National Oceanography Centre, Southampton

Cruise Report No. 48

RRS *James Cook* Cruise JC032

07 MAR-21 APR 2009

Hydrographic sections across the Brazil Current
and at 24°S in the Atlantic

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2010

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DOCUMENT DATA SHEET

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PUBLICATION DATE
2010

TITLE

RSS James Cook Cruise JC032, 07Mar – 21 Apr 2009. Hydrographic sections across the Brazil Current and at 24°S in the Atlantic.

REFERENCE

Southampton, UK: National Oceanography Centre, Southampton, 173pp.
(National Oceanography Centre Southampton Cruise Report, No. 48)

ABSTRACT

Hydrographic sections were occupied in the South Atlantic Ocean and during March - April 2009 aboard the *RRS James Cook* (JC032). Three of these sections intersected the Brazil current at three separate latitudes during the steam northwards from Montevideo. The main trans-Atlantic section was occupied at 24°S. The primary objective of this cruise was to measure ocean physical, chemical and biological parameters in order to establish regional budgets of heat freshwater and carbon. The main section completed an overall aim, devised under the Oceans 2025 project, to create a box around the South Atlantic and Southern Ocean region to expose the regional circulation scheme and basin-scale budgets of physical and biogeochemical properties by performing a box-inverse analysis of the new observations.

A total of 118 CTD/LADCP stations were sampled across the South Atlantic. In addition to temperature, salinity and oxygen profiles from the sensors on the CTD package, water samples from a 24-bottle rosette were analysed for salinity, dissolved oxygen and inorganic nutrients at each station. Water samples were collected from strategically selected stations and analysed onboard ship for SF_6, CFC's, pCO_2, TIC, alkalinity, and nutrient biogeochemistry. In addition, samples were collected from the ship's underway system to calibrate and compliment the data continually collected by the TSG (thermosalinograph). Full depth velocity measurements were made at every station by an LADCP (Lowered Acoustic Doppler Current Profiler) mounted on the frame of the rosette. Throughout the cruise, velocity data in the upper few hundred metres of the water column were collected by the ship's VMADCP (vessel mounted acoustic Doppler current profiler) transducers (75Hz and 150Hz) mounted on the hull. Meteorological variables were monitored using the onboard surface water and meteorological sampling system (SURFMET). Bathymetric data was collected using the EA600 echo sounder and EM120 swath system, which is attached to the hull.

This report describes the methods used to acquire and process the data aboard the ship during cruise JC032.

KEYWORDS

ADCP, Atlantic Ocean, biogeochemical budgets, Brazil Current, carbon budgets, Carbon Tetrachloride, Carbon, CFC, *James Cook*, climatic changes, cruise JC032 2009, CTD, hydrographic section, Lowered ADCP, Meridional Overturning Circulation, nutrients, oxygen, phytoplankton, potential temperature, salinity, Sulphur Hexafluoride, temperature, Vessel Mounted ADCP

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NOCS = National Oceanography Centre Southampton
UEA = University of East Anglia
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Name	Position	Affiliation
Paul Duncan	Computer/Ship systems Technician	NMF
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Name	Position/Rank
Peter Sarjeant	Master
Richard Warner	Chief Officer
Malcolm Graves	2nd Officer
Vanessa Laidlow	3rd Officer
George Parkinson	Chief Engineer
John Hagan	2nd Engineer
Ian Collin	3rd Engineer
Ian Wight	ETO
Paul Lucas	Purser
Kevin Luckhurst	CPOD
Steve Smith	CPOS
Iain Thompson	POD
Gerald Cooper	SG1A
John Dale	SG1A
Ian Cantlie	SG1A
Charles Cooney	SG1A
Leslie Hillier	ERPO
Darren Caines	Head Chef
Dean Hope	Assistant Chef
Graham Mingay	Steward
Brian Conteh	Assistant Steward

Background, Objectives and Overview

JC032 occupied a section across the Atlantic at 24°S. It immediately followed two other hydrographic cruises: JC030 was intended as a section across the entrance to the Weddell Sea, but was interrupted by a medical emergency. JC031 completed sections in the western and eastern Drake Passage, on the WOCE A21 and SR1b lines. Combining JC031 and JC032 with a US section from Africa to Antarctica at 30°E completed in February 2008, the Atlantic sector of the Southern Ocean is enclosed in a box. Inverse methods will be used to construct a basin-scale budget, with horizontal fluxes through the boundaries, of heat, salt, nutrients carbon and CFCs. Decadal variability will be investigated by comparison with previous occupations of the sections. The standard measurements on a CLIVAR hydrographic cruise were supplemented with some biological measurements. The cruise was funded under the Oceans2025 program at NOCS and a SOFI award at the University of East Anglia.

In total 118 CTDO (conductivity-temperature-depth-oxygen) stations were occupied with a 24-bottle rosette. After the loss of a set of 20-litre bottles during the previous cruise, JC032 was equipped with four 20-litre bottles deployed near the surface with the remaining depths sampled using 10-litre bottles. Other instruments on the package included a single WH300 LADCP (Lowered Acoustic Doppler Current Profiler), fluorometer and transmissometer. Two major incidents occurred with the CTD winch. On station 048, the gearbox on the storage drum failed with 3000 metres wire out. The station was abandoned and a delay of nearly 48 hours occurred while the package was recovered and the spare CTD wire commissioned. On station 061, a glitch in the winch system during deployment meant that the package was hauled up into the block and fell back to the deck from a height of about 2 metres, resulting in further significant delay while the fault was investigated and new operating procedures adopted. Several Niskin bottles were replaced due to cracks and damaged valves. All of the instruments mounted on the package were tested and found to be in working order although there were small calibration offsets.

Continuous underway sampling included: two vessel mounted ADCPs (VMADCP): OS75 and OS150; thermosalinograph (TSG); surface meteorology; bathymetry.

The embarkation of observers from Uruguay and Brazil meant that observations of the Brazil Current could be made within the 200-mile zones of those countries. The cooperation of the observers and the efforts that led to diplomatic clearance being granted were greatly appreciated by the Principal Scientist and all members of the scientific party.

The highly professional and friendly support provided by the ship’s personnel was fundamental to the success of the expedition. The were many outstanding individual contributions, but it is a particular pleasure to acknowledge those of the Chief Engineer and ETO, who seemed to spend as much time working on ship’s scientific equipment as they did in the engine room (their duties there no doubt covered in part by the other Engineer Officers), and the Master, whose considered leadership ensured that neither of the major winch incidents prevented the cruise from meeting all its objectives.

Itinerary and Cruise Track

Depart from Montevideo, Uruguay, 7th March 2009 – arrive in Walvis Bay, Namibia, 21st April 2009.

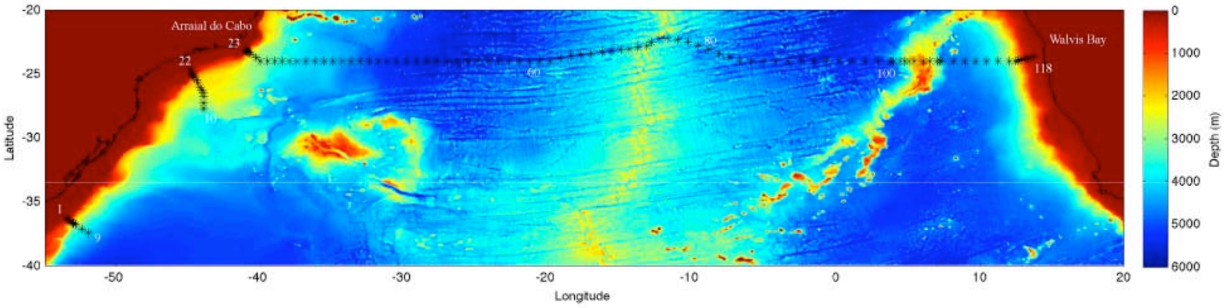

Figure 1: Bathymetric map of the JC032 study area and the positions of the stations sampled (*).

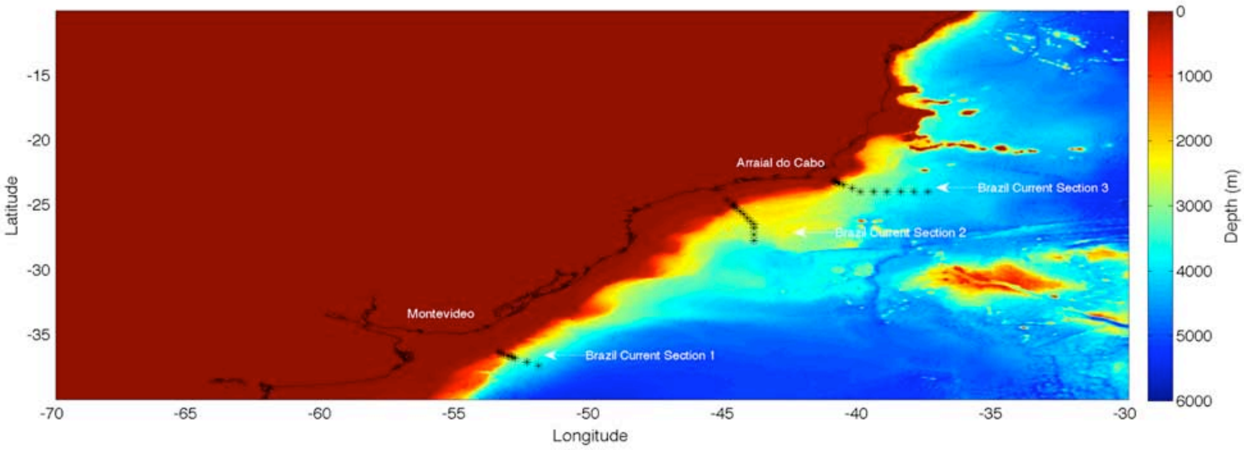

Figure 2: Bathymetric map of the Brazil current sections and the positions of the stations sampled (*).

Diary

J064 4th March in port
Cruise JC031 made port on the 3rd March 2009. Once all personnel from the previous cruise had disembarked, the handover was made to the Master Peter Sarjeant and Principal Scientist Brian King.

J064 5th March in port
Workstations and labs were already setup from JC031 so there was sufficient time to thoroughly test that the processing scripts were running properly by running test data.

J065 6th March - In port
A scientific meeting with was held at 9:00am, followed by a safety briefing at 10:00am.

It was noticed that the heading on the Ashtech system was reading 0. The unit was rebooted and is now functioning well.

The Vaisala temperature and humidity sensor has been temperamental since it was previously dismantled. The instrument was giving negative velocities of windspeed when tape was wrapped around the join between the two parts of the instrument. The instrument was taped up then put back into its screen.

J066 7th March (departed Montevideo)
In the morning emergency generator tests were run by powering the systems down. We set sail from our berth in Montevideo at approximately 13:00 local time (15:00 UTC).

A muster drill was performed soon after departure at 16:15 local time (18:15 UTC) to ensure that all personnel were acquainted with the emergency procedures. Fortunately this took place before a heavy downpour occurred at 16:50 local time (18:50 UTC).

The retractable keels were lowered at 18:45 local time (20:45UTC). This meant that the VMADCP instrument had to be restarted with the appropriate keel down configuration files (20:45 UTC).

Once far enough away from port the flow through the TSG was turned on (03:07 UTC). The conductivity of FSI initially read as 0. Subsequently, the FSI was reset, however, this then gave too high a salinity reading when compared to the SBE. Therefore the salinity from the SBE will be used for SVP records.

J067 8th March
CTD station sampling started first thing in the morning. Most people from all watches sampled the first station in order to get a feel for the sampling procedures. These stations comprised the first of our three planned Brazil current sections. A list of the first 5 stations demonstrates the frequency with which stations were sampled.

CTD Station 1: 200m water 09:03 UTC
CTD Station 2: 560m water 11:59 UTC - delay after winch problem.
CTD Station 3: 992m water 14.07 UTC
CTD Station 4: 1441m water 17:14 UTC
CTD Station 5: 2102m water 20.18 UTC

J068 9th March
CTD Station 6: 2500m of water 23:53 UTC
CTD Station 7: 3000m of water 04:27 UTC

At 14:58 UTC the position on the POSMV view briefly went red. It was noted that we should see whether the RTCM DGPS drops out at the same time if so then Paul Duncan our computer technician should be consulted.

It is possible that the Starboard TIR and PAR sensors are possibly mislabelled. Therefore at 16:07 UTC: Paul Duncan swapped the plugs around for the improperly fed sensors.

CTD Station 8: 3572m water 10:51 UTC
CTD Station 9: 4000m water 17:29 UTC

J069 10th March
We are currently steaming to Station 10, which will be the start of the Southern Brazil current section. Strong winds and a moderate swell have slowed the ship down to around 7/8 knots.

J070 11th March
We are continuing to steam to Station 10. As was the case yesterday strong winds and a moderate swell has slowed our progress to around 7/8 knots. However this is giving the science teams plenty of time to analyse the samples collected from the first nine stations and prepare for the next section.

J071 12th March 2009
One more day of steaming should bring us to Station 10 by tomorrow morning.

J072 13th March 2009
Normal scientific sampling resumed today as we arrived at Station 10.
CTD Station 10: 3043m water 10:18 UTC
CTD Station 11: 2861m water 16:06 UTC
CTD Station 12: 2594m water 22:30 UTC

J073 14th March
CTD Station 13: 2544m water 03:32 UTC
CTD Station 14: 2357m water 08:13 UTC
CTD Station 15: 2222m water 12:17 UTC
CTD Station 16: 2076m water 16:41 UTC
CTD Station 17: 1878m water 20:55 UTC

J074 15th March
CTD Station 18: 1512m water 00:52 UTC
CTD Station 19: 996m water 04:06 UTC

Due to a shallowing of the water depth, the VMADCP has been turned onto bottom tracking mode (04:23 UTC).

CTD Station 20: 504m water 06:36 UTC
CTD Station 21: 254m water 08:34 UTC

Whilst steaming to Station 21 we overshot our intended position by 1.4 miles in order to find the 250m contour.

LADCP processing of Station 20 indicates that beam 2 on the present transducer is weak.

An ADCP survey was carried out between Stations 21 to 22 to examine the extent of the Brazil current.

CTD Station 22: 127m water 12:12 UTC (only salinity samples were collected).

This completes this section of the Brazil current. Begin passage northwards towards the final Brazil current section.

J075 16th March
Steaming over night and should reach Station 23 (start of the Northern Brazil Current Section) just after midday.

CTD Station 23: 100m 13:32 GMT
CTD Station 24: 500m 14:42 GMT
CTD Station 25: 1000m 16:30 GMT
CTD Station 26: 1500m 19:27 GMT

J076 17th March
CTD Station 28: 2500m 02:02 GMT
CTD Station 29: 2864m 07:24 GMT
CTD Station 30: 3019m 12:49 GMT
CTD Station 31: 3014m 10:06 GMT

J077 18th March
Over the last couple of days there have been concerns over the ships freshwater production, as we seem to be consuming vast quantities more than we are producing. Despite attempts to try to conserve water the problem is deemed too serious to attempt a trans-Atlantic crossing without fixing this first. Therefore the decision has been taken by the Captain to put into port in Arraial do Cabo, Brazil in order to take on more fresh water and attempt to rectify the problem.

CTD Station 32: 3424m 00:59 GMT
CTD Station 33: 3489m 07:29 GMT

CTD Station 34: 3560m 13:36 GMT

Humidity is being read as very low by the sensor (9%). The sensor cap was replaced and realigned in the housing and is now giving stable measurements. (12:45 GMT).

Paul Duncan finished cleaning Vaisala connections at 16:39 GMT. All readings now appear stable.

CTD Station 35: 4061m 20:11 GMT

We stopped running salts through Autosal at ~02:45 GMT (1 bottle into Station 31) because of large jumps in the readings. The standby value is oscillating between values in the range of 45 - 88. We emptied the cell drain carboy and checked the machine but we have been unable to detect the cause of the problem.

At 00:05 GMT, the non-toxic underway supply was turned off in preparation for our steam into port. Also a swath survey was conducted on our way into port.

J078 19th March

Steaming to Brazil for water. Although an unfortunate turn of events with the freshwater situation, the steaming period has once again allowed all the scientific teams to get rid of some of the backlog of samples that has been building up over the last few stations.

J079 20th March (on passage to Station 36)

It was extremely clear and starry last night so the night-watch had the fantastic opportunity of observing the space shuttle and the ISS.

We came alongside in Cabo Frio 08:30 to take on freshwater and disembark Phillipe (our Brazilian observer). Three hours of shore leave were granted, which was unexpected but very welcome. Departed at 16:30 GMT with varying degrees of sunburn.

The non-toxic supply was switched back on at 23:00 ship's time.

J080 21st March (Start of long transect and voyage to Africa)

After steaming throughout the night and most of the day, we arrived at Station 36, which was a repeat of Station 35.

CTD Station 36: 4061m 21:56 GMT

Sinhue Torres reported strange results from bottle 5. Fired at 3750m and a duplicate of bottle 4, bottle 5 displayed a low oxygen value, (199µmols/l compared to 230µmols/l) a higher temperature, (10.5°C compared to 8.4°C) and no nutrients were found in the sample. CFCs and carbon were not sampled from this bottle. As far as we are aware the bottle had closed and was not leaking when brought on deck.

Bottle 5 has since been checked and caps seated correctly before next cast. Keep an eye on this bottle.

J081 22nd March
CTD Station 37: 4001m in water 05:13 GMT
CTD Station 38: 4112m in water 12:23 GMT
CTD Station 39: 4200m in water 17:30 GMT

J082 23rd March
CTD Station 40: 4250m water

We deployed Argo float 2 (platform No. 1901229): This was reset at 04:40 GMT and deployed on station at 06:55 GMT. The float was affectionately named "Lorna"

CTD Station 41: 4427m 10:54GMT
CTD Station 42: 4616m 18:37GMT

J083 24th March
CTD Station 43: 4750m 02:05GMT

Deployed Argo float 3 ("Millie"): Reset at 04:35 GMT and deployed at 06:12 GMT. Platform Number: 1901230.

CTD Station 44: 4990m in water 0953GMT
CTD Station 45: 5060m 17:59GMT

J084 25th March
CTD Station 46: 5146m 01:54GMT
CTD Station 47: 5241m 10:03GMT
CTD Station 48: Up until now everything has been running relatively smoothly, but at 19:25, the gearbox on CTD drum 1 failed. 3000m of wire have been paid out, and the CTD package is now halted at this depth, whilst we try to figure out the best way to resolve the problem.

J085 26th March
From 10:00 GMT the CTD wire was hauled by the traction system and spooled onto the storage drum which was turned by hand. A very dedicated effort by the CTD technicians and the ship's crew.

16:28 UTC a red light was noticed on the posmv viewer POSITION. This happened again at 18:43 UTC.

J086 27th March
CTD 49 came on board at around 17:30 UTC
CTD Station 50: 5440m in water 21:55 GMT

J087 28th March
CTD 50 on board at 03:19 GMT

Argo float 4480 was reset at 11:07 UTC and deployed at 12:38 UTC. Argo float number 4: platform number 1901240 (4480).

CTD Station 51: 5443m in water 07:50 GMT
CTD Station 52: 5480m in water 17:04 GMT

J088 29th March
CTD Station 53: 5668m in water 02:34 GMT
CTD Station 54: 5660m in water 11:45 GMT
CTD Station 55: 5671m in water 20:52 GMT.

J089 30th March
Hump day

CTD Station 56: 5210m in water 05:42GMT
CTD at Station 56 was close to a steep cliff face of a seamount therefore we made a slow approach to the bottom. To aid this the swath was left on until the CTD was on the upcast. Various swath angles showed good instrument performance. The SWATH System was left logging when on station.

CTD Station 57: 5219m in water 14:33GMT
CTD Station 58: 5209m in water 23:02GMT

J090 31st March
CTD Station 59: 5122m in water 07:38 GMT

Argo float number 5: 4469 (WMO 1901231) ("Sarah") was reset at 09:50 UTC and deployed 11:50 UTC.

CTD Station 60: 4970 in water 16:09 GMT

J091 1 April
At 00:30 GMT the Winch failed to stop when lifting off deck for deployment. The package was hauled up to the block the wire parted, and the CTD hit the deck in the water bottle annex. All CTD systems were checked and tested and don't appear to have sustained any damage. All the Niskin bottles were checked. Bottle number 21 was broken into two pieces so was replaced with Bottle 11 and renamed 21. The tap needed replacing on 14.

Alternatives to using the winch control 'belly' boxes were investigated.

CTD Station 61: 5100m in water 17:53 GMT

J092 2nd April
CTD Station 62: 4785m in water 02:22 GMT
Deployed float 6: platform number 1901233

CTD Station 63: 4446m in water 10:57 GMT
CTD Station 64: 4809m in water 19:47 GMT
The Ashtech heading read as 0 from 15:17 GMT onwards, so was reset.

J093 3rd April
CTD Station 65: 4676m in water 04:23 GMT
CTD Station 66: 4716m in water 13:20 GMT
CTD Station 67: 4969m in water 21:35 GMT

J094 4th April
Deployed float 7: "MONTY and the clan McLEAN" Platform number: 1901241.

It was noted that a large front was crossed in the NADW between Stations 68 and 69.

CTD Station 68: 4606m in water 06:20 GMT
CTD Station 69: 3905m in water 14:32 GMT
CTD Station 70: 4200m in water 21:44 GMT

J095 5th April
CTD Station 71: 4057m in water 05:11 GMT
CTD Station 72: 3818m in water 12:40 GMT
CTD Station 73: 3978m in water 20:19 GMT

Deployed float 8: platform number 1901232

J096 6th April
CTD Station 74: 4414m in water 02:55 GMT
CTD Station 75: 4385m in water 10:38 GMT
CTD Station 76: 4360m in water 18:00 GMT

J097 7th April
CTD Station 77: 4165m in water 02:36 GMT

Deployed float Number 9: "CHARLIE", platform number 1901235. This was reset at 05:00 GMT and deployed at 06:25 GMT.

CTD Station 78: 4072m in water 11:10 GMT
CTD Station 79: 4465m in water 19:25 GMT

J098 8th April
CTD Station 80: 5243m in water 04:16 GMT
CTD Station 81: 4426m in water 13:17 GMT
CTD Station 82: 4890m in water 21:42 GMT

Deployed float Number 10: Platform number 1901242 reset at 00:25 GMT and deployed at 01:50 GMT.

J099 9th April
The EA600 echo sounder lost contact with GTP transceiver (0 depth recorded) at approximately 02:30GMT so the system was rebooted.

CTD Station 83: 4881m in water 07:00 GMT
CTD Station 84: 4592m in water 16:02 GMT

The TECHSAS system froze at 20:40 GMT. The length of outage is unknown as watch keepers were out on deck sampling. Red panels were present throughout the entire no. of frames column. Paul Duncan rebooted the system at 20.45 GMT.

J100 10th April
CTD Station 85: 5234m in water 00:50 GMT

Ship time advances 1 hour today, a sign that we are slowly but surely making our way across the Atlantic.

CTD Station 86: 5137m in water 10:36 GMT
CTD Station 87: 4826m in water 21:05 GMT

J101 11th April
CTD Station 88: 5021m in water 06:57 GMT
CTD Station 89: 5273m in water 17:02 GMT

The CT lab flooded due to a pipe flowing out of sink. The pipe was secured and the water was mopped up.

J102 12th April
The flow rate out of the TSG pipe was found to be low for some reason. The TSG flow rates were checked but it seems that we will have to live with the low rate for the time being.

CTD Station 90: 5476m in water 03:10 GMT

Easter Sunday. The chefs prepared a fantastic lunch, which was enjoyed by all. Nobody is happier than Gerard who has been observing Lent.

CTD Station 91: 4367m in water 13:31 GMT
CTD Station 92: 5199m in water 22:35 GMT

J103 13th April
The Ashtech system was rebooted at 01:39GMT.

A quick repair had to be made to Niskin bottle in place 21, before the cast as the nylon lanyard had snapped.

CTD Station 93: 5264m in water 08:17 GMT.

The bottom end-cap lanyards were found not to be attached to the brass clips on bottles 16, 17 and 18.

The primary conductivity cell on the CTD was changed.

CTD Station 94: 5156m in water 18:05 GMT.

J104 14th April
The Niskin bottle in position 3 on the CTD was swapped.

CTD Station 95: 5010m in water 03:32 GMT.

Deployed float number 13 'KEEN MARINE' Platform number 1901243. Reset at 06:05 GMT and deployed at 07:25 GMT

CTD Station 96: 4183m in water 08:58 GMT.
CTD Station 97: 3661m in water 15:20 GMT.
CTD Station 98: 3025m in water 20:23 GMT.

J105 15th April
CTD Station 99: 2481m in water 01:13 GMT.
CTD Station 100: 1999m in water 05:40 GMT.
CTD Station 101: 1895m in water 11:21 GMT.
CTD Station 102: 2380m in water 16:07 GMT.
CTD Station 103: 1967m in water 21:36 GMT.

Deployed float number 14 Platform number 1901236. Reset at 22:48 GMT and deployed at 00:21 GMT.

J106 16th April
CTD Station 104: 3504m in water 01:49 GMT.
CTD Station 105: 4246m in water 05:58 GMT.
CTD Station 106: 4678m in water 14:19 GMT

J107 17th April
CTD Station 107: 4620m in water 23:10 GMT.

SVP probe sent down on CTD 107.

CTD Station 108: 4313m in water 08:04 GMT.

Deployed float number 15 Platform number 1901239. Reset at 11:02 GMT and deployed at 11:35 GMT.

The CTD cable needs 5 meters cutting off at the end because of bird caging. The re-termination took place at 13:19 GMT).

Finally after many attempts we managed to have a BBQ on deck without it raining.

CTD Station 109: 4051m in water 18:49 GMT

J108 18th April

The Ashtech needed rebooting again.

CTD Station 110: 3559 in water 02:57 GMT
CTD Station 111: 2831 in water 10:47 GMT
CTD Station 112: 2260m in water 16:05 GMT.
CTD Station 113: 1937m in water 19:10 GMT.
CTD Station 114: 22:18m in water 22:18 GMT

J109 19th April
CTD Station 115: 1013m in water 01:42 GMT
CTD Station 116: 503m in water 04:39 GMT
CTD Station 117: 305m in water 07:09 GMT
CTD Station 118: 205m in water 10:01 GMT

With the completion of Station 118 all CTD sampling is now over.

J110 20th April
VMADCP switched back to bottom tracking mode for calibration of the instrument.

J111 21st April
Arrived in Walvis Bay at approximately 09:00 local time. No berth available so anchored off shore with tens of other ships. All day was spent backing up data, packing up the labs and loading the containers. Boat transfer to shore was at about 1800 local time.

1. CTD Systems Operation

One hundred and eighteen, 24-bottle rosette CTD-O (Conductivity-Temperature-Depth-Oxygen) stations were occupied during JC032 (Figure 1). Stations 1-9 intersected the Brazil Current, near Uruguay. A second transect of the Brazil Current was completed between Stations 10-22. Stations 23-118 made up the main section. This work was accomplished in two parts. Stations 23-35 were those within the Brazilian 200 mile zone. After Station 35, the ship sailed into Arraial do Cabo to put the Brazilian observer ashore. A termination of the CTD wire was carried out whilst alongside. This resulted in a two-day hiatus in work. The section recommenced with Station 36, which was a repeat of Station 35.

Stations 1-47 were completed routinely. On the downcast on Station 48 a problem occurred with the gears on the CTD002 and the gearbox on the storage drum failed with 3000m of wire out on the downcast. The CTD was recovered using the traction system to haul the wire with the CTD storage drum turned by hand. The CTD was re-terminated with the wire from the CTD001 drum and work recommenced with Station 49. On deployment at Station 61 a problem occurred where the remote winch operation failed, as did the emergency stop on the belly box. The emergency stop on deck was not activated. This led to the CTD being hauled up to the block and then dropped from a height of about 2 metres when the wire snapped. One Niskin bottle was broken, and the primary conductivity and temperature sensors were knocked loose from the CTD frame. This resulted in a constant offset in both the primary conductivity and the oxygen. The decision was made not to change the sensors at this stage. The CTD was re-terminated and work commenced again. On cast 89, near the bottom of the downcast, the deck unit went down and had to be restarted. Shortly after this, the primary conductivity sensor received another offset. This lasted until Station 93 when the primary conductivity sensor failed completely near the end of the downcast and had to be replaced.

Gerard McCarthy, Carolina Gramcianinov, David Hamersley, Lorna McLean, and Paul Provost

2. CTD Data Processing and Calibration

2.1 Initial Processing Using SeaBird Programs

The files output by Seasave (version 7.18) have the appendices: .hex, .HDR, .bl, .CON. The .CON files for each cast contain the calibration coefficients for the instrument. The .HDR files contain the information in the header of each cast file. The .hex files are the data files for each cast and are in hex format. The .bl files contain information on bottle firings of the rosette.

Initial data processing was performed on a PC using the Seabird processing software SBE Data Processing, Version 7.18. We used the following options in the given order:

Data Conversion - turns the raw data into physical units. It takes the .CON files and .hex files. The input files were named *ctdnnn.hex* where *nnn* refers to the three-digit station number. The output files were specified as *ctd_jc032_nnn_ctm.cnv*, where *nnn* is the station number.

Align CTD - takes the .cnv file and applies a temporal shift to align the sensor readings. The offsets applied were zero for the primary and secondary temperature and conductivity sensors as the CTD deck unit automatically applies the conductivity lag to the conductivity sensors. An offset of 5 was applied to the oxygen sensor.

Cell Thermal Mass - takes the .cnv files output from Align CTD and makes corrections for the thermal mass of the cell, in an attempt to minimize salinity spiking in steep vertical gradients due to a temperature/conductivity mismatch. The constants applied were; thermal anomaly amplitude α= 0.03; thermal anomaly time constant $1/\beta$= 7.

2.2 Mstar CTD Processing

The entire Mstar software suite is written in Matlab and uses NetCDF file format to store all the data. There are four principal types of files:

- SAM files: store all information about rosette bottles samples, including upcast CTD data from when the bottles were fired. Data from chemistry samples corresponding with each bottle are uploaded into this file as well. Other information about the station is stored too.
- CTD files: store all data from CTD sensors. There are five CTD files: raw, 24Hz, 1Hz, psal and 2db. The program averages and interpolates the raw data until it has 2db resolution.
- DCS files: store information necessary to know CTD downcast (for e.g. start, bottom and end points of the cast). It is also used to merge in latitude and longitude.
- FIR files: keep information about CTD data in points when each rosette bottle was fired. Also stores information about winch work.

2.3 Processing Procedure Used on JC032

After having converted CTD with the SBE processes, there were two files to work on; *ctd_jc032_nnn_ctm.cnv* and *ctd_jc032_nnn.bl*. The first one contains all raw CTD data including cast information. The other one contains information about the firing of each bottle on the cast.

To start the CTD data processing, run *m_setup* in Matlab to add Mstar tools and information needed for the processing.

msam_01: creates an empty sam file to store all information about rosette bottle samples. The set of variables are available on M_TEMPLATES directory and can be changed according to what it needs to store. This file, named as *sam_jc032_nnn.nc*, contains space to store data for each sample bottle, their flags, and some CTD data at firing time.

mctd_01: reads the raw data (*ctd_jc032_nnn_ctm.cnv*) and stores it in a NetCDF file named *ctd_jc032_nnn_raw.nc*, which becomes write protected.

mctd_02: copies *ctd_jc032_nnn_raw.nc* into *ctd_jc032_nnn_24hz.nc* renaming the variables for the SBE sensor.

mctd_03: using 24Hz data (*ctd_jc032_nnn_24hz*) it averages to 1Hz data. Then, using the 1Hz file (*ctd_jc032_nnn_1hz*) it calculates potential salinity and potential temperature (*ctd_jc032_nnn_psal*).

mdcs_01: creates empty file named as *dcs_jc032_nnn* to store information about the start, bottom and end of the cast.

mdcs_02: populates *dcs_jc032_nnn* with information from the bottom cast. It takes the highest pressure point as bottom.

mdcs_03: selects and shows surface data < 20db (*ctd_jc032_nnn_surf*) then the analyst chooses the positions of the start and end scan numbers.

The start is selected by scrolling from the top of data printed out by *mdcs_03*. The operator identifies where the CTD went from being on deck (zero/negative pressure) to roughly 10 db and then the point where is it was brought back to the surface for start the downcast. The scan number at which the pressure begins to increase is selected as the start point of the downcast.

