 was filtered, the upcast was used for 50/2. The fluorometer endcap covers were left on for 2/1, 3/1 and 4/1. A fluorometer dark cast was made for 12/1. The transmissometer was changed on 69/1, then changed back on 83/1.

A total of 88 casts were made using the 36-place LADCP/CTD rosette, and 39 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 I8S. The calibration dates are listed in table 1.6.0.

Sensor	S/N	Calibration Date	Calibration Facility
Paroscientific Digiquartz Pressure	58952	17-December-06	SIO/ODF
Sea-Bird SBE3plus T1 Temperature	03P-4588	14-December-06	SBE
Sea-Bird SBE3plus T2 Temperature	03P-4226	14-December-06	SBE
Sea-Bird SBE4C C1 Conductivity	04-3176	30-November-06	SBE
Sea-Bird SBE4C C2 Conductivity	04-3058	30-November-06	SBE
Sea-Bird SBE43 Dissolved Oxygen	43-1129	N/A	N/A

Table 1.6.0 CLIVAR I8S CTD sensor laboratory calibrations.

1.7. CTD Shipboard Calibration Procedures

CTD #381 was used for all LADCP/CTD rosette casts on I8S. 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 on all casts except 50/2, the secondary sensors (T2 & C2) serving as calibration checks. The SBE35RT Digital Reversing Thermometer (S/N 3528706-0035) served as an independent calibration check for T1 and T2. *In-situ* salinity and dissolved O₂ check samples collected during each cast were used to calibrate the conductivity and dissolved O₂ sensors.

The variability of the environment that was observed on many of the deployments made sensor and check sample comparisons somewhat problematic. An independent metric of variability was inferred from comparing primary and secondary temperature data. This metric was used to filter check sample comparisons for calibration purposes.

1.7.1. CTD Pressure

The Paroscientific Digiquartz pressure transducer (S/N 58952) was calibrated in December 2006 at the SIO/ODF Calibration Facility. Calibration coefficients derived from the calibration were applied to raw pressures during each cast. Residual pressure offsets (the difference between the first and last submerged pressures) were examined to check for calibration shifts. All were < 0.7db, and the sensor exhibited < 0.3 db offset shift over the period of use. No additional adjustments were made to the calculated pressures.

1.7.2. CTD Temperature

A single primary temperature sensor (T1 SBE 3, S/N 03P-4588) and secondary sensor (T2 SBE 3, S/N 03P-4226) served the entire cruise. Calibration coefficients derived from the pre-cruise calibrations were applied to raw primary and secondary temperatures during each cast.

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 $0.001^{\circ}\text{C}/\text{year}$. The SBE35RT on I8S was set to internally average over approximately one ship roll period (8 seconds). It was located equidistant between T1 and T2 with the sensing element aligned in a plane with the T1 and T2 sensing elements.

Two independent metrics of calibration accuracy were examined. The primary and secondary temperatures were compared at each bottle closure, and the SBE35RT temperatures were compared to primary and secondary temperatures at each bottle closure. These comparisons showed all three temperatures to be within $\pm 0.001^{\circ}\text{C}$ with the SBE35RT between T1 and T2, so T1 and T2 were both corrected to the SBE35RT. No sensor drift was evident and only one sensor (T2) exhibited any secondary responses (to pressure). The residual differences after correction are shown in figures 1.7.2.0 and 1.7.2.1.

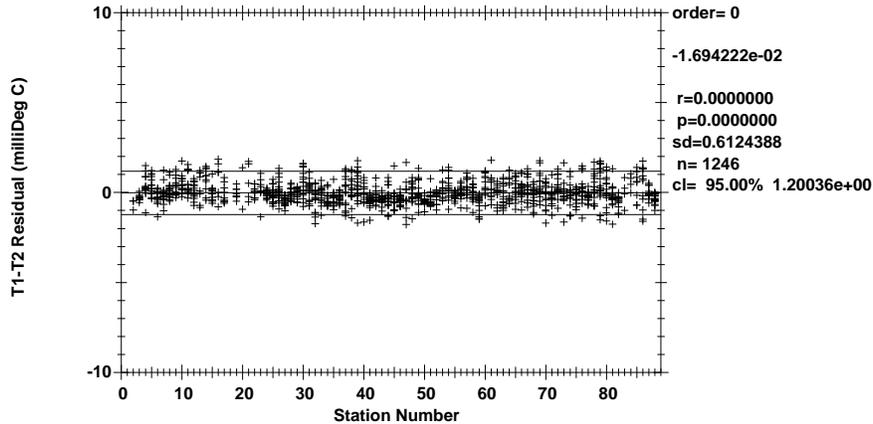


Figure 1.7.2.0 T1-T2 by station (P>1000db).

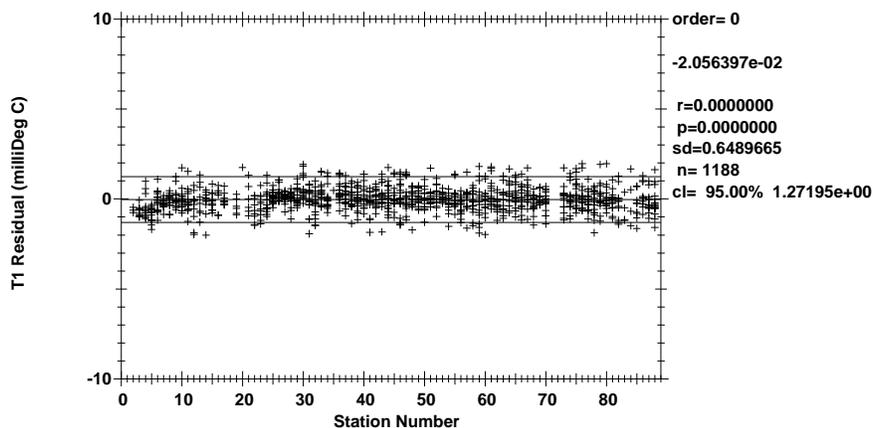


Figure 1.7.2.1 SBE35RT-T1 by station (P>1000db).

1.7.3. CTD Conductivity

A single primary conductivity sensor (SBE 4, S/N 04-3176) and secondary conductivity sensor (SBE 4, S/N 04-3058) served the entire cruise. Conductivity sensor calibration coefficients derived from the pre-cruise calibrations were applied to raw primary and secondary conductivities.

Comparisons between the primary and secondary sensors and between each of the sensors to check sample conductivities (calculated from bottle salinities) were used to derive conductivity corrections. To reduce the contamination of the comparisons by package wake, differences between primary and secondary temperature sensors were used as a metric of variability and used to qualify the comparisons. The coherence of this relationship is illustrated in figure 1.7.3.0.

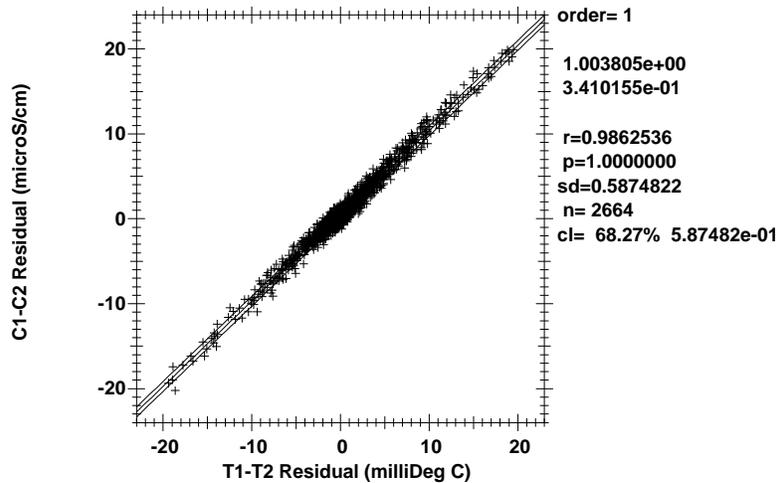


Figure 1.7.3.0 C1-C2 by T1-T2, all points.

One of the sensors (C2) exhibited a secondary pressure response. Otherwise the sensors tracked within ± 0.001 mS/cm the entire cruise exhibiting no drift. The uncorrected comparison between the primary and secondary sensors is shown in figure 1.7.3.1, and between C1 and the bottle conductivities in 1.7.3.2.

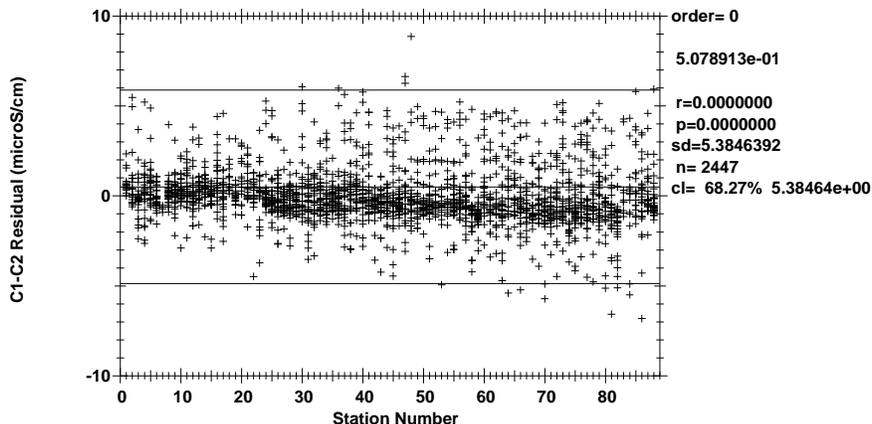


Figure 1.7.3.1 Uncorrected C1 and C2 conductivity differences by cast ($-0.005^{\circ} C \leq T1-T2 \leq 0.005^{\circ} C$).

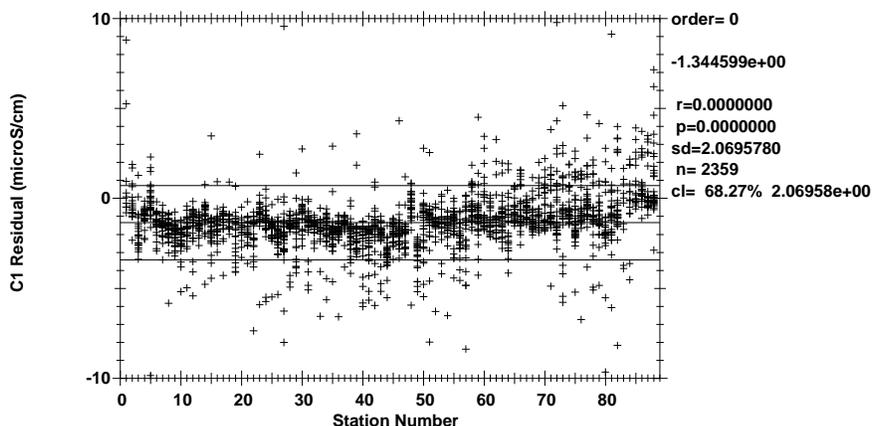


Figure 1.7.3.2 Uncorrected C1 residual differences from bottle conductivities by cast ($-0.005^{\circ} C \leq T1-T2 \leq 0.005^{\circ} C$). The comparison of the primary and secondary conductivity sensors by cast after applying shipboard corrections is summarized in figure 1.7.3.3.

