WHP Cruise Summary Information

WOCE section designation	A23
Expedition designation (EXPOCODE)	74JC10_1
Chief Scientist(s) and their affiliation	Karen Heywood, UEA Brian King, SOC
Dates	1995.03.20 – 1995.05.06
Ship	JAMES CLARK ROSS
Ports of call	Stanley, Falkland Islands to Rio de Janeiro, Brazil
Number of stations	128
Geographic boundaries of the stations	26°15.03''S 60°33.46''W 16°31.12''W 72°29.74''S
Floats and drifters deployed	10 Floats
Moorings deployed or recovered	none

Contributing Authors (in order of appearance)

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RRS *James Clark Ross* Cruise 10
20th March - 6th May 1995

World Ocean Circulation Experiment WOCE Hydrographic Programme One-Time Section A23

A Hydrographic Section from Antarctica to Brazil in the Southwest Atlantic

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UEA Cruise Report Series No. 1
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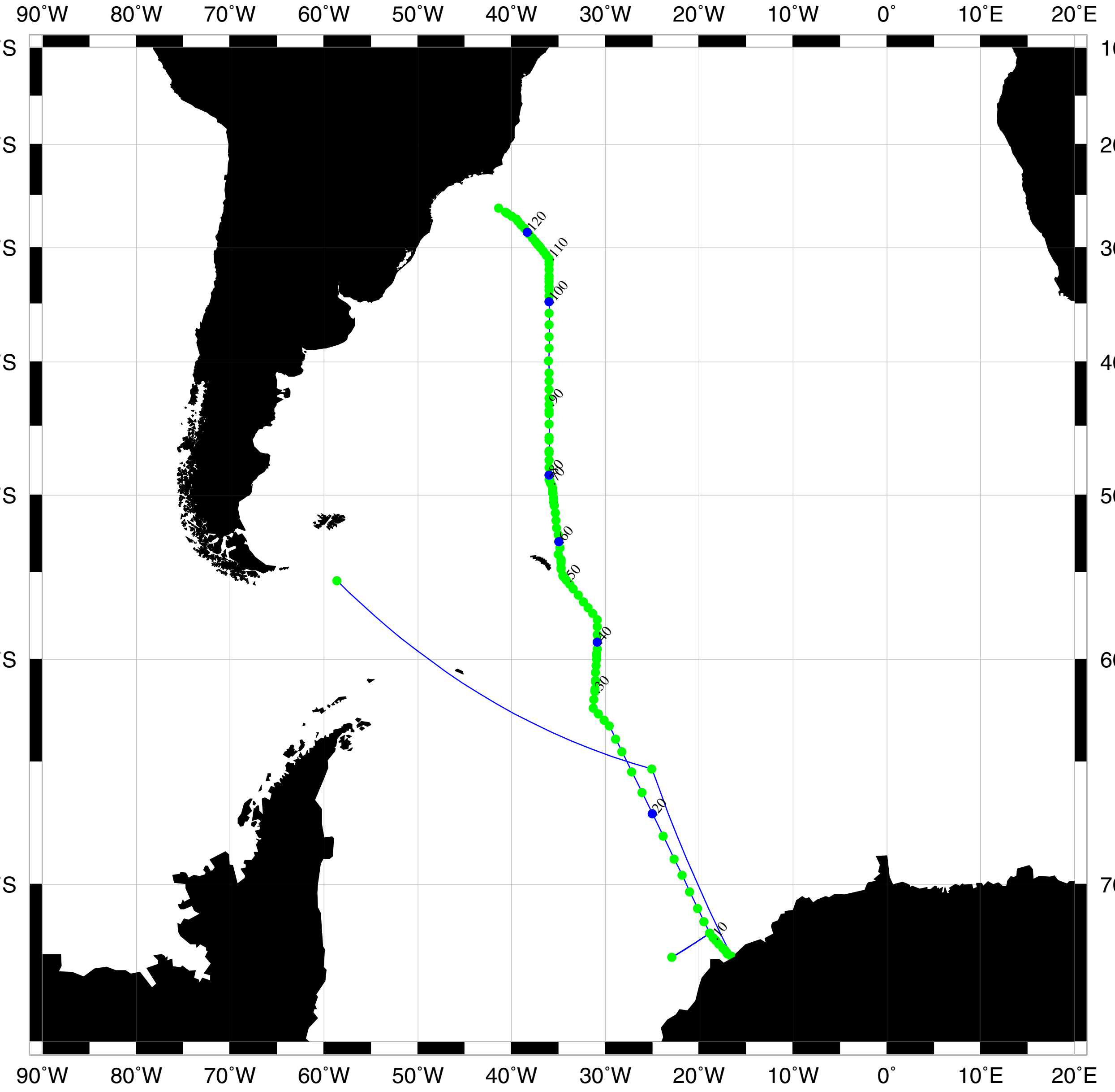
Contents

Instructions: Click on items below to locate primary reference(s) or use navigation tools above.

Station locations for A23 : HEYWOOD/KING



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1. A23 Cruise Narrative

1.1 Cruise Summary

This cruise was a part of the One-Time Survey of the World Ocean Circulation Experiment (WOCE). It is designated A23, and also known as JCR10. It took place on the *RRS James Clark Ross*, an ice strengthened vessel operated by the British Antarctic Survey. We left Port Stanley, Falkland Islands, on Monday 20th March 1995, and arrived in Rio de Janeiro, Brazil, on Saturday 6th May 1995 (Figure 1). A total of 128 $CTDO_2$ small volume stations were occupied (Figure 2 and Table 1).

1.2 Cruise Participants

1.2.1 Scientific Party

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1.2.2 Principal Investigators:

Chief Scientist	Karen J. Heywood
Co-Chief Scientist	Brian A. King
$CTDO_2$, Hydrography, ADCP	Karen J. Heywood, Brian A. King
Chlorofluorocarbons	Andy Watson
Nutrients	Richard Sanders
Helium/Tritium	Christine Rüth
Oxygen isotopes, Trace metals	Russell Frew
Iodine	Lucia Campos
Meteorology	Trevor Guymer
Optical measurements	Carlos Garcia
CO_2, Chlorophyll	Jane Robertson

1.2.3 Ship's Officers and Crew

Chris Elliott	Master
John Marshall	Chief Officer
Stewart Wallace	2nd Officer
Antonio Gatti	3rd Officer
Dave Cutting	Chief Engineer
Bill Kerswell	2nd Engineer
Bob Caldwell	3rd Engineer
Mal Inch	3rd Engineer
Mike Gloistein	Radio Officer
John Summers	Science Officer
Simon Wright	Science Engineer
Norman Thomas	Electrician
Ian Gemmell	Ship's Doctor
Hamish Gibson	Catering Officer
George Stewart	Bosun
Tony Gill	Bosun's Mate
Dave Peck	Seaman

Howie Owen	Seaman
Martin Bowen	Seaman
Keith Beck	Seaman
Charlie Chalk	Seaman
Del Summers	Motorman
Angus Macaskill	Motorman
Sean Hewitt	Chief Cook
Mick Davis	2nd Cook
Nick Greenwood	Steward
Dave Greenwood	Steward
Joe Hanley	Steward
Joe Charlton	Steward

1.3 Cruise Diary

by Karen J. Heywood

Throughout the cruise, ship's time was 3 hours behind universal time (UTC).

Friday 17th March (day 76)

The advance party of scientists joined the *James Clark Ross* in Stanley during the morning, having flown in from the UK on Tuesday. Christine Rüth flew in from Punta Arenas. The remainder of the scientific party should have arrived in Stanley but were delayed, first in the UK, and then in Dakar, following diversion from Ascension.

Saturday 18th March (day 77)

We continued with unloading and unpacking the containers and equipment from the scientific hold. Meteorological instruments were installed on the foremast. We still did not have diplomatic clearance to undertake scientific observations in Brazilian waters, although the paperwork was submitted last September. A telephone call was received from the Brazilian Navy, who were under the impression that we were due to sail from Rio Grande on Monday! They asked to speak to any Brazilians on board - they were not yet here.

Sunday 19th March (day 78)

The remainder of the scientists arrived, very tired, from Dakar early in the morning. The day was spent unpacking and setting up instruments and computers. Discussion with BAS continued regarding picking up a Brazilian observer.

Monday 20th March (day 79)

The ship sailed at 0900 from Stanley, to spend the afternoon bunkering at Mare Harbour. We left the Falklands at 1830. A safety briefing was held during the morning, at which we were also welcomed to the ship by the Master, Chris Elliott. During the afternoon a gathering of scientists was convened to discuss our plans. Logging of ADCP, surface temperature, salinity and fluorescence, meteorological parameters and navigation data commenced. Our track was westward to Punta Delgada, Chile, to pick up our Argentinian colleague, Dr. Ricardo Locarnini and his wife Sally Jo, since he had been refused permission to join the ship in the Falklands. It was a windy night. We discovered that all three of the salinometers were not working correctly, but eventually one of them was persuaded to work, although throughout the cruise its standby value was erratic and meaningless.

Tuesday 21st March (day 80)

The first radiosonde balloon was launched at 1400. The wind had abated but the swell remained. Pstar processing was successfully installed and the first data (ADCP, TSG and Ashtech) read in for test purposes. The radiometer was installed in the bow.

Wednesday 22nd March (day 81)

We awoke to find ourselves in the Straits of Magellan. The transfer of Sally and Ricardo from the Chilean pilot boat at 0700 was extremely quick and efficient. At last we could head east. It was a pleasant sunny day with winds of only force 5-6, much less swell, and we were able to make 13-14 knots. Routines of processing the underway data were now established and in full swing.

Thursday 23rd March (day 82)

Our first day of real action - and very successful. A test full depth CTD station was completed in 4200 m. Three ALACE floats were deployed, the second two at the CTD station and the first accompanied by an XBT. These activities took place just south of Burdwood Bank. Conditions were ideal for our CTD test dip - a very calm, sunny day with a gentle swell - and no problems were encountered. It was clear and cold with the odd hailstorm. We were particularly impressed by the ship's crew's efficient handling of the heavy CTD package and careful winch driving. ADCP penetration to 250 m was achieved even when steaming at 14 knots. In the evening we began a 2 hourly series of XBTs across the fronts of the Antarctic Circumpolar Current.

Friday 24th March (day 83)

There was much excitement in the early morning as we crossed the sharp temperature and salinity gradients of the Polar Front, meriting an extra XBT. The ADCP data later confirmed a very sharp front with peak currents of 1.6 m/s. The first whales and icebergs were seen during the day, and the sea surface temperature decreased steadily. A cocktail party was held in the Chief Scientist's cabin during the evening.

Saturday 25th March (day 84)

The weather deteriorated until by the afternoon we were only making 7 knots and the XBTs were decreased to 4 hourly.

Sunday 26th March (day 85)

The final XBT of our southbound ACC section was deployed at 0900. The southward steam continued with underway ADCP, surface temperature and salinity measurements, meteorological logging and radiosonde balloon launches.

Monday 27th March (day 86)

The edge of the Antarctic pack ice was encountered today.

Tuesday 28th March (day 87)

A second test CTD station was conducted at 0600, primarily as a determination of the CFC bottle blanks. Ideally we would have liked freon free water, but we knew that all of the Weddell Sea would contain CFCs at some level. The location was chosen on the basis of historical CFC data from Ajax and some German WOCE stations in the Weddell Sea to have low levels of CFCs. A successful trial deployment of Carlos Garcia's solar irradiance buoy was completed during the CTD deployment. Our first penguins standing on ice floes were seen. Ice maps obtained via the Rennell Centre, derived from satellite data, showed the ice filling in fast. Because of starting the cruise so late in the season, we were unable to reach the intended longitude of 35°W for the A23 section. The southern end of the section was replanned for 16°W. This was unfortunate since the 35°W section should have commenced in the Filchner-Ronne Depression where recently formed bottom waters should have been encountered. However it was clear from all sources of ice information that the ice coverage would prevent us from travelling along a longitude further west than 20°W. Andy Watson proposed a foray into the ice to do just one station further along the Antarctic continent. During the evening a brief presentation of the goals of the cruise was given to the assembled ship's company.

Wednesday 29th March (day 88)

The decision was made to complete the first 10 stations of the section, which would take us across the continental shelf and into water deeper than 4000 m, while ice conditions allowed. Reaching the shelf at 16°W near Cape Norwegia, we would be only a few tens of miles from 50% ice cover. If newly ventilated water was found, a westward foray into the ice would be unnecessary. The day was spent in pancake ice and snow lay on the ship. Our second scientific gathering was held in the evening.

Thursday 30th March (day 89)

We started the A23 section at last! We arrived close to the Antarctic continent at 16°W early in the morning. The edge of the ice shelf was some 20 miles further north than the charts showed. We completed our first A23 CTD station in 185 m of water one mile from the ice shelf, after some delay due to failure of the level A logging system. The CTD eventually went ahead using only the PC logging. On bringing the CTD inboard, we found the water in the bottles had already frozen due to the extremely cold air temperatures. Although we moved it into the heated water bottle annex, the damage had already been done and the resulting salinities were meaningless. At subsequent stations this was no longer a problem since the air temperatures increased dramatically away from the ice shelf; nevertheless sampling was undertaken in the water bottle annex and out of the wind.

Stations continued northwestwards perpendicular to the bathymetry on every 500 m depth contour down the slope, usually 5-10 miles apart. At least 2 hours were spent at each station to ensure good ADCP data across the Antarctic Coastal Current.

Friday 31st March (day 90)

CTD stations continued, with an irradiance buoy deployment during the morning. After a particularly noisy station it was necessary to reterminate the CTD cable, which delayed us for about 4 hours. On the following station, the rosette jammed at bottle number 4 and it was necessary to repeat the cast. We came out of the pancake ice today but there were many icebergs around, and it snowed. After completing station 11 (the 9th of the section) it was apparent that no particularly young water had been detected in the CFC data. Accordingly, we steamed to the southwest into the ice for 9 hours, to undertake a station as far west as possible. The steam came as a welcome break for the chemical sampling and analysis teams, who had been working hard to keep up with such closely spaced stations.

Saturday 1st April (day 91)

We arrived at the position of station 12 at 8 am and did the cast in thick pancake ice. It is believed that this is the southernmost position that the *James Clark Ross* has ever ventured to. Analysis of the CFC data afterwards showed little difference between this station and those of our section further to the east. Because the rosette has been misfiring badly, we exchanged the pylon for our spare one. This proved to be one of the best decisions of the cruise, since the replacement pylon behaved better than I have ever seen on a 24 bottle rosette before. We were back on the A23 section at 7 pm for station 13, a repeat of station 11. The day proved to be the first of a series of Saturdays on which exciting things were seen - this time Adelie and Emperor penguins, and the aurora australis.

Sunday 2nd April (day 92)

CTD stations continued on a bearing of 330°. We were in pancake ice all day. The oxygen sensor was replaced on the CTD since it had failed over the last few stations. Initial problems with contamination of CFC113 were resolved. There were some problems with the winch at 4500 m during the final CTD of the day. It refused to either veer or haul, but was eventually coaxed into submission.

Monday 3rd April (day 93)

The irradiance buoy was deployed during an afternoon CTD and got its cable severed by the prop. The buoy became detached and went under the ship. Luckily we were able to steam after it and grapple for it. It was successfully recovered but has 90 m of cable missing, feared to be round the prop. Luckily a spare cable was found on the ship, which henceforth was made more buoyant by tying plastic bottles to it. For the rest of the cruise, at least one deployment was made per day during CTD stations without mishap.

Tuesday 4th April (day 94)

Station spacing was widened to 60 miles across the Weddell gyre, where consecutive stations showed very similar structure. Poor (or no) ADCP data during steaming was thought to be possibly a combination of few scatterers, surface ice and the cold temperatures; there is little wind sea or swell, but even at 10 knots we obtained no data. A talk was given on tracers for the ship's company in the evening - Andy Watson on CFCs and Christine Rüth on helium and tritium.

Wednesday 5th April (day 95)

CTDs continued at 60 mile spacing. There were a large number of icebergs and penguins. Although the air temperatures were very cold, it was sunny.

Thursday 6th April (day 96)

Today we finally left the pancake ice, although there were still plenty of bergs around. In the early morning some time was lost due to winch problems. CTD station spacing was gradually reducing as we approached the Scotia Arc.

Friday 7th April (day 97)

After the CTD which came inboard at 2 am, a retermination of the cable was necessary. We finally began to steam meridionally along 31°W.

Saturday 8th April (day 98)

Three humpback whales came to study us for most of the morning. We were crossing the South Scotia Arc with closely spaced CTD stations. The barometer began to fall and it became noticeably rougher. Two XBTs were launched between CTD stations as we were entering the region of the Weddell Scotia Confluence.

Sunday 9th April (day 99)

We spent the day virtually hove to in very poor weather, making only 2 or 4 knots on a heading of 290°. No stations were possible from 10am for about 24 hours.

Monday 10th April (day 100)

The wind and swell had abated somewhat by 8 am so CTDs recommenced cautiously in heavy seas, again with XBTs in between. The evening CTD proved eventful. As the CTD neared the bottom, the signal suddenly disappeared. After a few anxious seconds, during which the voltage was turned up, it reappeared, and we reached the bottom satisfactorily. However on the upcast, as the same depth was passed, the signal disappeared again, and this time did not return. We hauled up to the surface - there was no means of firing bottles. We were relieved to find the package still on the wire, but work began to determine the problem. Eventually it was traced to a fault in the cable, about 3000 m from the end. It appears to have been a manufacturing fault, which caused a short circuit between the inner and outer layers. The night was spent cutting 500 m lengths off our precious CTD cable, each length confirming that we were nearing the fault, until eventually 3000 m of cable lay coiled in the hold. This left us with a CTD cable about 4800 m long; not enough to complete the deep stations (about 6000 m) in the Argentine Basin.

Tuesday 11th April (day 101)

By early morning the CTD cable had been reterminated and was ready for use; luckily the relatively shallow water depths meant that we could continue full-depth stations. However it is hoped that we shall be able to make use of a 17 mm cable with the deep-tow winch; this has 10000 m of cable and will, we hope, be pressed into service when necessary. CTDs continued onto the South Georgia shelf. Later in the day, the CTD cable got kinked, probably due to the heavy seas, and had to be reterminated again, causing some concern whether we had sufficient kits remaining for the large number of reterminations. By now the team of Bob, Paul and Robin were undertaking the task with great speed and skill, in fact we reckoned they could probably do it with their eyes shut! Trevor and Robin gave a talk on the meteorology programme of the cruise. A wake was held in the evening to mourn the loss of the CTD cable, and also to celebrate the (supposed) mid-point of the cruise.

Wednesday 12th April (day 102)

In the early morning we approached close to South Georgia. CTDs were closely spaced up to 500 m depth, and down again. We passed quite close to South Georgia, taking the opportunity for some ADCP data in bottom tracking. The weather by this time was calm with no swell. Whales, seals and dolphins were spotted.

Thursday 13th April (day 103)

The early hours of Thursday found us zigzagging up the valley between the Georgia and Scotia basins, seeking the sill which would determine which waters were able to transfer between the basins. The shallowest position was found at about 0430 UTC. CTDs continued into the Georgia Basin.

Friday 14th April (day 104)

A further ALACE float was successfully launched soon after midnight. CTDs and XBTs continued. As the water depth increased, it was necessary to attempt use of the deep tow 17 mm cable, and the wire change was completed during the morning. It was found to work satisfactorily, although in deep waters it had to be paid out more slowly than the original CTD cable.

Saturday 15th April (day 105)

CTDs continued across the Georgia Basin in water depths greater than 4500 m. Station spacing was decreased as we approached the Polar Front and the gap in the Falkland Ridge.

Sunday 16th April (day 106)

Easter Sunday. In the early hours of the morning, one of the crew members was taken seriously ill with a stroke. It was immediately clear that a medical evacuation would be necessary. As soon as the CTD was inboard, we steamed for Stanley at full speed. The final station (71) was undertaken just into the Polar Front, an unfortunate place in which to break the section.

Monday 17th April (day 107)

We steamed for Stanley, using the break from CTD stations to catch up on data analysis. We requested from BAS an extension to the cruise to make up for the time lost in the medevac, and were pleased to be granted an extra 7 days.

Tuesday 18th April (day 108)

The steam for Stanley continued. During the evening Brian and Elaine gave a talk on the ADCP.

Wednesday 19th April (day 109)

We arrived in Stanley during the evening, and our sick colleague was winched ashore and taken to hospital. Thankfully the medical care he had received since his stroke meant that his condition had not deteriorated (he was subsequently airlifted to the UK and taken to hospital in London where he is recovering slowly). Advantage was taken of the few hours in port to have the prop inspected by divers in case Carlos's cable was fouling it (it was not). Fresh supplies of fresh fruit and vegetables, and chocolate, were taken on board. By late evening we had left Stanley and were returning to our work area at full speed.

Thursday 20th April (day 110)

Our eastward steam continued. After some days of rough and grey weather, we were given a respite with brilliant sunshine and calm seas.

Friday 21st April (day 111)

We arrived back in the work area. We had decided to return to station 67, four stations south of the last station prior to the medevac. The was to ensure that we crossed the whole of the polar front. A series of XBTs were launched on the eastward track and it was clear that we were close to the front. However the SST remained frustratingly high, and on repeating station 67 (station 72) it was evident that the polar front was still to the south of us, and had moved some 100 miles in the week since we had left. (Noise on the CTD during this cast meant that the bottles fired at random depths and were useless for analysis.) Accordingly we headed south watching the surface temperature and salinity characteristics. XBTs were deployed at the position of the former station 66, and halfway to station 65, and it was decided to stop at the position of the old station 65 (station 73). This was definitely south of the Polar Front. Our northward progress was resumed with stations closely spaced across the frontal region. See Figure 3 for station locations of the two crossings of the front.

Saturday 22nd April (day 112)

CTD stations continued, changing to the 17 mm cable where the water depth demanded it.

Sunday 23rd April (day 113)

Early morning found us repeating station 71, almost exactly 7 days after we had left it. An ALACE float was deployed just north of the gap in the Falkland Ridge. These stations in the Argentine Basin were the deepest we encountered during the cruise (5500-6000 m). It was necessary to slow the veer rate to only 10-15 m/minute as the CTD approached the sea bed. The Polar Front was well resolved with closely spaced stations.

Monday 24th April (day 114)

Problems with the winch in the early hours caused some alarm as it ran out of control and the CTD plummeted (station 82). The package was stopped 100 m above the sea bed, to everyone's relief. Winch problems during the upcast meant that the cast eventually took nearly 6 hours. Difficulties with supplying enough traction continued for much of the remainder of the cruise when using the 17 mm cable, necessitating slow deployments and great attention from all concerned. This was somewhat surprising since the system is meant to cope with 10000 m wire out. Station 83 was aborted at 600 m when the winch proved to be playing up again, after an hour of experimentation. It was decided to steam on another 8 miles during which the winch could be inspected and overhauled. Station 84 was completed successfully. Further problems with the winch on station 85 led to a decision to abort the cast at 300 m and steam on another 12 miles north during which winch repairs would be undertaken. The Subantarctic Front was clearly observed with peak velocities over 50 cm/s.

Tuesday 25th April (day 115)

After further winch tests, a successful full-depth CTD cast was completed and further stations continued more reliably. Constant vigilance and skill shown by the winch drivers was required henceforth when using the 17 mm cable. An ALACE float was successfully deployed. The evening talk was given by Jane and Russell on isotopes.

Wednesday 26th April (day 116)

CTD station 89 was undertaken for CFC bottle blanks, firing all bottles at 2600 m, the peak of North Atlantic Deep Water. CTD stations continued as we crossed into subtropical water.

Thursday 27th April (day 117)

CTD stations continued along 36W. The 7th ALACE float was launched. The Subtropical Front was crossed. Station spacing was increased to 60 miles to make up for lost time.

Friday 28th April (day 118)

Stations at 60 mile spacing continued.

Saturday 29th April (day 119)

Stations at 60 mile spacing continued. It was no longer necessary to bring the CTD into the water bottle annex since weather conditions were much improved. A partial eclipse of the sun was observed during the afternoon, reckoned to be about 10-15% at maximum. A barbecue planned for the evening was postponed due to relatively cold and windy weather.

Sunday 30th April (day 120)

Station spacing was reduced as the Rio Grande Rise was approached. The 9th ALACE float was deployed. In the evening a “Should Have Been in Rio” party was held.

Monday 1st May (day 121)

CTDs were deployed on depth contours up the flank of the Rio Grande Rise. A bottom pressure recorder was deployed in 2600 m on behalf of the Proudman Oceanographic Laboratory; the BPR is being loaned to the Brazilians in aid of their WOCE effort. Stations continued to a depth of 1000 m; thereafter the cruise track turned northwest towards Rio de Janeiro. This was the warmest and sunniest day of the cruise, and proved an excellent time for the first cruise barbecue.

Tuesday 2nd May (day 122)

CTDs continued into the Vema Channel. The final ALACE float was deployed. The evening talk slot was taken by Andrew and Dave who talked about ocean models and ALACE floats.

Wednesday 3rd May (day 123)

A CTD station was located in the deepest part of our transect across the Vema Channel. Closely spaced stations were located on the western side of the channel. A formal end of cruise meal was held in the evening and was greatly enjoyed by all.

Thursday 4th May (day 124)

CTDs continued on the western side of the Vema Channel.

Friday 5th May (day 125)

Despite the lengthy negotiations over many months, and much faxing and telephoning around the world, we were unable to get permission from the Brazilian government to complete the final 7 CTD stations of the A23 section, which lay within their 200 mile limit. We had spent much effort trying to arrange to pick up one or more Brazilian observers, either by ship-to-ship transfer or by collection in Rio de Janeiro (given that they had not appeared in either the Falklands or Punta Delgada as requested). Therefore CTDs had to cease after station 128, which was in 2500 m of water. This was extremely frustrating since it meant that we did not measure the transport or water masses of the Brazil Current. We therefore steamed for Rio de Janeiro a day earlier than planned. The final cruise barbecue and RPC was brought forward by 24 hours and held on the aft deck.

Saturday 6th May (day 126)

The ship arrived in Rio de Janeiro in the morning.

2. CTDO$_2$ Measurements

2.1 CTD/Rosette Operation

by Bob Kirk, Paul Woodroffe and Robin Pascal

CTD and multisampler equipment used during this cruise was provided by IOSDL. Much of the instrumentation was shipped by container to Cape Town and put aboard the *James Clark Ross* there. A spare multisampler pylon and some water bottles with spares were transferred from *RRS Discovery* whilst both ships were in South Africa. Backup equipment consisted of spare CTD, transmissometer, rosette, Niskin bottles, and underwater frame. The CTD/rosette unit and laboratory computers were set up in Port Stanley before sailing. The 10 mm CTD wire was reterminated with a suitable connector, and the whole system powered up for testing before leaving port. In summary the CTD instrumentation used was as follows:

Instrument	Serial No.	Range
CTD NBIS MKIIIb	DEEP01	6500m, 32.676°C, 65 mmhos.
Transmissometer	No. 35	7000 m rated, 0 - 4.32 volts.
Simrad Altimeter	9309055	7000 m rated, 0 - 200 m range.
Rosette Multisampler	IOSDL1, IOSDL2	24 x 10 l Niskin bottles.
SIS Pressure Sensors	P6132, P6293	6000 dB
SIS Thermometers	T400, 401, 714, 743, 746	–2°C to +40°C
Fluorimeter	88/12360	
IOSDL 10 kHz pinger		

Shipboard laboratory equipment included two data demodulation and display systems, with power supplies and rosette control modules. Each system included the following units:-

EG&G demodulator, model 1401.
IBM PS/2 PC system with 80 Mbyte tape drive.
EG&G non data interrupt rosette firing module.
Kepco power supply unit ATE150-0.7M

Problems with the CTD/rosette system are as follows:

Station	Comments
001	Systems test cast. No level A bottle data.
003	Level A hang-up.
004	Cast 1. Rosette failure 500 m from surface. Cast 2. Niskin samples from 500 m to surface.
005-009	Rosette double firing. Some Niskin samples missed. Seawater ingress in sea cable connection. Wire reterminated.
010-012	Rosette problems, some samples missed. Rosette pylon replaced with spare unit IOSDL 2.
013-015	Oxygen cell performance deterioration noted. Sensormedics oxygen sensor replaced.

Station	Comments
016-017	Some slippage on traction winch, back tension increased.
020	Bottle 5 failure due to snagged lanyard.
021	Leaking bottle at position 20 replaced after stn 021. 10 kHz pinger battery replaced.
022-030	Occasional misfires reported by rosette firing unit. Cable retermination due to water in connection.
035	Transmissometer Air Value 4.25 v. Blanked 0.017 v.
036-044	Some lack of signal from altimeter near bottom. Niskin bottle at position 20 replaced again after stn 037 due to leaks.
045	Major failure of CTD cable, identified after cast as a short circuit 3000m from the end of the cable. Most data recovered. Cable cut and reterminated. Operating depth limited to 4800 m available cable.
046-047	Cable reterminated to remove kink on recovery after station 047.
053	Transmissometer Air Value 4.295 v. Blanked 0.017 v.
054-063	10 kHz pinger batteries changed. 17 mm deep tow Rochester cable terminated with suitable connector to enable deep stations to be occupied.
064	First station with 17 mm coaxial cable.
065-071	Some gaps in level A data. Slippage on traction winch noted.
072	Transmissometer Air Value 4.295 v. Blanked 0.018 v. 17 mm cable damaged in winch room. Reterminated.
073	10 mm CTD cable used.
074	17 mm cable kinked during deployment. Cast done with 10 mm cable. 17 mm cable reterminated.
077	17 mm coaxial cable reconnected. Noise problems traced to a loose earth cable inside winch drum.
078-094	Some problems with traction unit and Seametrix wire out metering.
095	10 kHz pinger batteries replaced.
096-102	Level A logging has intermittent gaps.
103	10 mm CTD cable now used for remainder of cruise as casts shallower.

The cruise programme was completed despite a variety of problems being encountered. Environmental conditions varied from −10°C, plus wind chill, to +25°C by the end of the cruise. The extreme cold made cables and wires stiff leading to leakages of seawater into terminations and sampling of water bottles inside the protection of the annexe necessary.

Shipboard data logging was via the RVS designed level A interface. This unit gave problems throughout the cruise in various forms, usually leaving gaps of varying length in the one second averaged data. This necessitated transfer of raw data files by diskette from the CTD acquisition computer to fill in gaps.

Winch performance using both 10 mm and 17 mm coaxial cable also caused some concern. Traction problems whilst using both wires are described fully in the deck engineer's contribution to this report.

We were unlucky to have such an unusual failure (short circuit) in the 10 mm CTD cable, which meant we had to discard 3000 m of wire. The immediate effect of this was that we were left with only 4800 m of usable wire on the drum, which would be insufficient to allow our deepest stations to be carried out. Fortunately with great assistance from the BAS deck engineers we were able to improvise mechanical and electrical terminations to enable use of the 17 mm Rochester coaxial deep tow cable. This solution worked successfully and allowed the programme to continue. Reterminations were required to cure accidental damage to this cable, which otherwise performed faultlessly. Once the deepest stations were completed the 10 mm CTD cable was again used as this could be hauled and veered at a slightly higher speed.

Initial pylon problems were eventually overcome by using the spare unit IOSDL2. Other than routine battery changes to pingers and the SIS temperature and pressure sensors the equipment performed well. Some water bottles developed leaks and were replaced. Niskin bottle numbering and position on the pylon were carefully noted throughout the cruise.

The altimeter unit suffered from corrosion problems probably due to faulty earthing arrangements however it did perform well throughout the cruise and enabled each cast to approach within 10 m of the sea bed. Attempts to prevent corrosion occurring using earthing links and sacrificial anodes were not particularly successful. This problem will be investigated further.

There were some signal dropouts on transmissometer and fluorimeter signals. This would occur on occasional casts in a depth band between 100 and 200 m during the downcast only. It was felt that this could be due to power supply noise and will also be investigated further. The present arrangement of power provision to external sensors attached to the CTD is at the limit of its capabilities, and further development is required to accommodate new sensors. The CTD data were generally very good.

Finally we would like to thank the whole ship’s company for their good humour and enthusiasm throughout the cruise, in often difficult conditions. The two deck engineers nursed temperamental winches with patience and skill, and made a great contribution to the success of the CTD operations.

2.2 Ship’s Winch Systems

by Simon Wright

This has been the most extensive CTD programme undertaken by the *James Clark Ross* to date. It is the hope of the Deck Engineer that the Scientific party will feel that the programme has been satisfactorily completed without being seriously affected by problems experienced by the ship’s winch System. I for my part feel that we have achieved a reasonable success rate with sometimes less than ideal arrangements. But at the end of the day the programme has been completed successfully.

There now follows a summary of the faults and problems experienced during JR10 that relate to the ship’s winches & deployment equipment.