To find the end of upcast, scroll the data up from the bottom and identify where the CTD came back onboard. The operator chooses the point before an abrupt change in conductivity due to the CTD coming out of the water.

mctd_04: using information on *dcs_jc032_nnn* it selects the CTD downcast data from *ctd_jc032_nnn_psal* file and averages it into 2db resolution (*ctd_jc032_nnn_2db*).

mdcs_04: loads position from navigation file and merges it on the cast’s points previously defined on *mdcs_03* and store it on *dcs_jc032_nnn_pos.nc*.

mfir_01: extracts information about fired bottles from *ctd_jc032_nnn.bl* and copies them into a new file named *fir_jc032_nnn_bl.nc*.

mfir_02: using *fir_jc032_nnn_bl* and *ctd_jc032_nnn_1hz* it merges the time from the CTD using scan numbers and puts it into a new file (*fir_jc032_nnn_time.nc*).

mfir_03: stores the CTD data at each bottle firing time in *fir_jc032_nnn_ctd*. The CTD data are taken from *ctd_jc032_nnn_psal* and selected according to the firing time information stored in *fir_jc032_nnn_time*.

mfir_04: copies information of each bottle from *fir_jc032_nnn_ctd* onto *sam_jc032_nnn*.

mwin_01: creates a new file named *win_jc032_nnn.nc* to store information about winch working (for e.g. angles, rate and tension).

mwin_03: using time stored in *fir_jc032_nnn_time*, it selects wire-out from *win_jc032_nnn* at each bottle firing location to *fir_jc032_nnn_winch*.

mwin_04: pastes wire-out information from *fir_jc032_nnn_winch* into *sam_jc032_nnn.nc*.

mbot_01: creates a bottle file (*bot_jc032_nnn*) to store information regarding the state of each Niskin bottle. It uses a text file named as *bot_jc032_01.csv* (on BOTTLE_FILE/ directory) that must be always updated after each station with the number of the bottle, position on rosette, and a flag number.

mbot_02: copies information from *bot_jc032_nnn* to *sam_jc032_nnn.nc*.

mdep_01: applies full water depth into all files. The depth is taken from the LDEO processing of the LADCP.

mdcs_05: applies positions from *dcs_jc032_nnn_pos.nc* to all files. If a file on the set doesn't exist yet it won't be uploaded.

2.4 Sample Files

Chemistry and tracer data from the various groups were merged with CTD data to create master sample files. The sample files (*sam_jc032_nnn.nc*) were created whilst processing each CTD station. These were, at this stage, filled with upcast conductivity, temperature, oxygen and pressure from both primary and secondary sensors coincident with bottle firings. Winch data were merged on, as were Niskin bottle flags.

Merging of these data took two steps for each tracer: the first step generated an Mstar file, which contained all the tracer data for a given section – these were the programs named *moxy_01*, *mnut_01*, *mcfc_01* and *mco2_01*. This step contains code specific to the format of the data received from the various groups. The files were named *oxy_jc032_nnn.nc*, for example in the case of oxygen. The second step was to merge these individual Mstar files onto the master sam file for the station. This was performed by the programs *moxy_02* etc.

This method of processing provided an efficient and consistent method of assimilating data from the many different components of an interdisciplinary cruise like JC032. It also facilitated the production of contour plots of the various station data as we progressed through the section.

2.5 Calibration of the Primary Conductivity Sensor

The conductivity sensor was calibrated against conductivities derived from bottle samples. The CTD used on JC032 was equipped with two conductivity and temperature sensors. The primary conductivity-temperature sensor was attached near the bottom of the main frame. The secondary sensor was attached to the fin of the CTD. The secondary conductivity sensor was noted to have hysteresis and hence the primary sensor was chosen for calibration as the final conductivity. The differences between the two sensors and their uncorrected offsets are shown in Figure 3.

Upcast conductivity – present in the sam file at bottle depths as 'ucond' – was calibrated against conductivity derived from bottle samples. A multiplicative correction factor applied to conductivity is associated with a deformation of the conductivity cell. The shape of this correction is comparable to an additional correction to salinity. As the calibration was applied at the transition between the raw files and the 24Hz files, it was necessary to do a conductivity correction.

The ratio between conductivity derived from bottle samples and upcast conductivity was investigated. While the ratio was close to unity, there was an offset roughly equivalent to 0.002 in salinity. The ratio also showed a trend against pressure. From 1000m to 4500m, the CTD conductivity had a linearly decreasing trend with depth and from 4500m to the maximum depths encountered (around 5700m) the conductivity trend tended towards higher conductivities. No trends were noted in salinity residuals against temperature or conductivity.

The calibration was applied by correcting conductivities with a multiplicative factor decided by a pressure lookup table. This reduced the interquartile range of salinity residual to 0.001 (equivalent to an interquartile range of 0.00003 in conductivity ratio). This calibration removed the trend with pressure deeper than 1000m. Above 1000m there were large gradients in both temperature and salinity. In this region the bottle conductivities often read lower than those of the CTD. This was interpreted as a Niskin bottle flushing issue. The water in the Niskin was from a few metres deeper than the CTD was reading. Hence no extra correction was applied to the CTD in this region.

The calibration had to be reviewed after the CTD was dropped at Station 61. The primary conductivity did receive a conductivity offset of 1.0001 (equivalent to 0.004 in salinity). This was traced to the primary conductivity by comparison with both the secondary sensors and previous casts. Close investigation of the temperature sensors revealed no similar offset. The same procedure as mentioned previously was applied to calibrate these data. The result was similar. The spread of the data was restricted to 0.002 in salinity and the trends with pressure were removed.

The primary conductivity sensor began to fail on Station 89. Near the bottom of the downcast, at scan 155720, the conductivity ratio jumped by a factor of 1.000076 (equivalent to 0.003 in salinity). This adjustment was made to the 24Hz files before the pressure correction was applied. This remained a constant offset until the sensor had failed completely on Station 93 and began wandering in comparison to the secondary sensor. It failed near the bottom of the downcast at scan 143986. For the remainder of the downcast the conductivity data from the secondary sensor were pasted in so as to have the most accurate data available in the 2db file. The upcast data were not corrected for this cast.

The new conductivity sensor was fitted from Station 94. This sensor was seen to be stable and well calibrated. A small pressure effect of a similar shape to that seen in the original sensor was noted, although the effect was less obvious with this sensor. This was corrected for in the same manner as before. The similarity of the shape of the pressure offset, which needed to be applied to both of the primary sensors, may indicate that there was some issue with the pressure sensor.

2.6 Calibration of the Oxygen Sensor

The oxygen sensor was attached to the primary conductivity-temperature sensor on the CTD frame. Early on in the cruise, the sensor was noted to suffer from large hysteresis between the down and up casts. This is shown in Figure 4. No correction for this hysteresis was applied, but the downcast oxygen (rather than the upcast) was calibrated against bottle samples. The downcast data were matched with the bottle samples (taken on the upcast) on density. Density was chosen as a parameter more representative of the water mass than pressure/depth, which may change between downcasts and upcasts. The residuals calculated were shown to have a dependence on pressure. This pressure effect was corrected for by applying an additive correction with respect to pressure. The results reduced the residuals to below 1µmol/kg.

After the drop on Station 61, the oxygen sensor received an offset of roughly 2.5µmol/kg. Due to the sensors' excellent stability before the drop, the decision was taken not to replace the sensor. The sensor remained stable after this and did not change after the primary conductivity sensor was replaced after Station 93. The correction to this jump involved the same procedure as beforehand. The final residuals are shown in Figure 5.

2.7 Calibration of the Transmittance Sensor

The transmittance sensor was noted to be producing values of the order of 104 – 105% in clear water. This was adjusted in post-processing by capturing the maximum voltage recorded in clear water and setting this to a transmittance of 99.9%. The other values in the station were adjusted accordingly.

2.8 Addition of Metadata to the Mstar Files

Position, time and full water depth were added to the header of all Mstar files including the *sam* and *ctd_2db* files.

Time: Time exists in Mstar files in seconds from the Mstar time origin. The Mstar time origin is parsed out from a UTC timestamp in the header of the SeaBird CTD files.

Position: Latitude and longitude in both decimal degrees, and degrees and minutes, were pasted into the files. The time according to the bottom of the cast was found from the DCS files with the posmvpos position merged on.

Water Depth: Water depth was added after processing of the LADCP was complete. The LDEO with CTD processing provides an estimate of full water depth by combining CTD depth with a height above the bottom estimate provided by the LADCP. A backup water depth was provided by a combination of the altimeter and depth of the package from the CTD data. This was not used in the final file.

2.9 Niskin Bottles

Four 20L bottles were used for the surface measurements (positions 21 to 24) and the remaining twenty positions held 10L bottles. During sampling the bottles were checked for problems such as leaking and dribbling and any issues were noted on the deck log. During the processing of the data, quality control flags were assigned and are as follows (refer to the WOCE operations manual):

2 = No problems noted (data assumed to be good)
3 = Leaking (these bottles are therefore not sampled)
9 = Samples not drawn from this bottle (e.g. a duplicate depth but no issues with bottle)
10 = Tap dribbling before the top valve was opened

Flag number 10 was introduced on this cruise after a number of incidences where the tap of a bottle was dribbling before the valve was opened. It was thought unlikely that the water in these bottles would have been contaminated (often it was the surface bottle affected) but it was flagged as anomalous and data was recorded from these bottles. Flags 2, 3 and 9 are taken from the WOCE operations manual.

During Station 61 the CTD was dropped on deck during deployment. As a result the 20L Niskin bottle in position 21 was broken and was replaced by a spare 20L bottle, which was subsequently named number 25 for processing purposes.

On a number of casts, the chemistry team reported anomalous results in oxygen and nutrient samples from bottle 3 suggesting that water had been picked up in another part of the water column. Anomalous salinity samples furthered the suspicion that the bottle contains water from higher in water the column. This was reported in four stations (81, 85, 91 and 93) and the bottle was given a quality control flag of 3. A new 10L bottle was installed in position 3 (this was named number 26 for processing) before the deployment of cast 95. However, after analysing data from cast 96 the nutrient team once again reported anomalous data. For two additional casts the bottle was not fired in order to determine if bottle 3 was closing by itself somewhere else in the water column. On both occasions when the CTD was recovered this bottle remained open. Again on cast number 107 anomalous results in oxygen and nutrients and salinity were found. On following casts, where possible, this bottle was used as a duplicate of the 'bottom-50' depth and was not sampled.

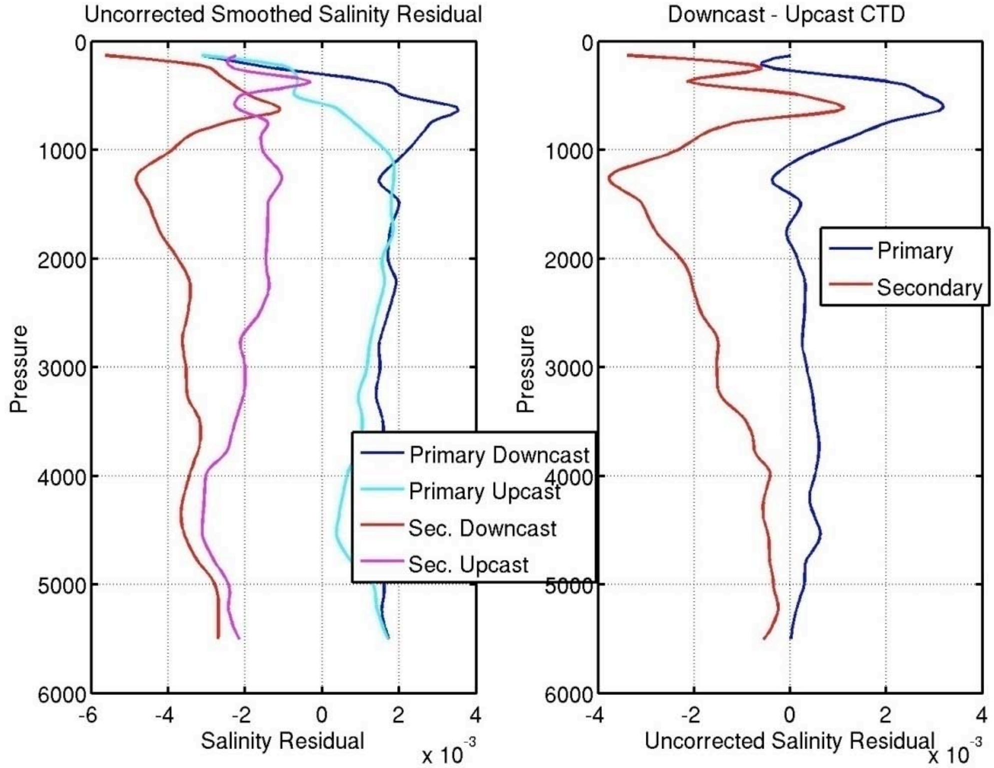

Figure 3: Raw data from the original primary and secondary conductivity (salinity) sensors.

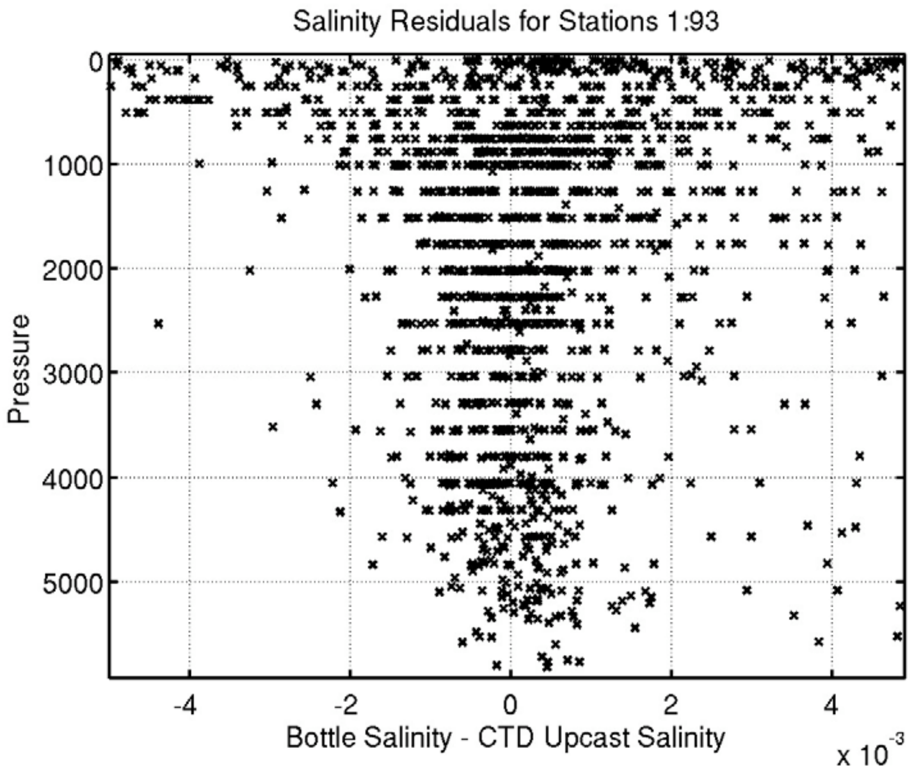

Figure 4: Salinity Residuals for the original conductivity sensor after adjustment for a pressure effect.

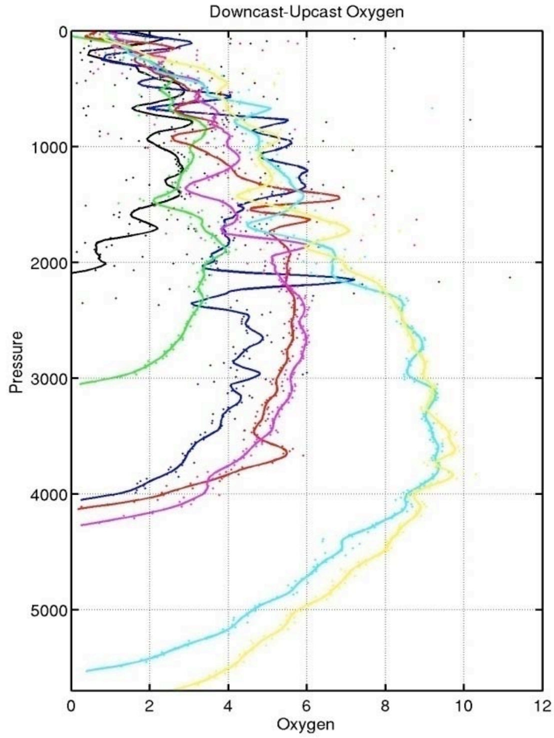

Figure 5: A selection of stations were taken in this graph and are represented by different colours. Data is taken from the 1Hz files. Both the upcast and the downcast were put on a regular grid and the upcast subtracted from the downcast. These data points are represented by the dots. The lines show the dots after smoothing with a running average. Hysteresis was seen to be present in the oxygen sensor. The downcast oxygen was reading higher than the upcast up to a maximum of 10 μmol/kg on the deepest casts.

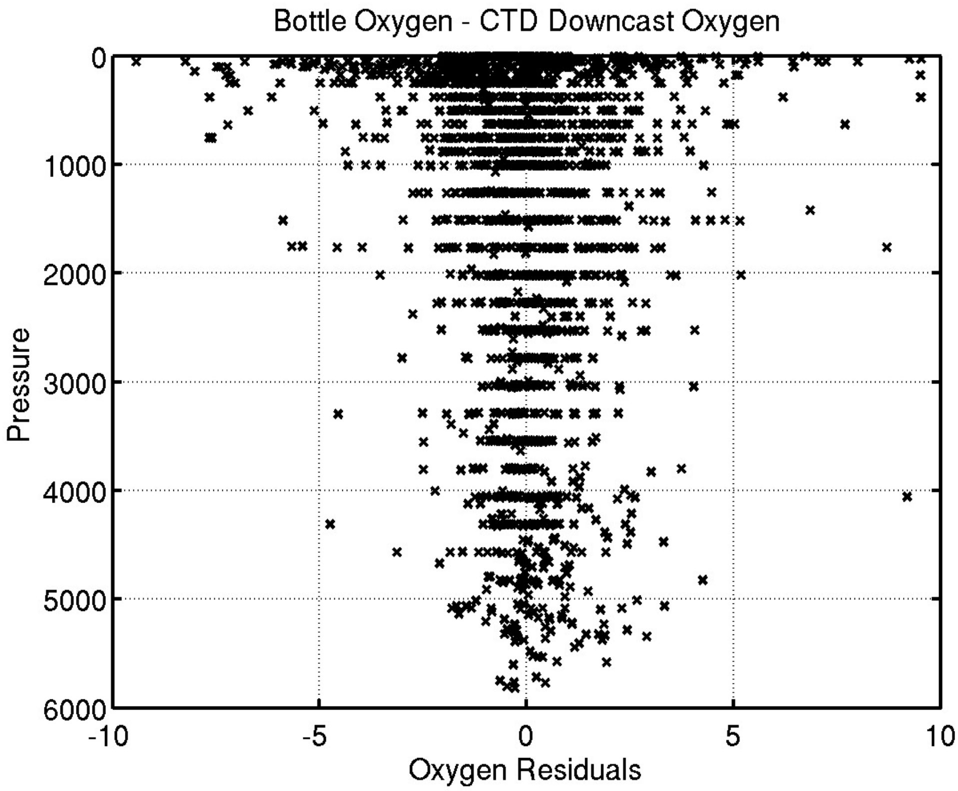

Figure 6: Oxygen residuals calculated from bottle oxygen minus pressure corrected downcast CTD data

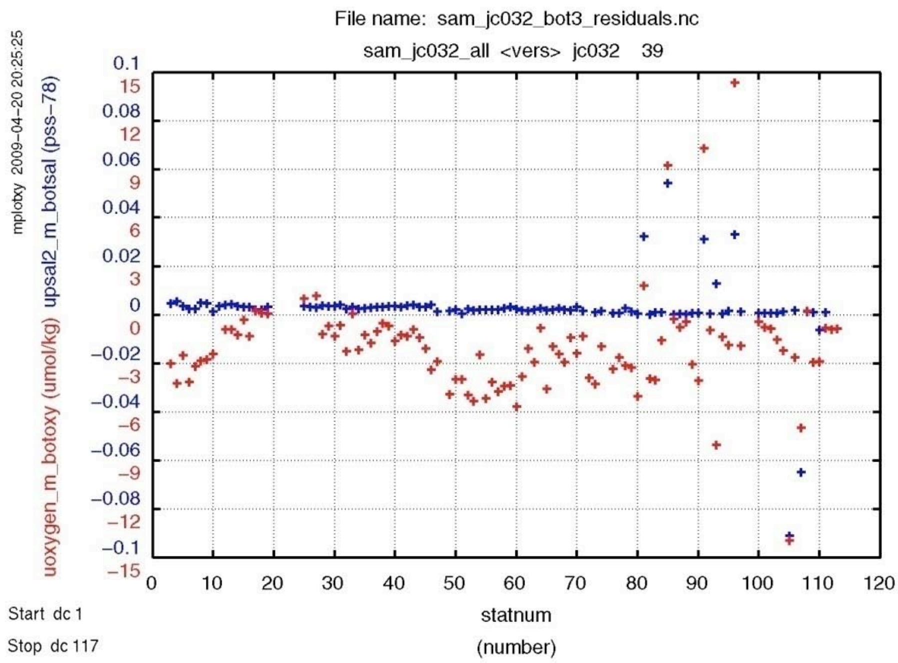

Figure 7: Oxygen outliers found from Niskin 3

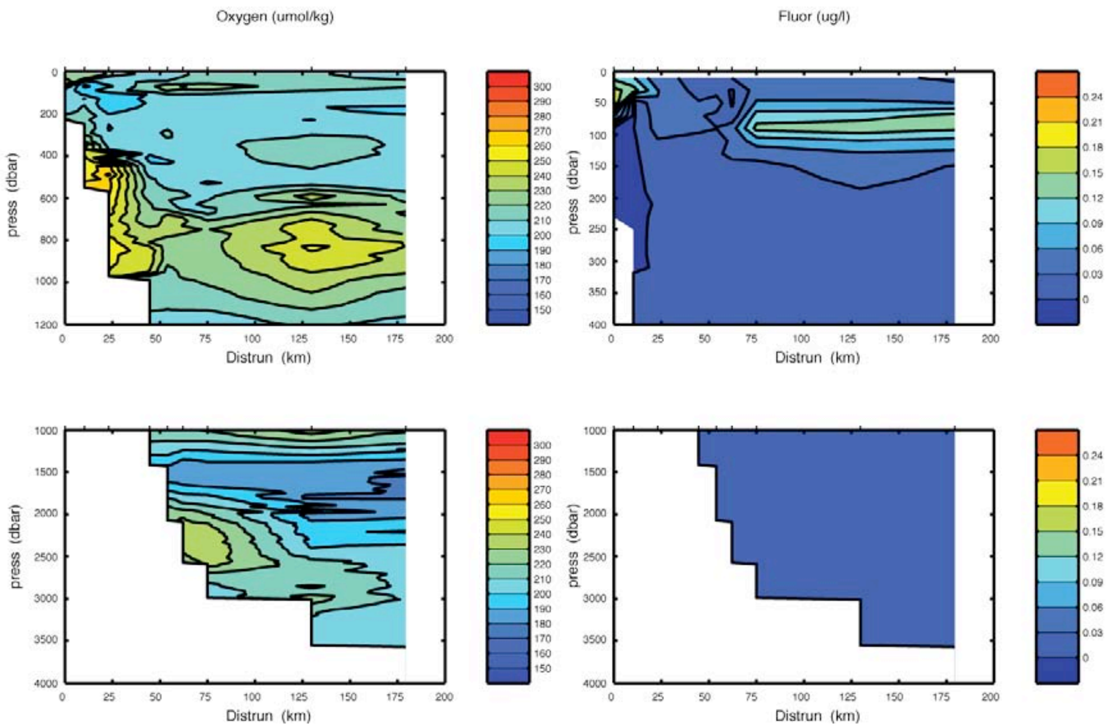

Figure 8: CTD oxygen and fluorescence parameters across the first Brazil current transect

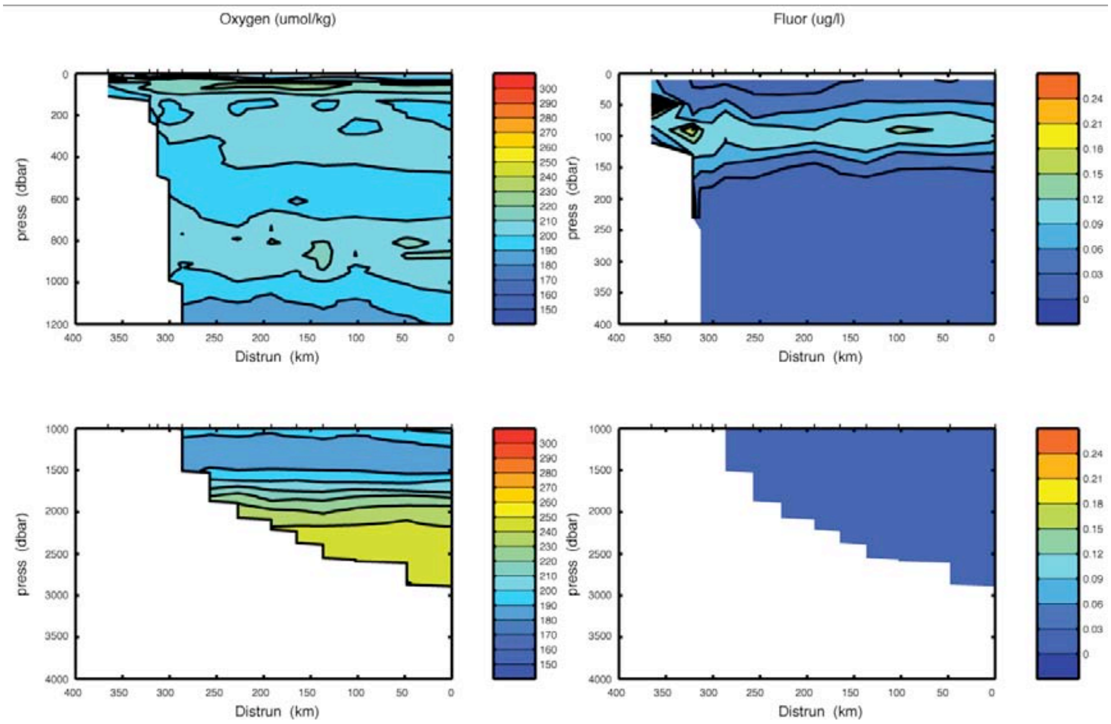

Figure 9: CTD oxygen and fluorescence parameters across the second Brazil current transect

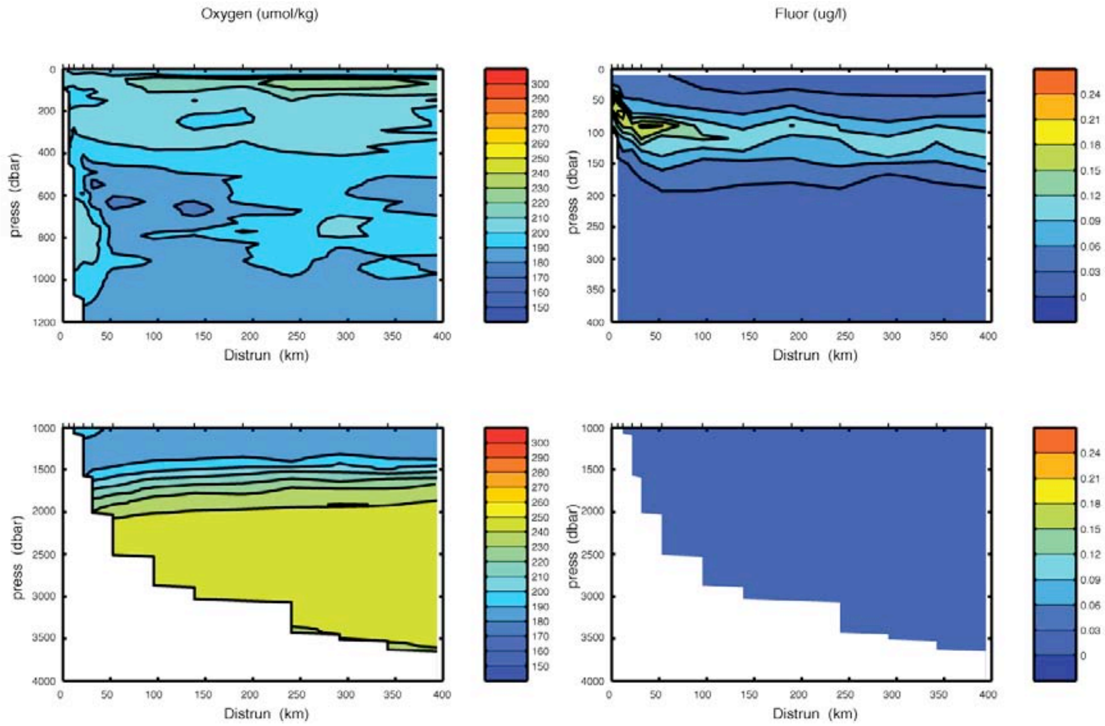

Figure 10: CTD oxygen and fluorescence parameters across the third Brazil current transect

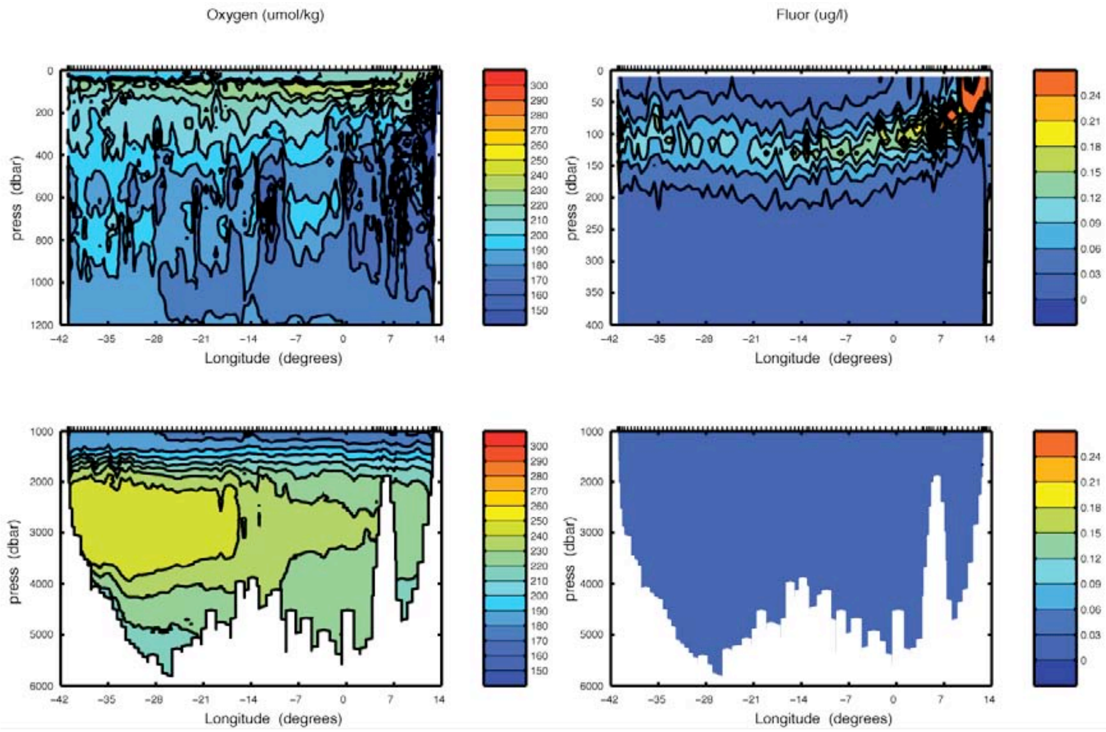

Figure 11: Contour plot of the oxygen parameter along the Atlantic 24°S hydrographic section

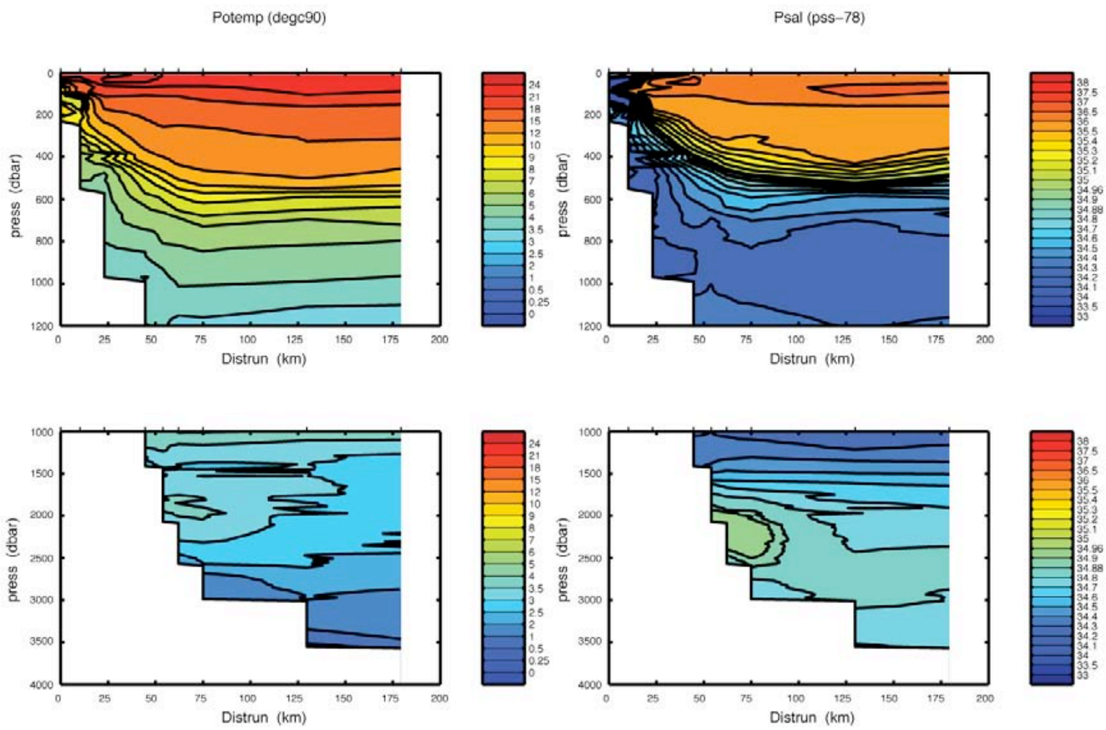

Figure 12: Potential temperature and salinity parameters across the first Brazil current transect