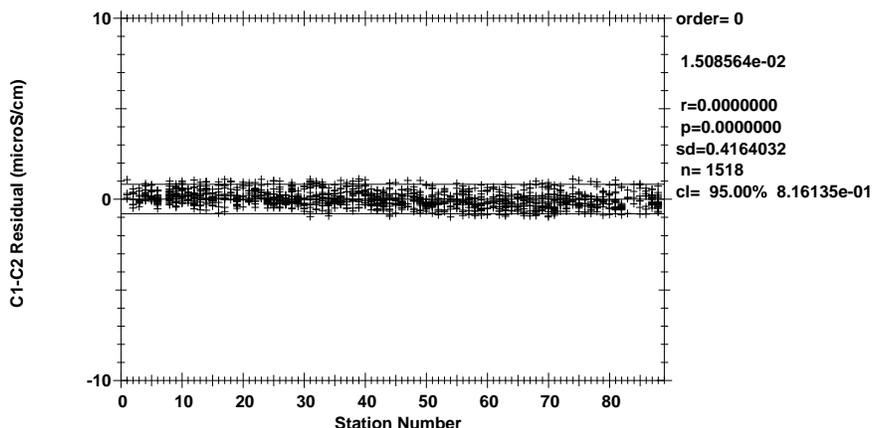


Figure 1.7.3.3 Corrected C1 and C2 conductivity differences by cast ($-0.001^{\circ} C \leq T1-T2 \leq 0.001^{\circ} C$). Salinity residuals after applying shipboard T1/C1 corrections are summarized in figure 1.7.3.4, 1.7.3.5, 1.7.3.6 and 1.7.3.7.

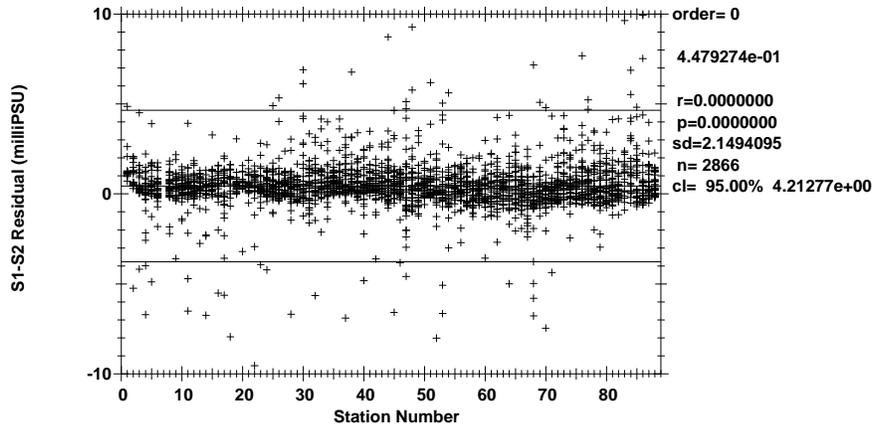


Figure 1.7.3.4 Corrected C1 and C2 salinity differences by cast (P>0db)

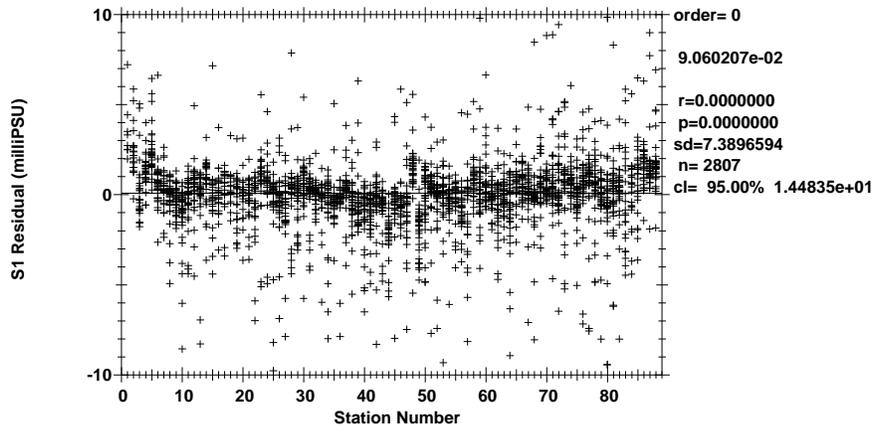


Figure 1.7.3.5 salinity residuals by cast (P>0db).

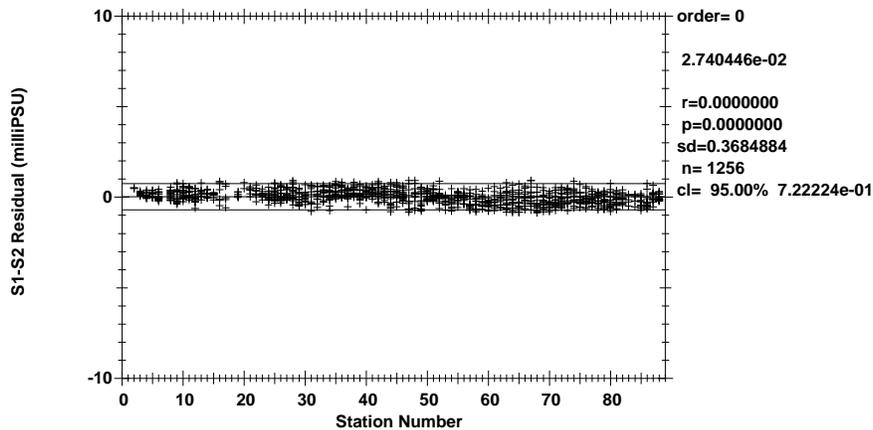


Figure 1.7.3.6 Corrected C1 and C2 salinity differences by cast (P>1000db)

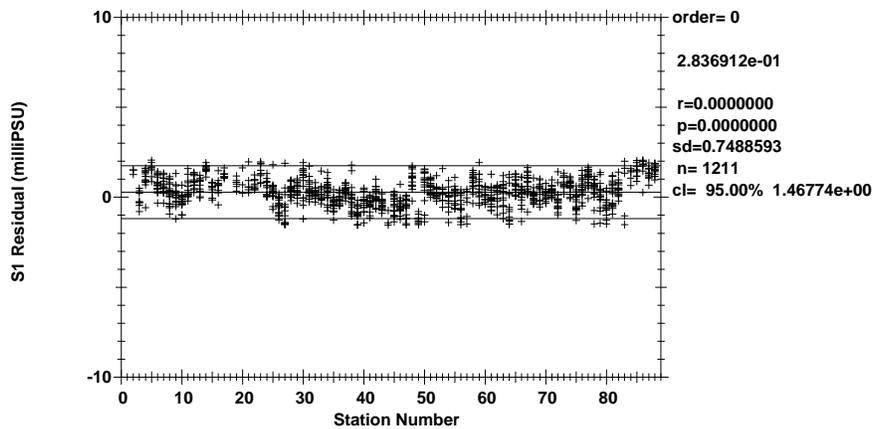


Figure 1.7.3.7 salinity residuals by cast (P>1000db).

Figures 1.7.3.6 and 1.7.3.7 represent estimates of the salinity accuracy of CLIVAR I8S. The 95% confidence limits are ± 0.00072 PSU relative to C1, and ± 0.00147 PSU relative to the bottle salts.

1.7.4. CTD Dissolved Oxygen

A single SBE43 dissolved O_2 (DO) sensor was used during this cruise (S/N 43-1129). The sensor was plumbed into the primary T1/C1 pump circuit after C1.

The DO sensors were calibrated to dissolved O_2 check samples at bottle stops by calculating CTD dissolved O_2 then minimizing the residuals using a non-linear least-squares fitting procedure. The fitting procedure determined the calibration coefficients for the sensor model conversion equation, and was accomplished in stages. The time constants for the exponential 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 bottle oxygen data were smoothed and the bottle oxygen recalculated prior to the final fitting of CTD oxygen.

The residuals are shown in figures 1.7.4.0-1.7.4.2.

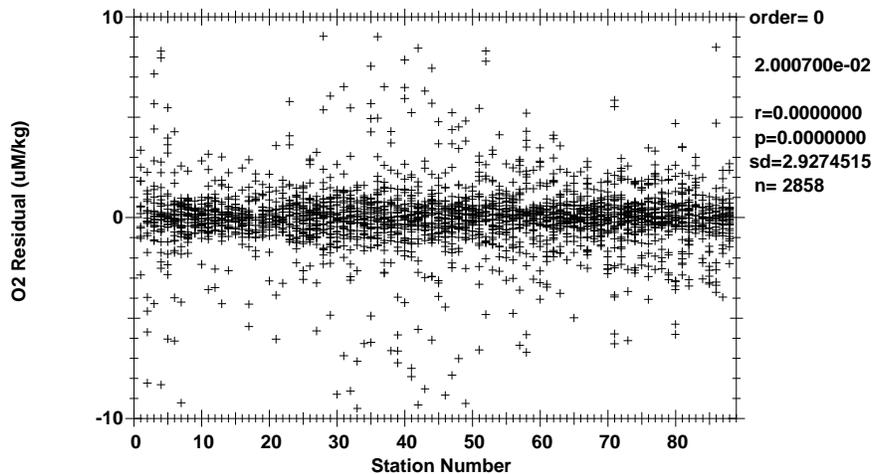


Figure 1.7.4.0 O₂ residuals by cast (all points).

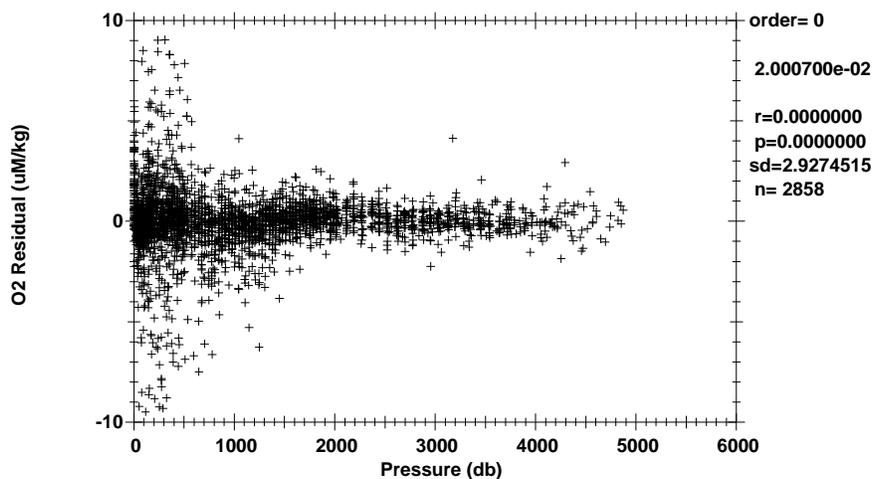


Figure 1.7.4.1 O₂ residuals by pressure (all points).

