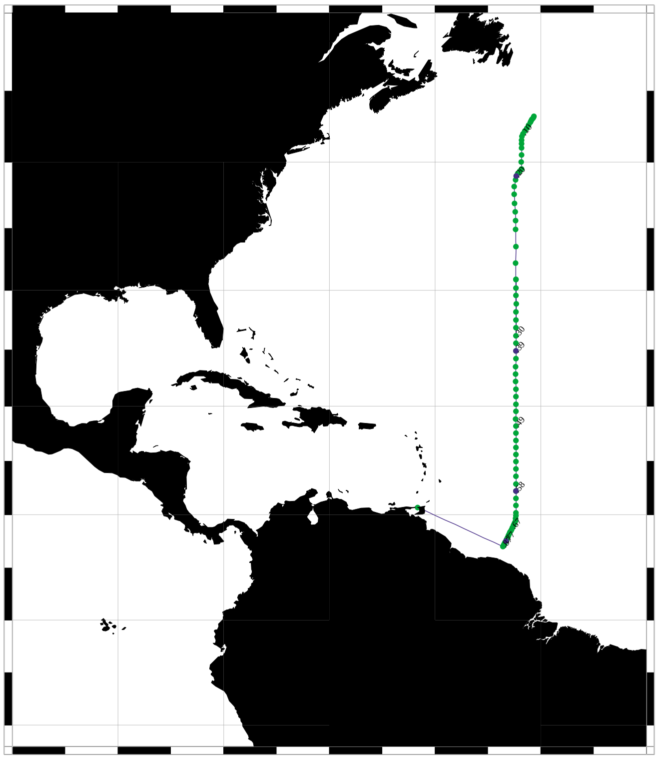
A. Cruise Narrative (A20_2003a)

A.1 Highlights



WHP Cruise Summary Information

WOCE section designation	**A20_2003a**
Expedition designation (ExpoCode)	**316N200309**
Chief Scientists and their affiliation	**Dr. John Toole / WHOI** **Dr. Alison MacDonald / WHOI**
Dates	2003 September 22 - 2003 October 20
Ship	*R/V Knorr*
Ports of call	Woods Hole, Ma. - Port of Spain, Trinidad
Number of stations	88
Stations' Geographic boundaries	43°14.98'N 61°38.8'W 50°36.97'W 6°58.63'N
Floats and drifters deployed	5 profiling ARGO floats
Moorings deployed or recovered	0
Contributing Authors	None listed
Data Submitted by:	Oceanographic Data Facility Scripps Institution of Oceanography La Jolla, Ca 92093-0214

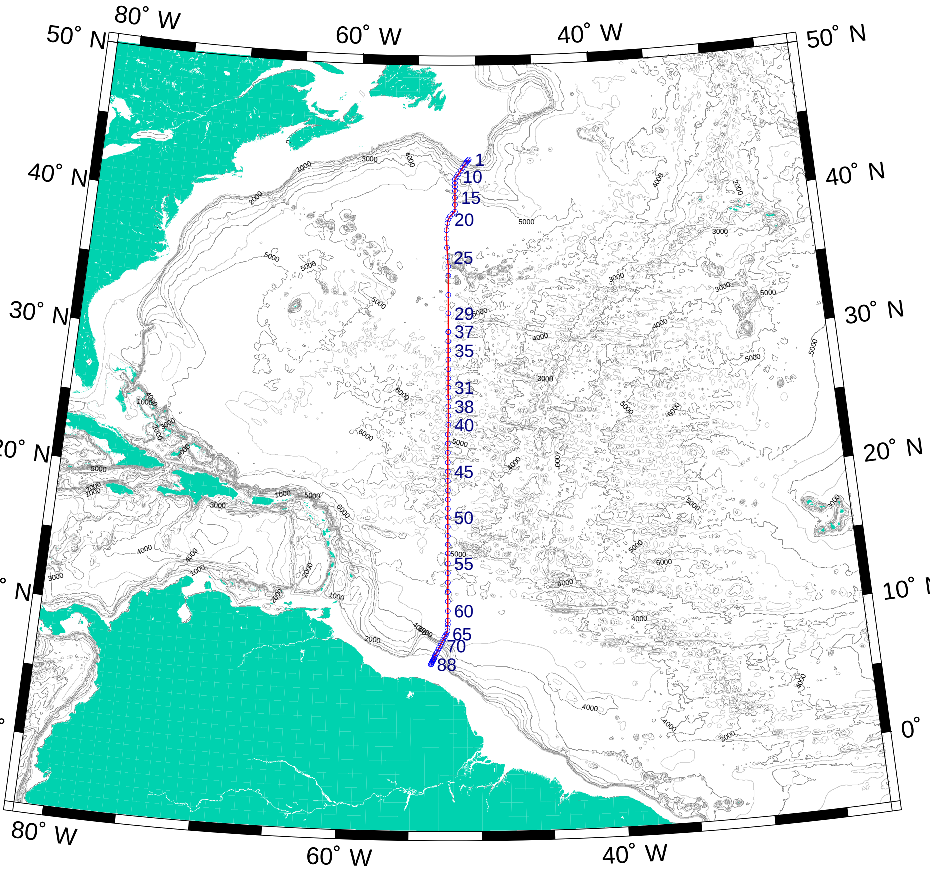
WHP Cruise and Data Information

Click on headings below to locate primary reference or use navigation tools above. (Shaded headings were not available when this report was assembled)

Cruise Summary Information	Hydrographic Measurements
Description of scientific program	**CTD Data**
	CTD - general
Geographic boundaries of the survey	CTD - pressure
Cruise track SIO PI	CTD - temperature
Description of stations	CTD - conductivity/salinity
Description of parameters sampled	CTD - dissolved oxygen
Bottle depth distributions (figures)	
Floats and drifters deployed	**Bottle Data**
Moorings deployed or recovered	Salinity
	Oxygen
Principal Investigators for all measurements	Nutrients
Cruise Participants	CFCs
	Helium
Problems and goals not achieved	Tritium
Other incidents of note	Radiocarbon
	CO_2 system parameters
Underway Data Information	Other parameters
Navigation	**DQE Reports**
Bathymetry	CTD
Acoustic Doppler Current Profiler (ADCP)	S/O_2/nutrients
Thermosalinograph and related measurements	CFCs
XBT and/or XCTD	^{14}C
Meteorological observations	
Atmospheric chemistry data	
Acknowledgments	**Data Processing Notes**

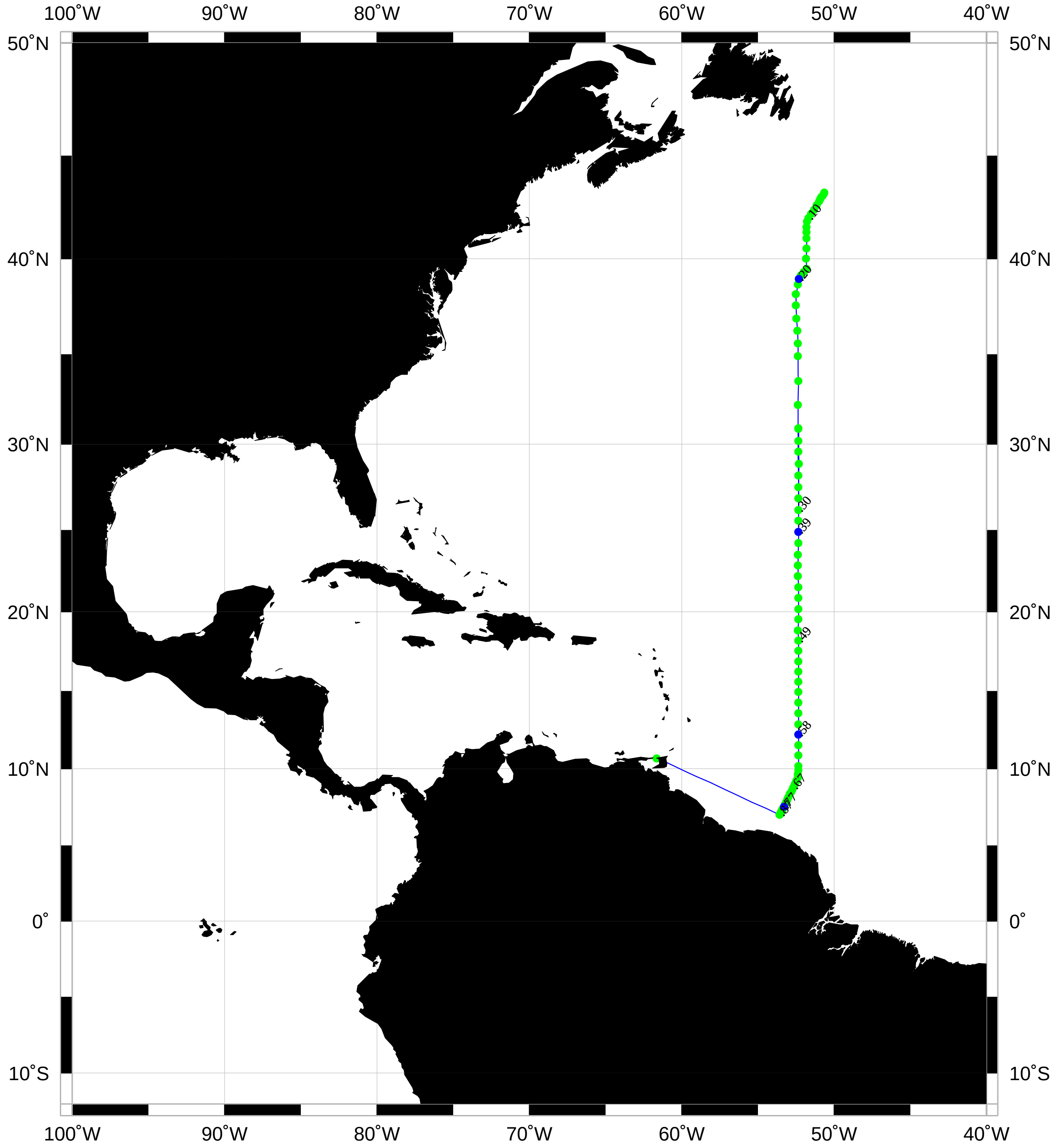
References
Measurement Techniques
Dissolved Inorganic Carbon

A20-2003a • *R/V Knorr* • Toole / MacDonald



Submitted by ODF

Station locations for A20_2003a • Toole/MacDonald



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Summary

A hydrographic survey consisting of LADCP/CTD/rosette sections and float deployments in the western North Atlantic was carried out September to October 2003. The R/V Knorr departed Woods Hole, Ma. on 22 September 2003. A total of 88 LADCP/CTD/Rosette stations were occupied, and 5 profiling ARGO floats were deployed from 24 September - 18 October. Water samples (up to 36), LADCP and CTD data were collected in most cases to within 10 meters of the bottom. Salinity, dissolved oxygen and nutrient samples were analyzed from every bottle sampled on the rosette. The cruise ended in Port of Spain, Trinidad on 20 October 2003.