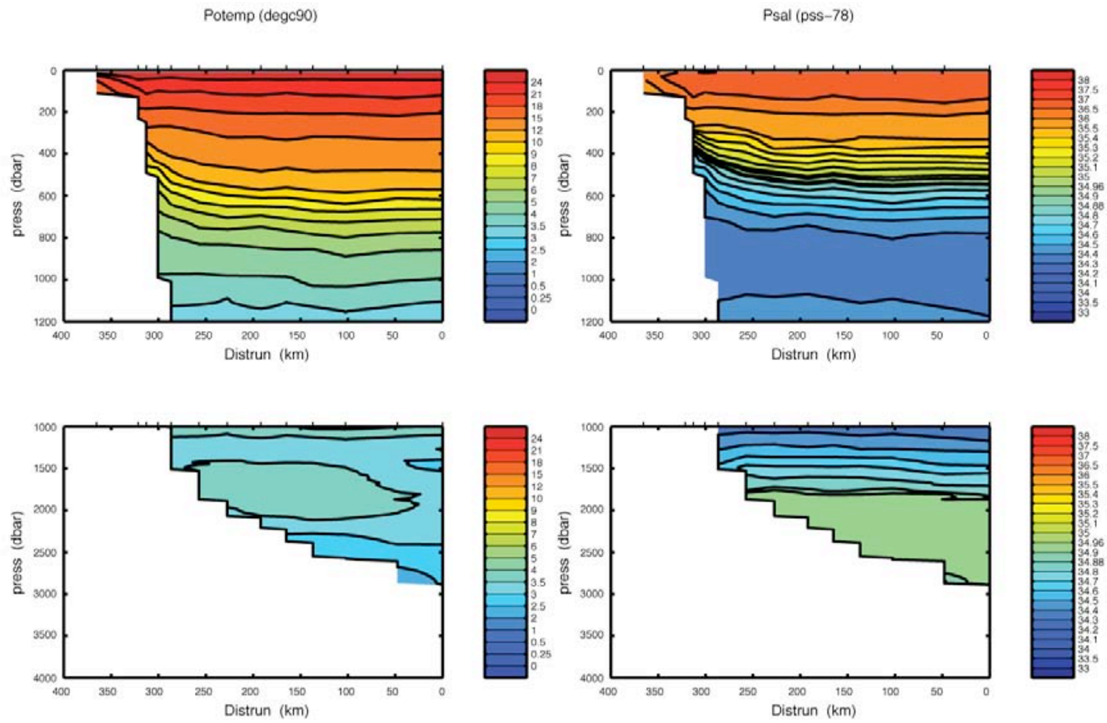

Figure 13: Potential temperature and salinity parameters across the second Brazil current transect

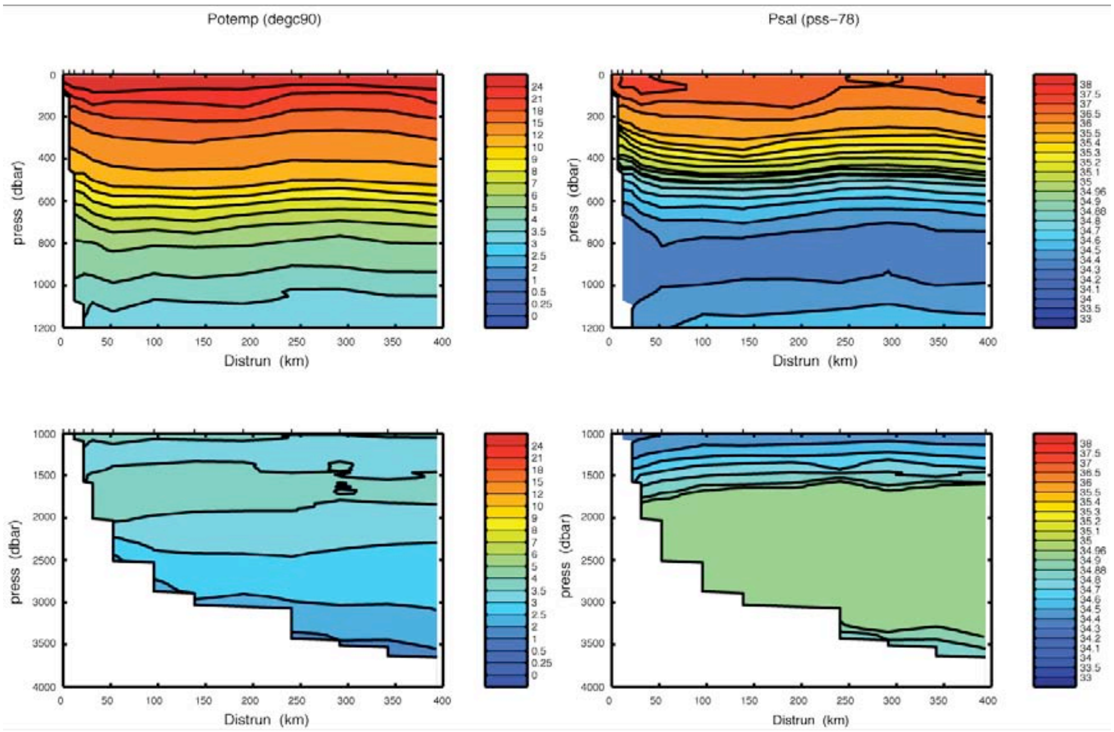

Figure 14: Potential temperature and salinity parameters across the third Brazil current transect

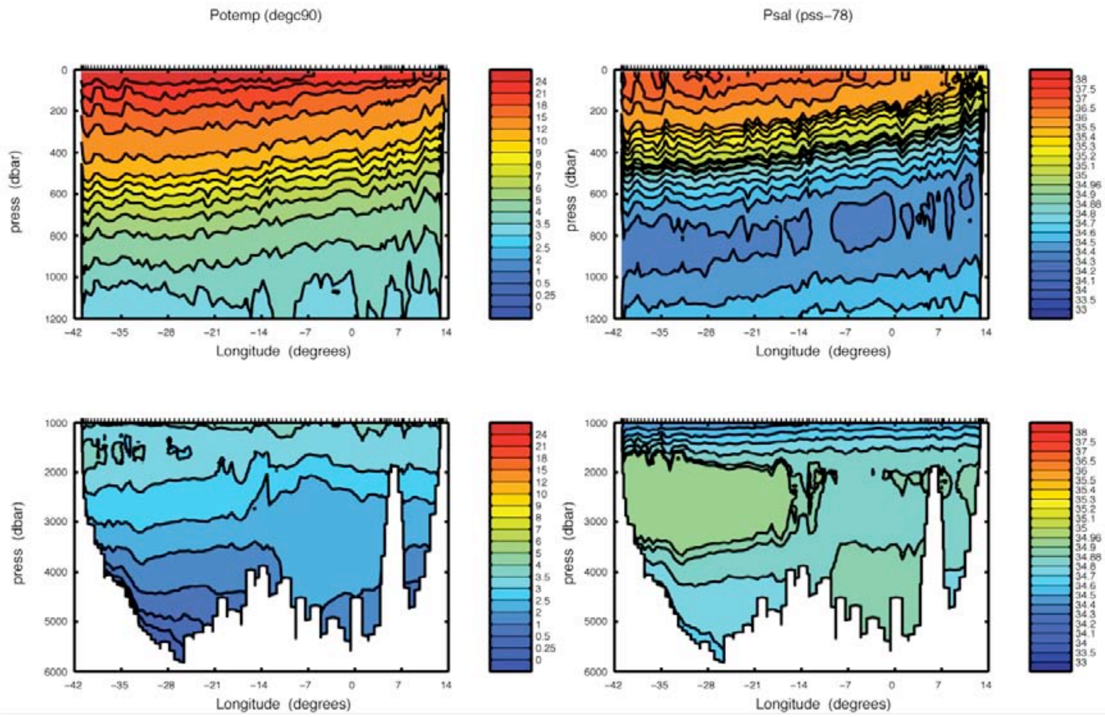

Figure 15: Contour plot of potential temperature along the Atlantic 24°S hydrographic section

Gerard McCarthy

3. Water Sample Salinity Analysis

3.1 Sampling

For the purpose of measuring salinity, samples were collected in 200ml glass bottles from each bottle fired at each station. In addition to this, TSG samples were collected every 4 hours. Two crates were set aside for TSG samples. The TSG crates did not have complete sets of sample bottles because some were substituted and re-labelled to make up complete crates for sampling the CTD. Standard procedure for sampling from both the CTD and the TSG was to rinse the sample bottles using sample water from the Niskin bottles on the rosette, and then fill the bottle completely to collect the sample. It was considered good practise to run the samples for the TSG through the hose for approximately 1 minute in order to flush through any water that may have been sitting in the system since the previous sample was taken. The rim and the inside of the lid of each bottle were wiped dry using disposable paper towels to prevent salt crystals forming. Each sample bottle was then sealed with a disposable plastic stopper and its respective screw cap. When a crate was completed it was taken into the constant temperature (CT) laboratory and left for a minimum of 24 hours to equilibrate with the temperature of the laboratory. It was necessary to record the identity of the crate and the time it was placed in the CT lab so that it could be easily identified when a crate was ready to be analysed.

3.2 Laboratory Setup

The CT lab space was shared between the salinity and noble gas analysis (Alba Gonzalez Posada). For the purpose of salinity analysis, a Guildline 8400B laboratory salinometer, serial number 68426, was used. The temperature of the laboratory should be between 22-23°C, lower than temperature of the water bath in the Autosal, which in this case was set to 24°C. Over the duration of this cruise the room temperature was recorded in the watchkeeping logs, and was found to fluctuate between 21.5-23.5°C. It is possible that these temperatures are slightly erroneous because the thermometer is situated against the casing of the Autosal. When measuring different areas of the room, it was found that near air conditioning outlets the temperature could be as low as 16°C. The same components and setup for the Autosal are used on this cruise as on JC031. The only adjustment that has been made is the addition of an on/off switch on the peristaltic pump. The object of this was simply to improve the functionality of the pump for the analyst.

3.3 Analysis

Salinity analysis duties were shared between the members of the physics watch; Brian King, Gerard McCarthy, Lorna McLean, David Hamersley, Alex Brearley, and Carolina Gramcianinov. In the beginning there were inevitably a few teething problems in terms of getting new analysts familiarised with the Autosal, either because they had never performed any salinity measurements before, or because they had done so on a different type of salinometer. One of the problems that commonly occurred was failure to alter the suppression settings of the salinometer when necessary. However, this was not a major problem as the values were easily corrected by hand after the analysis was complete. Various changes, which will be discussed in this report, were made to the analysis procedures from the previous cruise (JC031) after discussion between Brian King and the rest of the physics watch. The number of remaining seawater standards was found to be approximately 170. This meant that the number of standards was limited for the number of stations on this cruise. It was therefore determined that salinity analysis should only be performed when 3 or more crates had equilibrated to room temperature. This way the number of standards used for analyses could be minimised.

Additional methods for ensuring efficient use of standards included flushing the cell in the Autosal with old standard before the usual prescribed three flushes with new standard. The reason behind this was to bring the salinity of the sample in the cell closer to the value of the new standard to increase the likelihood of any previous sample being completely flushed out. When entering bottle numbers into the data logging software, standards were designated *9nnn*, where *'nnn'* relates to the sequential number of the standard e.g. the first standard used was 9001. This number, along with the times and crates associated with the respective standard were recorded in a standardisation log sheet.

The same standard seawater samples, produced by Ocean Scientific Instruments Ltd. (OSIL), were used throughout the cruise. Batch number: P150, K_{15} ratio: 0.99978, K_{15} ratio x2: 1.99956. Instead of running standardisations and altering the standardization setting on the Autosal (which was set at 490), it was agreed that standards would be run as samples and then adjusted for the difference between the measured value and labelled value. Several Matlab scripts were written by Gerard McCarthy to perform the adjustments to the salinities of the bottle samples and the TSG samples.

There were several adjustments to the standardisation setting of the Autosal at the beginning of the cruise. At Station 1 the standardisation setting was changed from 490 to 583, this was changed again to 570 at Station 4. The standardisation setting was finally changed to 490 when analysing Station 10, because it was found that the values were too close to the 2.00000 suppression setting to allow a coherent standardisation to be achieved. After this station it was agreed that the standardisation setting should be kept the same and only to run standards as samples. Doing this meant that the salinity adjustments had to be performed manually using the scripts generated by Gerard McCarthy, which would otherwise have been performed by the data logging software from standardisations.

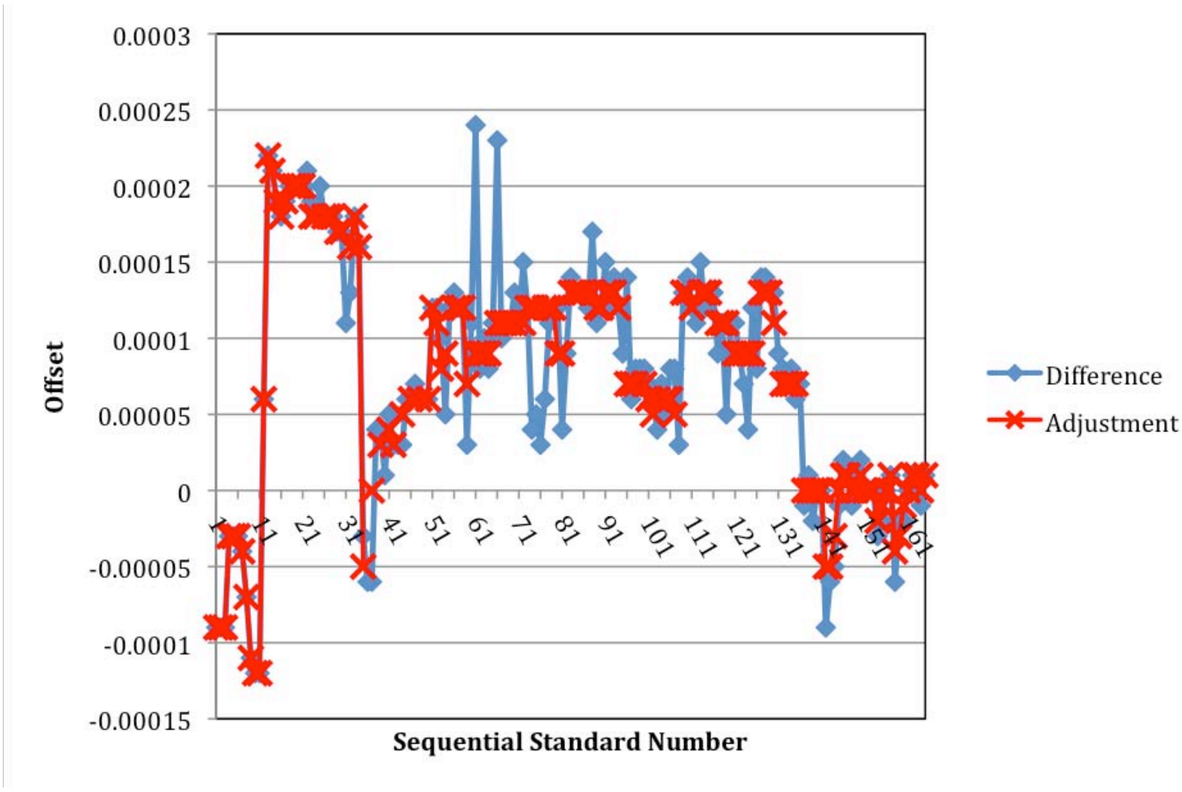

Figure 16: Comparison of standardisation adjustments and differences.

Figure 16 plots the differences that were calculated between the label value on the standard bottles and the measured value of the standard. Adjustments were made to the calculated differences in order to try and smooth out the readings that were thought to be attributed to noise. It can be seen that there has been considerable drift in the values of the standards measured by the salinometer. These adjustments were made manually to the salinity data, using scripts written in Matlab. (See table 1 for salinity standard adjustments).

It has been frequently noted by the members of the physics team, that the readings from the salinometer show much less variation (noise) on the 2.00000 suppression, as opposed to the 1.90000 suppression. It is thought that this could potentially be an electronic fault that occurs when the suppression switch is put on this setting. The degree of the variability on this suppression has been found to increase at certain times throughout this cruise, but has always returned to periods of relative stability. However, due to the uncertainty that the noise is having on the final average calculated by the software, it was decided by Brian King that the analysts should record the readings visually, so that efforts could be made to observe how much of an effect the noise was having on the computer calculated average. Findings showed that there was generally a difference between the computer-calculated and manually calculated average of approximately 1 or 2 counts (0.00001-0.00002). Despite the noise observed on the salinometer display, this does not appear to hugely affect the calculated average. However, continued visual observation was suggested in order to maintain a record that could be consulted if results produced by the data-logging software continued to appear anomalous.

3.4 Specific Observations

This section merely draws attention to specific incidents that are considered to be relevant to the reliability and quality of the salinity samples. This should not only serve as an account of the salinity analysis that has taken place on JC032, but also as an indication of potential problems that may be encountered on future cruises.

Whilst analysing Station 10, it was realised by the analyst that the drainage can was overflowing with the drainage pipe dangling in the can. It is believed that this could have caused an electrical circuit that possibly altered the electrical conductivity in the cell, hence leading to comparatively large variation in the data. The issue was explained to the physics team and the situation has thus been rectified by emptying the drainage can at the end of every set of analyses.

For the crate sampled at Station 25, Brian King checked both temperature sensors separately on different temperature settings. The temperature sensors are wired in series allowing each of the sensors to operate independently. The two temperature sensors are separated in their calibration by approximately 10-20 m°C (millidegrees Celsius). When temperature sensor 1 is selected the heater lamps should stay on temporarily to bring the temperature of the bath up, whereas when sensor 2 is selected the lamps should remain off until the temperature of the bath has fallen sufficiently. When changing between these temperature sensors the lamps should be observed to see how long it takes for them to begin cycling again.

The analysis of Station 31 was suspended after the first sample bottle was run and it was decided that the readings being produced by the Autosal were far too variable. The machine was left to settle and was re-run the following day when the readings being produced appeared to be stable. It should be noted the sample, that was originally run before analysis was suspended, was re-run despite the bottle being half empty for several hours, so it is likely that the salinity of this sample may have altered from its original value.

On several occasions, the plastic insert was found to be very loose in the sample bottle. This could have potentially led to some evaporation from the sample, which would have altered the salinity. In addition to this, samples were intermittently found to have no plastic inserts. These samples were not analysed on the basis of them being contaminated.

The third sample collected at Station 60 was analysed but the last reading taken from the bottle yielded a very high value 8 counts higher than the previous readings. Due to the large variability an additional reading was taken which was found to be within one count of the first two readings, this value was replaced manually in the spreadsheet.

Sample bottle 8 was discarded from the analysis of Station 70 due to pieces of blue paper towel found in the sample.

At Station 76 a second crate of samples from the bottom -50m bottle (Niskin bottle 2) were collected with the view to assess the stability of the Autosal, however these samples were not actually analysed in the end as the Autosal appeared to have become stable again by this point.

The problem of large variability and instability in the readings from the Autosal continued, consequently, from Station 80 onwards it was decided to allow the software to log the data as usual, but to also perform readings using the visual display. The reason for this was so that we could manually filter out the noisy readings from the Autosal, and have a basis for comparison in the variability of the results. It was found that there was generally very little difference in the final averages calculated by the software and the averages calculated from the visual readings taking by the analyst. The averages taken for processing were those calculated by the software, but if the averages had a difference of more than two counts then a note was made in order to flag the result as potentially noisy.

3.5 Processing

Various additions were made to the Excel spreadsheet files created by the data logging software. However, the files were edited differently according to whether the files contained CTD or TSG data. For TSG samples, the files were amended by adding the collection times of each TSG sample in the following format; *'dddhhmmss'*. For CTD samples unique sample numbers were assigned according to the station number and the position the sample was taken from on the CTD rosette. For example, for the first bottle of Station 67 would be recorded as 6701. It was necessary to consult the CTD log sheets to check whether any bottles were missing due to leaks or misfires. Similarly, special identification numbers were given to standards that were run. This basically consisted of adding another two nines onto the sequential numbers of the standards, e.g. *'999nnn'*. After all the files had been edited accordingly, they were saved as comma delimited csv files.

It was necessary to determine the adjustments to give to the values from each crate due to the choice not to standardise at the beginning of the cruise. From the differences that were determined an adjustment value was chosen according to the variability in adjacent difference values. After these amendments to the files had been made, the files could be processed using Matlab scripts prepared by Gerard McCarthy. Separate scripts existed for CTD and TSG samples. The difference between these scripts is that the TSG script parses out the data in terms of time whereas the script for the bottle samples sorts the data according to sample number. Both scripts perform the task of applying the adjustments from the standards to the respective datasets.

3.6 Assessment

The Guildline 8400B laboratory salinometer has been used heavily on consecutive cruises, and thus in this regard it has been deemed to provide reliable results. However, it is recommended that certain aspects of this piece of equipment be investigated further, such as the high degree of variability in the readings when the machine is set to the 1.90000 suppression.

Table 1: Differences and adjustments calculated for standardisations for each run

Station	Crate	Difference	Adjustment	Run Position	Comments
1	7	-0.00009	-0.00009	?	
2	7	-0.00009	-0.00009	?	
3	7	-0.00009	-0.00009	?	(bottles 41-48)
3	4	-0.00003	-0.00003	?	(bottles 73-77)
4	4	-0.00003	-0.00003	?	
5	6	-0.00003	-0.00003	?	
6	28	-0.00004	-0.00004	?	
7	28&20	-0.00007	-0.00007	?	
8	20&25	-0.00011	-0.00011	?	
9	39	-0.00012	-0.00012	?	
TSG 001	3	-0.00012	-0.00012	?	
10	7	0.00006	0.00006	?	(bottles 25-38)
10	7	0.00022	0.00022	?	(bottles 39-44)
11	28	0.00021	0.00021	?	
12	6	0.00019	0.00019	?	
13	38	0.00018	0.00018	?	
14	4	0.00019	0.00019	?	
15	11	0.0002	0.0002	?	
16	20	0.0002	0.0002	?	
17	39	0.0002	0.0002	?	
18	23	0.0002	0.0002	?	
		0.00021		END	
19	1	0.00019	0.00018	START	
20	1	0.00018	0.00018	END/START	
		0.0002		END	
21	25	0.00018	0.00018	START	
22	25	0.00018	0.00018	END/START	
TSG 002	5	0.00018	0.00018	END/START	
23	11	0.00017	0.00017	END/START	
24	11	0.00017	0.00017	END	
		0.00011		START	
25	4	0.00013	0.00016	MID	
26	25	0.00018	0.00018	MID	
27	6	0.00016	0.00016	END	
28	20	-0.00003	-0.00005	START	Standard left in?
		-0.00006		END	
29	38	-0.00006	0	START	
		0.00004		END	
30	7	0.00004	0.00003	START	
		0.00001		END	
31	23	0.00005	0.00004	START	
32	39	0.00003	0.00003	START	
		0.00003		END	
33	6	0.00003	0.00005	START	
		0.00006		END	
34	25	0.00006	0.00006	START	
		0.00007		END	
35	4	0.00006	0.00006	START	
		0.00006		END	
TSG 003	3	0.00006	0.00006		

36	39	0.00012	0.00012	START	
37	11	0.00012	0.00011	END/START	
38	25	0.0001	0.00008	END/START	
39	28	0.00005	0.00009	END/START	
		0.00012		END	
40	23	0.00013	0.00012	START	
TSG 004	5	0.00012	0.00012	END/START	
41	6	0.00012	0.00012	END/START	
42	20	0.00003	0.00007	END/START	Standard left in?
		0.00011		END	
43	11	0.00024	0.00009	START	
44	39	0.00008	0.00009	END/START	
45	7	0.0001	0.00009	END/START	
46	4	0.00008	0.00009	END/START	
		0.00011		END	
47	1	0.00023	0.00011	START	MilliQ left in?
TSG 005	3	0.0001	0.00011	END/START	
49	23	0.00011	0.00011	END/START	
50	11	0.00011	0.00011	END/START	
51	28	0.00013	0.00011	END/START	
		0.00011		END	
52	20	0.00015	0.00011	START	
53	6	0.00012	0.00012	END/START	Warm standard
54	39	0.00004	0.00012	END/START	Warm standard
55	7	0.00005	0.00012	END/START	Warm standard
		0.00003		END	Warm standard
TSG 006	5	0.00006	0.00012	START	Warm standard
56	25	0.00011	0.00012	END/START	
57	28	0.00012	0.00012	END/START	
58	11	0.00012	0.00009	END/START	
59	20	0.00004	0.00009	END/START	
		0.00009		END	
60	38	0.00014	0.00013	START	
61	11	0.00013	0.00013	END/START	
62	6	0.00013	0.00013	END/START	
63	23	0.00013	0.00013	END/START	
		0.00012		END	
TSG 007	3	0.00017	0.00013	START	
64	25	0.00011	0.00012	END/START	
65	1	0.00012	0.00012	END	
66	28	0.00015	0.00013	START	
67	7	0.00012	0.00013	END/START	
68	11	0.00014	0.00013	END/START	
69	6	0.00012	0.00012	END/START	
		0.00009		END	
70	1	0.00014	0.00007	START	
71	38	0.00006	0.00007	END/START	
TSG 008	5	0.00008	0.00007	END/START	
		0.00008		END	
72	4	0.00008	0.00007	START	
73	25	0.00007	0.00006	END/START	
74	11	0.00006	0.00005	END/START	

75	39	0.00004	0.00006	END/START	
		0.00007		END	
76	20	0.00005	0.00006	START	
77	6	0.00008	0.00006	END/START	
78	38	0.00008	0.00005	END/START	
		0.00003		END	
79	1	0.00013	0.00013	START	
80	11	0.00014	0.00013	END/START	
81	23	0.00012	0.00012	END/START	
		0.00011		END	
82	28	0.00015	0.00013	START	
TSG009	3	0.00012	0.00013	END/START	
83	4	0.00013	0.00013	END/START	
		0.00013		END	
84	39	0.00009	0.00011	START	
85	6	0.00011	0.00011	END/START	
86	25	0.00005	0.00011	END/START	
		0.00011		END	
87	1	0.00011	0.00009	START	
88	23	0.00009	0.00009	END/START	
TSG010	5	0.00007	0.00009	END/START	
89	7	0.00004	0.00009	END/START	
90	6	0.00012	0.00009	END/START	
		0.00008		END	
91	11	0.00014	0.00013	START	
92	28	0.00014	0.00013	END/START	
93	20	0.00013	0.00013	END/START	
94	7	0.00013	0.00011	END/START	
		0.00009		END	
95	6	0.00008	0.00007	START	
96	4	0.00007	0.00007	END/START	
97	38	0.00008	0.00007	END/START	
98	25	0.00006	0.00007	END	
		0.00007			
99	1	-0.00001	0	START	
100	39	0.00001	0	END/START	
101	11	-0.00002	0	END/START	
TSG 11	3	0	0	END/START	
		0	0	END	
102	23	-0.00009	-0.00005	START	
103	6	-0.00006	-0.00005	END/START	
104	20	-0.00005	-0.00003	END/START	
		-0.00001	0	END	
105	4	0.00002	0.00001	START	
106	11	0.00001	0.00001	END/START	
107	1	-0.00001	0	END/START	
		0.00001	0	END	
108	25	0.00002	0.00001	START	
109	7	0	0	END/START	
110	6	0	0	END/START	
		0	0	END	
111	1	-0.00003	-0.00002	START	

TSG 12	5	-0.00002	-0.00001	END/START	
		0	0	END	
112	11	0.00001	0.00001	START	
113	20	-0.00006	-0.00004	END/START	
114	38	-0.00002	-0.00003	END/START	
115	39	-0.00002	-0.00001	END/START	
116	23	0	0	END	
117	23	0.00001	0.00001	START	
TSG 13	3	0.00001	0.00001	END/START	
118	28	-0.00001	0	END/START	
		0.00001	0.00001	END	

David Hamersley, Gerard McCarthy and Lorna McLean

4. Inorganic Nutrient Analysis

4.1 Method

Seawater was collected for the analysis of micro-molar concentrations of dissolved inorganic nutrients; nitrate and nitrite (hereafter nitrate), phosphate and silicate. Samples were collected directly into 30ml plastic pots after these had been rinsed with sample water at least three times. When required, samples were stored in a fridge at approximately 4°C until analysis. Samples were usually analysed within 4 hours of collection.

In general, analyses were started within 30 minutes of sample collection using a segmented continuous-flow Skalar San^{plus} Autoanalyser set up for analysis and data logging with the Flow Access Software version 1.3.11. This system follows the method described by *Kirkwood (1996)*, with the exception that the pump rates through the phosphate line were increased by a factor of 1.5, which improves reproducibility and peak shape. In addition, a dilution loop (2.9x, Figure 17) was set up by Dr. Paul Morris for cruises JC030-32 in anticipation of high silicate concentrations within the study regions.

For JC032 the analysis was calibrated using the set of standards shown in Table 2. Top nitrate and silicate standards were based on the highest values reported by *Siedler et al., (1996)*. The phosphate calibration range of standards was left as used during JC030 and JC031.

Table 2 shows target and actual standard concentrations. Target concentrations are values aimed at when preparing working standards (i.e., every day used standards). Actual concentrations are values corrected by taking into account *i)* the weight of the dry chemical used to prepare a given standard (Table 3) and, *ii)* the calibrated volume of the pipettes used for diluting stock standards (i.e., high concentration standards).

Stock standard solutions of ~5µmol L^{-1} prepared in Milli-Q water were used to produce working standards. Working standards were prepared in a saline solution (40g NaCl in 1L of Milli-Q water, here after artificial seawater), which was also used as a diluent for the analysis.