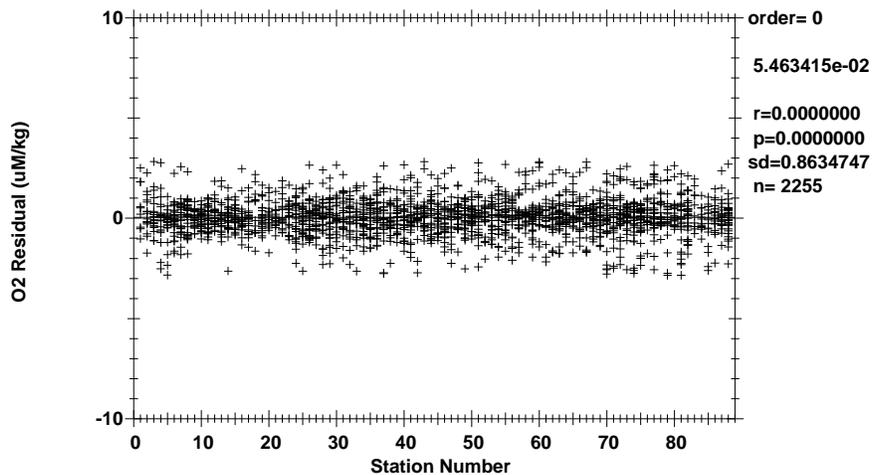


Figure 1.7.4.2 O₂ residuals by cast (-0.005° C ≤ T1-T2 ≤ 0.005° C).

The standard deviations of 2.93 uM/kg for all oxygens and 0.86 uM/kg for low-gradient 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 O_2 conversion equation for Clark cells follows Brown and Morrison [Brow78] and Millard [Mill82], [Owen85]. ODF models membrane and sensor temperatures with lagged CTD temperatures and a lagged thermal gradient. *In-situ* pressure and temperature are filtered to match the sensor response. Time-constants for the pressure response τ_p , two temperature responses τ_{T_s} and τ_{T_f} , and thermal gradient response τ_{dT} are fitting parameters. The thermal gradient term is derived by low-pass filtering the difference between the fast response (T_f) and slow response (T_s) temperatures. This term is SBE43-specific and corrects a non-linearity introduced by analog thermal compensation in the sensor. The O_c gradient, dO_c/dt , is approximated by low-pass filtering 1st-order O_c differences. This gradient term attempts to correct for reduction of species other than O_2 at the sensor cathode. The time-constant for this filter, τ_{og} , is a fitting parameter. Dissolved O_2 concentration is then calculated:

$$O_{2ml/l} = [c_1 O_c + c_2] \cdot f_{sat}(S, T, P) \cdot e^{(c_3 P_f + c_4 T_f + c_5 T_s + c_6 \frac{dO_c}{dt} + c_7 dT)} \quad (1.7.4.0)$$

where:

$O_{2ml/l}$	= Dissolved O_2 concentration in ml/l;
O_c	= Sensor current (μ amps);
$f_{sat}(S, T, P)$	= O_2 saturation concentration at S,T,P (ml/l);
S	= Salinity at O_2 response-time (PSUs);
T	= Temperature at O_2 response-time ($^{\circ}$ C);
P	= Pressure at O_2 response-time (decibars);
P_f	= Low-pass filtered pressure (decibars);
T_f	= Fast low-pass filtered temperature ($^{\circ}$ C);
T_s	= Slow low-pass filtered temperature ($^{\circ}$ C);
$\frac{dO_c}{dt}$	= Sensor current gradient (μ amps/secs);
$\frac{dT}{dt}$	= low-pass filtered thermal gradient ($T_f - T_s$).

1.8. Bottle Sampling

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

- CFCs
- He_3
- O_2
- Dissolved Inorganic Carbon (DIC)
- Total Alkalinity
- C_{13} and C_{14}
- Dissolved Organic Carbon (DOC)
- Tritium
- Nutrients
- CDOM
- PIC/POC
- 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-8.0.8) running on a Linux system. A web service (OpenAcs-5.2.3 and AOLServer-4.0.10) 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 (WOCE) Hydrographic Programme (WHP) [Joyc94].

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

1.10. Salinity Analysis

Equipment and Techniques

Two Guildline Autosol 8400A salinometers (S/N 57-396, 53-503) located in the hydro lab, were used for salinity measurements. 57-396 was used for casts 1/1-47/1 and 50/1-88/3, 53-503 for casts 48/1-49/2. These salinometers were modified by SIO/STS to provide an interface for computer-aided measurement. The water bath temperature was set and maintained at a value near the laboratory air temperature (24° C).

The salinity analyses were performed after samples had equilibrated to laboratory temperature, usually within 6-8 hours after collection. The salinometers were standardized for each group of analyses (usually 1-2 casts, up to ~75 samples) using at least two fresh vials of standard seawater per group. Salinometer measurements were made by computer, the analyst prompted by the software to change samples and flush.

Sampling and Data Processing

A total of 3306 salinity measurements were made (429 for Trace Metals) and approximately 180 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 sample prior to filling. The bottles were sealed with custom-made plastic insert thimbles and Nalgene screw caps. This assembly provides very low container dissolution and sample evaporation. Prior to sample collection, inserts were inspected for proper fit and loose inserts replaced to insure an airtight seal. The draw time and equilibration time 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 (if any) 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 data. The corrected salinity data were then incorporated into the cruise database.

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-147 was ± 0.0145 PSU for all salinities, and ± 0.0015 PSU for salinities deeper than 1000db.

Laboratory Temperature

The temperature in the salinometer laboratory varied from 21 to 25.4° C, during the cruise, except for the period stated above when room temperature was 25 to 27° C. (The air temperature thermometer had been moved and was not monitoring appropriate room temperature in the vicinity of the autosal. The air temperature change during any particular run varied from -1.0 to +0.9° C.

Standards

IAPSO Standard Seawater Batch P-147 was used to standardize all casts.

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 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 every day (approximately every 2-4 stations), unless changes were made to the system or reagents. Reagent/distilled water blanks were determined every day or more often if a change in reagents required it to account for presence of oxidizing or reducing agents.

Sampling and Data Processing

2917 oxygen measurements were made. Samples were collected for dissolved oxygen analyses soon after the rosette was brought on board. 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 $\mu\text{M/kg}$ 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) 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 20° C normalities and the blanks were plotted versus time and were reviewed for possible problems. The blanks and thiosulfate normalities for each batch of thiosulfate were smoothed (linear fits) in two groups during the cruise and the oxygen values recalculated.

Volumetric Calibration

Oxygen flask volumes were determined gravimetrically with degassed deionized water to determine flask volumes at ODF's chemistry laboratory. This is done once before using flasks for the first time and periodically thereafter when a suspect volume is detected. The 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 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 and nitrite) were performed on an ODF-modified 4-channel Technicon AutoAnalyzer II, generally within one to two hours after sample collection.

The methods used are described by Gordon *et al.* [Gord92]. The analog outputs from each of the four colorimeter channels were digitized and logged automatically by computer (PC) at 2-second intervals.

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.

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 bypassed, and a 50mm flowcell was used for measurement.

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 $\sim 55^\circ C$ to enhance color development, then passed through a 50mm flowcell and the absorbance measured at 820nm.

Explicit corrections for *carryover* in nutrient analyses are not made. In a typical AutoAnalyzer system, sample to sample carryover is $\sim 1-2\%$ of the concentration difference between samples. This effect is minimized by running samples in order of increasing depth such that concentration differences between samples are minimized. The initial surface samples were run twice since these samples followed standard peaks.

Sampling and Data Processing

3306 nutrient samples were analyzed of these 429 were analyzed for Trace Metal casts.

Nutrient samples were drawn into 45 ml polypropylene, screw-capped "oak-ridge type" centrifuge tubes. The tubes were cleaned with 10% HCl and rinsed with sample 2-3 times before filling. Standardizations were performed at the beginning and end of each group of analyses (typically one cast, up to 36 samples) with an intermediate concentration mixed nutrient standard prepared prior to each run from a secondary standard in a low-nutrient seawater matrix. The secondary standards were prepared aboard ship by dilution from primary standard solutions. Dry standards were pre-weighed at the laboratory at ODF, and transported to the vessel for dilution to the primary standard. Sets of 7 different standard concentrations were analyzed periodically to determine any deviation from linearity as a function of absorbance for each nutrient analysis. A correction for non-linearity was applied to the final nutrient concentrations when necessary. A correction for the difference in refractive indices of pure distilled water and seawater was periodically determined and applied. In addition, a "deep seawater" high nutrient concentration check sample was run with each station as an additional check on data quality. The pump tubing was changed 3 times.

After each group of samples was analyzed, the raw data file was processed to produce another file of response factors, baseline values, and absorbences. Final nutrient concentrations were then determined from this file. The data were then added to the cruise database.

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 a per-analysis measured analytical temperature.

Standards

Primary standards for silicate (Na_2SiF_6) and nitrite ($NaNO_2$) were obtained from Johnson Matthey Chemical Co.; the supplier reported purities of >98% and 97%, respectively. Primary standards for nitrate (KNO_3) and phosphate (KH_2PO_4) were obtained from Fisher Chemical Co.; the supplier reported purities of 99.999% and 99.999%, respectively. The efficiency of the cadmium column used for nitrate was monitored throughout the cruise and ranged from 99-100%.

No major problems were encountered with the measurements. The temperature of the laboratory used for the analyses ranged from 23.0° C to 24.5° C.

References

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Brow78.

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Bottle Depth Scheme

The bottle depths used during I8S followed the 3-scheme plan originally developed by Paul Robbins, adapted slightly for high latitudes. Stations rotated through the three schemes, so samples collected principally on alternate stations received the same pattern, but every six stations. The table shows the three schemes used during I8S.