Introduction

Knorr cruise 173 was conceived to reoccupy two meridional hydrographic sections in the western North Atlantic as part of the CLIVAR/Global Carbon Program of repeat hydrography. The section designated "A20" by the World Ocean Circulation Program that lies nominally along 52° 20'W was sampled during leg 1. The return leg to Woods Hole reoccupied the A22 section along 66° W. Meridional hydrographic sections near 52° W had been made on three occasions prior to our cruise: in the 1950's, 1980's, and in 1997. The sampling plan for the 2003 occupation was simply to make a full-depth hydrographic station at (virtually) each site sampled in 1997. (The extremely tight station spacing at the northern end of the section done in 1997 was relaxed slightly in 2003.)

A sea-going science team gathered from ten oceanographic institutions around the U.S. participated on the cruise. Several other science programs were supported with no dedicated cruise participant. The science party and their responsibilities are listed below:

Science party and responsibilities

John Toole	Chief Scientist	WHOI
Alison Macdonald	Co-Chief Scientist	WHOI
Rebecca Zanzig	Student participant	UW

Hydrographic Operations and Data Analysis

Scott Allen		SIO
Ruth Curry		WHOI
Frank Delahoyde		SIO
Carl Mattson		SIO

Water sample analysts

John Calderwood	Oxygen	SIO
Bettina Sohst	Oxygen	UCSC
Susan Becker	Nutrients	SIO
Erik Quiroz	Nutrients	U. Southern Miss.
Deborah LeBel	CFC	LDEO
James Happell	CFC	RSMAS
Eugene Gorman	CFC	LDEO
Ryan Ghan	CFC	LDEO
Marilyn Roberts	DIC	PMEL
Kevin Sullivan	DIC	AOML
George Anderson	TALK	SIO
J. Martin Hernandez Ayon	TALK	SIO
Josh Curtis	He-3/Tritium	WHOI
Norm Nelson	CDOM,DOC,DON	UCSB

Jonathan Klamberg	CDOM,DOC,DON	UCSB
Stuart Goldberg	CDOM,DOC,DON	UCSB
Tim Newberger	LADCP	LDEO

R/V Knorr Science Technicians

Robert Laird
Amy Simoneau

Other science programs

Shipboard ADCP	Eric Firing	U. Hawaii
	Jules Hummon	U. Hawaii
Surface C14	Ann McNichol	WHOI
	Robert Key	Princeton
C13 profiles	Paul Quay	UW
Profiling ARGO floats	Allyn Clarke	BIO, Canada
Transmissometer profiles	Wilf Gardner	TAMU

Cruise Narrative

Skirting Hurricane Fabian during her transit from the Mediterranean, the R/V Knorr arrived back in Woods Hole on schedule and was available for loading during the week of September 15. Most groups took full advantage of this time to set up and test their instrumentation. Fortunately the threat that Hurricane Isabel would disrupt these activities was averted when that storm passed well inland of the Cape. Departure from Woods Hole occurred at 1300 local on September 22 in fine weather.

Unlike in 1997 when the section was staged out of Halifax, Nova Scotia, we were immediately faced with a 3-day transit to the head of the section at the southern tip of the Grand Banks. Enroute to the Banks, a full-depth test station was occupied in approximately 4000 m of water on Sept. 24. Station 1 of the A20 section was occupied in the evening of September 25.

Study of satellite-derived sea surface temperature images, both relayed from shore and captured directly aboard Knorr with the Terascan system, suggested the presence of a warm water flare extending north from the Gulf Stream that nearly paralleled our planned station track. We therefore diverged from the 1997 station plan at station 11, orienting the next set of casts along 51° 48’ W to sample east of the flare. After grazing the western edge of a small Gulf Stream Ring, the section extended south on this meridian within a trough (southward meander) of the Stream until intersecting the "North Wall" at station 17. Shipboard ADCP data showed strong surface currents directed to the Southeast here, and so the station track was adjusted to the Southwest to cross the Gulf Stream more-or-less perpendicularly to the flow. As the surface currents turned more zonal with distance south, the section track was oriented more meridionally.

Profiling drifting floats supplied by Allyn Clarke (Bedford Institute of Oceanography) were deployed at predetermined sites along this segment of the A20 track. During this period, Hurricane Juan formed and moved north to our west, eventually striking Haifax, Nova Scotia.

By station 26 at Lat. 35.5° N we were across the main core of the Gulf Stream and back on the 1997 station plan that placed stations every 40 nmi through the center of the subtropical gyre. But intensifying to our east was Hurricane Kate that forecasts showed would soon intersect our cruise track. Hoping to extend south of her projected course, station spacing was widened to 80 nmi (skipping every other planned station) between latitudes 34.8° and 33.5° N (Stas. 27-29). Facing increasing winds and swells, the planned station at 30° 51’N was deferred and we ran south to escape the storm.

Sampling resumed with Station 30 situated at 26.2° N on the nominal A20 meridian, with subsequent stations directed back to the north at 40 nmi spacing. By adjusting weight on the water-sampler frame and reducing lowering/raising rates on the sea cable, we were able to slowly work our way back to the deferred station site despite rather confused swell and wave conditions. Sea cable re-terminations were required after several of these stations to remove wire kinks presumably caused by snap loading of the sea cable caused by ship roll/heave. Upon completion of the station at 30° 51’ N (number 37) we transited back south to resume working the line. During the transit (referred to by one New Englander as a "school snow day") many of the science party and crew put up with very poor radio reception to cheer the Red Sox to victory in Game 5 against the A’s. Station 38 at Lat. 25.5° N was occupied in the late afternoon of October 7 in much improved weather and sea conditions.

The station work was continued south as planned along the nominal A20 longitude to station 64 in excellent weather conditions. Thereafter, the cruise track was directed to the southwest in order to perpendicularly cross the bathymetric contours off the Surinam coast. At this time, tropical storm/hurricane Nicholas began to form east of our track about Longitude 48° W. Fortunately it was far enough west and north of our position that it did not impact our sampling. However, dense cloud cover and rain were experienced for the first time on the cruise, impacting the UCSB incubation experiments.

During the up-cast of Station 66, one of the electrical conductors in the sea cable developed a short to ground. The underwater package was recovered and operations were shifted to the other winch/wire system. A second cast was made at this site to pick up the upper-ocean water samples that were missed after the wire problem. Just landward of Station 66, we crossed into the territorial waters of Surinam. All underway data files were closed and reopened at this point to facilitate delivery of territorial-waters data to Surinam. During station work on the evening of October 17/18 the R/V Knorr contingent of Red Sox Nation was agonized by their team’s loss of ALCS game 7 to the Yankees.

Hydrographic sampling on the A20 line was completed on October 18 at 02:51 GMT with station 88 at 6° 59.0’ N, 53° 34.2’ W in 77 m of water. The vessel was then directed to Trinidad, arriving off Port O’Spain in the morning of October 20. R/V Knorr was secured quayside by 09:10 and was cleared shortly thereafter.

Apart from the three stations that were skipped about the middle of the subtropical gyre when we were running from Hurricane Kate, all other planned hydrographic stations were successfully occupied. The science parties and the officers and crew of the R/V Knorr are to be commended for their hard work and careful measurements. All of the sampling teams were briefed on the schedule for submitting preliminary and final data sets and agreed to meet the target submission dates.

1. Description of Measurement Techniques

1.1. CTD/Hydrographic Measurements Program

The basic CTD/hydrography program consisted of salinity, dissolved oxygen and nutrient measurements made from bottles taken on CTD/rosette casts, plus pressure, temperature, salinity, dissolved oxygen and transmissometer from CTD profi les. A total of 92 CTD/rosette casts were made, usually to within 10 meters of the bottom. No major problems were encountered during the operation. The distribution of samples is illustrated in fi gures 1.1.0, 1.1.1, 1.1.2, and 1.1.3.

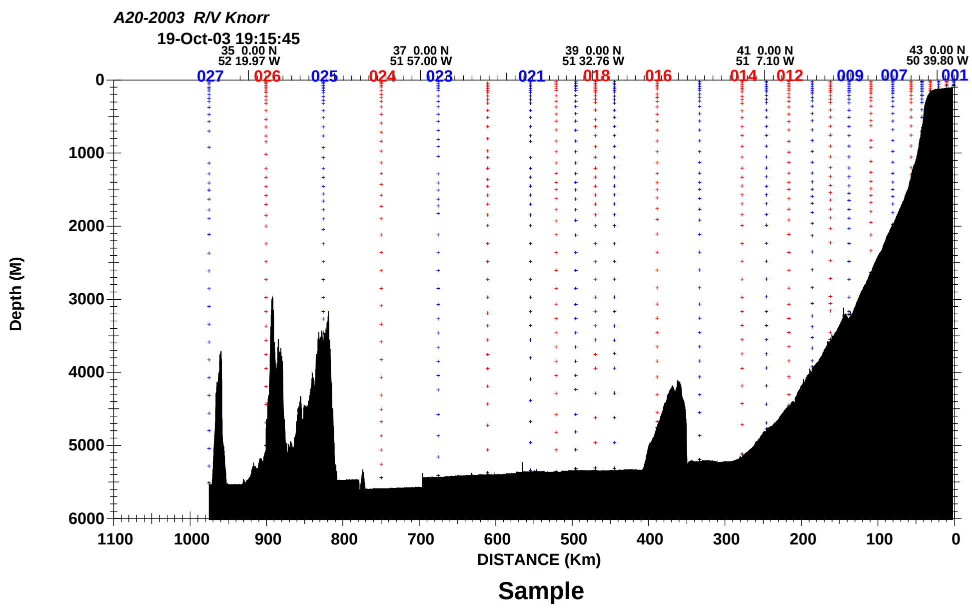


Figure 1.1.0 Sample distribution, stations 1-27.