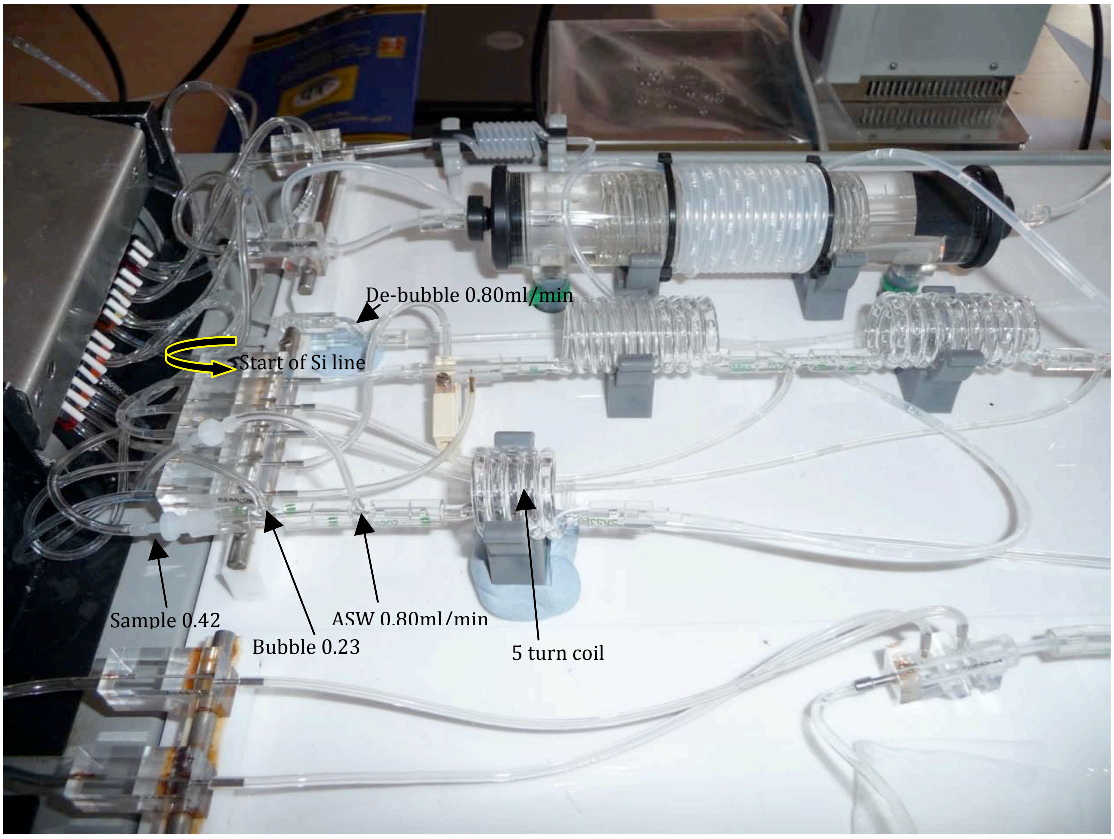

Figure 17: Details of the dilution loop for the silicate line

Table 2: Set of calibration standards (*Std*) used for dissolved inorganic nutrient analysis. Bold numbers are target concentrations, otherwise actual concentrations. Concentration units are μmol L^{-1}

	Nitrate		Phosphate		Silicate	
Std 1	**40**	39.89	**4.0**	4.0	**120**	120.05
Std 2	**25**	24.93	**3.0**	3.0	**80**	80.03
Std 3	**15**	14.96	**2.0**	2.0	**40**	40.02
Std 4	**5**	4.99	**1.0**	1.0	**10**	10.00
Std 5	**1**	1.00	**0.5**	0.5	**1**	1.00
Std 6	-----------------		---------------		**140**	140.05

Table 3: Compounds used to prepare stock standard solutions, weight dissolved in 1L of Milli-Q water and Molarity of the solution

Compound	Weight (g)	Molarity 1L stock solution
KH_2PO_4	0.6820	**5.0115**
Na_2SiF_6	0.9445	**5.0224**
$NaNO_3$	0.4255	**5.0061**
$NaNO_2$	0.3465	**5.0221**

At the start of the cruise all labware used was washed with 10% HCl and rinsed with Milli-Q water, and was similarly treated prior to any further use.

The autoanalyser was washed through with 10% Deacon 90 and with Milli-Q water for at least 30 minutes each after each run, except when the time between stations was not enough to do so, in which case the autoanalyser was left with the reagent tubing connected ready for the next run. New pump tubing was installed at the start of the cruise and turned around to use the other half of the tubing just before starting the main crossing of the Atlantic section. Tubing was replaced again on the 7th April, just before Station 79. The bulbs in the two detectors were also replaced at the start of the cruise. During JC030 it was observed this produced a smoother baseline and cleaner peaks.

Time series of baseline, instrument sensitivity, calibration curve correlation coefficient, and nitrate reduction efficiency were compiled to check the performance of the autoanalyser over the course of the cruise.

4.2 Observations

1. Most of the stations from the three transects made across the Brazilian boundary current and close to the Namibian coast were analysed in pairs or in sets of three stations over shallow waters. However, stations along the main trans-Atlantic section were individually analysed. Station 22 was an ADCP cast without any water sampled. Station 48 was renamed Station 49 due to an issue with the winch which required two casts to be made at the same station. CTD 48 was not sampled.

2. New batches of artificial seawater were prepared almost once a week and 3 sets of calibration standards were produced and used from Stations 1, 50 and 89, respectively. Both artificial seawater and standards were analysed prior to being used in order to check for contamination and consistency.

3. During the run for Stations 14 and 15 the baseline of the nitrate and silicate analysis changed suddenly and affected almost half of the calibration standards. Peak heights (in digital units) from the three nutrient signals were checked for consistency with previous and following runs. It was determined that the phosphate line was not affected, but the silicate and nitrate signals needed to be edited in the Flow Access software individually. This was done by comparing peak heights and cancelling the signals that were evidently wrong, and by correcting the peaks that were not properly picked by the software. After correcting these errors, results seemed consistent with previous and further analyses, although bulk nutrient results were higher relative to other runs. This may suggest that results from this run may have been slightly overestimated by about 0.05, 1 and 2µmol L^{-1} at concentrations over 1.5, 25 and 80µmol L^{-1} for phosphate, nitrate and silicate respectively (with the effect decreasing at lower concentrations). Attention should be paid to these two stations when producing contour sections or depth profiles in order to verify whether they are consistent with adjacent stations.

4. The auto-sampler we started the cruise with broke on the 4th April 2009. The sample tray would start spinning all of a sudden in the middle of a run, which thus needed to be re-started. Initially, the sampler would work after shutting it off and turning it on again, but after three further runs it stopped working. One of the technicians looked into the problem, but could not fix it. This did not present a problem for the analysis since spare auto-samplers were brought onboard.

5. Bottom samples (in general Niskin bottles 1 to 3 or 4) at Station 9 and Stations 35 to 57 exhibited silicate concentrations higher than the top silicate standard (i.e., 120µmolL^{-1}). Since concentrations higher than this were only expected within the deepest section of the western South Atlantic Basin, the calibration set of standards (i.e., Table 3) was kept unchanged. However, the following steps were taken. Samples drawn from Niskin bottles 1 to 4 were taken in duplicate. One of these were analysed unmodified and another was analysed whilst 50% diluted. In addition, a 140µmol-Si L^{-1} standard was prepared and analysed unmodified and also 50% diluted in every run from Station 42 to 59. This standard was measured in order to test whether the calibration equation held up to this concentration and also to test whether diluting the samples produced reliable results. The mean concentration of this silicate standard was 140.3±1.7µmol L^{-1} and the mean concentration of the 50% diluted standard times 2 was 139.9±1.7µmol L^{-1} (Figure 18). This suggests *i)* that the calibration equation holds at least up to this concentration and *ii)* that diluting samples also produced reliable results. Having processed these measurements, it was decided to keep the original high concentration sample values unmodified since these were never higher than 140µmol-Si L^{-1}. In case these values require further revision, it is possible to include the extra silicate standard as part of the calibration set in the Flow Access software and results can be recalculated. However, given that the results above were satisfactory, this process was deemed unnecessary while on the cruise.

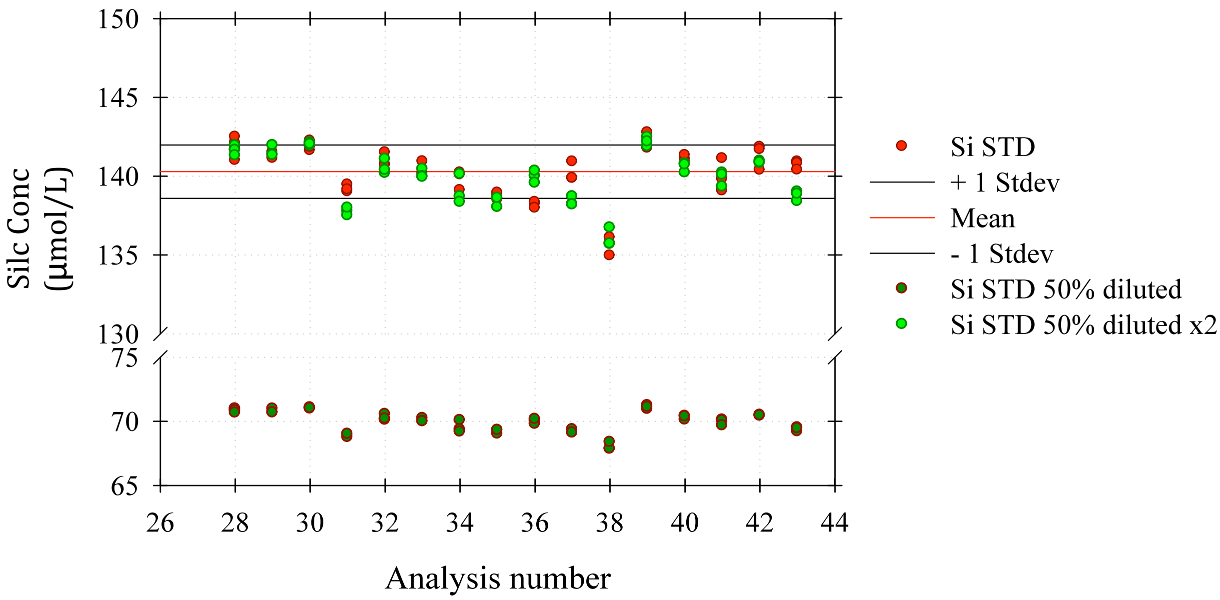

Figure 18: 140µmol L^{-1} silicate standard measured unmodified (red dots) and 50% diluted (dark green dots). Light green is the 50% diluted standard times 2. The red line represents the mean concentration of the measurements and the black lines are ±1 standard deviation.

6. Niskin bottle number 3 produced anomalous results at Stations 81, 85, 91, 93, 96, 105 and 107. These were characterised by higher levels of phosphate and nitrate, low levels of silicate and low levels of dissolved oxygen relative to adjacent Niskin bottles. These notes were given to the physics group in order to compare results with salinity determinations.

4.3 Performance of the Analyser

The performance of the autoanalyser was monitored by producing time series plots of the following parameters: standards concentration, baseline, calibration slope (instrument sensitivity), calibration correlation coefficient, nitrate reduction efficiency, low nutrient seawater and bulk nutrient seawater. These are plotted against run/analysis number rather than date or station number given that runs sometimes included 2 or 3 stations, with an average of 3 runs per day. A total of 97 plus 3 test runs were done.

The precision of the method was determined by monitoring the variations of the complete set of standards measured throughout the cruise. Results of the standard measurements are summarised in Table 4 and shown in Figure 19. Triplicate analyses were performed on the first and last sample of every station and sometimes a third sample was also analysed as a replicate. These showed that the sample variability of replicates from a given mean concentration was in general <0.8% (n=459). The limits of detection of this method were determined from the concentrations of lowest standard of each nutrient. The limits of detection of this method during JC032 were 0.03µmol L^{-1} for PO_4^{3-}, 0.15µmol L^{-1} for NO_3^- and 0.2µmol L^{-1} for $Si(OH)_4$.

Table 4: Mean and variation of all standards measured, and precision of the analysis at each concentration (µmol L^{-1})

	NO_3^-	Prec.	PO_4^{3-}	Prec.	$Si(OH)_4$	Prec.
Std 1	39.85 ± 0.39	1%	3.99 ± 0.02	0.4%	120.03 ± 0.6	0.5%
Std 2	24.95 ± 0.22	0.9%	3.01 ± 0.01	0.5%	79.99 ± 0.34	0.4%
Std 3	14.79 ± 0.18	1.2%	2.01 ± 0.01	0.6%	39.92 ± 0.19	0.5%
Std 4	4.87 ± 0.1	2.0%	1.00 ± 0.01	0.9%	9.94 ± 0.07	0.7%
Std 5	1.05 ± 0.05	4.6%	0.50 ± 0.01	1.7%	1± 0.07	6.9%

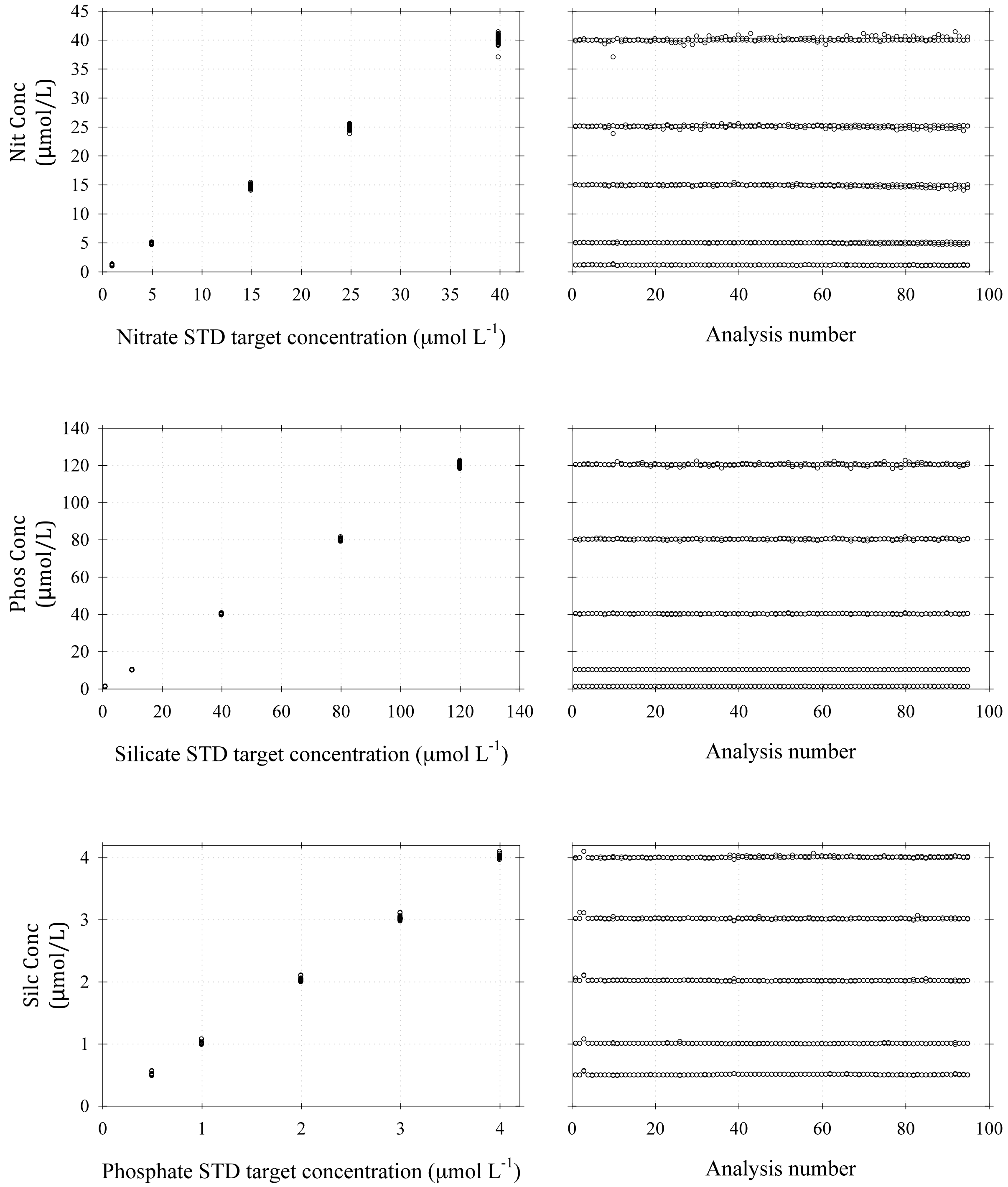

Figure 19: Complete set of 'measured' standards plotted against the 'prepared or intended' concentration (left side panels). 'Measured' standards plotted against respective analysis number (right side panels)

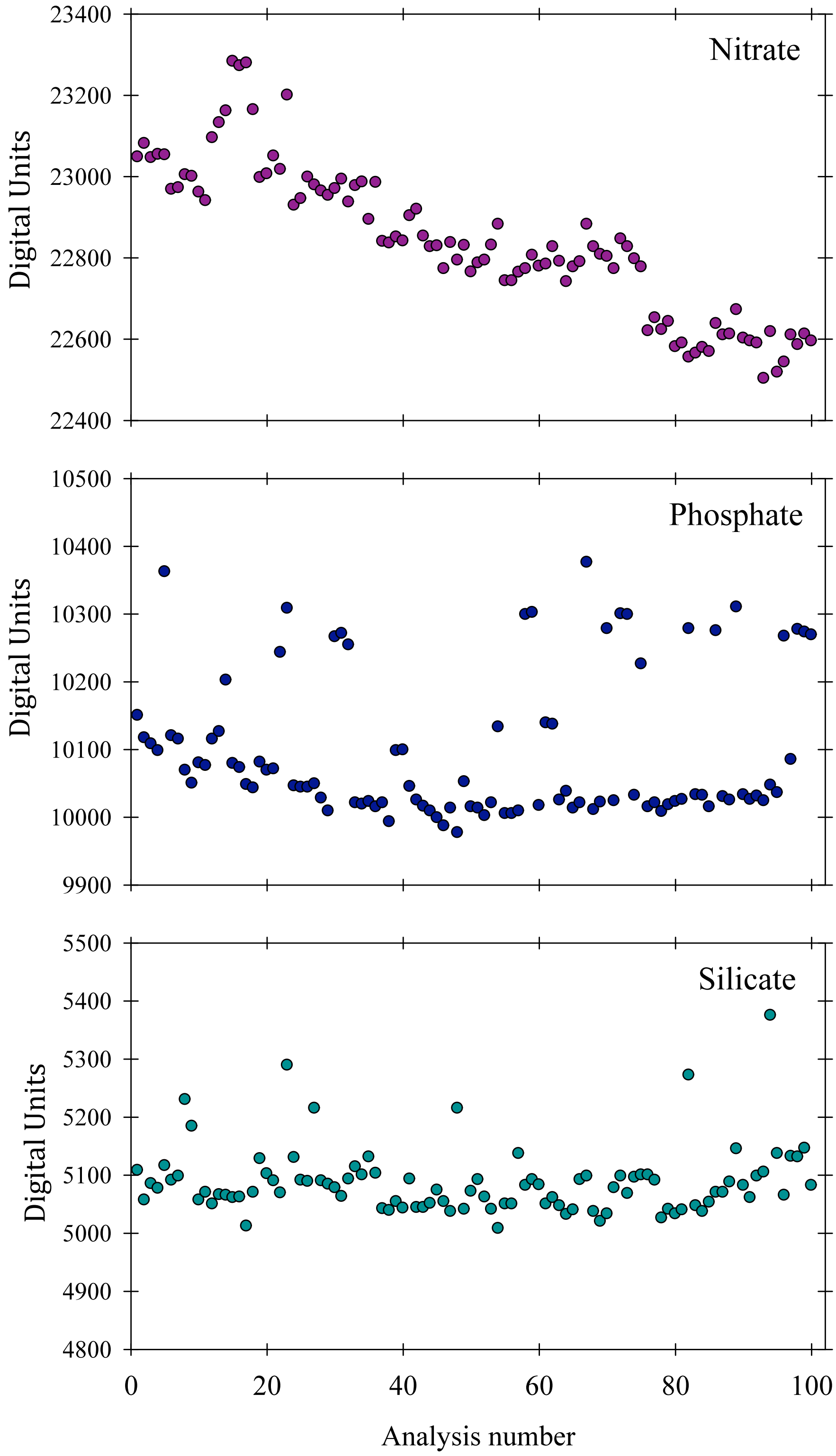

Figure 20: Baselines time series. The baseline for nitrate has a trend of decreasing digital units with time

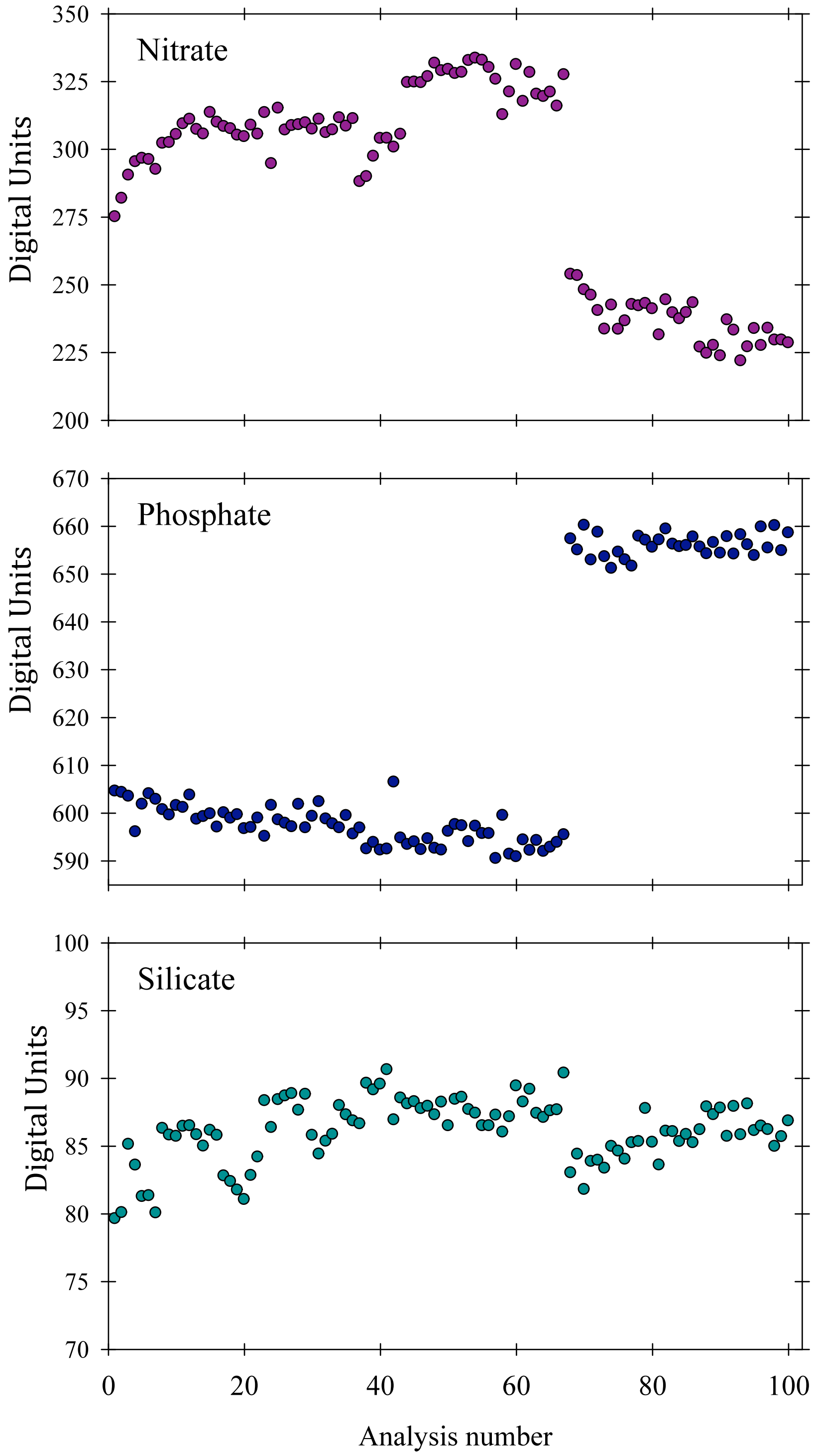

Figure 21: Calibration slopes time series. These show the sensitivity of the three different autoanalyser channels (i.e., nitrate, silicate and phosphate), with increasing values (in digital units) indicating better sensitivity. The calibration slopes for nitrate and silicate decrease with time, though the slope for phosphate shows the opposite trend. This shift however, does not affect analysis results as suggested by the reproducibility of bulk nutrients (Figure 24)

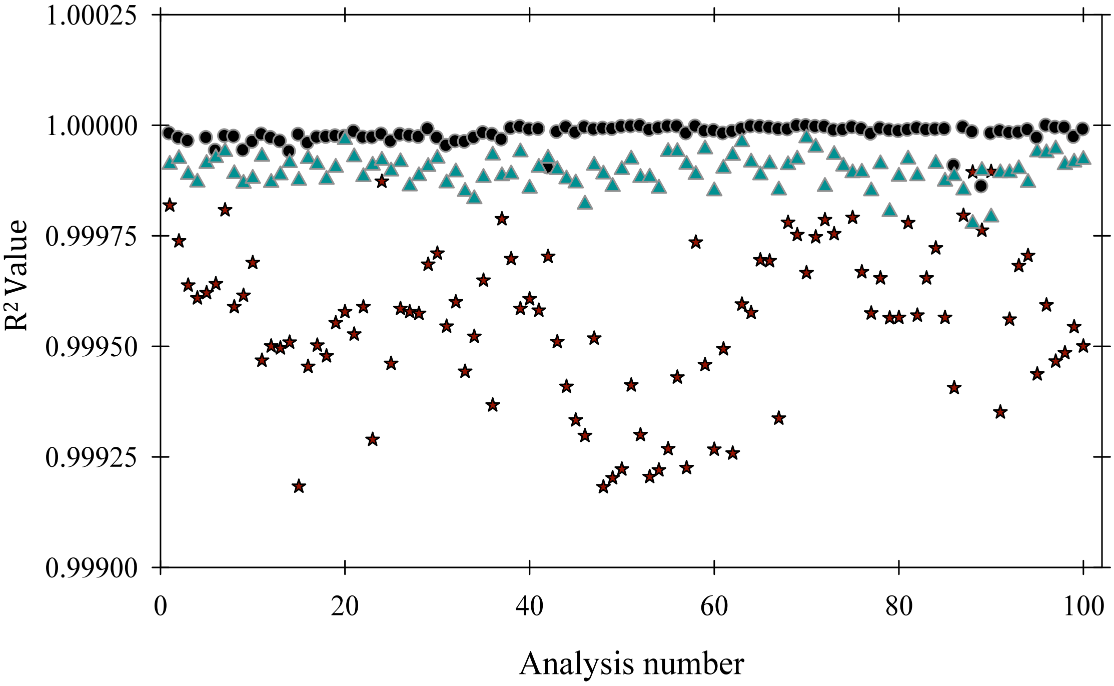

Figure 22: Calibration correlation coefficients. All r2 values were better than 0.999.

4.4 Low Nutrient Seawater

Certified Ocean Scientific Instruments Ltd. (OSIL), Low Nutrient Seawater (LNSW) was measured in duplicate in every run in order to test artificial seawater for contamination. LNSW has been also used as a quality control in order to check for the reproducibility of low nutrient concentrations. However, during the ANDREX cruise (JC030) measurements of LNSW showed increasing nitrate concentrations with time. This was also observed during JC032 (Figure 23, black dots). A simple experiment was carried out in order to test Nitrile gloves as a potential source of nitrate, since this was the only cause of contamination thought of in the lab. Two nutrient pots were filled with Milli-Q water. A small piece of a Nitrile glove was placed inside one of the pots, and the other pot was left as a control. Both were left for 24 hours and the contents were then measured. The pot with the piece of glove inside produced nitrate concentrations higher than 40µmol L^{-1}, while the control produced undetectable levels. The original container of LNSW has a screw cap and a plastic insert (similar to those used for salinity bottles). This insert has to be removed every time LNSW is used, thus if gloves are worn this would contaminate the contents gradually. We opened a new bottle of LNSW and decided to remove the insert from it, leaving only the screw cap. This seemed to have stopped the LNSW from being contaminated (see Figure 23). However, following the replacement of the tubing, one of the duplicates is affected by the carry-over from a previous high concentration standard, resulting in higher concentrations being calculated. This same effect can be seen for silicate measurements (Figure 23, green dots). Phosphate was always undetectable, suggesting there are no major sources of phosphate carry-over or contamination during the analysis or while handling the samples.

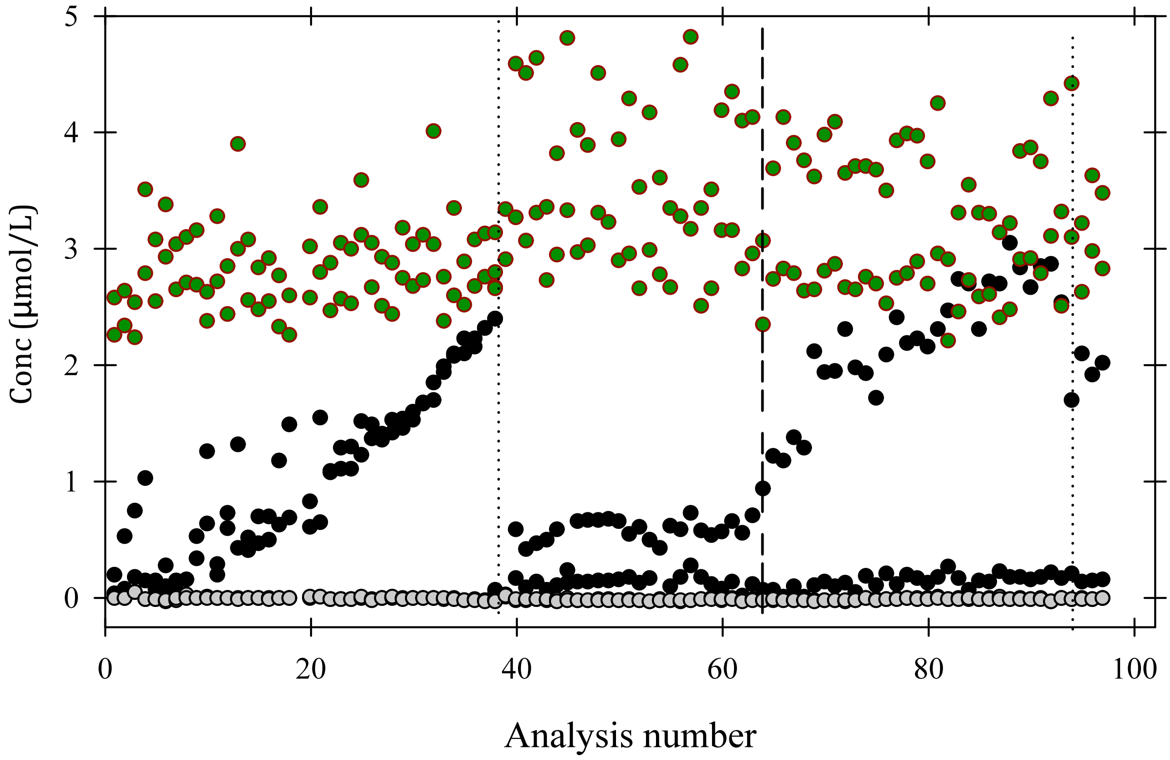

Figure 23: Low Nutrient Seawater (LNSW) time series. Green dots represent silicate, black dots represent nitrate and grey dots represent phosphate concentrations. Dotted lines show when a new LNSW batch was used. Dashed line shows when the autoanalyser tubing was replaced, after which the carry-over effect in the first replicate of the nitrate line increased. LNSW was analysed in duplicate.

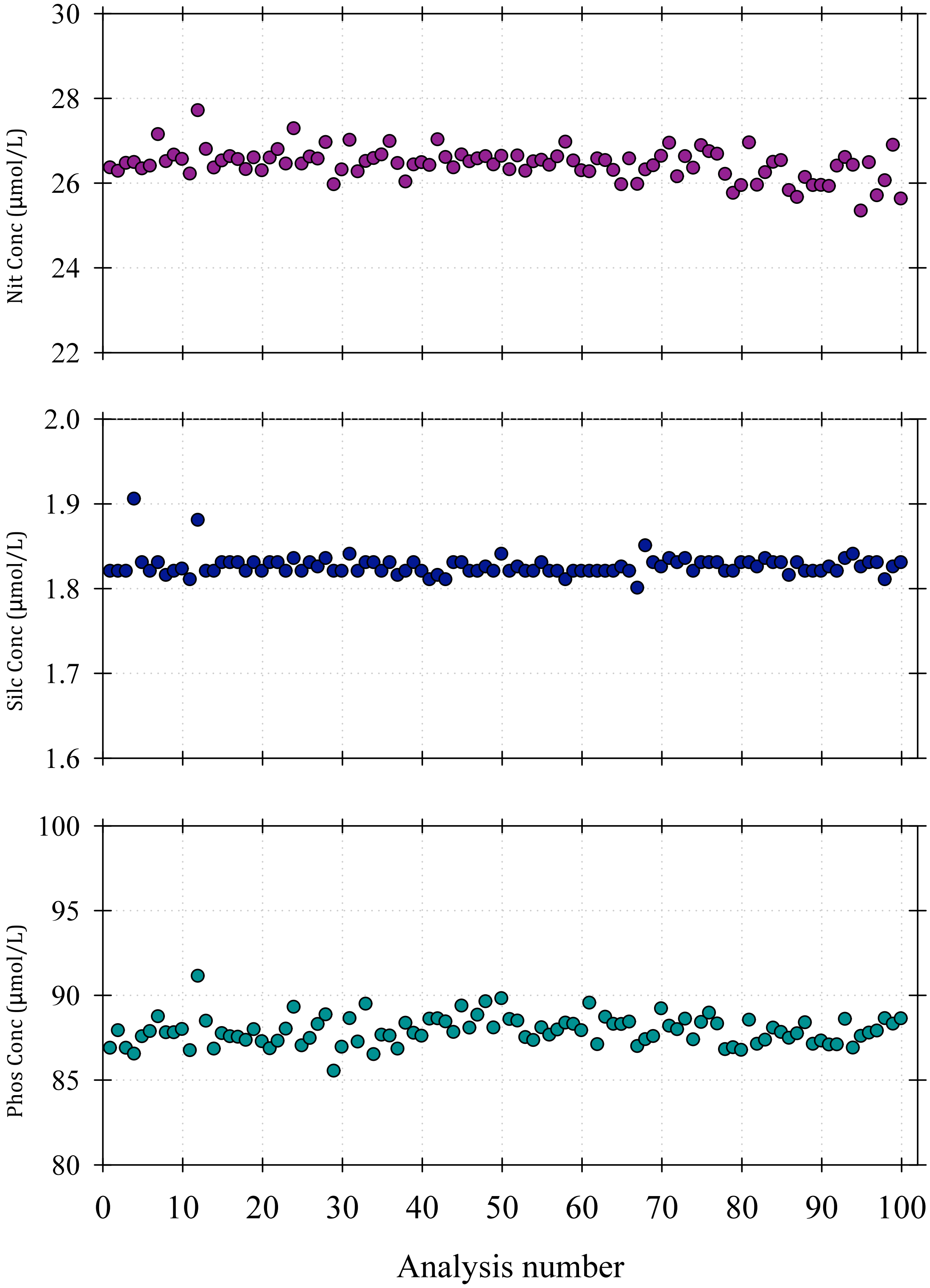

Figure 24: Time series of bulk nutrient seawater concentrations. The average concentration was 26.4±0.4µmol L^{-1}, 87.9±0.8µmol L^{-1}, 1.83±0.01µmol L^{-1} ($\overline{x}$ ±σ, n=100) for nitrate, silicate and phosphate respectively.