	<u>Scheme #1</u>		<u>Scheme #2</u>		<u>Scheme #3</u>	
1	surface		surface		surface	
2	25		35		15	
3	50		70		40	
4	75		90		85	
5	100		120		135	
6	150		140		160	
7	200		170		185	
8	250		220		235	
9	300		270		285	
10	350		320		335	
11	400		370		385	
12	450		420		435	
13	500		470		485	
14	600		520		570	
15	700		640		670	
16	800		740		770	
17	900		840		870	
18	1000		940		970	
19	1100		1040		1070	
20	1200		1140		1170	
21	1300		1240		1270	
22	1400		1340		1370	
23	1500		1440		1470	
24	1600		1540		1570	
25	(1700)		(1640)		(1670)	
26	1800		1740		1770	
27	(1900)		(1840)		(1870)	
28	2000		1940		1970	
29	2250		2100		2170	
30	2500		2350		2420	
31	2750		2600		2670	
32	3000	<u>Z < 4400</u>	2850		2920	<u>Z < 4400</u>
33	3300	(3250)	3100	<u>Z < 4300</u>	3250	(3170)
34	3600	(3500)	3400	(3350)	3550	(3420)
35	3900	(3750)	3700	(3600)	3850	(3670)
36	4200	(4000)	4050	(3850)	4150	(3920)
	4550	(4250)	4400	(4100)	4500	(4170)
	4900	(bottom)	4750	(bottom)	4850	(bottom)
	bottom-200	5050	bottom-200			
	bottom	bottom-	bottom			
		200				
		bottom				

Argo floats

(Annie Wong)

During the CLIVAR/CO₂ 2007 repeat of I8S, 14 autonomous CTD profiling floats were deployed along the cruise track in waters deeper than 2000 dbar. These floats are part of the Argo project (www.argo.ucsd.edu), and are provided by Dr. Steve Riser from the University of Washington. Each of these floats has been ballasted differently for different latitudes. Of these 14 floats, 9 contain oxygen sensors, and 2 are “ice floats” that are part of the Antarctic field trial. These 2 “ice floats” are programmed to remain subsurface and store data when under sea ice. All floats were deployed at CTD stations, at the end of all station casts. All floats were deployed from the starboard stern of the ship, with the ship moving forward at about 1 knot. No CTD oil slick was found at any of the deployment stations. Deployment was done by using a rope to lower the floats from the deck to the water. All 14 floats successfully self-activated via pressure activation. Data from all Argo floats are publicly available in real-time via the two global servers at www.usgoda.gov and www.coriolis.eu.org. The following are the approximate positions where the 14 floats were deployed.

Float ID	Latitude	Longitude
5058	65 09' S	84 18' E
5062	63 57' S	83 08' E
5074	57 37' S	82 23' E
5079	56 54' S	83 18' E
5093	56 03' S	84 15' E
5071	53 06' S	87 29' E
5094	50 07' S	90 25' E
5072	47 09' S	93 09' E
5095	44 00' S	95 01' E
5073	41 00' S	94 59' E
5075	37 59' S	94 59' E
5100	35 00' S	95 00' E
5119	33 30' S	95 00' E
5092	32 00' S	95 00' E

Total Dissolved Inorganic Carbon (DIC)

The DIC analytical equipment was set up in a seagoing container modified for use as a shipboard laboratory. The analysis was done by coulometry with two analytical systems (PMEL-1 and PMEL-2) used simultaneously on the cruise. Each system consisted of a 5011 coulometer (UIC, Inc.) coupled with a SOMMA (Single Operator Multiparameter Metabolic Analyzer) inlet system developed by Ken Johnson (Johnson et al., 1985,1987,1993; Johnson, 1992) of Brookhaven National Laboratory (BNL). In the coulometric analysis of DIC, all carbonate species are converted to CO₂ (gas) by addition of excess hydrogen to the seawater sample, and the evolved CO₂ gas is carried into the titration cell of the coulometer, where it reacts quantitatively with a proprietary reagent based on ethanolamine to generate hydrogen ions. These are subsequently titrated with coulometrically generated OH⁻. CO₂ is thus measured by integrating the total change required to achieve this.

The coulometers were each calibrated by injecting aliquots of pure CO₂ (99.99%) by means of an 8-port valve outfitted with two sample loops (Wilke et al., 1993). The instruments were calibrated at the beginning and end of each full station with a set of the gas loop injections.

Secondary standards were run throughout the cruise on each analytical system; these standards are Certified Reference Materials (CRMs) consisting of poisoned, filtered, and UV irradiated seawater

supplied by Dr. A. Dickson of Scripps Institution of Oceanography (SIO), and their accuracy is determined shoreside manometrically. On this cruise, the overall accuracy and precision for the CRMs on both instruments combined was 0.75 $\mu\text{mol/kg}$ respectively ($n=131$). Preliminary DIC data reported to the database have not yet been corrected to the Batch 78 CRM value, but a more careful quality assurance to be completed shoreside will have final data corrected to the secondary standard on a per instrument basis.

Samples were drawn from the Niskin-type bottles into cleaned, precombusted 300-mL Pyrex bottles using Tygon tubing with silicone ends. Bottles were rinsed once and filled from the bottom, overflowing half a volume taking care not to entrain any bubbles. The tube was pinched off and withdrawn, creating a 6-mL headspace, and 0.12 mL of 50% saturated HgCl_2 solution was added as a preservative. The sample bottles were sealed with glass stoppers lightly covered with Apiezon-L grease, and were stored at room temperature for a maximum of 24 hours prior to analysis.

Over 2500 samples were analyzed for discrete DIC; full profiles were completed on odd numbered stations, with replicate samples taken from the surface, oxygen minimum, Salinity Maximum, and bottom Niskin-type bottles. On the even numbered stations, samples were drawn throughout the water column with focus on the upper 1000m. The replicate samples were interspersed throughout the station analysis for quality assurance of the integrity of the coulometer cell solutions. No systematic differences between the replicates were observed.

In addition to the samples drawn from the Niskin-type bottles, we collected underway surface (~5 meter) sea-water samples from the sea chest. We did on 4 hour intervals this during the transit from New Zealand to station 1 and during the transit to Australia after the end of station 88.

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Underway pCO₂

Equipment and Analytical Techniques: Underway pCO₂ System (Version 2.5) AOML:

The shipboard automated underway pCO₂ system is situated in the hydrolab. It runs on an hourly cycle during which three gas standards, eight headspace samples from the equilibrator, and three ambient air samples are analyzed. The system consists of an equilibrator box where surface seawater from the bow intake is equilibrated with headspace, a valve box that contains the infrared analyzer, and a computer and interface boards that control valves and log sensors.

The equilibrator is a cylindrical Plexiglas™ chamber approximately 22.5 cm high and 8.8 cm wide. Surface seawater flows through a spiral spray head in the top at a rate of 2 ± 0.5 l/min. The water spray through the ~0.5-l headspace and the turbulence of the water streams impinging on the surface of 0.5 l of water cause the gases in water and headspace to equilibrate. Excess water flows through an outlet at the bottom of the equilibrator into an over-the-side drain. Two vents in the top of the equilibrator insure that the headspace remains at the measured laboratory pressure. Headspace gas circulates in a closed loop driven by a KNF pump at 150 ± 50 ml/min. From the equilibrator the gas passes through a condenser, a column of magnesium perchlorate, a mass flow meter (MFM), a $1.0 \mu\text{m}$ Acro® disk filter, the 12 ml sample cell of a Licor™ Model 6251 non-dispersive infrared analyzer (IR), and back into the equilibrator headspace.

A second KNF pump draws marine air from an intake on the bow mast through 100 m of 0.95 cm (= 3/8") OD Dekoron™ tubing at a rate of 6-8 l/min. A filter of glass wool at the intake prevents particles from entering the gas stream. At designated times, the program diverts 175 ± 25 ml/min of air from this line into the Licor sample cell for analysis. Excess marine air empties into a rotometer on the front panel of the valve box.

Both sample streams (equilibrator headspace and marine air) are analyzed bone dry. They pass first through a cold trap (condenser) at 3° C and then through a column of magnesium perchlorate. Standard gases also run through the magnesium perchlorate.

A custom developed program run under LabView™ controls the system and graphically displays air and water XCO₂ readings. The program logs the voltage and temperature of the infrared analyzer, water flow, gas flows, equilibrator temperature, and barometric pressure. The program writes all of this data to disk at the end of each measurement phase.

The details of instrumental design can be found in Wanninkhof and Thoning (1993), Ho et al. (1995), and Feely et al. (1998).

Sampling Cycle:

The system runs on an hourly cycle during which three standard gases, three marine air samples, and eight surface water samples (from the equilibrator headspace) are analyzed on the schedule listed below. A Valco multi-port valve selects the gas to be analyzed. Each measurement phase starts by flowing either standard (@~50ml/min), equilibrator headspace (@~150 ml/min), or marine air (@~175 ml/min) through the Licor. Fifteen seconds before the end of each phase, a solenoid valve stops the gas flow. Ten seconds later, the program logs all sensors and writes the data to disk.

Table 2.14. Hourly sampling cycle for the underway pCO₂ system (version 2.5).

Minutes after the Hour	Sample
4	Low standard
8	Mid standard
12	High standard
16.5	Water (= headspace of equilibrator)
21	Water
25.5	Water
30	Water
34	Air (marine air from the bow line)
38	Air
42	Air
46.5	Water
51	Water
55.5	Water
60	Water

Standards:

The unit is standardized every hour with three compressed air standards containing known amounts of CO₂ gas in (natural) air. The standard gases are purchased from NOAA/CMDL in Boulder and are directly traceable to the WMO scale.

The standards used on the cruise are:

Tank #	Mole Fraction CO ₂ (ppm) (= XCO ₂)
CA06827	284.71
CA05334	380.98
CA06380	448.29

Units:

All XCO₂ values are reported in parts per million (ppm), and fCO₂ values are reported in micro atmospheres (μ atm).

Data Availability:

The system ran well during the entire cruise from February 4 to March 17 except for one period from 1230 to 1630 GMT on February 8 when the seawater system shut down temporarily. The data will be posted on the web approximately 1 month after the end of the cruise at:

<<http://www.aoml.noaa.gov/ocd/gcc/index.php>>.

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Alkalinity

(Susan Alford and George Anderson, Last Revised: March 15, 2007)

Description of Equipment and Technique

Analysis of samples was carried out using an open cell system per A.G. Dickson (complete reference info to be provided later) using a two-step titration. While the sample was being stirred slowly, an approximately 2.5 ml aliquot of acid was added to bring the pH of the sample to ~3.5. After 4.5 minutes of vigorous stirring and bubbling with CO₂ free air, additional aliquots of 0.05 mls of the acid were added.

Sampling and data processing techniques

On every other station, complete profiles were drawn with up to 3 duplicates. On the alternate stations, sampling was done in conjunction with the D.I.C and C-14 sampling programs and typically consisted of less than full profiles.

The samples were drawn from Niskin bottles into rinsed 280ml pyrex serum bottles. To avoid organic contamination during sampling, a silicon drawing tube (provided by the CDOM sampling group) was used. Following collection, the samples were poisoned with 0.056 microliters of a saturated mercuric chloride solution.

The volume of sample to be run for analysis was measured using a 100 ml calibrated pipet. The filling and emptying of the pipet were controlled using an automated system consisting of a peristaltic pump, an aquarium pump (making the pipet a blow-out unit), solenoid pinch valves and a ChronTrol programmable timer/controller. This system allowed for the measurement of each sample to be run, the dispensing of this volume into the cell to be used during analysis, and the rinsings of the pipet between samples.

During analysis, after each addition of acid during the titration, the volume added, a cell temperature, and a millivolt reading were electronically recorded. The data was then processed by applying a modified linear fit to the data falling between pH 3.5 and 3.0 in order to calculate a preliminary alkalinity value for each sample that was run.