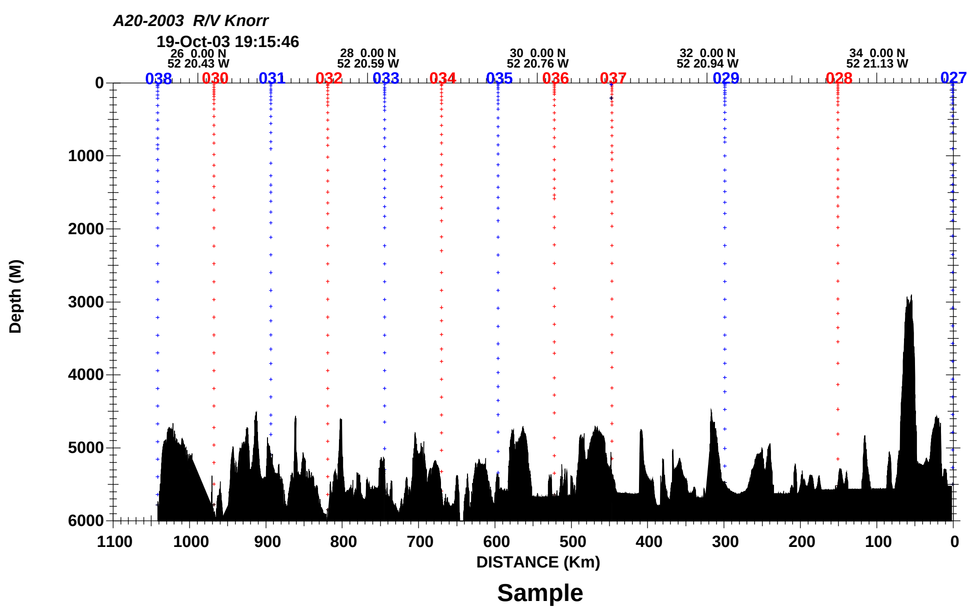
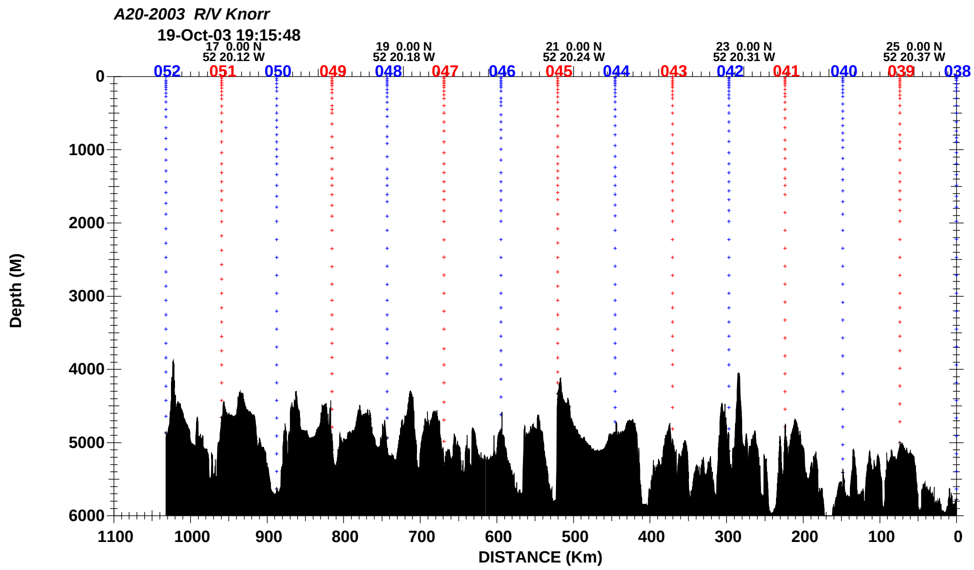
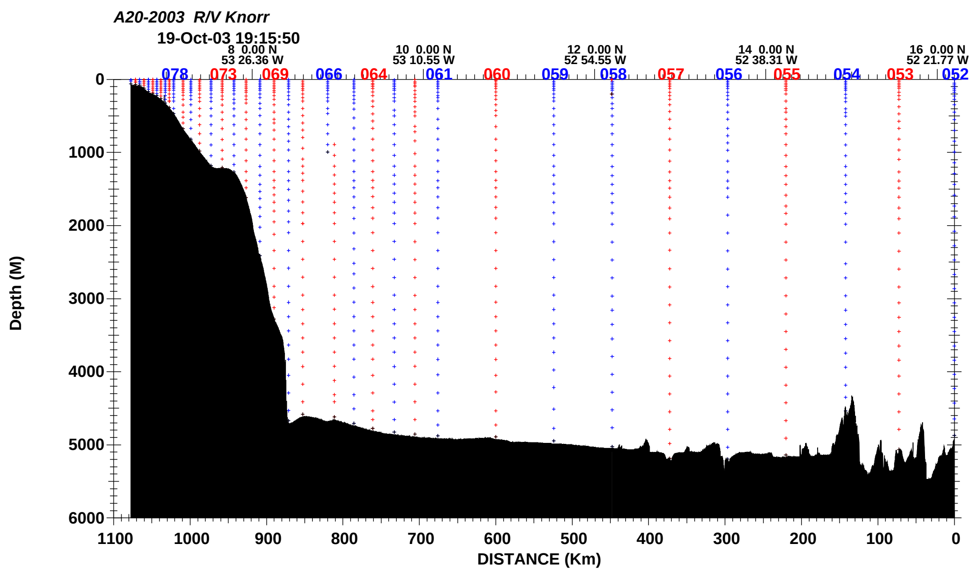


Figure 1.1.1 Sample distribution, stations 27-38.



Sample

Figure 1.1.2 Sample distribution, stations 38-52.



Sample

Figure 1.1.3 Sample distribution, stations 52-88.

1.2. Water Sampling Package

LADCP/CTD/rosette casts were performed with a package consisting of a 36-bottle rosette frame (ODF), a 36-place pylon (SBE32) and 36 10-liter Bullister bottles (ODF). Underwater electronic components consisted of a Sea-Bird Electronics (SBE) 9*plus* CTD (ODF #474) with dual pumps, dual temperature (SBE3), dual conductivity (SBE4), dissolved oxygen (SBE43), transmissometer (Wetlabs C-Star) and fluorometer (Seapoint Sensors); an SBE35RT Digital Reversing Thermometer, RDI LADCPs (Workhorse 300khz/Broadband 150khz) and a Simrad 1007 altimeter.

The CTD was mounted horizontally along one side of the bottom center of the rosette frame. The SBE sensors and pumps were deployed horizontally along the CTD pressure case, as were the transmissometer and fluorometer. The LADCP battery pack was mounted alongside and outboard from the CTD. The LADCPs were vertically mounted inside the bottle rings on the opposite side of the frame from the CTD and LADCP battery pack, with one set of transducers pointing down, the other up. The SBE35RT temperature sensor was mounted horizontally on a support strut, within 0.25 meters of the CTD pump intakes. The altimeter was mounted on the inside of support strut outboard from the LADCP battery pack.

The rosette system was suspended from a UNOLS-standard three-conductor 0.322" electro-mechanical sea cable. The R/V Knorr's starboard-side CTD winch was used on stations 1-11 and 30-66. This winch developed mechanical problems on cast 11/1, and a sea cable short on cast 66/1. The port-side CTD winch was used on stations 12-29 and 66-88. The sea cable on this winch developed numerous kinks due to storm surge twisting, particularly on cast 36/1. Several sea cable reterminations were made on this cruise.

The deck watch prepared the rosette 10-20 minutes prior to each cast. All valves, vents and lanyards were checked for proper orientation. The bottles were cocked and all hardware and connections rechecked. Once stopped on station, the LADCP was turned on and the rosette moved into position under the starboard boom via an air-powered cart and tracks. As directed by the deck watch leader, the CTD was powered-up and the data acquisition system started. Two stabilizing tag lines were threaded through rings on the rosette frame, and syringes were removed from the CTD sensor intake ports. The deck watch leader directed the winch operator to raise the package, the 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. The CTD console operator then directed the winch operator to bring the package close to the surface, pause for typically 30 seconds and begin the descent.

Each rosette cast was lowered to within 10-20 meters of the bottom (with a few exceptions).

Each Bottle on the rosette had a unique serial number. This bottle identifi cation was maintained independently of the bottle position on the rosette, which was used for sample identifi cation. No bottles were changed or replaced on this leg, although parts of a few of them were replaced or repaired.

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 air tugger-powered tag lines for added safety and stability. The rosette was moved into the CTD hangar for sampling. The bottles and rosette were examined before samples were taken, and anything unusual noted on the sample log.

Routine CTD maintenance included soaking the conductivity and CTD DO sensors in distilled water between casts to maintain sensor stability. Rosette maintenance was performed on a regular basis. O-rings were changed as necessary and bottle maintenance was performed each day to insure proper closure and sealing. Valves were inspected for leaks and repaired or replaced as needed.

1.3. Underwater Electronics Packages

CTD data were collected with a SBE9*plus* CTD (ODF #474). This instrument provided pressure, dual temperature (SBE3), dual conductivity (SBE4), dissolved oxygen (SBE43), transmissometer (Wetlabs C-Star), fluorometer (Seapoint Sensors) and altimeter (Simrad 1007) channels. CTD #474 supplied a standard Sea-Bird format data stream at a data rate of 24 frames/second (fps).

