Preliminary Cruise Report

Ship Name: *R/V Melville*

Chief Scientist*:* Dr. Deirdre Byrne, School of Marine Sciences, University of Maine, Orono, ME 04459-5741
Tel: 207-581-4324 email: dbyrne@umeoce.maine.edu

Cruise Dates: 28 December, 2002 -16 January, 2003
Area of Operations: SA2 (So. Atlantic)
Clearance Country: South Africa
Operating Institution: Scripps Institution of Oceanography

Ports of Call: Cape Town
Cape Town

Foreign Participants: Yes

Project Title:
Collaborative Research: Agulhas-South Atlantic Thermohaline Transport Experiment (ASTTEX)

Acknowledgments:
We would like to thank the captain and crew of the R/V Melville for a productive cruise; their attention to helping us achieve the science goals of the cruise was greatly appreciated. We would also like to thank the National Science Foundation for supporting the cruise, with additional research support provided by NASA. Marine and Coastal Management, South Africa, provided collaborating personnel, ground support, XBTs, storage for our instrument cases for the duration of the experiment, and the use of their calibration lab after the cruise. The Ministry of Fisheries and Marine Resources, Namibia, provided collaborating scientific and technical personnel under the aegis of the BENEFIT program.

This report was prepared by Deirdre Byrne, primary principal investigator of the ASTTEX project and chief scientist on the deployment cruise, and by Christopher Duncombe Rae, collaborating principal investigator.

Description of Scientific Program:

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1. Introduction

The *R/V Melville* Cruise Vancouver 06 was conducted to deploy the moorings which will provide the principal *in situ* observations for the Agulhas-South Atlantic Thermohaline Transport Experiment (ASTTEX), and to take a calibration CTDO cast at each mooring site. ASTTEX is a pilot project to measure variability in the Agulhas Current component of the Indian-Atlantic interocean exchange (the "warm water route"). A secondary objective of the cruise was to further survey the water mass variability in the vicinity of the mooring deployment locations. An ancillary project was to survey upwelling conditions along the South African coast. Summaries of the projects supported by this cruise are presented in sections following the cruise narrative.

2. Cruise Narrative

The *R/V Melville* departed Cape Town on cruise Vanc-06 at 16:00 SAST on 2 January 2003. Departure was delayed 24 hours due to technical difficulties downloading a file that would provide a firmware upgrade to the principal ASTTEX instruments. A map of the cruise track and stations is presented in Figure 1. Sea Beam data were collected continuously along-track with the exception of those periods when the ship was stopped on station, and during the shelf survey when water depths were not sufficient. Meteorological observations and information on surface temperature and salinity and near-surface currents (from a hull-mounted ADCP) were also collected underway. While still at the dock, the CTDO/rosette package was deployed over the side to test the Niskin bottle seals, tripwires, and data transmission and communications between the package and the deck unit. Everything appeared to be in working order.

XBT casts were begun as the ship reached the 500 m isobath. The ship's XBT acquisition software was initially set to acquire "Fast-Deep" profiles, while we had brought model T-7 XBTs; data from the first XBT were not recoverable. However changing the configuration file solved the problem, a the first successful XBT cast was made at 34.5032S, 17.6663E. In all, five XBT casts were taken as we steamed to the location of the test CTDO station (36.0463S, 15.9605E).

The test, or "shakedown" CTDO station (#1) was occupied at 06:00Z on January 3. After a couple of attempts to deploy the CTDO package when the hydro cable jumped the sheave and jammed in the block, a successful cast was started at 08:20Z and taken to the full water column depth. One purpose of this station was to fully test our water sampling and analysis procedures. Duplicate samples were taken at a number of depths to test for inter-operator consistency. O-ring seals on Niskin bottles 15 and 17 were found to be leaking. This cast proved to have been taken within an Agulhas Ring, providing a valuable addition to historic information about the strength and character of thermohaline anomalies found within the Cape Basin.

All systems were found to be operating properly. Meanwhile the temperature in the water sample analysis lab was fluctuating a great deal, and the cooling system for this room had to be enabled; it had been inadvertently disabled during some maintenance work on the ship. Lab temperatures were considerably more stable after the cooling was reinstated, and the acquisition of high-quality conductivity (salinity) measurements became accordingly easier.

Two additional CTDO stations (#2, #3) along Jason-1 groundtrack 133 (along-track points 781 and 792) south of the location of the ASTTEX moored array were occupied before steaming to the first mooring deployment location. These full-depth stations were occupied at 21:16Z on January 4, and 04:43Z on January 5, and were located at 40.3180S, 10.5485E and 39.7797S, 10.9350E, respectively. These locations were chosen to provide some additional samples of southern Cape Basin hydrography and in addition to coordinate with a hydrographic section occupied by the R/V Polarstern in November, 2002. The southernmost of our stations formed the northern end of a section occupied by the Polarstern as it steamed south, with the intent that these two sections could be combined into one full transect. 24 bottle samples for salinity and dissolved oxygen were acquired at each of these two stations. Niskins 2 and 18 did not trip at station #2.

We arrived at our first mooring deployment site, (39.2407S, 11.3147E) at 18:40Z on January 5, 2003. PIES 12 (SN 52) was deployed without problems. A full-depth calibration CTDO cast (#4) was taken. Water column depth was 5086 m. The Niskin bottle at position 18 on the rosette again did not trip, and thereafter was removed from the sampling sequence. The dynamic positioning capability of Melville made both the accurate positioning of the moorings during deployment and the maintainence of that position for the subsequent calibration CTDO casts remarkably simple.

Our second mooring deployment site, (38.7000S, 11.6887E) at 04:21Z was reached on January 6, 2003. PIES 11 (SN 64) was deployed without problems. A full-depth calibration CTDO cast (#5) was taken. Water column depth was 5140 m.

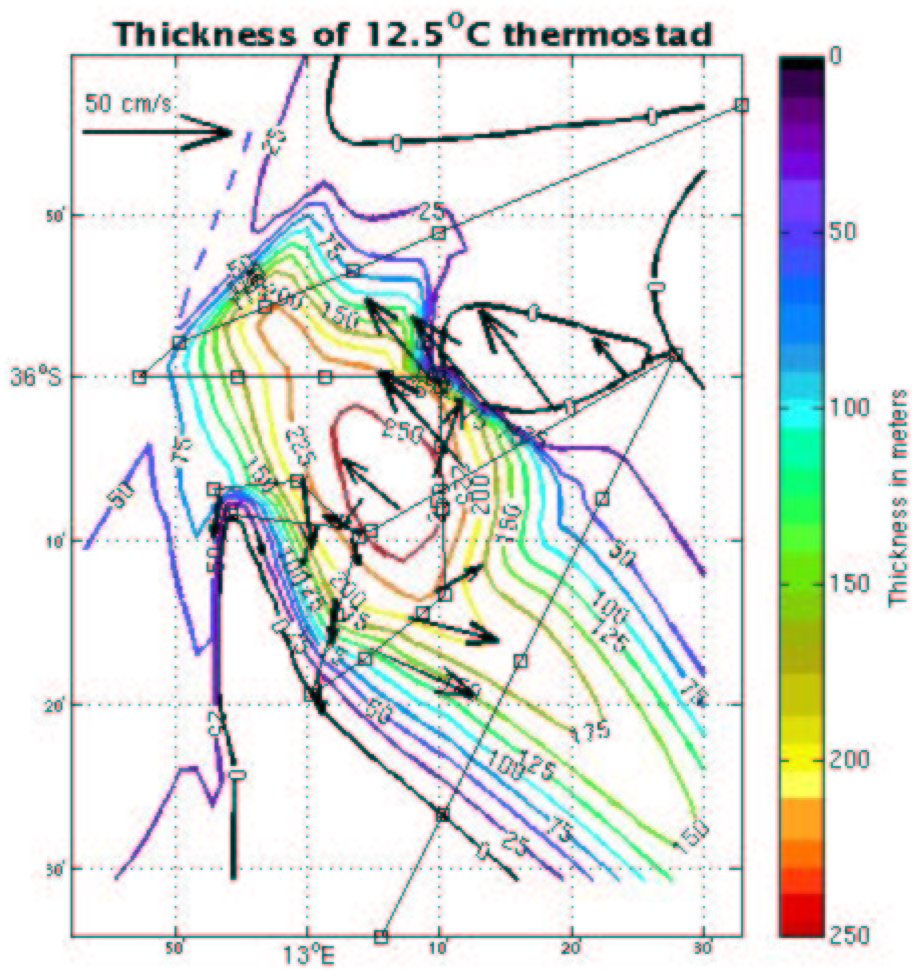
The third mooring deployment site (38.1577S, 12.0558E) was occupied at 13:15Z on January 6, 2003. PIES 10 (SN 54) was deployed without problems. A full-depth calibration CTDO cast (#6) was taken. Water column depth was 5100 m. At this point we decided that it would be useful to launch an XBT at the halfway mark between each mooring location to provide additional information about the surface and central water masses present in the region, a procedure we followed throughout the rest of the cruise. We were particularly interested in obtaining additional hydrography of water columns containing 12-13C thermostads. The significance of this thermostad derives from the fact that several rings containing a core of such water have been observed in the region, sources of a strongly anomalous thermohaline signal in the Cape Basin. As of yet few samples of these rings have been taken; in addition there remains a controversy over whether these rings are of Indian Ocean or Atlantic Ocean origin.