As titrations were completed, all preliminary alkalinity values were plotted versus pressure to check for samples that should be rerun. Having this plot available proved very helpful in this regard.

Calibration

All equipment used in our analyses was calibration ashore prior to the cruise during the timeframe of December 2006 through January 2007. This includes: YSI and Guildline thermometers, Keithley multimeter, Dosimat model 665 buret with a 5ml exchange unit, 100ml Pyrex pipet, Cole-Parmer 0-200 ml/min flowmeter and spares.

Error Estimates

The stability of the alkalinity system was monitored using Batch 78 of the Dickson Laboratory DIC/ALK reference materials (certified value: 2158.57 +/- 0.45 μ moles/kg) The CRM data were plotted versus time to monitor system performance. The preliminary data indicate an offset of ~1 μ moles/kg needs to be applied to the data, with the measured values being higher than the certified value.

Replicate Analyses

When duplicate samples were collected from the Niskin bottles, the surface or near surface bottle, an intermediate depth bottle, and the bottom or near bottom bottle were sampled. These replicates were interspersed amongst the other samples during analysis with the deep replicate being run first, the surface replicate about half-way through the station samples and the mid-depth replicate just before the sample from Niskin 1, the deepest sample in the cast.

For calculations completed on analyses thus far, the standard deviation of the difference between preliminary alkalinity values of duplicates and the “matching” bottle drawn from the same Niskin average to be about 1.5 $\mu\text{moles/kg-sol}$, scattering equally around zero.

Standards

The stability of the alkalinity system was monitored using Batch 78 of the Dickson Laboratory DIC/ALK reference materials (certified value: 2158.57 +/- 0.45 $\mu\text{moles/kg}$)

Reagents

A saturated mercuric chloride solution prepared onshore in January 2007 was used to poison all samples before the samples were analyzed. In addition, a well-characterized ~0.1 molar hydrochloric acid in 0.6 molar sodium chloride solution was used for all titrations.

DOC/DON

A total of 1522 seawater samples were collected and frozen during the I8 leg for DOC/DON analysis. The frozen seawater samples will be returned to the University of Miami, Rosenstiel School of Marine and Atmospheric Science for analysis using High Temperature Catalytic Oxidation (HTCO). For further information about the analysis or data availability please contact Dr. Dennis Hansell (dhansell@rsmas.miami.edu).

Carbon-14

A total of 470 seawater samples were collected and preserved for ^{14}C analysis. The samples will be returned to Woods Hole Oceanographic Institution for analysis. For more information about the data or analysis please contact Ann McNichol (amcnichol@whoi.edu).

Chlorofluorocarbon (CFC) Measurements

PI: John L. Bullister

Samplers and Analysts: David Wisegarver
Eric Wisegarver
David Cooper

Samples for the analyses of dissolved CFC-11 and CFC-12 were drawn from 2000 water samples collected during the expedition. Water samples were collected in specially designed Niskin bottles, that use a modified end-cap design 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 for

CFC were the first samples drawn from the 10-liter bottles. Care was taken to coordinate the sampling of CFCs with other samples to minimize the time between the initial opening of each bottle and the completion of sample drawing. In most cases, dissolved oxygen, ^3He , samples were collected within several minutes of the initial opening of each bottle. To minimize contact with air, the CFC samples were drawn directly through the stopcocks of the 10-liter 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 approximately 0 degrees Centigrade until 30 minutes before being analyzed. At that time, the syringe was placed in a bath of surface seawater heated to 25 degrees C.

For atmospheric sampling, a ~100 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 a Kadet pump. The air was compressed in the pump, with the downstream pressure held at ~1.5 atm. using a backpressure regulator. A tee allowed a flow (100 ml min⁻¹) of the compressed air to be directed to the gas sample valves of the CFC analytical systems, while the bulk flow of the air (>7 l min⁻¹) was vented through the backpressure regulator. Air samples were

only analyzed 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 16 locations along the cruise track. At each location, at least five measurements were made to increase the precision. The measured concentrations are reported in Tables 1 and 2. Concentrations of CFC-11 and CFC-12 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).

For seawater analyses, water was transferred from a glass syringe to a glass-sparging chamber (~190 ml). The dissolved gases in the seawater sample were extracted by passing a supply of CFC-free purge gas through the sparging chamber for a period of 6 minutes at 175 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 1004. A neslab cryocool was used to cool the trap, to -70C. After 6 minutes of purging, the trap was isolated, and it was heated electrically to ~175 C. The sample gases held in the trap were then injected onto a precolumn (~60 cm of 1/8" O.D. stainless steel tubing packed with 80-100 mesh Porasil B, held at 80 C) for the initial separation of CFC-12 and CFC-11 from later eluting peaks. After the F12 had passed from the pre-column through the second precolumn (5 cm of 1/8" O.D. Stainless steel tubing packed with MS5A, 80 C) and into the analytical column #1 (~170 cm of 1/8" OD stainless steel tubing packed with MS5A and held at 80 C) the outflow from the first precolumn was diverted to the second analytical column (~150 cm 1/8" OD stainless steel tubing packed with Carbograph 1AC, 80-100 mesh, held at 100 C). After CFC-11 had passed through the first precolumn, the remaining gases were backflushed from the precolumn and vented. Column #1 and the precolumns were in a Shimadzu GC8 gas chromatograph with electron capture detector (340 C). Column #2 was in a Shimadzu Mini2 gas chromatograph, also with electron capture detector (250 C).

Both of the analytical systems were calibrated frequently using a standard gas of known CFC 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 EC detector were similar to those used for analyzing water samples. Four sizes of gas sample loops were used. Multiple injections of these loop volumes could be made to allow the system to be calibrated over a relatively wide range of concentrations. Air samples and system blanks (injections of loops of CFC-free gas) were injected

and analyzed in a similar manner. The typical analysis time for seawater, air, standard or blank samples was ~11 minutes. Concentrations of the CFCs in air, seawater samples, and gas standards are reported relative to the SIO98 calibration scale (Cunnold et. al., 2000). Concentrations in air and standard gas are reported in units of mole fraction CFC in dry gas, and are typically in the parts per trillion (ppt) range. Dissolved CFC concentrations are given in units of picomoles per kilogram seawater (pmol kg⁻¹). CFC concentrations in air and seawater samples were determined by fitting their chromatographic peak areas to multi-point calibration curves, generated by injecting multiple sample loops of gas from a working standard (PMEL cylinder 45186) into the analytical instrument. The response of the detector to the range of moles of CFC passing through the detector remained relatively constant during the cruise. Full-range calibration curves were run at intervals of 4-5 days during the cruise. Single injections of a fixed volume of standard gas at one atmosphere were run much more frequently (at intervals of ~90 minutes) to monitor short-term changes in detector sensitivity.

On this expedition, based on the analysis of 150 duplicate samples, we estimate precisions (1 standard deviation) of less than 1% or 0.005 (whichever is greater) for both dissolved CFC-11 and CFC-12 measurements. A very small number of water samples had anomalously high CFC 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 during the sampling or analysis processes. Measured concentrations for these anomalous samples are included in the preliminary data, but are given a quality flag value of either 3 (questionable measurement) or 4 (bad measurement). A quality flag of 5 was assigned to samples which were drawn from the rosette but never analyzed due to a variety of reasons (e.g., leaking stopcock, plunger jammed in syringe barrel).

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Trace Metals

(Joe Resing, NOAA/PMEL)

Hydrographic sampling for the trace elements Al and Fe was conducted during leg 1 of I8S aboard the R.V. *Revelle*. Samples were collected using a specially designed rosette system which consists of 12 x 12L Go-Flo bottles mounted on a powder-coated rosette frame. The package is equipped with a SeaBird SBE 911 ctd that also has an SBE 43 oxygen sensor and a Wet Labs FL1 fluorometer. The package is lowered using a Kevlar conducting cable and bottles were tripped at pre-determined depths from the ship using a deck box. Water samples were collected in the upper 1000 m at a total of 37 stations, spaced at ~1 degree intervals.

Dissolved Al, Fe and Mn were determined on these water samples using shipboard FIA (C.I. Measures, University of Hawaii). In addition samples were collected for shore-based ICP MS determinations of dissolved and dissolvable Fe, Ni, Cu, Zn, Cd, and Pb by isotope dilution (W.M. Landing, FSU). Additional samples were collected by Amir Hamidian for shore-based Cd determinations at Otago University, New

Zealand. Particulate samples were also collected for shore-based determination of trace elements by EDXRF.

Trace Metals Rosette Sampling:

(Dr. William M. Landing and Clifton S. Buck/FSU)

We deployed the trace metals rosette at 37 stations, collecting roughly 450 samples. Bad weather (high winds and rough seas) prevented us deploying at several stations. We had some electrical issues that caused two casts to be aborted at Stations 042 and 043 respectively. The problems were resolved by a combination of reseating of signal cables and retermination of the Kevlar cable. We also did not collect samples at Station 001 because the bottles did not trip correctly as the pylon was frozen while on deck from a fresh water rinse normally given to the rosette before deployment.

Subsamples were taken from each GoFlo bottle for at-sea analysis of salinity, nutrients, and dissolved total Fe and Al (Bill Hiscock of the Measures Group). Archived subsamples are described below.

Aerosol Sampling

(Clifton Buck, FSU Oceanography PhD student)

Aeolian transport and deposition of soluble aerosol Fe is believed to influence phytoplankton primary productivity in the majority of the open ocean (far from Fe inputs from rivers and coastal sediments). The purpose of the FSU aerosol sampling program is primarily to measure the concentration of total aerosol Fe, and to quantify the aerosol Fe fractions that are soluble in natural surface seawater and in ultra-pure deionized water. Additional analyses are conducted on the samples in an effort to understand the atmospheric processes that yield differences in the aerosol Fe solubility.

The aerosol sampling equipment consists of four replicate filter holders deployed on a 20' fold-down aerosol tower mounted on the forward, starboard corner of the 03 deck of the ship. One of the replicate filters (0.4 μm Nuclepore polycarbonate track-etched) is used for total aerosol measurements (see below); one replicate filter (0.45 μm polypropylene) is used to quantify the seawater-soluble fraction; one replicate filter (0.45 μm polypropylene) is used to quantify the ultra-pure deionized water soluble fraction; and one replicate filter (0.45 μm polypropylene) is used for precision (QA) tests or stored as a backup sample. Size-fractionated aerosols are also collected for 72 hour intervals starting every fourth day using a MOUDI cascade impactor (>3.2 μm , 1.0 μm , 0.56 μm , 0.056 μm).

Air is pulled through the filters using two high-capacity vacuum pumps. The sampling is controlled by a Campbell Scientific CR10 datalogger that immediately shuts off the flow when the wind might blow stack exhaust forward towards the sampling tower, or when the wind drops below 0.5 m/s. Air flow is measured using Sierra mass-flow meters.