2nd April (Station 17); 3rd April (Station 18)

The CTD Winch (Ten Tonne Traction Winch) experienced traction problems when starting to haul on these casts. This was when operating below 4500 m and with an outboard tension in excess of 1.7 Tonne. The CTD storage drum normally operates with a back tension setting of 500 kg, this was increased to 600 kg. It was also found that the drier was suffering from blocking with ice and was hence being carried down on to the winch. The drier was changed to one with larger clearing holes and the deck crew instructed to keep it ice free with hot water if required. The combined effect was no further traction problems and the winch reached 5000 m without noticeable difficulty.

6th April (Station 27)

On start up the Seametrix Winch Monitoring System failed to find the CTD drum and hence would not give a line out reading. The normal method of restarting the program again would not solve the problem, so a total shut down and restart was performed. Due to the Uninterruptable power supply the fuses were removed in the traction winch room to allow a total restart. This was successful and no further problems have been experienced with the system to date.

10th April (Station 45)

It was reported that the CTD lost communications at 3000 m, by increasing power communications were regained 100 m further on in the deployment. On recovery the CTD again lost communications at the same point, but this time completely. Once recovered onboard systematic checks were made to the system and the cable was identified to be at fault. The indications were that the fault lay approximately one third of the cable's length from the outboard end. The cable was 8000 m long and the evidence of the deployment indicated the fault was around 3000 m. The cable was received to deck and cut into 500 m lengths. The cable was tested after each cut to ensure that we were closing on the fault. The fault was removed in the 500 m length that arrived at 3000 m of cable removed. The cable was then reterminated and operations recommenced.

Further investigations led to an operating limit of 4800 m of wire out being placed on operation with this cable. The fault was traced to a strand of copper wire having worked its way through from the central conductor to come into contact with the return path armour.

In order to prepare for operations over 4800 m it was decided to press the 17 mm Conducting Cable (Thirty Tonne Traction Winch) into service. The cable was reeved to the aft deck so that it could be operated on in the Rough Workshop. The termination consisted of stripping back about 4 m of both layers of armouring as it is a coaxial cable. The mechanical termination was done by John Summers, Deck Officer (Science Operations). The idea was to use the removable hard eye used for the Super Aramid Cable. Then bind the conducting cable with Kevlar to improve the cables fit to the eye. The cable was then secured by six Bull Dog grips over a 1 m length. The electrical termination was then made by Bob Kirk (IOS) and Paul Woodroffe (ISG).

15th April

The Conducting cable was starting to experience slippage so its back tension setting was increased to 800 kg from the usual 600 kg. This helped to give the winch better traction to greater depths.

19th April

Started to experience problems with the Allen bolts in wheels No. 5 & 6 (inboard end). Some of them started to slacken off initially and then some of the heads broke off. This is not a difficult job to rectify and as long as operators checked them after each deployment not a major hazard to the system. However it was something not experienced before and appears to stem from the conducting cable running in the outer most groove causing these wheels to flex during operation. This could be a function of the increased back tension, but is more likely to be due to the number of operations with this cable not being experienced before.

21st April (Stations 72, 73, 74); 22nd April (Stations 75, 76, 77)

The back tension was increased to 1000 kg as standard to assist with traction. During Station No.72 bad data was experienced coming from the CTD. The reason for this was thought to be a kink that was noticed in the traction winch room, so it was decided to reterminate the cable on recovery. During the same cast the winch driver noticed that problems were occurring with No. 3 sheave. These were similar to those experienced when gearbox problems have been the cause. To limit the strain on this gearbox operations were therefore limited to five and six driven sheaves mode, this limits the winch's top speed to about 56 m/min.

Station 73 proceeded using the 10 mm CTD wire as the depths were within its capabilities. Unfortunately when coming to deploy Station 74 the wire twisted and was kinked in the gantry system. Bad data was again experienced on deployment, so the cast was performed again on the 10 mm wire while another termination was completed, as were stations 75 & 76 that followed.

Station 77 was the first back with the Conducting Cable, however the bad data fault was still in existence. It was traced to a loose wire connection inside the conducting storage drum where the cables conductors are connected to the slip rings. It was after this cast that a policy of cleaning the sheaves of the winch was introduced. This was due to a mastic type substance being deposited by the cable onto the sheaves, this should reduce as the cable is worked.

23rd April (Station 82)

This was the second cast to about 5800 m to be done. The winch worked well being able to deploy the package at 40 m/min to within 140 m of the bottom. This was helped by increasing the back tension to 1200 kg below 4500 m and engaging the outboard compensator during the deployment. The winch was halted 140 m from the bottom to switch to six driven drums and take the compensator out of circuit as this is still not a full tested device. As soon as the brakes were lifted the system ran away under the weight of the package and wire. The winch was brought under control again and stopped at 94 m above the sea bed. It was decided that this was close enough for this deployment. The winch was then hauled to the second bottle depth. When hauling from this second depth problems were experienced. A slow haul was obtained by driving in the traction winch room itself, later control was returned to the winch control room and the cast recovered normally.

24th April (Stations 83, 84, 85); 25th April (Station 86)

The winch was checked and appeared OK, but at 600 m on Station 83 the winch tried to haul and was found to be not working correctly. The Station was then abandoned and the package returned to deck for further investigation. While moving an hour along the track pressure was returned to the storage drum after bleeding all the component parts. Station 84 then took place, which was the deepest of the cruise at 5925 m, it was monitored carefully during the whole deployment. The back tension was reported to be lower than expect when hauling, but apart from that nothing more unusual occurred.
Station 85 had reached 300 m before deciding to abandon it due to erratic back tension readings and an inability to alter them electrically. After preliminary tests the whole proportional pressure reducing valve was replaced. The new valve gave us back control over the back tension although the pressures were not initially totally convincing, so a test deployment was undertaken. By 250 mI was able to give the winch a clean bill of health and Station 86 started officially. No further major problems occurred with the thirty tonne winch system, although traction when the outboard weight exceeds five tonne is still suspect.

30th April (Station 103)

Returned operations to the 10 mm CTD Cable on the ten tonne winch system for the rest of the stations.

2.3 CTDO$_2$ Data Collection and Processing
by Brian King

Data Capture and Reporting

CTDO$_2$ data are passed from the CTD Deck Unit to a small dedicated microcomputer ('Level A') where one-second averages of all the raw values are assembled. This process is supposed to include checking for pressure jumps exceeding 100 raw units (equivalent to 10 db for the pressure transducer on the CTD) and discarding of spikes detected by a median-sorting routine. The rate of change of temperature is also estimated. Unfortunately, this route of data capture proved to be very troublesome, with problems and fixes described below. The one-second data are passed to a SUN workstation and archived. Calibration algorithms are then applied (as will be described) along with further editing procedures. Partially processed data are archived after various stages of processing. CTD salinity and dissolved oxygen concentrations are reconciled with sample values, and any necessary adjustments made. CTD temperatures and pressures are compared with reversing measurements. The downcast data are extracted, sorted on pressure and averaged to 2 db intervals: any gaps in the averaged data are filled by linear interpolation. Information concerning all the CTD stations is shown in the accompanying station list (Table 1 at the end of this report or in the accompanying .SUM file). With reference to the stated requirements for WHPO data reporting, note in passing:

(a) The number of frames of data averaged into the 2 db intervals is not reported. The data processing path does not keep track of this information.
(b) Many stations had the 1 or 3 db level missing from the averaged 2 db files; i.e. the shallowest level was the 5 db level. The practice adopted during the cruise was to leave the CTD 'soaking' for 5 minutes at 10 metres depth, before hauling to near the surface and beginning the downcast. The closest approach to the surface after the soaking depended mainly on what was judged to be sensible in the prevailing sea state, and the zero offset on the winch wire out meter. On such stations, the data have been extrapolated to the surface by replicating the T, S and O_2 data from the shallowest available level, to provide a complete profile commencing with a 1 decibar data cycle. Such extrapolated data have been assigned a data quality flag of 2.

In general downcast CTD data are reported. However, on a number of stations, the upcast data were considered to be more satisfactory. On these stations, the sorted, averaged 2 db file was therefore compiled from the upcast data for all variables. Full details will be provided with the supporting documentation when the data are submitted to the WHPO.

Level A data capture problems

The performance of the CTD level A microprocessor throughout the cruise was highly unsatisfactory. For a number of stations (007 to 011) it refused to pass any data at all onto the shipboard computing system. It simply hung up, producing no output data cycles. Repeated resetting and rebooting failed to solve the problem.

The level A software includes various data checks performed on the raw 16 Hz data before averaging to one-second output data cycles. In an effort to reduce the level A processing to the simplest possible, new software was installed in which as much as possible of the level A processing was disabled. Either by luck or judgement, this seemed to restore satisfactory data throughput, although at the cost of reducing data quality control. Fortunately the quality of the CTD data stream seemed to be high (i.e. very few bad frames), so this was considered to be a reasonable way to proceed.

Although the majority of the data were now being logged through the level A, it still had a tendency to go through periods where data throughput dropped to zero again. These would typically be periods of one or two minutes in which only one or two out of every 10 seconds contained any output data. At the same time, the level A would produce a string of 'serial overrun' error messages. The meaning of this error message, and the circumstances under which it occurs, were unknown.

The data dropouts were systematic, but not exactly reproducible. For example, from stations 079 to 104, they generally occurred about one hour after the station began, but with significant variation which was apparently random. The occurrence seemed to be independent of whether or not the level A had been rebooted immediately prior to the station commencing.

Since these periods of mainly absent data were unacceptable, data were also recovered from the raw 16 Hz files logged on the PC attached to the CTD deck unit. These were transferred to the Unix system via floppy disk, decoded from binary to ASCII, read in to the PSTAR processing software and reduced to one-second averages. Since data recovered by this route had no UTC time stamp, relevant data cycles were extracted and joined (based on matching raw pressures) with data from the level A which included a time stamp. More than 50 part-stations and 5 complete stations required data to be recovered from this back-up route.

Temperature calibration

The following calibration was applied to the CTD temperature data:-

$$T = 4.25 \times 10^{-6}\ Traw^2 + 0.998524\ Traw - 0.016825$$

This calibration was in degrees C on the ITS-90 scale, which was used for all temperature data reported from this cruise. It was determined from a 13 point calibration on 23 Nov 1994. For the purpose of computing derived oceanographic variables, temperatures were converted to the 1968 scale, using

$$T68 = 1.00024\ T90$$

as suggested by Saunders (1990). However, all reported temperatures are in the ITS-90 scale.

In order to allow for the mismatch between the time constants of the temperature and conductivity sensors, the temperatures were corrected according to the procedure described in the SCOR WG 51 report (Crease *et al*., 1988). The time constant used was 0.20 seconds. Thus a time rate of change of temperature (called deltaT) was computed, from 16 Hz data in the level A, for each one-second data ensemble. Temperature T was then replaced by T + 0.2 deltaT.

Temperatures less than zero

It is known that CTD temperatures from the NBIS MkIIIb can exhibit non-linear behaviour near zero. Before the cruise, the behaviour of this instrument had been examined with this potential problem in mind and no significant non-linear behaviour found. However, on the cruise, it became apparent that the CTD temperatures showed an offset whenever the raw temperature counts fell below zero. This was manifested as a negative offset in salinity in the lower part of the water column. Examination of several stations showed that the offset occurred at no preferred conductivity or pressure, but always at zero raw temperature. A temperature correction was therefore estimated to remove the salinity offset. The CTD temperature calibration program was modified to add –0.0014 degrees to temperature whenever the raw value was less than zero. This effect will be further investigated in the instrument's post-cruise calibration.

Pressure calibration

The following calibration was applied to the CTD pressure data, based on the 9th Nov 1994 calibration at 10°C:-

$$P = 6.21 \times 10^{-7}\ Praw^2 + 0.995907\ Praw - 5.4$$

A further correction was made for the effect of temperature on the CTD pressure offset:-

$$Pnew = Pold - 0.3\ (Tlag - 10)$$

Here Tlag is a lagged temperature, in °C, constructed from the CTD temperatures. The time constant for the lagged temperature was 400 seconds. Lagged temperature is updated in the following manner. If T is the CTD temperature, tdel the time interval in seconds over which Tlag is being updated, and tconst the time constant, then

$$W = \exp\ (-\ tdel/tconst)$$

$$Tlag(t=t0+tdel) = W \times Tlag(t=t0) + (1 - W) \times T(t=t0+tdel).$$

The values of 400 seconds for tconst and the sensitivity of 0.3 db per °C are based on laboratory tests.

A final adjustment to pressure is to make a correction to upcast pressures for hysteresis in the sensor. This is calculated on the basis of laboratory measurements of the hysteresis. The hysteresis after a cast to 5500 m (denoted by dp5500(p)) is given in the table. Intermediate values are found by linear interpolation. If the observed pressure lies outside the range defined by the table, dp5500(p) is set to zero. For a cast in which the maximum pressure reached is pmax dbar, the correction applied to the upcast CTD pressure (pin) is

$$pout = pin - (dp5500\ (pin) - ((pin/pmax) * dp5500\ (pmax)))$$

Laboratory measurements of hysteresis in pressure sensor: dp5500(p) = (upcast – downcast) pressure at various pressures, p, in a simulated 5500m cast, were used to create the following table of pressure hysteresis corrections.

Table of pressure hysteresis corrections.

p (db)	dp5500(p) (db)
5500	0.0
5000	0.0
3500	1.0
3000	2.0
2000	4.8
1500	5.9
1000	6.0
400	3.9
0	0

Extraction of upcast data for calibration

Following procedures developed on previous cruises, CTD data were extracted for salinity and oxygen calibration as follows:

The Niskin bottle firing events were logged using a level A microprocessor dedicated to that purpose. This provided accurate times of the bottle closures.

The CTD data after nominal calibration were merged onto the firing events using linear interpolation on time; the time for both the CTD data and the firing events were provided by the ship's master clock, and were therefore reliable.
After coefficients for calibration of the CTD oxygen or salinity had been calculated and applied to the 1 Hz data, the averaging and merging procedure was repeated as often as necessary, until the calibration was finalised. In this way, residuals were always calculated between the sample values and the latest estimate of the calibrated CTD data.

Salinity calibration

Salinity was calibrated during the course of the cruise, by comparison with upcast sample salinities. This was done on a station by station basis. A cell conductivity ratio was estimated from early stations, and this was applied as an initial calibration. The initial calibration was changed at station 047 to ensure that first-look data were sufficiently accurate to enable bottle misfires to be identified by comparison with sample salinities. The initial calibration was followed by the correction to conductivity ratio:-

$$\text{Cnew} = \text{Cold} \ (1 - 6.5 \times 10^{-6} (T-15) + 1.5 \times 10^{-8} P)$$

Salinity calibration was then completed by comparison of CTD conductivities with conductivity computed from samples using analysed salinity and CTD *in situ* temperature and pressure. Least-squares linear regression was used to determine a conductivity ratio and offset for each station. Poorly-fitting samples, which generally occurred in regions of strong vertical gradient, were excluded. After fitting two parameters for each station, the rms of Bottle minus CTD salinities for 1049 good samples deeper than 1500 metres was 0.001. Figure 4 shows the salinity residuals for all stations and depths.

The agreement between upcast and downcast T/S profiles was generally adequate. It was therefore decided that the calibration of upcast CTD salinities by comparison with sample salinities would provide adequately calibrated downcast CTD salinity data.

Where necessary, salinity was further corrected by detailed inspection of individual stations. Offsets due to fouling or other problems were removed on a case by case basis.

Oxygen calibration

CTD oxygens were calibrated by fitting to sample values using the following formula:-

$$O_2 = oxsat(T,S)\ rho\ (oxyc + c)\ e^{a(W\,ctdT\ +\ (1-W)\ oxyT)+bP}$$

where the coefficients rho, a, b, the oxyc offset c and the weight W were chosen on a station by station basis to minimise the rms residual. W is forced to lie in the range 0 to 1.

Since there is, in general, disagreement between upcast and downcast CTD oxygens, it is necessary for the calibration procedure to bring downcast CTD oxygens into agreement with samples collected on the upcast. For each sample, we thus need to extract a downcast CTD data cycle (press, temp, oxyc, oxyt) for calibration against sample oxygen. On some recent cruises, it has been appropriate to do this by finding data cycles which match in potential density or potential temperature. This is appropriate where vertical gradients of these quantities lead to a well-defined matching. However, the procedure adopted at the start of the cruise, and maintained throughout, was to extract the downcast data cycle with matching pressure.

Having extracted the relevant downcast data cycles, a simple gradient algorithm was used to find up to five fitted parameters for each station that minimised the least squares residual. A certain amount of subjective manual intervention was employed to ensure that the temperature weight W and the oxyc offset remained reasonable. As with salinity calibration, individual samples were excluded from the fit as necessary.

Transmissometer

Transmissometer SN35 was used throughout the cruise. The instrument apparently provided good data throughout, except for a problem with dropouts to zero volts. This required a certain amount of editing to produce clean transmissometer profiles.

Many stations had layers of reduced transmisstance over the bottom few hundred metres, of which the most spectacular was station 57. Approximately 160 m off the bottom, corresponding to the water with potential temperature colder than -0.49°C, the transmittance dropped below 30% (per metre). A 50 m layer had transmittance less than 10 precent, with minimum values of 3% at 10 m of bottom. These values were lower than anything anyone could recall having seen before.

The transmittance data were corrected for air voltage, and zero offset thus:

$$Trans = 1.0032 \times (4.355/4.297) (0.500 + 0.001\ Transraw - 0.017) \times 20$$

The CTD had been modified so that the transmissometer voltage was offset by 0.500 volts. This meant that a clear-air voltage of 4.2 volts was transmitted by the CTD as 3.7 volts, and could be read off the deck unit directly, without needing to remove the leads from the instrument and employ a voltmeter. Otherwise, the maximum voltage that this CTD can digitise is 4.096 volts. Allowing for the 0.500 offset, the blank value on deck was observed to be 0.017, unchanged from previous cruises.

Measurements of the clear air voltage (after carefully cleaning the optical surfaces) were made from time to time during the cruise: 4.295 volts (after allowing for the 0.5 volt offset) was considered the most appropriate value to use.

Further corrections were applied for the refractive index of seawater and to convert to 'potential transmittance', by taking account of the density of seawater.

Fluorometer

A full-depth fluorometer was mounted on the underwater frame, and data logged for all stations. A nominal calibration was applied to the data. In the absence of on-board chlorophyll analyses, no further processing was carried out. Raw fluorometer voltage output is stored in the data files.

Digital Reversing Temperature and Pressure instruments

Five temperature and two pressure instruments were available, and were deployed to provide an extra reference in the event of drift in the CTD sensors, and to confirm bottle firing depths. There was no evidence for overall drift of the CTD-RTM residuals during the cruise. However, the positive correction required to make T746 agree with the CTD seemed to drift downwards by a couple of millidegrees.

Temperature: RTMs had been calibrated at IOSDL prior to the cruise, and these calibrations have been applied to the observations. Mean and standard deviations of CTD-RTM differences are given in the following table. Statistics are calculated for CTD-RTM differences smaller than 20 millidegrees. Temperature differences for all stations are plotted in Figure 5.

Inst	Slope	Offset	Mean	Std dev	Num < 0.020	Num obs
T714	1.00088	-0.0151	0.0096	0.0032	101	119
T746	1.00050	-0.0051	0.0057	0.0035	111	121
T401	1.00063	-0.0193	0.0061	0.0027	112	118
T743	1.00027	0.0005	0.0022	0.0059	70	100
T400	1.00013	0.0014	0.0012	0.0040	117	123

Pressure: RPMs had calibrations supplied by the manufacturer. These have always been found to be unsatisfactory in the past, so raw RPM data were noted and entered into sample files. The manufacturer's calibration for P6132H is known to produce residuals of the order of 15 decibars relative to the CTD. However, raw values were still sufficiently good for checking bottle firing depths.

P6132H: The residuals for this instrument are of a generally quadratic form. The manufacturer's calibration can be represented as

$$P= -6.0 + 1.0148\ P6132 - 0.0000029\ P6132^2$$

to within 1 decibar.

If this calibration is applied to the observed P6132 data, then the residuals are as shown in Figure 6. The form of this distribution is similar to that from a previous cruise (Discovery 199 which was WHP A11), although the D199 were perhaps 3 decibars greater at depths below 3000 metres. These residuals can be reasonably well fitted by

$P \rightarrow P*1.0056$ for $0 < P < 1800$

$P \rightarrow P + 10$ for $1800 < P$

and this is the suggested correction for future use of this instrument.
P6293H: The residuals for this instrument (without any calibration) are shown in Figure 6 (offset by 40 decibars).

They can be fitted by

$P \rightarrow 5 + P*0.9938$ for $0 < P < 2400$

$P \rightarrow P - 10$ for $2400 < P$

Crease, J. *et al*. 1988. The acquisition, calibration and analysis of CTD data. Unesco Technical Papers in Marine Science, No 54, 96pp.

Saunders, P.M. 1990 The International Temperature Scale 1990, ITS-90. WOCE Newsletter No 10, p10. (Unpublished manuscript).

3. Rosette Water Sample Analysis

The locations of water samples collected using the CTD Rosette system are shown in Figure 7.

3.1 Salinity Sample Analysis

by Andrew Coward, Dave Stevens, Carlos Garcia, Elaine McDonagh and Brian King

Two out of three available Guildline Autosal salinometers were kept at operating temperature in the *James Clark Ross* Micro-radio laboratory. Early in the cruise two of the available machines developed electronic faults and consequently all salinity bottle samples (just over 2800 samples) were processed through the remaining machine. This machine, the IOS 8400B, proved reliable and stable despite fluctuations in the laboratory temperature which meant the machine was often operated in room temperatures close to the bath temperature of 24°C. The difficulty in maintaining stable room temperatures in individual labs with the current air-conditioning system is known to the ship’s engineers and is likely to be addressed in the coming refit.

Standby values were not recorded for the 8400B due to an apparent fault with the standby/read/zero selector which meant that the standby reading changed continuously. This fault cleared itself during the last week of the cruise, most likely due to mechanical easing. Zero values, however, remained stable and drifted upwards by only 2 or 3 points over the entire 7 weeks.

Necessary maintenance was basic and minimal. The cell needed to be cleaned with a Decon solution on three occasions, the capillaries were syringed clear of water droplets on two occasions and the leather washers in the air pumps dried out and had to be replaced.

Symptoms and fault diagnosis of the two casualties were:

1. IOS 8400. Continuously flashing display in all modes. Fault traced to shorted capacitor which had caused knock-on effects to components on the power supply board. Spares were not available on board ship.
2. BAS 8400. Wildly unstable readings. Fault investigated but not traced.

3.2 Dissolved Oxygen
by Richard Sanders, Russell Frew and Sally Jo Locarnini

The following report is an abbreviated version of an internal UEA report written by Richard Sanders in 1995 (Report on the maintenance of precision and accuracy in measurements of dissolved oxygen over 47 days of measurements on WOCE leg A23).

Sampling Procedures

All stations on this cruise were sampled using the same 24-bottle rosette. Misfires were infrequent and the only technical problem which potentially affected oxygen analysis occurred on station 3 when the water froze in the water bottles as the rosette stood on deck before being brought into the water bottle annex. Thereafter the rosette was brought into the annex until weather conditions allowed sampling on deck (after station 97). Oxygen was sampled on every station, except 13 and 85. Sampling always followed that for CFCs, He/Tr and dissolved iodide on any stations where these were sampled. The maximum delay between the rosette arriving on deck and a sample being drawn was 2 hours. Samples were drawn directly from niskin bottles into 120ml oxygen bottles through short pieces of silicone rubber tubing. The pieces of tubing were stored under seawater to ensure complete wetting of the interior surfaces. The bottles were volume calibrated to ±0.001 ml by their manufacturers (Hampshire Glass Ltd.). The bottles were allowed to overflow with three times their own volume of water before being fixed. They were then fixed using reagents (1 ml) dispensed from pump bottle dispensers (Anachem Ltd) and stored stoppered for a maximum of 4 hours before analysis. The fixing temperature was measured using a Digi-Sense thermocouple thermometer to a precision of ±0.1°C. Duplicate samples were taken from almost every cast, the exceptions being the deepest, most closely spaced stations where time constraints precluded this. Overall 10% of the samples were duplicated.

Equipment and techniques

Whole bottle titrations were carried out using a Metrohm Dosimat 665 automatic 1 ml burette with an end point detector operating at 350nm manufactured by the mechanical workshops at the School of Ocean Sciences, University College of North Wales (UCNW), Bangor, Gwynnedd, Wales. This machine operates by stepwise additions of sodium thiosulphate solution until a transmittance previously defined as 100%, i.e. that corresponding to a fully titrated bottle is reached, with a variability of no more than 0.2%. It is thus critically sensitive to:

a) The optical characteristics of the oxygen bottles; we operated throughout the cruise with two standard sets of oxygen bottles from Southampton Oceanography Centre.

b) The stability of the light source. This consists of a 20W Osram tungsten halogen lamp with a 36 degree reflector (RS component no. 566-904). If the variability in this light source exceeds 0.2% then a stable end point cannot be determined and the titration will not be completed. The lamp was replaced on 01/05/1995 before the titration of station 106 due to increasing instability (estimated to be <0.1%) caused by ageing. The instrument was sited in the main laboratory aboard the ship which has no temperature control facility beyond the laboratory thermostat.

Method

Samples were acidified (1ml) immediately prior to titration using a BCL Compet bottle top dispenser (Boehringer Mannheim). The total titration time (from acidification to end point detection) was <4 minutes. The software supplied with this machine requires the fixing and *in situ* temperatures to calculate oxygen concentration which was reported as μmol O_2 l^{-1} at *in situ* temperature. The *in situ* temperature was taken from the CTD logsheet available after each cast. Thus in the case of a misfire i.e. where a bottle was not fired at the depth indicated on the CTD logsheet an incorrect *in situ* temperature may have been used. The results of the titration were recorded on diskette and a paper copy retained. Three batches of thiosulphate were made up using preweighed solid throughout the cruise (on 22/03/95, 16/04/95 and 05/05/95), titre volumes were approximately 0.5 ml for deep water samples with the smallest increment delivered by the burette being 0.1µl, or 0.02% of the deep water titre. The normality of thiosulphate batch 2 was deliberately reduced to increase the titre volume delivered and maximize the accuracy of the procedure. Thiosulphate normality was determined at least every fourth day by titration against a standard solution of potassium iodate made up on the ship, and weekly against a standard Potassium Iodate solution (Sagami Chemical Research centre, lot no APM 8047).

Standards

Primary potassium iodate standards were prepared on the ship from weighed dried salts. The salt was dried at 110°C for two hours, cooled over silica gel in a dessicator overnight before weighing to a precision of better than 0.01%. 0.3567g was dissolved completely in 1l of distilled water giving a 0.01N solution.

Calculations

The equation used to calculate dissolved oxygen (UCNW) has been compared to the equation given in the WOCE operations manual (Culberson, 1991, equation 8) using data from station 75. The results obtained from the two calculations, shown below, indicate that there is no difference between the two calculation methods.

Equation	Station 75 # 1	Station 75 # 2	Station 75 # 4
WOCE	5.06	5.04	4.87
UCNW	5.06	5.04	4.87

Duplicate measurements

The mean overall precision of the oxygen determinations from duplicate measurements on individual casts was 0.26%. It was consistently lower than 0.4% and improved through the cruise.

Consistency of internal QC measurements

To counter deterioration of the sodium thiosulphate used in the titration a primary standard of potassium iodate was titrated approximately every fourth day. Fresh Potassium iodate standards were prepared on 22/03/95, 05/04/95, 26/04/95 and 02/05/95. All three batches of thiosulphate used appear to have been stable throughout the cruise with the exception of one determination on 25/04/95 which gave an apparent thiosulphate normality of 0.2002, this normality was used in the calculation of results from stations 86 and 87. Determinations either side of this determination gave results of 0.1971 and 0.1975, including a certified standard on 21/04/95. This value is considered to be erroneous from inspection of oxygen results from stations 80-90, the initial oxygen results from stations 86 and 87 have therefore been reduced by 1.35% in the final data set.

Accuracy – comparison with Sagami Chemical Co. Standard Solutions

A certified reference solution of 0.01N potassium iodate manufactured by the Sagami Chemical Co Ltd was analysed to counter deterioration in the internal iodate standard used. The mean normality of each batch of thiosulphate determined using both internal standards and certified reference materials and the precision of these analyses are shown below. The precisions of these analyses are taken to define the reproducibility of the measurements.

	Thiosulphate 1	Thiosulphate 2	Thiosulphate 3
Mean normality	0.2480	0.1979	0.2544
Precision (%)	0.3	0.2*	0.2

* This figure excludes the erroneous determination on 25/04. If this is included then this precision is altered to 0.6%.

Comparison of our results with historical data

The results obtained on A23 are compared with three other cruises, given below.
A23 station 87 (44°52.1´S, 36°00.1´W) with A11 station 278 (44°59.4´S, 35°45.1´W)
A23 station 41 (58°38.1´S, 30°49.5´W) with Ajax station 114 (57°39.1´S, 31°02.8´W)
A23 station 62 (52°11.9´S, 35°10.7´W) with SAVE station 275 (52°22.8´S, 35°14.7´W)

Results from the Ajax and SAVE cruises, supplied in ml l^{-1}, have been converted to µM by multiplying by 44.66 (Culberson, 1991).

The deep results obtained at station 278 on A11 are indistinguishable from deep A23 values. The deep results obtained from Ajax 114 are systematically 7µM (3%) higher than deep A23 results. SAVE 275 results are systematically 4µM (1.7%) higher than A23 values.

Conclusions

Based on the analysis of duplicate samples, the poorest analytical precision obtained was 0.4% with a mean of 0.26%. This suggests that these measurements did not completely meet the WOCE criteria for precision. The internal potassium iodate QC standard and the certified reference material suggest that the reproducibility of the measurements are at worst 0.3%. This suggests that the measurements are within the WOCE guidelines for accuracy. The comparison with historical data suggests that the oxygen results compare well with A11 data and that there are minor offsets between A23 oxygen results and both SAVE and Ajax data.

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Note on the dissolved oxygen measurements collected during WOCE cruise A23
by Ricardo A. Locarnini

The dissolved oxygens measured during WOCE cruise A23 in the Southern Ocean have been compared to the dissolved oxygens measured in cruises Ajax (Scripps Institution of Oceanography/Texas A&M University, 1985), ABCS1 (Worley and Orsi, 1986), ABCS2 (Withworth *et al*., 1988), SAVE 5 (Scripps Institution of Oceanography, 1992), and FS Meteor 11/5 (Roether *et al*., 1990), hereafter referred to as Control Cruises, or CC. Dissolved oxygens from the central Argentine Basin measured during WOCE cruise A11 (Institute of Oceanographic Sciences Deacon Laboratory, 1993) are also considered.

Dissolved oxygens during CC were determined by manual titration with starch endpoint (Carpenter, 1965; Anderson, 1971). During A23, dissolved oxygens were determined by automatic titration with a photometric endpoint; during A11 a photometric endpoint was used for stations 12247-12257, and an amperometric endpoint for stations 12258-12337. There is no documentation reporting an intercalibration of the automated techniques used during WOCE cruises A11 and A23 with manual techniques or other authomated systems.

The comparison here presented relies heavily on data collected by the Scripps Institution of Oceanography (SIO). A comparison of the SIO manual method with three automated techniques (amperometric and photometric) showed that, for oxygen concentrations around 6.2 ml l^{-1}, SIO dissolved oxygens measurements were just 0.3% to 0.5% higher than those determined by the Woods Hole Oceanographic Institution, the University of Delaware, and the Bedford Institute of Oceanography (Culberson et al., 1991). The present comparison reveals that the dissolved oxygens measured during A23 are about 2.8% lower than those determined during CC (Figure 8). A similar difference between A11 dissolved oxygens and historical values has been reported (Institute of Oceanographic Sciences Deacon Laboratory, 1993). The difference is significant and renders the dissolved oxygens measured during WOCE cruises A11 and A23 incompatible with the rest of the historical data base.

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Worley, S. J. and A. H. Orsi. 1986. Physical, chemical, and CTD data from the Abyssal Boundary Current Studies cruise in the southwest Atlantic during January-February 1986. Texas A&M University Reference 86-6-T.

3.3 Nutrients

by Richard Sanders, Russell Frew, Sally Jo Locarnini and Lucia Campos

The following report is an abbreviated version of an internal UEA report written by Richard Sanders in 1995 (Report on the maintenance of precision and accuracy in measurements of nutrients over 47 days of measurements on WOCE leg A23).

Sampling Procedures

All stations on this cruise were sampled using the same 24-bottle rosette. Misfires were infrequent and the only technical problem which potentially affected nutrient analyses occurred on station 3 when the water froze in the waterbottles as the rosette stood on deck before being brought into the water bottle annexe. Thereafter the rosette was brought into the annexe after each cast until weather conditions allowed sampling on deck (after station 97). Nutrients were sampled on every station, except 13, 85, and 89. Sampling always followed that for dissolved oxygen, and followed CFCs, He/Tr, CO_2, trace metals and iodide on stations where any of these parameters were sampled. The maximum delay between the rosette arriving on deck and a sample being drawn was 2 hours. Samples were drawn directly into virgin polystyrene 30ml coulter counter vials (Elkay) which were rinsed three times before filling. They were then stored for a maximum of 12 hours in a refrigerator at 4°C before analysis.