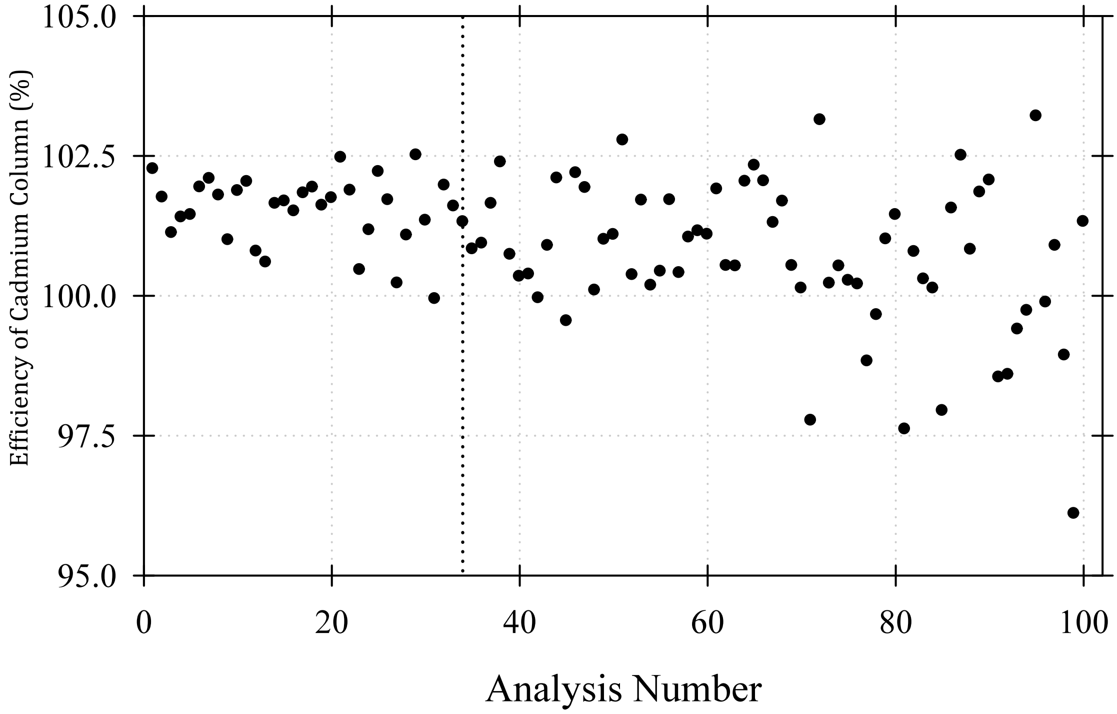

Figure 25: The efficiency of the cadmium column in reducing nitrate to nitrite is tested by measuring a nitrite standard of similar concentration to the top nitrate standard (40µmol L^{-1} for JC032). This figure shows the ratio of nitrate to nitrite for all analysis carried out. A new cadmium column was installed at the beginning of the cruise and this was further replaced on the 25/03/2009 just before CTD 49 (run 34). The average cadmium reduction efficiency was 101±1%.

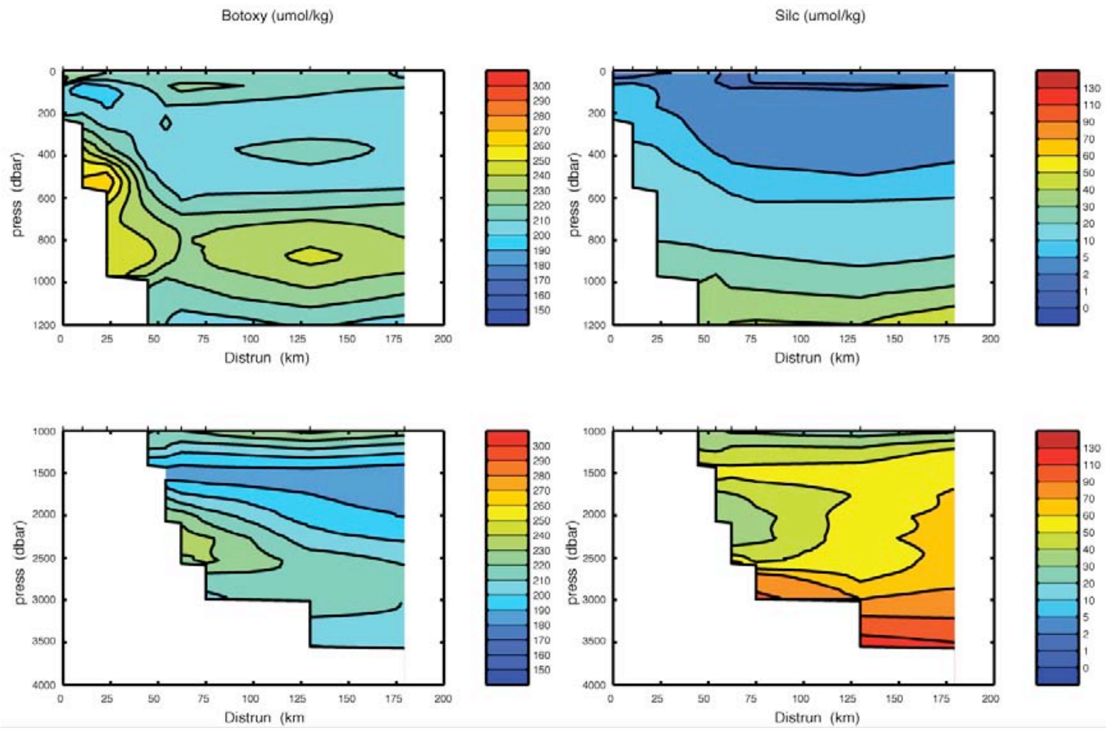

Figure 26: Bottle oxygen (left) and Silicate (right) parameters for the first Brazil Current transect

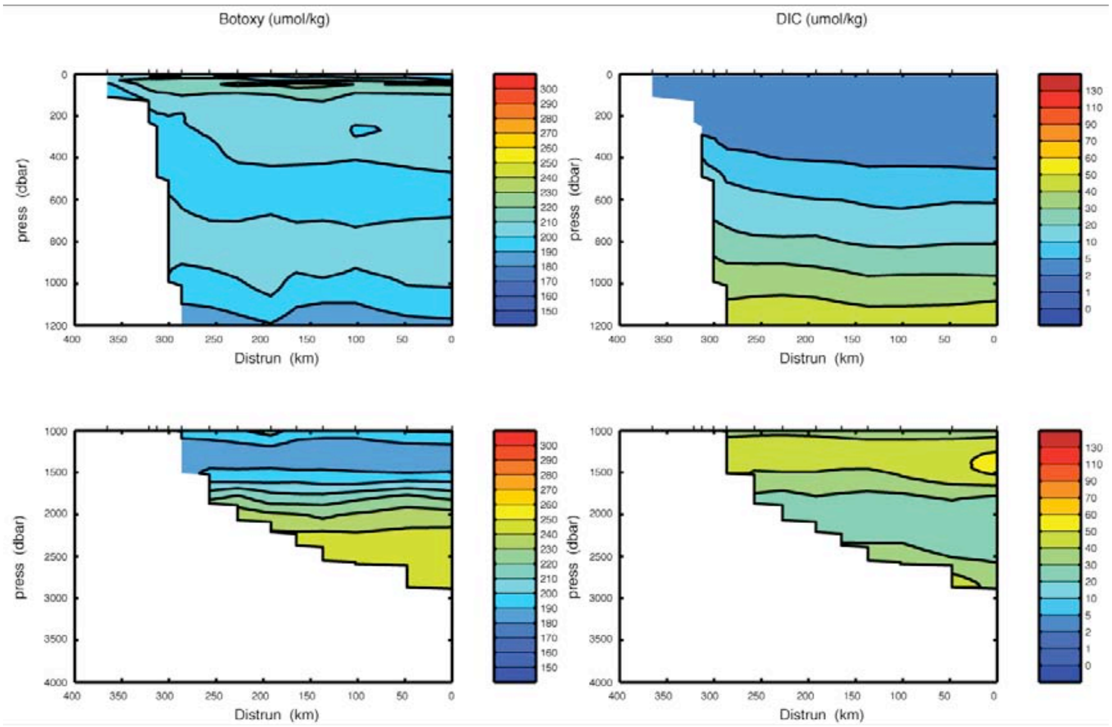

Figure 27: Bottle oxygen (left) and Silicate (right) parameters for the second Brazil Current transect

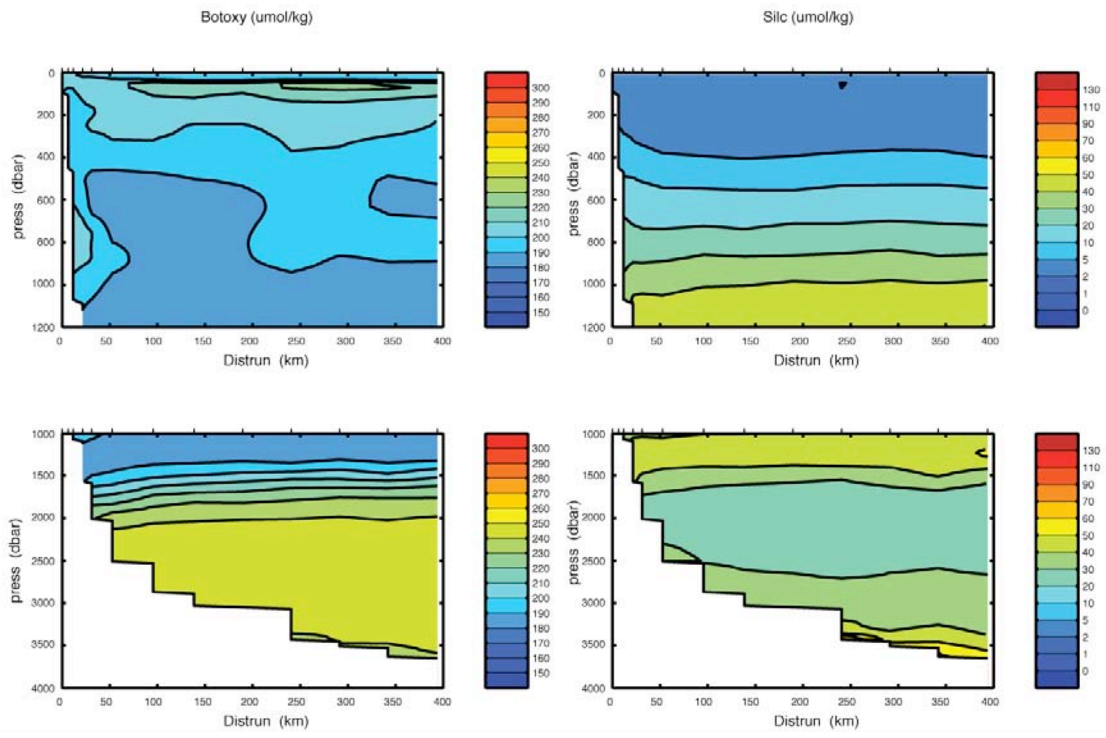

Figure 28: Bottle oxygen (left) and Silicate (right) parameters for the third Brazil Current transect

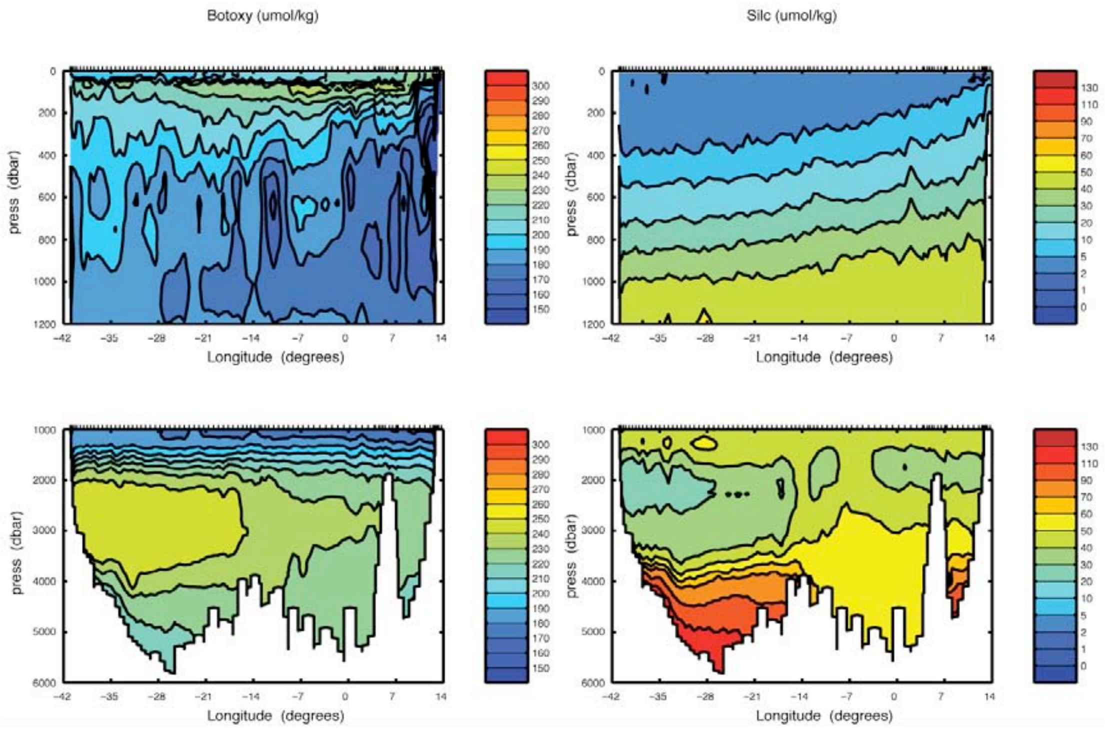

Figure 29: Bottle oxygen (left) and Silicate (right) parameters for the main transect

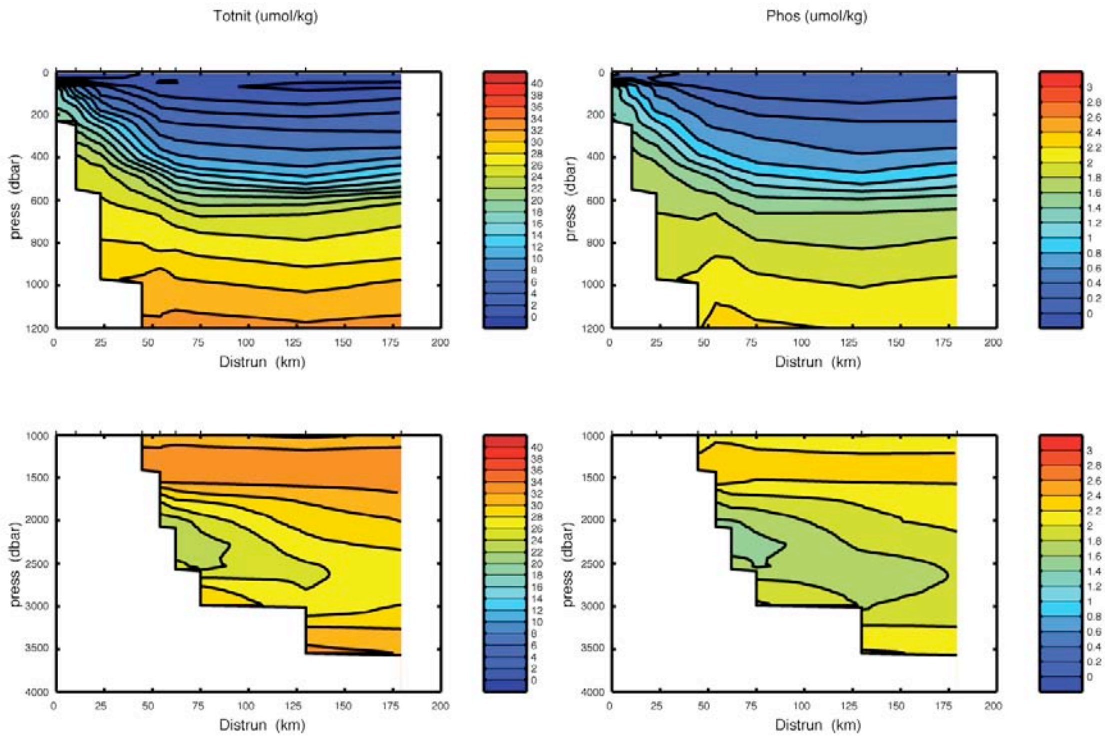

Figure 30: Total nitrate (left) and phosphate (right) parameters for the first Brazil current transect

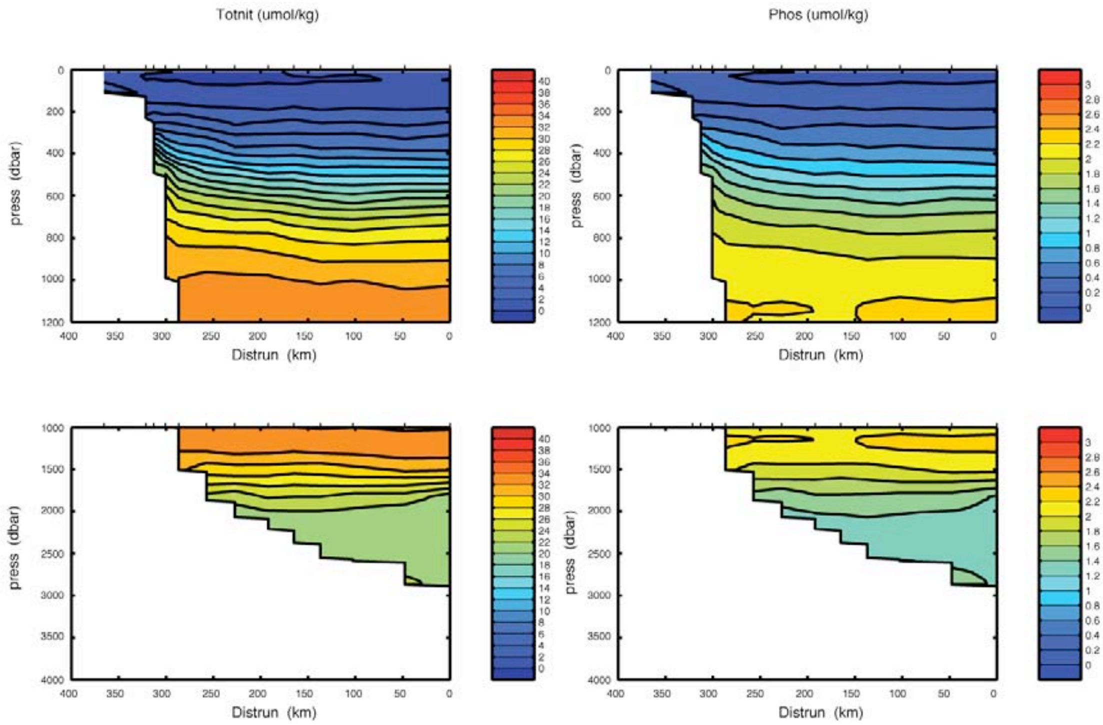

Figure 31: Total nitrate (left) and phosphate (right) parameters for the second Brazil current transect

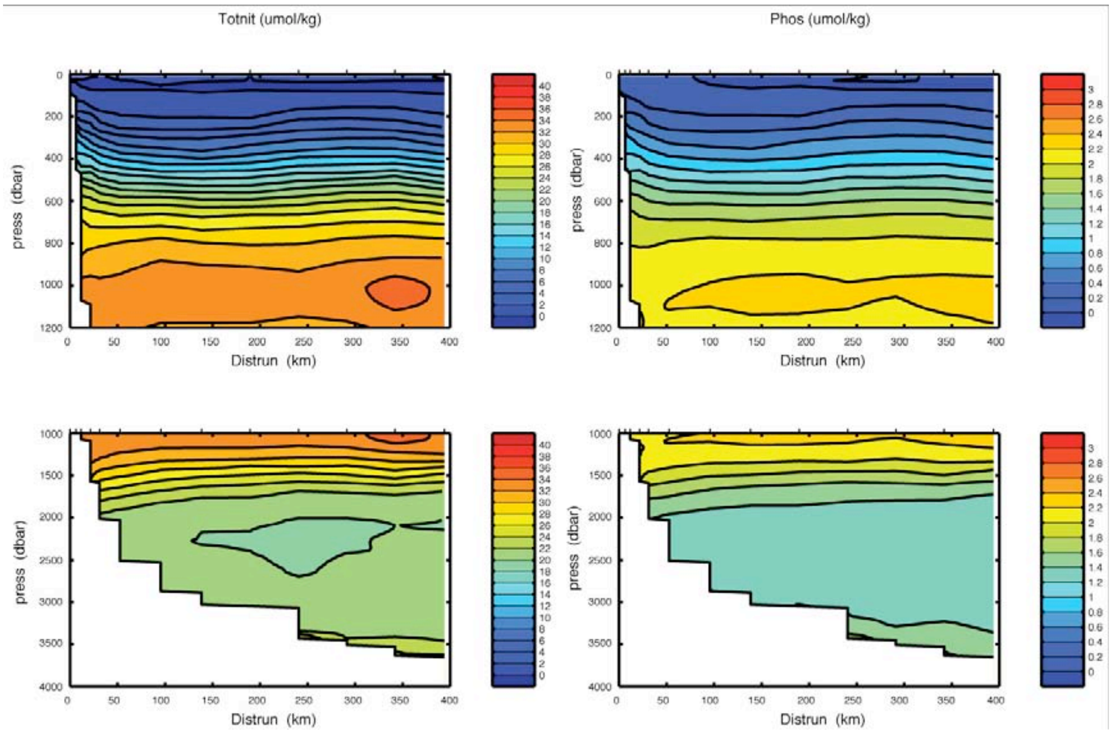

Figure 32: Total nitrate (left) and phosphate (right) parameters for the third Brazil current transect

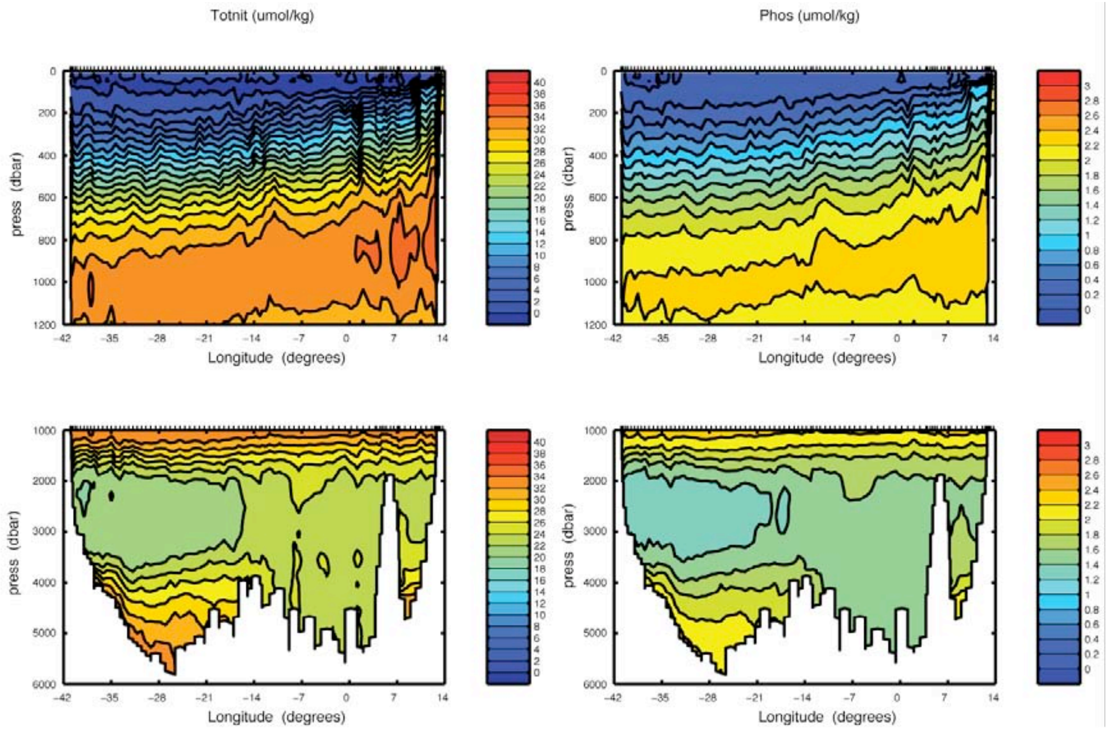

Figure 33: Total nitrate (left) and phosphate (right) parameters for the main transect

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5. Dissolved Oxygen

All stations occupied during JC032 were sampled for dissolved oxygen (DO). Sampling for DO was done just after CFCs were sampled. Seawater was collected directly into pre-calibrated glass wide neck bottles using a Tygon® tube. Before the sample was drawn, bottles were flushed with seawater for several seconds (approximately 3 times the volume of the bottle) and the temperature of the water was recorded simultaneously using a handheld thermometer. The fixing reagents (i.e., manganese chloride and sodium hydroxide/sodium iodide solutions) were then added. Care was taken to avoid bubbles inside the sampling tube and sampling bottle. Samples were thoroughly mixed following the addition of the fixing reagents and were then kept in a dark plastic crate for 30-40 min to allow the precipitate to settle to <50% the volume of the bottle. Once the precipitate had settled all samples were thoroughly mixed for a second time in order to maximize the efficiency of the reaction. Analyses were carried out within two hours of sample collection.

5.1 Methods

DO determinations were made using a Winkler Ω-Metrohm titration unit (794 DMS Titrino) with an amperometric system to determine the end point of the titration (*Culberson and Huang, 1987)*. Chemical reagents were prepared in advance at NOCS following the procedures described by *Dickson (1994)*. Recommendations given by *Dickson (1994)* and by *Holley and Hydes (1994)* were adopted. In general, thiosulphate calibrations were carried out every 4-5 days using a 1.667µmol L^{-1} certified OSIL iodate standard. Calibration values are summarised in Table 5 and shown in Figure 33. Calculations of oxygen concentrations were facilitated by the use of an Excel spreadsheet provided by Dr. Richard Sanders (NOCS). This spreadsheet has been modified/corrected to include the calibrated dispensing volumes of the pipettes used (i.e., reagents and iodate standard additions have been calibrated).

5.2 Observations

1. Generally, replicate measurements of randomly selected samples are carried out in order to test for reproducibility. At least 1 Niskin bottle is always sampled in duplicate and any misfires are used to either duplicate other Niskin bottles or to sample in triplicates. In recent cruises (e.g., ASBO I and ASBO II) the mean difference between replicates was to be better than 0.3µmol-O_2 L^{-1}. However, we have encountered problems with a batch of oxygen bottles recently bought (July 2007). Bottle lids started falling apart due to manufacturing defects. This situation prompted us to use bottles of different makes and lid designs. As a consequence, the mean difference of replicate samples during JC030 (ANDREX) was ≤0.8µmol-O_2 L^{-1}.

2. During JC030 it was also noticed that in many cases the first oxygen measurement was producing lower concentrations than expected (e.g., relative adjacent samples). It was thought one reason for this might be that after the first titration, the thiosulphate within the dispenser may have been slightly diluted by the sample being titrated since after the endpoint is detected the system waits for a few seconds until the reading is stable. This would actually indicate that in the following titrations required by the thiosulphate would be higher if diluted. Another potential reason was that the calibrated glass bottle designated to sample the first Niskin bottle was responsible for these results. Unfortunately, due to a medical emergency resulting in the early termination of JC030, these ideas were not tested then.

3. During JC032 it was confirmed that using old bottles of different design and with worn out lids produced variable results. It was thus decided to form a single set with the best bottles available and this set was used for most of the cruise. Reproducibility improved this way.

4. During JC032 it was also found that placing the electrode in artificial seawater for at least 5 minutes before starting a set of titrations produced better reproducibility of the first replicates. In addition, a small amount of thiosulphate was dispensed prior to the first replicate analysis. The problem of having relatively low concentrations in the first oxygen bottle titrated was solved in this way.

5. It was decided that the first bottle would always be replicated and any misfires would be used to replicate any other sample. In total, 218 replicates (2 or 3) were performed and the results of these showed that the mean difference of replicate measurements was ≤0.6μmol-O_2 L^{-1} (Figure 34).

6. In addition to showing calibration results, Table 5 indicates the station numbers where a given calibration was used to calculate oxygen concentrations. A new solution of thiosulphate was prepared on the 26th March 2009, and a calibration was done right after. Later calibrations however, suggested the first one was rather odd. Even when blank and standard volume titres change between calibrations, the difference between them is constant (Table 5, STD-BLK). Consequently, oxygen concentrations from stations where the odd calibration was originally used were recalculated with a calibration performed on the 31st March 2009 instead. At a later date, 19th April 2009, analysis of the residuals of the measurements versus the CTD oxygen sensor suggests that the stations corrected for the above issue, were actually offset and these were then re-calculated again with the original calibration. This issue will be reviewed further.

7. Niskin bottle number 3 produced anomalous results at various stations. Usually lower relative to adjacent Niskin bottles. See point 6 in the nutrients section.

8. A calibration was done on the 17th April 2009, but produced odd values and thus was not used. A final calibration done on the 19th April 2009, confirms this was the case and suggests the thiosulphate solution remained stable throughout its use (Table 5).

Table 5: JC032 O_2 determinations; number of thiosulphate calibrations, dates on which calibrations were carried out, mean blank titre volume (BLK), standard titre volume (STD), STD minus BLK, molarity of thiosulphate solution and stations affected by each calibration (*new thiosulphate solution prepared).