Sea-Bird SBE32 36-place Carousel Water Sampler	S/N 0187
Sea-Bird SBE35RT Digital Reversing Thermometer	S/N 0034
Sea-Bird SBE9*plus* CTD	S/N 09P9852-0474
Paroscientifi c Digiquartz Pressure Sensor	S/N 69008
Sea-Bird SBE3*plus* Temperature Sensor	S/N 03P-4138 (Primary)
Sea-Bird SBE3*plus* Temperature Sensor	S/N 03P-2359 (Secondary)
Sea-Bird SBE4C Conductivity Sensor	S/N 04-2419 (Primary)
Sea-Bird SBE4C Conductivity Sensor	S/N 04-1908 (Secondary 1/1-1/17)
Sea-Bird SBE4C Conductivity Sensor	S/N 04-2572 (Secondary 18/1-57/1)
Sea-Bird SBE4C Conductivity Sensor	S/N 04-2319 (Secondary 58/1-88/1)
Sea-Bird SBE43 DO Sensor	S/N 43-0255
Wetlabs C-Star Transmissometer	S/N 507DR
Seapoint Sensors Fluorometer	S/N 2273
Simrad 1007 Altimeter	S/N 0201075
RDI Workhorse 300khz LADCP	S/N 3898-XR
RDI Workhorse 300khz LADCP	S/N 3898-VXR
RDI Workhorse 300khz LADCP	S/N 149
RDI Workhorse 300khz LADCP	S/N 150
RDI Workhorse 300khz LADCP	S/N 754
RDI Broadband 150khz LADCP	S/N 1546
LADCP Battery Pack	

Table 1.3.0 A20 Rosette Underwater Electronics.

The CTD was outfi tted with dual pumps. Primary temperature, conductivity and dissolved oxygen were plumbed on one pump circuit and secondary temperature and conductivity on the other. The primary temperature and conductivity sensors (T1 #4138 and C1 #2419) were used for reported CTD temperatures and conductivities on casts 1/1-1/57. The secondary temperature and conductivity sensors (T2 #2359 and C2 #2319) were used on casts 58/1-88/1.

The SBE9 CTD and the SBE35RT Digital Reversing Thermometer were both connected to the SBE32 36-place pylon providing for single-conductor sea cable operation. All 3 sea cable conductors were connected together to improve reliability. Power to the SBE9 CTD, SBE32 pylon, and SBE35RT was provided through the sea cable from the SBE11*plus* deck unit in the main lab. The Simrad altimeter and LADCP were powered by battery packs.

1.4. Navigation and Bathymetry Data Acquisition

Navigation data were acquired (at 1-second intervals) from the ship's Seanav GPS receiver by one of the Linux workstations beginning September 22. Data from the ship's Knudsen 320B/R Echosounder (12 KHz transducer) were also acquired, corrected using Carter tables [Cart80] and merged with the navigation. The Knudsen bathymetry data were noisy and subject to washing out on station when the bow thrusters were engaged.

Bathymetric data from the ship's multibeam (SeaBeam) echosounder system were also logged by the R/V Knorr's underway system.

1.5. Real-Time CTD Data Acquisition System

The CTD data acquisition system consisted of an SBE-11*plus* deck unit and four networked generic PC workstations running RedHat 9 Linux. Each PC workstation was confi gured with a color graphics display, keyboard, trackball, 60 GB disk, CD-R and CDRW drives. Two of the four systems also had 8 additional RS-232 ports via a Rocketport PCI serial controller. The systems were networked through 2 100BaseTX ethernet switches which were also connected to the ship's network. These systems were available for real-time operational and CTD data displays, as well as providing for CTD and hydrographic data management and backup. Hardcopy capability was provided by a networked HP 1600CM color printer.

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 for controlling CTD deployments as well as real-time operational displays for CTD and rosette trip data, GPS navigation, bathymetry and the CTD winch.

CTD deployments were initiated by the console watch once the ship was stopped on station. A console operations log was maintained by the watch containing a description of each deployment, a record of every attempt to close a bottle and any pertinent comments. The deployment software presented the operator with a short dialog instructing them to turn on the deck unit, examine the on screen raw data display for stable CTD data and to notify the deck watch that this was accomplished. When the deck watch was ready to put the rosette over the side, the console watch was notified and the CTD data acquisition started. Time, GPS position and bottom depth were automatically logged at 1 second resolution. Both raw and processed (2 Hz time-series) CTD data were automatically backed up by one of the other workstations via ethernet. The deployment software display changed to indicate that a cast was in progress. A processed data display appeared, as did a rosette bottle trip display and control for closing bottles. Various real-time plots were then initiated to display the progress of the deployment.

Once the deck watch had deployed the rosette, the winch operator would immediately lower it to 10 meters. The CTD pumps were configured with an 8 second startup delay, and would be on by this time. The console operator would check the CTD data for proper operation, then instruct the winch operator to bring the package to the surface and then descend to a target depth (wire-out). The lowering rate was normally 60 meters/minute for this package, depending on sea cable tension and sea state.

The console watch monitored the progress of the deployment and quality of the CTD data through interactive graphics and operational displays. Additionally, the watch decided where to trip bottles on the up cast, noting this on the console log. The altimeter channel, CTD depth, wire-out and bathymetric depth were monitored to determine the distance of the package from the bottom. The on-screen winch and altimeter displays allowed the watch to refine the target wire-out relayed to the winch operator and safely approach to within 10-20 meters of the bottom.

Bottles were closed on the up cast by operating a "point and click" graphical trip control button. The data acquisition system responded with trip confirmation messages and the corresponding CTD data in a rosette bottle trip window on the display. All tripping attempts were noted on the console log. The console watch then directed the winch operator to raise the package up to the next bottle trip location. The console watch was also responsible for creating a sample log for the deployment which was used to record the correspondence between rosette bottles and analytical samples taken.

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

1.6. CTD Data Processing

ODF CTD processing software consists of over 30 programs running in a Unix run-time environment. The initial CTD processing program (ctdrtd/ctdba) is used either in real-time or with existing raw CTD data to:

- Convert raw CTD scans into scaled engineering units, and assign the data to logical channels
- Filter various channels according to specified criteria
- Apply sensor- or instrument-specific response-correction models
- Decimate the channels according to specified criteria
- Store the output time-series in a CTD-independent format

Once the CTD data are reduced to a standard format time-series, they can be manipulated in various ways. Channels can be additionally filtered. The time-series can be split up into shorter time-series or pasted together to form longer time-series. A time-series can be transformed into a pressure-series, or into a larger-interval time-series. The pressure, temperature and conductivity laboratory calibration coefficients are applied during the creation of the initial time-series. Oxygen conversion equation coefficients and any adjustments to pressure, temperature or conductivity are maintained in separate files and are applied whenever the data are accessed.

The CTD data acquisition software acquired and processed the data in real-time, providing calibrated, processed data for interactive plotting and reporting during a cast. The 24 Hz data from the CTD were filtered, response-corrected and decimated to a 2.0 Hz time-series. Sensor correction and calibration models were applied to pressure, temperature, conductivity and O_2. Rosette trip data were extracted from this time-series in response to trip initiation and confirmation signals. The calibrated 2.0 Hz time-series data, as well as the 24 Hz raw data, were stored on disk and were backed up via ethernet to a second system. At the end of the cast, various consistency and calibration checks were performed, and a 2-db pressure-series of the down cast was generated and subsequently used for reports and plots.

CTD data were examined graphically at the completion of deployment for potential problems. The two CTD temperature sensors were compared, intercompared with the SBE35RT Digital Reversing Thermometer and checked for sensor drift. CTD conductivity sensors were compared and monitored by examining differences between CTD values and check-sample conductivities. Additionally, deep theta-salinity comparisons were made between down and up casts as well as adjacent deployments. The CTD O_2 sensor data were calibrated to bottle check-sample data.

The sea cable/winch problems on this cruise did not significantly affect the CTD data, any noise being filtered out during the data acquisition. No additional filtering was done on any of the CTD data.

The initial 10 M yo in each deployment resulting from lowering then raising the package to the surface to start the pumps was removed during the generation of the 2.0 db pressure-series.

Density inversions can be induced in high-gradient regions by ship-generated vertical motion of the rosette. Detailed examination of the raw data shows significant mixing can occur in these areas because of "ship roll". To minimize density inversions, a "ship-roll" filter which disallowed pressure reversals was applied during the generation of all 2.0 db pressure-series down-cast data.

1.7. CTD Laboratory Calibration Procedures

Laboratory calibrations of the CTD pressure, temperature and conductivity sensors were used to generate Sea-Bird conversion equation coefficients applied by the data acquisition software at sea.

Pressure calibrations were last performed on CTD #474 at the ODF Calibration Facility (La Jolla) 26 August 2003, immediately prior to A20-2003.

The Paroscientific Digiquartz pressure transducer (S/N 69008) was calibrated in a temperature-controlled water bath to a Ruska Model 2400 Piston Gauge Pressure Reference. Calibration curves were measured at 4 temperatures from -1.38 to 29.30° C to two maximum loading pressures (1191 and 6081 decibars).

The SBE3*plus* temperature sensors (primary S/N 03-4138, secondary S/N 03-2359) were calibrated at SBE on 08 August 2003.

The SBE4 conductivity sensors (primary S/N 04-2419, secondaries S/Ns 04-1908, 04-2572 and 04-2319) were calibrated on 08 August 2003, 08 August 2003, 08 August 2003 and 03 May 2003 at SBE respectively..

The SBE35RT Digital Reversing Thermometer (S/N 0034) was calibrated on 05 April 2002 at SBE.

Laboratory pressure, temperature and conductivity calibrations will be repeated post-cruise.

1.8. CTD Shipboard Calibration Procedures

CTD #474 was used for all A20-2003 casts. Secondary temperature and conductivity sensors served as calibration checks for the primary temperature and conductivity on casts 1/1-57/1, and were used for reported data (the primary temperature and conductivity sensors serving as calibration checks) on casts 58/1-88/1. The SBE35RT Digital Reversing Thermometer served as an independent temperature calibration check. *In-situ* salinity and dissolved O_2 check samples collected during each rosette cast were used to calibrate CTD conductivity and dissolved O_2.

1.8.1. CTD Pressure

Pressure sensor conversion equation coefficients derived from the pre-cruise pressure calibration were applied to raw pressures during each cast. No additional adjustments were made to the calculated pressures, but the pressure was lagged (tc=1.4 secs) on casts 1/1-57/1 to better match the T1/C1 response due to pump alignment problems.