Equipment and techniques

All nutrient analyses were performed on a Skalar San^{Plus} autoanalyser which logs directly to a PC. The machine required no ship-board alterations and generally performed well. Sample cups were rinsed with copious quantities of distilled water and dried in an oven at 50°C prior to use. The sampling time was 150 seconds and the wash time 75 seconds. The nitrate line was only cleaned whenever the peak shape began to deteriorate due to the time required to achieve a stable baseline following cleaning. The silicate and phosphate lines were cleaned approximately every other day. The instrument was sited in the biological laboratory aboard the ship which theoretically has a stabilized temperature regime. However it became apparent after station 7 that the temperature stability was inadequate and therefore temperature control which had previously only been applied to the phosphate line was introduced to the silicate line. All tubes were changed during the mid-cruise break and resulted in serious problems with bubbles on the phosphate line between stations 71-74 caused by an excessive flow through the spectrophotometer cell, most samples affected were reanalysed but some were not. Problems were experienced with baseline drift in maintaining both steady day to day baselines and steady within run baselines, the suspected causes are reagent deterioration and insufficient warm up time before use respectively. The data logging system failed on stations 125-127 for an unknown reason, possibly human error, an excessively loaded hard disk or an overlong analytical run, these stations have been manually calculated from the chart recorder traces made for all stations and are excluded from this report. However the data logger was resurrected for the final station, 128, and the analysis of the final batch of certified standards.

Methods
Nitrate

The standard method of a buffered cadmium/copper reduction before low pH complexation with sulphanilamide and N-(1-napthyl)ethylenediamine dihydrochloride was used (Kirkwood, 1994). On-line reduction was achieved through a brand new copperised cadmium column manufactured by Skalar fitted at the beginning of the cruise. By station 60, analytical run 32, it was noted that small pieces of cadmium were entering and remaining within the flow cell. Bubbles subsequently entered this column on analytical run 37, stations 70-71, causing a baseline shift. This column and flow cell were removed in an attempt to solve this problem during the mid cruise break. This was not successful and a partially used column was fitted at this point to counter the problem of cadmium/copper particles entering the flow cell. A further bubble entered this column at the end of run 66 (stations 125-127).

Phosphate

The standard method utilising molybdate, sulphuric acid, potassium antimony tartrate and ascorbic acid was used with a split reagent to eliminate reagent instability (Kirkwood, 1994). Temperature control was used throughout.

Silicate

The standard method utilising molybdate-ascorbic acid was used with a temperature controlled regime (Kirkwood, 1994) introduced after station 7. This line required desensitizing to produce linear calibrations up to 160μM. In the absence of a shorter cell than 4 cm a dilution loop was introduced into the line which diluted both samples and standards 10-fold with the intersample wash and standard matrix solution.

Standards

Primary standards were prepared on the ship from pre-weighed dried salts. The salts were dried at 110°C for two hours, cooled over silica gel in a dessicator overnight before weighing to a precision of better than ±0.01%. Two primary standards were made up for each nutrient in 1l glass volumetric flasks and transferred immediately to 1l polycarbonate plastic flasks. They were then analysed and all proved indistinguishable from their pair. One from each pair was then discarded and the other stored in a refrigerator at 4°C and used as the primary standard, being allowed to equilibrate to room temperature for two hours before use. For nitrate 0.506 g of potassium nitrate was used, for silicate 0.960 g of sodium silica fluoride and for phosphate 0.6805 g of potassium dihydrogen orthophosphate. Four mixed secondary standards were prepared daily with concentrations: nitrate 40, 30, 20, 10 μM, silicate 160, 120, 80, 40 μM, phosphate 3.2, 2.4, 1.6, 0.8 μM. Daily prepared standards were not compared with the previous days. A new primary silicate standard was made up, stored in a Teflon lined nalgene bottle and run in parallel with the old standard for four analytical runs (40-44) including one (42) on which certified standards were run. This new silicate standard was then used from analytical run 49 stations 92-93 onwards. All these standards were left in the coldroom aboard ship and were brought back to the laboratory for independent analysis.

Analytical runs

Between one and four stations were run together depending on circumstances. Certified standards were run frequently through the course of the cruise (silicate seven times, nitrate six and phosphate five) within selected runs. The standard run consisted of initial baseline and drift checks before the four standards in duplicate in the following order 4, 3, 2, 1, 1, 2, 3, 4 where 4 was the most concentrated standard and 1 the least concentrated. These were followed by drift and baseline checks before samples were introduced. Further drift and baseline checks were run every 25 samples. A minimum of two samples were duplicated for each station. Calibration was by means of a least squares linear fit forced through the origin. The gains on the colorimeter channels were left unchanged throughout the cruise, baselines were shifted as required to maintain full dynamic range. The sensitivity of the nitrate and silicate lines line were decreased to ensure that the top standard was well within the full scale deflection after analytical run 10. The intersample wash solution and the matrix for standard preparation was 40 g l^{-1}. Analar sodium chloride solution (BDH). All sodium chloride was preweighed (40 g) into high-density plastic pots. A single batch was used throughout the cruise (Lot K2117 1933 446), this was analysed in our laboratory prior to departure and found to contain undetectable levels of the three nutrients. The initial shipboard review of the data as it was generated was followed by a further post cruise review. The raw data from each station was reanalysed and any erroneous calibration, baseline or drift points eliminated. The criterion used to correct these peaks was solely where electrical noise or a bubble caused by the ship's motion had caused a peak which had been falsely assigned as good. New results files were then generated and entered onto the cruise database at UEA in the week ending 18/8/95.

Instrument stability

Each run was calibrated using a first order polynomial forced through the baseline (i.e. y = ax). For each analytical run the sensitivity of the analyser was recorded as the calculated first order calibration coefficient (a). Mean analytical sensitivities for the entire cruise and in groups of 10 analytical runs are shown below.

Run Nos.	Nitrate sensitivity μM/bit	Nitrate precision (%)	Phosphate sensitivity μM/bit	Phosphate precision (%)	Silicate sensitivity μM/bit	Silicate precision (%)
1-10	0.01230	5.07	0.00101	1.75	0.04844	8.74
11-20	0.01156	4.59	0.00101	2.21	0.05210	7.38
21-30	0.01103	2.62	0.00103	1.36	0.05305	7.66
31-40	0.01193	13.94	0.00102	1.67	0.05214	4.28
41-50	0.01364	13.69	0.00102	1.16	0.05489	7.01
51-60	0.01172	3.49	0.00101	0.82	0.05400	7.47
61-67	0.01168	3.45	0.00101	1.57	0.05220	9.13
1-67	0.0119	11	0.001	1.67	0.05330	8.06

There is considerable variability in the silicate calibration coefficient, with no discernible pattern. The phosphate calibration coefficient varied very little and the nitrate coefficient showed one erratic period between runs 36-48. The correlation coefficient was recorded for each analytical run, this data is shown summarised in groups of ten stations below.

Run Nos.	Nitrate r-value	Nitrate precision (%)	Phosphate r-value	Phosphate precision (%)	Silicate r-value	Silicate precision (%)
1-10	0.99945	0.03	0.99976	0.01	0.99972	0.02
11-20	0.99943	0.02	0.99973	0.02	0.99981	0.01
21-30	0.99914	0.04	0.99976	0.02	0.99969	0.03
31-40	0.99868	0.21	0.99966	0.02	0.99988	0.01
41-50	0.99714	0.31	0.99963	0.03	0.99972	0.03
51-60	0.99922	0.06	0.99971	0.02	0.99969	0.02
61-67	0.99955	0.02	0.99978	0.01	0.99971	0.03
1-67	0.9989	0.16	0.99970	0.02	0.99980	0.02

The nitrate calibrations were the poorest, with an erratic period between runs 36 and 48.

Duplicate measurements

Summary statistics of the duplicate measurements made (two or three at each station, 243 in total) are shown below grouped in batches of 10 determinations. The mean precisions were; nitrate 0.4%, phosphate 0.65%, silicate 0.35%. A deterioration in phosphate precision is apparent in the latter part of the cruise.

Run Nos.	Nitrate std dev (μM)	Nitrate precision (%)	Phosphate std dev (μM)	Phosphate precision (%)	Silicate std dev (μM)	Silicate precision (%)
6-7	0.15	0.37	0.01	0.38	0.66	0.41
8-11	0.19	0.48	0.01	0.42	0.67	0.42
12-14	0.09	0.23	0.01	0.40	0.47	0.29
14-17	0.09	0.23	0.01	0.35	0.80	0.50
18-19	0.09	0.22	0.02	0.73	0.90	0.56
20-21	0.14	0.34	0.02	0.62	0.49	0.30
22-23	0.05	0.12	0.01	0.40	0.55	0.34
24-25	0.05	0.14	0.02	0.57	0.32	0.20
26-28	0.20	0.49	0.02	0.69	0.63	0.39
28-30	0.08	0.20	0.01	0.42	0.46	0.29
30-32	0.07	0.18	0.01	0.39	0.40	0.25
32-34	0.08	0.21	0.01	0.33	0.28	0.17
35-38	0.52	1.31	0.02	0.72	0.58	0.36
39-41	0.31	0.78	0.02	0.54	0.33	0.21
41-42	0.14	0.34	0.02	0.49	1.00	0.62
43-45	0.25	0.64	0.03	0.93	0.71	0.44
46-49	0.17	0.43	0.02	0.57	1.27	0.79
49-51	0.09	0.24	0.02	0.69	0.52	0.33
52-53	0.17	0.42	0.03	0.82	0.43	0.27
45-56	0.19	0.47	0.02	0.55	0.33	0.21
56-59	0.18	0.45	0.04	1.37	0.46	0.29
59-61	0.17	0.42	0.04	1.39	0.53	0.33
62-63	0.23	0.58	0.02	0.62	0.68	0.42
63-67	0.20	0.50	0.04	1.23	0.49	0.31
1-128	0.16	0.41	0.02	0.65	0.58	0.36

Internal QC measurements

An aliquot from the deep water sample was run as an unknown in each analytical run after run 23, prior to this it was only run with each fresh batch of secondary standards prepared, i.e. daily. The results from these analyses are shown below in groups of 10 analytical runs.

Run No.s	Nitrate µM	Nitrate reproducibility(%)	Phosphate µM	Phosphate reproducibility(%)	Silicate µM	Silicate reproduc.(%)
1-10	33.9	0.76	2.37	1.26	127.4	1.5
11-20	33.5	0.91	2.34	2.09	126.6	1.66
21-30	33.6	0.5	2.34	1.05	126.2	1.08
31-40	34	0.6	2.31	0.59	126.4	0.89
41-50	34	1.43	2.34	2.6	125.8	1.55
51-60	33.9	1.24	2.3	1.51	129.2	0.77
61-67	33.5	0.69	2.51	1.58	126.7	0.72
1-67	33.8	1.24	2.35	2.48	126.8	1.3

Comparison with Sagami Chemical Co. Standard Solutions

Certified standard reference material solutions of nutrients in seawater produced by the Sagami Chemical Co. Japan in a matrix of 30 g/l sodium chloride were used. Three different solutions were used: a 50 µM silicate solution supplied in a high density polythene bottle, a 20 µM nitrate solution supplied in a glass bottle and a 1 µM phosphate solution supplied in a sealed glass ampoule. Each solution were opened and immediately analysed at approximately weekly intervals throughout the course of the cruise. All of the phosphate and silicate standards supplied had passed their guaranteed lifetime, as had one of the nitrate standards. Summary statistics of these analyses are shown below.

	Nitrate (20µM)	Phosphate (1µM)	Silicate (50µM)
Mean (µM)	20.02	0.86	49.63
Reproducibility (%)	1.1	0.80	0.54
n	30	24	35

These results allow us to compare variations in the determinations of certified materials with variations in the bulk sample. The precision of both is determined not only by within-run noise but also by day to day differences in blank quality and secondary standards and thus give a measure of reproducibility. The reproducibility for each certified reference material is better than the corresponding reproducibility for the bulk water sample arguing that real variability in the bulk water sample was responsible for the apparent variations detected. The nominal concentrations were compared with the mean values determined analytically using t-tests. There is no significant difference at the 99% confidence level between these two concentrations for nitrate and silicate. There is a large discrepancy between these values for phosphate, implying that the results obtained were approximately 17% too high. Since the duplicate initial preparations agreed, the nominal shipboard standard concentration was retained until it could be independently analysed, the possibility of a matrix effect examined and the results obtained using it had been compared with historical data. The original solution was reanalysed independently at the Fisheries laboratory, Pakefield Road, Lowestoft, Suffolk and found to have a concentration of 5.127 mM, compared to a nominal concentration of 5mM. This 2.5% difference offers no evidence to dismiss the data. The possibility of a matrix effect has been examined and discounted. A comparison with historical data (discussed below) suggests that the Sagami certified phosphate standards were inaccurate. Similar standards (both certified and prepared) were used on Discovery cruise D213 and large discrepancies found between the two (Holley, 1995).

Note on the nitrate results

It will be noted from the various tables and within this report that the quality of the nitrate results deteriorated between analytical runs 36-48, stations 70-93, a period which did not include an intercalibration with a certified reference material. This deterioration was caused by an unknown factor which caused a slight offset to develop in the calibration curves. The values obtained for the bulk QC standard were split into two categories based on the linear regression correlation coefficient to investigate the impact of this on the results, shown below.

	All determinations	r>0.999	r<0.999
n	50	38	12
Mean (μM)	33.83	33.8	34
Reproducibility (%)	1.24	1.18	1.36

A paired t-test was used to compare the means of these two groups. There is no significant difference at the 99% confidence level between these two concentrations.

Comparison of the results with historical data

The results obtained on A23 were compared with three other cruises, given below.
A23 station 87 (44°52.1´S, 36°00.1´W) with A11 station 278 (44°59.4´S, 35°45.1´W)
A23 station 41 (58°38.1´S, 30°49.5´W) with Ajax station 114 (57°39.1´S, 31°02.8´W)
A23 station 62 (52°11.9´S, 35°10.7´W) with SAVE station 275 (52°22.8´S, 35°14.7´W)

The maximum percentage offsets between the A23 results and these other datasets are summarised below.

	A11	Ajax	SAVE	WOCE criteria
Nitrate	3	0	7	1
Phosphate	2	2	0	1-2
Silicate	0	3	3	1-3

The phosphate and silicate results are within the WOCE criteria, the nitrate results are outside them.

Conclusions

The precision of the measurements, estimated as nitrate 0.4%, phosphate 0.65%, silicate 0.35%, do not completely meet the WOCE criteria (nitrate 0.2%, phosphate 0.4% and silicate 0.2%). Based on the certified reference material the nitrate and silicate measurements appears good with errors less than the specified 1% (nitrate) and 1-3% (silicate). The phosphate measurements appear to be too high from the measurements made on the certified reference material, however there is evidence from historical data that the certified reference material is incorrect. Based on comparisons with historical data the phosphate and silicate measurements are within WOCE guidelines whereas the nitrate measurements are outside them.

Holley, S. E. 1995. Report on the maintenance of precision and accuracy of measurements of dissolved nutrients - silicate, nitrate and phosphate - over 40 days of measurements on D213. James Rennell centre for Ocean Circulation.

Kirkwood, D. S. 1994. Practical notes on the determination of nutrients in seawater. In The SAN*plus* segmented flow analyser and its applications-seawater analysis, publication number 07300194 Skalar analytical, De Breda, The Netherlands.

3.4 CFCs and Carbon Tetrachloride Transient Tracers

by Andy Watson, Kim Van Scoy and Jackie Kleinot

We determined four transient tracer halocarbons using a gas chromatograph equipped with an electron capture detector (ECD). The tracers were CCl_3F (CFC11), CCl_2F_2 (CFC12) CCl_2FCClF_2 (CFC113) and CCl_4 (carbon tetrachloride). A total of > 1500 samples were run, that is, more than two thirds of all the water bottle samples collected.

Analysis

The system was a modification of that described by Haine *et al.* (1995) and Haine (1992). A 30 m long DB 624 “megabore” column operated isothermally at 50°C was used to separate the compounds, preceded by a pre-column (about 1 m of the same material). The precolumn was switched out of the gas stream shortly after the beginning of the analysis, and served to shorten the analysis by venting late-eluting compounds. The carrier gas was 99.999% helium flowing at 4 ml min^{-1}, and a make-up flow of oxygen-free nitrogen was supplied to the detector at a rate of 40 ml min^{-1}.

Volatiles were extracted from sea water by purging a known volume (38.80 ml) of water, with a mixture of nitrogen/1% hydrogen, rendered free of halocarbons by passing over a palladium catalyst at 280°C. The volatiles were then concentrated on an unpacked stainless steel trap at temperatures of less than −140°C, the temperatures being maintained using the vapour above liquid nitrogen. Analysis time per sample was 10 minutes, with one sample being purged while the previous one was eluting on the GC.

Calibration

Two gas standards were used for calibration, one being a working standard prepared at PML and originally calibrated against standards derived from the “barn dilution” technique (Lovelock and Watson, 1978; Haine *et al*., 1995). This standard has ratios of concentrations of the gases similar to those found in seawater. The other standard was whole dried air supplied by J. Butler of the NOAA environmental analysis laboratory at Boulder, Colorado. The two standards were intercalibrated during the cruise and preliminary concentrations are reported relative to the NOAA standard.

Extensive multi-point calibrations were carried out to obtain the non-linearity of the detector before beginning the A23 line, at the midpoint of the cruise and at the end. Fourth-order polynomials were fitted through these points. The residuals were examined to ensure that there was no systematic lack of fit. A Working standard, a NOAA standard and a blank were run about every 7 samples. For the preliminary data, the variation of these standards with time was smoothed with a one-day average, and a "stretch" factor for each cast was calculated, that being the factor by which the standard peak had to be scaled to bring it on to the calibration curve. These factors were then applied to the sample measurements.

The calibration strategy described above is a departure from our previous practice (on VIVALDI and ADOX cruises) where we ran more limited calibrations before most casts. However, the frequency of stations on A23 precluded this technique.

Sample handling

Samples were collected in 100 ml glass syringes with metal stopcocks, directly from the Niskin bottles and as soon as possible after recovering the rosette to the deck. The syringes were stored in a box covered with seawater until analysed, the sea water being frequently renewed from the deep water collected from niskins, and kept low in halocarbons by continuously purging with nitrogen. Samples were run within 12 hours of collection.

Station 002 was specifically to test the CFC sampling blank, with all Niskin bottles being tripped at the same depth. The location was such that the CFC concentration of the water was close to 0.1 pM CFC11 however, which was too high to be of much use to determine blanks. Another station of this kind was done at 089 into North Atlantic Deep Water. For this station, means and standard deviations of the 24 bottles for CFC11 and CFC12 were 0.021 +/– 0.006 and 0.004 +/– 0.005 pmol/l respectively. Thus at this time the mean CFC11 bottle blank was at least 0.01 pmol/l, since this amount would have to be subtracted from the CFC11 mean to produce a feasible CFC11/CFC12 ratio. Later stations towards the end of the cruise showed consistently lower CFC11 and CFC12 readings. The sampling blank needs further analysis to arrive at a best (and probably time-dependent) value, but for the preliminary data, we have assumed that the CFC11 and CFC12 means given above were due to the sampling blanks and have subtracted them from all data. No sampling blank correction was made for the other compounds: for CFC113 it is clearly below the system blank of about 0.005 pmol, while for CCl_4 it is probable that the value found in NADW at station 089 (0.12 ± 0.011 pmol/l) is a property of the water, and not a sampling blank.

Contamination: Occasional contamination problems were encountered during the first half of the cruise. Analysis of air in the laboratory and sampling area (the water bottle annexe) sometimes showed greatly enhanced CFC113 and CFC11 levels. Fortunately this contamination affected only a few samples, and it showed a characteristic pattern of enhancements which enabled them to be identified and discarded. The co-operation of all the ship's staff in limiting the release of aerosols, refrigerants and chlorinated solvents was essential, and we are very grateful to everyone on board for their assistance. No problems were encountered after about the half-way point of the cruise.

Precision: One or two duplicate syringes were collected from most casts, and in addition on almost all casts, two bottles were fired at the same depth at the bottom of the cast, and both were sampled and analysed. So far in our analysis of results, the calculation of precision for these latter pairs has not been made. However, a preliminary error analysis has been done on the duplicate syringes. 1-σ standard deviations calculated for each of the 77 pairs of samples were plotted against the mean of the two duplicates, and functions of the form σ = Max(k1, k2*mean) fitted to the results, where k1 and k2 are constants to be determined by the fitting procedure. The (highly preliminary) results obtained were:

CFC12: σ = 0.007 pmol l/1 or 1.7% (whichever is greater)
CFC11: σ = 0.006 pmol l/1 or 1.3% (whichever is greater)
CCl_4: σ = 0.015 pmol l/1 or 1.6% (whichever is greater)
CFC113: σ = 0.004 pmol l/1 (across the whole range of concentrations).

Haine, T.W.N., 1992, The use of transient tracers to study upper ocean processes, PhD thesis, University of Southampton.

Haine, T.W.N., A.J. Watson and M.I. Liddicoat, 1995, Chlorofluorocarbon-113 in the northeast Atlantic, Journal of Geophysical Research, 100 (C6), 10745-10753.

Lovelock, J.E. and A.J. Watson, 1978, The electron-capture detector, theory and practice II, J. Chromatography, 158, 123-138.

3.5 Helium

by Christine Rüth

514 samples were taken at 50 stations; at 22 stations the full profile was sampled, while on the rest only bottom water was taken. Of special interest was the equatorward path of the Antarctic Bottom Water, so that sampling was more dense around ridges and gaps that separate and connect the various oceanic basins crossed during the cruise. All stations chosen were also sampled for CFCs, which will enable future correlation of the two tracers.

40 ml samples were taken in 1 m long copper tubes, that were pinched off on both ends for sealing. The tubes were banged along the side, before closing, to remove any air bubbles that may have formed along their inside wall. The samples were then stored in the hold and transported back to Bremen University. There all the gas dissolved in the water will be extracted. He isotope ratio, as well as ^{4}He and Ne concentrations, will then be measured in a He-isotope mass spectrometric system.

3.6 Tritium

by Christine Rüth

360 samples were taken at 36 stations; at 19 a full profile was taken, while we focused on the bottom water on the other stations. Our goal was to trace the equatorward flow of Antarctic Bottom Water; therefore all the connections between the basins were sampled carefully. All the stations chosen were sampled also for CFCs and Helium for future correlation.

1-litre samples were taken in glass bottles that were sealed with a screw cap. The samples were transported back to Bremen University. There, the gas will be extracted to remove all the Helium dissolved in the water. This degassed water is then stored for about 6 months. After this time, He3 as a tritium-decay product is measured in a mass-spectrometric system. Knowing the storage time and the sampling time, it is possible to derive the tritium concentration in the water when it was sampled.

3.7 CO_2

by Jane Robertson

Measurements of TIC and pCO_2 were made during the cruise on approximately one third of the stations. A selection of depths were chosen to reflect the main features in the water column. TIC was measured using a coulometric system and referenced against WOCE TIC CO_2 standards daily. pCO_2 was determined using a FID gas chromatograph. Both analytical systems on board worked well for the majority of the time with some down time for valve failures on the TIC equipment. The sampling for CO_2 was arranged to coincide with other measurements for carbon isotopes on the majority of the CTDs. Calibration and final processing of the CO_2 data took place over the next few months after the cruise and the CO_2 data were incorporated to the A23 database.

3.8 Oxygen Isotopes

by Russell Frew

120 of the 128 stations were sampled for oxygen isotopes. Samples were drawn directly from the Niskins into glass bottles with a single rinse for new bottles or three rinses for re-used bottles (salinity). Three types of sample bottle were used; 125 ml winchesters, 250 ml salinity bottles with plastic neck inserts and 60 ml glass vials. The winchesters and glass vials were further sealed with hot wax to prevent evaporation. Samples in salinity bottles were stored in the scientific hold while all other samples were stored in the +4°C cool store.

3.9 Trace Metals

by Russell Frew

15 stations were sampled for trace metals. Samples were drawn directly into acid-cleaned low-density polyethylene or fluorinated bottles. Two people were employed in the sampling process, one “dirty hands” person to open the outer plastic bags and present the bottle in a clean fashion to the “clean hands” sampler. Stations were selected where no other tracer samples were being taken so the trace metals could be drawn first, though occasionally one or two of the deepest bottles were sampled for CFCs first. Sample bottles were labelled with station # - position # and stored in the +4°C cool store. Separate samples were taken for aluminium, these were drawn into 250 ml polyethylene bottles after all other samples had been taken.

After the last CTD station was completed, the Niskin bottles in the rosette odd-numbered positions were rinsed thoroughly and then filled with de-ionised water. They were left for 3 hours before being sampled in the same manner as above. These de-ionised water samples will serve as bottle blanks and give an estimate of the sampling/analysis blank. During the filling process it was noticed that most of the springs were cracked and rusting. Separate samples were also taken for aluminium blanks.

3.10 Carbon-13
by Russell Frew

32 stations were sampled for carbon isotopes on the dissolved inorganic carbon (DIC). Samples were chosen to match Jane Robertson's CO_2 work and trace-metal samples. Samples were taken directly after oxygen in a manner identical to that of an oxygen sample without the fixing step. Immediately after sampling the carbon isotope samples were subsampled into 10 ml glass vials and sealed with a blow-lamp.

The glass vials had been treated with 50 µl of 1 g/l HgCl and dried at 50°C. Before being filled with sample the vials were flushed with dry N_2 from liquid N_2 boil off. Subsamples were taken from the glass bottles with a glass syringe, filtered through an in-line filter (0.2 µm) directly into the glass vial. Vials were labelled with station # - position # and placed in plastic bags similarly labelled. The top of the vial, removed during the sealing process, was retained so the total sample size can be determined by mass.

3.11 Iodide
by Lucia Campos

Iodide was measured on unfiltered seawater samples using cathodic stripping voltammetry. A 10 ml seawater aliquot was placed into the voltammetric cell where 100 µl borate 1M and 100 µl Triton-X-100 0.2% were added. After purging the aliquot with argon for 5 minutes, iodide was preconcentrated onto the mercury drop for 30 seconds to 2 minutes, depending on the initial iodide sample concentration. The potential was scanned from 0 to –0.5V using square wave. The current produced was then measured, and iodide standard additions were performed in order to at least double the original peak size.

The instrument used was a µAutolab-Eco Chemie potentiostat interfaced with a Metrohm 663 VA Stand mercury electrode. The current produced was of the order of nA, and in this case the ship vibration can be a potential problem. The instrument was set up in the wet lab on the *James Clark Ross* where vibration only became a problem when the 10 tonne traction winch was replaced by the 30 tonne winch. The signal to noise ratio became poor but it was readily improved after padding the instrument with a fair amount of high density foam. The signal to noise ratio was also poor when the wind force was above 7-8, and therefore no measurements were performed in those conditions.

The greatest problem encountered during the cruise was that of iodide contamination from the oxygen reagents and bottles during the sampling procedure. The oxygen method uses molar levels of iodide while iodide concentrations in seawater can be as low as 0.5-1.0 nM. To handle this problem the iodide sampling was quickly performed just before the oxygen sampling. The latter was done using one person to fill up the sampling bottles and another person to do the oxygen fixing. Both samplers wore plastic gloves which were disposed of soon after sampling; in this way we tried to avoid contamination of the Niskin bottles. Furthermore the oxygen bottles were rinsed with underway seawater before each new sampling procedure took place. The iodide analyst also avoided sampling or measuring oxygen.

Although all the precautions mentioned above were taken, the deionised water in the prep lab got highly contaminated with iodide. The contamination was probably only on the water outlet handle, and the oxygen analysts were asked to wear clean gloves when collecting water. Also as a precaution, the iodide analyst used a different water outlet in the chemistry lab.

3.12 Chlorophyll
by Carlos Garcia

Water samples were acquired at several depths (normally at 5, 50, 100 and 150 m) on 72 stations to provide a basis for relating chlorophyll a fluorescence signals to pigment mass concentration. Because two *in situ* fluorometers were employed to measure chlorophyll a fluorescence (underway and rosette), underway water samples were also taken during the cruise. For chlorophyll concentrations, the fluorescence measurements will be compared to the standard fluorometric method for calibration purposes.

Water samples were taken at the site, and simultaneously with, the surface in-water upwelled radiance measurements for development of pigment algorithms. Determination of chlorophylls a, b and c, as well as carotenoid pigments, will be made using the HPLC (High Performance Liquid Chromatography) technique. Additional analysis by the standard fluorometric method will also be made for comparisons between both methods.

4. Expendable Bathythermographs (XBTs)
by Ricardo Locarnini

A total of 74 Sippican Ocean Systems Inc. expendable bathythermograph probes, XBTs, were launched using a hand-held launcher. From them, we obtained 71 good temperature profiles, for a 96% success rate (Table 2). T-7 (maximum depth 760 m) probes were used in 73 launches, and one T-5 (1830 m) probe was used upon deployment of an ALACE float in the northern Scotia Sea.

An XBT section was completed across the Scotia Sea while in transit from the Strait of Magallanes to the beginning of the A23 line in the southern Weddell Sea. XBTs were also launched along the A23 section between $CTDO_2$/hydrographic stations to improve the resolution of the temperature field and to identify the location of major frontal features, e.g. the Subantarctic Front. Additional XBTs were used to locate the Polar Front when returning to the A23 section after an unscheduled detour to Port Stanley (see 1.3 Cruise Diary).

A Sippican MK-9 deck unit, a Viglen Genie 1 PC, and the software package provided by Sippican were used to log, display, and archive depth and temperature data during and immediately after launching an XBT. The data from each successful launch were exported as individual ASCII files into the PC hard disk, and backups were saved in 3.5" 1.4 Mb floppy disks and in the ship’s UNIX system.

5. Navigation

5.1 Bestnav File

by Andrew Coward

A standard pexec navigation file was maintained throughout the cruise. This is chiefly the RVS “bestnav” position data at 30 second intervals with the following additions:

1. E & W velocities calculated using posspd
2. Replacement distrun values calculated using pdist

A minor modification was made to the standard navexec0 script to mark “out of range” heading values (often 666.666) as absent data values. The file abnav2301 contains the processed navigation data for the entire cruise track. The final pstar version code is FE.

Best drift data

Pexec versions of the RVS “bestdrf” data were produced throughout the cruise. These data give estimates of the current velocities derived from differences between dead-reckoning calculations (based on EM_LOG velocities) and actual position fixes from GPS at 30 second intervals. The script drfexec0 performs the following steps:

1. converts RVS data into Pstar format
2. reverses the sense of the velocity components to give current estimates rather than necessary ship corrections.
3. merges with the navigation file to add lat lon and distrun to the dataset

Step one produces a file called drf23nnn where nnn is an incrementing day counter. Step 3 produces a file called drf23nnn.merge. For the majority of the cruise, files were produced on a daily basis; the exception occurred only during the first 10 days where the first 9 days worth of data may be found in the 001 family of files.

A second script, drfexec1, was used to produce 10 minute averages (drf23nnn.merge.av). These data were used to produce a daily vector plot of the estimated currents for comparison with the top bin of the ADCP dataset.

Doppler Log

The doppler log was switched on during Julian day 087 and daily pstar versions of the RVS data were constructed from that time using the getdat utility. No specific zig-zag calibration manoeuvres were carried out during the cruise. An attempt was made to derive the amplitude correction and mis-alignment angle using the series of manoeuvres over the South Georgia shelf edge. However the paucity of data (5 turns) meant that reliable estimates could not be obtained.

5.2 GPS Heading

by Brian King and Elaine McDonagh

The *James Clark Ross* is fitted with an Ashtech GPS 3DF heading, pitch and roll system. The antenna array was installed in September 1993, and was used for the occupation of SR1 (Drake Passage) in November of that year with the receiver borrowed from RRS Discovery. In September 1994 a new receiver for the *James Clark Ross* was purchased out of UK WOCE capital funds and installed. The antennas are what Ashtech describe as 'aircraft type' and are installed on the wheelhouse roof. The standard Ashtech 30 metre cable runs are sufficient to reach the receiver, which is located in the wheelhouse, without extension or in-line amplifiers. The parameter settings used in the receiver, which include details of the antenna geometry, are given below.

The receiver generates an NMEA message GPPAT once per second. This message includes time, position, PRH (pitch, roll, heading) and some data quality indicators. The message is logged into the shipboard computer system via a level A microprocessor located in the electrical locker just aft of the wheelhouse. Since the level A adds a time stamp from the ship's master clock, comparison of the two times can be used as a check on the behaviour of the latter.