We have collected 24-hour integrated aerosol samples each day for the entire leg (23 days of sampling) for the following analyses:

Total aerosol Si, Al, Fe (to be analyzed using Energy Dispersive X-Ray Fluorescence by Dr. Joe Resing at NOAA/PMEL).

Seawater-soluble aerosol Al and Fe (to be run back at FSU).

Ultra-pure water soluble Si, Al, Ti, Fe, chloride, sulfate, nitrate, sodium (to be run back at FSU). The MOUDI size-fractionated aerosol filters are also leached with ultra-pure water for these same analytes.

Other Sampling

We collected archived samples from each trace metal cast (37 stations, approx. 650 samples) for FSU shore-based analysis of dissolved Fe, Ni, Cu, Zn, Cd, and Pb using isotope dilution ICPMS.

We collected 237 samples for Amir Hamidian of University of Otago who will analyze them for dissolved Cd.

The TSM from each trace metal cast was collected on 47 mm 0.4 um Nuclepore filters for EDXRF analysis of total particulate Si, Mn, Fe, and Al (Joe Resing, NOAA/PMEL).

200 mL of rain was collected during a squall at 40°S and 95°E. The samples were filtered and frozen for analyses at FSU for soluble Si, Al, Ti, Fe, chloride, sulfate, nitrate, and sodium.

Lowered Acoustic Doppler Current Profilers

Two lowered acoustic Doppler current profiler systems were brought on this cruise. All instruments were manufactured by Teledyne R.D. Instruments. One system was from University of Hawaii, and consisted of 150kHz broadband ADCP (BB150), manufactured in the mid-1990s. The other was a pair of 300kHz "work horse" ADCPs, one of which was a higher-powered prototype (WH300 and HP-WH300, respectively). Both systems are self-contained, attached to the rosette but not attached to the CTD cable. Either system, when deployed, is powered by a 48V lead-acid gel cell (or absorbed glass mat) battery system, contained in an oil-filled plastic box sealed by a urethane sheet. These batteries are a vast improvement over the older gas-filled pressure cases (usually aluminum). The newer batteries are known as the Safe Orange Battery due to the color of the case. In 300-400 CLIVAR casts there has been no sign of any of the internal oil getting out, and we maintain a vigilant watch for any leaks.

Mainly due to the lower frequency, the older BB150 instruments are capable of greater profiling range than the newer instruments. Each ping has more range, so a given vertical slab is sampled more during a cast by a BB150 than a WH300, which has half the range (or less) in a given profile. RDI does not manufacture the BB150 any longer. The only current viable replacement is the WH system. An individual WH300 can profile to the bottom of the ocean when particles exist throughout the water column (e.g. high latitudes). In regions of low scattering (center of a gyre) they often cannot profile below 1000-1500m. WH instruments are usually used in pairs with one looking up and one looking down, to increase the number of samples in a vertical slab during a cast. The HP-WH300 is a prototype RDI hopes will improve profiling range, especially in regions of low scattering.

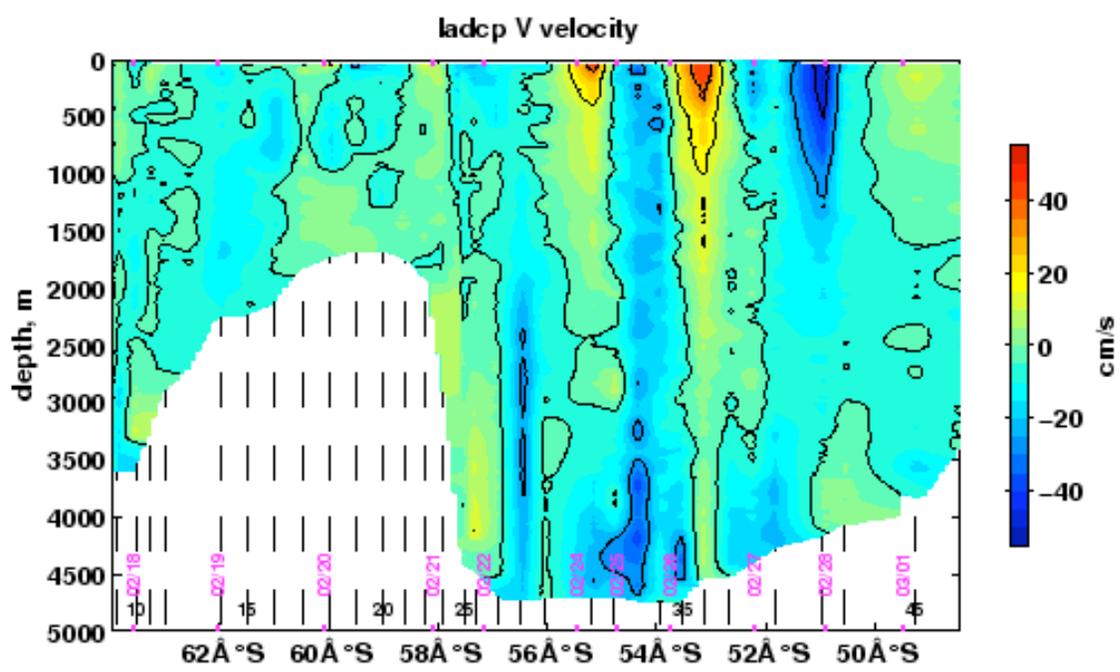
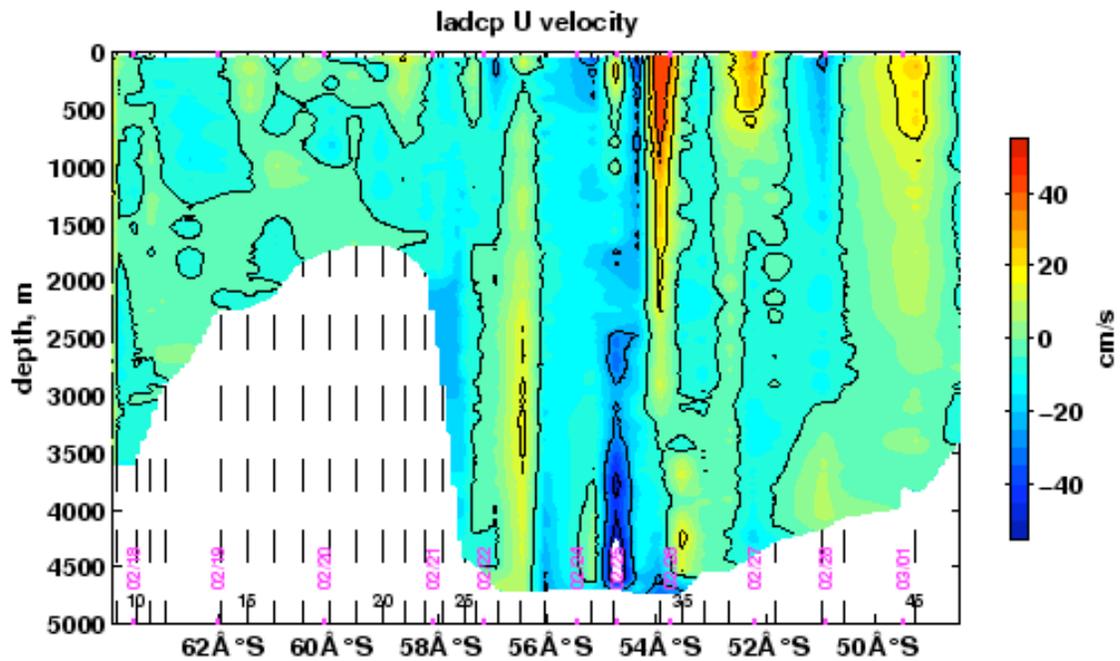
The plan for this cruise was to use the WH pair until scattering was sufficiently low that they were not profiling to the bottom. At that time we would switch to the BB150, which would extend the range of each ping, and hence the depth to which the instrument can profile.

During the long steam to the first station communication with the HP-WH300 was problematic, and after opening the pressure case and reseating the PCMCIA memory card, it was determined that the bulkhead connector was also bad. Because the WH300 was potentially too weak an instrument to work alone, the BB150 was put on for the first station. Unfortunately, the BB150 was in a confused state, or its up/down mercury switch was stuck in the wrong position. The first 7 casts were full of reasonable-looking data which were acquired with some incorrect transformation, so the final velocities are junk. On cast 8 we switched to the remaining functional instrument, the WH300. That instrument did in fact profile to the bottom until cast 48. However, with increasing frequency, it only returned a very short cast (truncated after minutes). Between casts 8 and 48, 4 casts were lost from this problem, three of which occurred close together.