Residual offsets at the beginning and end of each cast (the difference between the fi rst/last pressures in-water and 0) were monitored during the cruise to check for shifts in the pressure calibration. All residual differences were 0.5 decibar or less.

There was no apparent shift in pressure calibration during the cruise. This will be verifi ed by a post-cruise laboratory pressure calibration.

1.8.2. CTD Temperature

Temperature sensor calibration coeffi cients were derived from the pre-cruise calibrations and applied to raw primary and secondary temperatures.

Two independent metrics of calibration accuracy were examined. The primary and secondary temperatures were compared at each rosette trip, and the SBE35RT and primary temperatures were compared at each rosette trip. These comparisons are summarized in fi gures 1.8.2.0 and 1.8.2.1.

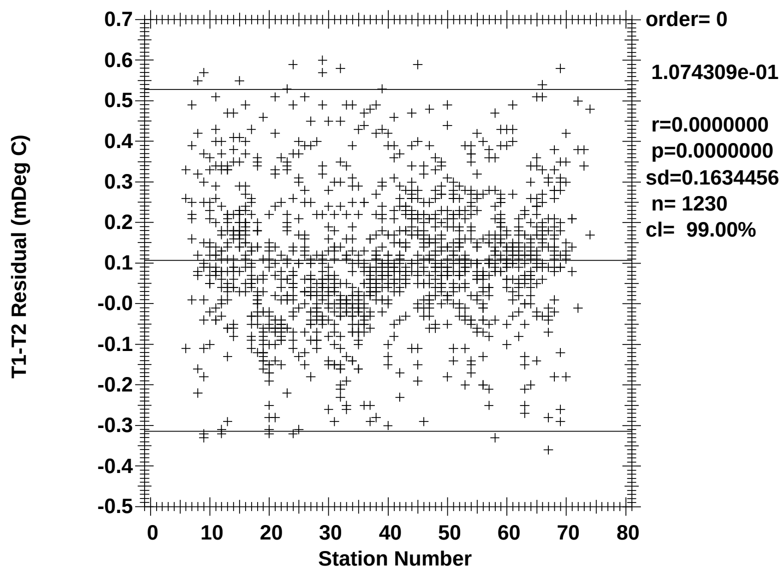


Figure 1.8.2.0 Primary and secondary temperature comparison, p>1000db.

The comparison between primary and secondary temperatures shows a small (0.00011 °C) mean calibration offset, well within the reported accuracy of the SBE temperature calibrations.

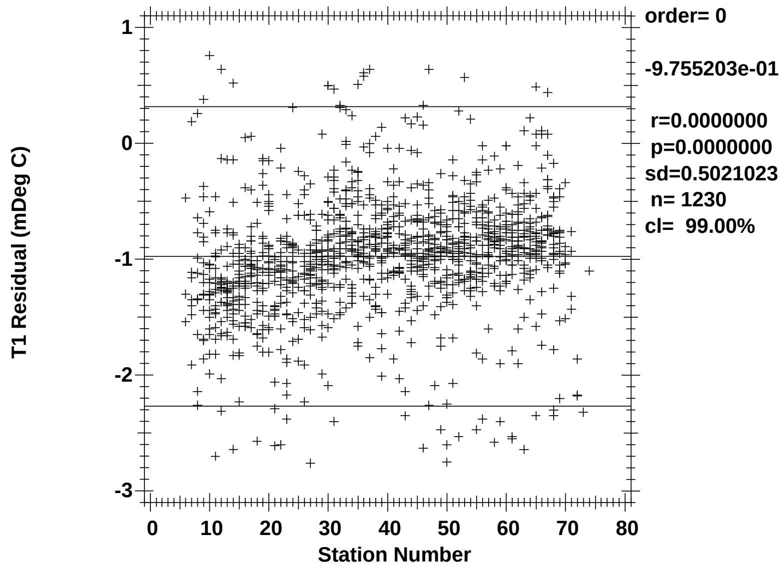


Figure 1.8.2.1 Primary and SBE35RT temperature comparison, p>1000db.

The comparison between SBE35RT and T1 temperatures shows a distinct linear trend as well as a mean difference of -0.00098° C. Given the age of the SBE35 calibration (05 April 2002) and the unlikelihood that both T1 and T2 would track so closely if they were both drifting, these differences are attributed to the SBE35RT.

1.8.3. CTD Conductivity

Conductivity sensor conversion equation coefficients were derived from the pre-cruise calibrations and applied to raw primary and secondary conductivities.

Three secondary conductivity sensors were used on A20: #1908 (1/1-17/1), #2572 (18/1-57/01) and #2319 (58/1-88/1). The first two secondary sensors were replaced because of excessive noise and drift. The third sensor was stable. Prior to cast 58/1 C1-C2 conductivity differences were not a useful metric of calibration accuracy.

The primary conductivity sensor (#2419) was fairly stable and noise-free. Comparisons to bottle salinities showed a mean conductivity correction slope of -0.000309376 and well-behaved offset groupings. The conductivity correction offsets are summarized in figure 1.8.3.0.

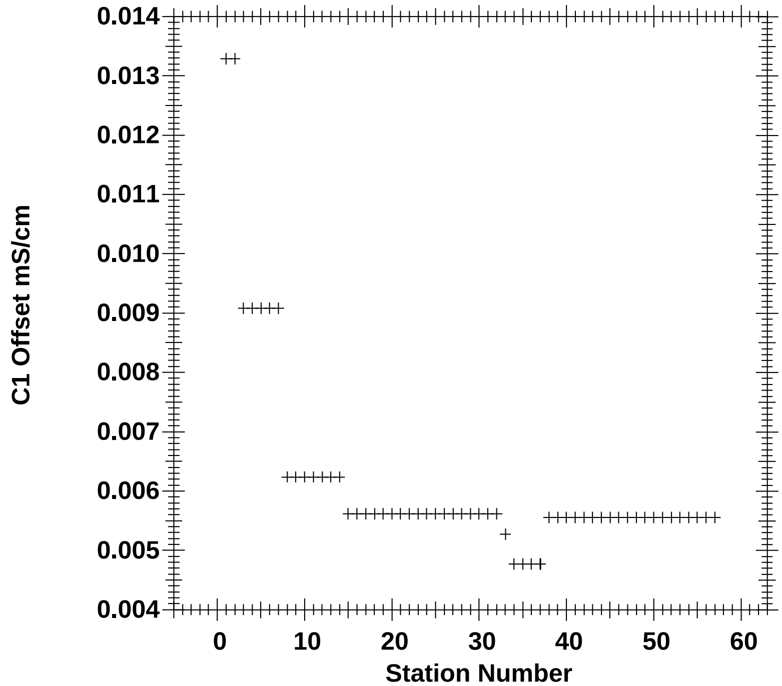


Figure 1.8.3.0 Primary conductivity correction offsets.

Comparisons of the stable secondary conductivity sensor (#2319) to bottle salinities showed no significant conductivity correction slope and a minor constant offset of 0.00021 mS/cm.

A systematic uniform offset of 0.0015 PSU between downcast and upcast C1 salinities was observed prior to cast 58/1. This was attributed to the sensor and pump configuration (horizontal) and the location of the P1 pump exhaust port (˜30° from vertical, per SBE specs). Both P1 and P2 pumps were rotated so that the exhaust ports were aligned horizontally and the C1 salinity offset was reduced to ˜0.0007 PSU. C2 exhibited almost no offset. This discrepancy was perhaps due to the inclusion of the SBE43 DO sensor in the P1 circuit. As a result of this experiment, T2 and C2 were used for reported salinities and temperatures on casts 58/1-88/1. Correcting T1/C1 salinities for casts 1/1-57/1 was done by applying a lag (tc=1.4 seconds) to pressure.

The salinity residuals after applying the shipboard calibration are summarized in figures 1.8.3.1 and 1.8.3.2.

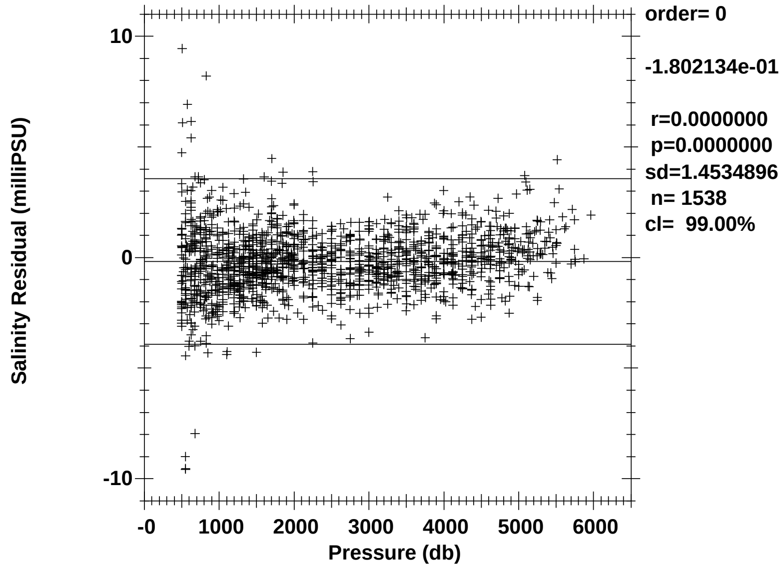


Figure 1.8.3.1 C1 and C2 salinity residuals by pressure, p>500db.

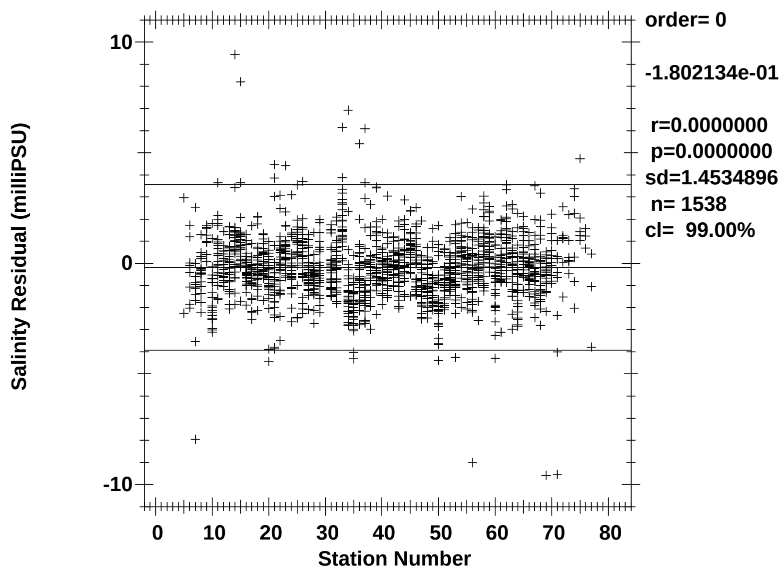


Figure 1.8.3.2 C1 and C2 salinity residuals by station, p>500db.