The receiver has two serial ports. While one is being used for output of the NMEA messages, the other can be connected to a PC for data display or raw data logging. A full modem connection runs from the electrical junction box in the Nav. Bridge Deck electrical locker to the one in the UIC room. The latter has a serial cable connection to a Viglen dedicated to GPS data logging (used during this cruise for logging binary pseudorange data from the Trimble 4000). Ashtech supply software (program DATALOGR) that enable the Viglen to be used for logging ASCII or binary data, and to give a graphical or text display of position and attitude.
At the end of JR10, the manuals for both the Ashtech and the Viglen were located in a box file in the rack of manuals in the wheelhouse. The software disks for the Viglen were left with the BAS shipboard computer group.

The data return provided by the Ashtech was quite sufficient for the post-processing correction of heading for ADCP data. After severe data quality control, acceptable headings were obtained for the order of 65% of all one-second samples. When combined with shipboard gyro data, and reduced to two-minute averages of gyro error, 82% of bins contained a measurement. The remaining gaps were filled with linear interpolation. In an attempt to improve the data return further, we experimented with the period parameters that control the Kalman filter used by the receiver; the data return was assessed in 24 or 48 hour periods. However, no improvement on the original values was achieved and the period settings were returned to zero.

Ashtech parameters

The Ashtech receiver parameters used were as follows (mainly set in menu 4 or its submenus).

Menu 4

position	0,0,0	
Alt known	N	
Ranger	0	
Unhealthy SV	Y	
Rec intvl	060	
Min SV	4	
elev mask	10	
pdop mask	40	
PortA		
	nmea	off
	real time	off
	VTS	off
	baud	9600
PortB (level A logging)		
	nmea	on
	baud	9600
	options	PAT ON

1 second send rate

ATTD CNTRL MENU

max rms	010
search ratio	0.5
one sec update	Y
3SV search	N

	tau	T0	Q	R
Hdg	999	000	1.0e–2	1.0e0
pitch	020	000	4.0e–2	1.0e0
roll	020	000	4.0e–2	1.0e0

Kalman filter reset N

ATTD SETUP MENU

	X	Y	Z
1-2	2.943	4.745	0
1-3	11.493	4.753	–0.006
1-4	13.222	0	0
OFFST	0	0	0

max cycle 0.200 smoothing N
max magnitude 0.080 max angle 020

5.3 GPS Position and Differential GPS

by Brian King

Real-time position fixing

The ship's GPS receiver was upgraded to the latest model of Trimble 4000 DS receiver in September 1994; the upgraded receiver has more channels (nine instead of eight) and serial ports (four instead of two) than its predecessor. Initially, the four serial ports were used for the following functions :

Port 1: Power in. This port can be used simultaneously for data I/O, but is not so configured at present.

Port 2: Cycle printouts once per second to the level A microprocessor. These messages were unchanged from the previous receiver, and provided the real-time navigation logged by the shipboard computer system.

Port 3: Connected by Full modem cable to the GPS Viglen in the UIC room. Data output controlled by the Viglen, and used to log binary raw pseudorange data for DGPS post-processing. (Also alternative power in port.)

Port 4: At the start of the cruise, before leaving Stanley, this was configured to send NMEA position and speed messages to the ship's VMS (the main source and display of navigation information to the ship's officers, and the one used, for example for CTD station keeping). The ship's officers had observed that the Shipmate GPS, the previous source of GPS for the VMS, which tracks fewer satellites than the Trimble, was prone to losing position fix, while the Trimble rarely did so. Accordingly, the Trimble became the source of GPS for ship operations.

Note that on four-port Trimble 4000s, the correspondence between the nominal port numbering and the nomenclature on the back panel is non-obvious. The correspondence is detailed in the yellow-covered Trimble manual located in the wheelhouse, which was further annotated with the function and current settings allocated to each port at the end of JR10.

At the end of the cruise, after docking in Rio de Janeiro, a firmware upgrade for the receiver was carried out. A floppy disk containing the latest receiver firmware had been issued by Trimble early in 1995. The upgrade was performed by attaching 'power in' to Port 3, and the Viglen to Port 1. A software upgrade program was then run on the Viglen. Trimble supplied two versions of the upgrade program. The first, which selected the baud rate itself, did not work. After uploading the new firmware, it left the receiver totally hung, although the upgrade software exited normally and claimed that the process was completed. After power cycling the receiver, it always came back in the hung state. Fortunately the second program, which forced the baud rate to 9600, was able to communicate with the receiver through the serial port. The upgrade proceeded as described in the notes, and the receiver was able to be rebooted. Notes about the upgrade are kept with the Trimble manual.

Differential GPS (DGPS) in post-processing

The Trimble utility LOGST was used to log binary raw pseudorange data for later postprocessing to DGPS positions. Reference station data will be obtained by FTP from stations in the IGS network. The syntax of the LOGST command is described in an appendix in the Trimble manual. The command we used was

LOGST -a c:\trimble\download\data\a231 -n 60 -u 5 -p 1 -b 384 -c 1

This generates hourly files, for example A2310790.R00 , whose size depends on the number of satellites tracked but is typically about 70 kb. These files are logged to the Viglen's hard disk. 50 days worth of files fitted comfortably onto the disk. The output port on the receiver needs to be configured before issuing the LOGST command. Edward Cooper at RVS has produced notes on the sequence of commands that are required in the receiver. If the sequence is not used correctly, the Viglen R00 files will not contain the correct header and trailer information; they appear as T00 files instead and need to be appended, eventually to an R00 file, before further processing.

The R00 files contain pseudorange data at 10-second intervals, phased to include exact minutes of GPS time. The IGS station data are recorded at 30-second intervals, again phased to include exact minutes of GPS time. Note that from 1 July 1994, and at the time of the cruise, GPS time is 10 seconds ahead of UTC.

The data will be post-processed ashore using GPSURVEY software purchased from Trimble. At the time of writing (May 1995) Trimble have yet to deliver the software, although we are promised that the software is ready and production of disks and documentation is in progress. GPSURVEY takes Trimble .DAT files as input, and utilities are required to convert R00 files (from the Viglen) and RINEX files (from the IGS stations) to .DAT format.

6. Acoustic Doppler Current Profiler (ADCP)
by Steven Alderson

The *James Clark Ross* has a 150 kHz RDI ADCP unit mounted in the hull. The transducer is offset from the fore-aft direction by approximately 45°. The firmware version was 17.07 and the data acquisition software (DAS) was version 2.48. The instrument was largely used in water track mode, except for sections when the water depth was shallower than about 500 m when bottom tracking mode was implemented. These shallower sections included the early section from Stanley to Punta Delgada and the crossing of Burdwood Bank. In both modes, data was recorded at 2 minute averaged intervals in 64 × 8 m bins. The bottom track mode in addition had one bottom ping per four water pings. The 'blank beyond transmit' was 4 m and the depth of the transducer was approximately 5 m.

The transducer on the *James Clark Ross* is enclosed in an oil-filled sea chest recessed into the hull in order to protect it from ice. This chest is closed by a 33 mm thick window of low density polyethylene and filled with silicone oil. The temperature of the oil is reported to the DAS as 'water temperature'. Sound speed is calculated in the DAS using water temperature and a fixed salinity of 35. This is then used to convert the raw data to water speed.

Data quality was reasonable, with data down to 250-300 m. Underway data at the southern end of the section when passing through thin ice however was poor.
Four corrections are applied to the data.

- The time stamp applied to each data average or ensemble is derived from a software clock which drifts linearly by 2-3 seconds in 4 hours.
- The use of an equation of state for seawater in calculating the sound speed is also an error which needs to be removed.
- The orientation of the transducer on the hull (misalignment angle), causes some of the velocity of the ship when underway to be mapped into the calculated water velocities when the ship's velocity is subtracted from the ADCP velocity.
- A similar problem arises through the use of the ship's gyro data to convert fore-aft and port-starboard components as measured by the ADCP into east and north.

1. Clock correction

A correction is derived by keeping a log of the time differences between the ADCP display time and the ship's master clock. This is then added to the time base in the data files to give UTC.

2. Sound speed

As described by King and Alderson in the cruise report for the Drake Passage repeat section SR1 (Observations on the R.R.S. *James Clark Ross* across Drake Passage in November 1993, King, B.A. and S.G. Alderson, Unpublished Cruise Report. Southampton Oceanography Centre), a correction needs to be made to all water velocities calculated by the DAS, in order to allow for the oil filled chest surrounding the transducer. The software should use the sound speed of oil, but instead uses that of seawater with a fixed salinity and a temperature measured in the oil. To allow for this the velocities are multiplied by the ratio of the sound speed in oil to that in water at the same temperature. Specifically,

$$F = 1.0055 \, (1.0 - 0.004785 \, T + 0.0000355 \, T^2),$$

where T is the measured temperature.

3. Misalignment angle

The misalignment angle (and any remaining amplitude error) was calculated as follows:

i) Two minute ensembles were merged with GPS positions, and ship's east and north speed calculated. Absolute ADCP bottom tracking velocities were also calculated.
ii) All good data were then examined and divided into periods of between 20 and 30 minutes in which a) at least 10 consecutive ensembles had bottom tracking data; b) speed had a typical range of no more than 20 cm/s; c) direction over the ground did not vary by more than a few 10's of degrees.
iii) Each such period was then averaged to give estimates of speed and direction over the ground from both the ADCP and GPS.
iv) The misalignment angle is then found from the vector difference between these two velocities for each period.

A water track misalignment angle was also estimated using a series of turns made near South Georgia. The table below shows a summary of the angular corrections obtained by both methods over available data intervals. Data were calibrated with the initial values –2.38° and 0.99.

Mean amplitude correction	SD of amplitude correction	Mean angular correction	SD of angular correction	Comment
0.993	0.008	–2.381	0.275	Stanley to Rio de Janeiro
1.004	0.005	–2.386	0.212	Antarctic continental shelf
0.994	0.003	–2.392	0.174	Passage to Stanley
0.949	0.005	–2.055	0.257	Passage to Rio de Janeiro
1.012		–2.2		Water tracking

4. Gyro error

The gyro, which allows the ADCP velocities relative to the ship to be converted into earth based co-ordinates, is susceptible to drift and oscillations of order a few degrees. This is compensated for by calculating the difference between the Ashtech GPS3DF and gyro headings over a 2 minute interval and rotating the ADCP vectors into an Ashtech frame of reference.

7. Underway Observations

7.1 Bathymetry

by Ricardo Locarnini

Sea-floor depth was acquired using a Simrad EA500 hydrographic echosounder and a hull-mounted transducer. Uncorrected depths, assuming a sound speed of 1500 m/s, were passed via a RVS level A interface to the level C system for processing, and logged every 30 seconds. Pairs of time and uncorrected depths were extracted from the level C system at 3 minute intervals, and corrected depths were calculated for each pair using echo-sounding correction algorithms. Each set of time, uncorrected depth, and corrected depth were matched to the corresponding latitude, longitude, and distance logged in the navigation file. New sets of data thus merged were usually generated every 48 hours, and appended to a master file. Data in this last file were used to produce the sea-floor profile along the A23 section, and to obtain the water column depth at the location of each $CTDO_2$/hydrographic station occupied. Corrected depth was plotted as a function of distance in 1000 km segments and revealed a significantly clean data set: depth spikes comprise about 1% of the total data points extracted.

7.2 Ocean Logger

by Paul Woodroffe and Dave Stevens

Meteorological and sea surface data are logged onto the RVS ABC system via the Ocean Logger. The Ocean Logger is PC based, which enables it to emulate the function of many RVS “Level A” units and allows real time display of data. Instruments with an analogue output are connected to small self contained digitising Rhopoint modules located close to the instrument concerned. These modules are interrogated from the controlling PC using the

RS485 standard. Other instruments have digital outputs and these are connected directly to RS232 standard ports on the PC. The PC also has an input from the ship's master clock.

For A23 it was necessary to connect an additional 13 meteorological instruments to the system. Fortunately the Rhopoint/RS485 architecture made this relatively easy, though it was necessary to make software changes. The following problems were experienced:

1) The best achievable sample period was 5 seconds. We can normally achieve a 2 second sample period, but the 13 additional channels took too long for the Viglen 386 to interrogate and process.
2) The thermosalinograph was noticed to be responding strangely to rapid temperature change. In order to investigate this further, the "Level A" message was changed to include conductivity and temperature rather than calculated salinity. The conductivity was found to be lagging the temperature by about 60 seconds. No solution was found to this problem.
3) Whilst investigating (2) it was noticed that communication with the TSG was often corrupted and values therefore rejected by the Ocean Logger. The cause was that the processing load of the additional 13 channels had made the timing of the TSG comms critical. The software was modified to overcome this problem.
4) The Rhopoint module on channel SP8 (wind direction) would occasionally hang up. A knock on effect of this was that the sample period increased, as the PC attempted to communicate with the faulty module. Therefore level A messages are more sparse during the periods when the module was hung up.

Instrument Summary

Instrument	Type	Location	Field Name
Air Temp	Vector T351	foremast	ATEMP
Humidity	Not used	–	HUM
PAR Sensor	Didcot DRP1	foremast	PAR
TIR Sensor	Kipp & Zonen CM5	foremast	TIR
Sea Temp (sci)	4-Wire PRT	Tranducer space	SSTEMP
Sea Temp (met)	Met Office (Not used)	–	MSTEMP
Flow Meter	Liter Meter	Prep Lab	FLOW
Thermosalinograph	Sea Bird SBE21	Prep Lab	TSTEMP/COND
Fluorometer	Turner Designs	Prep Lab	FLUOR
Barometer	Vaisala PA11	UIC	PRESS

In addition to these, the Level A message contains 13 extra fields labelled SP1- SP13.

The thermosalinograph was run continuously throughout the cruise. However blockages occurred when steaming through sea ice, so the coverage at southerly latitudes is at best intermittent.

The Ocean Logger passed salinity, temperature at the inlet and temperature at the thermosalinograph to the level B at 5 second intervals. During the cruise it was noted that the reported salinity was rather spiky at temperature changes. At 19:00 UTC on day 110, the oceanlogger was modified so that conductivity was reported as the SAL variable. At the suggestion of Dr. King the salinity was calculated using a lagged temperature. This was because the reported conductivity responded much more slowly than the temperature to changes in properties of the water in the TSG housing. The following weights were applied to the 5 second temperature values: 0.05 (current value), 0.05, 0.04, 0.04, 0.04, 0.04, 0.04, 0.04, 0.03, 0.03, 0.03, 0.03, 0.03, 0.03, 0.03, 0.03, 0.03, 0.39 (oldest value). The resulting temperature was then used to calculate the salinity. This approach appeared to be successful in reducing the spikiness. Subsequently, conductivities were calculated for the data collected before day 110 and the salinities were recalculated using the same approach.

7.3 Underway Water Sampling

by Russell Frew

A range of samples were taken from the non-contaminated sea-water supply to investigate the biogeochemical processes in the surface waters across the various frontal systems encountered along the transect. Two outlets were used to allow simultaneous sampling of various parameters. Nutrients were sampled from an outlet in the prep lab, while trace-metals and iodine were sampled in the micro-radio lab where the environment and likely contamination could be more controlled. The laminar flow bench in the micro lab was covered with polythene and used for trace metal processing.

A total of 76 stations were sampled for the following parameters:

- Total, dissolved and particulate trace metals
- Aluminium
- Reactive Nutrients
- Total nutrients (60 samples)
- Dissolved inorganic nitrogen (DIN) isotopes
- Dissolved inorganic carbon (DIC) isotopes
- Particulates for carbon (POC) and nitrogen (PON) isotopes
- Particulates for carbon, hydrogen and nitrogen analysis (58 samples)
- Iodine (47 samples)
- Particulate iodine (47 samples)

Filters were stored in the –20°C freezer. DIN and total nutrient samples were poisoned with 1 ml/l HgCl and stored in the 4°C cool store. Trace metal and aluminium samples were stored in the 4°C store.

7.4 Water Vapour

by Russell Frew

An attempt was made to collect water vapour for oxygen and deuterium analysis to investigate the fractionation between the seawater and atmosphere along the transect. A sampler consisting of two stainless steel funnels, arranged to prevent sea-spray getting into the sample, was mounted up the forward mast. A 12 mm hose was run down the mast to the mail room where a pump was located. Air was thus pumped through a cold trap where the water was frozen out and collected. Cooling was achieved by positioning the trap above liquid nitrogen which proved to require constant attention to maintain the optimal temperature of –80°C. At high latitudes the air was so dry it required 4-6 hours of pumping to get 1 ml of sample. 6 samples were collected in this manner, before sampling was abandoned due mainly to lack of time. Temperature control of the trap is critical as it must be cold enough to freeze out all the water vapour without being so cold that the water freezes before encountering the walls of the trap.

7.5 Underway Chlorophyll
by Carlos Garcia

In addition to the filtrations made for chlorophyll on CTD stations, water was also collected from the non-contaminated sea water supply. These samples were taken at the following times:

Date	**Time (UTC)**
2303	1600
2403	1200
2403	2350
2503	1325
2603	0100
2603	1203
2703	0023
2803	1010
2903	0115
2903	1250
0204	2037
0304	1101
0304	1615
0404	0040
0404	2034
0604	1638
0704	0224
2404	0109
2404	0255
2404	2307
2504	1137
2504	1951
2604	0305
2704	2343
2904	0240
3004	0232
3005	2300
0205	0400

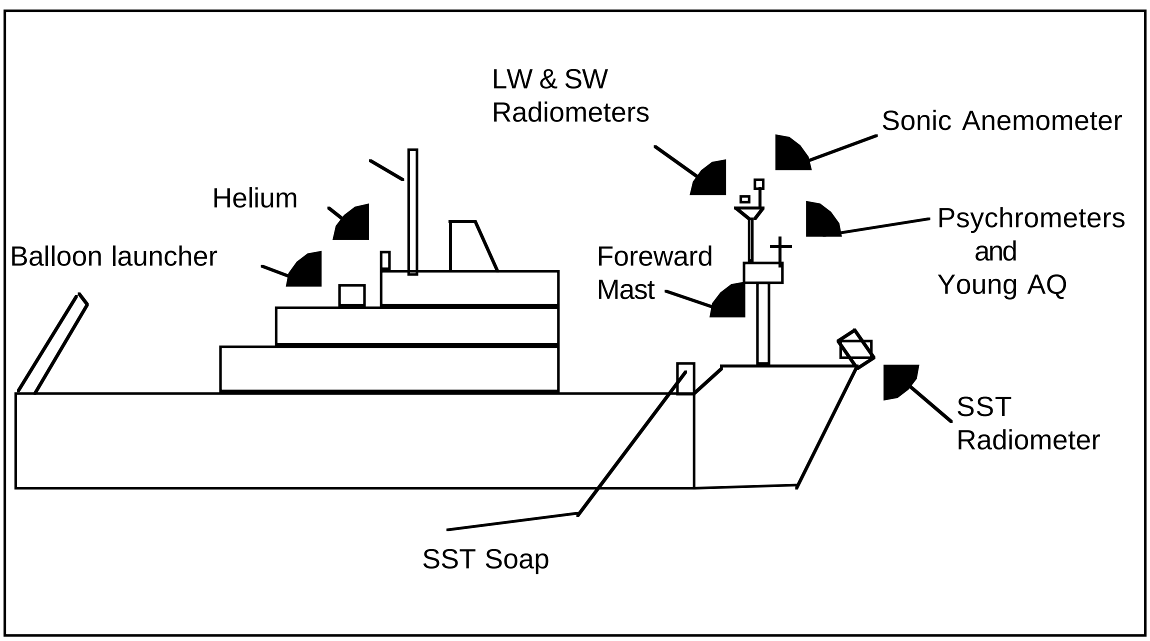
8. Meteorological Measurements
by Trevor Guymer, Robin Pascal, David Stevens, Brian King and Steven Alderson

During the A23 cruise several meteorological systems were deployed on the ship; these included Radiosonde balloons, Sonic Fast Sampling System, SST Radiometer and an enhancement of the BAS Ocean Logger system by the addition of extra sensors to produce

1-minute surface meteorological parameters. In addition, routine WMO observations were made and various satellite data products were received. Before describing the measurement systems some general information on their installation is given.

Mobilisation of the meteorological equipment was first started during refit in summer 94, when a small platform was added to the very top of the forward mast. This provided a base for mounting upward looking shortwave and longwave radiation sensors on gimbal mounts with an unobscured view of the sky. The platform also had two mounting poles for Gill Sonic anemometers on each of the forward corners of the platform. These enabled two anemometers to be mounted, a ship's sonic anemometer and an IOSDL Scientific sonic anemometer to be used for surface stress measurements.

Sensors were mounted on the forward mast and interfaced onto the Ocean Logger RS-485 network via an interface box containing Rhopoint modules. These modules digitise the sensor outputs, enabling the sensor interface box to be connect directly to the BAS system data expansion port. Two pairs of psychrometers were mounted on cross-trees either side of the forward mast main platform, with the port cross-tree also having a Young AQ wind monitor. Upward looking longwave and shortwave radiation sensors were mounted on gimbals on the new platform on the mast top. A sea surface temperature sensor 'sst soap' was deployed from the starboard crane and trailed just behind the ship's bow wave. In extreme conditions, particularly when the sst radiometer was not deployed the sensor was brought on deck. A schematic view of sensor locations is shown in the following figures.



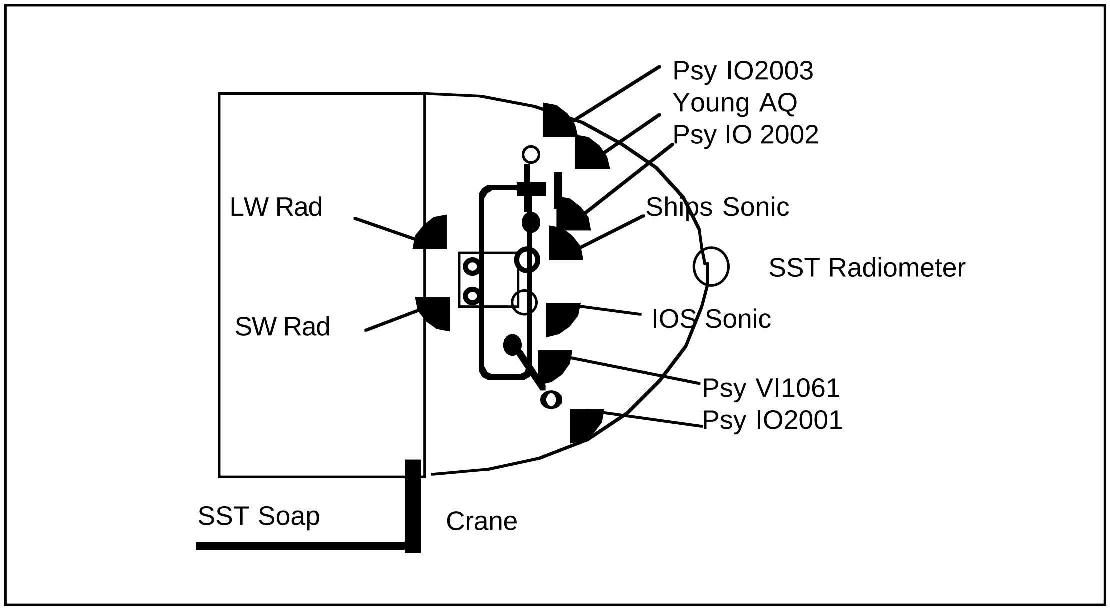


Figure M1. IOSDL Meteorological Sensor Positions

Radiosondes

Vaisala RS80-15 radiosondes were launched twice per day to measure the temperature and water vapour structure of the troposphere. In addition to providing a record of general meteorological conditions during the cruise they will be used to correct the SST radiometer for reflected sky radiation and as a source of validation data for satellites. A total of 88 sondes (Table M1) were launched from the bridge navigation deck aft of the wheelhouse, as shown in Fig. M1. Balloons were inflated in a special restrainer designed to hold the balloon in a safe position even during strong winds. A new top flap had been purchased prior to the cruise but on assembly was found to be a poor fit, limiting the size to which balloons could be inflated. However, this did not appear to have serious consequences and virtually all of the sondes reached the 200 mb level, the majority going on to reach at least 50 mb. Sondes were launched successfully in winds up to Force 9, the main problem being that on 3 strong wind occasions turbulence caused the cord between the balloon and sonde to snap taut and break and the sonde to fall on the deck. With its high position relative to the A-frame and the lack of obstructions the bridge deck of the *James Clark Ross* is an excellent point for radiosonde deployments. Launches were possible for a wide range of relative wind directions so that it was not normally necessary to have the ship alter course. For winds on the port beam, balloons were released over the top of the stowed midships crane. The 403 MHz antenna located near this position gave good signals most of the time, although the first flight was very noisy. Antenna connections were checked and tightened which cured the problem. The most serious problem encountered was that two of the 10 Helium cylinders were discovered to be empty when first opened; presumably they had leaked since delivery to the *James Clark Ross* in Grimsby in September 1994. However, more gas than usual was obtained from each cylinder by connecting the hose directly to the outlet valve rather than via a regulator. For the last 3 balloons helium gas was kindly donated by the PML chemistry group as it was surplus to their requirements.

The data were initially logged on a BBC Master, converted to DOS and transferred to a PC, then converted to Excel spreadsheets using a Basic program, eventually being transferred to Unix.

Table M1. Radiosonde launches

Flight No.	Jday	Launch time (UTC)	File	Notes
001	080	1717	080-1700	1
002	081	1742	081-1700	
003	082	1126	082-1100	
004	082	2315	082-2300	
005	083	1129	083-1100	2
006	083	2314	083-2300	
007	084	1128	084-1100	
008	084	2329	084-2300	Cap on
009	085	1144	085-1100	
010	085	2309	085-2300	
011	086	1123	086-1100	
012	086	2315	086-2300	
013	087	1139	087-1100	
014	087	2329	087-2300	
015	088	1135	088-1100	
016	088	2337	088-2300	
017	089	1140	089-1100	
018	089	2328	089-2300	
019	090	1111	090-1100	
020	090	2316	090-2300	
021	091	1152	091-1100	
022	091	2330	091-2300	
023	092	1141	092-1100	
024	092	2354	092-2300	
025	093	1155	093-1100	
026	093	2341	093-2300	
027	094	1146	094-1100	
028	094	2349	094-2300	
029	095	1115	095-1100	
030	095	2319	095-2300	
031	096	1139	096-1100	
032	096	2300	096-2300	3
033	097	1131	097-1100	
034	097	2303	097-2300	
035	098	1230	098-1100	4
036	098	2336	098-2300	

Table M1. Radiosonde launches (continued)

c

Flight No.	Jday	Launch time (UTC)	File	Notes
037	099	1140	099-1100	Cap on
038	099	2336	099-2300	5
039	100	1140	100-1100	
040	100	2333	100-2300	
041	101	1140	101-1100	
042	102	0002	101-2300	
043	102	1136	102-1100	
044	102	2338	102-2300	
045	103	1148	103-1100	
046	103	2326	103-2300	
047	104	1147	104-1100	Cap on
048	104	2320	104-2300	
049	105	1143	105-1100	
050	105	2349	105-2300	
051	106	1215	106-1100	
052	106	2327	106-2300	
053	107	1135	107-1100	
054	107	2332	107-2300	
055	108	1159	108-1100	
056	110	1147	110-1100	
057	111	0010	110-2300	
058	111	1140	111-1100	
059	111	2328	111-2300	
060	112	1150	112-1100	
061	112	2324	112-2300	
062	113	1144	113-1100	
063	113	2327	113-2300	
064	114	1149	114-1100	
065	114	2334	114-2300	
066	115	1157	115-1100	
067	115	2328	115-2300	
068	116	1143	116-1100	
069	116	2322	116-2300	
070	117	1157	117-1100	6
071	117	2318	117-2300	
072	118	1156	118-1100	
073	118	2324	118-2300	
074	119	1159	119-1100	
075	119	2319	119-2300	Cap on

Table M1. Radiosonde launches (continued)

Flight No.	Jday	Launch time (UTC)	File	Notes
076	120	1152	120-1100	
077	120	2319	120-2300	
078	121	1210	121-1100	
079	121	2318	121-2300	
080	122	2318	122-1100	
081	122	2323	122-2300	Cap on
082	123	?	Erased	7
083	123	1220	123-1100	8
084	123	?	123-2300	
085	124	1157	124-1100	
086	124	2336	124-2300	
087	125	1150?	125-1100	
088	125	1705	125-1700	

Notes

1. Very noisy, so tightened antenna connections
2. Logging started at 200m
3. ? launch time. Long flight, continued on file 097-0100
4. Sonde fell off 1st balloon
5. Sonde fell off 1st balloon
6. Not logged till 250 mb, data on descent to 680 mb
7. Dragged in sea, no transmission
8. Replacement for 082

Sonic Fast Sampling System

The Sonic fast sampling system comprises of a Solent sonic research anemometer, Sonic interface, laptop PC 486dx and a Sony Magneto-Optical Drive RMO-S550. This system acquires 3-component wind speed data from the sonic anemometer, spectrally processes the data and stores spectral parameter files at quarter-hourly intervals. The system writes data to three media as follows:-

1) Raw data are written to magneto-optical as a binary .RAW file after the 10 minute acquisition period.
2) Processed spectral data and parameterised data are written to hard disc as ASCII .PRN files after the processing phase is completed.
3) Parameterised data are written to floppy disk as ACSII .MWS files after the processing phase is completed

The IOSDL Gill Instruments Sonic anemometer (37) was mounted on a specially produced fixture on top of the forward mast. This was to minimise effects from the super-structure on the wind flow passing the anemometer. The anemometer was oriented with north facing forwards so there was an unobstructed air flow when the wind came over the bows. Between days 95 to 97 the anemometer failed to work properly due to freezing fog icing up the transducers. Apart from this the system worked almost continuously producing spectral estimates every 15 minutes and logging them to disk. Periodically data were downloaded to floppy disc and transferred to PSTAR where further processing was performed using scripts adapted from those used on previous WOCE cruises. Plots of friction velocity as a function of wind speed were produced and compared with previous results to confirm that the system was operating satisfactorily.

Radiometer

Sea surface temperature was measured by a Satellites International Ltd STR 100-1 infra-red radiometer located at the bow. The purpose was to assist the validation of similar data obtained from remote sensing satellites, particularly ERS-1, and to examine the difference between this radiometrically-determined temperature and the bulk temperature obtained by a towed thermistor and the TSG. A23 provided an excellent opportunity to span a large SST range (−1.8°C to 26°C) and a variety of meteorological conditions. A bonus was the dataset collected over several days when the ship was steaming through ice. Clear differences in the signature from different stages of sea-ice were observable.

Special mounts had been installed prior to the cruise which enabled the radiometer to either view the surface at 23° away from nadir or, in rough weather, to be swung to an inboard position for increased protection or complete removal if the bows were in danger of going under water. In severe cases the radiometer was removed from the bows altogether and brought into the lab. When there were was only a slight risk of spray a bung was inserted into the aperture. This arrangement proved very satisfactory and data were obtained up to winds of 24 m/s with no damage to the instrument itself although the base plate suffered some distortion. Had the radiometer been located on the foremast platform it would have been difficult, if not impossible, to protect and unprotect it as quickly as desired and much less data would have been recorded. It was also observed that once spray was bad enough to threaten the radiometer, it also reached the foremast platform so there would have been no advantage in that location.

During the early stages, ways of improving the internal calibration procedure were investigated as this had been a major problem in the past. It was concluded that the instrument drifts were extremely small but that bad calibrations dominated. Furthermore, in the extremely low temperatures which occurred in the ice, the instrument often hung in the calibration mode, possibly because the motor switching the black bodies into view could not operate as efficiently. For both of these reasons it was decided to decrease substantially the frequency of calibrations but to increase the number of cals on each occasion from 1 to 10. The logging and instrument control program was rewritten to effect this and intervals between cals of 4 to 12 hours were used for most of the cruise. Occasionally, bad cals still occurred. Several attempts were also made to calibrate the radiometer by siting it over a stirred bucket of known temperature; the towed thermistor probe was placed in the same bucket for comparison. In general, these showed similar behaviour to laboratory calibrations before the cruise. On one occasion the sky radiation was measured by pointing the radiometer upwards and noting variations in cloud cover.

Data were logged on a BBC Master computer and then transferred to a PC as an Excel spreadsheet. Data files were also transferred to the SUN computers and converted to PSTAR format. By combining these with Oceanlogger files preliminary analyses could be made of differences between skin and bulk temperatures in relation to wind, and the heat and radiative fluxes.

Surface meteorological instrumentation (1-minute means)

Installation of the meteorological sensors was completed in Stanley with very little problem, and interfaced to the BAS Ocean logger. Initially the sampling rate was set to 2 s but with the addition of extra sensors a 5 s sampling rate was found to be more satisfactory. The Ocean logger output was logged by the level B and was started shortly after midday on day 80.

On day 82 the SST trailing thermistor (Soap) was connected into the Ocean Logger system, but initially was only deployed during CTD stations. When the Soap was compared to the TSG it was observed that it had a –0.3 deg offset . Some signal dropouts were also detected and these persisted after the sensor was replaced by the spare on day 100. The SST sensor electronics (27) were replaced on day 109 with electronics (28), producing very good agreement with the TSG and cured all signal problems.