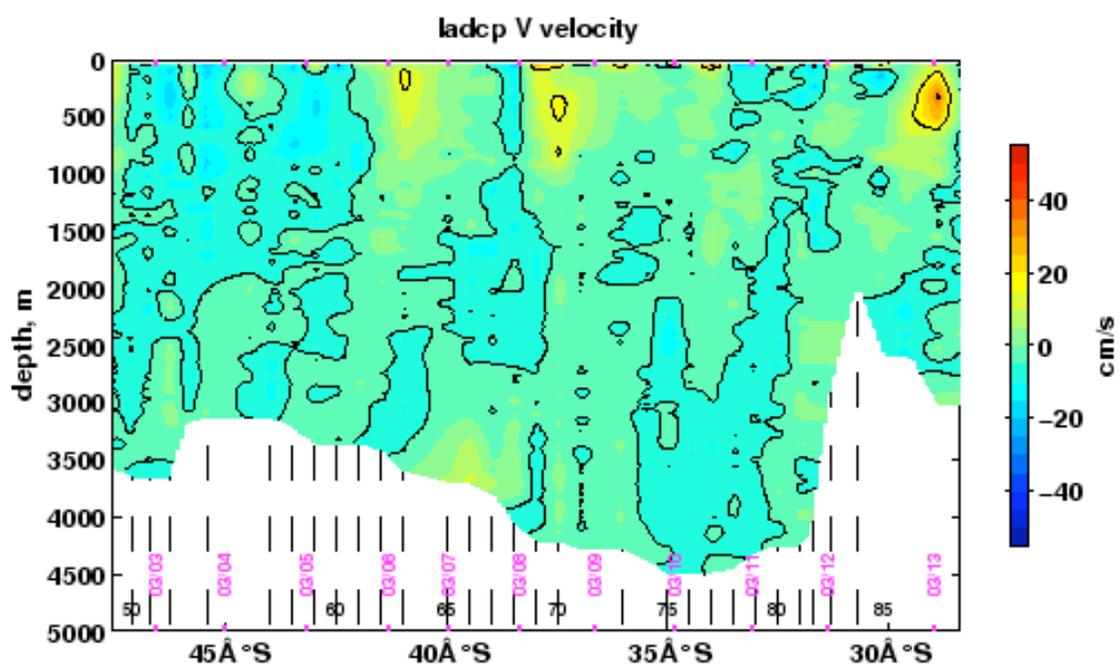
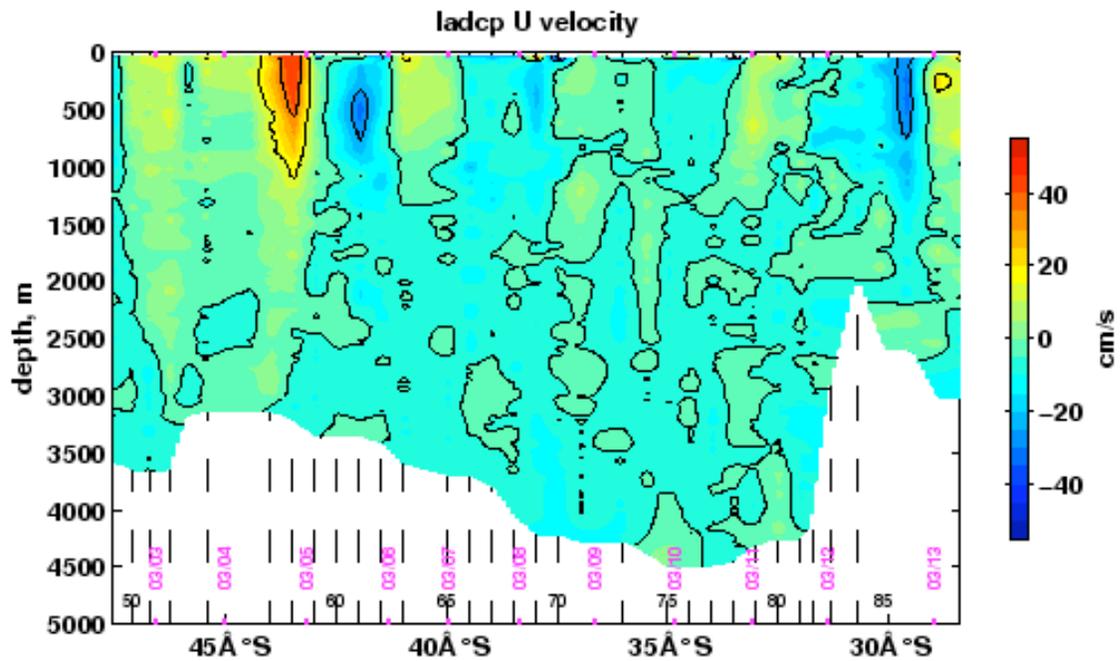
On cast 49 we switched to the BB150. It has a single eroded pin in the bulkhead connector but is still functional. A new cable and attention to seating the cable appear to have kept its connector in good condition because the instrument had no problems from station 49 to 88 the BB150 had no problems. One cast was lost because the serial port on the acquisition computer failed at the time of deployment. Because of all the earlier communications trouble, a quick decision was made to send the cast down with the LADCP not pinging. During the cast the PC was rebooted and the serial port functioned again. As it turns out, the PC involved suffered a catastrophic hard drive (or other hardware) failure at the end of the cruise (after all casts and backups). It is not clear whether the serial port failure was a harbinger of bad news. Two casts were lost due to operator error.

In all, 34 WH300 casts were obtained and 38 BB150 casts were obtained. No data were acquired with the HP-WH300. Spare bulkhead connectors and o-rings are en route to Fremantle awaiting a future date with these instruments.

Final LADCP processing is the responsibility of the LDEO group, but the components are in place. The shipboard data from the NB150 are of sufficient quality that they can be used on the second leg "live", and on this leg a final processed dataset will be available for the LADCP operator. GPS position files are available for the entire cruise, and ODF (the CTD group) has provided a 1/2second time series of pressure, temperature, salinity, and other variables, for use with LADCP processing. Preliminary processing for leg 1 shows good agreement between the shipboard and lowered ADCP data in the upper 200m.



WH300 casts



bb150 casts

Shipboard Doppler Current Profilers

The Revelle has three Doppler sonars for measuring ocean velocity. One of these, a commercial 150kHz narrowband instrument, 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. Comparison of the ocean velocity data from the HDSS and RDI instruments will enable a decision as to whether the HDSS velocities should be included in the shipboard final ocean velocity dataset.

The CLIVAR Shipboard Ocean Velocity component

The primary instrument (NB150) was made by R.D. Instruments (now owned by Teledyne) in the late 1980s. The original commercial acquisition and averaging software ran under DOS and required a fairly slow computer. A new acquisition system written at the University of Hawaii was temporarily installed on a laptop for the P16S CLIVAR leg in Jan 2005. The laptop was subsequently replaced with an SIO-owned rack-mount unit.

The acquisition system (UHDAS, University of Hawaii Data Acquisition System) is written in C and Python; processing software is in C, Python, and Matlab. UHDAS acquires data from the NB150 instrument, gyro heading (for reliability), Ashtech heading (for accuracy), and GPS positions from various sensors. 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. This scheme insulates the heading correction against short gaps or loss of fixes. For Ashtech gaps (up to 2 hours), the previous available correction is used.

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.

UHDAS provides access to regularly-updated figures and data via the ship's network. The software used is all open-source and is available 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.

Shipboard Doppler sonar work on this cruise

NB150:

UHDAS is undergoing a transformation to remove dependence on Matlab. This transition will take some time and of necessity takes place in increments. On this cruise, work towards that transition included development of preliminary versions of all figures used in batch processing and on the web site. The UHDAS system provided a valuable test platform for the figures but they will not be incorporated into the system as they have been tested for robustness. Updates to acquisition and processing code were implemented that addressed various bugs and improved reliability. A revised transducer angle (orientation relative to the ship) is possible after this cruise and will be updated on the acquisition computer.

A new Ashtech receiver was shipped out to Dunedin for this cruise because the previous one (an older ADU2 unit) had failed. The new (replacement) deck unit is using the original antennas and survey configuration. For the most part it has been reliable, but there were several times when it locked up and had to be restarted (trace the correct power cable on the bridge, unplug it, wait 15 seconds, and plug it in -- a reset using the button was insufficient). Post-processing of the NB150 data will include an improved heading correction to account for the few long gaps.

HDSS:

On the P16S 2005 CLIVAR cruise, CODAS processing steps were adapted for use with the HDSS data. Those instruments had, at the time, three beams and two beams out of four, for the 140kHz and 50kHz instruments, respectively. In January 2006 the 140kHz was repaired and the broken 50kHz beams were replaced. The HDSS data acquisition system is also undergoing a transformation, but for the moment, the data format and associated peculiarities are consistent with the present CODAS processing code. One change to CODAS processing was made to accommodate a newer and more precise binary data storage standard required in newer Matlab versions (newer Matlab failed to read the binary HDSS data without this change). This will be passed along to the proprietors of the HDSS system for their use.

HDSS data will be compared to NB150 data after the best final processing of each has been finished. If the data look good, they will be included in the ADCP archive along with the NB150 data.

Chromophoric DOM

Project Title: Chromophoric DOM -- A Photoactive Tracer of Geochemical Process

PIs: D. Siegel, N. Nelson, C. Carlson
University of California, Santa Barbara

Support:

NASA Ocean Biology and Biogeochemistry; NSF Chemical Oceanography

Field Team (I8S):

N. Nelson (PI), D. Menzies (Sr. Engineer)

Field Team (I9N):

C. Swan (GS), E. Wallner (GS)

Project Goals:

Our goals are to determine chromophoric dissolved matter (CDOM) distributions over a range of oceanic regimes on selected sections of the CO₂/CLIVAR Repeat Hydrography survey, and to quantify and parameterize CDOM production and destruction processes with the goal of mathematically constraining the cycling of CDOM. CDOM is a poorly characterized organic matter pool that interacts with sunlight, leading to the production of climate-relevant trace gases, attenuation of solar ultraviolet radiation in the water column, and an impact upon ocean color that can be quantified using satellite imagery. We believe that the global distribution of CDOM in the open ocean is controlled by microbial production and solar bleaching in the upper water column, and relative rates of advection and remineralization in intermediate and deep waters. Furthermore, changes in the optical properties of CDOM and its relationship with DOC over time suggest the use of CDOM as an indicator of the prevalence of refractory DOC in the deep ocean. We are testing these hypotheses by a combination of field observation and controlled experiments. We are also interested in the deep-sea reservoir of CDOM and its origin and connection to surface waters and are making the first large-scale survey of the abundance of CDOM in the deep ocean.

Activities on I8S and I9N:

Profiling Instruments

Once each day we are casting a hand-deployed free-fall Satlantic MicroPro II multichannel UV/Visible spectroradiometer. This instrument has 14 upwelling radiance sensors and 14 downwelling irradiance sensors in wavelength bands ranging from 305 to 683 nm. The package also mounts a WetLabs ECO chlorophyll fluorometer, plus ancillary sensors including X-Y tilt, internal and external temperatures. The instrument is allowed to trail away behind the port-side stern, then free-falls to 150m and is hand-recovered. We are using the radiometric data to study the effects of CDOM on the underwater light environment, to validate satellite ocean radiance sensor data, and to develop new algorithms employing satellite and in situ optical sensor data to retrieve ocean properties such as CDOM light absorbance, chlorophyll concentration, and particulate backscattering.

On the core CTD we are deploying a WetLabs UV fluorometer (Ex 370 nm, Em 460 nm), which stimulates and measures fluorescence of CDOM. We are evaluating the use of this instrument to supplement or enhance bottle CDOM measurements, as bottle samples often do not have the depth resolution needed to resolve the observed strong near-surface gradients in CDOM concentration, and on cruises such as this we are not able to sample CDOM on every station. Differences between the fluorescence and absorption profiles, may reveal gradients in chemical composition of CDOM. On I8S the fluorometer has performed very well: problems with temperature compensation encountered on P16N have been corrected. Signal to noise ratios remain low for the open ocean areas we are studying.

This fluorometer is ganged to a WetLabs C-star 660 nm 0.1m pathlength beam transmissometer belonging to Dr. Wilford Gardner, TAMU. The transmissometer is used to gauge particle load in the water column, which can be calibrated to produce estimates of particulate carbon. Decline of the particle load with depth can then be related to POC flux, another element of the carbon system.

Bottle Samples

CDOM is at present quantified by its light absorption properties. We are collecting samples of seawater for absorption spectroscopy on one deep ocean cast each day. CDOM is typically quantified as the absorption coefficient at a particular wavelength or wavelength range (we are using 325 nm). We determine CDOM at sea by measuring absorption spectra (280-730 nm) of 0.2µm filtrates using a liquid waveguide spectrophotometer with a 200cm cell. On I8S duplicate samples were collected at a rate of ca. 2 samples per cast. RMS differences in absorption coefficient at 325 nm between the duplicate samples were just over 0.003 m^{-1} , which is ca. 4% of the average absorption coefficient at that wavelength.