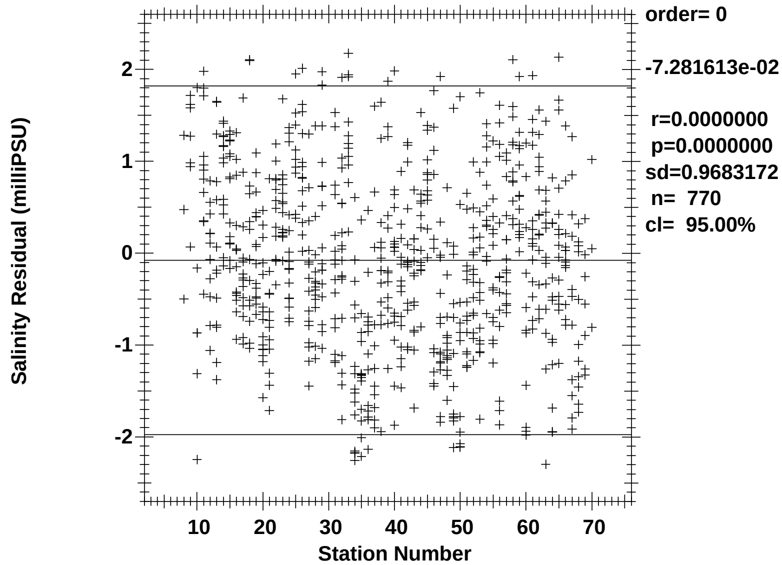


Figure 1.8.3.3 C1 and C2 salinity residuals by station, p>2000db.

Excluding thermocline and gradient values (early and late stations were shallow and also excluded), figure 1.8.3.3 represents an estimate of the salinity accuracy of CTD #474. The 95% confidence limit is ±0.0019 PSU, in agreement with the generally accepted limit of repeatability for bottle salinities (±0.002PSU).

1.8.4. CTD Dissolved Oxygen

One SBE43 dissolved O_2 (DO) sensor was used for this cruise (#43-0225). The sensor was plumbed into the P1/T1/C1 intake line in a horizontal configuration after C1 and before P1 (per SBE spec).

One characteristic of this type of sensor (membrane-covered polarigraphic oxygen detector or MPOD) is a flow dependence. Non-pumped sensors of this type exhibit a significantly decreased response at bottle stops. The pumped SBE43 reduces but does not eliminate this problem, perhaps due to pump or flow rate variations in the primary sensor circuit. DO sensor calibration to check samples is somewhat problematic as sensor data from the bottle stop does not provide a representative comparison.

The DO sensor calibration method used for this cruise was to match down-cast CTD DO data to up-cast bottle trips along isopycnal surfaces, then to minimize the residual differences between the *in-situ* check sample values and CTD O_2 using a non-linear least-squares fitting procedure. Since this technique only calibrates the down-cast, only the 2.0 pressure series downcast data contain calibrated CTD O_2.

A small (<0.02 ml/l) but significant non-linearity apparent in the O_2 residuals as a function of pressure was corrected with an additional empirical 4th-order polynomial pressure correction. The explanation for this non-linearity requires further investigation.

Figures 1.8.4.0, 1.8.4.1 and 1.8.4.2 show the residual differences between bottle and calibrated CTD O_2 for all points excluding the thermocline and surface gradients. Figure 1.8.4.3 shows the residual differences for pressures > 1000 db.

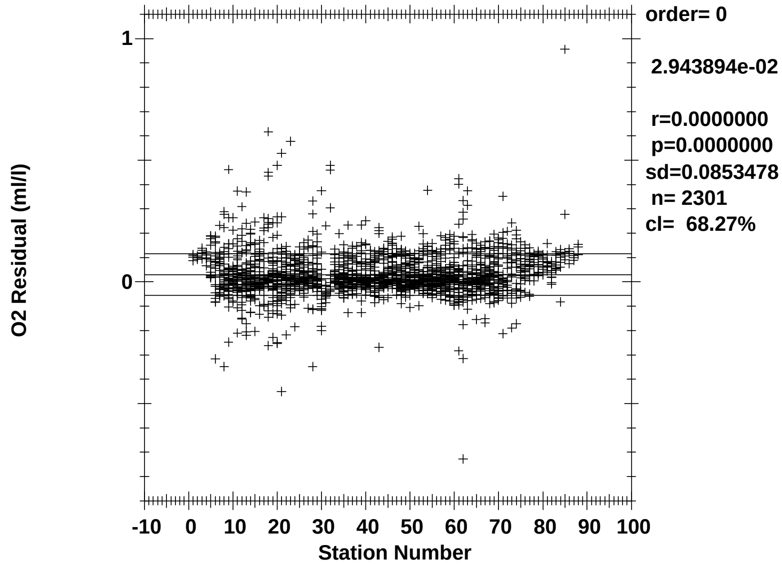


Figure 1.8.4.0 O_2 residuals by station number.

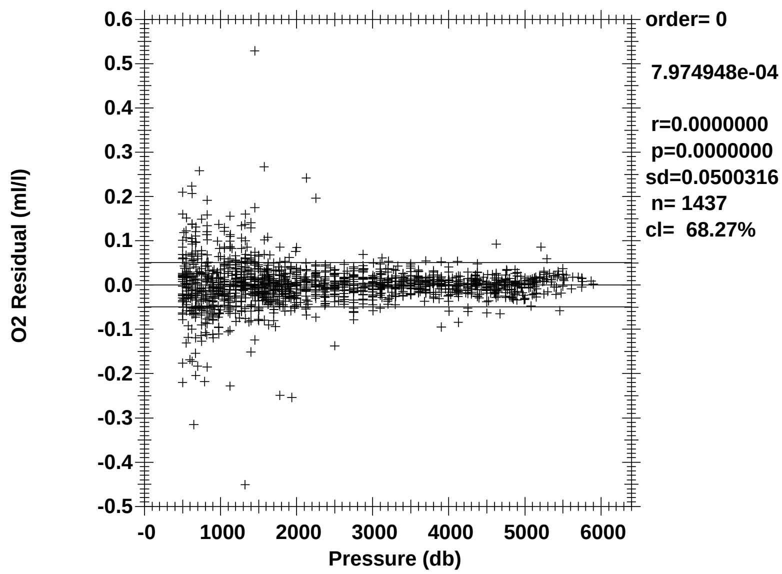


Figure 1.8.4.1 O_2 residuals by pressure.

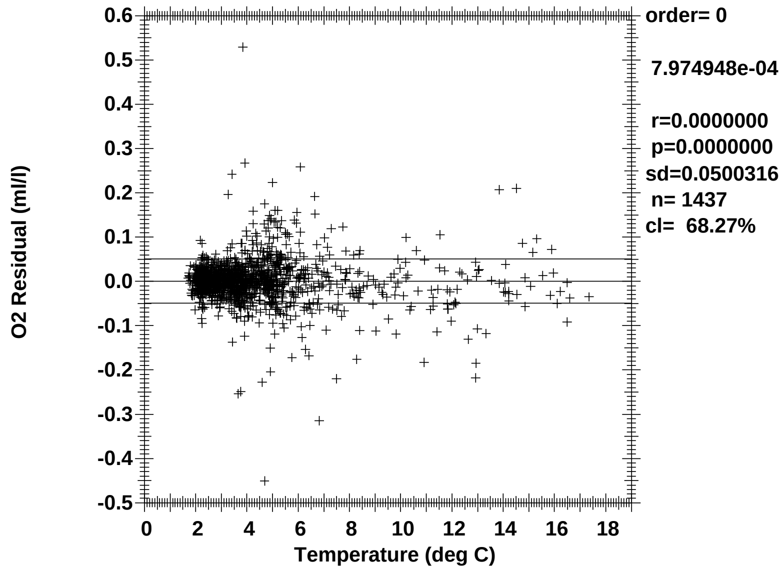


Figure 1.8.4.2 O_2 residuals by temperature.

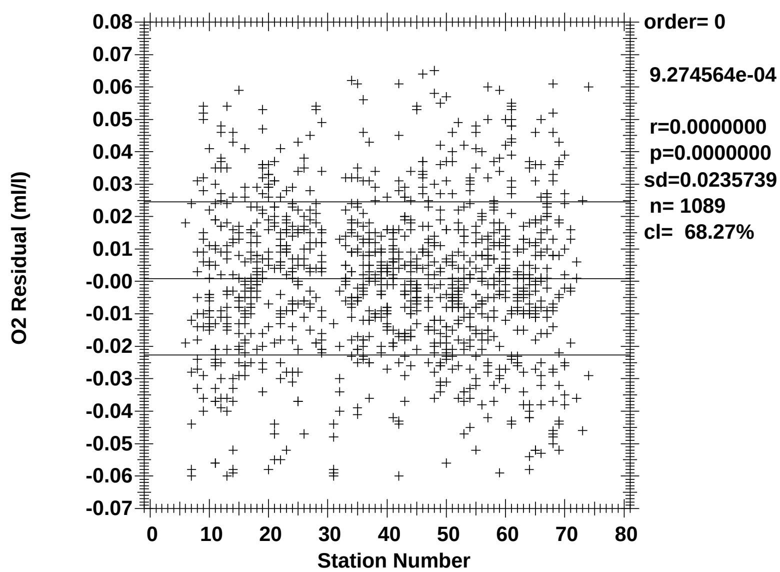


Figure 1.8.4.3 O_2 residuals by station number, p>1000db .