Calibration no.	Date	BLK (mL)	STD (mL)	STD-BLK	Thiosulphate Molarity	Used from CTD No.
1	07/03/2009	0.0026	0.4969	0.4943	0.1998	1
2	12/03/2009	0.0029	0.2522	0.2493	0.1981	10
3	21/03/2009	0.0030	0.2519	0.2489	0.1984	36
4*	26/03/2009	0.0022	0.2499	0.2477	0.1994	49
5	31/03/2009	0.0006	0.2474	0.2468	0.2001	60
6	02/04/2009	0.0015	0.2482	0.2467	0.2002	63
7	06/04/2009	0.0019	0.2481	0.2462	0.2006	76
8	10/04/2009	0.0017	0.2485	0.2468	0.2001	85
9	14/04/2009	0.0015	0.2479	0.2464	0.2004	94
10	17/04/2009	0.0021	0.2515	0.2494	0.1980	---
11	19/04/2009	0.0019	0.2486	0.2467	0.2001	---

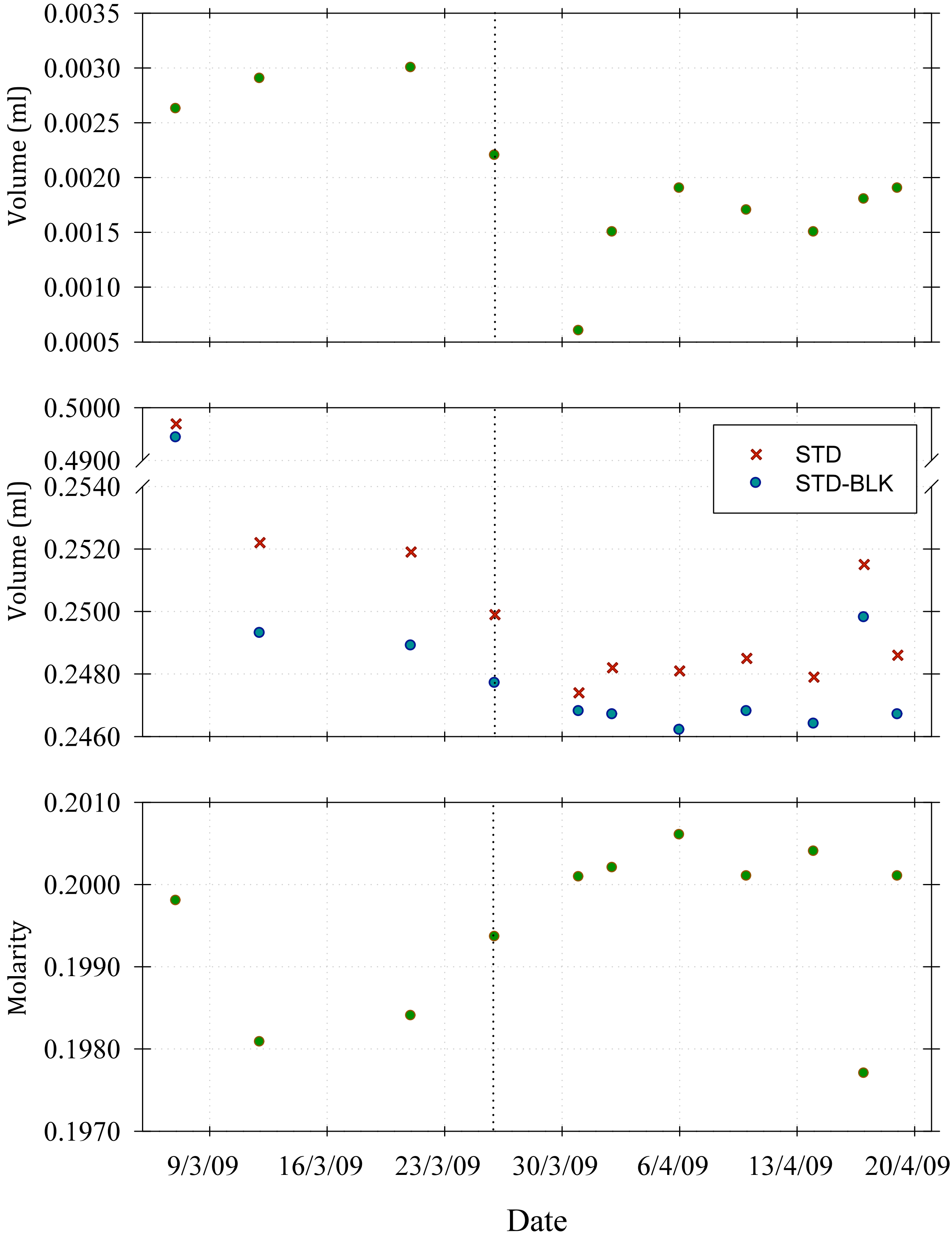

Figure 34: Dissolved oxygen analysis calibrations. Blank volume titre, standard volume titre, standard minus blank (STD, STD-BLK), and thiosulphate molarity. Dotted line indicates when a new thiosulphate solution was prepared. Values plotted here are shown in Table 5.

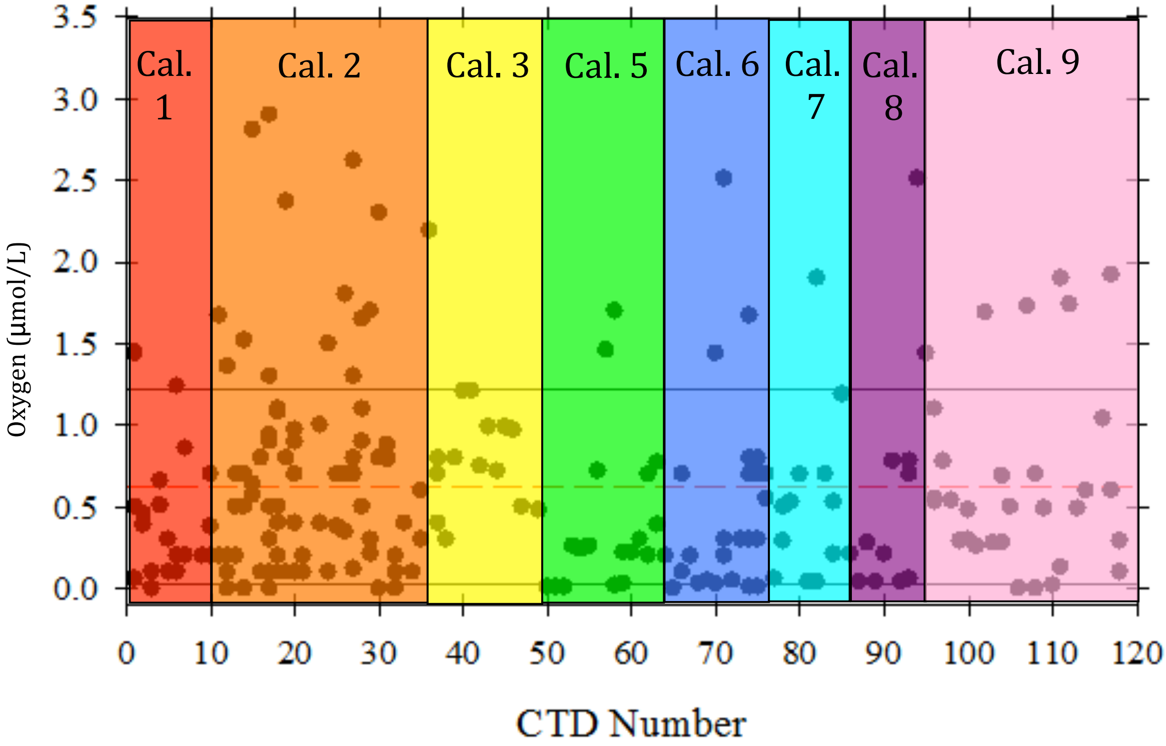

Figure 35: The absolute replicate difference (µmol/L) for the oxygen bottles in each CTD cast. The mean (0.61µmol L^{-1}) and the standard deviation (± 1) are specified with a red dash and black lines respectively. Overlaid are the calibration numbers. Niskin 1 was always sampled in duplicate. From CTD 28 onwards only one set of bottles was used to sample due to deficiencies noted in the other sampling bottle sets.

5.3 References

Culberson, C.H. and Huang, S. (1987), Automated amperometric oxygen titration, *Deep Sea Research*, 34, 875-880.

Dickson, A.G. (1994), Determination of dissolved oxygen in seawater by Winkler titration. Technical report, WOCE operations manual, WOCE report 68/91 Revision 1 November 1994.

Holley, S.E. and Hydes, D.J. (1994), Procedures for the determination of dissolved oxygen in seawater. Technical report, James Rennell Centre for Ocean Circulation.

Kirkwood, D. (1996), Nutrients: Practical notes on their determinations in seawater. ICES Techniques in marine environmental sciences. 17, 1-25.

Siedler, G., Müller T. S., Onken R., Arhan M., Mercier H., King B. A. and Saunders P. M (1996), The zonal WOCE sections in the South Atlantic. In: Wefer, G., Berger W. H., Siedler G. and Webb D. J. (Eds). The South Atlantic: Present and Past Circulation. Springer-Verlag, Germany, pp 83-104.

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6. Inorganic Carbon Parameters

The analytical equipment for the carbon parameters was set up in the seagoing laboratory container of the Laboratory for Global Marine and Atmospheric Chemistry (LGMAC), University of East Anglia (UEA), Norwich, UK. Discrete CTD samples were analysed for total inorganic carbon (DIC) and total alkalinity (TA). Additionally, a continuous, automated instrument for the analysis of sea surface pCO_2 and atmospheric pCO_2 was run throughout the cruise.

6.1 Methods

6.1.1 CTD Sampling Strategy for Inorganic Carbon

Water samples for the determination of DIC and TA were drawn from the 20L and 10L Niskin bottles on the CTD rosette and collected in 500ml glass bottles according to the Standard Operating Procedure (SOP) # 01 *(Dickson et al., 2007)*, to avoid gas exchange with the air. All samples were poisoned with mercuric chloride (100µl per 500ml sample) to kill all organisms that may alter the chemistry of the sample. Samples were kept cold and stored in the dark until they were put into a 25^{o}C water bath to bring to this temperature prior to analysis. A total of 1666 samples were drawn from 116 CTD stations (last Station number 118, with Station 22 only sampled for physics, and Station 48 failed). Samples for DIC and alkalinity were not taken from all depths of each station: generally, the top two (5m and 25m or 50m) and the bottom two (bottom and bottom – 50) were always sampled, and in between, alternative depths with neighbouring stations were sampled. This way it is possible to sample all stations (instead of every second station) and attempt to analyse all samples during the cruise, yet give best resolution of data for optimum interpolation across the section. All stations were analysed during the cruise. This was comprised of all depths from a total 112 stations, and the top two and the bottom two depths of Stations 68, 79, 104, and 107. Figure 36 shows the depth-longitude grid of samples analysed for DIC and TA during the cruise.

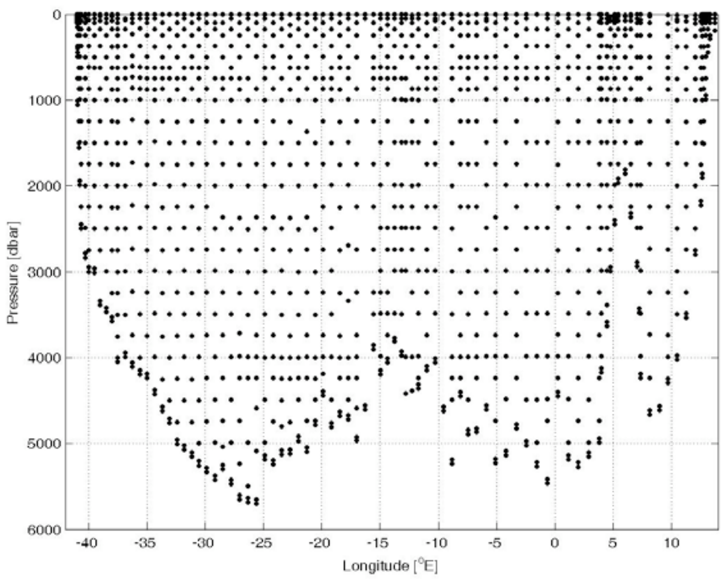


Figure 36: Depth-longitude grid of samples analysed for DIC and TA

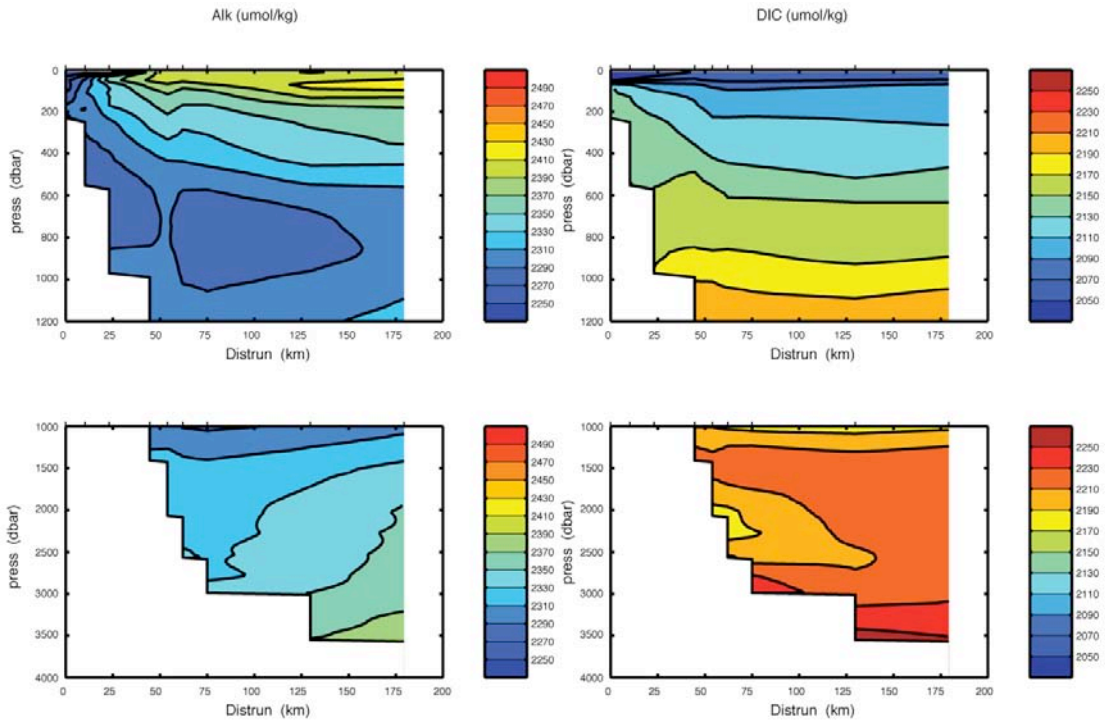


Figure 37: Alkalinity (left) and dissolved inorganic carbon (right) parameters for the first Brazil current transect

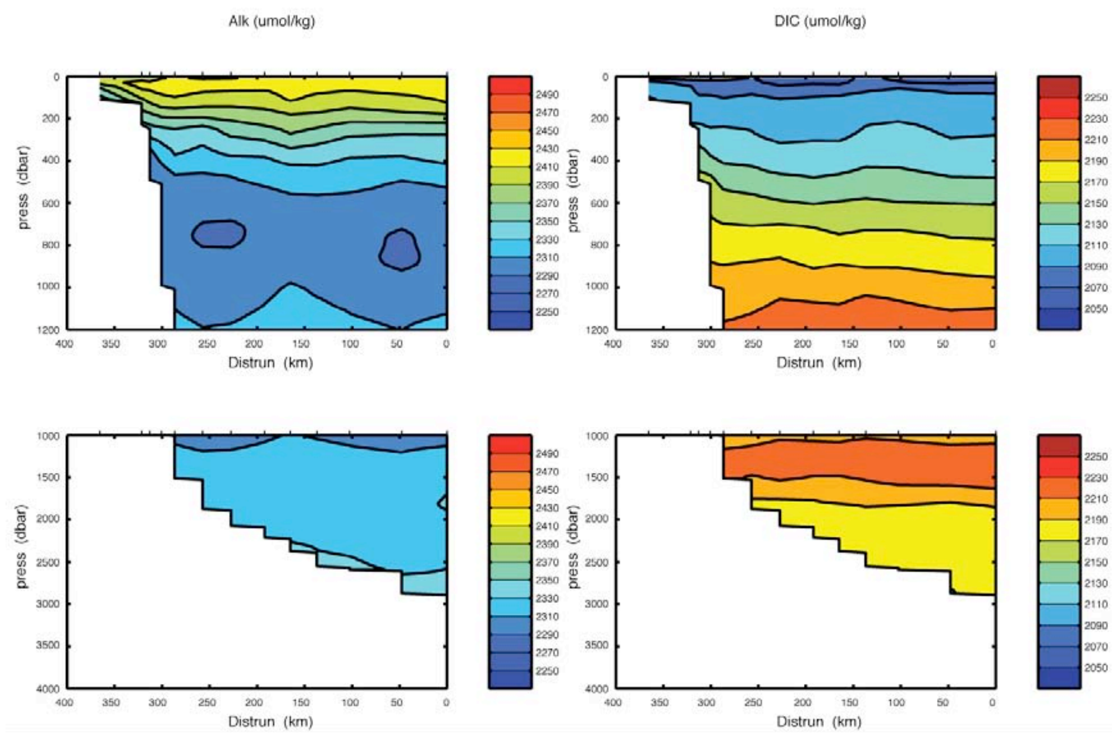


Figure 38: Alkalinity (left) and dissolved inorganic carbon (right) parameters for the second Brazil current transect

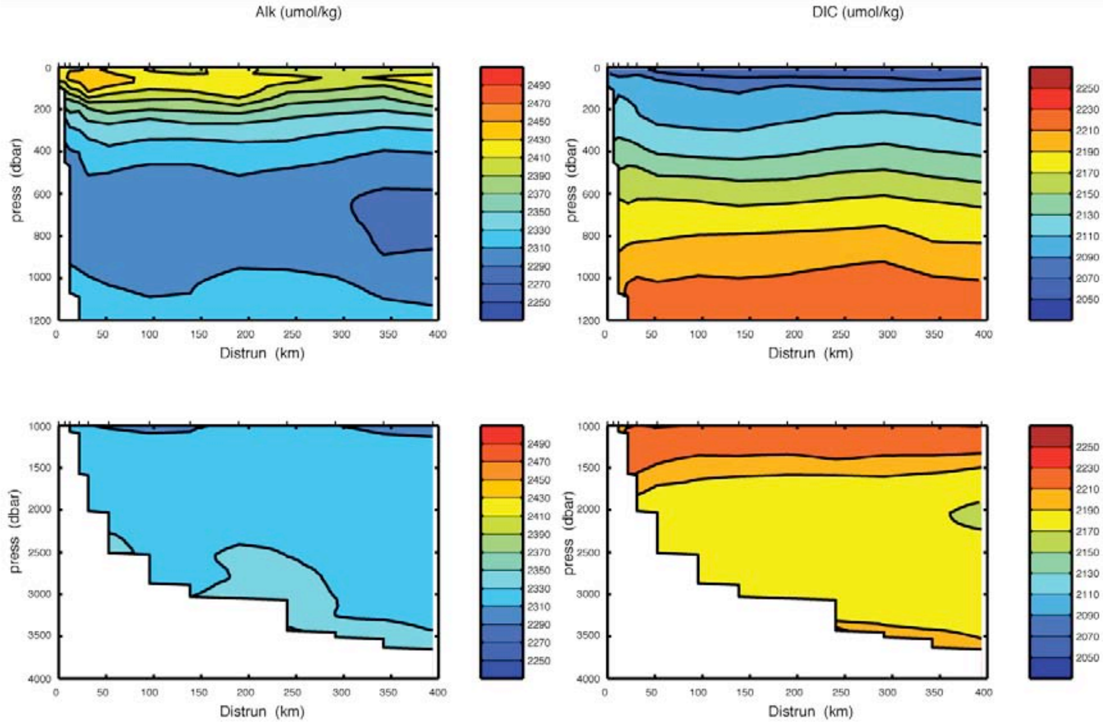


Figure 39: Alkalinity (left) and dissolved inorganic carbon (right) parameters for the third Brazil current transect

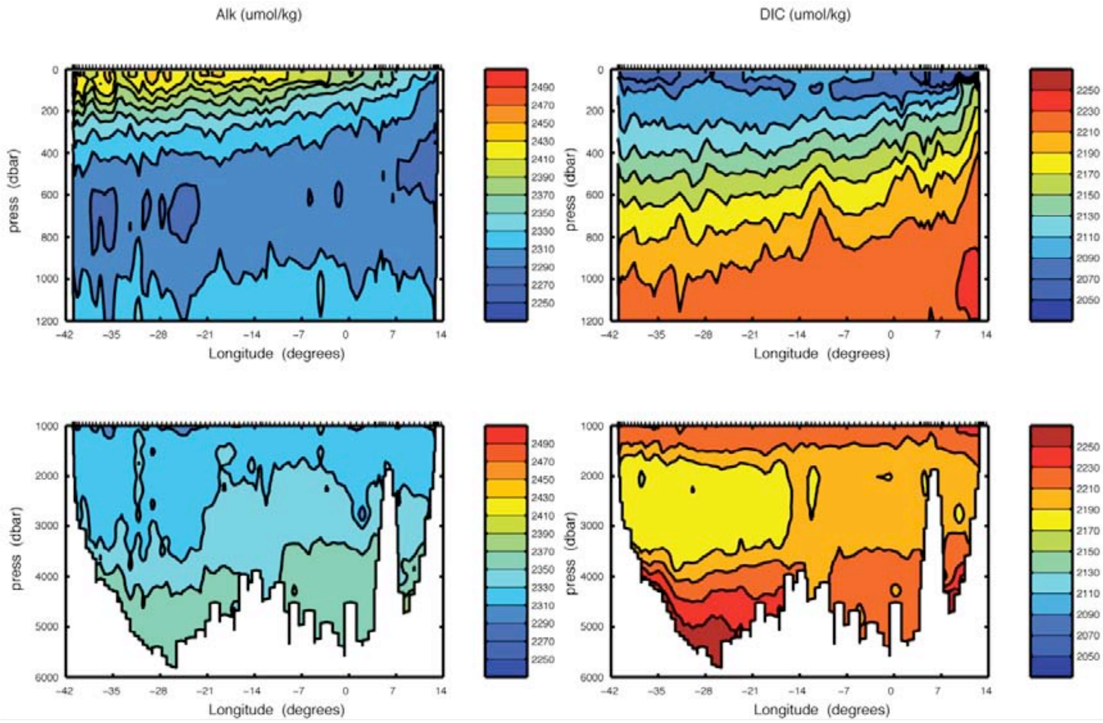


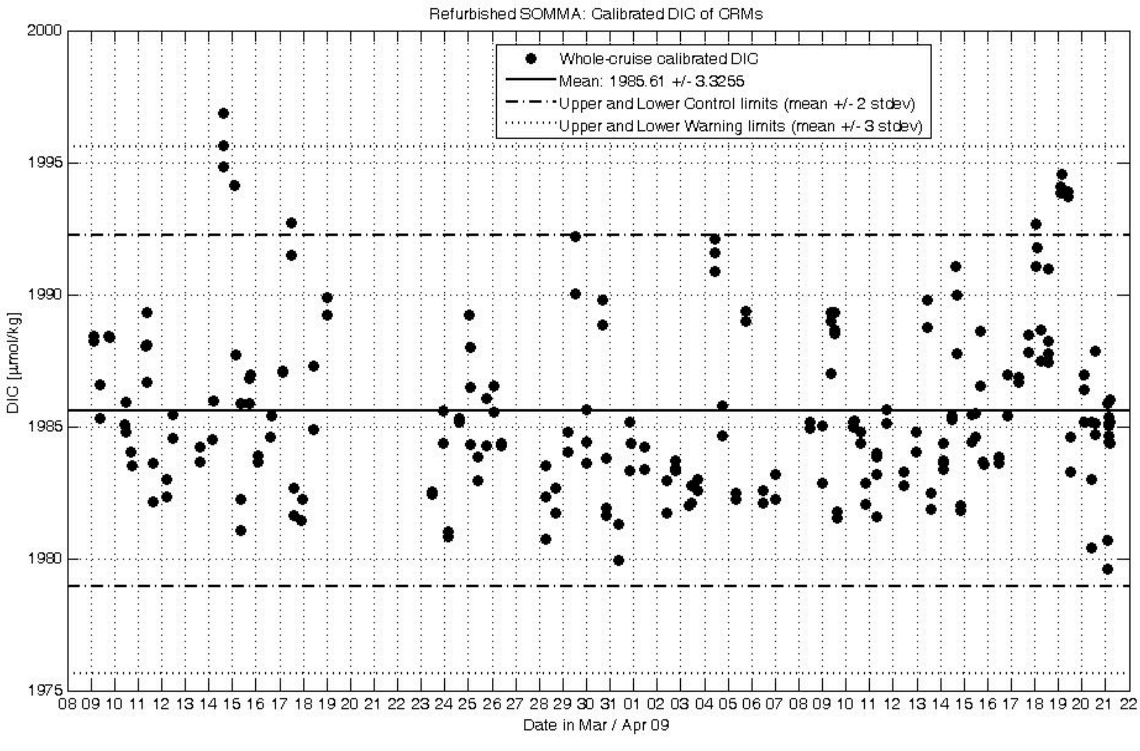
Figure 40: Alkalinity (left) and dissolved inorganic carbon (right) parameters for the main transect

6.1.2 Dissolved Inorganic Carbon Analyses

Water samples were first analysed for Dissolved Inorganic Carbon (DIC, also denoted as Total CO_2 [TCO_2]). Total inorganic carbon was analysed by coulometry (*Dickson et al. (2007)* SOP #02). All inorganic dissolved carbon is converted to CO_2 by addition of excess phosphoric acid (1M, 8.5%) to a calibrated volume of seawater sample. Oxygen-free-Nitrogen (OfN) gas, passed through soda lime to remove any traces of CO_2 is used to carry the evolving CO_2 to the coulometer cell, where all CO_2 is quantitatively absorbed, forming an acid that is coulometrically titrated.

Two different instruments were used during JC032 for this analysis. Firstly a stand-alone DIC analyser consisting of a coulometer and a CO_2 extraction unit based on the Single Operator Multiparameter Metabolic Analyzer (SOMMA), developed by Kenneth Johnson *(Johnson et al., 1993; Johnson et al., 1985; Johnson et al., 1987; Johnson and Wallace, 1992)*, and modified at UEA (called hereafter refurbished SOMMA); and secondly a coulometer with a Versatile Instrument for the Detection of Titration Alkalinity (VINDTA), combined DIC/alkalinity instrument (version 3C, serial number #007, (*Mintrop, 2004)*). For both, samples were brought to 25°C prior to analysis. Two replicate analyses were made on each sample bottle; the coulometer counts were calibrated against Certified Reference Material (CRM, batch 90).

First DIC calibration has been done during the cruise for each instrument, by setting the mean of all DIC coulometer readings to the certified reference value of batch 90 (1985.61 ± 0.89µmol kg^{-1}). Figure 40 shows these "calibrated" CRM values for (a) for the refurbished SOMMA instrument and (b) for the VINDTA #007, together with the mean, control limits and warning limits *(Dickson et al., 2007)*; whole-cruise CRM values varied by ± 3.3µmol kg^{-1} for the refurbished SOMMA and by ± 3.4µmol kg^{-1} for the VINDTA #007.



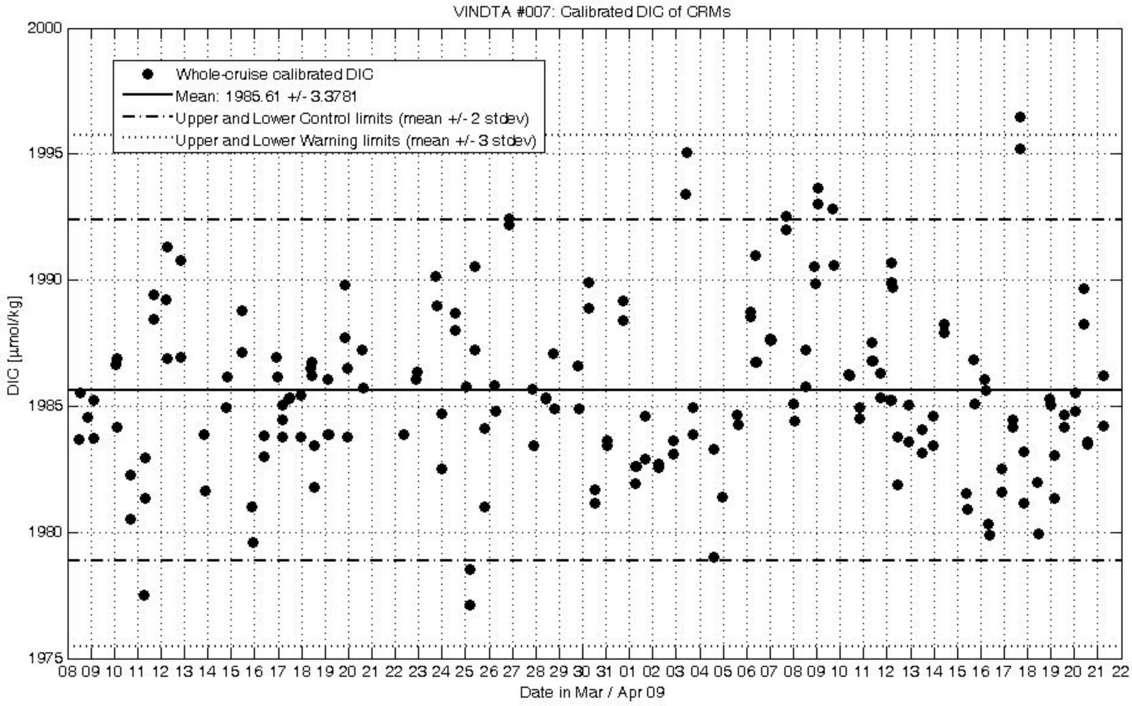
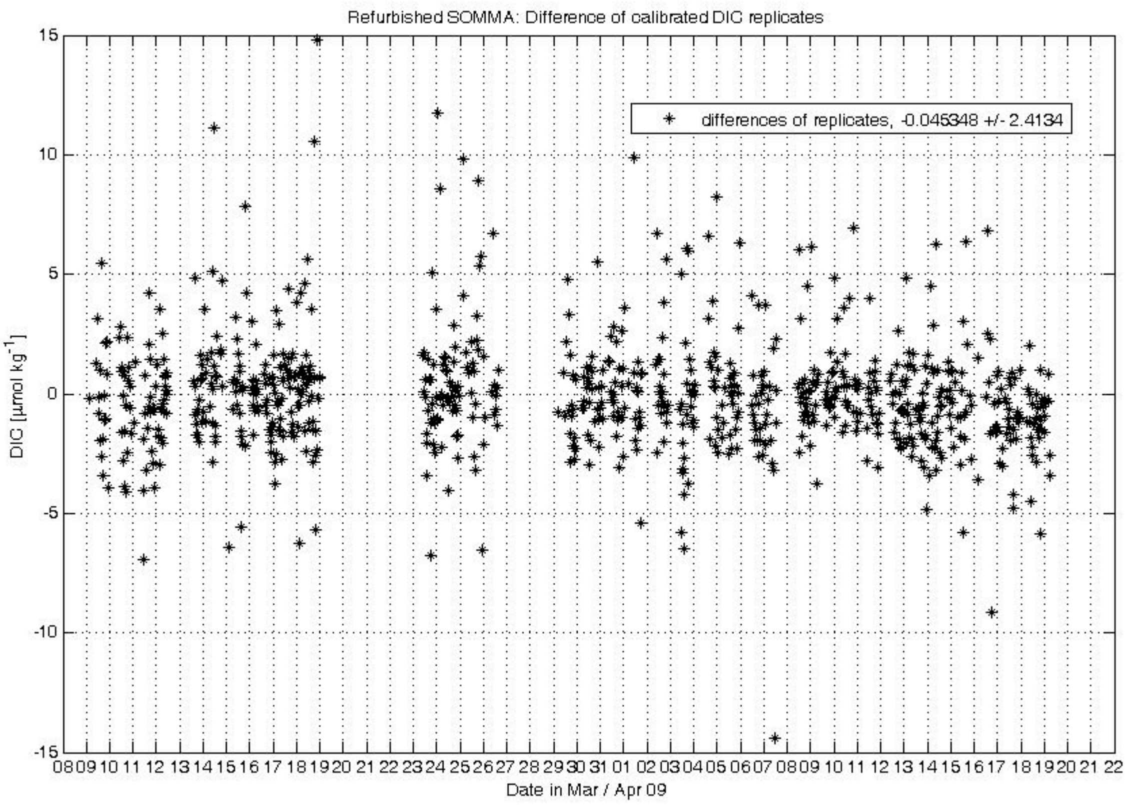


Figure 41: Calibrated CRM values for (a) for the refurbished SOMMA instrument and (b) for the VINDTA #007.



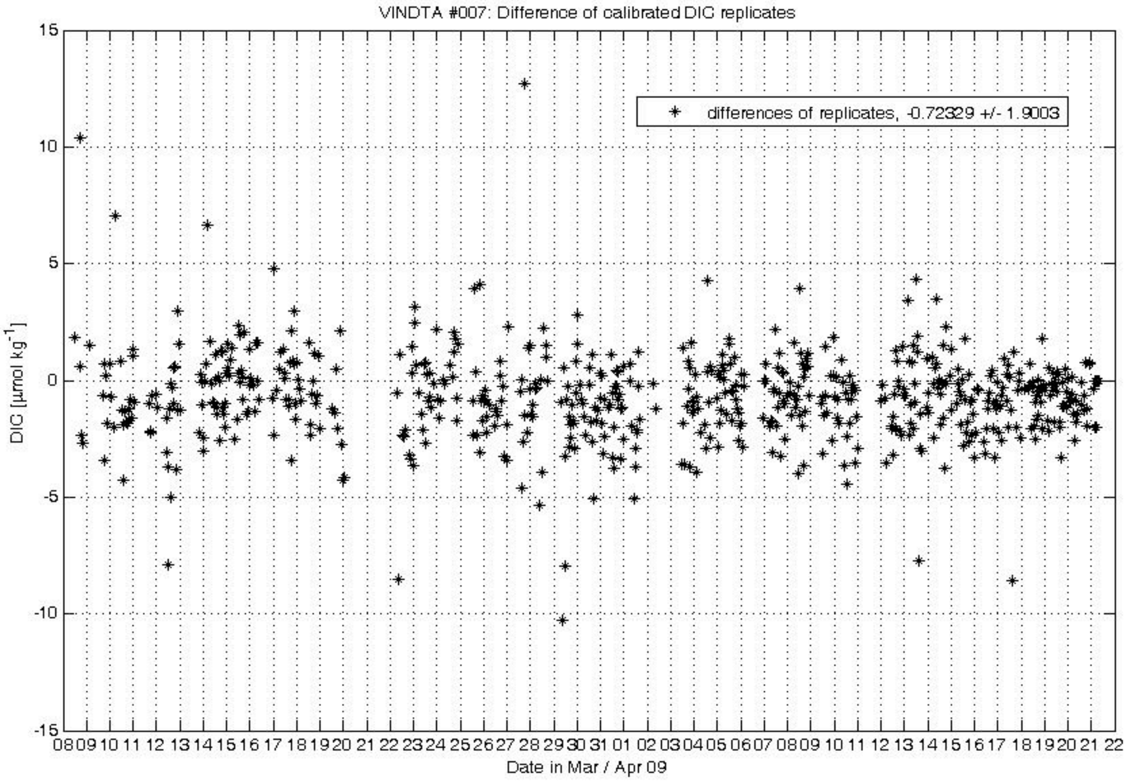


Figure 42: Differences between replicates of all samples analysed for DIC, (a) for the refurbished SOMMA instrument and (b) for the VINDTA #007; differences were 0 ± 2.4µmol kg^{-1} for the refurbished SOMMA and -0.7 ± 1.9µmol kg^{-1} for the VINDTA #007.