We arrived at our fourth mooring deployment site, (37.6635S, 12.3845E) at 22:30Z on January 6, 2003. PIES 09 (SN 61) was deployed without problems. A full-depth calibration CTDO cast (#7) was taken early on January 7. Water column depth was 5071 m. The CTDO data was very spiky (although salvageable) and the decision was made to re-terminate the hydro wire.

We reached the fifth mooring deployment site, (37.4160S, 12.5469E) at 07:10Z January 7, 2003. This was a CMM mooring site. Each of the Edgetech acoustic releases (four in all) were lowered to 1000 m on the hydro wire and tested on station at this site. At 08:15Z, CMM 3 was deployed without problems at a depth of 5060 m. At first we had some difficulty disabling the acoustic release on this mooring, but were able contact the release by steaming 1 km off-station and trying again. The reply from the release was quite weak and was not detected until the receive sensitivity was set very high.

The sixth mooring deployment site (37.1185S, 12.7402E) was occupied at 12:35Z on January 7, 2003. PIES 08 (SN 66) was deployed without problems. A full-depth calibration CTDO cast (#8) was taken at the site. Water column depth was 5113 m. Some spiking was still detected in the CTDO sensor data (all sensors), but much less than before. The portable salinometer began behaving poorly at this juncture, with bath temperature periodically spiking 0.04 - 0.1C above the set temperature. This abnormal behavior was detected on both of the bath thermometers. An email was sent to Guildline to inquire about potential sources of this problem. This problem was not resolved during the cruise, and instead salinity samples were collected for on-shore processing at the Marine and Coastal Management (MCM) calibration facility. Twelve positions on the rosette were sampled for salinity in all subsequent deep (z > 1000 m) CTDO casts for calibration purposes. WOCE-quality double capped bottles were used to collect these samples, and the quality of the results is not expected to have been affected by the delay in processing them.

We arrived at our seventh mooring deployment site, (36.5723S, 13.0902E) at 22:18Z on January 7, 2003. PIES 07 (SN 60) was deployed without problems. A full-depth calibration CTDO cast (#9) was started at 00:22Z on January 8 at the site. Water column depth was 4920 m.



A slight trace of a 12.5C thermostad was detected in the XBT cast midway between the seventh and sixth mooring deployment sites. Several more XBT were launched on the way to the sixth site to better define the geographic extent of this water mass. The hull-mounted ADCP indicated strong coherent currents consistent with the presence of a mesoscale ring. The thickness of the nearly isothermal layer of water at 12 - 12.5C increased to almost 300 m.

We reached the eighth mooring deployment site (35.9760S, 13.4652E) at 08:25Z on January 8. PIES 06 (SN 51) was deployed without any problems. A full-depth calibration CTDO cast (#10) was taken at the site. The water column depth was 4838 m. No thermostad was observed at site PIES 06, so the decision was made to cease mooring deployment activity and conduct a short survey of the vicinity. Satellite data suggested that if a ring was present, it most likely located to the west of the ship, and so the survey was begun to the west.

Figure 1

Over the next 22 hours, 21 XBT casts and three 2000 m CTDO stations revealed a coherent anti-cyclonic mesoscale ring with a core of relatively uniform water estimated to reach 255 - 265 m thick at the ring center. Coherent swirl velocities of up to ~50 cm/s were observed throughout the top of the water column (50 m -250 m) in the ADCP data (Fig. 1).

The ninth mooring deployment site (35.4260S, 13.8040E) was occupied at 14:22Z on January 9, 2003. PIES 05 (SN 55) was deployed without problems. A full-depth calibration CTDO cast (#14) was started at 16:05Z at the site. The water column depth was 4590 m.

We arrived at our tenth mooring deployment site, (34.8318S, 14.1633E) at 23:45Z on January 9, 2003. PIES 04 (SN 50) was deployed without problems. A full-depth calibration CTDO cast (#15) was started at 01:26Z on January 10 at the site. The water column depth was 4643 m.

We reached the eleventh mooring deployment site, (34.8270S, 14.1708E) at 05:20Z on January 10, 2003. This was the site of the largest mooring, the ASTTEX validation mooring. A bathymetric survey was conducted to find an appropriate deployment site. Deployment of the mooring began at 07:00Z several n.m. downwind of the eventual deployment location and the mooring gear was streamed out behind the ship. Payout of all 4376 meters of cable was accomplished without incident. The anchor was released at 12:15Z. The water depth at the deployment site was 4640 m.

We returned to the ninth mooring site to obtain a second calibration CTDO cast. PIES pressure sensors have an approximately 24-hour temperature equilibration time, thus calibrations are most useful if conducted 12 to 24 hours after deployment. CTDO #16 was occupied at PIES site 05 at 21:30Z on January 10, 2003. At 23:15Z communications were lost with the winch operator, and the CTD package touched bottom. The problem was apparently caused by an intermittent outage of the intercom system. No apparent damage was done to the CTDO sensors, Niskin bottles or rosette frame.

We then re-occupied the tenth mooring site to obtain a similar, deployment-lagged calibration cast. CTDO station #17 at PIES site 04 was occupied at 07:30Z on January 11. Satellite imagery indicated the possible presence of a mesoscale cyclonic feature to the northwest of this mooring site. While the existence of coherent, cyclonic vortices in the Cape Basin have been verified with *in situ* drifters, the water mass composition of these features remains unknown. We decided to conduct a second XBT survey in the hope of locating a cyclonic feature and conducting a short hydrographic survey in it. The XBT survey was begun at 10:31Z on January 11. Several failed XBT casts necessitated replacement of the launcher cable. The survey was continued until 17:58Z. No coherent cyclonic feature had been found in either the XBT or ADCP data, so at that point the survey was terminated and we continued steaming toward our twelfth mooring deployment site.

The twelfth mooring deployment site (34.1237S, 14.5830E) was occupied at 22:18 on January 11, 2003. PIES 03 (SN 59) was deployed without problems. A full-depth calibration CTDO cast (#18) was started at 22:30Z at the site. The water column depth was 4415 m.

The thirteenth mooring deployment site (33.7721S, 14.7880S) was reached at 04:42Z on January 12. CMM 2 was deployed without incident at the site in about 35 minutes. The water column depth was approximately 4215 m.

We arrived at the fourteenth mooring deployment site (33.4195S, 14.9912E) at 08:30Z on January 12. PIES 02 (SN 49) was deployed without incident at the site. The water column depth was 3903 m.

We returned to the twelfth mooring deployment site for a second full-depth calibration cast (CTDO #19) at PIES site 03. The station was occupied at 14:30Z on January 12..

We re-occupied the fourteenth mooring deployment site for a second full-depth calibration cast (CTDO #20) at PIES site 02. The station was occupied at 22:05Z on January 12.

We reached the fifteenth mooring deployment site (32.6639S, 15.4204E) at 06:21Z on January 13. CMM 1 was deployed without incident in about 40 minutes. The water column depth was approximately 2930 m.

The sixteenth and last mooring deployment site (31.9567S, 15.8127E) was occupied at 11:40Z on January 13. PIES 01 (SN 48) was deployed without problems. A full-depth calibration CTDO cast (#21) was started at 12:40Z at the site. The water column depth was 1069 m.

We began a shelf transect along MCM monitoring line R at 14:15Z on January 13. CTDO stations #22 through #31, progressing from the shelf edge to 180 m depth, were occupied during this transect, which ended at 08:30Z on January 14. The CTDO sensors spiked frequently on the upcast at these stations, apparently because of severe clogging in the tubing. Abundant organic matter in the benthic boundary layer appeared to be causing the problem, and rinsing the tubing and sensor thoroughly after each upcast helped. After CTDO #28, the orientation of the pump outlet on the CTD package was altered so that the outflow was directed horizontally instead of vertically. This final adjustment eliminated the clogging (and spiking) completely.

An outbound transect along MCM monitoring line S was begun at 10:55Z on January 14. CTDO stations #32 through #36, progressing from 140 m to 910 m depth were occupied as part of this transect. The transect ended at 22:10Z on January 14.

We returned to the sixteenth mooring deployment site (PIES site 01) at 23:56Z on January 14 to conduct a second full-depth calibration CTDO cast. This cast was completed without incident.

We arrived MCM monitoring line S, station 13 (CTDO #38) at 01:00Z on January 15. The water column depth was 1800 m. A full-depth CTDO cast was obtained at this site.

Our final CTDO station (#39) was occupied at the site of CMM 1 (33.0679S, 16.4803E). The cast was completed at 08:44Z on January 15. We arrived at the dock in Cape Town at 06:12Z on January 16.