We also concurrently collecting samples for bacterial abundance and DOM characterization (including carbohydrate and neutral sugar analysis) to compare the distribution of these quantities to that of CDOM. In surface waters (< 300m) we are also estimating bacterial productivity of field samples by measuring the uptake of bromo-deoxyuridine (BrdU), a non-radioactive alternative to the standard bacterial productivity technique using tritiated thymidine.

Because of the connections to light availability and remote sensing, we are collecting surface samples (from the ship's uncontaminated seawater system) for chlorophyll, carotenoid, and mycosporine-like amino acid pigment analysis (HPLC), chlorophyll a (fluorometric), and particulate absorption (spectrophotometric). We are sporadically collecting large volume (ca. 2L) samples for CDOM photolysis experiments back at UCSB, and occasionally collecting large volume samples for POC analysis to compare with transmissometer data. We have the cooperation of the Trace Metals group for the large-volume subsurface samples from their Go-Flo bottles. We are only analyzing the CDOM and chlorophyll a at sea and the rest of the samples we are preparing and storing for later analysis.

Outreach Team

The I8S Public Outreach Team is a collaboration between Pien Huang, Cassandra Lopez, and Daniel Park, formed through an independently submitted proposal to Chief Scientist Jim Swift. By using oceanography as an example, they intend to inform the public of the basic scientific process. They will reach both classrooms and the general adult public by means of written and multimedia features in print and on the web.

We have been documenting our experiences on an informal blog which has gathered a solid readership beyond our family and friends by becoming a surprise hit with Ms. Brice's 8th grade class. Throughout the cruise, we have been lucky to have had outreach opportunities presented to us. Mid-cruise, we were invited to submit materials to a new NSF program which feeds articles to the widely read and distributed website LiveScience.com. Our primary efforts, however, have been focused on gathering material for longer articles and a feature-length documentary.

We brought to this cruise very few preconceptions of oceanography, but through first-hand experience we have improved our understanding of ocean measurement. We've realized that data collection is a difficult and often tedious process, but having participated in field work we now appreciate this necessary effort in the context of developing and clarifying ocean and climate models. Better data inform better models which in turn will forecast climate to the benefit of society. We hope our projects will enable the public to see and value the contributions of every member of this cruise.

And of course we've really enjoyed our time on the Revelle and the chance we've had to work closely with so many fun and talented people!

Graduate Students

Each of the four graduate students was asked to write some form of report or comments of their choice about their participation.

JJ Becker (UCSD/SIO)

"Jim,

"Thanks for allowing me to participate on the I8S cruise. It was a pleasant trip and I hope I added something to effort. I especially enjoyed making the occasional plot and spreadsheet; always nice to be useful.

"I have down loaded the CTD and multi-beam data and plan on using it very soon in a upcoming paper relating the first derivative of each to the other.

"I greatly enjoyed my time with Rob. He has a pleasant manner and is a natural teacher. It was a pleasure to work with Jean again, as his knowledge of the ship and the science made my life easier and my time more productive.

"Finally it was pleasant and instructive to stand watch with you. I learned a great deal about the way NSF and the funding process really works and also enjoyed spending time with you. I hope I can participate again in another one of your cruises."

David Ullman (University of Wisconsin)

"My participation as a graduate student on board the I8S cruise has contributed immensely to my graduate education. I have been able to get a glimpse of the true nature of oceanography work. Back in the land-locked state of Wisconsin, I had been struggling with my research in carbon cycle modeling because of a disconnect between my first-hand work experience and my physical surroundings, never experiencing the deep blue sea in the flesh. I used to always joke that I study the North Atlantic in Wisconsin using a supercomputer in Colorado. Before embarking on this voyage, I was excited to resolve this disconnect.

Being my first time at sea, I did not know what to expect. Would I get sea sick? Could I do the work required of me? Would I enjoy the people on board? Would I like the food? Fortunately, the answer to all these questions was "yes" (unfortunately so was the first one, but I found my sea legs eventually).

"For the most part, the work was quite enjoyable, a different change of pace from my life of working with FORTRAN, FERRET, and MATLAB. Literally getting my hands dirty (and wet), I enjoyed the challenges that came with life on a ship, working on the rosette and its instruments and the related computing tools to "drive" this VW-beetle-on-a-wire to the ocean floor. Preparing the rosette allowed for a basic understanding of the mechanics of ocean data collection. Deployment and recovery were particularly challenging and exciting (I know I'm not supposed to use this word), a physical challenge to guide a 15 foot pole in 40 knot winds to attach a tag line in rough seas. Sampling and the art of the "sample-cop" was a fun time, usually a jovial yet professional atmosphere as everyone joked and sampled their way around the rosette. And while the actual "driving" of the rosette had its boring moments, I did enjoy sitting at the computer hearing Jim's sea/life stories and picking his brain for a better understanding for big-picture and small-scale physical oceanography. It was fun to watch the data write itself in front of our eyes, truly real-time oceanography.

"Perhaps the best part of this cruise were the people on board. From the stories I've heard, things are not always as nice as on this cruise. Everyone was pleasant, helpful, and knowledgeable. Life on this ship could have been much worse if the scientists and crew were not so agreeable. I feel fortunate to have experienced my first cruise with such a group. I really enjoyed hearing about everyone's previous experiences, quite amazing to have so many experts in oceanography in such a small amount of space. I felt comfortable to ask any kind of question, and most questions could be answered by someone on board. I really tried to draw upon all the expertise on board. My goal on this trip was to be a sponge for information. Fortunately there was a lot of water to absorb on a boat in the middle of the sea. I was particularly glad to have J.J. as my partner-in-crime, a man with a great amount of experience and knowledge (and a superior sense of humor). The pairing of experienced and inexperienced graduate students was a great idea.

"Finally, I would like express my great thanks to Jim Swift for allowing me to come along on this cruise. I know that it was quite a gamble to bring along some unknown kid from the Midwest all the way to the Southern Ocean, but I'm glad that he took the chance. I hope that my presence on this cruise was as helpful to the research goals of the project as it has been to my own education.

Dian Putrasahan (UCSD/SIO)

The I8S cruise is the first research cruise that I have participated and it has been a wonderful experience. At the beginning of the cruise, the main concern was the extent and duration of my seasickness. It was rather worrying if the motion sickness did not wear off, since it would affect my ability to work onboard. However, the one-and-a-half week steam to the first station gave ample time to adapt to the motion and switch my time schedule to get into the work shift (midnight to noon).

"Being a modeler, I had no idea how data is collected, how much effort it took and the obstacles that can occur such as equipment and instruments that would generate outrageous results or discontinuities, mechanical problems with the cable, human mistakes, data outliers, etc. This cruise has exposed me to some of the many problems that come along with data collection at sea, not only sampling uncertainties, but also working in rocky conditions. However, it was during this period of time that I got to learn many things.

"As a graduate student, the main task was to help deploy and retrieve the rosette, as well as sample for nutrients and salts. Occasionally, I would be on the console watching and relaying the wire out, observing the tension in the cable, and calculating how far deep the rosette can go, making sure it does not hit the bottom. In the course of casting at stations, one realizes the importance of teamwork for the deployment and retrieval of the rosette. There were 5 people on the deck working together to cast at the stations (2 at the outboard, one on the inboard, the resident technician (person in-charge) and the boom operator). It was very important to secure the taglines and ensuring they do not knot. For this, I learnt how to tie the bowline knot. Most of the time, I was the boom operator, in which I had to listen carefully for instructions to pull in or push out the frame and landing the rosette onto the cart. After the rosette has been retrieved, I would flush the sensors with freshwater and proceed to sample cop. A sample cop is there to make certain that samples were taken in the right sequence, with the extraction for gas samples given as a priority. Half-way through being a sample-cop, I would usually pass it on to someone else so as to help draw nutrient and salt samples. This in itself has now become second nature. Once all the samples have been taken, the Niskin bottles are then drained, and then I would that sample logs to make copies, scan them, and place them online for all to use. It is then followed by preparing the rosette for the next cast, which includes closing the vents and spigots and cocking the Niskin bottles.

"Aside from sampling, I had learnt to run salts on the auto-sampler. First it was learning how to do it, trying to have it become second nature. And then slowly noticing how the salinity profile looked like and comparing them to the CTD salinity profile. It was important to note the air and bath temperature (no more than +- 3°C between air and bath temperature) to avoid drifting of the salinity readings. The sensitivity of salinity to temperature was clearly visible when drifting occurred. It was also essential to observe how the cells fill up, whether bubbles formed, and the pump speed to use to obtain more stable and reliable readings. It was vital for the salt runs to keep up with the sampling as there is a limited number of sampling bottles. Many a times, longer intervals are given between stations so as to allow more time for the analysis of chemicals.

"This cruise has certainly given me great insights of doing fieldwork as an oceanographer. I have gained much knowledge and experience from it and would hope to contribute back from what I have received. I would be delighted to participate again in the future."

Lora Van Uffelen (UCSD/SIO)

"During the midnight to noon hours of the past six weeks I could barely be missed traversing the main hallway on the R/V Roger Revelle wearing a selection of brightly colored attire. This attire was indicative of the tasks I was performing during my stint as a CLIVAR I8-S student research assistant in the southern ocean.

"First of all, there was the mustang or "pumpkin" suit. This was a head-to-toe cocoon of vivid orange that kept me nice and warm out on the deck while we were deploying the rosette amongst the icebergs. It doubled as a safety work vest while we were handling tag lines, leaning over the side of the ship to hook the rosette, and bringing it safely back aboard.

"After the rosette was secured in the sampling bay, the pumpkin suit was traded for a pair of yellow rain pants for the water-sampling phase of the rosette process. These coveralls were protection against the sometimes sub-zero waters that came spilling out of the 36 Niskin bottles as we worked our way around the rosette filling flasks for nutrient and salt analysis.

"Lastly, there was the LADCP "uniform," which consisted of a pair of brightly colored Croc shoes and the teal LADCP fanny pack. The Crocs were only part of the uniform because coincidentally Dr. Jules Hummon, who graciously imparted her knowledge of Lowered Acoustic Doppler Current Profilers, happened to wear orange Croc shoes while I sport yellow ones. I had the opportunity on this cruise to learn a lot about the instrumentation and data collection process of the LADCP, and was able to look at some of the data immediately after it was acquired. This was particular interest to me since my research area is ocean acoustics. The fanny pack held such treasures as black electrical tape, which was used to seal the dummy plug onto the instrument's connector before it was deployed, and paper towels and kimwipes to dry the connector after recovery. After the package was brought on deck, the data was downloaded and quality checked and the battery was recharged for the next cast.

"Other things that kept us busy were monitoring the progress of the CTD as it descended, tripping bottles at specified depths on its ascent to the surface, preparing the rosette for a cast by cocking the bottles open, and playing sample cop while the various sampling groups took their turns around the rosette. Despite the darkness of the night shift hours, this cruise was full of not only bright colors, but also great experiences. Besides my introduction to the LADCP, I have learned more about the geography and oceanography of the southern ocean, have seen my first iceberg and my first aurora australis, and I finally know how to tie a bowline."