Two Vector Instrument psychrometers VI1065 and VI1061 were mounted on cross-trees on the port and starboard side of the forward mast main platform. In addition two new IOSDL designed psychrometers IO2002, IO2001 were mounted with the other psychrometers to enable an intercomparison between the two types of sensors. When the first daily plots of the met variables were produced it was clearly seen that psychrometer VI1065 was very noisy and so was replaced on day 83 by psychrometer IO2003.

A Young AQ wind monitor (6992) was also mounted on the port cross-tree to provided wind speed and direction, oriented with north facing aft minimising the effect of the null point between 0-360 deg. Although problems were encountered with the Rhopoint module sampling the wind direction, which would hang-up and fail to respond to commands from the Ocean logger. This could usually be overcome by resetting the power supply for the modules.

During the cruise it was noticed that changes in the longwave radiometer (ep2796) output with sky conditions were opposite in sign to those expected, but with reasonable mean values. It was deduced that this was caused by the internal battery being inserted the wrong way round. During the port call at Stanley on day 109 the longwave sensor was replaced by ep7225 and gave good data thereafter. Confirmation that the battery had been wrongly connected was also obtained.

Calibrations for the sensors used are given in Table M2.

Equation used: Y= C0 + C1*X + C2*X^2 + C3*X^3CH.

Table M2. Sensor calibrations

Cruise: WOCE A23 James Clark Ross Calibration Form Day 80				
CH.	SENSOR	SERIAL NO.	FORMULA	POSITION
SP 1	Psychrometer	VI1065 DRY	C0 –19.28116 C1 9.730875E–4 C2 7.679805E–6 C3 5.086662E–10	FWDM PORT
SP 2	Psychrometer	VI1065 WET	C0 –20.41007 C1 3.670989E–3 C2 6.768202E–6 C3 8.516418E–10	FWDM PORT
SP 3	Psychrometer	IO2002 DRY	C0 –10.33327 C1 3.824724E–2 C2 2.116376E–6 C3 –1.058462E–11	FWDM PORT
SP 4	Psychrometer	IO2002 WET	C0 –10.14934 C1 3.835115E–2 C2 2.067005E–6 C3 –9.144532E–11	FWDM PORT
SP 5	Young AQ Wind Speed	WS6992 Prop 54322	C0 0, C1 0.0984 C2 0, C3 0	FWDM PORT
SP 6	SW RAD	KZ2837	C0 0, C1 0.221 C2 0, C3 0	FWDMT PORT
SP 7	LW RAD	EP2796	C0 0, C1 0.274 C2 0, C3 0	FWDMT STBD
SP 8	Young AQ Wind Dir	WS6992	C0 0, C1 0.072 C2 0, C3 0	FWDM PORT
SP 9	Psychrometer	VI1061 DRY	C0 –40.07216 C1 1.961398E–2 C2 –1.708591E–6 C3 2.82523E–9	FWDM STBD
SP 10	Psychrometer	VI1061 WET	C0 –34.84936 C1 1.356776E–2 C2 1.602459E–6 C3 2.421478E–9	FWDM STBD
SP 11	Psychrometer	IO2001 DRY	C0 –10.28309 C1 3.823172E–2 C2 2.079835E–6 C3 –4.192271E–11	FWDM STBD
SP 12	Psychrometer	IO2001 WET	C0 –10.25585 C1 3.791665E–2 C2 2.659912E–6 C3 –3.233736E–10	FWDM STBD

Table M2. Sensor calibrations (continued)

Cruise: WOCE A23 James Clark Ross Calibration Form Day 80				
CH.	SENSOR	SERIAL NO.	FORMULA	POSITION
SP 13	SST SOAP	Elec 27 PD001	C0 –1188.025 C1 1.751935 C2 –8.693343E–4 C3 1.50187E–7	FDECK STBD

Cruise: WOCE A23 James Clark Ross Calibration Form Day 83				
CH.	SENSOR	SERIAL NO.	FORMULA	POSITION
SP 1	Psychrometer	IO2003 WET	C0 –19.28116 C1 9.730875E–4 C2 7.679805E–6 C3 5.086662E–10	FWDM PORT
SP 2	Psychrometer	IO2003 DRY	C0 –10.26829 C1 0.0378289 C2 2.640831E–6 C3 –3.063094E–10	FWDM PORT

Cruise: WOCE A23 James Clark Ross Calibration Form Day 100				
CH.	SENSOR	SERIAL NO.	FORMULA	POSITION
SP 13	SST SOAP	Elec 27 PD002	C0 –1007.652 C1 1.443255 C2 –6.951976E–4 C3 1.173376E–7	FDECK STBD

Cruise: WOCE A23 James Clark Ross Calibration Form Day 108				
CH.	SENSOR	SERIAL NO.	FORMULA	POSITION
SP 7	LW RAD	EP7225	C0 0, C1 0.240 C2 0, C3 0	FWDMT STBD
SP 13	SST SOAP	Elec 28 PD002	C0 –1102.54 C1 1.510403 C2 –6.962005E–4 C3 1.12033E–7	FDECK STBD

Routine Met. Observations, Sea-Ice and SST Data from Satellites

Throughout the cruise 3-hourly met. observations were made to WMO standards, including winds, air temperatures (Assmann psychrometer), sea temperatures (bucket), and visual observations of clouds, wind and swell waves and present weather. The bucket temperatures were the only source of SSTs for part of the time because sea-ice prevented proper operation of the TSG and towed thermistor systems. Because there were insufficient scientific personnel to maintain observations through the entire 24 hours, records made by the bridge officers at 03 and 06 UTC were used. The first of these was additional to their normal duties and this extra effort is much appreciated.

Wind conditions during the cruise were mostly moderate with Force 8s or more occurring on Days 79 (while steaming in lee of the Falklands), 84, 99, 107, 109, 119 and 122. Even when winds fell light there was nearly always a residual swell of about 2 m. Air temperatures reached their lowest of –10°C at the closest point of approach to the ice shelf on Day 89 and reached their maximum of 26°C near Rio de Janeiro on Day 125. Precipitation was generally light and for Days 84 to 99 fell mainly as snow.

In addition to ice information received on the ship using normal channels, arrangements were made for satellite data to be sent from the Mullard Space Science Laboratory and the James Rennell Centre. This was vital because ice conditions in the region were significantly worse than expected from climatology and modifications to the original track were needed. The data consisted of sea-ice concentration derived from a passive microwave radiometer flying on the U.S. DMSP series and the pulse peakiness parameter from the ERS-1 altimeter. For our purposes the former was more useful since the *James Clark Ross* is capable of steaming through thin ice. Good correspondence was found between the 0% contour and thin pancake ice, and the regular flow of such data to the ship proved to be of considerable assistance in planning the route south and the return from the ice shelf. Detailed ice observations were made by the bridge and will be used to validate the satellite estimates, particularly when the ship ventured into thicker ice.

Some satellite SST images were also sent electronically to the ship as JPEG files and displayed using an image processing package on the SUNs. They were obtained by the real-time ERS-1 ATSR facility in Tromso, Norway and relayed to the ship via the Rennell Centre. In terms of operational use the images were limited by the fact that coverage of a given region is obtained only once every few days and, given the large cloud amounts which prevailed, no passes were obtained for the region of immediate interest. However, some of the images of the SW Atlantic did show considerable structure and, in principle, could be of valuable assistance to future cruises.

9. Shipboard computing

9.1 Level ABC system
by Paul Murphy

Data Recording

The ship is fitted with the standard RVS data recording system known as ABC. This is a three-layer system:

A each instrument is assigned a Level A device to record its data, which is based on a Motorola 68000-series processor running OS/9. This time-stamps each data packet as it arrives, checks that the data is within acceptable limits, decodes binary data if necessary, and passes the data packet over a serial line to the Level B system in SMP format (Shipboard Message Protocol).

B The Level B system, based on a Motorola 68000-series processor with a VME bus and running OS/9, archives data packets onto QIC-format tape, and provides a status monitoring and data display capability in several areas of the ship. Packets are collected from all logged instruments, and then forwarded via Ethernet to the Level C system.

C. The Level C system, a Sun Sparcstation IPC running SunOS 4.1.3 and Sunview, collects data from the Level B system and stores it in cyclic data files. This system also provides a data analysis and display capability.

Additionally, data are logged from the ADCP directly to the Level C system via a serial line, and from the Oceanlogger direct to the Level B via a serial line.

Data Streams and variables recorded

Raw data

Name	Variables	No. of records	Size	Start Time	Stop Time	Data interval
adcp	bindepth, roll, pitch, heading, temp, velps, velfa, velew, velns, velvert, velerr, ampl, good, bottomew, bottomns, depth	2098432	205 Mb	95 080 16:45	95 126 11:27	2:00
adcpraw1	rawdopp, rawampl, rawgood, beamno, bindepth	6611712	219 Mb	95 080 16:43	95 116 18:21	2:00
adcpraw2	rawdopp, rawampl, rawgood, beamno, bindepth	1782272	59 Mb	95 116 18:23	95 126 11:27	2:00
anemom	wind_dir, wind_spd	3499890	54 Mb	95 078 16:00	95 126 18:05	5
bottles	code1, code2	2716	49 Kb	95 086 19:55	95 125 16:50	random
ctd17d1	press, temp, cond, trans, alt, fluor, oxyc, oxyt, deltat, nframes	1310773	81Mb	95 082 00:36	95 125 17:07	1
dop_log	speedfa, speedps	3361148	52 Mb	95 078 16:00	95 126 18:05	1
em_log	speedfa	1494154	14 Mb	95 078 16:00	95 126 18:05	1
gps_ash	sec, lat, lon, hdg, pitch, roll, mrms, brms, attf	4069803	230 Mb	95 078 16:00	95 126 18:05	1
gps_trim	lat, lon, pdop, hvel, hdg, svc, s1, s2, s3, s4, s5	4145349	283 Mb	95 078 17:12	95 126 18:05	1
gyro	heading	4092400	40 Mb	95 078 16:00	95 126 18:05	
sim500	uncdepth, rpow, angfa, angps	1126053	30 Mb	95 079 11:23	95 126 11:07	1
transit	lat, lon, it	689	21 Kb	95 078 17:59	95 126 16:41	random
oceanlog	atemp, mstemp, sstemp, hum, par, tir, fluor, flow, sp1, sp2, sp3, sp4, sp5, sp6, sp7, sp8, sp9, sp10 sp11, sp12, sp13, press, sal, tstemp	768249	111 Mb	95 079 11:50	95 126 12:31	2

Processed data

Name	Variables	No. of records	Size	Start Time	Stop Time	Data interval
bestdrf	vn, ve, kvn, kve	138064	4 Mb	95 078 17:38	95 126 18:04	30
bestnav	lat, lon, vn, ve, cmg, smg, dist_run, heading	138294	7 Mb	95 078 17:38	95 126 18:04	30
proctd	press, temp, cond, trans, alt, fluor, oxyc, oxyt, nframes, salin, potemp, oxygen	1310681	97 Mb	95 082 00:36	95 125 17:07	1
prodep	uncdepth, cordepth, cartarea	1125081	24 Mb	95 079 11:30	95 126 11:07	1
relmov	vn, ve, pfa, pps, pgyro	138492	5 Mb	95 078 16:00	95 126 18:04	30

Recording problems

1. The Level A for the IOS CTD was not set up on arrival. A new application was developed and installed to record the CTD data. Once installed, it was found that the data frame definition was incorrect, with the ALT and TRANS variables transposed. This was corrected, and the application re-installed.

2. Several problems were encountered with the CTD Level A, resulting in occasional data loss. Although several possible causes were investigated, none were shown to influence the results. Further investigation by RVS is essential to avoid future problems, and should be conducted using the raw CTD data which was recorded during JR10.

3. IOS have previously made use of an application to record the time of bottle firing from the CTD deck unit. This has not previously been used on the *James Clark Ross*, and was not installed on the system. A new application was written which recorded the data successfully. For future cruises, requirements for this type of application should be made clear during the planning stage to allow the software to be installed prior to departure.

4. Several Level A systems suffered from clock problems. On one occasion, six reported a jump in the master clock or instability in the master clock at the same time. All were reset, and worked without further problems.

5. The Ashtech GPS receiver regularly loses contact with the satellites. When this happens, no fix can be produced, and so the receiver outputs a heading of 666 degrees to show that it has no fix. The upper limit for heading in the GPS_ASH application is set to 360 degrees, and as a result the GPS_ASH Level A reports frequent errors. Although the limit can be changed using a terminal from the Level A console port, this change should be incorporated into the application.

Unix Computing

The facilities available for general use were:

1 Sun Sparcstation 20 Model 50 with 64 Mb RAM, 4.2 Gb disk, 17" monitor, running Solaris 2.3
1 Sun Sparcstation IPC with 24 Mb RAM, 2 Gb disk, 17" monitor, running SunOS 4.1.3
1 Sun Sparcstation IPC with 24 Mb RAM, 140 Mb disk, 17" monitor, running SunOS 4.1.3

The standard suite of NERC applications was installed on all machines, including Uniras 6v1f and 6v3b, PSTAR v2, v4 and v4a, and Sun C and Fortran compilers.

User space on these machines was limited to 1.7 Gb, accessible from all machines, due to the space taken up by applications and general user files. Usage was high throughout the cruise, with files having to be archived to tape or optical disk on a regular basis to make space available for new data.

Widespread use of PSTAR, with its requirement to convert from RVS datafile format to PSTAR format before analysis can begin, resulted in extremely high network loads during peak times as navigation and instrument data files were read across the network, converted, and written back across the network. However, although this resulted in network delays, this had no further impact on facilities.

PC Systems

Three Viglen PCs were available for general use. These are 486 DX/2 machines, running at 66 MHz. All ran DOS 6.22, with Windows 3.1, and Netware 3.12 providing access to the standard suite of NERC applications on a central server. These were widely used for file transfer, word processing, and X-Windows sessions using Exceed version 4.

Communications

RRS *James Clark Ross* runs the standard BAS message and data transfer system, based on a DEC Vax 4300, providing a daily link to BAS HQ in Cambridge. Access to the system is via a text-based system on the Vax system, or via Wordperfect Office running on the PCs.

During JR10, the system was heavily used, with message traffic levels twice to three times as high as during BAS cruises. Data transfers were also more common than during BAS cruises, with regular transfer of JPEG image files and Wordperfect documents.

9.2 PEXEC
by Steven Alderson

Version 4 of the PEXEC software was installed on jruc at the beginning of the cruise and ran without problems. A number of programs were created or modified during the cruise:

pltop: Modified. Internal UNIRAS buffer size exceeded, so modified to use smaller chunks at a time.
ppoly: New. Absence of program mcalm2. ppoly is more general polynomial calibration program.
minmid: Modified. Overlapping input files now allowed.
bfdissY: Modified. Corrected to avoid fractional power of negative number.
metflx: Modified. Restriction on number of variables removed.

A copy of PEXEC was later installed on jrua (SPARC 20) as version 4a. Non-graphics programs ran as normal. Programs that used Uniras were sometimes unreliable. This problem has not been tracked down. A script which attempted to rotate a postscript plot before submission to printer rainbow seemed to cause the printer queue to jam. However, this problem also occurred intermittently when submitting plots from jruc, so again it is unresolved.

9.3 Data Archives

by Andrew Coward

Normal pexec archiving procedures were carried out throughout the cruise. Any files given a .arch extension were archived to both cartridge tape and erasable optical disk. Summary tables containing both filename and pstar version code are available for perusal and hence quick location of required files. The amount of data written to each cartridge was limited to 127 MB in order to fit the equivalent of two tapes onto each side of an erasable optical disk. Sufficient disk space was available on a disk mounted independently of the user's space for the staging of data so that each tape need only contain 1 tar file in addition to a tape header file. Scripts were written to carry out the following operations:

1. move archive files from user space to the staging area. The maximum amount of data to be moved can be altered at run-time.
2. create both tape and disk copies and the summary files.
3. confirm that the file sizes on optical disk match the original file sizes
4. clear the staging area after successful completion.

Data Tape names are of the form **A23_nnc_mm** where nnc is a 2-digit number and either A or B, and refers to the disk number and side. mm is a 2-digit number referring to the tape number. i.e. **A23_08A_30** is the 30th tape which is duplicated on side A of disk number 8. The original directory structure, 1 level below /users/misc/pstar, is retained on both tape and optical disk. For example, a file called abnav2301.arch residing in /users/misc/pstar/bestnav which is archived to tape A23_08A_30 will be stored as ./bestnav/abnav2301.arch within a tar file on tape and as EO_HOME/A23_08A_30/bestnav/abnav2301.arch on disk, where EO_HOME is the mount point of the optical disk.

9.4 A23 World Wide Web (WWW)

by Dave Stevens and Matthew Beare

Prior to the cruise a number of WWW pages were set up describing A23. The address for these pages is http://www.mth.uea.ac.uk/ocean/a232/welcome.html. During the cruise a number of updates (including newsletters, photographs and graphics illustrating initial results) were sent back to UEA for inclusion on the WWW server. Textual information was sent by the routine daily e-mail transfers. Photographs were taken using a Connectix QuickCam connected to an Apple powerbook. Graphics were grabbed from Sun screen images using the shareware software xv. The binary data describing the photographs and graphics were transferred by ftp as required. Between 19th March and 8th May the WWW server delivered 4750 files of which 829 were to UEA clients, 1509 were to other UK clients and 2412 were to other countries.

10. Buoy and Float Deployments

10.1 ALACE Floats

by Dave Stevens

Ten Autonomous LAgrangian Circulation Explorer (ALACE) floats were kindly provided by Dr. Russ Davis and Dr. Ray Peterson of Scripps. The ALACEs track the flow at a pre-set depth and periodically surface to report their position and pressure, temperature and (in some cases) salinity measurements via the ARGOS system. Of the ten ALACEs provided, two (371T and 380C) were pre-set to track the flow at 800 m with the remaining eight set for 1000 m. Three of the floats had conductivity cells and were thus able to report salinity. The ALACEs were assembled in the rough workshop. Deployment took place on the aft deck with the ship making slight headway.

Three floats were deployed in the Falkland Current south of the Burdwood Bank on the outward steaming leg. Due to time restrictions the first float was deployed shortly before a T-5 XBT (All other deployments were at CTD stations).

Table A1: Details of ALACE deployments on the outward steaming leg. ALACEs with serial numbers followed by the letter T do not have conductivity cells.

Serial no.	Deployment time	Latitude	Longitude	Station
371T	95:082:12:45	55°02.14'S	60°32.26'W	XBT001
380C	95:082:18:21	55°30.99'S	58°37.46'W	CTD001
372T	95:082:18:23	55°31.01'S	58°37.39'W	CTD001

The remaining seven ALACEs were deployed at an approximate spacing of 1.5° along the main A23 section starting at 52°S. Deployments further south would have run the risk of the ALACE surfacing under ice.

Table A2: Details of ALACE deployments on the A23 section.

Serial no.	Deployment time	Latitude	Longitude	Station
373T	95:104:03:58	52°02.14'S	35°10.28'W	CTD062
390C	95:113:15:43	48°35.53'S	35°59.32'W	CTD080
374T	95:115:14:12	44°51.95'S	36°00.06'W	CTD087
391C	95:117:09:44	41°32.25'S	35°59.51'W	CTD093
375T	95:118:22:04	37°54.87'S	35°58.36'W	CTD097
377T	95:120:09:31	34°21.75'S	35°59.75'W	CTD101
376T	95:122:13:09	30°00.41'S	36°52.77'W	CTD113

During the cruise Dr. Peterson was able to confirm, by e-mail, that the first four ALACEs had been successfully deployed and had completed at least one cycle.

10.2 POL Deep Sea Pressure Recorder

by Bob Kirk

A Proudman Oceanographic Laboratory bottom pressure recording instrument had been left aboard ship, to be prepared and deployed during this cruise. We were requested to deploy the instrument at a particular depth on the flank of the Rio Grande Rise and this was done immediately following the completion of CTD Station 107 on day 121.

The instrument cover was removed and the relocation flashing light and radio beacon mast was secured in place. Ropes holding the instrument to its ballast frame were removed, and pyros were attached to the mechanical release mechanism. The cables between the twin acoustic release units and the pyros were left unconnected until final assembly.

Data logger initialisation and logging start were carried out according to instructions left. After opening the end cap of the instrument pressure case power was switched on, tape advanced, and the scan start button were pressed to begin logging. Correct operation of the system was verified by checking the scan indicator light exactly 15 and 30 minutes after scan reset. The end cap of the pressure case was replaced after careful checks were made of the O-ring seal. A securing strop between the pressure case and the frame of the instrument was attached.

Just before launch the cables from the acoustic release units were checked to ensure there was no voltage on them and then connected to the pyros. Both the relocation devices, a radio beacon and flashing light, were activated and checked for proper operation. A final visual check was made of the instrument to ensure everything was secure.

The Pressure Recorder was deployed using the midships crane without hitting the side of the ship, and the recovery line was released as the instrument sank below the surface to prevent possible fouling of the ballast weight. Acoustic beacons were activated by the shipboard 10 kHz. system and monitored as the ship left the area to continue CTD stations. All seemed in order. Arrangements have been made to recover the instrument on a future cruise by another group.

BPR Deployment Details

Reset Time	1140 UTC.
Scan button pressed	1145 UTC.
Scan LED monitored at	1200 UTC and 1215 UTC.
Launch Time	1613 UTC
Launch Position	31 59.9 S, 36 00.7 W.

Depth 2604 m uncorrected.
Radio Beacon (ser. no. 20225) frequency 160.725 MHz.
Acoustic Release Unit 2326 Beacon 320 Hz. Release 418 Hz. Period 1.10 s.
Acoustic Release Unit 2483 Beacon 322 Hz. Release 342 Hz. Period 1.12 s.

10.3 Spectral radiance measurements

by Carlos Garcia

Upwelled spectral irradiance measurements were made at 0.5 m using a Tethered Spectral Radiometer Buoy (TSRB) made by Satlantic, Inc.. The instrument measures seven (412, 443, 490, 510, 555, 670, 683 nm) upwelled radiances at 0.5 m, surface incident irradiance at 490 nm, and sea surface temperature. Absolute radiometric units are within 5%. The 7 spectral radiance sensors match SeaWiFS channel characteristics. The optical drifter system was developed at Dalhousie University (Canada). The instrument is attached to a buoy which is linked to the deck unit. Measurements of the multi-spectral upwelling radiances and surface incident irradiance are made simultaneously. Changes in skylight are monitored by the 490 irradiance sensor placed at the top of the buoy mast. The TSRB collects optical data at a distance of approximately 90 m from the ship. This is a mandatory requirement for all measurements to be incorporated into SeaWiFS validation and pigment algorithm data base. The instrument was successfully deployed at 38 stations. All deployments were made at the beginning of CTD stations. Multispectral optical data were collected during 10-20 minutes to allow for fluctuations in the measurements. Conversions of digital numbers into physical units were performed after data collection. Preliminary analysis has shown that the TSRB had an excellent performance, being a reliable instrument for multispectral radiance measurements in near surface waters.

Acknowledgements

This cruise was funded by the Natural Environment Research Council through its WOCE Community Research Programme and Special Topic. We are very grateful to all those who enabled the cruise to take place so successfully, particularly our colleagues at BAS and the whole ship's company.

Table 1. A23 Station List

Stn. Num.	Date mmddyy	Time UTC	Lat. (° ′ S)	Lon. (° ′ W)	Corr. depth(m)	Off bot.(m)	Max. press(db)	# sam.	Notes
001	032395	2018	55 30.84	58 36.69	4199	10	4271	22	8
002	032895	1005	65 20.91	25 00.81	4918	–	969	24	4,6
003	033095	0944	72 27.65	16 31.31	187	8	183	23	4,5,6,7,8,9
004	033095	1509	72 22.76	16 56.59	494	11	497	9	8,9
005	033095	1714	72 20.65	17 01.72	1000	10	1005	10	4,5,6,9
006	033095	2009	72 16.49	17 13.59	1518	8	1535	14	7,8
007	033095	2338	72 11.15	17 27.68	1995	7	2023	23	4,5,6,9
008	033195	0403	72 04.11	17 53.93	2528	9	2563	16	
009	033195	0806	71 57.34	18 13.13	3003	12	3045	17	4,5,6,8
010	033195	1834	71 50.86	18 31.41	3515	11	3569	22	4,6,7,9
011	033195	2349	71 42.26	18 51.75	4001	10	4067	18	4,5,6
012	040195	1241	72 29.60	22 55.25	3851	17	3909	22	4,5,6,8,9
013	040195	2360	71 42.30	18 51.55	3999	10	4067	23	4
014	040295	0550	71 18.28	19 29.66	4332	9	4415	20	4,6
015	040295	1144	70 51.35	20 08.14	4330	9	4407	22	7,9
016	040295	1817	70 15.39	20 59.26	4517	10	4599	22	4
017	040395	0046	69 39.32	21 49.21	4608	9	4693	22	4,8
018	040395	0900	69 03.39	22 37.80	4713	10	4801	21	4,5,6,9
019	040395	1726	68 09.26	23 50.04	4816	10	4907	21	7

Stn. Num.	Date mmddyy	Time UTC	Lat. (° ′ S)	Lon. (° ′ W)	Corr. depth(m)	Off bot.(m)	Max. press(db)	# sam.	Notes
020	040495	0235	67 15.57	24 59.68	4807	8	4899	19	4,5,6
021	040495	1147	66 21.61	26 05.85	4864	10	4955	22	4,8,9
022	040495	1951	65 27.70	27 10.42	4910	9	5003	24	4,7,9
023	040595	0501	64 33.92	28 12.31	4923	10	5015	22	4
024	040595	1326	63 57.93	28 52.62	4792	11	4889	22	4,5,6,9
025	040595	2050	63 20.80	29 34.13	4717	10	4823	22	4,9
026	040695	0253	63 04.37	30 06.92	4879	9	4971	22	4,5,6
027	040695	0928	62 46.97	30 41.63	4832	13	4917	22	4,8,9
028	040695	1459	62 29.47	31 15.69	4754	10	4853	22	4,7
029	040695	2101	62 04.52	31 11.01	4853	10	4941	22	4,5,6
030	040795	0341	61 39.67	31 06.66	3338	79	3393	20	4
031	040795	0846	61 33.06	31 06.23	4063	14	4127	20	4,5,6,9
032	040795	1356	61 10.21	31 02.78	3474	101	3431	21	4,5,6,9
033	040795	1719	61 06.56	31 02.48	2517	9	2547	18	4,8,9
034	040795	2128	60 41.97	31 00.59	1588	14	1595	15	4,5,6,7
035	040895	0131	60 18.91	30 57.51	2764	6	2803	20	
036	040895	0539	59 59.68	30 55.79	2995	10	3031	22	4,5,6
037	040895	0940	59 45.97	30 54.33	3797	9	3851	24	4
038	040895	1332	59 40.43	30 53.79	2883	13	2917	20	4,8,9
039	040895	1752	59 26.14	30 51.61	3444	11	3495	21	4,5,6,9
040	040895	2240	59 03.02	30 49.82	3129	15	3163	20	4,7,8
041	040995	0441	58 38.11	30 49.47	3487	19	3543	21	4
042	040995	1111	58 12.78	30 49.32	3996	38	4033	24	4
043	041095	1230	57 48.09	30 49.96	3555	20	3609	19	4,5,6
044	041095	1730	57 27.49	31 19.67	3772	149	3833	20	4,7,9
045	041095	2239	57 07.11	31 48.88	3419	121	3455	4	4
046	041195	0907	56 46.54	32 18.24	3222	10	3277	19	4
047	041195	1401	56 22.86	32 52.37	3132	9	3175	22	4,5,6,8
048	041195	1913	55 59.42	33 25.17	3048	11	3087	19	4,5,6,7,9
049	041195	2354	55 43.53	33 47.13	3523	6	3579	20	
050	041295	0355	55 29.08	34 08.00	2454	10	2493	18	4,5,6
051	041295	0727	55 15.57	34 26.62	1491	9	1519	14	4
052	041295	0933	55 12.91	34 30.48	522	11	527	10	4
053	041295	1510	54 49.61	34 40.95	492	2	495	10	4,5,6,9
054	041295	1653	54 43.06	34 40.39	973	10	981	12	4,9
055	041295	1939	54 26.28	34 40.74	1938	11	1957	16	9
056	041295	2247	54 17.72	34 40.38	3250	12	3293	19	7,8
057	041395	0234	54 13.16	34 40.12	4189	10	4261	24	4,5,6,8
058	041395	0858	53 54.03	35 01.00	3553	10	3601	20	4,5,6
059	041395	1337	53 30.11	34 49.95	3548	8	3601	20	4,5,6,9
060	041395	1841	53 05.07	34 54.68	3596	12	3643	20	9

Stn. Num.	Date mmddyy	Time UTC	Lat. (° ′ S)	Lon. (° ′ W)	Corr. depth(m)	Off bot.(m)	Max. press(db)	# sam.	Notes
061	041395	2351	52 37.86	35 00.03	3787	7	3847	21	8
062	041495	0506	52 11.96	35 10.70	4216	10	4283	21	4
063	041495	1107	51 42.12	35 15.01	4705	6	4783	22	4,5,6
064	041495	1724	51 11.94	35 19.96	4845	12	4913	22	4,5,6,7,9
065	041495	2322	50 42.53	35 24.92	4105	9	4163	21	
066	041595	0514	50 12.43	35 29.35	3379	11	3425	20	4,6
067	041595	1035	49 50.09	35 35.05	4580	9	4661	22	4
068	041595	1530	49 35.13	35 37.42	5042	12	5127	23	4,7,9
069	041595	2038	49 20.07	35 39.43	5036	12	5117	23	4,5,6
070	041695	0213	49 08.93	35 51.76	5140	9	5235	23	4,5,6
071	041695	0841	48 55.98	35 55.05	5096	8	5191	22	4,5,6
072	042195	1324	49 49.56	35 36.39	4948	8	5041	24	9
073	042195	2123	50 42.49	35 24.91	4103	12	4163	21	4,6,8
074	042295	0329	50 27.59	35 27.90	3244	11	3287	19	8
075	042295	0727	50 12.68	35 30.60	3555	11	3605	20	4
076	042295	1214	49 52.38	35 34.47	4394	10	4469	21	7,9
077	042295	1832	49 32.91	35 38.36	5027	13	5107	23	4,9
078	042395	0057	49 13.87	35 48.55	4987	12	5085	23	6,8
079	042395	0706	48 54.90	35 56.97	5237	10	5337	23	4,5,6
080	042395	1325	48 36.03	35 59.70	5380	8	5483	23	4,6,7,9
081	042395	2101	48 04.00	35 59.98	5602	15	5729	24	4,8,9
082	042495	0438	47 32.23	35 59.83	5787	89	5821	24	4,9
083	042495	1241	47 00.07	36 00.00	5864	–	597	0	No bottles
084	042495	1644	46 52.39	36 00.10	5848	50	5927	24	4,5,6,7,9
085	042595	0018	46 03.96	36 00.00	5569	–	305	2	
086	042595	0622	45 52.01	36 00.10	5555	14	5661	24	4,8,9
087	042595	1616	44 52.10	36 00.10	5457	9	5561	24	4,7,9
088	042695	0040	44 04.13	35 59.67	5251	9	5351	24	8,9
089	042695	0610	43 51.93	35 59.64	5207	8	5307	24	4
090	042695	1236	43 22.00	36 00.02	5185	8	5283	24	4,5,6,9
091	042695	1909	42 51.87	36 00.28	5191	7	5295	24	4,7,9
092	042795	0231	42 12.02	36 00.03	5176	8	5271	24	4,9
093	042795	1009	41 32.28	35 59.42	5183	11	5275	24	4,8,9
094	042795	1747	40 52.55	35 59.17	5012	10	5109	24	4,9
095	042895	0230	39 52.09	36 00.64	4683	6	4759	23	4,9
096	042895	1110	38 52.14	35 59.76	4922	8	5001	24	4,8,9
097	042895	2005	37 53.81	35 59.11	4935	9	5021	24	4,5,6,7,9
098	042995	0504	36 51.76	35 59.55	4895	8	4971	24	4,9
099	042995	1342	35 51.88	35 59.93	4647	8	4713	24	4,8,9
100	042995	2252	34 51.97	35 59.90	4673	13	4737	24	4,9
101	043095	0734	34 22.00	35 59.29	4605	11	4685	24	4,9

Stn. Num.	Date mmddyy	Time UTC	Lat. (° ′ S)	Lon. (° ′ W)	Corr. depth(m)	Off bot.(m)	Max. press(db)	# sam.	Notes
102	043095	1411	33 52.12	36 00.23	4346	35	4413	24	4,5,6
103	043095	1926	33 32.32	35 59.70	4412	9	4475	24	
104	050195	0112	33 05.28	36 00.01	4073	5	4127	23	4,8
105	050195	0532	32 50.81	35 59.26	3499	8	3543	21	9
106	050195	0940	32 33.82	35 59.66	3005	9	3029	18	4
107	050195	1449	32 00.01	36 00.37	2619	11	2645	18	9
108	050195	1923	31 33.12	36 00.36	2007	8	2019	15	4,7,9
109	050195	2237	31 15.14	36 00.38	1498	9	1503	15	8,9
110	050295	0137	31 01.07	36 00.16	1030	8	1031	11	4,9
111	050295	0449	30 41.49	36 15.31	981	10	985	11	9
112	050295	0824	30 19.33	36 34.47	1495	18	1493	13	4
113	050295	1214	30 00.27	36 52.78	2045	6	2063	15	4,9
114	050295	1514	29 51.30	37 01.55	2513	8	2551	18	9
115	050295	1823	29 43.65	37 08.47	3009	14	3051	20	4,7
116	050295	2216	29 36.71	37 16.04	3675	9	3723	23	9
117	050395	0222	29 26.45	37 26.37	4065	4	4131	24	4,6
118	050395	0733	29 05.51	37 46.10	4344	10	4401	24	4,9
119	050395	1326	28 42.40	38 08.01	4326	9	4389	24	4,6,7,8,9
120	050395	2155	28 31.89	38 18.39	4678	8	4749	24	4,5,6,7,9
121	050495	0325	28 11.79	38 37.61	4231	23	4291	24	4
122	050495	0845	27 51.66	38 56.66	4261	8	4315	24	4,9
123	050495	1406	27 31.50	39 15.60	4240	8	4295	24	4,6,8,9
124	050495	1848	27 17.41	39 28.70	3988	9	4049	23	4,9
125	050595	0013	27 01.48	39 57.58	3911	15	3981	24	4,5,6
126	050595	0546	26 44.90	40 27.11	3397	10	3437	21	4
127	050595	0950	26 38.90	40 38.53	3008	7	3059	20	4,9
128	050595	1546	26 15.20	41 20.65	2577	10	2595	17	9

Notes

1) Date, time, and position are reported for the time at the bottom of the cast.
2) Salinity, dissolved oxygen, silicate, nitrate+nitrite, and phosphate were sampled for all stations and bottles with the exception of only salinity for stations 013 and 085, and only salinity and dissolved oxygen for station 089. No bottle samples were available for 083.
3) Oxygen isotopes were sampled for all stations and bottles with the exception of stations 002, 013, 027, 045, 072, 083, 085, and 089.
4) CFC11, CFC12, CFC113, and $CC1_4$ were sampled at these stations.
5) Tritium was sampled for these stations.
6) Helium was sampled for these stations.
7) Total Inorganic Carbon and pCO_2 were sampled for these stations.
8) Iodide was sampled for these stations.
9) Chlorophyll was sampled for these stations.