Post-cruise data quality control will include calibration of DIC readings for each coulometer cell used during JC032, identification and removal of further outliers, and accounting for the instruments' drift during the cruise.

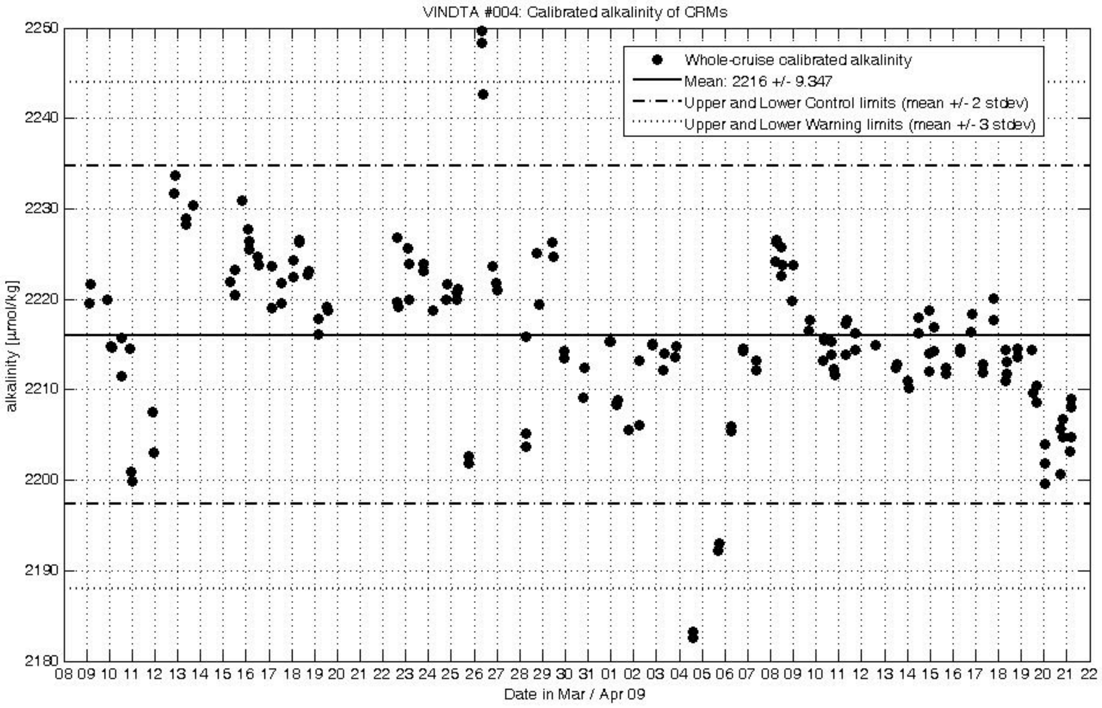
6.1.3 Titration Alkalinity Analyses

The alkalinity measurements were made by potentiometric titration (*Dickson et al., 2007*) with two VINDTA instruments (#004 and #007, version 3C, *Mintrop, 2004*). The systems use a highly precise Metrohm Titrino for adding acid, an ORION-Ross pH electrode and a Metrohm reference electrode. The pipette (volume approximately 100ml), and the analysis cell have a water jacket around them. The titrant (0.1M hydrochloric acid, HCl) was made in the home laboratory; Batch A was used throughout the cruise. Samples on Vindta #004 were run after DIC analysis on the refurbished SOMMA (see above). Samples on the VINDTA #007 were run for both DIC and alkalinity at 25°C. Replicate analyses were run for all samples. Alkalinity values were calibrated using CRM batch 90 (certified at 2216.00 ± 0.52µmol kg^{-1}).

Figure 43 shows alkalinity CRM values recorded by (a) VINDTA #004 and (b) VINDTA #007, showing a whole-cruise variation of ± 9.3µmol kg^{-1} on VINDTA #004 and ± 5.2µmol kg^{-1} on VINDAT #007 after preliminary data quality control during the cruise.

The alkalinity cell stirrer of VINDTA #004 stopped working on 9 March 2009, resulting in a few hours of downtime. The quality of alkalinity measurements made immediately before and after this will be investigated during post-cruise quality control. A major technical/electrical breakdown occurred on VINDTA #004 at approximately 01:00 on 4 April 2009, when the peristaltic pumps and temperature sensors stopped working; this resulted in almost 12 hours of downtime for repairs. Following the repairs, calibration by CRM revealed alkalinity readings approximately 30μmol kg^{-1} below expected values, which recovered during the following 48 hours. A low CRM outlier occurred on 25 March 2009, the reason for this is going to be investigated during post-cruise quality control.

Post-cruise data treatment will include recalculation of alkalinities with CTD temperature, salinity, and nutrients, after recalibration of alkalinity pipettes' volume and temperature sensors. Post-cruise data quality control will then include identifying and removing further outliers, and accounting for drift in the instruments' alkalinity, especially for VINDTA #007.



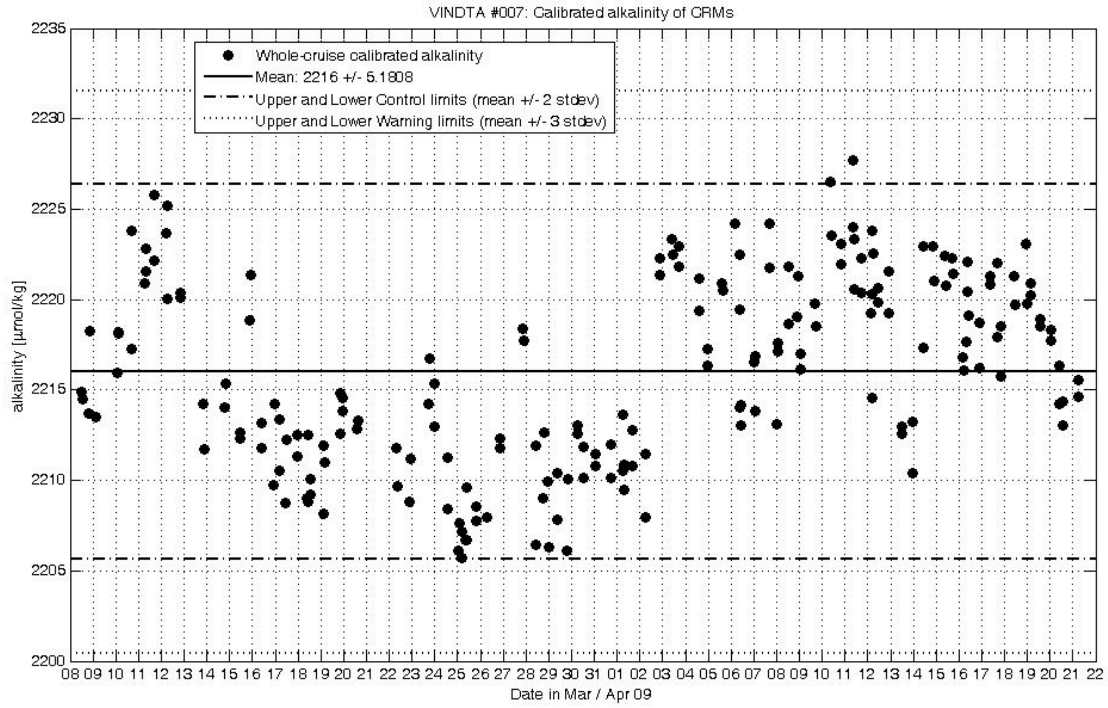
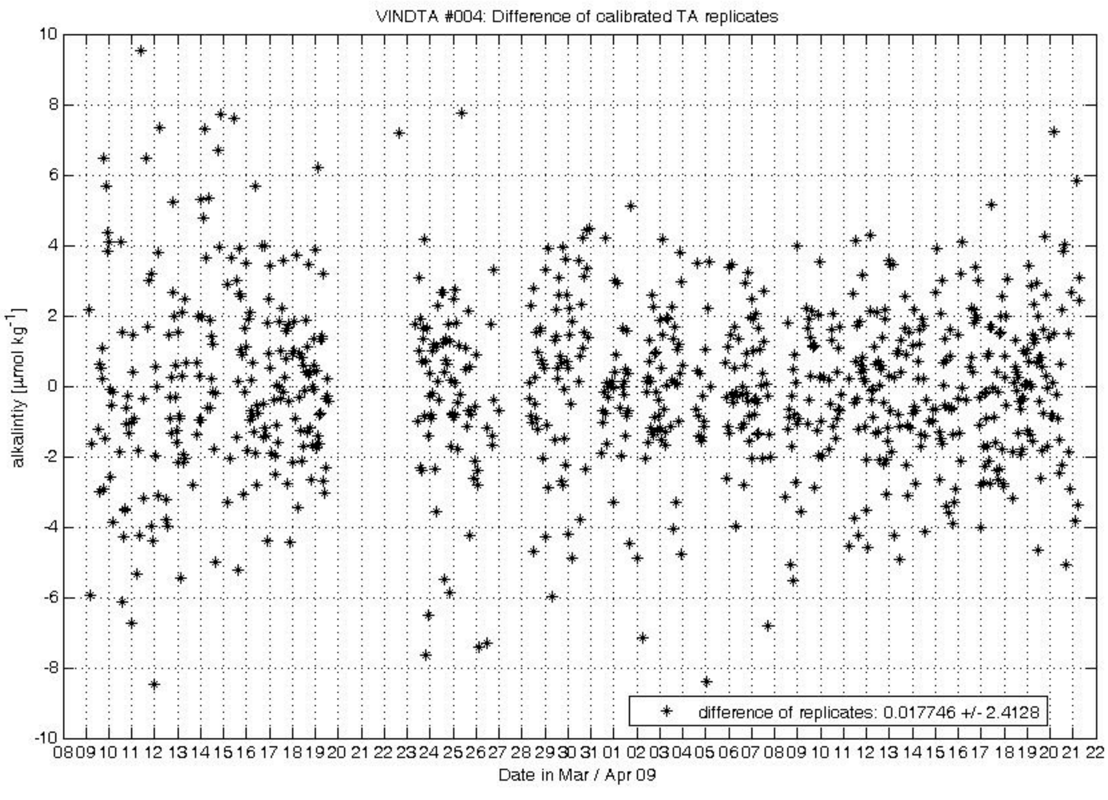


Figure 43: Alkalinity CRM values recorded by (a) VINDTA #004 and (b) VINDTA #007.

The differences between replicates of all samples analysed for alkalinity are shown in Figure 44 (a) for the VINDTA #004 and (b) for the VINDTA #007; differences were 0 ± 2.4µmol kg^{-1} for the VINDTA #004 and 0.4 ± 2.5µmol kg^{-1} for the VINDTA #007.



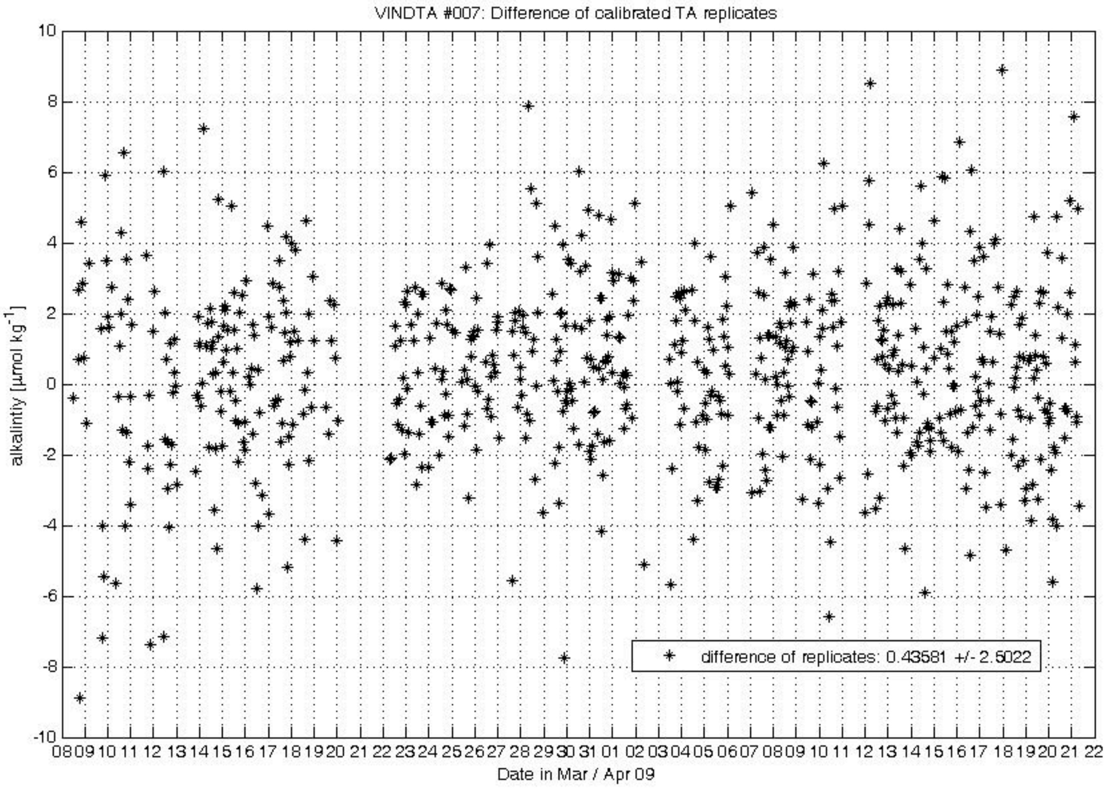


Figure 44: The differences between replicates of all samples analysed for alkalinity (a) for the VINDTA #004 and (b) for the VINDTA #007

6.1.4 Continuous Seawater Supply for Underway pCO_2

The ship's seawater supply provided a high volume of water for underway sampling. A screw pump transported the water from 5m depth at the bow to the UEA laboratory container on the aft deck. Temperature and salinity of the intake water were determined by the ship's remote sensor (temperature) and the thermosalinograph (TSG) (salinity) in the CTD bottle annex. In the laboratory container the seawater passed an oxygen sensor, a strainer with a bypass, and finally the equilibrator for pCO_2 analysis. The seawater flow across the equilibrator was kept fairly low in order to avoid bubbles leaving the equilibrator. Flow across the bypass was kept high.

6.1.5 Partial Pressure of CO_2 in Surface Water and Marine Air

Continuous measurements of pCO_2 (read as xCO_2 in ppm or μmol mol^{-1}) in surface water and marine air were made throughout the cruise with the UEA underway pCO_2 system. Marine air was pumped through tubing from the deck, to a height of about 16m above the bridge (Monkey Island). Seawater from the ship's surface water supply was introduced at a rate of 2-3L min^{-1} into the equilibrator. Two Pt-100 probes accurately determined the water temperature in the equilibrator. A long vent kept the headspace of the equilibrator close to atmospheric pressure. The CO_2 content and the moisture content of the headspace were determined by an infrared LI-COR 7000 analyser. The analysis of the CO_2 content in the headspace was interrupted for that of the CO_2 content in marine air (20 minutes per 6 hours) and in three CO_2 standards (30 minutes per six hours each). Samples from the equilibrator headspace and marine air were only dried sufficiently to avoid condensation in the detector. Gas standards bought from BOC amounting to mixing ratios of 248.44 +/- 0.03 (25-B18), 350 (35-B04) and 455.59 +/- 0.08µmol CO_2 mol^{-1} (45-B18) had been calibrated against certified NOAA standards. The analyses were carried out at a flow speed of 100ml min^{-1} through the LI-COR at a slight overpressure. A final analysis for each parameter was made at atmospheric pressure with no flow. The flow and overpressure did not have a discernable effect on the CO_2 and moisture measurements, once corrections for the pressure had been performed. The correction by *Takahashi et al. (1993)* will be used to correct for warming of the seawater between the ship's water intake and the equilibrator. The pCO_2 measurements will be time stamped by our own GPS positions. The precision and accuracy of the pCO_2 data are likely to be approximately 1µatm, as determined during previous cruises (e.g., *Bakker et al., 2001*).

6.2 References

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7. Chlorofluorocarbons (CFCs) and Sulphur Hexafluoride (SF_6)

7.1 Sample Collection and Analysis Technique

Water samples for CFCs (F11, F12, F113 and CCl_4) and SF_6 were collected from 20L or 10L Niskin bottles attached to the CTD sampling rosette. The samples were analysed onboard as soon as possible after collection using a coupled SF_6 and CFC system. The method combines the LDEO CFC method (W. Smethie, E. Gorman) and the Plymouth Marine Laboratory (PML) SF_6 method (Law et al.) with a common valve for the introduction of gas and water samples. This system has the advantage of simultaneous analysis of SF_6 and CFCs from the same water sample, but takes longer than the individual systems. The throughput time averaged just less than 30 minutes per sample. Representative samples were collected from CTD bottles to ensure the optimum depth coverage, since not all bottles could be analysed in the time available. Samples were collected in 500ml ground glass stopper sealed bottles. The bottles were rinsed with sample water, and then filled from the bottom using Tygon tubing. The bottles were overflowed at least one full time before being sealed. Full bottles were then stored in the sampling hanger in cool boxes containing deep cold seawater. Ice packs were added to maintain a temperature below 5°C. As per WOCE protocol, CFC/SF_6 samples were the first samples drawn from the Niskin bottles.

The samples were introduced to the system by applying nitrogen (N_2) pressure to the top of the sample bottles, forcing the water to flow through and fill a 25cm^3 calibrated volume for CFCs and a 300cm^3 calibrated volume for SF_6. The measured volumes of seawater were then transferred to separate purge and trap systems. Each purge and trap system was interfaced to an Agilent 6890 gas chromatograph with electron capture detector (GC-ECD). The samples were stripped with N_2 and the CFCs and SF_6 were respectively trapped at -80^{O}C on a Unibeads trap and at -100 ^{O}C Porapak Q trap immersed on the headspace of liquid nitrogen. Then the traps were heated to 100^{O}C for CFCs and 60^{O}C for SF_6 and injected into the respective gas chromatograph. The SF_6 separation was achieved using a molecular sieve packed 2m main column and 2m buffer column. The CFC's separation was achieved using a 1m Porasil B packed pre-column and a 1.5m carbograph AC main column. The carrier gas was pure oxygen-free nitrogen, which was cleaned by a series of chemical scrubbers.

Air samples were periodically collected via a tube running from the bow of the ship, pumped into the laboratory. The tube was flushed for approximately a half hour before beginning analysis. Air samples were trapped in an identical manner to standards, using either a 1ml or 2ml sample.

7.2 Calibration

The CFC/ SF_6 concentrations in air and water were calculated using an external gaseous standard. The standard supplied by NOAA corresponds to clean dry air slightly enriched in SF_6, F11 and CCl_4. The calibration curves were made by multiple injections of different volumes of standard that span the range of tracers measured in the water. Examples of fitting calibration data are given in Figure 45. Complete calibration curves were made at the beginning, middle and end of the cruise. The changes in the sensitivity of the systems were checked by measuring a fixed volume of standard gas every 8-10 runs. The preliminary data presented in this report have not been adjusted for any such variation, which should be minimal for all gases with the exception of CCl_4.

A blank correction may be used to compensate for any trace CFC or SF_6 originating from the sampling bottles, handling and/or measurement procedures. This correction is normally estimated from analysis of either samples collected in waters that are free of CFCs or water collected after sparging all the CFCs out of a sample. Zero CFC water was not observed in the South Atlantic Ocean, so blanks were run by re-sparging a sample from the deep water. In a preliminary analysis of the data, there does not appear to be any systematic contamination, and no blank corrections have been applied to the preliminary data presented in this report.

7.3 Precision and Accuracy

The precision of the measurements can be determined from duplicate samples drawn on the same Niskin bottles. During this cruise, duplicate samples were routinely drawn from the surface seawater (nominal 5m) Niskin bottle, time permitting. During JC032, 27 duplicate samples were analysed, from which we calculate the following precision, expressed as the ratio of standard deviation to mean concentration:

SF_6	CFC12	CFC11	F113	CCl_4
2.42%	1.36%	0.92%	3.72%	4.51%

Additional factors affecting accuracy include sparging and trapping efficiency (functions of temperature and flow rate), final determination of calibrated volumes, and chromatographic considerations, such as interferences and baseline variation. These effects will all be assessed and accounted for in the final dataset, but have not been addressed for the purpose of this preliminary report. Particular difficulty was noted for CCl_4, where significant variation in standards was noted.

Any potential effects from sample deterioration or contamination in storage were minimised by storing them at low temperature and analysing the samples as soon as possible after collection. Most samples were analysed within a day of collection.

7.4 Data

This data set comprises the third part of three consecutive South Atlantic cruises on the *RRS James Cook* by the UEA CFC/SF_6 team. A total of 1706 samples were analysed during JC032 along the four transects, with 283 samples on the two initial coastal transects and 1423 samples along the 24°S transect of the South Atlantic. A brief summary of some aspects of the data is presented here. Final interpretation and validation will be carried out at UEA by Drs. A. Watson and M.-J. Messias.

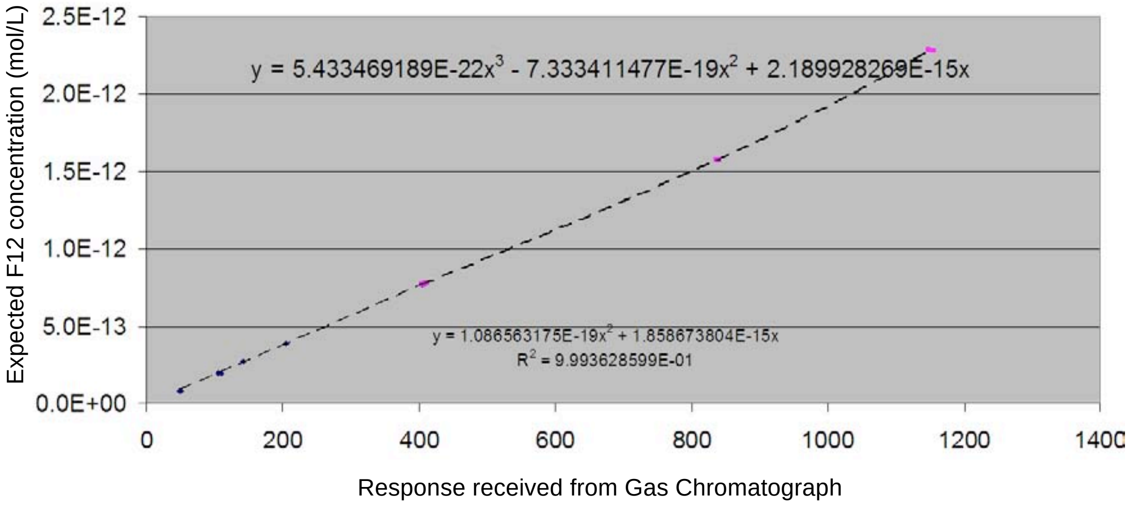

Figure 45: Calibration data from JC032. Units are shown as mol/L equivalent in seawater.

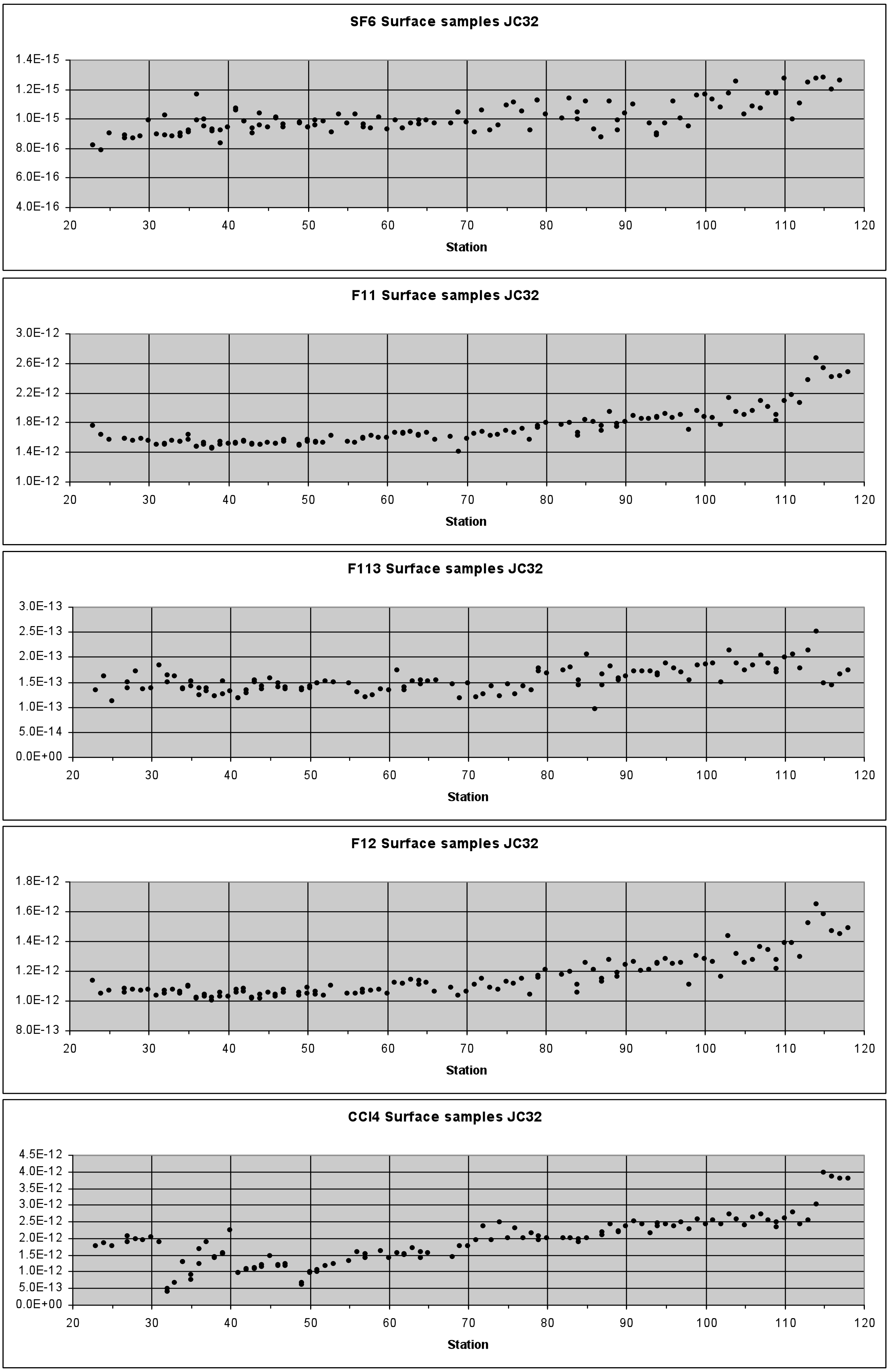

Figure 46: Combined surface seawater data from the 24°S JC032 transect. Units are mols/L.

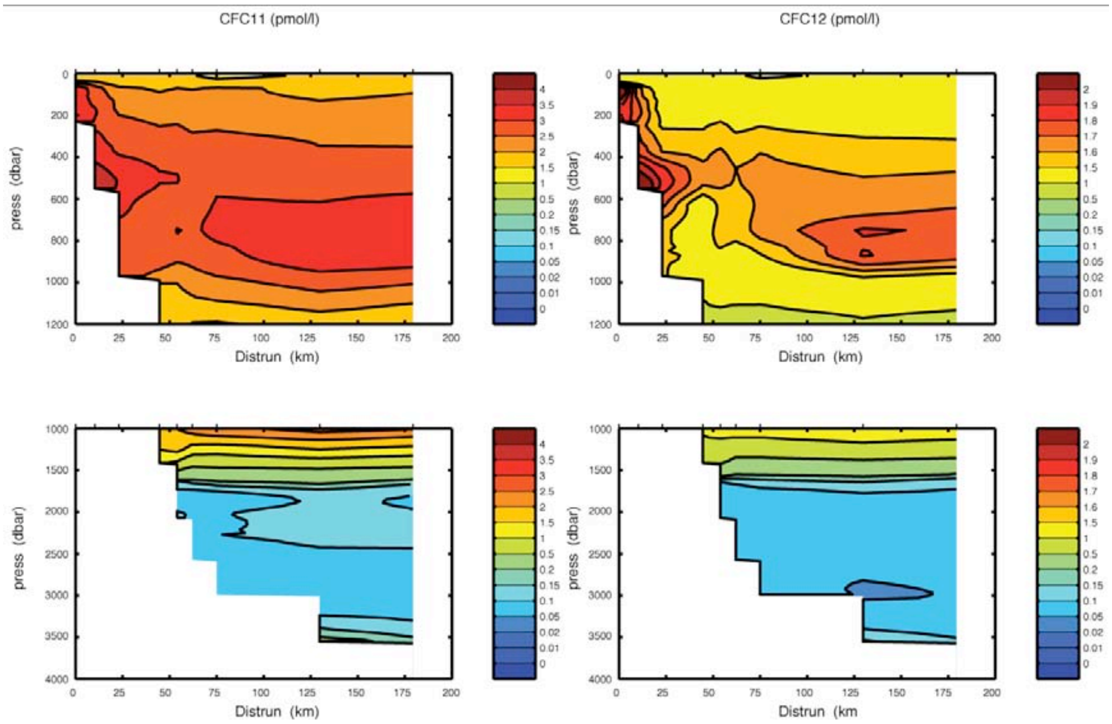

Figure 47: CFC11 (left) and CFC12 (right) parameters for the first Brazil current transect

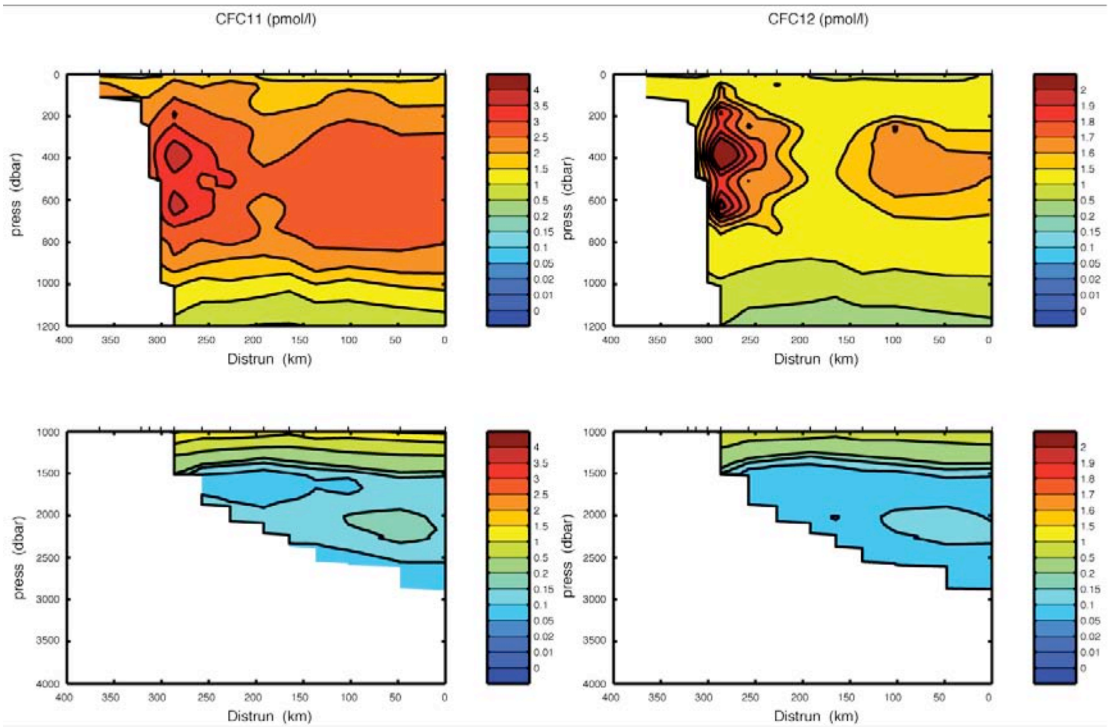

Figure 48: CFC11 (left) and CFC12 (right) parameters for the second Brazil current transect