3. Preliminary Results

3.1 Principal Project: Deployment of ASTTEX Moorings and Calibration CTDO

3.1.1 Introduction

Mass and thermohaline fluxes and their connection to global climate are still the subject of controversy. At a number of locations around the world, interocean transport variability and the contrast in water mass properties between adjacent oceans can be large, with a potentially significant effect on the global climate. The Agulhas Retroflection region is a location of strong and variable interocean transport, where warm, salt-enriched waters from the South Indian Ocean enter the South Atlantic. The Agulhas Retroflection region as part of the warm water route is the only possible source for waters warm and saline enough to maintain the observed balance in the Atlantic thermocline, a balance which preconditions it for the formation of North Atlantic Deep water (NADW). The injection of Indian Ocean water into the southeastern South Atlantic affects South Atlantic surface, central, and intermediate waters, and it is their temporal and spatial variability, which give rise to thermohaline flux anomalies, that are the subject of the ASTTEX project.

ASTTEX is designed to examine the fluxes of heat, salt and mass entering the South Atlantic ocean via the Agulhas Retroflection. The goal of the experiment is to provide a quantitative, multi-year Eulerian measurement of the strength and characteristic scales of Agulhas-South Atlantic mass and thermohaline fluxes, which contain a strong mesoscale component, resolving those fluxes on density horizons. While it has been estimated that up to half of the Agulhas-South Atlantic exchange is contained in mesoscale rings and eddies [Byrne, 2000] and the strength of this mesoscale component could potentially vary a great deal in time, this has yet to be confirmed by a single, consistent set of observations -- principally for want of a method with which to make the measurement. Ship-based surveys lack the temporal resolution required and the only prior mooring deployment that spanned the Cape Basin (conducted as part of the Benguela Sources and Transport experiment) was at large-scale resolution. An additional element of uncertainty is added by the extreme variability in size, strength and thermohaline signature of individual Agulhas eddies, the latter characteristic an important variable which cannot be detected by satellite measurements and so must be measured *in situ*.

3.1.2 Methods

In the Cape Basin, water masses originating in the Indian Ocean create strong thermohaline anomalies which persist when integrated through the water column. These integrated heat and salt anomalies, in turn, are expressed in the measurable quantities of vertical acoustic travel time (τ), which depends principally on the mean temperature of the water column, and steric height of the water column (ϕ), which depends on both the mean temperature and the mean salinity. We have developed a new technique: the Gravest Empirical Mode-Enhanced Thermohaline Transport Analysis (GEM-ETTA) designed to statistically predict the presence and strength of this thermohaline variability in the water column based on historic hydrography, ϕ and τ. Acoustic travel time (τ) is measured directly, and ϕ calculated from a combination of bottom pressure (BP) and sea surface height (SSH). The information retrieved from the ASTTEX moorings, interpreted using GEM-ETTA, will provide a two-year time series of Indian-Atlantic thermohaline flux measurements.

The Vancouver 06 cruise provided a platform for deployment of twelve pressure-sensor equipped, inverted echo sounders (PIES) that will measure BP and τ across the Cape Basin. The array follows Jason-1 groundtrack 133; in combination with bottom pressure, SSH from altimetry will be used to compute ϕ. In addition to the PIES, three near-bottom current meter moorings will provide deep reference velocities for the barotropic component of the flow field. One larger mooring, spanning the water column from bottom to 200 m below surface, is measuring temperature, salinity and velocity directly at a variety of depths to validate the GEM-ETTA method. All the ASTTEX moorings are equipped with internally recording instruments from which the data will not be available until the moorings are recovered at the end of the experiment. Results presented here are thus from the data actually collected during the cruise, and not the mooring data.

PIES moorings require *in situ* calibration of the acoustic travel time, which can be computed from a CTDO cast. This calibration was provided by taking at least one CTDO cast at each PIES mooring location after deployment. When logistical constraints permitted, the calibration station was occupied again after some hours had elapsed; the time lag allows for better temperature equilibration of the bottom pressure sensor, hence a better data sample from the PIES instrument. The CTDO transect accomplished as a part of the mooring deployment and calibration procedure provides a snapshot of hydrographic conditions that obtained in the Cape Basin during the cruise; it may be viewed as a single sample of the kind of information that will be collected by the moorings over a two-year period. Bottle samples of both oxygen and salinity were collected to calibrate the CTDO casts themselves. Nutrient samples were not collected due to the last-minute withdrawal from the cruise of a collaborating South African investigator, Dr. Alan Meyer, whose research interests had led him to plan that work.

3.1.3 Some Results

The actual cruise schedule followed the pre-cruise plan fairly closely. All sixteen mooring deployments in the Cape Basin were accomplished without incident and all of the moored instruments functioned properly during final checkout and during *in situ* interrogation after deployment (only the PIES are able to be so interrogated). Due do extremely good weather and the smooth deployments we were able to devote additional time to conducting the mesoscale surveys and shelf transects. The total distance along which underway data were collected was approximately 3500 km. Sixty-seven temperature-depth profiles were collected with XBTs, and thirty-nine profiles of salinity, temperature, pressure and oxygen with the CTDO package and rosette system.

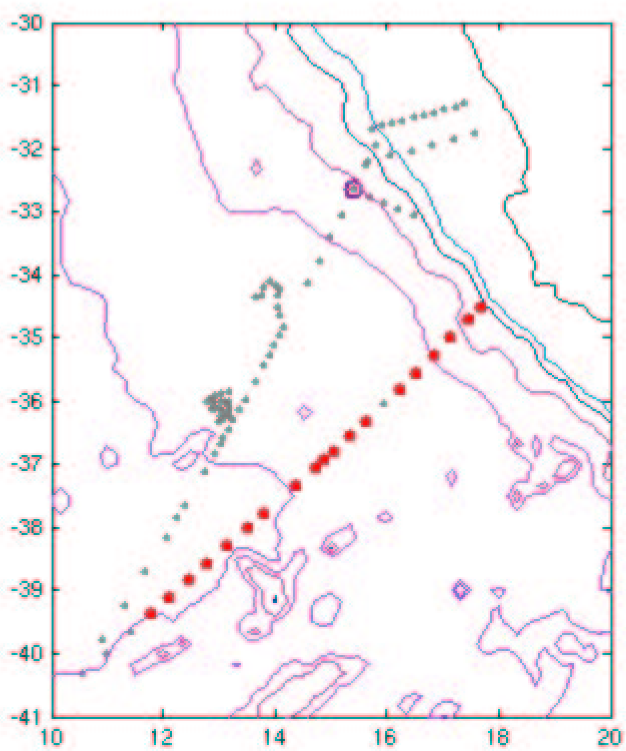


Figure 2: Location of southbound XBT section.

All of the instruments worked fairly well; a fair percentage of XBTs failed either due to problems with the probe or because of connections between the launcher and the data acquisition system before the latter problem was identified and corrected. However, we had plenty of spares on hand. As we moved into shallower waters, the CTDO package suffered from excessive sensor spiking, apparently due to particulate matter in the benthic boundary layer. We were able to flush the sensors and tubing; the re-orientation of the pump outlet after station #28 helped prevent any further such problems. The Niskin bottle at position 18 on the rosette routinely failed to trip after the first couple of casts, but we were able to collect a sufficiently number of samples using the 23 other bottles.

We crossed near the center of a strong Agulhas ring about 32 hours after getting underway, while steaming southwest toward the first fixed CTDO station (Fig. 2). The depth of the 10-degree isotherm in the section of the ring we sampled, a measure of its intensity, is estimated to have been over 750 m; the climatological value for this location is 418 m [Levitus, 1998] (Fig. 3).

Because it was encountered so early in the cruise, we were not able to spare the time to conduct a CTDO survey of this ring. Coincidentally, however, the CTDO test station was occupied at the northeastern edge of this ring and there is strong remnant of Red Sea Water visible in the intermediate water at the station. The temperature-salinity relation at the test station is pictured in Fig. 4.