The standard deviations of 0.050 ml/l for all oxygens and 0.027 ml/l for deep oxygens are only intended as indicators of how well the up-cast bottle O_2 and down-cast CTD O_2 match. 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 follows Brown and Morrison [Brow78] and Millard [Mill82], [Owen85]. ODF models membrane and sensor temperatures with lagged CTD temperatures. *In-situ* pressure and temperature are filtered to match the sensor response. Time-constants for the pressure response τ_p, and two temperature responses τ_{Ts} and τ_{Tf} are fitting parameters. 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. Oxygen partial-pressure is then calculated:

$$O_{pp} = [c_1 O_c + c_2] \cdot f_{sat}(S,T,P) \cdot e^{(c_3 P_l + c_4 T_f + c_5 T_s + c_6 \frac{dO_c}{dt})} \qquad (1.8.4.0)$$

where:

O_{pp}	= Dissolved O_2 partial-pressure in atmospheres (atm);
O_c	= Sensor current (μamps);
$f_{sat}(S,T,P)$	= O_2 saturation partial-pressure at S,T,P (atm);
S	= Salinity at O_2 response-time (PSUs);
T	= Temperature at O_2 response-time (° C);
P	= Pressure at O_2 response-time (decibars);
P_l	= Low-pass filtered pressure (decibars);
T_f	= Fast low-pass filtered temperature (° C);
T_s	= Slow low-pass filtered temperature (° C);
$\frac{dO_c}{dt}$	= Sensor current gradient (μamps/secs).

1.9. Bottle Sampling

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

- CFCs
- O_2
- He_3
- DIC/Total Alkalinity
- DOC/DON/DCNS/CDOM
- Tritium
- I_{129}
- C_{13} and C_{14}
- Nutrients
- Salinity

The correspondence between individual sample containers and the rosette bottle 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 analysis.

1.10. Bottle Data Processing

Bottle data processing began with sample drawing, and continued iteratively until the data were considered to be problem-free. One of the most important pieces of information, the sample log sheet, was filled out during sample drawing and served both as a sample inventory and as a guide for the technicians in carrying out their analyses. Any problems observed with the rosette before or during the sample drawing were noted on this form, including indications of bottle leaks, out-of-order drawing, etc. Additional clues regarding bottle tripping or leak problems were found by individual analysts as the samples were analyzed and the resulting data processed and checked.

The next stage of processing began after individual analyses were associated with rosette bottles and their CTD-derived parameters (pressure, temperature, conductivity, etc.). The rosette cast and bottle numbers were the primary identification for all ODF-analyzed samples taken from the bottle. At this stage, bottle tripping problems were usually identified and resolved, sometimes resulting in changes to the pressure, temperature and other CTD properties associated with the bottle. All CTD information for each bottle trip (confirmed or not) was retained, so resolving bottle tripping problems consisted of correlating CTD trip data with the rosette bottles.

Diagnostic comments from the sample log, and notes from analysts and data processors were associated with each deployment as part of the quality control procedure. Sample data from bottles suspected of leaking were checked to see if the properties were consistent with the CTD profile and with adjacent stations. The analysts reviewed and sometimes revised their data as additional calibration or diagnostic results became available.

Quality coding of CTD and water samples was done using a coding scheme developed for the World Ocean Circulation Experiment (WOCE) Hydrographic Programme (WHP) [Joyc94]. Based on the outcome of investigations of the various comments in the quality files, WHP water sample codes were selected to indicate the reliability of the individual parameters affected by the comments. WHP bottle codes were assigned where evidence showed the entire bottle was affected, as in the case of a leak, or a bottle trip at other than the intended depth.

WHP water bottle quality codes were assigned as defined in the WOCE Operations Manual [Joyc94] with the following additional interpretations:

2	No problems noted.
3	Leaking. *An air leak large enough to produce an observable effect on a sample is identified by a code of 3 on the bottle and a code of 4 on the oxygen. (Small air leaks may have no observable effect, or may only affect gas samples.)*
4	Did not trip correctly. *Bottles tripped at other than the intended depth were assigned a code of 4. There may be no problems with the associated water sample data.*
5	Not reported. *No water sample data reported. This is a representative level derived from the CTD data for reporting purposes. The sample number should be in the range of 80-99.*
9	The samples were not drawn from this bottle.

WHP water sample quality flags were assigned using the following criteria:

1	The sample for this measurement was drawn from the water bottle, but the results of the analysis were not *(yet)* received.
2	Acceptable measurement.
3	Questionable measurement. *The data did not fit the station profile or adjacent station comparisons (or possibly CTD data comparisons). No notes from the analyst indicated a problem. The data could be acceptable, but are open to interpretation.*
4	Bad measurement. *The data did not fit the station profile, adjacent stations or CTD data. There were analytical notes indicating a problem, but data values were reported. Sampling and analytical errors were also coded as 4.*
5	Not reported. *There should always be a reason associated with a code of 5, usually that the sample was lost, contaminated or rendered unusable.*
9	The sample for this measurement was not drawn.

WHP water sample quality flags were assigned to the CTDSAL (CTD salinity) parameter as follows:

2	Acceptable measurement.
3	Questionable measurement. *The data did not fit the bottle data, or there was a CTD conductivity calibration shift during the up-cast.*
4	Bad measurement. *The CTD up-cast data were determined to be unusable for calculating a salinity.*
7	Despiked. *The CTD data have been filtered to eliminate a spike or offset.*

WHP water sample quality flags were assigned to the CTDOXY (CTD O_2) parameter as follows:

1	Not calibrated. *Data are uncalibrated.*
2	Acceptable measurement.
3	Questionable measurement.
4	Bad measurement. *The CTD data were determined to be unusable for calculating a dissolved oxygen concentration.*
5	Not reported. *The CTD data could not be reported, typically when CTD salinity is coded 3 or 4.*
7	Despiked. *The CTD data have been filtered to eliminate a spike or offset.*
9	Not sampled. *No operational CTD O_2 sensor was present on this cast.*

Note that CTDOXY values were derived from the down-cast pressure-series CTD data and matched to the up-cast bottle data along isopycnal surfaces. If the CTD salinity is footnoted as bad or questionable, the CTD O_2 is not reported.

1.11. Salinity Analysis

Equipment and Techniques

Two Guildline Autosal Model 8400A salinometers (S/N 57-263 and 57-266) located in the forward analytical lab were used for measuring salinity on all stations (57-263: 1/1-1/8, 11/1-30/1, 53/1-59/1; 57-266: 10/1, 31/1-52/1,60/1-88/1). The salinometers were modified by ODF to contain an interface for computer-aided measurement. The water bath temperatures were set and maintained at a value near the laboratory air temperature. They were set at 24° C for the entire leg.

The salinity analyses were performed after samples had equilibrated to laboratory temperature, usually within 16-36 hours after collection. A temperature-controlled waterbath was used to assist sample equilibration. The salinometer was standardized for each group of analyses (1-7 casts, up to ~50 samples) using at least one fresh vial of standard seawater per group. A computer (PC) prompted the analyst for control functions such as changing sample, flushing, or switching to "read" mode. The salinometer cell was flushed and results were logged by the computer until two successive measurements met software criteria for consistency. These values were then averaged for a final result.

Sampling and Data Processing

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 collecting each sample, inserts were inspected for proper fit and loose inserts were 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 one run at the end as an unknown was applied linearly to the data to account for any drift. The data were incorporated into the cruise database. 2530 salinity measurements were made and approximately 60 vials of standard water were used. The estimated accuracy of bottle salinities run at sea is usually better than ±0.002 PSU relative to the particular standard seawater batch used.

Laboratory Temperature

The temperature in the salinometer laboratory varied from 20.9 to 25.8° C, during the cruise. The air temperature change during any single run of samples was less than ±1.2° C.

Standards

IAPSO Standard Seawater (SSW) Batches P-140 and P-141 were used to standardize all salinity measurements.

1.12. Oxygen Analysis

Equipment and Techniques

Dissolved oxygen analyses were performed with an 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 (~65 gm/l). Pre-made liquid potassium iodate standards were run at the beginning of each session of analyses, which typically included from 1 to 3 stations. Reagent/distilled water blanks were determined every other day or more often if a change in reagents required it to account for presence of oxidizing or reducing agents. The auto-titrator generally performed well. A leak in the thiosulfate delivery tubing affected samples on 26/1-28/1, 30/1, 32/1-33/1 and 38/1.

Sampling and Data Processing

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 draw temperature was measured with a small platinum resistance thermometer embedded in the drawing tube. Reagents 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 1-6 hours of collection, then the data were 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.

As samples warmed up to room temperature they would occasionally degas which would cause a noisy endpoint due to gas bubbles in the light path. 2503 oxygen measurements were made.

The blank volumes and thiosulfate normalities were smoothed (linear fits) at the end of 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 bottle 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 and bottled in ODF's chemistry laboratory prior to the cruise. The normality of the liquid standard was determined at ODF by calculation from weight. A single standard batch was used during A20-2003. Potassium iodate was obtained from Acros Chemical Co.

and was reported by the supplier to be >99.4% pure. All other reagents were "reagent grade" and were tested for levels of oxidizing and reducing impurities prior to use.

1.13. 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 hour after sample collection. Occasionally samples were refrigerated up to 4 hours at ~4° C. All samples were brought to room temperature prior to analysis.

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 ~55° C to enhance color development, then passed through a 50mm flowcell and the absorbance measured at 820nm.

Sampling and Data Processing

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 6-7 different standard concentrations were analyzed periodically to determine any deviation from linearity as a function of concentration for each nutrient analysis. A correction for non-linearity was applied to the final nutrient concentrations when necessary.

After each group of samples was analyzed, the raw data file was processed to produce another file of response factors, baseline values, and absorbances. Computer-produced absorbance readings were checked for accuracy against values taken from a strip chart recording. 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 an assumed laboratory temperature of 25° C.

2540 nutrient samples were analyzed. The pump tubing was changed 2 times.

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 effi ciency 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 20.9° C to 25.5° C, but was relatively constant during any one station (±1.5° C).