10) Trace metals were sampled for stations 003, 006, 010, 019, 026, 035, 047, 060, 065, 078, 088, 103, 111, 118, 126.
11) Carbon isotopes were sampled for stations 003, 006, 019, 022, 026, 028, 033, 034, 040, 044, 048, 056, 060, 064, 065, 068, 076, 078, 080, 084, 087, 088, 091, 097, 103, 108, 111, 115, 118, 119, 120, 126.
11) Irradiance buoy was deployed at stations 002, 010, 019, 032, 033, 038, 039, 044, 048, 053, 054, 055, 059, 060, 064, 068, 072, 076, 077, 080, 081, 083, 084, 087, 090, 091, 096, 097, 099, 107, 108, 113, 114, 119, 123, 124, 128.

Table 2. A23 XBT List

Probe	Date mmddyy	Time (UTC)	Latitude ° ′ S	Longitude ° ′ W	Corr depth	Max depth
001	032395	1301	55 02.34	60 33.46	2596	1830
002	032495	0214	56 56.48	57 11.02	4788	760
003	032495	0402	56 06.95	56 32.75	4468	760
004	032495	0558	56 17.62	55 53.03	4717	760
005	032495	0704	56 23.60	55 32.24	4969	760
006	032495	0808	56 29.90	55 11.87	4950	760
007	032495	1005	56 42.03	54 29.50	4752	760
008	032495	1203	56 54.51	53 46.17	4024	760
009	032495	1405	57 06.66	53 01.38	4072	760
010	032495	1606	57 19.18	52 13.84	3253	760
011	032495	1757	57 31.58	51 31.01	4180	760
012	032495	2009	57 45.96	50 40.25	3968	760
013	032495	2205	57 57.98	49 54.57	3926	760
014	032595	0012	58 11.20	49 04.52	3953	760
015	032595	0159	58 22.98	48 23.54	3890	760
016	032595	0359	58 35.51	47 38.48	3030	760
017	032595	0601	58 47.62	46 50.59	3090	219
018	032595	0811	59 00.63	45 58.51	2886	760
019	032595	1004	59 10.68	45 14.98	1640	760
020	032595	1202	59 21.17	44 29.81	1400	760
021	032595	1218	59 22.76	44 24.20	1537	760
022	032595	1408	59 32.66	43 48.99	3677	760
023	032595	1600	59 41.02	43 20.48	4305	241
024	032595	2002	59 58.66	42 20.53	4264	760
025	032695	0008	60 15.86	41 09.30	2178	760
027	032695	0821	60 50.61	38 56.43	3442	199
028	032695	0825	60 50.97	38 55.03	3611	760
029	040795	2320	60 30.80	30 58.74	2296	760
030	040895	0354	60 06.97	30 57.24	1937	760
031	040995	0200	58 49.23	30 49.38	3570	309
032	040995	0744	58 25.64	30 49.73	2615	760

Probe	Date mmddyy	Time (UTC)	Latitude ° ′ S	Longitude ° ′ W	Corr depth	Max depth
033	041095	1522	57 35.63	31 07.87	3465	760
034	041095	2016	57 17.19	31 35.11	3433	760
035	041195	0137	56 56.82	32 04.14	3338	760
037	041195	1203	56 31.03	32 40.86	3377	760
038	041195	1657	56 10.00	33 10.72	3309	760
039	041195	2129	55 51.90	33 35.72	2874	760
040	041295	0215	55 35.06	33 58.27	3105	760
041	041295	0542	55 23.67	34 15.47	2236	760
042	041295	1840	54 29.00	34 39.75	1705	760
043	041395	2127	52 50.42	34 57.83	3715	760
044	041495	0237	52 24.44	35 05.33	3939	760
045	041495	0758	51 58.26	35 12.52	4491	760
046	041495	1426	51 26.70	35 17.82	4701	760
047	041495	2038	50 56.76	35 23.06	4908	760
048	041595	0237	50 27.54	35 28.01	3212	760
049	041595	0757	49 59.02	35 33.87	4290	760
050	041595	1326	49 39.08	35 36.84	5070	760
051	041595	1823	49 25.45	35 39.08	4691	760
052	041595	2324	49 13.76	35 47.42	5039	760
053	041695	0511	49 02.15	35 54.51	4985	760
054	042195	0630	49 43.61	37 29.70	5147	760
055	042195	0726	49 45.10	37 08.80	5156	760
056	042195	0825	49 46.25	36 46.64	5120	760
057	042195	0927	49 47.21	36 22.88	5024	760
058	042195	1026	49 48.84	35 59.98	4696	760
059	042195	1722	50 10.19	35 30.33	3789	760
060	042195	1846	50 26.85	35 26.92	3075	760
061	042395	1712	48 18.33	36 00.06	5402	760
062	042495	0105	47 47.33	36 00.07	5714	760
063	042495	1002	47 15.59	36 00.20	5860	760
064	042595	1159	45 17.36	35 59.83	5537	760
065	042595	2103	44 21.54	35 59.80	5313	760
066	042695	0922	43 37.99	36 00.24	5208	760
067	042695	1555	43 07.10	36 00.12	5175	760
068	042695	2251	42 32.26	35 59.98	5149	760
069	042895	0715	39 17.96	35 59.71	4918	760
070	042895	0817	39 05.16	35 59.69	4911	760
071	042895	1736	37 58.93	35 59.82	4927	760
072	050595	0311	26 52.27	40 13.88	3803	760
073	050595	1258	26 26.57	41 00.14	2747	760

Notes

1) All XBTs were T-7 probes, with the exception of a T-5 probe for XBT001.
2) XBT026 and XBT036 did not record useful temperature data.

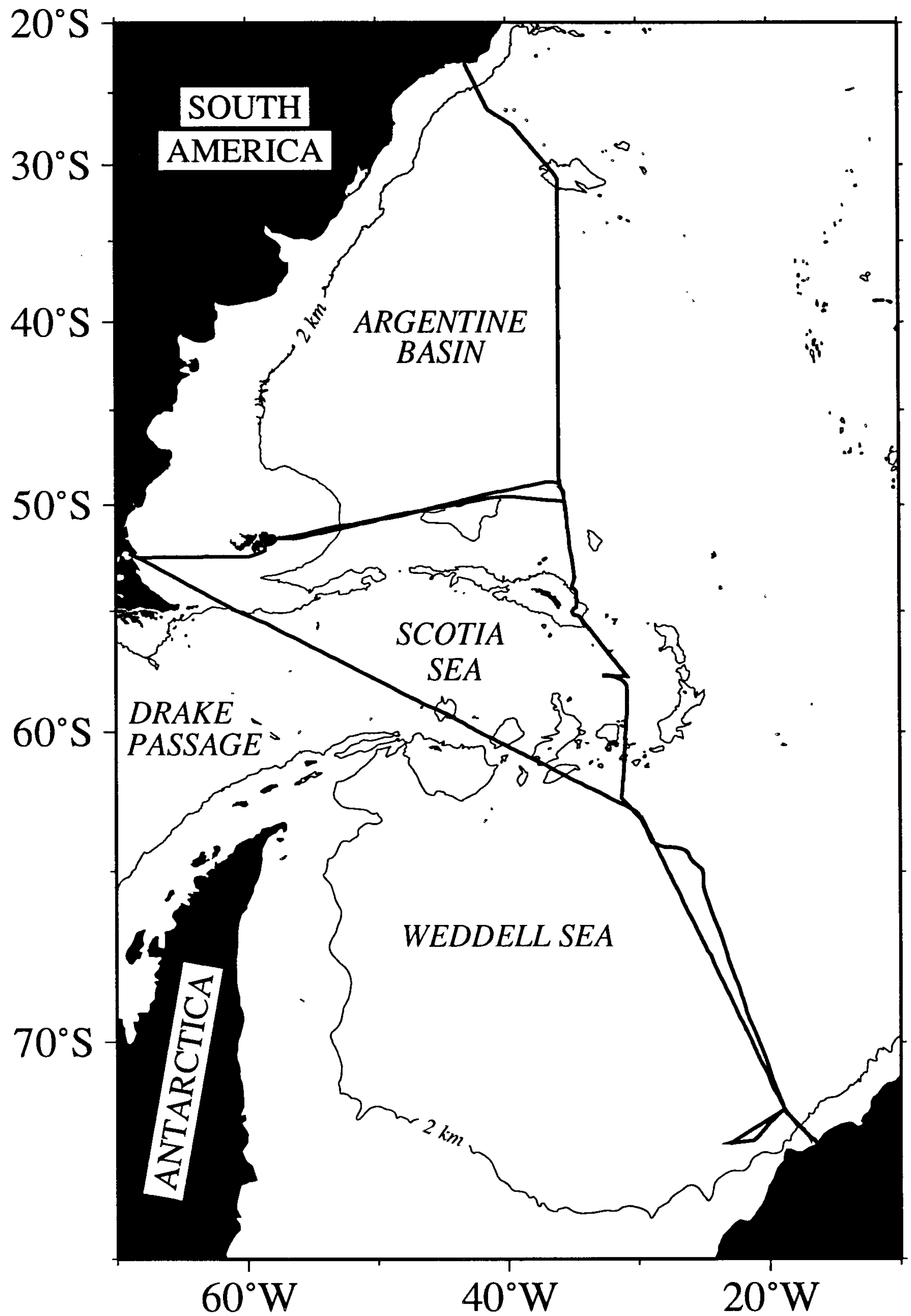


Fig. 1 Cruise track: UK WOCE cruise A23, 20 March – 6 May 1995. The 2-km isobath is also shown.

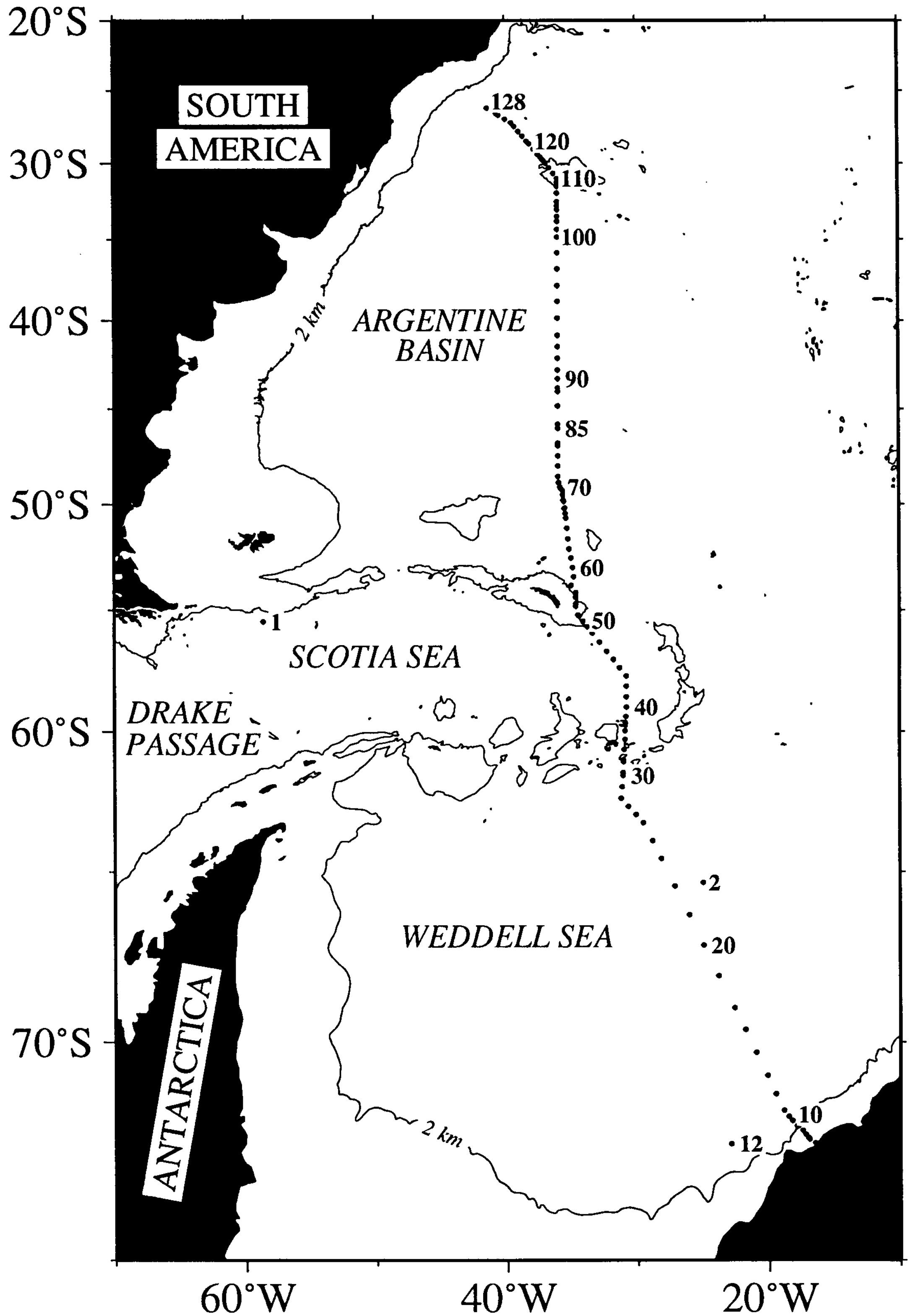


Fig. 2 Station locations: UK WOCE cruise A23, 20 March – 6 May 1995. The 2-km isobath is also shown.

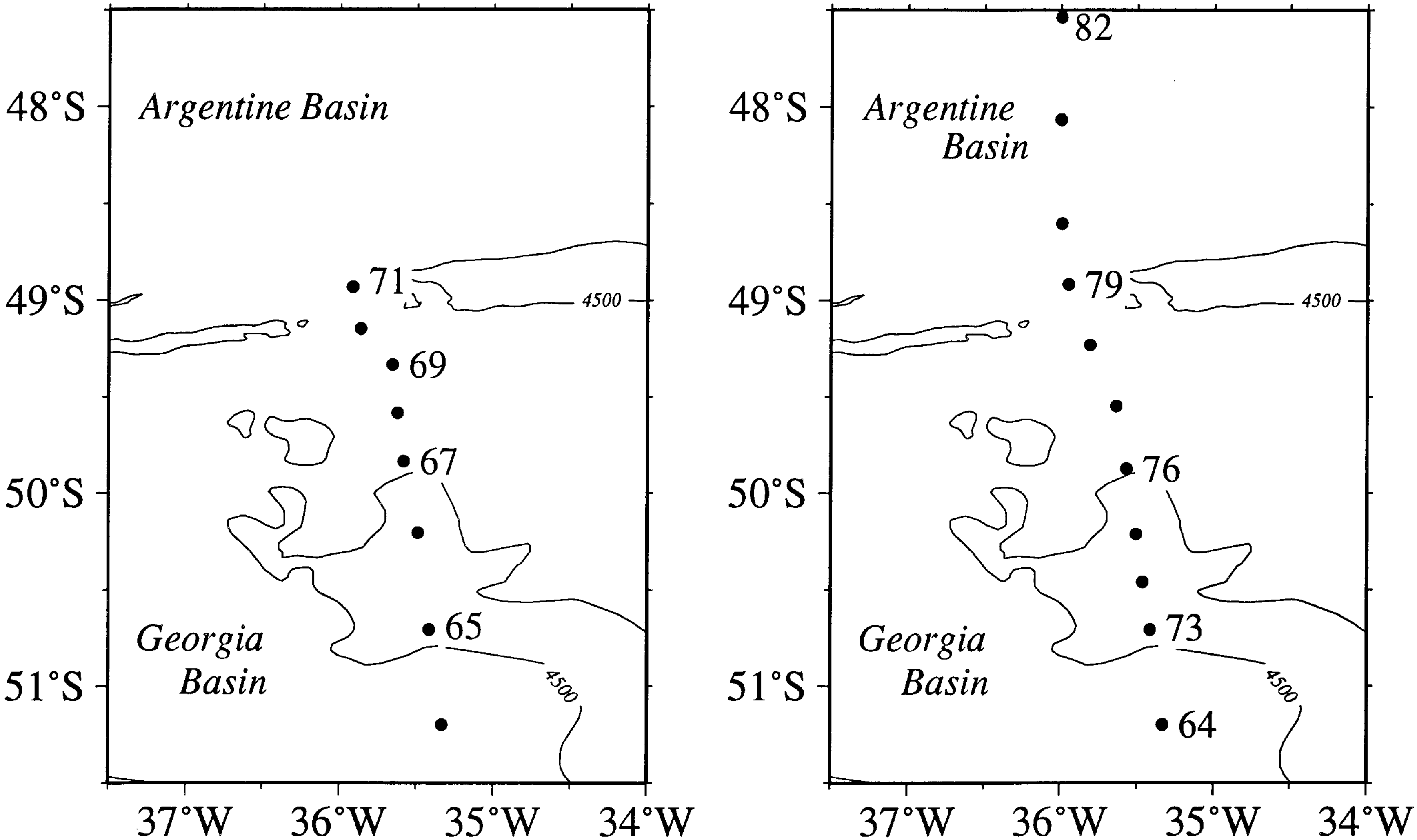


Fig. 3 Location of UK WOCE cruise A23 stations around the Falkland Ridge.

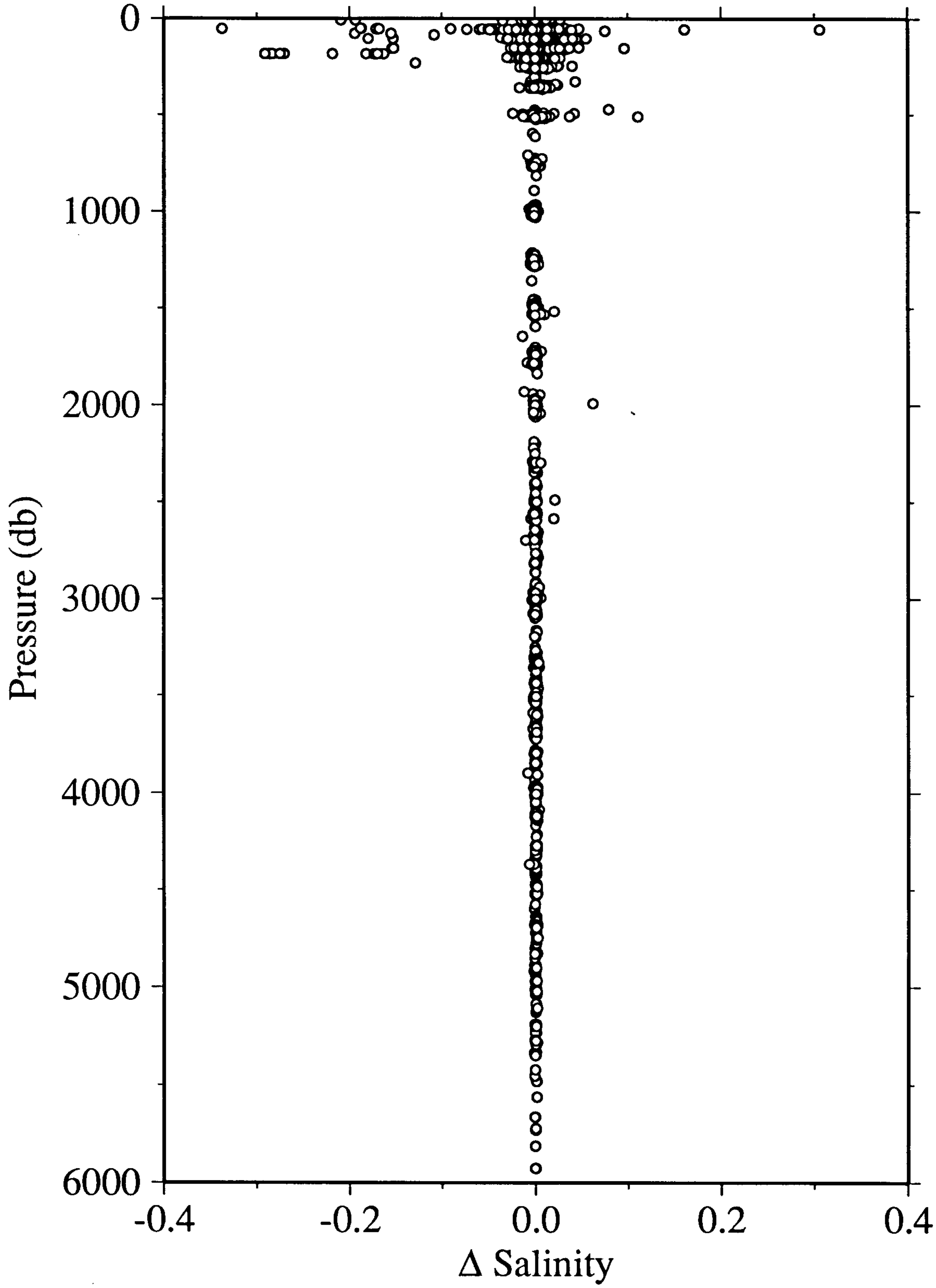


Fig. 4 Differences between CTD salinities and bottle salinities for all stations.

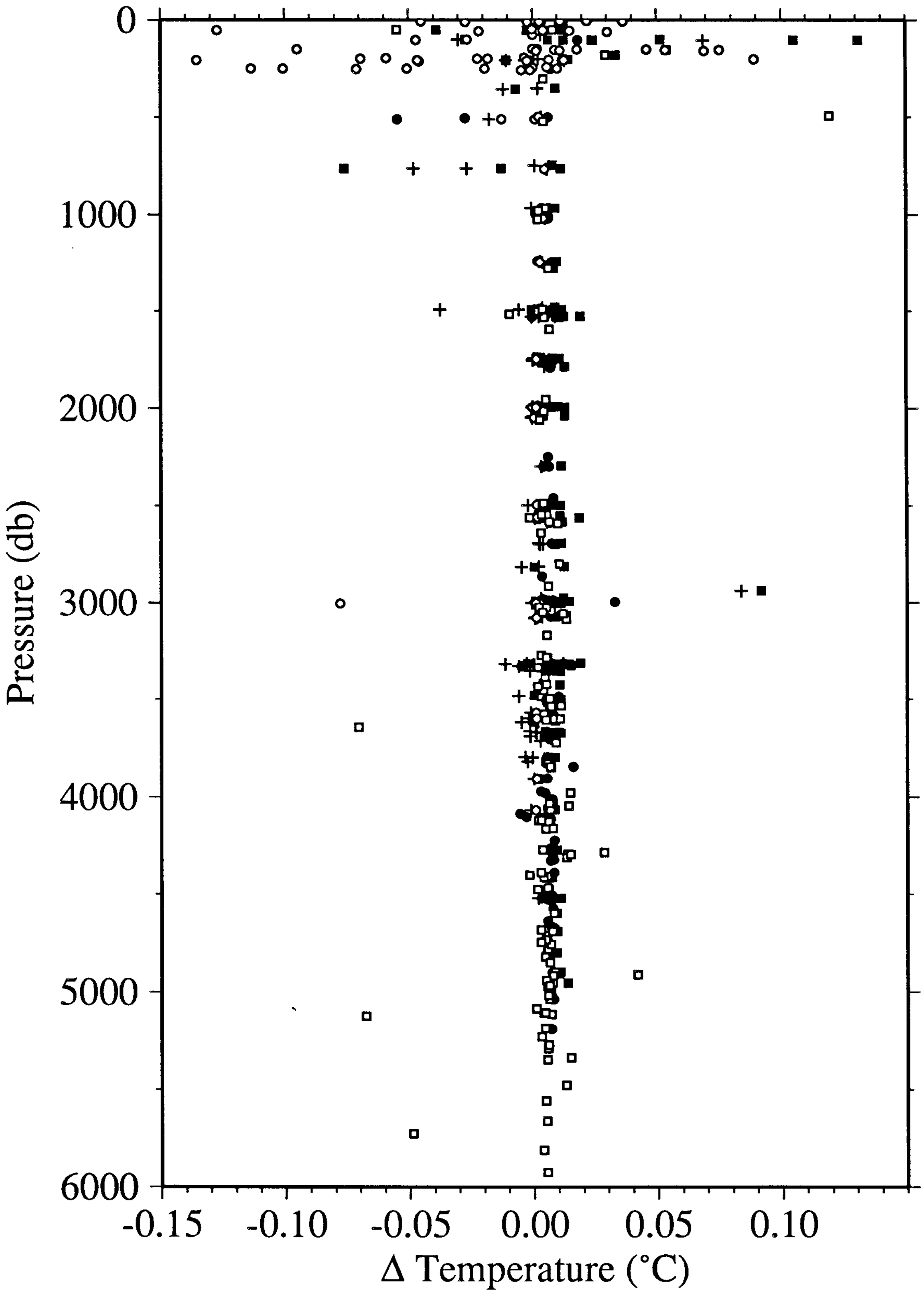


Fig. 5 Differences between temperatures from the CTD and reversing thermometers for all stations: T400, pluses; T401, full circles; T714, full squares; T743, empty circles; T746, empty squares.

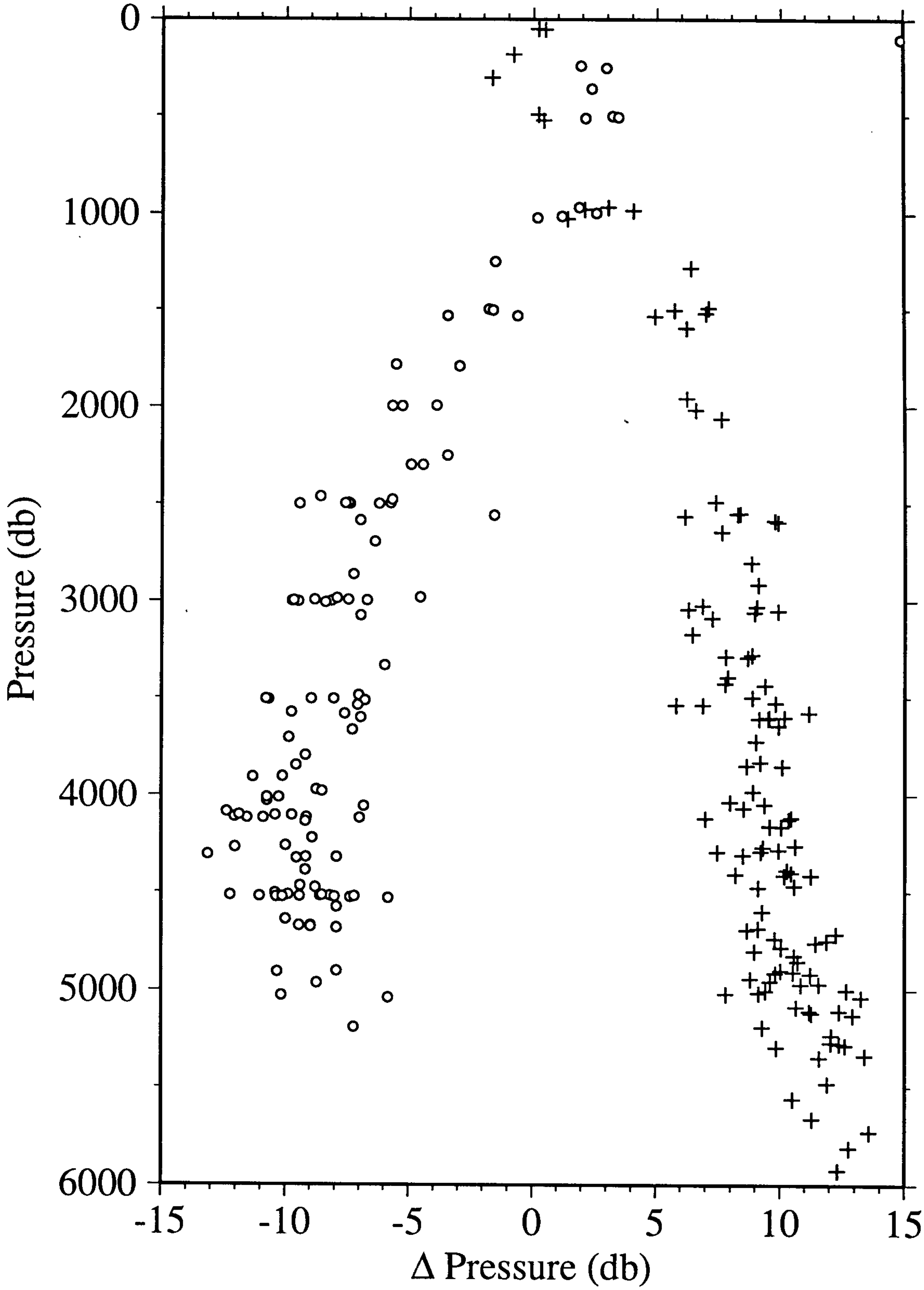


Fig. 6 Differences between pressures from the CTD and reversing pressure meters calibrated according to the manufacturers calibration: P6132H, pluses; P6293H, open circles.