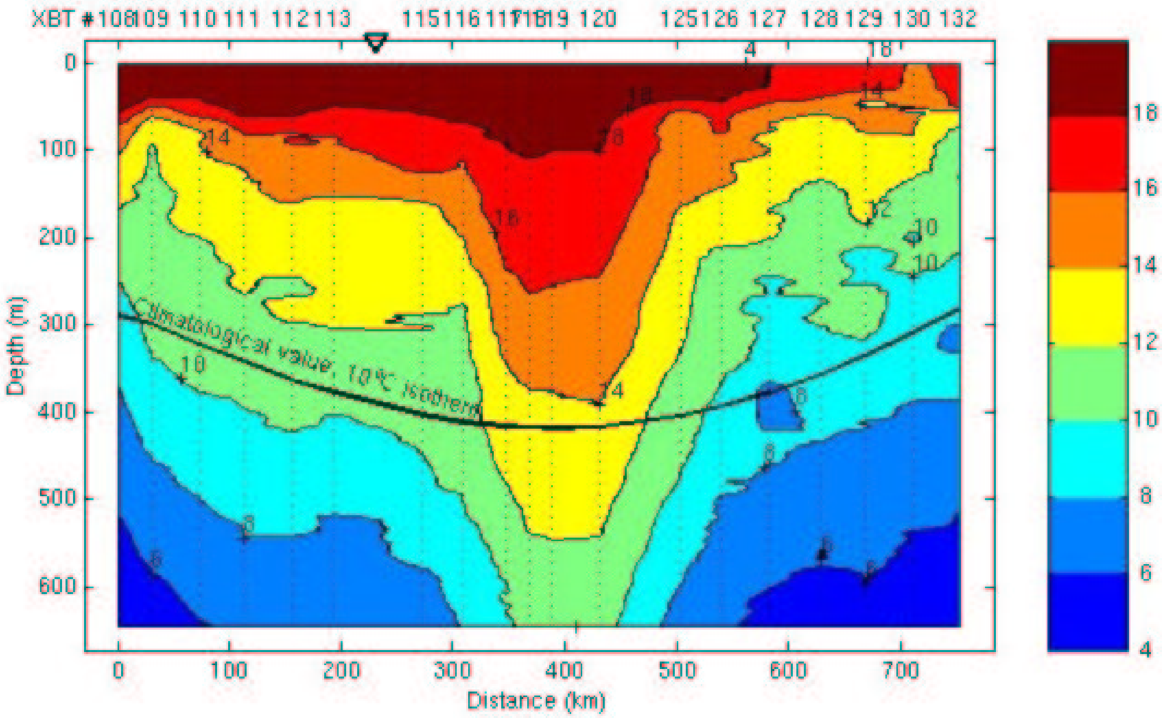
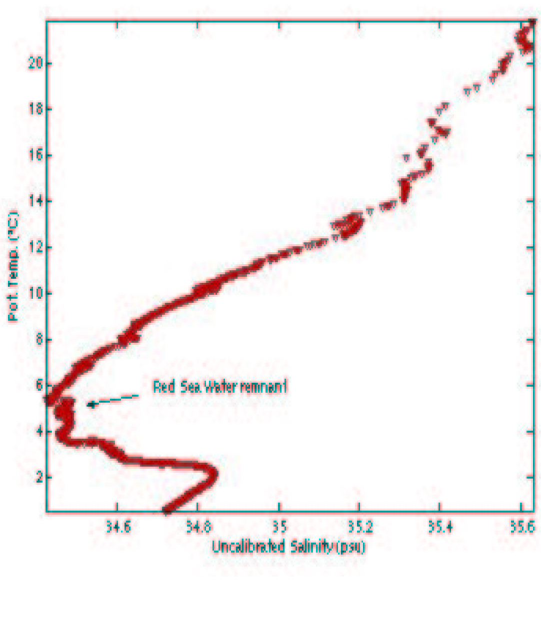


Figure 3: XBT section of Agulhas ring. Black triangle shows position of test CTDO station.



The ring was encountered only 150 km southeast of the position of PIES moored array. As rings in the Cape Basin propagate approximately northwest (see Byrne et al., [1995]), and the diameter of the section we crossed was over 300 km, the thermohaline signal of the Indian Ocean waters at the moorings is expected to be a strong one.

The transect along the mooring array had less in the way of water masses of indisputably Indian Ocean origin. One ring (described in the Cruise Narrative) was encountered. Weak remnants of Red Sea Water were also present at some stations. The station positions along the mooring line are shown in Fig. 5, the uncorrected salinity along this section is shown in Fig. 6, the temperature section in Fig. 7 and the temperature-salinity relationship in Fig. 8. Data from the two mesoscale surveys have not been included in these sections.

Figure 4: Temperature-Salinity relationship for test station. Salinity is uncorrected data.

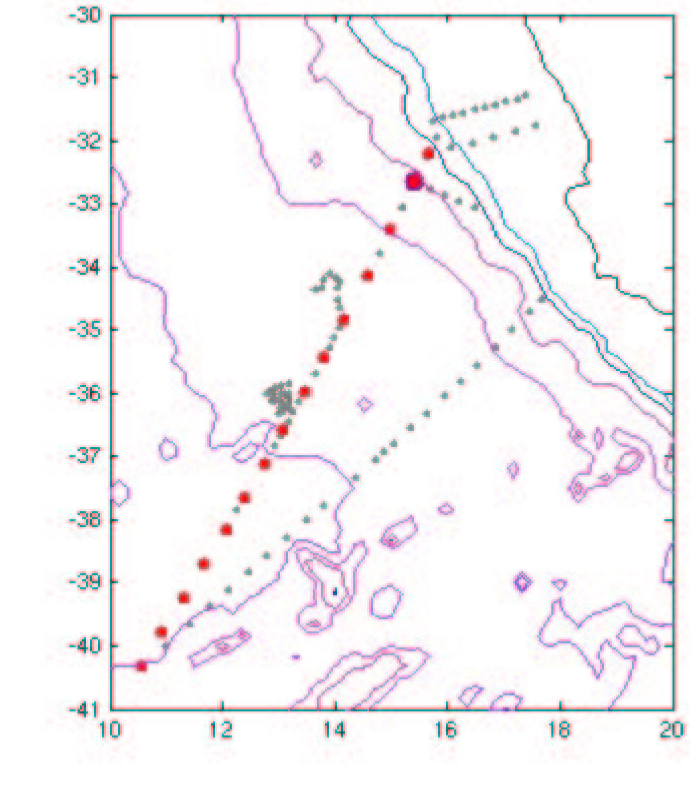


Figure 5: Position of CTDO stations along moored array section.

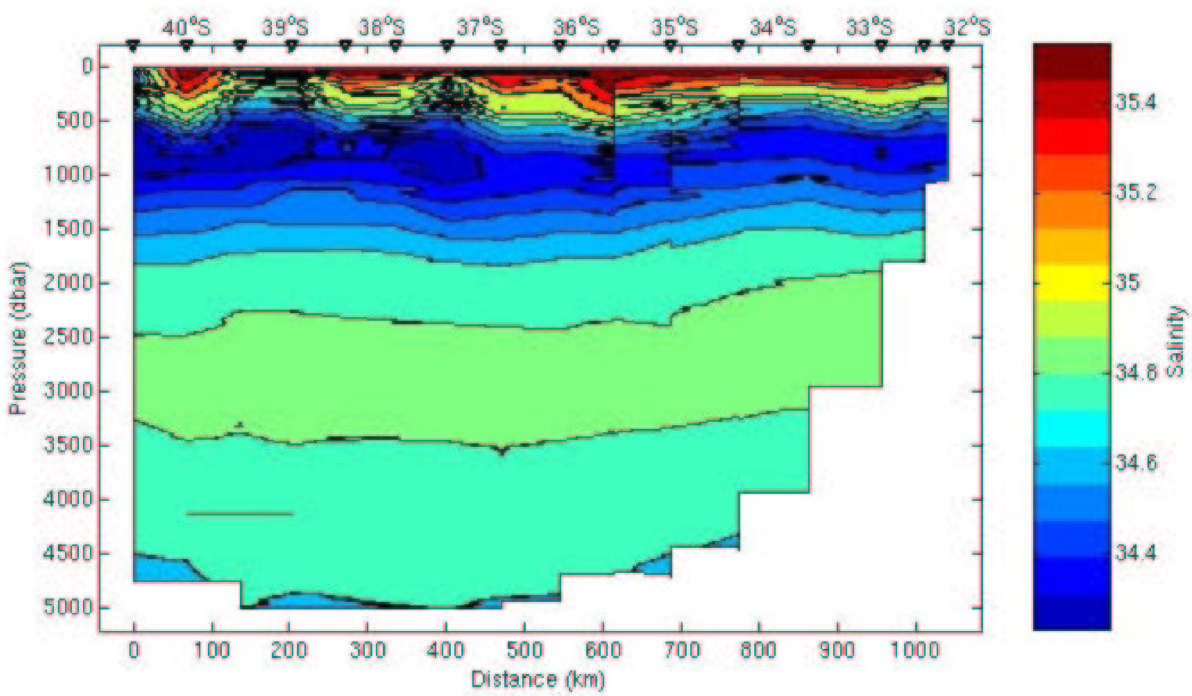


Figure 6: Salinity section along moored array.

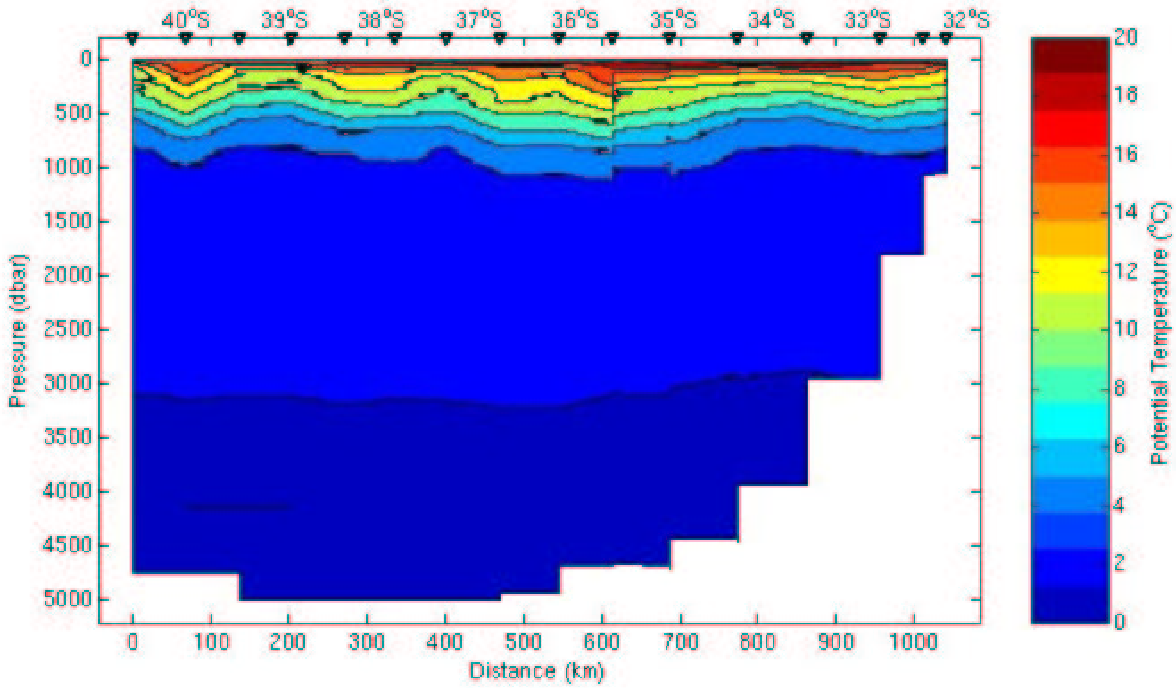


Figure 7: Temperature section along moored array.