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2. Lowered Acoustic Doppler Current Profiler

Velocity profi les were obtained during the standard hydrographic casts of the Knorr A20 cruise using self contained ADCPs (Acoustic Doppler Current Profi lers) attached to the CTD rosette. Dual WH300 ADCPs (RDI Instruments Inc.) were used for Stations 1 through 37 and the test station 999. A single broadband 150 khz ADCP (RDI Instruments Inc.) was used for stations 38 through 84. Lowered ADCP data for stations 85 through 88 was not collected given that these stations were too shallow to obtain meaningful information. An experimental high power version of the WH300 ADCP was used on casts 1-11 and initially exhibited promising (higher range) results. Unfortunately a failed transducer on that instrument required that it be replaced with a standard WH300 ADCP for subsequent casts.

Based on the instrument range and the magnitude of the error associated with the velocity estimates, the dual WH300 ADCPs performed well in the high back-scatter region on the northern portion of the transect. The range of these instruments declined steadily and the velocity error increased as the ship proceeded south into lower back-scatter waters, requiring the switch to the higher powered broadband 150 khz instrument after station 37. While the performance of the broadband 150 khz instrument was adequate in the low back-scatter waters of the main gyre, the range and velocity error steadily improved as the ship made progress south. Poor velocity estimates in the upper 200 meters of the water column is common when profiling with a single ADCP and is not entirely understood. This proved to be the case when the single BB150 ADCP was used during this cruise. The hull mounted ADCP data will be used to fill in for the poor surface data that was obtained while using the single BB150 ADCP. Additional post processing will be done to optimize the threshold settings that will allow our bottom tracking routines to decrease the error in the velocity estimates when the paired WH300 ADCPs were used. However, preliminary examination of the velocity profiles indicates good correlation with the geostrophic velocities computed from the temperature and salinity data.

3. Chromophoric DOM

Our goals are to determine chromophoric dissolved matter (CDOM) distributions over a range of oceanic regimes on meridional 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. 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.

3.1. Activities on A20 and A22:

We are collecting samples of seawater for absorption spectroscopy on one deep ocean cast (24 depths) 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 0.2um filtrates using a liquid waveguide spectrophotometer with a 200cm cell. We are concurrently collecting samples for bacterial abundance, dissolved organic carbon, dissolved organic nitrogen (see below), and carbohydrates 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). At selected stations (continental slope, subtropical, and tropical stations) we will collect extra seawater for a) microbial culture experiments and b) solar bleaching experiments. In these experiments we will examine the rate of CDOM production relative to microbial productivity in culture, and quantify the rate of solar bleaching of CDOM near the surface. Because of the connections to light availability and remote sensing, we are collecting samples for pigment analysis (HPLC), chlorophyll a (fluorometric), and particulate absorption (spectrophotometric) when possible. We are also deploying a Satlantic free-fall profiling spectroradiometer (ca. once per day) to quantify the underwater light field, and we have a Satlantic surface irradiance meter continuously logging the solar spectrum during daylight hours. Fluorometric analysis is being done at sea after 48 hour extractions.

Also:

We are collecting samples for dissolved organic carbon and dissolved organic nitrogen analysis, which are a core part of the CO2/CLIVAR project. The PIs for this part of the study are D. Hansell (U. Miami) and C. Carlson (UCSB), who can provide more details. We are collecting and freezing approximately 150ml (each) from 24 depths on each A cast. Samples in the upper 1000m are filtered (using GF/F glass fiber filters) at the time of collection. These samples will be analyzed at UCSB after the end of the A22 leg.

4. 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 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 (99.995%) by means of an 8-port valve outfitted with two sample loops. The instruments were calibrated at the beginning, middle, and end of each station with a set of the gas loop injections.

Secondary standards were run throughout the cruise on each analytical system; these standards were Certified Reference Materials (CRMs) consisting of poisoned, filtered, and UV irradiated seawater supplied by Dr. A. Dickson of Scripps Institution of Oceanography (SIO), and were determined shoreside manometrically. Despite equipment problems in the beginning of the cruise, the overall accuracy and precision for the CRMs on both instruments combined was 1.0±1.7 µmol/kg respectively (n=88). Preliminary DIC data reported to the database have not yet been corrected to the Batch 61 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 500-mL Pyrex bottles using Tygon tubing. Bottles were rinsed once and filled from the bottom, overflowing half a volume, and care was taken not to entrain any bubbles. The tube was pinched off and withdrawn, creating a 5-mL headspace, and 0.2 mL of saturated HgCl2 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 12 hours prior to analysis.

Over 1600 samples were analyzed for DIC; full profiles were completed at the 'A' stations, with replicate samples taken from the surface, oxygen minimum, and bottom Niskin-type bottles. At a minimum, replicate surface samples were taken at every 'B' stations, and when time permitted, additional depths to 1000m were sampled. The replicate samples were run at different times during the station analysis for quality assurance of the integrity of the coulometer cell solutions. No systematic differences between the replicates were observed.

REFERENCES:

Johnson, K.M., A.E. King, and J.McN. Sieburth (1985): Coulometric DIC analyses for marine studies: An introduction. Mar. Chem., 16, 61-82.

Johnson, K.M., P.J. Williams, L. Brandstrom, and J.McN. Sieburth (1987): Coulometric total carbon analysis for marine studies: Automation and calibration. Mar. Chem., 21, 117-133.

Johnson, K.M. (1992): Operator's manual: Single operator multiparameter metabolic analyzer (SOMMA) for total carbon dioxide (CT) with coulometric detection. Brookhaven National Laboratory, Brookhaven, N.Y., 70 pp.

Johnson, K.M., K.D. Wills, D.B. Butler, W.K. Johnson, and C.S. Wong (1993): Coulometric total carbon dioxide analysis for marine studies: Maximizing the performance of an automated continuous gas extraction system and coulometric detector. Mar. Chem., 44, 167-189.

Wilke, R.J., D.W.R. Wallace, and K.M. Johnson (1993): Water-based gravimetric method for the determination of gas loop volume. Anal. Chem. 65, 2403-2406.

5. Argo Float Deployments

At the request of Dr. Allyn Clarke of the Bedford Institute of Oceanography, five free-drifting, profiling floats were launched during the 2003 A20 occupation. A total of eight Metocean Provor floats were shipped to

Woods Hole one week prior to our departure. A BIO technician, Murray XXXX traveled to WHOI and initiated the floats' operation program. A subset of 5 of these were deployed on A20; the others are to be launched during A22. Operationally, the units were activiated during the up-cast of pre-selected stations by the removal of a magnet from the instrument pressure vessel. Then, as the R/V Knorr began to move off the station, the float was lowered into the sea using a slip line off the vessel stern. Though awkward to carry out given the Knorr's deck arrangement, we belive that all five systems were succesfully deployed. The table below gives launch details:

Serial no.	Date	Time	CTD no.	Lat.	Lon.
MT-111	Sep 26	1524 Z	8	42 25.79 N	51 18.51 W
MT-107	Sep 27	0521 Z	11	41 50.22 N	51 46.96 W
MT-116	Sep 27	2319 Z	14	41 3.52 N	51 46.60 W
MT-109	Sep 29	1645 Z	20	38 56.52 N	52 15.08 W
MT-110	Oct 01	0325 Z	25	36 13.91 N	52 24.01 W

WHPO/CCHDO Data Processing Notes

Date	Contact	Data Type	Data Status Summary
10/29/03	Delahoyd	CTD	Submitted with the following headers:

Format for A22 2db pressure-series downcast CTD data:

Pressure	(decibars)
Temperature	(ITS-90 Deg C)
Salinity	(PSS-78)
Dissolved O2	(uM/kg)
Potential Temperature	(ITS-90 Deg C)
Sigma Theta	
Transmissometer	(0-5Volts)

Date	Contact	Data Type	Data Status Summary
02/11/04	Delahoyd	BTL	Submitted

These data were provided by:

Parameter/Program	Name	E-mail Address
Chief Scientist	John Toole-WHOI	jtoole@whoi.edu
Co-Chief Scientist	Alison McDonnald-WHOI	amacdonald@whoi.edu
CTDO/S/O2/Nutrients	James Swift-SIO	jswift@ucsd.edu
DIC	Dick Feely- PMEL	feely@pmel.noaa.gov
CFC	William Smethie-LDEO	bsmeth@ldeo.columbia.edu
TALK	Andrew Dickson-SIO	adickson@ucsd.edu
CDOM, DOC, DON	Craig Carlson-UCSB	carlson@lifesci.ucsb.edu
He/Tr	William Jenkins-WHOI	wjenkins@whoi.edu
Surface C14	Ann McNichol-WHOI	amcnichol@whoi.edu
Surface C14	Robert Key-Princeton	key@princeton.edu
C13 profiles	Paul Quay-UW	pdquay@u.washington.edu

The data included in these files are preliminary, and are subject to final calibration and processing. They have been made available for public access as soon as possible following their collection. Users should maintain caution in their interpretation and use. Following American Geophysical Union recommendations, the data should be cited as: "data provider(s), cruise name or cruise ID, data file name(s), CLIVAR and Carbon Hydrographic Data Office, La Jolla, CA, USA, and data file date." For further information, please contact one of the parties listed above or whpo@ucsd.edu. Users are also requested to acknowledge the NSF/NOAA-funded U.S. Repeat Hydrography Program in publications resulting from their use.

Date	Contact	Data Type	Data Status Summary
03/10/04	Diggs	Cruise ID	Data File Relocated

The A20 data is formally online at a new location:

http://whpo.ucsd.edu/data/co2clivar/atlantic/a20/a20_2003a/index.htm

You'll notice that the expocode for the WHPO website is now 316N200309 (was 316N173/1). This is consistent with the way the WHPO/CCHDO now keeps records and assigns expedition codes. Each cruise has an NODC shipcode, then the 4-digit year and the 2-digit month taken from the first date of the cruise. We realize that this may cause problems for individuals who refer to A20 by the old expocode.

Date	Contact	Data Type	Data Status Summary
04/14/04	Kappa	DOC	Updated Cruise Report as follows:
	Produced an ASCI version of the original PDF report Added WHPO/CCHDO Summary pages to PDF and ASCI reports Added internal links to figures and WHPO/CCHDO sections in PDF report Added he WHPO/CCHDO - generated Station Location Plot to PDF report Added these Data Processing Notes to the PDF and ASCI reports		