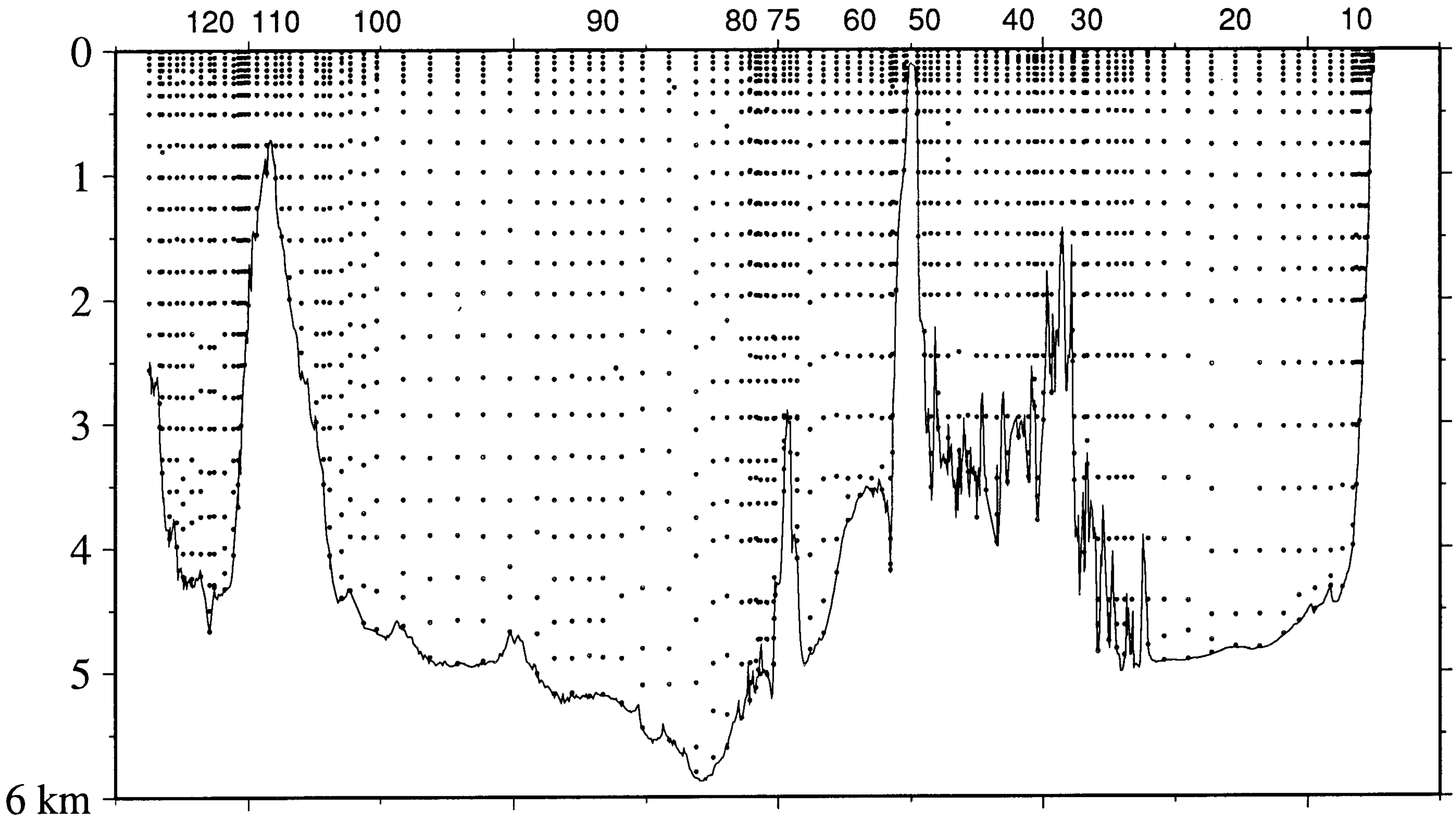


Fig. 7 Location of 10-litre water samples collected on UK WOCE cruise A23.

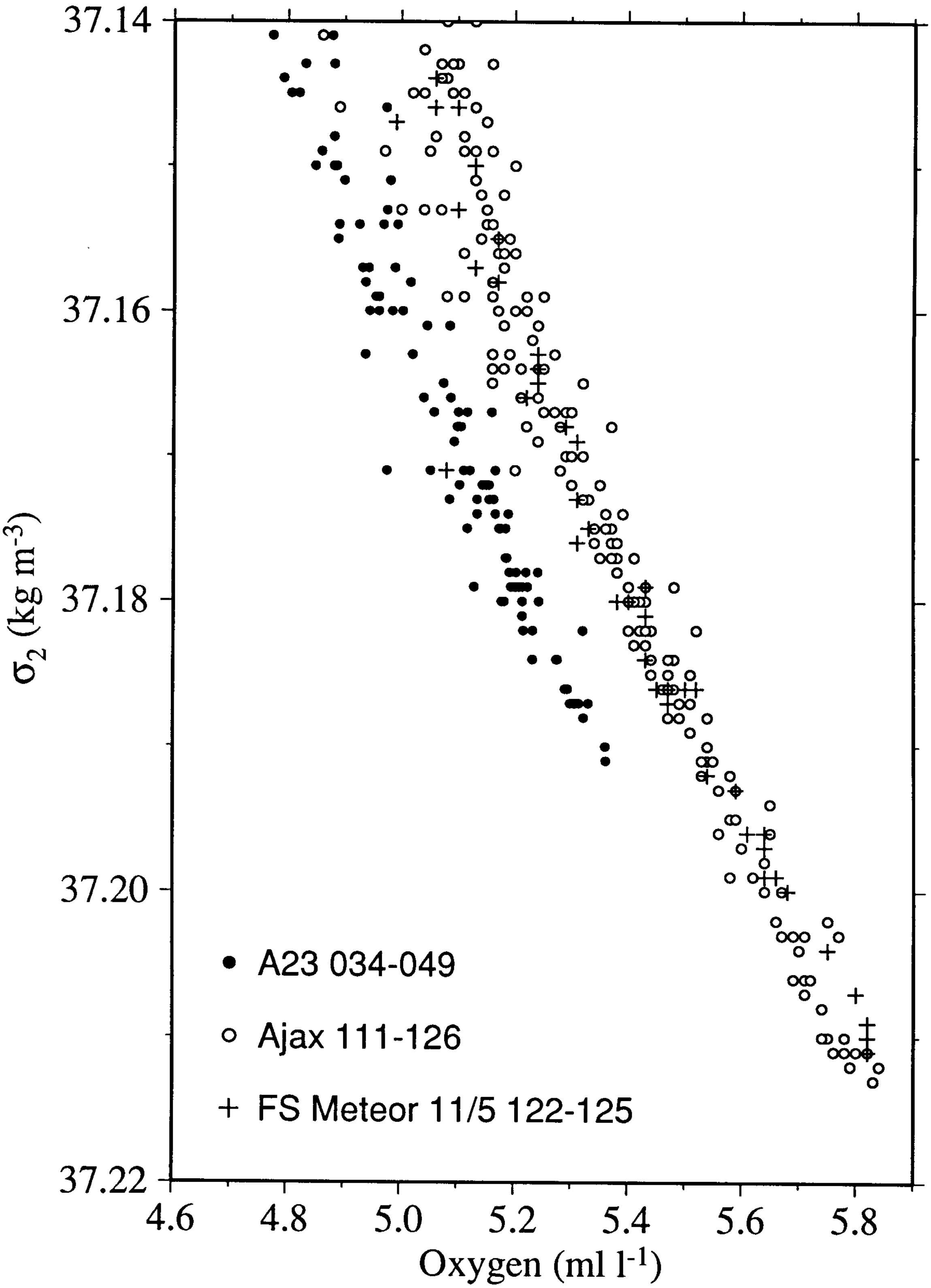


Fig. 8 Dissolved oxygen as a function of potential density anomaly for stations occupied in the Scotia Sea during three different cruises.

74JC10/1
A23
King, Heywood, Bacon, Paylor, Sanders, Watson
3/20-5/6/95
R/V James Clark Ross

A23 section: stations 3-128, delete 83 and 85 (aborted stations)

Data status: proprietary, including plots
----
sum:
no errors detected by sumchk
----
hyd:
no errors detected by wocecvt
data are reported from high pressure to low pressure
use seaorder prior to gridding
Problems with plotting CCL4 and CFC-11 so not included.
Likely a problem in the gridded file and possibly in
the data file, but no chance to check.
----
ctd:
no problems with format

Data Quality Check of WOCE section A23 (Robert Millard) 2001 NOV 29

The cruise track for WOCE section A23 is shown in Figure 1 has the start position of every tenth station identified. A23 is a section from South to North beginning at 72 S in the Weddell Sea and ending at 26.5 S off of the coast of Brazil. The station positions are taken from the station summary file and so check the format and beginning positions data of this file. Three depth contours (0, 3000 and 5000 meters) are shown from TBASE to help identify the basins and distinguish deep-water masses for various station groupings.

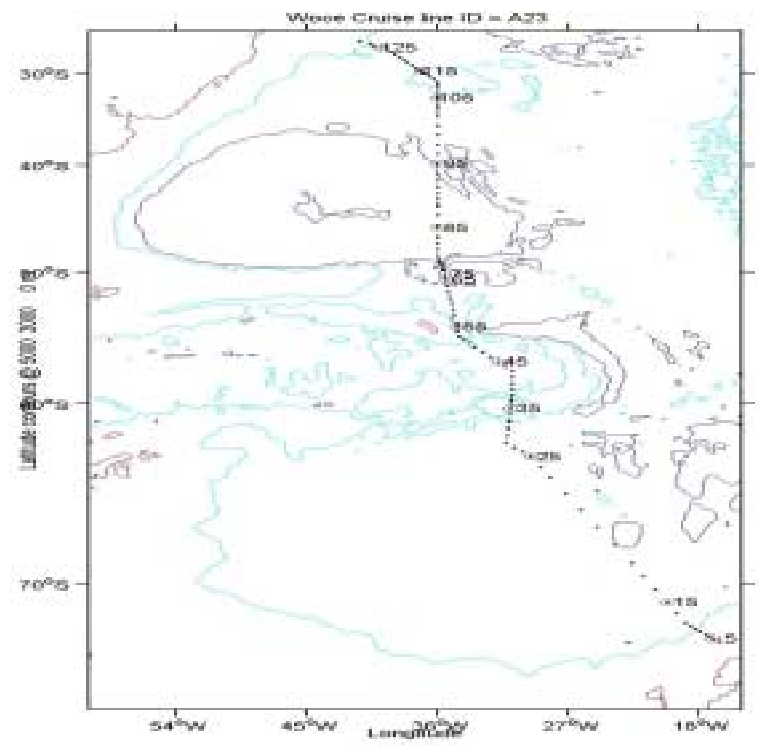


Figure 1: Plot beginning station positions A23 from summary file.

WOCE section A23 begins in the Antarctic crossing first the Weddell Sea, the Scotia Sea & Georgia Basin and final the Argentine Basin. The section traverses nearly 50 degrees of latitude and covers a range of water types. An overall plot of potential temperature/salinity for all good CTD and bottle salinities of A23 is shown in Figure 2a while in Figure 2b shows an expanded plot for the deepwater. The potential temperature/salinity plots in Figures 3 through 5 split stations by geographic area with an overall and deepwater plot shown for each region. The stations of the Weddell Abyssal Plain are shown in Figures 3a & b, the Scotia Sea & Georgia Basin in Figure 4a and b and finally the salinity data of the Argentina Basin are shown in Figures 5a and b. The good ("2") water sample (+) and up cast CTD salts (o) as marked in the quality word Q1 are included on all of these Theta/S plots. Examination of the deep-water theta/s plots show the CTD salinity well matched to water sample salinities across the entire cruise but occasional small glitches (see Figures 3b, 4b and 5b) can be seen in the downcast CTD salinity.

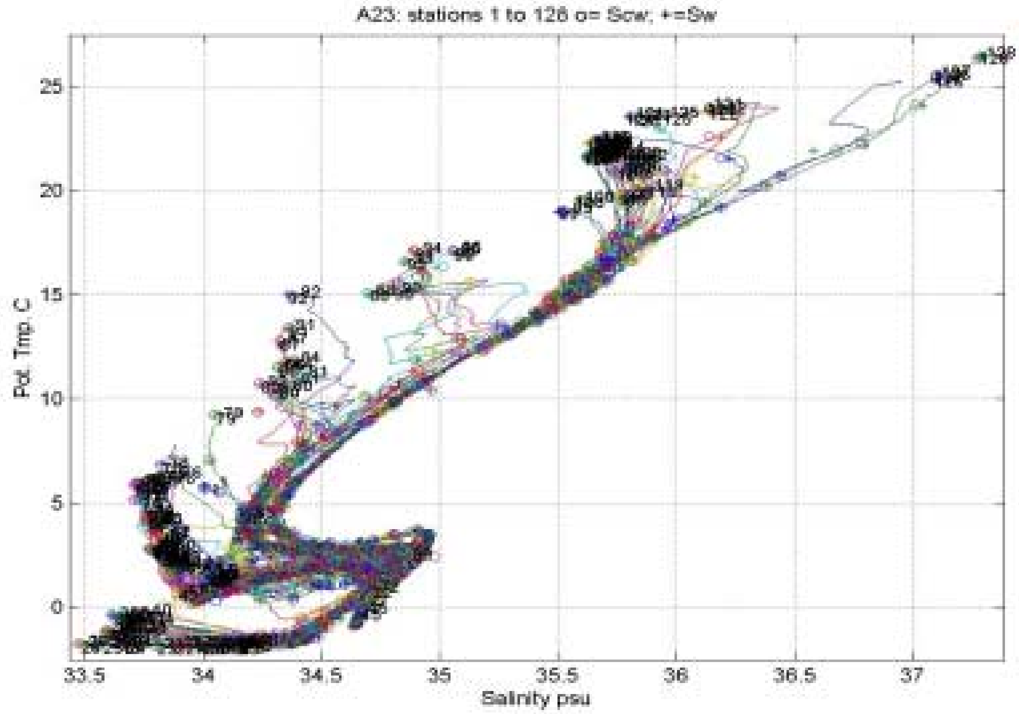


Figure 2a: Overall potential temperature versus salinity for all 2 decibar data files plus all good bottle and CTD salinities from water sample.

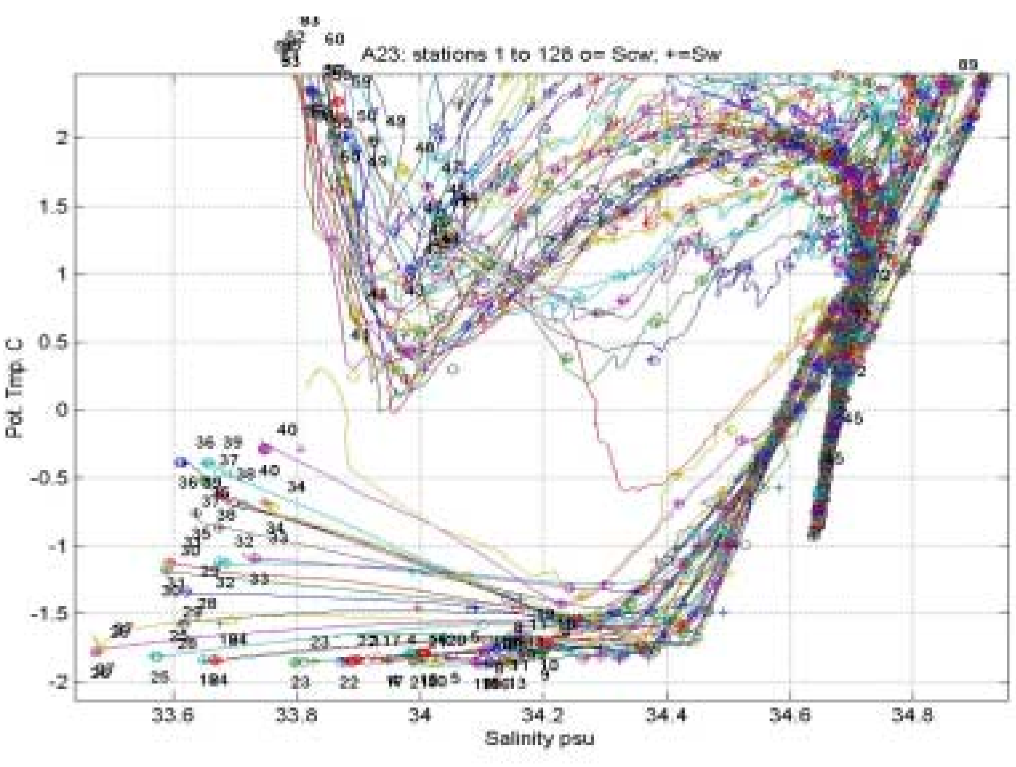


Figure 2b: A plot of potential temperature versus salinity in the deep water for all 2-decibar data files plus all good bottle and CTD salinities from water sample file.

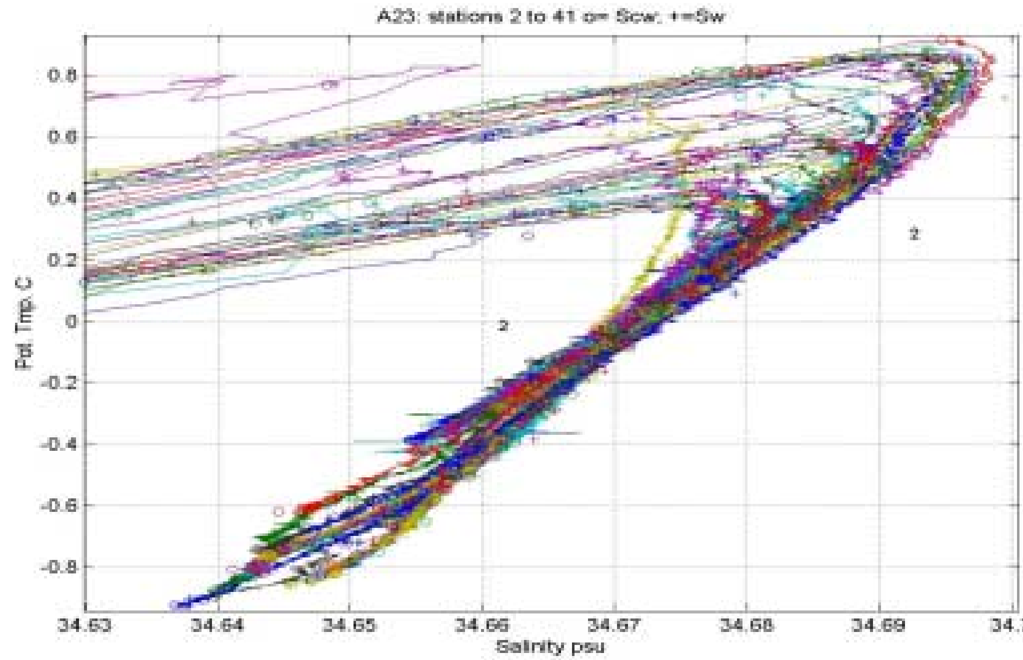


Figure 3a: Overall potential temperature versus salinity 2-decibar data files plus all good bottle and CTD salinities from water sample file for the Weddell Sea.

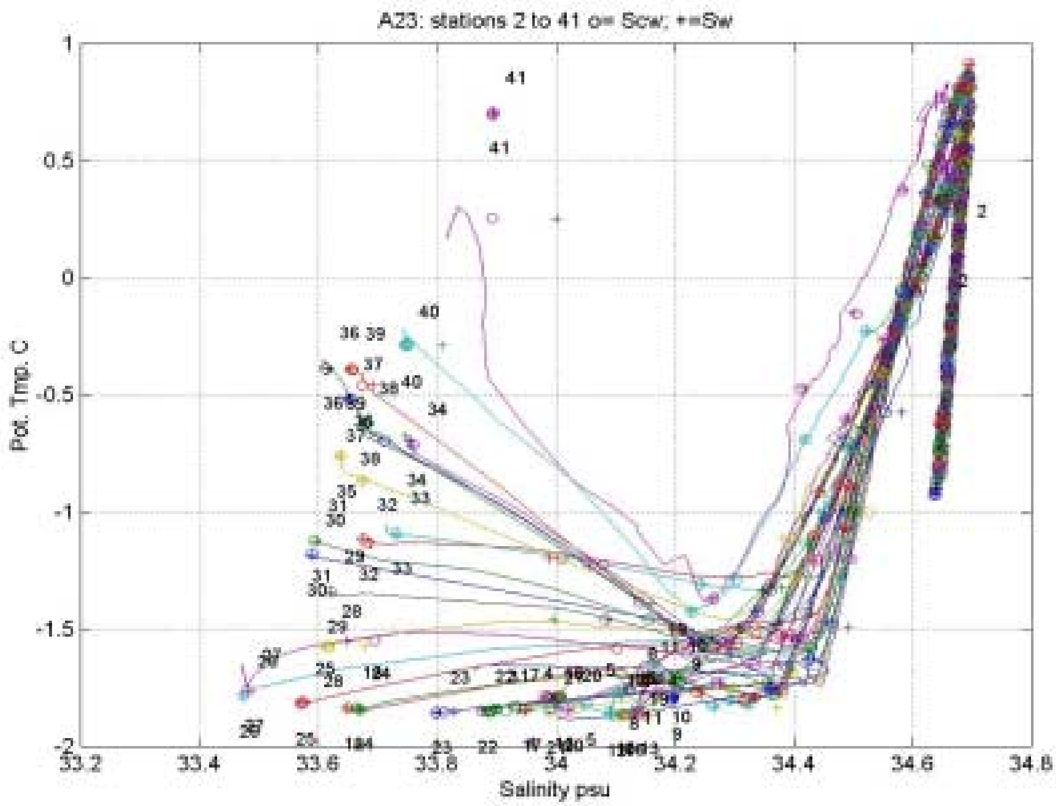


Figure 3b: Deep-water potential temperatures versus salinity plot for 2-decibar data plus all good bottle and CTD salinities from water sample file for the Weddell Sea.

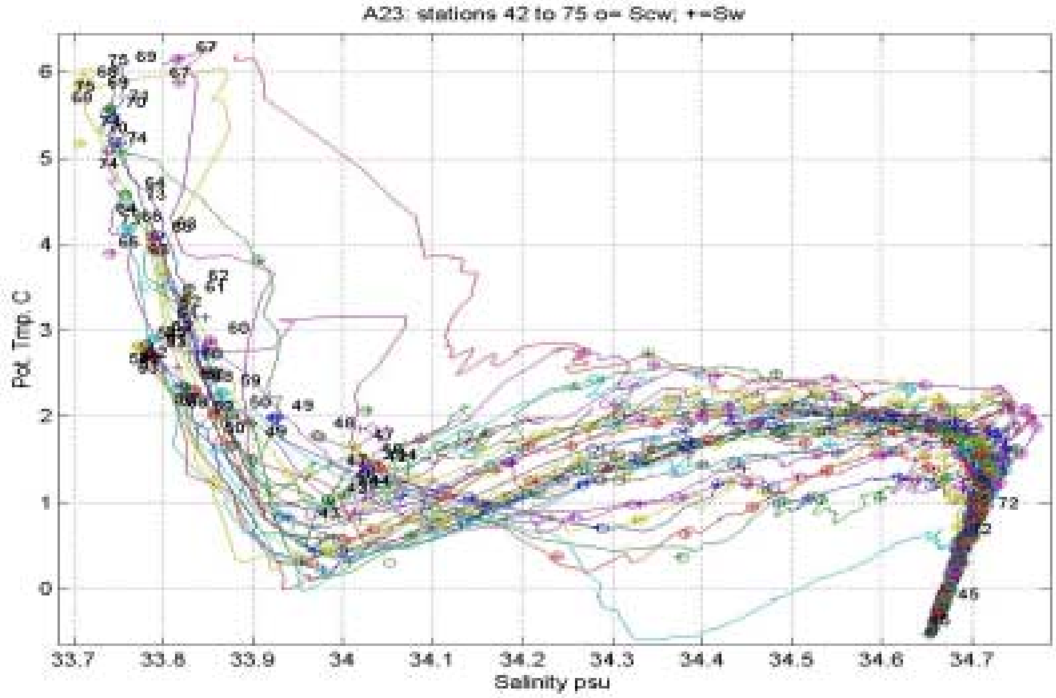


Figure 4a: Overall potential temperature versus salinity 2-'decibar data files plus all good bottle and CTD salinities from water sample for the Scotia Sea & Georgia Basin.

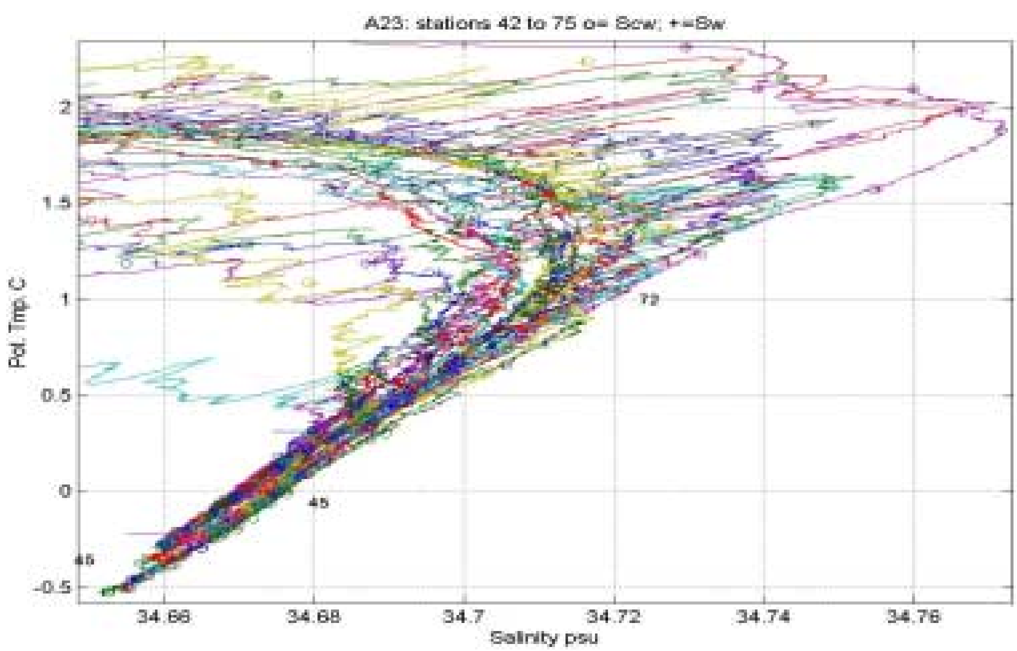


Figure 4b: Deep-water potential temperature versus salinity 2-decibar data files plus all good bottle and CTD salinities from water sample for the Scotia Sea & Georgia Basin.

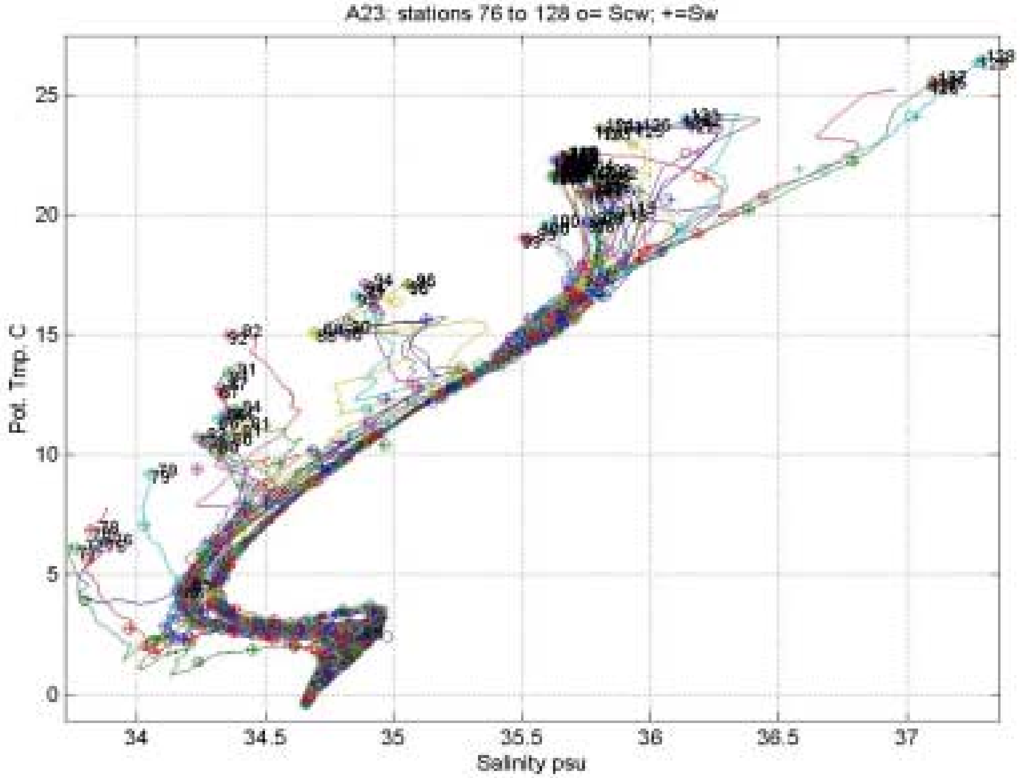


Figure 5a: Overall potential temperature versus salinity 2 decibar data files plus all good bottle and CTD salinities from water sample for the Argentine Basin.

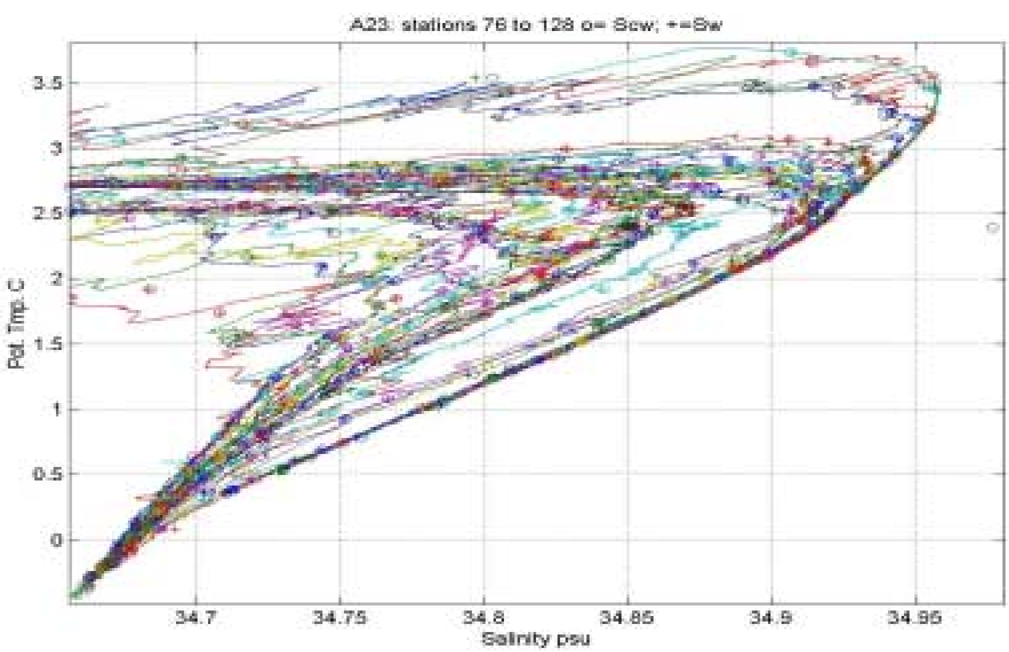


Figure 5b: Deep-water potential temperature versus salinity 2-decibar data files plus all good bottle and CTD salinities from water sample for the Argentine Basin.

The salinity noise of the 2-decibar data is estimated by differencing the filtered salinity with a cut-off wavelength of 24 decibar from the unfiltered salinity at depths below 4000 decibars. Assuming the absence of deep salinity structure on scales less than 24 decibars below 4000 decibars, the standard deviation of the differences becomes an estimate of the salinity noise with the minimum RMS value of this estimator across all stations being perhaps the best noise estimator. An examination of the 2-decibar salinity noise estimates for WOCE line A23 shows an average RMS salinity noise across all stations of 0.00023 psu with a minimum salinity noise level equal 0.00016 psu at station 81. This compares with values ranging from 0.00012 psu to 0.00047 psu for other WOCE cruises tested. The 2-decibar oxygen values are missing (i.e. set to -9.0) for all stations and therefore no oxygen noise estimate is available. An examination of the salinity in the deep water for the 2-decibar CTD profiles shows that occasionally the CTD salinity has spurious data values. These salinity glitches are usually towards low salinity and are perhaps due to temporary biological fouling of the conductivity cell. A plot of salinity versus pressure for a few stations (33, 35, 37, & 38) that exhibit the salinity noise problem is shown in figure 6. Salinity glitches were found in the following stations: 9, 31, 33, 35, 37, 38, 40, 46, 49, 56, 78 and 79.