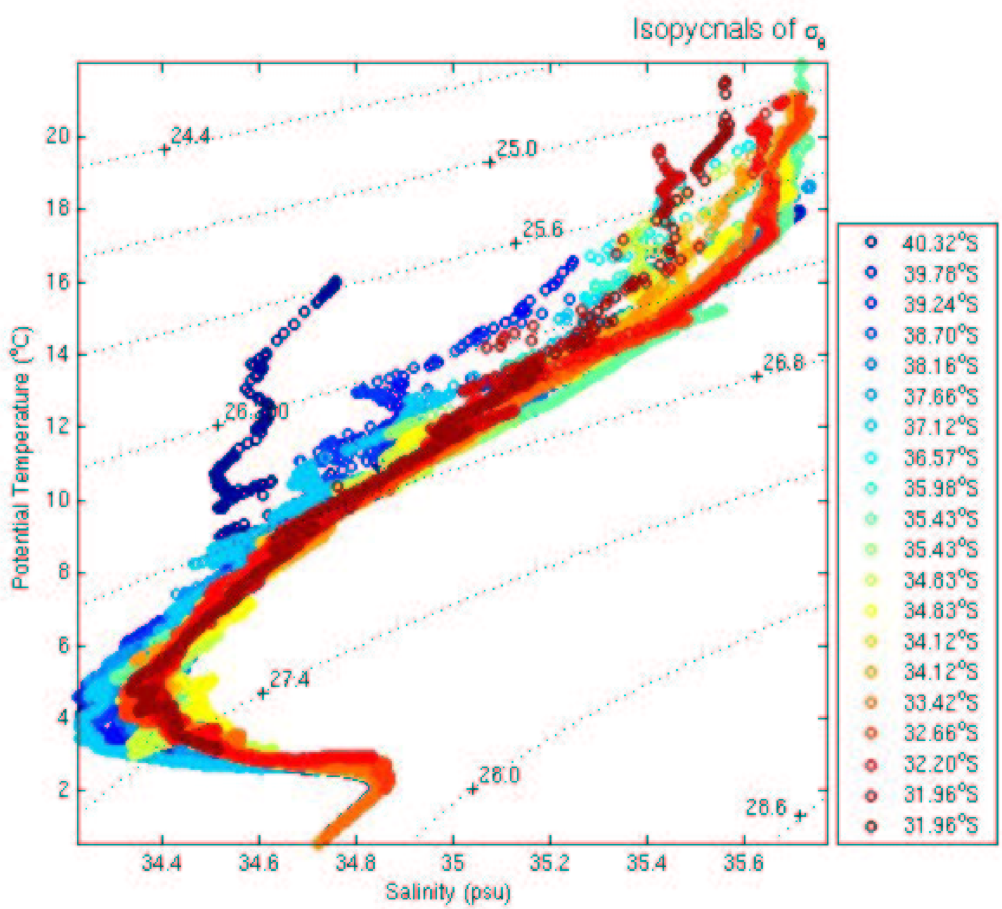


Figure 8: Temperature-salinity relationship for ASTTEX CTDO casts. Salinity is uncorrected.

3.2 Ancillary Project: Cross-Shelf Sections

3.2.1 Introduction

The continental shelf in the region north of St. Helena Bay, from about 33S, widens considerably and the embayment of St Helena Bay creates a relatively sheltered area that is one of the major nursery areas for the pelagic fisheries in the South African West Coast region. The cyclonic circulation within the greater St. Helena Bay contributes to the retention of the pre-recruits and late larvae within the system. Coastal wind driven upwelling of central water draws micronutrients into the photic zone enhancing primary and secondary production and food for the pre-recruit fish. Two sections were occupied across the continental shelf in support of a BENEFIT monitoring program which links with similar lines run in Angola and Namibia. Each transect samples across the shelf in areas important to the early life history of target fish resources. The St. Helena Bay Monitoring Line provides seasonal and interannual information on the hydrology and productivity of the area as related to the young fish stages. It is expected that the timeseries will obtain data on harmful algal blooms, low oxygen water and on intrusions of Agulhas Bank water along the west coast.

3.2.2 Methods and Measurements

The CTDO stations occupied across the shelf cut across the northern part of the St. Helena Bay circulation. These station lines were designated MCM Line R (on a heading of 076T toward a point 31:12.1S, 17:47.9E on the coast) and MCM Line S (on a reciprocal heading 254T from a point 31:37.9S, 18:08.5E on the coast). These lines were chosen because of their convenient proximity to the ASTTEX moored array and oriented parallel to the St. Helena Bay Monitoring Line. On Line R, ten CTDO stations were occupied at ten mile intervals from 110 n.m. (204km) to 20 n.m. (37km) from the coast. The vertical sections of temperature, salinity and oxygen (uncorrected raw data) in the upper 300m for Line R are shown in Fig. 9.

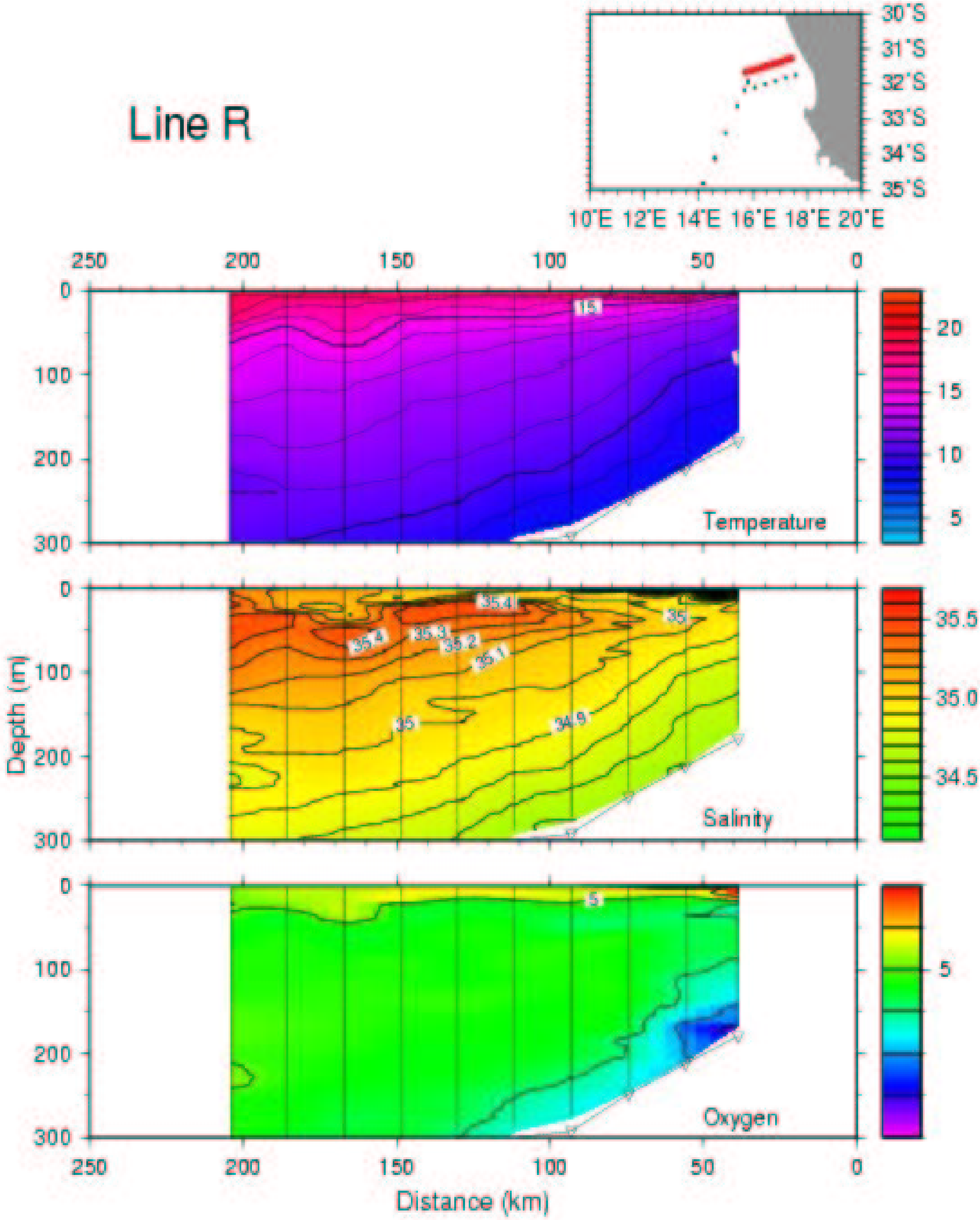


Figure 9: MCM monitoring line R.