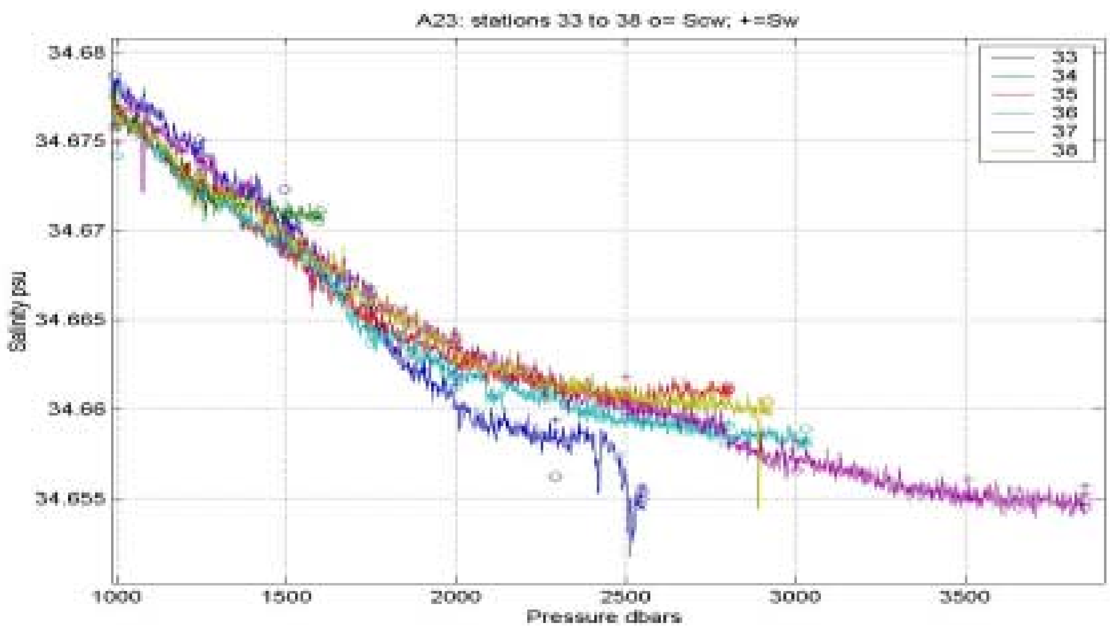
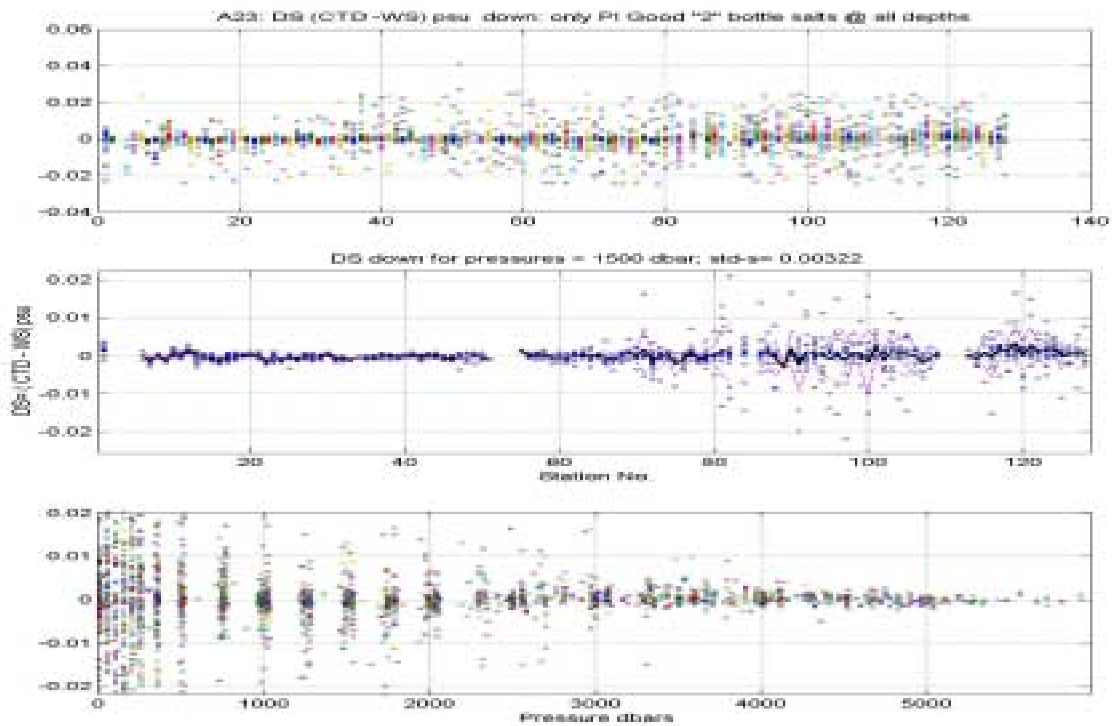


Figure 6: Deep-water salinity versus pressure from six 2-decibar data files illustrating occasional CTD salinity glitches towards lower values- stations 33 & 37 near bottom & 37 @ 1100 decibars.

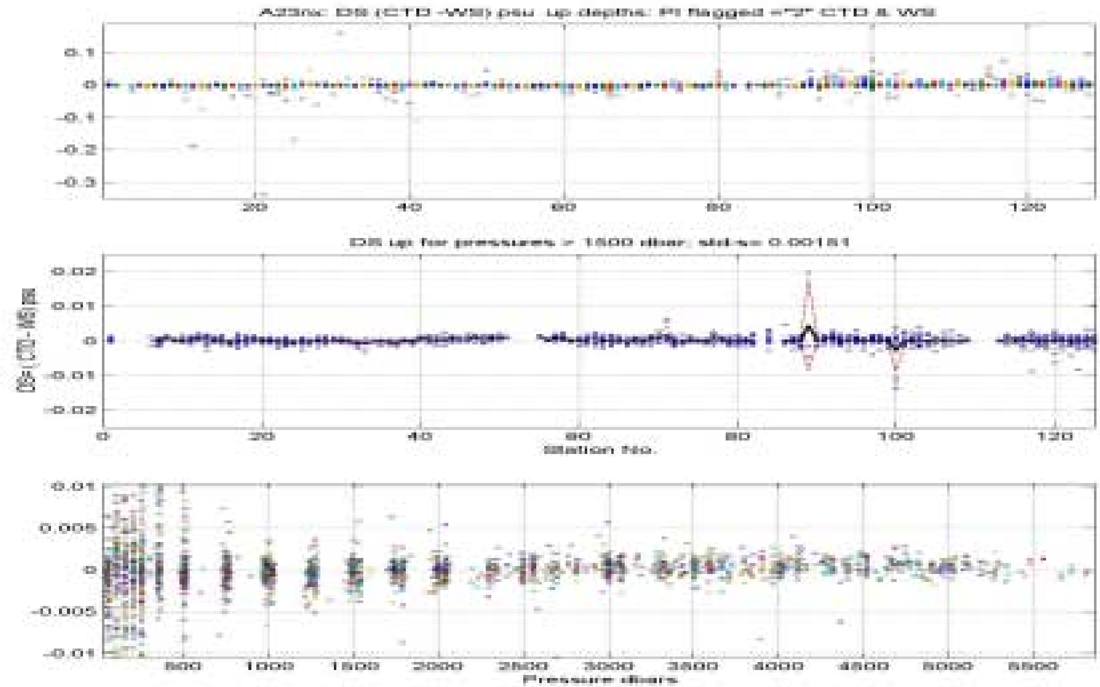
Plots comparing the difference of good down cast water sample salinities from the pressure-interpolated salinity values of the 2-decibar down profiles are shown in Figure 7a-c. An increased scatter is observed in the salinity differences, particularly in the stronger vertical gradient region near the surface when compared to up cast only comparisons shown in Figure 8a-c. The lower panel plot (Fig. 7c) is useful in for verifying how well the bottle and downcast CTD salinity match over the entire water column in the deep-water. Panel 7b shows the mean salinity difference below

1500 decibars (solid black curve) and indicates that the downcast 2-decibar CTD salinity is well matched to the deeper bottles salts. Panel 7c, salinity differences versus pressure, shows that the down cast CTD salinities are well matched to the water sample salts at all depths.



Figures 7a, b, & c: Good water sample and 2-decibar CTD salinity data interpolated at up cast bottle stop pressures. Center panel is for pressures greater than 1500 decibars and shows matched CTD & bottle salinities. The lower panel shows the CTD salinity matches bottle values at all depths.

Figure 8 repeats the water sample salinity comparisons but uses the up cast CTD salinity of the water sample file. The upper panel of Figure 8 is the difference of all good water samples and represents 96.8% of all bottle salts. Note that all of the CTD salinities are flagged as good in the water sample file except for one value marked as missing (9). The maximum good water sample salinity difference Ds= (CTD-WS) seen in Figure 5a is |Ds|=0.338 psu. The center panel plots the mean salt for P>1500 decibars (black line) and shows that CTD salinity matches the water sample salts in the deep-water and the differences have a tight standard deviation of 0.0015 psu across all stations. The lower panel suggests that up cast CTD salts are also very well matched to the bottle salts at all depths.

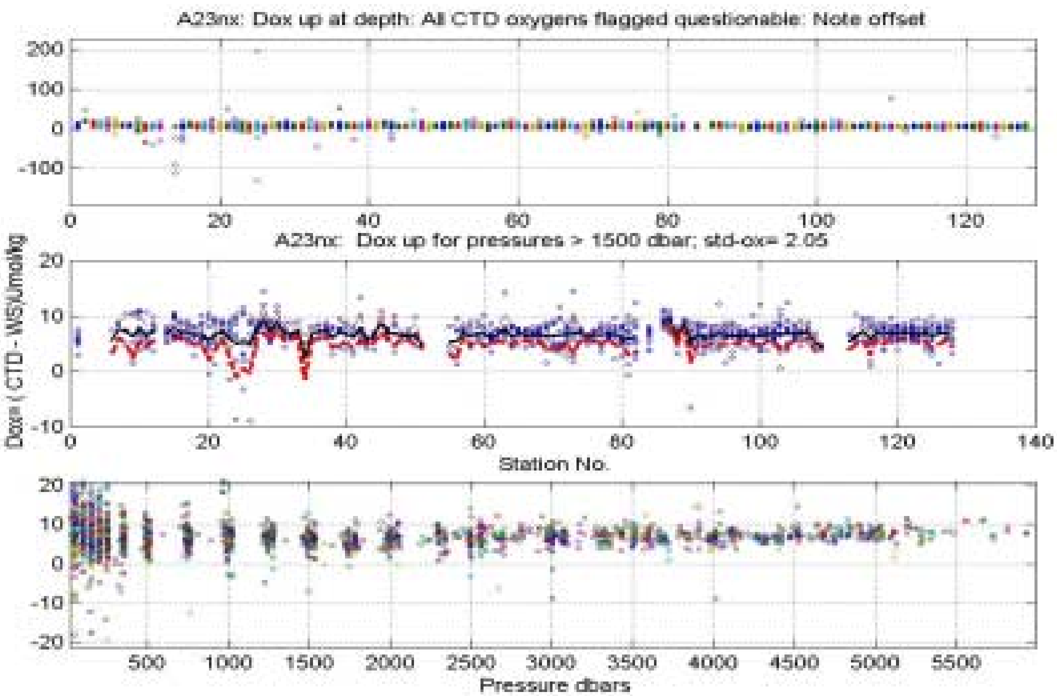


Figures 8a, b, & c: Good water sample & CTD salinity data (PI QC) from up profile water sample data file. Center panel is for pressures greater than 1500 decibars and shows matched CTD and bottle salinities. The lower panel shows the CTD salinity matches bottle values at all depths.

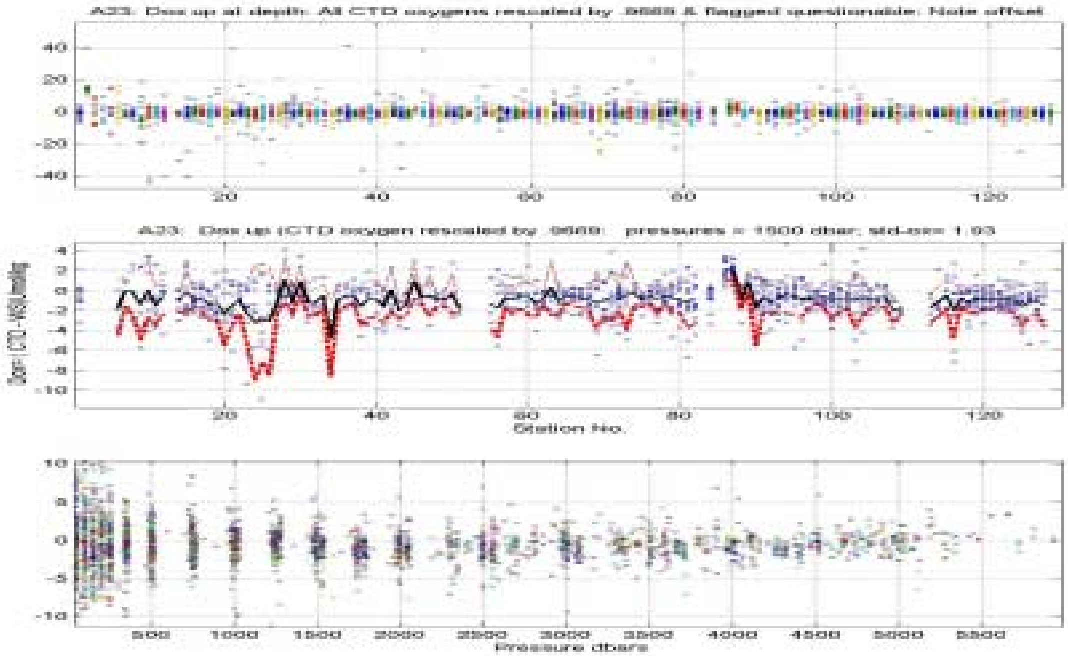
There is no reliable CTD oxygen data in either the 2 decibar down casts files or the up cast water sample file. All oxygen values are set equal to —9.0 in the 2-decibar-____.wct file while the up cast CTD oxygen values are systematically high compared with bottle oxygen values. The cruise report (see excerpt below) suggests that 2-decibar down profile oxygen data is the origin of the bottle file oxygen data and so I m not sure why the 2-decibar CTD oxygen values are missing and how the bottle file were obtained. The A23 cruise data report describes the following oxygen extraction procedure for obtaining interpolated up cast CTD oxygen values from the down cast 2-decibar data at each bottle stop pressure levels.

> *Having extracted the relevant downcast data cycles, a simple gradient algorithm was used to find up to five fitted parameters for each station that minimized the least squares residual. A certain amount of subjective manual intervention was employed to ensure that the temperature weight W and the oxyc offset remained reasonable. As with salinity calibration, individual samples were excluded from the fit as necessary.*

The CTD oxygen values in bottle file are systematically higher than the water sample values by 7.2 uM/kg overall and 6.6 uM/kg below 1000 decibars. The bottle file CTD oxygen values are all flagged as questionable by the PI except for a single missing value. Since the CTD oxygen values are found to be systematically higher than the bottle oxygen values, the questionable 3 CTD oxygen flag is carried over to the second DQE quality flag. The CTD oxygen values in the 2 decibar files are all set to missing = -9 which seems curious since CTD oxygen values are available, although systematically offset, in the bottle file. A least-squares-regression between CTD and bottle oxygen values yielded a slope (multiplicative factor) of 0.9669 and a bias of 0.0. This simple linear transformation of oxygen does not account for the complexity of the oxygen algorithm but still brings the CTD oxygen into much better agreement with bottle oxygen values suggesting that with a little more effort that the CTD oxygen could be made useful in both the bottle file and perhaps the 2-decibar data files as well.



Figures 9a, b, & c: Good water sample & CTD oxygen data (PI QC) from up profile water sample data file. Center panel is for pressures greater than 1500 decibars and shows a systematic offset between CTD to Bottle oxygen of 7.2 uM/kg. The lower panel shows the CTD oxygen to be high compared to bottle values at all depths.



Figures 10a, b, & c: DQE adjustment of CTD oxygen data (*0.9669) compared with good water sample of up cast.

Figure 10 suggests that a simple rescaling of CTD oxygen achieves a much better matched to bottle values. This is demonstrated particularly well for pressures greater than 1500 decibars in examining figures 10 b and 10 c. The CTD oxygen values could benefit from further calibration work.

Comparison of Intersecting WOCE sections

To check and validate the salinity data from WOCE line A23 to other WOCE sections, bottle salinity data from 2 intersecting WOCE cruises A10, and A11 are compared with corresponding A23 stations at crossover stations at latitudes 30 S (A10), and 45S (A11). The water sample salinity values for A10, and A11 (black squares) are plotted versus potential temperature along with neighboring stations of WOCE line A23. Figure 11 a and b show that A23 salinities match the water sample salts of these two intersecting WOCE lines pretty closely although the salinity comparison of WOCE line A10, Figure 11a, involves stations to depths between 1500 and 2500 decibars where the theta/S relationship is less stable than deeper. The water sample salinities of WOCE section A11 are slightly fresher than A23.

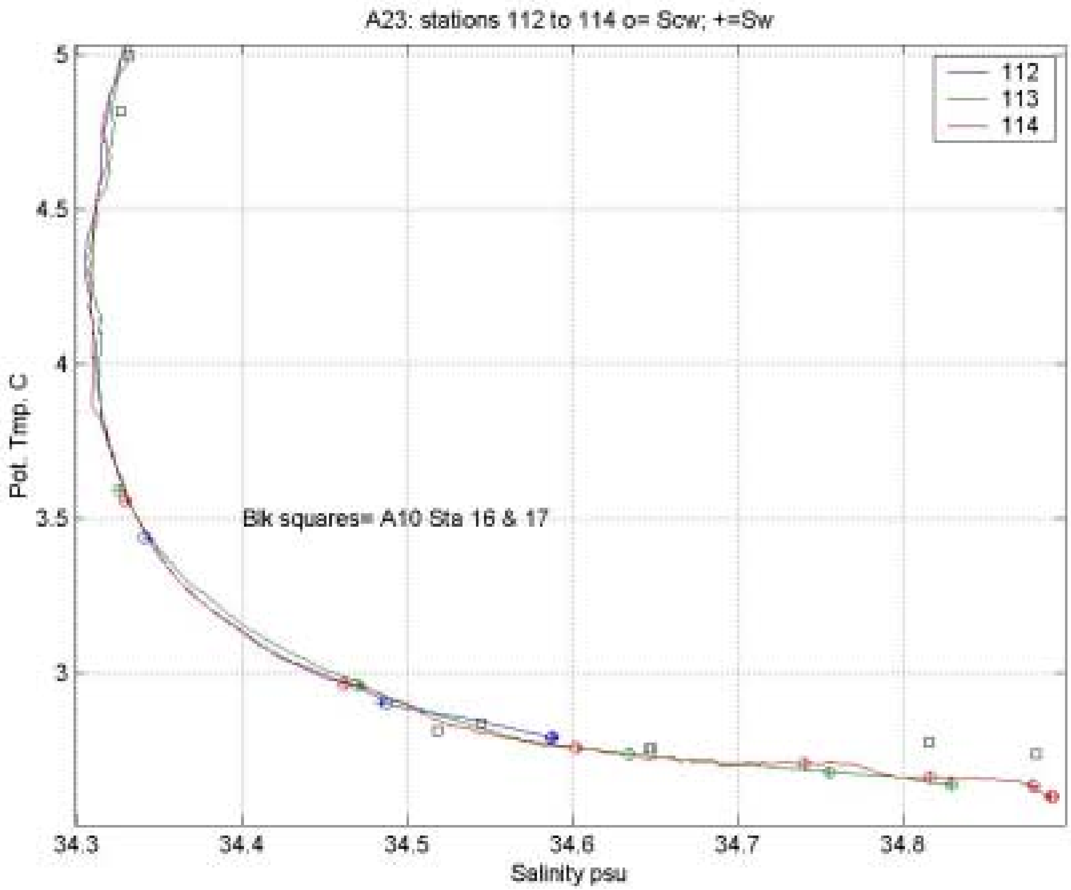


Figure 11a: Salinity versus Potential Temperature for an intersecting East/West section A10 at 30 S. Shallow depths comparison but water sample salinities closely matched A23.

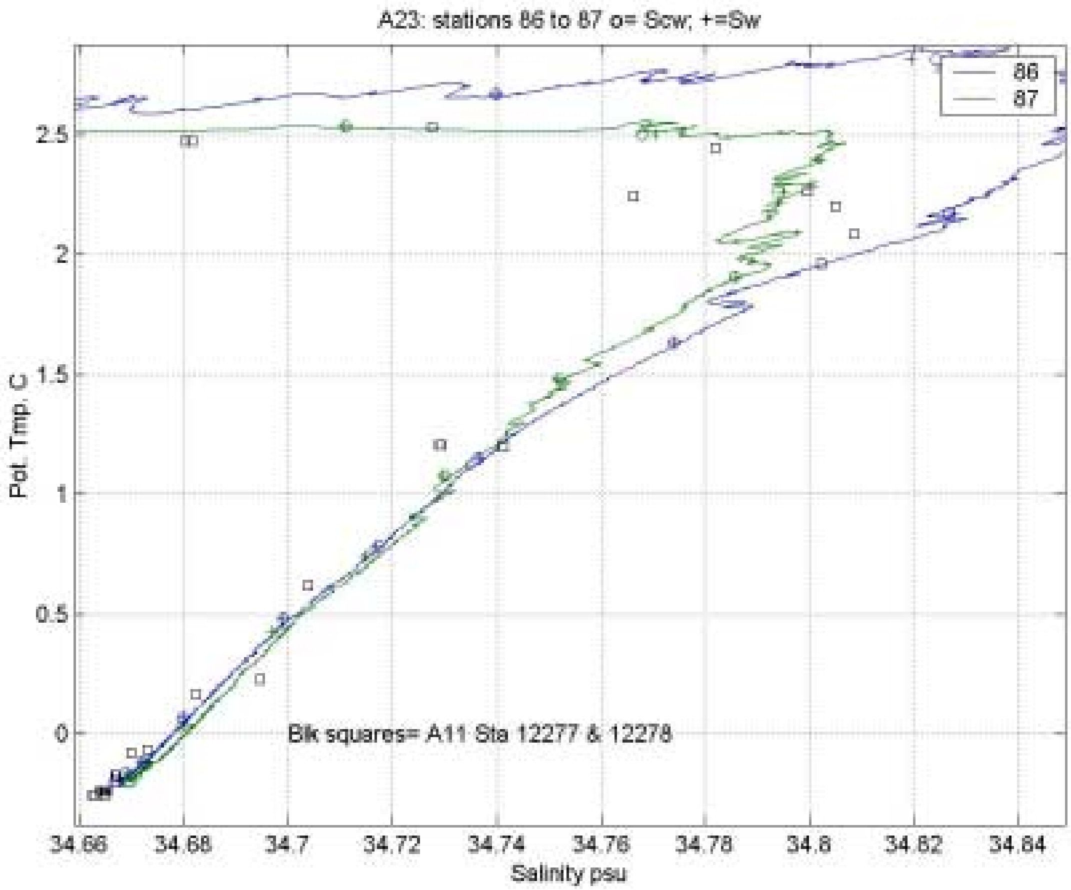


Figure 11b: Salinity versus Potential Temperature for an intersecting East/West section A11 at 45 S. Water sample of A11 are only slightly fresh compared with those of A23.

Density Inversions

The listing below repeats the density instabilities shown in Figure 12. Most of the density inversions are in the upper water column at depths less than 500 decibars in the higher temperature gradient region and could indicate temperature and conductivity sensor lag mismatches. Station 80 shows a density inversion below 2000 decibars associated with a very strong temperature (and salinity gradient) likely causing a conductivity/temperature lag mismatch in calculating salinity.

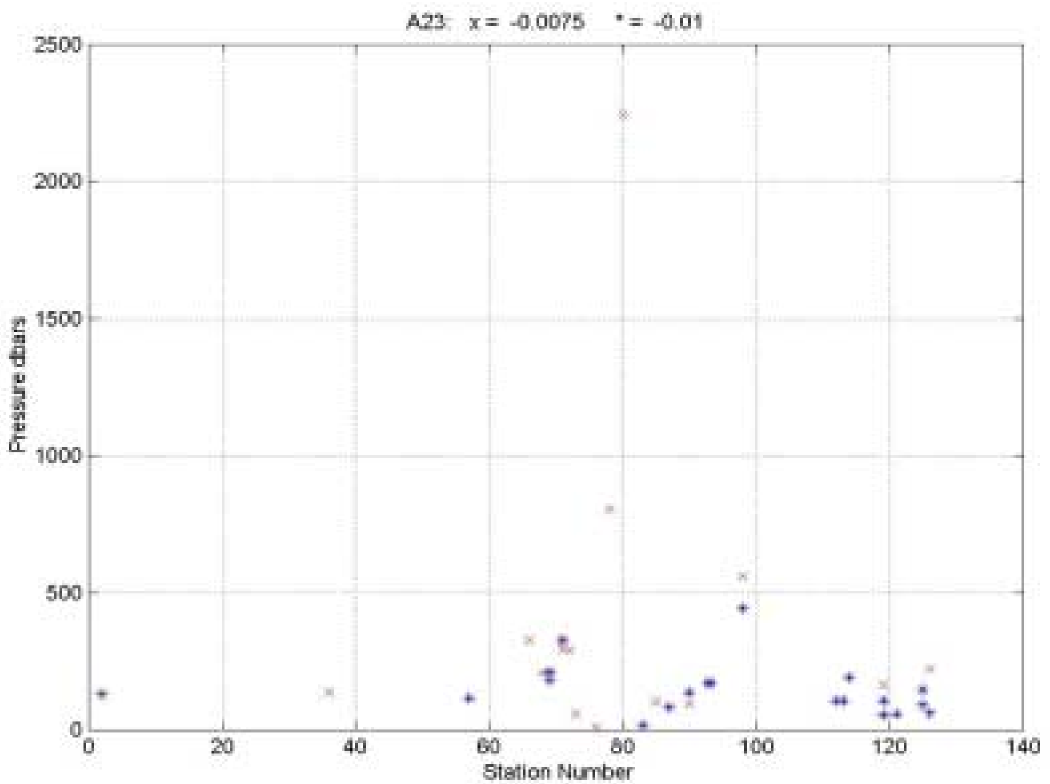


Figure 12: Plot of density instabilities < -0.01 kg/m3/dbars (+) and < -0.0075 kg/m3/dbars (x) versus pressure and station number where they occur.

Dsg/dp = -0.01 kg/m3/dbar

Dsg/dp	Sta#	P_dbar	Salinity
-0.0102	2	131	34.5076
-0.0157	57	115	33.9685
-0.0120	69	181	34.1250
-0.0125	69	207	34.2252
-0.0125	71	323	34.1435
-0.0116	83	17	34.3266
-0.0160	87	83	35.0550
-0.0343	90	137	34.5374
-0.0120	93	167	34.8309
-0.0124	93	173	34.7888
-0.0105	98	443	34.8825
-0.0172	112	105	35.7461
-0.0148	113	105	35.6875
-0.0125	114	191	35.5115
-0.0355	119	53	36.1626
-0.0201	119	105	36.0424
-0.0149	121	57	36.1305
-0.0103	125	91	36.8283
-0.0108	125	147	36.3697
-0.0195	126	63	36.9438

Dsg/dp = -0.0075 kg/m3/dbar

Dsg/dp	Sta#	P_dbar	Salinity
-0.0102	2	131	34.5076
-0.0087	36	135	34.4753
-0.0157	57	115	33.9685
-0.0088	66	329	34.3489
-0.0083	68	209	34.2238
-0.0120	69	181	34.1250
-0.0125	69	207	34.2252
-0.0085	69	213	34.1999
-0.0087	71	295	34.0598
-0.0125	71	323	34.1435
-0.0088	71	331	34.0714
-0.0091	72	289	34.2738
-0.0077	73	59	33.9211
-0.0078	76	9	33.7490
-0.0079	78	805	34.5071
-0.0078	80	2245	34.7670
-0.0116	83	17	34.3266
-0.0097	85	103	34.3968
-0.0160	87	83	35.0550
-0.0097	90	95	34.6192
-0.0343	90	137	34.5374
-0.0120	93	167	34.8309
-0.0124	93	173	34.7888
-0.0105	98	443	34.8825
-0.0090	98	559	34.4141
-0.0172	112	105	35.7461
-0.0148	113	105	35.6875
-0.0125	114	191	35.5115
-0.0355	119	53	36.1626
-0.0201	119	105	36.0424
-0.0096	119	163	35.7429
-0.0149	121	57	36.1305
-0.0103	125	91	36.8283
-0.0108	125	147	36.3697
-0.0195	126	63	36.9438
-0.0077	126	223	35.6703

Bottle file Salinity & oxygen DQE second Quality word changes

The A23 bottle salinity and oxygen values of water sample data file A23hy.txt CTD were screened and a second DQE quality word (Q2) appended reflecting any changes to the PI Quality word (Q1). The following criteria was used to test the validity of the water sample salinity and oxygen values: for pressures less than 1000 decibars any bad data with a Ds<0.004 psu or Dox < 4.3 Um/kg are flagged as good in Q2. . A second test of the good Q1 salinities with Ds>.1 psu at pressure values of less than 1000 decibars flags six questionable bottle salinity values in Q2. These scans are identified with a ? in the data listing below. For pressures greater than 1000 decibars, any good bottle salinities with a Ds>0.007 psu (approximately 2.8 standard deviations) or water sample oxygen differences Dox>4.3 Um/kg are flagged as questionable . In the case of good water sample salinity or oxygen values flagged as questionable in Q2, the corresponding CTD value is also marked questionable in Q2.

Three bad bottle salts at a depth less than 1000 decibars with |ds|< 0.004 psu were flagged as good "2" in Q2. Six bottle salts exceed the CTD salinity by more than 0.1 psu and both CTD and water sample salts were flagged as questionable in Q2. Below 1000 decibars, seven bottle salts differ from CTD salinity by more than 0.007 psu (~ 2.8 standard deviations) and both the bottle and CTD salts are marked as questionable in the (Q2) DQE quality field. Most of the erroneous deep-water salinities are seen in figure 8b as well as listed below.

The CTD oxygen values in the bottle file are found to be systematically lower than the bottle values by 7.2 uM/kg at all depths and stations as was shown in figure 9. Therefore all CTD oxygen values in the bottle file are flagged as questionable 3 in both Q1 and Q2. A few of the shallow water sample oxygen values flagged as questionable match the CTD oxygen within 4 uM/kg and were marked as good in Q2.

The scans in the water sample data file A23NX.HYD where the second quality word Q2 does not match the PI s Q1 are listed below by Salinity and then Oxygen Changes:

Salinity changes:

A23NX.CHG

Changed WS Salts flags ds>.1 or ds< 0.004& pw<1000 or ds> 0.007 for pw >1000 decibars

STNNBR	CASTNO	SAMPNO	BTLNBR		CTDPRS	CTDTMP	CTDSAL	CTDOXY	THETA	SALNTY	Q1	Q2	
			*******				*******	*******		*******	*		
10	2	1024	24	108	104.1	-0.7760	34.5209	249.8	-0.7790	34.5176	22332	22322	
12	1	1201	1	53	50.1	-1.8318	34.1352	289.7	-1.8327	34.3225	22322	23332	?
12	1	1202	2	53	50.1	-1.8318	34.1352	289.7	-1.8327	34.3233	22322	23332	?
21	1	2121	21	57	54.1	-1.8331	34.0337	346.2	-1.8341	34.3715	22322	23332	?
25	1	2520	26	56	53.0	-1.5816	34.1021	734.6	-1.5827	34.2703	22322	23332	?
31	1	3119	19	59	56.1	-1.4575	34.1567	323.2	-1.4587	33.9959	22322	23332	?
41	1	4118	18	87	84.1	0.6453	33.8920	331.8	0.2524	34.0004	22322	23332	?
63	1	6315	15	365	357.6	2.1701	34.5319	178.4	2.1500	34.5331	22332	22322	
65	1	6511	24	9	6.3	4.0552	33.7893	316.7	4.0548	33.7877	22344	22324	
89	1	8903	3	2597	2584.4	2.5750	34.8705	230.6	2.3751	34.8507	22322	23332	
100	1	10012	12	1659	1645.8	2.8325	34.5961	186.5	2.7144	34.6099	22322	23332	
100	1	10011	24	1943	1930.1	2.9230	34.7370	199.9	2.7786	34.7488	22322	23332	
100	1	10008	8	2709	2696.8	2.9103	34.9008	245.8	2.6927	34.9113	22322	23332	
117	1	11712	12	1795	1782.1	2.8078	34.7262	203.3	2.6781	34.7349	22322	23332	
123	1	12305	5	3904	3895.0	0.7880	34.7201	225.9	0.5000	34.7284	22322	23332	
125	1	12513	13	1545	1532.1	3.4664	34.7811	211.0	3.3500	34.7710	22322	23332	

Oxygen Changes:

% all CTD oxygens are flagged as questionable since they all have a systematic 7+Um/kg offset!!!
% here the shallow water bottle oxygen values within 4 uM/kg of the CTD oxygen are reflagged as 2 good.
Changed WS oxygen flags dox< 4.2 & pw< 1000 or dox > 4.2 for pw >1000 dbars

			*******				*******	*******		*******	*******	**	
3	1	304	4	105	102.9	-1.8377	33.8967	353.5	-1.8396	34.0765	350.7	22344	22342
3	1	305	5	105	102.9	-1.8365	33.8988	353.5	-1.8385	34.0520	350.2	22344	22342
31	1	3116	16	210	204.8	0.3797	34.6551	204.5	0.3715	34.6574	203.3	122323	22322
31	1	3112	12	762	752.5	0.3410	34.6825	207.4	0.3073	34.6828	204.0	122323	22322
34	1	3414	14	58	55.7	-1.2244	34.0782	336.9	-1.2258	34.0539	336.4	22324	22322
51	1	5108	8	257	252.0	1.9287	34.3485	204.9	1.9153	34.3498	202.1	22323	22322
62	1	6215	15	261	254.9	1.5902	34.3837	208.4	1.5774	34.3845	209.0	22323	22322
121	1	12123	23	62	54.9	23.9293	36.1460	215.1	23.9177	36.1917	212.8	22323	22322