The oxygen section indicates the decreasing oxygen concentrations near the bottom in the inshore stations but the survey did not extend sufficiently close inshore to show the extreme oxygen depletion (concentrations of less than 0.5ml/L) usually found in this part of the shelf. The salinity data show evidence of recent upwelling indicated by the inversion near the surface extending offshore from 50km from the coast (from the 2nd CTDO station). This upwelled water has been at the surface long enough for the temperature signature to be masked by surface warming. The temperature signal of the upwelling front is not fully developed, appearing between the 1st and 2nd inshore stations on the line. On line S six stations were occupied at twenty nautical mile intervals from 30n.m. (56 km) to 130 n.m. (241 km) from the coast. The section surveyed along Line S (Fig. 10) began further offshore than that of on Line R and thus the inshore stations on this line do not show any oxygen depletion. Upwelling features are also evident in the salinity section here with the surface haline front better developed between the third and fourth stations (150 km offshore) than in the section along Line R. These data also indicate that the upwelling event was sufficiently old for the surface temperature signal to be reduced.

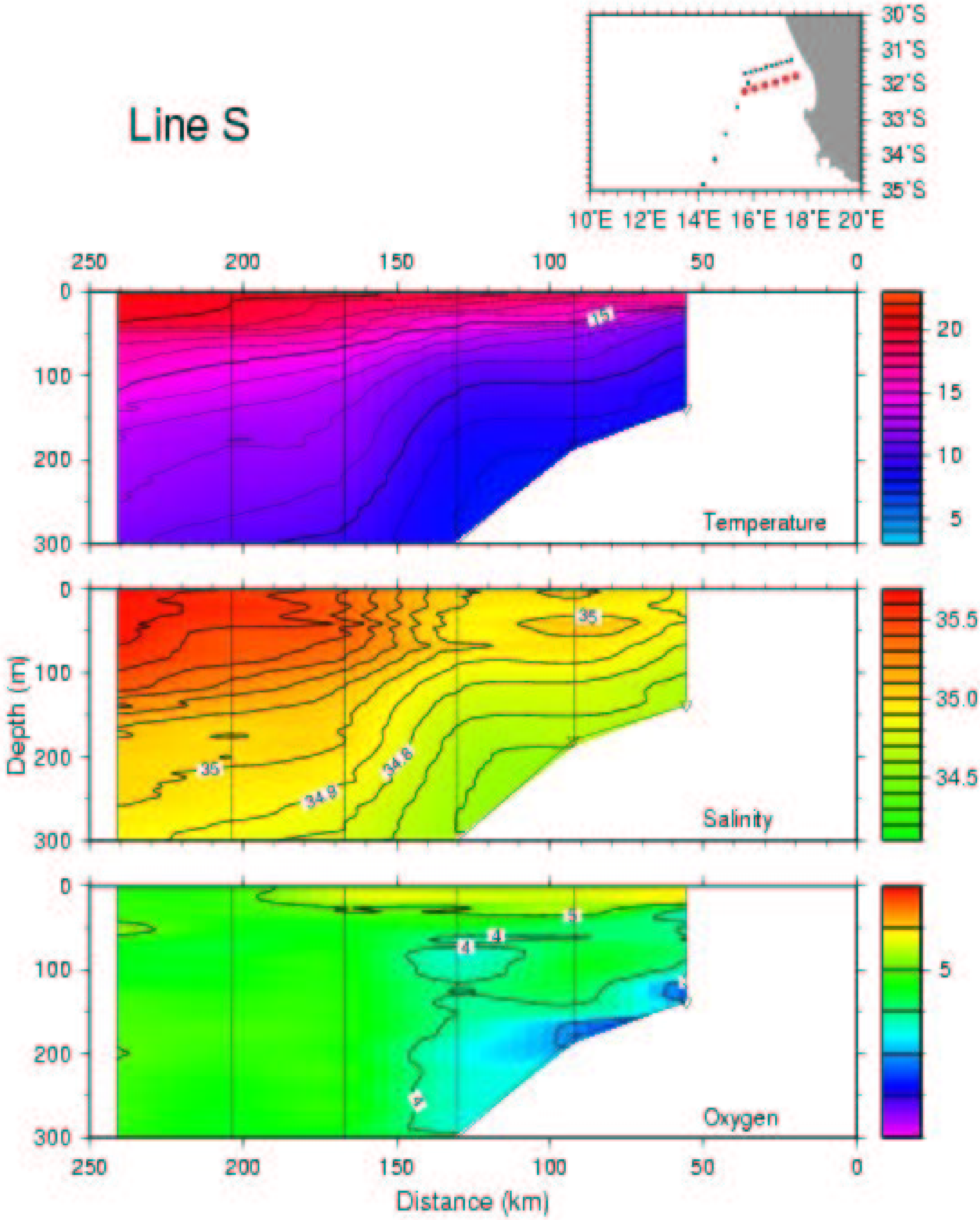


Figure 10: MCM monitoring line S.

3.2.3 Results

The initial results from the sections show evidence of a fairly recent upwelling event which has sufficiently decayed to lose its temperature signal in the upper fifty meters but not the salinity signal. These data will be compared with data from the St. Helena Bay monitoring line occupied in January, and other routine cruises in the area. Evidence of oxygen depleted water was not found in the sections which extend to approximately 50 km from the coast. There does not appear to be evidence of a strong shelf edge jet. The distribution of temperature and salinity suggests generally northward flow across both sections. The lines do not extend close enough inshore to resolve fully the cyclonic circulation within the bay.

3.3 Data Observations and Samples Collected

Copies of all underway and CTDO data were provided to MCM (South Africa) and MFMR (Namibia) at the end of the cruise. Processed XBT and CTDO data will be available by October, 2003. We anticipate at least one publication from the cruise data, with a probable publication date of March 2005.

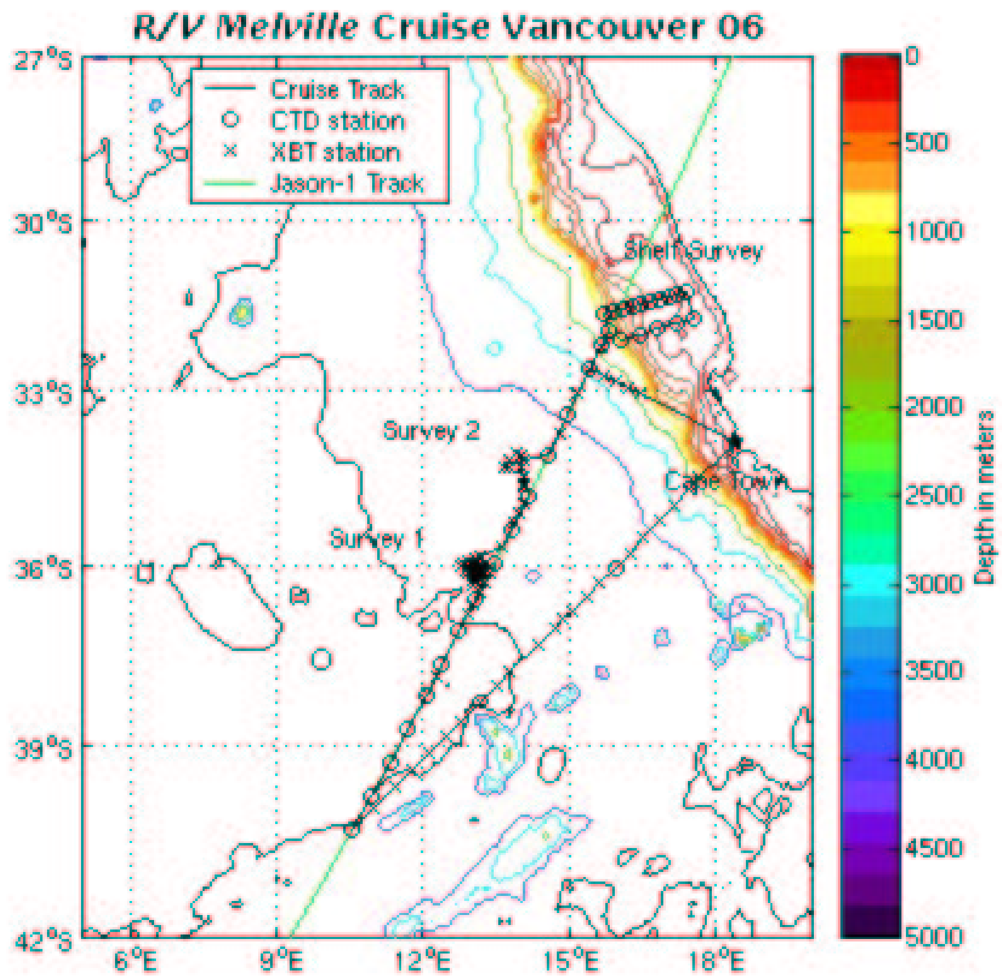
Schedule for delivery for all data results and reports:

Data collected	**Delivery to Host Country**
39 CTDO profiles	October 2003
67 XBT profiles	October 2003
Sea Beam bathymetry	October 2003
Underway ADCP	October 2003

4. Cruise Participants: Scientific Personnel

Name	Organization	Nationality
Deirdre Byrne	UM	US
Neal Pettigrew	UM	US
Linda Mangum	UM	US
D. Randolph Watts	URI	US
Sheekela Baker	URI	US
Gene Pillard	SIO	US
Christopher Duncombe Rae	MCM	South Africa
Franklin Frantz	MCM	South Africa
Raymond Roman	UCT	South Africa
Aina Iita	MFMR	Namibia
Jeremia Titus	MFMR	Namibia
Abbreviations		
UM: University of Maine		
URI: University of Rhode Island		
MCM: Marine and Coastal Management, Department of Environmental Affairs and Tourism, Republic of South Africa		
MFMR: Ministry of Fisheries and Marine Resources, Republic of Namibia		
UCT: University of Cape Town		

5 Appendix A. Cruise track



6 Appendix B. Event Log/Position Data Sheet

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POSITION DATA SHEET

CRUISE: Vancouver 06 VESSEL: R/V MELVILLE SHEET: 1 OF 6

Date	YEAR	GMT	Latitude	Longitude	Remarks	Int.
JAN 02	03	1406	33 54.206	018 25.389	DEPART CAPE TOWN VANCOUVER 6	JF
JAN 03	03	0244	35 30.093	016 34.858	DEPLOYED SOLO FLOAT #178	BW
JAN 03	03	0712	36 02.796	015 57.632	DEPLOYED TEST CTD #1	PAB
JAN 03	03	0815	36 02.796	015 57.642	CTD #1 ON DECK	PAB
JAN 03	03	0823	36 02.795	015 57.636	REDEPLOYED TEST CTD #1A	PAB
JAN 03	03	0955	36 02.798	015 57.639	TEST CTD #1A AT DEPTH 4597M	JF
JAN 03	03	1141	36 02.792	015 57.645	TEST CTD #1A ON DECK	JF
JAN 04	03	2127	40 19.094	010 32.908	DEPLOYED CTD #2	PAB
JAN 04	03	2305	40 19.093	010 32.888	CTD #2 AT DEPTH 4734M	JF
JAN 05	03	0106	40 19.088	010 32.895	CTD #2 ON DECK	JF
JAN 05	03	0125	40 18.971	010 32.994	DEPLOYED SOLO FLOAT #179	JF
JAN 05	03	0455	39 46.791	010 56.088	CTD #3 DEPLOYED	BW
JAN 05	03	0632	39 46.794	010 56.070	CTD #3 AT DEPTH 4685M	PAB
JAN 05	03	0833	39 46.795	010 56.069	CTD #3 ON DECK	PAB
JAN 05	03	1015	39 46.795	010 56.069	ACOUSTIC RELEASE TEST DEPLOYED	JF
JAN 05	03	1114	39 46.793	010 56.069	ACOUSTIC RELEASE ON DECK	JF
JAN 05	03	1117	39 46.787	010 56.071	RELEASE TEST #2 DEPLOYED	JF
JAN 05	03	1228	39 46.795	010 56.070	RELEASE TEST #2 ON DECK	JF
JAN 05	03	1230	39 46.795	010 56.068	RELEASE TEST #3 DEPLOYED	JF
JAN 05	03	1313	39 46.794	010 56.070	RELEASE TEST #3 ON DECK	JF
JAN 05	03	1316	39 46.795	010 56.070	RELEASE TEST #4 DEPLOYED	JF
JAN 05	03	1405	39 46.796	010 56.070	RELEASE TEST #4 ON DECK	BW
JAN 05	03	1840	39 14.446	011 18.896	PIES #052 DEPLOYED	PAB
JAN 05	03	2047	39 14.440	011 18.886	CTD #4 DEPLOYED	PAB
JAN 05	03	2224	39 14.439	011 18.886	CTD #4 AT DEPTH 5161M	JF

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POSITION DATA SHEET

CRUISE: Vancouver 06 VESSEL: R/V MELVILLE SHEET: 2 OF 6

Date	YEAR	GMT	Latitude	Longitude	Remarks	Int.
JAN 06	03	0043	39 14.415	011 18.862	CTD #4 ON DECK	JF
JAN 06	03	0420	38 42.000	011 41.320	PIES #064 DEPLOYED	EB
JAN 06	03	0608	38 42.003	011 41.325	CTD #5 DEPLOYED	PAB
JAN 06	03	0746	38 42.004	011 41.322	CTD #5 AT DEPTH 5163M	PAB
JAN 06	03	1001	38 42.003	011 41.325	CTD #5 ON DECK	JF
JAN 06	03	1315	38 09.454	012 03.393	PIES #054 DEPLOYED	JF
JAN 06	03	1518	38 09.466	012 03.351	CTD #6 DEPLOYED	JF
JAN 06	03	1648	38 09.462	012 03.356	CTD #6 @ DEPTH 4940M	BW
JAN 06	03	1911	38 09.467	012 03.352	CTD #6 ON DECK	PAB
JAN 06	03	2231	37 39.812	012 23.078	PIES #061 DEPLOYED	JF
JAN 07	03	0025	37 39.812	012 23.077	CTD #7 DEPLOYED	JF
JAN 07	03	0205	37 39.812	012 23.072	CTD #7 @ DEPTH 5097M	BW
JAN 07	03	0419	37 39.812	012 23.075	CTD #7 ON BOARD	EB
JAN 07	03	0716	37 24.829	012 32.808	START DEPLOYMENT CMM #3	PAB
JAN 07	03	0812	37 24.956	012 32.819	ANCHOR DEPLOYED CMM #3	PAB
JAN 07	03	1212	37 07.141	012 44.422	PIES #066 DEPLOYED	JF
JAN 07	03	1415	37 07.115	012 44.418	CTD #8 DEPLOYED	BW
JAN 07	03	1550	37 07.117	012 44.412	CTD #8 @ DEPTH 4901M	BW
JAN 07	03	1558	37 07.116	012 44.420	CTD #8 @ FINAL DEPTH 5125M	BW
JAN 07	03	1816	37 07.326	012 44.464	CTD #8 ON DECK	PAB
JAN 07	03	2227	36 34.338	013 05.411	PIES #060 DEPLOYED	JF
JAN 08	03	0021	36 34.340	013 05.413	CTD #9 DEPLOYED	JF
JAN 08	03	0200	36 34.340	013 05.414	CTD #9 @ DEPTH 4955M	BW
JAN 08	03	0412	36 34.341	013 05.414	CTD #9 ON BOARD	EB
JAN 08	03	0418	36 34.341	013 05.413	DEPLOYED SOLO FLOAT #192	EB

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POSITION DATA SHEET

CRUISE: Vancouver 06 VESSEL: R/V MELVILLE SHEET: 3 OF 6

Date	YEAR	GMT	Latitude	Longitude	Remarks	Int.
JAN 08	03	0826	35 58.463	013 27.959	PIES #051 DEPLOYED	PAB
JAN 08	03	1007	35 58.544	013 27.923	CTD #10 DEPLOYED	JF
JAN 08	03	1144	35 58.495	013 27.932	CTD #10 At DEPTH 4868M	JF
JAN 08	03	1359	35 58.495	013 27.932	CTD #10 ON DECK	BW
JAN 08	03	1932	36 09.706	013 03.880	CTD #11 DEPLOYED	PAB
JAN 08	03	2016	36 09.703	013 03.875	CTD #11 AT DEPTH 2000M	PAB
JAN 08	03	2116	36 09.707	013 03.882	CTD #11 ON DECK	PAB
JAN 08	03	2339	36 13.274	013 10.338	CTD #12 DEPLOYED	JF
JAN 09	03	0023	36 13.342	013 10.273	CTD #12 AT DEPTH 2000M	JF
JAN 09	03	0128	36 13.344	013 10.274	CTD #12 ON DECK	JF
JAN 09	03	0345	36 00.004	013 09.997	CTD #13 DEPLOYED	BW
JAN 09	03	0438	36 00.001	013 10.001	CTD #13 MAX DEPTH 2020m	EB
JAN 09	03	0546	36 00.015	013 09.946	CTD #13 ON DECK	PAB
JAN 09	03	1422	35 25.547	013 48.220	PIE 055 DEPLOYED	BW
JAN 09	03	1609	35 25.462	013 48.197	CTD #14 DEPLOYED	BW
JAN 09	03	1742	35 25.563	013 48.151	CTD #14 @ DEPTH 4624M	BW
JAN 09	03	1935	35 25.586	013 48.174	CTD #14 ON DECK	PAB
JAN 09	03	2347	34 49.909	014 09.785	PIES #050 DEPLOYED	JF
JAN 10	03	0130	34 49.912	014 09.804	CTD #15 DEPLOYED	JF
JAN 10	03	0306	34 49.911	014 09.801	CTD #15 @ DEPTH 4688M	BW
JAN 10	03	0700	34 46.265	014 08.233	START VALIDATION MOORING DEP.	PAB
JAN 10	03	1632	34 49.900	014 10.659	ANCHOR DEPLOYED	BW
JAN 10	03	1800	34 49.620	014 10.250	CT MOORING INSTALLED POS'N	EB
JAN 10	03	2130	35 25.587	013 48.206	CTD #16 DEPLOYED	PAB
JAN 10	03	2307	35 25.562	013 48.235	CTD #16 @ DEPTH 4637	JF

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POSITION DATA SHEET

CRUISE: Vancouver Φ6 VESSEL: R/V MELVILLE SHEET: 4 OF 6

Date	YEAR	GMT	Latitude	Longitude	Remarks	Int.
JAN 11	03	0128	35 25.560	013 48.236	CTD #16 ON DECK	JF
JAN 11	03	0542	34 49.875	014 09.729	CTD #17 DEPLOYED	EB
JAN 11	03	0715	34 49.721	014 08.821	CTD #17 AT DEPTH 4690M	PAB
JAN 11	03	2030	34 07.418	014 34.989	PIES 059 DEPLOYED	PAB
JAN 11	03	2230	34 07.421	014 34.992	CTD # 18 DEPLOYED	JF
JAN 11	03	2355	34 07.431	014 34.986	CTD #18 AT DEPTH 4380	JF
JAN 12	03	0204	34 07.429	014 34.984	CTD #18 ON DECK	BW
JAN 12	03	0442	33 46.272	014 47.264	START CMM2 DEPLOYMENT	EB
JAN 12	03	0516	33 46.549	014 47.609	DROP CMM2 ANCHOR	EB
JAN 12	03	0835	33 25.188	014 59.523	PIES 049 DEPLOYED	PAB
JAN 12	03	1426	34 07.414	014 34.980	CTD #19 DEPLOYED	BW
JAN 12	03	1556	34 07.419	014 34.983	CTD #19 @ DEPTH 4421M	BW
JAN 12	03	2214	33 25.171	014 59.489	CTD #20 DEPLOYED	JF
JAN 12	03	2331	33 25.201	014 59.466	CTD #20 AT DEPTH 3900M	JF
JAN 13	03	0130	33 25.202	014 59.470	CTD #20 ON DECK	JF
JAN 13	03	0621	32 39.669	015 25.515	START CMM1 DEPLOYMENT	PAB
JAN 13	03	0704	32 39.835	015 25.222	CMM1 ANCHOR DEPLOYED	EB
JAN 13	03	1202	31 57.410	015 48.751	PIES #042 DEPLOYED	JF
JAN 13	03	1245	31 57.405	015 48.759	CTD #21 DEPLOYED	JF
JAN 13	03	1319	31 57.405	015 48.760	CTD #21 AT DEPTH 1056m	JF
JAN 13	03	1405	31 57.404	015 48.761	CTD #21 ON DECK	BW
JAN 13	03	1554	31 41.468	015 43.521	CTD R # 11 DEPLOYED	BW
JAN 13	03	1623	31 41.266	015 43.085	CTD R # 11 @ DEPTH 840M	BW
JAN 13	03	1647	31 41.264	015 43.083	CTD R # 11 ON DECK	BW
JAN 13	03	1804	31 38.860	015 54.929	CTD R # 10 DEPLOYED	PAB

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POSITION DATA SHEET

CRUISE: Vancouver Ø6 VESSEL: R/V MELVILLE SHEET: 5 OF 6

Date	YEAR	GMT	Latitude	Longitude	Remarks	Int.
JAN 13	03	1826	31 38.861	015 54.941	CTD R # 10 @ DEPTH 552M	PAB
JAN 13	03	1844	31 38.861	015 54.944	CTD R # 10 ON DECK	PAB
JAN 13	03	2003	31 36.279	016 06.296	CTD R # 9 DEPLOYED	PAB
JAN 13	03	2022	31 36.281	016 06.291	CTD R # 9 @DEPTH 452M	PAB
JAN 13	03	2036	31 36.282	016 06.297	CTD R # 9 ON DECK	PAB
JAN 13	03	2153	31 33.679	016 17.626	CTD R # 8 DEPLOYED	JF
JAN 13	03	2211	31 33.683	016 17.630	CTD R # 8 AT DEPTH 420M	JF
JAN 13	03	2233	31 33.683	016 17.628	CTD R # 8 ON DECK	JF
JAN 13	03	2345	31 31.039	016 28.873	CTD R # 7 DEPLOYED	JF
JAN 14	03	0000	31 31.033	016 28.877	CTD R # 7 AT DEPTH 335M	JF
JAN 14	03	0014	31 31.032	016 28.874	CTD R # 7 ON DECK	JF
JAN 14	03	0126	31 28.368	016 40.241	CTD R # 6 DEPLOYED	JF
JAN 14	03	0140	31 28.368	016 40.245	CTD R # 6 AT DEPTH 285M	JF
JAN 14	03	0153	31 28.369	016 40.243	CTD R # 6 ON DECK	BW
JAN 14	03	0317	31 25.718	016 51.541	CTD R # 5 DEPLOYED	BW
JAN 14	03	0333	31 25.721	016 51.546	CTD R # 5 @ DEPTH 270M	BW
JAN 14	03	0346	31 25.720	016 51.547	CTD R # 5 ON DECK	BW
JAN 14	03	0500	31 23.038	017 02.852	CTD R # 4 DEPLOYED	EB
JAN 14	03	0514	31 23.035	017 02.848	CTD R # 4 AT DEPTH 239M	EB
JAN 14	03	0525	31 23.033	017 02.849	CTD R # 4 ON BOARD	EB
JAN 14	03	0634	31 20.311	017 14.207	CTD R # 3 DEPLOYED	PAB
JAN 14	03	0645	31 20.332	017 14.203	CTD R # 3 @ DEPTH 201M	PAB
JAN 14	03	0654	31 20.347	017 14.201	CTD R # 3 ON DECK	PAB
JAN 14	03	0803	31 17.563	017 25.394	CTD R # 2 DEPLOYED	PAB
JAN 14	03	0811	31 17.599	017 25.415	CTD R # 2 @ DEPTH 160M	PAB

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POSITION DATA SHEET

CRUISE: Vancouver Ø6 VESSEL: R/V MELVILLE SHEET: 6 OF 6

Date	YEAR	GMT	Latitude	Longitude	Remarks	Int.
JAN 14	03	0821	31 17.617	017 25.453	CTD R # 2 ON DECK	PAB
JAN 14	03	1110	31 46.063	017 34.624	CTD S # 3 DEPLOYED	JF
JAN 14	03	1118	31 46.084	017 34.694	CTD S # 3 AT DEPTH 129M	JF
JAN 14	03	1127	31 46.174	017 34.727	CTD S # 3 ON DECK	JF
JAN 14	03	1329	31 51.383	017 11.948	CTD S # 5 DEPLOYED	JF
JAN 14	03	1337	31 51.396	017 11.931	CTD S # 5 AT DEPTH 182M	JF
JAN 14	03	1553	31 56.731	016 49.131	CTD # S 7 DEPLOYED	BW
JAN 14	03	1608	31 56.534	016 49.003	CTD # S 7 @ DEPTH 294M	BW
JAN 14	03	1624	31 56.468	016 48.843	CTD # S 7 ON DECK	BW
JAN 14	03	1825	32 01.950	016 26.492	CTD S # 9 DELPOYED	PAB
JAN 14	03	1840	32 01.958	016 26.490	CTD S # 9 @ DEPTH 377M	PAB
JAN 14	03	1854	32 01.960	016 26.490	CTD S # 9 ON DECK	PAB
JAN 14	03	2117	32 07.159	016 03.679	CTD S # 11 DEPLOYED	PAB
JAN 14	03	2141	32 07.159	016 03.679	CTD S # 11 @ DEPTH 900M	PAB
JAN 14	03	2203	32 07.162	016 03.681	CTD S # 11 ON DECK	JF
JAN 14	03	2345	31 57.377	015 48.768	CTD #37 DEPLOYED	JF
JAN 15	03	0010	31 57.384	015 48.768	CTD #37 AT DEPTH 1045M	JF
JAN 15	03	0037	31 57.384	015 48.768	CTD #37 ON DECK	JF
JAN 15	03	0228	32 12.245	015 40.818	CTD # S 13 DEPLOYED	BW
JAN 15	03	0309	32 12.248	015 40.814	CTD # S 13 @ DEPTH 1790M	BW
JAN 15	03	0344	32 12.245	015 40.815	CTD # S 13 ON DECK	BW
JAN 15	03	0653	32 39.258	015 25.125	CTD #39 @ CMM1 DEPLOYED	PAB
JAN 15	03	0753	32 39.260	015 25.122	CTD #39 @ CMM1 @ DEPTH 2930M	PAB
JAN 15	03	0844	32 39.259	015 25.122	CTD #39 @ CMM1 ON DECK	PAB
JAN 16	03	0612	33 54.227	018 25.412	ARRIVE CAPE TOWN	JF