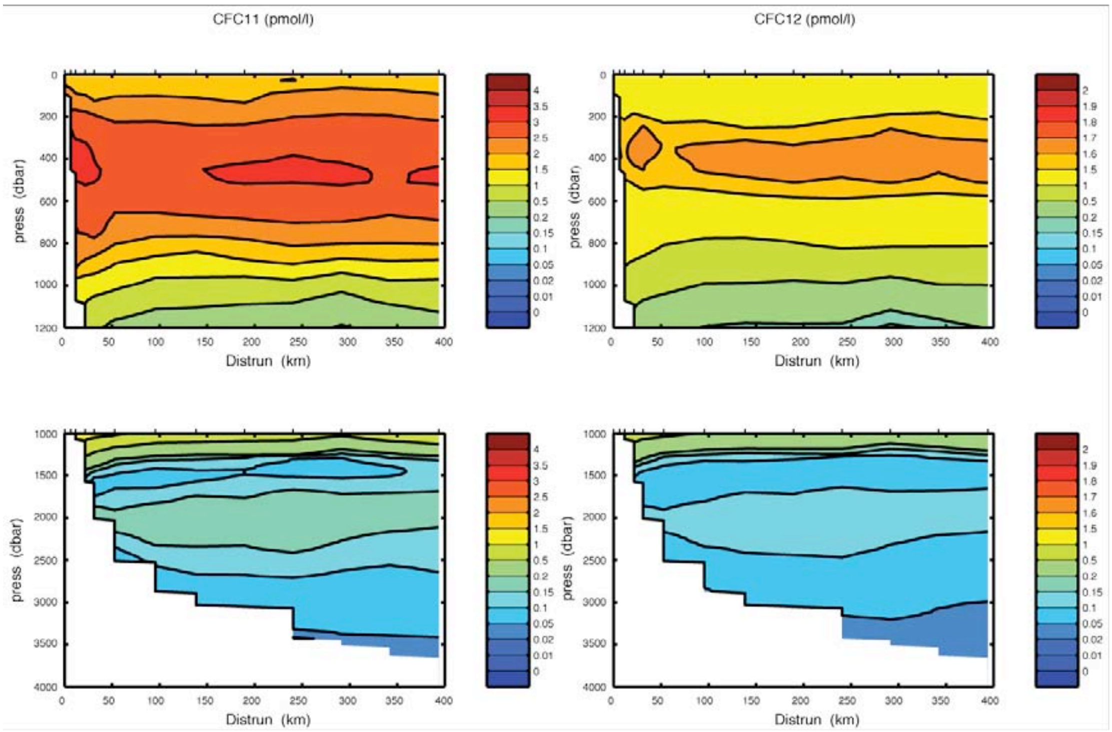

Figure 49: CFC11 (left) and CFC12 (right) parameters for the third Brazil current transect

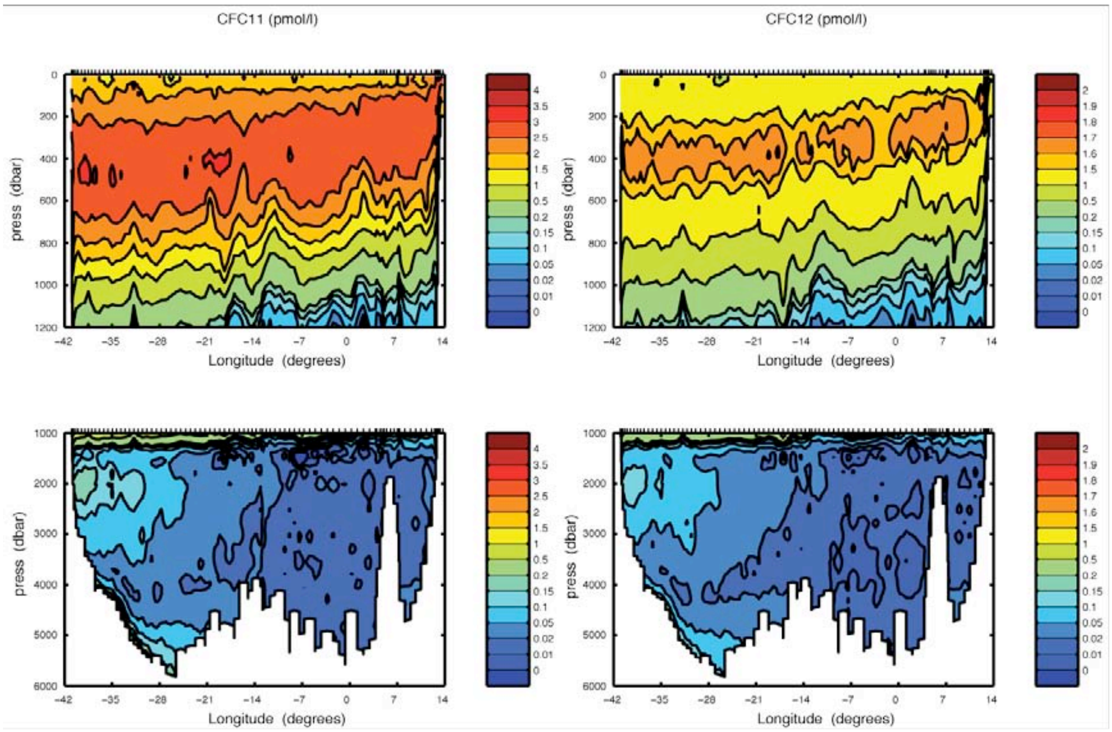

Figure 50: CFC11 (left) and CFC12 (right) parameters for the main transect

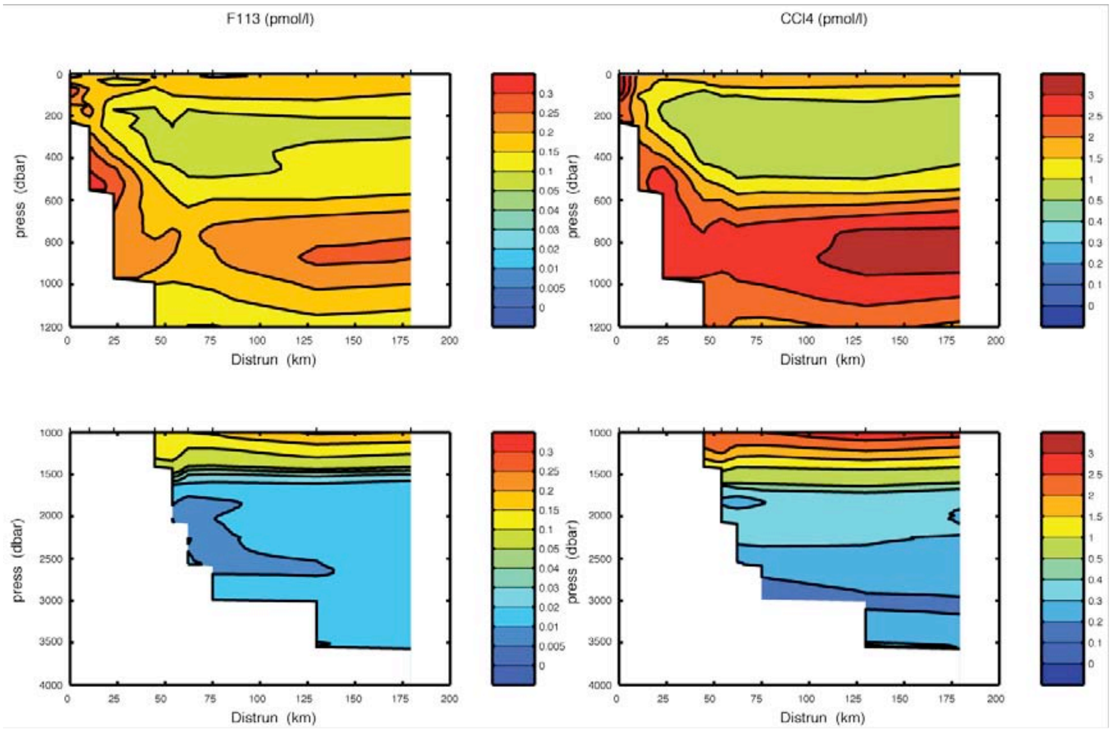

Figure 51: Fl13 (left) and CCl_4 (right) parameters for the first Brazil current transect

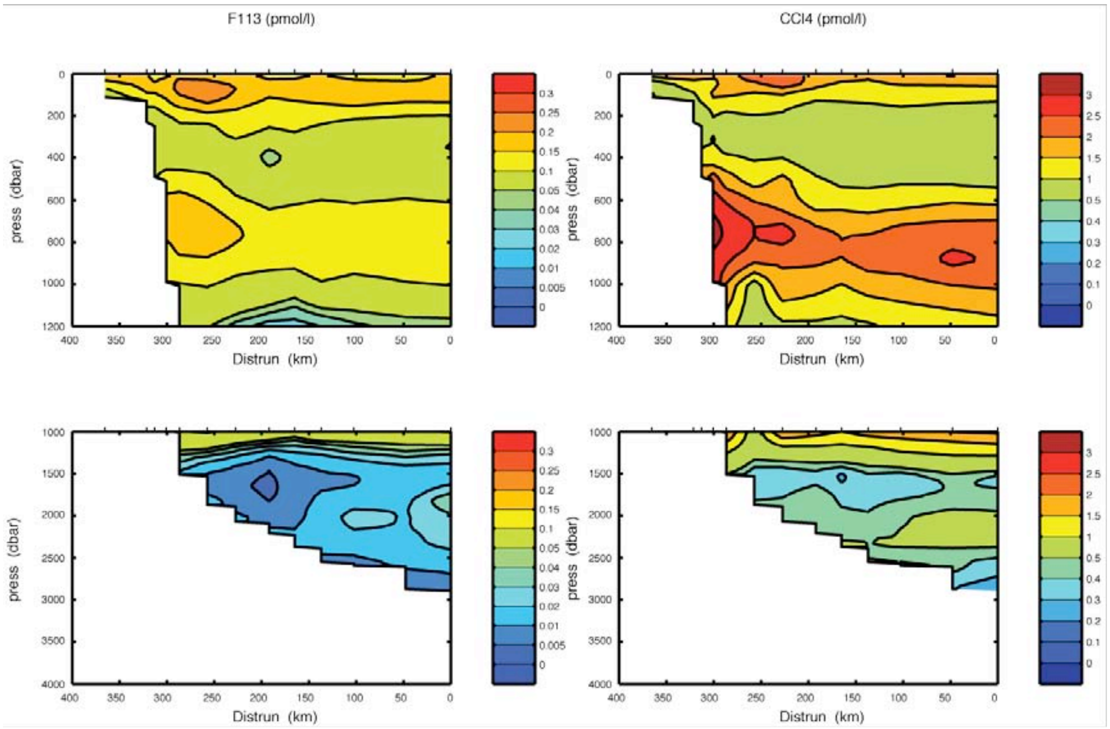

Figure 52: Fl13 (left) and CCl_4 (right) parameters for the second Brazil current transect

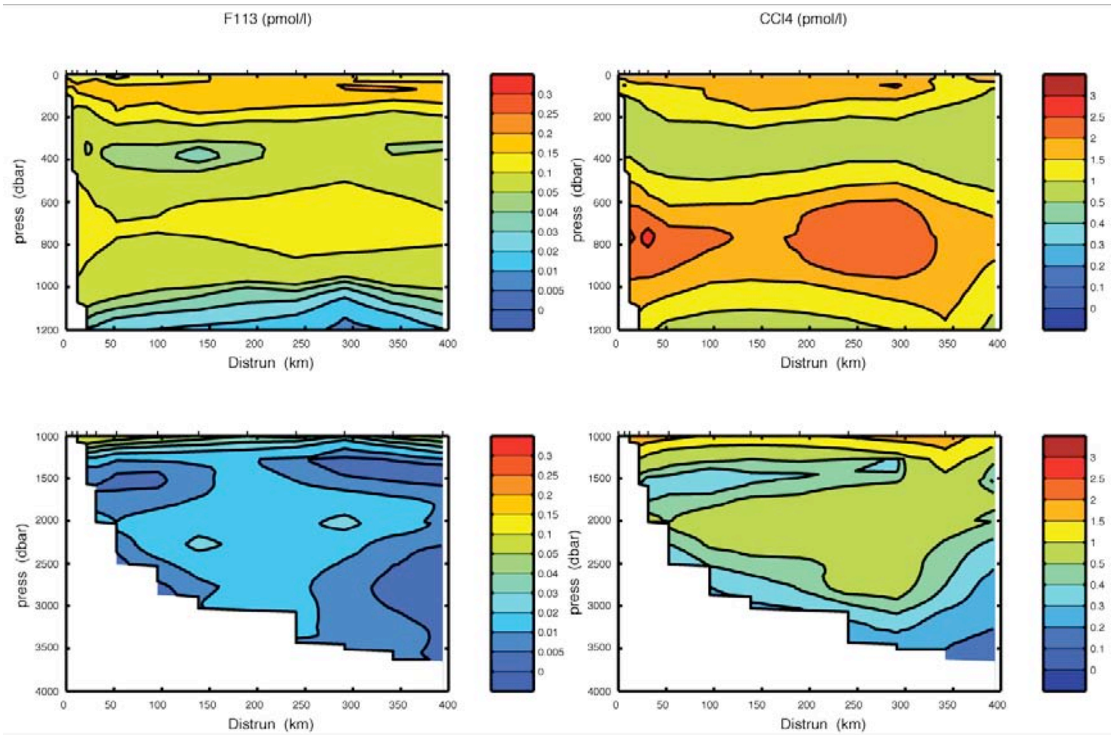

Figure 53: Fl13 (left) and CCl_4 (right) parameters for the third Brazil current transect

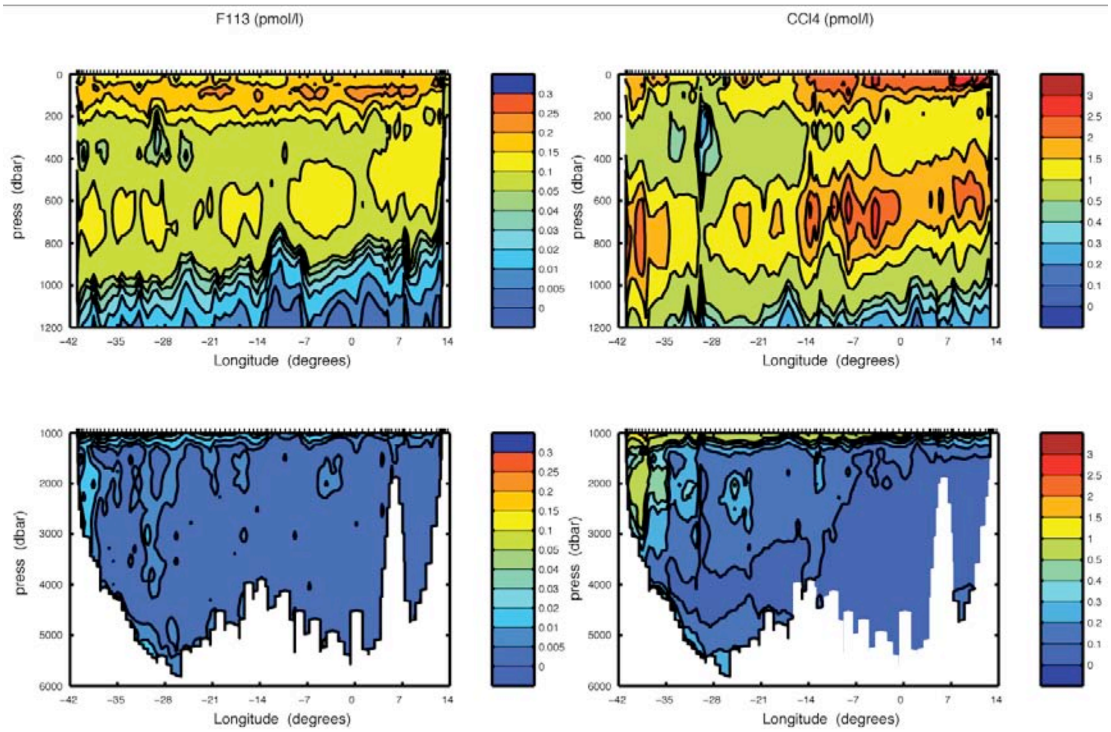

Figure 54: Fl13 (left) and CCl_4 (right) parameters for the main transect

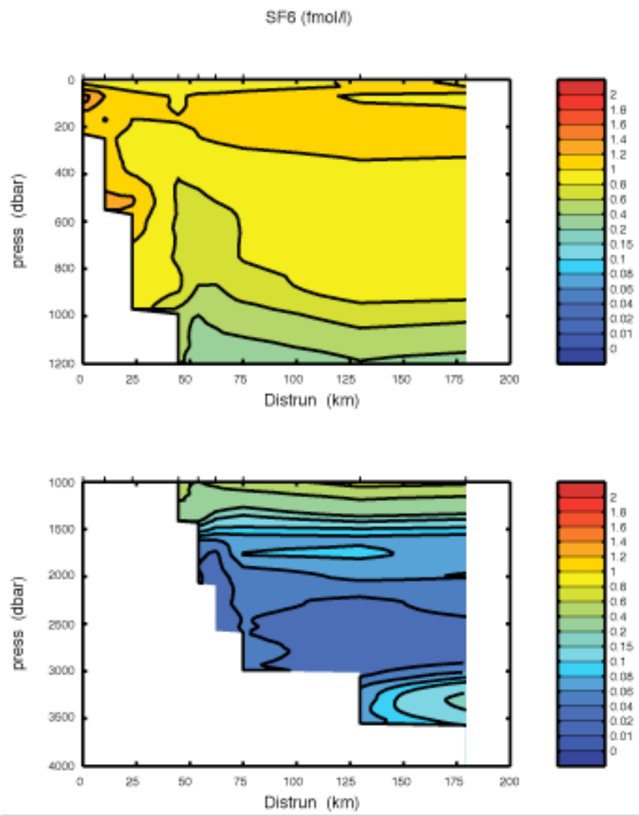

Figure 55: SF_6 parameter for the first Brazil current transect

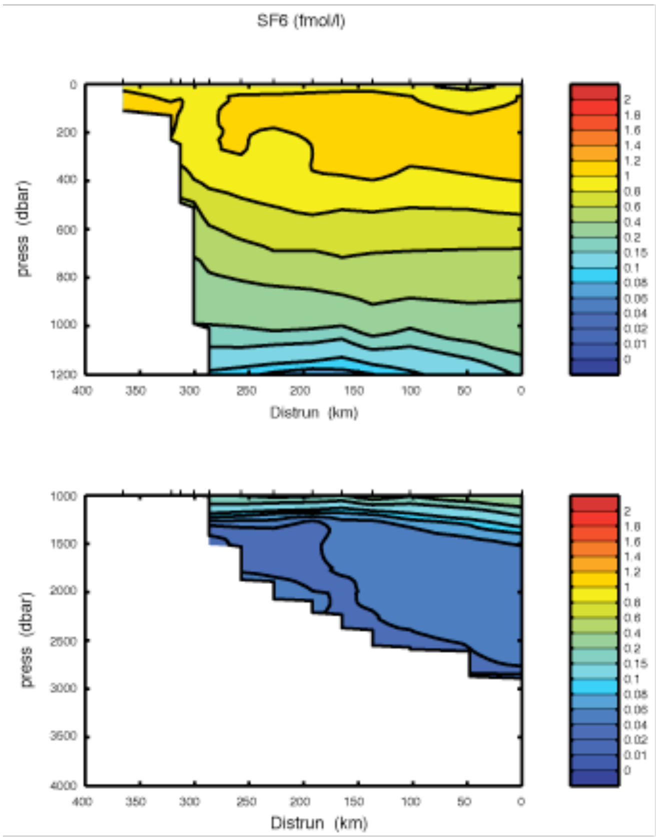

Figure 56: SF_6 parameter for the second Brazil current transect

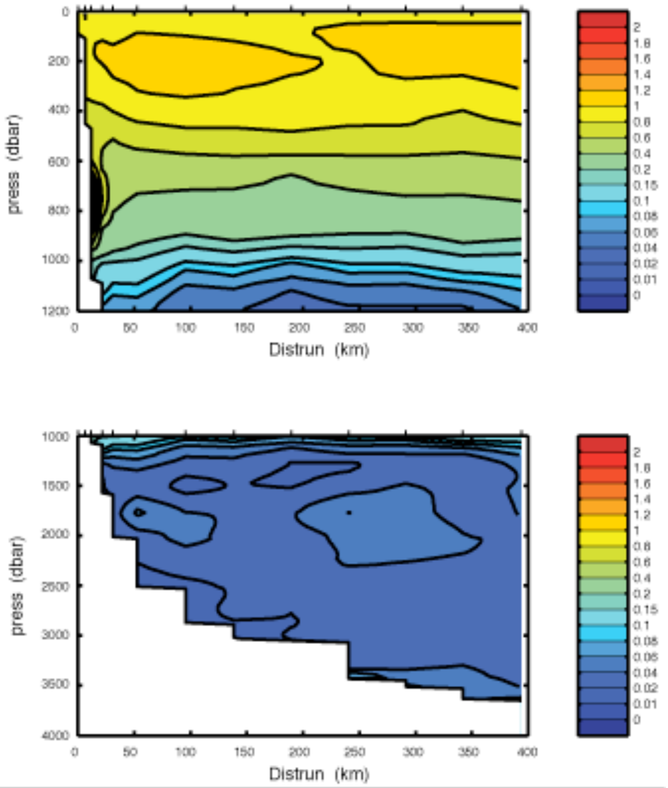

Figure 57: SF_6 parameter for the third Brazil current transect

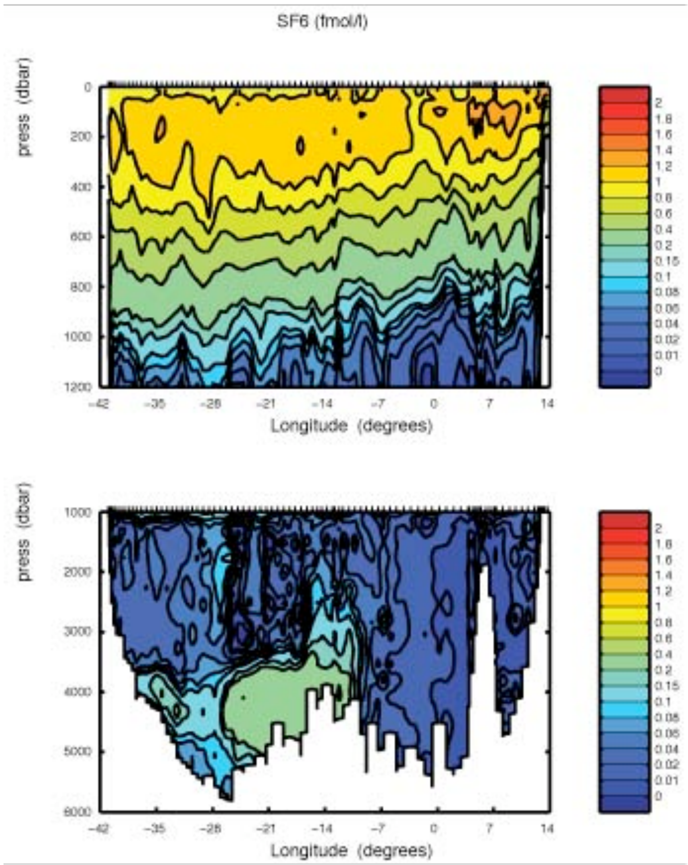

Figure 58: SF_6 parameter for the main transect

David Cooper, Steve Woodward and Andrew Brousseau

8. Instrumentation

8.1 EM-120 Multibeam Echo Sounder

This system has been run off and on for the majority of the duration of the cruise, with the expectation that the raw data will be taken back to NOCS and processed there by other scientific personal that specialise in multi-beam processing. The Uruguayan Observer has also been given a subset of the data, as they have the necessary processing software to clean up the data.

For the majority of the cruise, the weather conditions have been very good, and so the data quality has also been good. The system is, however, still suffering from the "banding problem" which has been reported on previous cruises. In addition it may have picked up an additional fault, which appears as one or two deep trenches, on either side of the centre of the ship's track. Kongsberg hydrographic personnel are due to sail on JC034T, and hopefully they will be able to diagnose the problems.

There are two Valeport Midas sound velocity profilers on board, one of which is in calibration, and has (at the time of writing) been used on two CTD casts. More batteries have been ordered for this unit, as it will be needed on JC034T. The other profiler will be sent for calibration when the vessel reaches Southampton.

8.2 EA-600

Hard copy output from this system was finally set up with some shore-side support from Chris Barnard. Only one previous cruise has used the hard copy facility of the EA-600, but I suspect this will now become the norm.

There is a problem with the EA-600. The computer often looses contact with the transceiver (which it talks to via a dedicated network link). The only solution at the moment seems to be power-cycling the transducer and then restarting the EA-600 software.

8.3 Vessel-Mounted ADCP

The two RDI Ocean Surveyor ADCP systems (75 and 150KHz) were used during the cruise with the port drop keel lowered, to help give better data. The plan was to copy the data across to the data32 area every so often, just using the Windows Explorer utility. Unfortunately, this would not work, as the system would claim that we did not have permission to read the files that were to be transferred. Eventually it was found that the data could be transferred using PSFTP (A Windows secure FTP client). Unfortunately, that was not the end of the matter, as after a few days, one or other of the machines' network stacks would crash, necessitating a reboot in order to transfer the data.

Network access to the Main Lab LaserJet was set up during this cruise (it had already been set up, but the IP address was incorrect). Again, this worked for a while, but once the networking had crashed, there was no printing until the next reboot. We may have to consider trying alternative network cards in these systems. Currently, the systems are using networking hardware integrated into their motherboards.

8.4 Chernikeeff EM Log

During the last 24 hours at sea, an attempt is being made to obtain a better EM Log calibration, although this is being hampered by adverse wind conditions, which will probably preclude accurate low-speed data points.

8.5 TECHSAS

Due to worries over the accuracy (and possible imminent failure) of the FSI sea-surface temperature sensor, the principal scientist asked about the possibility of getting access to the sea-surface sound velocity data (from the AML SmartSV) used by the multibeam echo sounders.

A small cable was made to split the RS-232 signal from the probe, so that it could also be sent to the TECHSAS system (via the ship's FieldBus wiring) as well as to the EM-120 computer. Once there, the raw message was observed on the TECHSAS system, and initially just displayed on the screen.

After a day or so, a TECHSAS module had been written to log the data. The module suffered from two problems. Firstly the displayed sound velocity data has a few extra characters added to it, which appear to come from the maximum and minimum data limits. This does not affect the logged data. The second problem was that the probe was putting out data at quite a high frequency – one that was just not necessary. After a while a modification to the module was made so that it logged just one in every ten data values. This works, but now, when TECHSAS logging is stopped, the module does not seem to want to stop logging with all the other modules.

The scientific party identified TECHSAS time-keeping problems, and it seems that they only affect modules that are used by the SSDS (Scientific Ship Display System – AKA little green boxes). TECHSAS imparts data to the SDSS in two parts, firstly, the modules that log the necessary data (e.g. GPS, Winch, Gyro) re-write a small file with the latest message. Secondly, a small shell script reads these files and transmits the data over an RS-232 line to the SSDS distribution box. The only thing I can think of that can be causing these timing problems, is that the overhead of writing to these additional files somehow adversely affects the time keeping of the modules. If this is the case, a new program, monitoring the UDP data broadcasts from TECHSAS could write data to the RS-232 line without the need for any disc access, or any need for the TECHSAS modules to write to the disc.

8.6 Seapath 200 logging

The Seapath 200 positioning system was purchased by Platform Systems after it was noted that the Applanix PosMV was the only system providing attitude data to the vessel's dynamic positioning system. In addition, at the time, the Seapath DPS-116 was the only system providing position information.

The Seapath 200 was purchased and set up as GPS 2 on the bridge DP system. Up until this cruise, its data has never been used scientifically. After problems with the system (and it not getting adequate differential corrections from the Seastar receiver) it was noted in the manual that the system had an Ethernet port and could output NMEA data over UDP.

The system was connected to the ship's network and configured to output both position and attitude data on two different UDP ports. The TECHSAS system was then configured to listen for the information on those ports. Unfortunately, it seems that when the Seapath system sends multiple NMEA sentences (e.g. a GGA and VTG) at the same time, it does not split them into separate packets, and the current TECHSAS modules ignore all but the first NMEA sentence in a packet. The way to get around this is to add some code to check for line breaks within a packet, and then parse the individual messages within a packet. At present this has not been done, but may be done by the end of the JC034T trials.

It should be made clear that the Seapath 200 has not been a total disaster. Basic position information has been successfully logged for a large part of JC032, and Ben Moat has done some work indicating that the Seapath 200 may give significantly better position data than the Applanix PosMV. Consequently, in future cruises we should consider making the Seapath 200 position the primary fix file in Level C bestnav processing.

8.7 Level C

With the additional data being logged via TECHSAS, changes were made to the fromtechsas.ini file to enable the data to be logged on the Level C streams.

Normal relmov and bestnav navigational processing was performed with the PosMV position as primary fix file and the Seapath DPS-116 as secondary fix file.

Since the EA-600 was setup to use 1500m/s as its sound velocity, prodep was used to correct the depth for Carter Area.

Windcalc was also run to provide a stream with absolute wind speed.

8.8 SSDS

A wiring problem was corrected on the SSDS so that displays were available at both the forward and aft ends of the Deck Lab.

8.9 Mk II Splitter

A Prototype Mk II splitter system was installed at the start of the cruise, and a splitter cable installed so that it received the same messages that the Mk I splitter received. Further development of the software was undertaken during the cruise to change it from being a “hard coded” system to using a configuration file (currently identical to the setup of the original Mk I splitter). This will allow the relatively easy addition of a user interface (web or terminal-based) later on. It is intended to give the system a major test during the passage back to the UK and during JC034T. One minor barrier to the full acceptance of this system is minor problems with the performance of the Edgeport 416 under Linux. We are in contact with Digi, (the manufacturers) and they are working on a solution. This problem affects not only us, but also Deep Platforms at NOCS, and also many users outside of NOCS.

8.10 Dartcom HRPT/CHRPT System

The system was primarily used to have a quick look at what the weather was like in the immediate area around the vessel. Both visible light and IR (night-time) images were collected from the NOAA and Chinese satellites. There were problems with the acquisition computer setup towards the beginning of the cruise, but these were quickly solved. There is also an intermittent problem with the Orbit dish controller failing to respond to commands from the acquisition computer. Normally a restart of the controller would remedy this.

8.11 Network Storage

Data32, a 300GB external RAID1 array on the Cook3 workstation, was used for shared storage of various data. CTD and LADCP data were immediately copied over after each cast. Access to the area was available to all scientists on their laptop computers, as well as both of the Sun workstations installed in the Main Lab. The area was backed up to LTO-2 tape every evening using *tar*.

8.12 End of Cruise Media

At the end of the cruise LTO-2 tapes of Level C data, TECHSAS data and the data32 area will be given to the principal scientist.

Paul Duncan

9. Underway Temperature and Salinity

9.1 Introduction

Near surface oceanographic parameters were measured by sensors located in the non-toxic supply. These included fluorescence, light visibility (transmittance) of the surface waters, and an FSI thermosalinograph measuring conductivity, housing temperature and sea surface temperature. Salinity was not measured directly. The FSI salinity was calculated from the conductivity variable using the script *mcalc_sal.m*. The conductivity ratio was calculated by *sw_condr.m*, which divides the measured conductivity by the conductivity at S=35psu, T=15°C, p=0db. Salinity was calculated from the conductivity ratio using *sw_salt.m*, which uses the UNESCO algorithm from *Fofonoff and Millard, (1983)*. Pressure was set to zero. The housing temperature was used for temperature, since this is the temperature at which the conductivity is measured by the instrument. A new TSG system (SBE45 microTSG) provides another source of underway salinity data. In contrast to the FSI, the salinity was calculated in real time using the SBE45 housing temperature and conductivity. The sea surface temperature (SST) was measured at a depth of 5.5m below the sea surface. This section describes the calibration of the underway temperature *(Section 9.2)* and salinity *(Section 9.3)* measurements.

Table 6: Underway SST and salinity instrument details

Instrument	Serial number	Calibration Y=C0+C1*X+C2 *X^2+C3*X^3	Sensor position	Parameter (Accuracy)
FSI OTM	1374	C0= -1.4333E-2 C1= 1.00118E0 C2= -1.0617E-4 C3= 2.16844E-6	Water sampling room	Thermosalinograph – housing temperature
FSI OCM Conductivity	1333	C0= 0 C1= 1	Water sampling room	Thermosalinograph – conductivity
FSI OTM Remote temperature	1370	C0= 3.91747E-2 C1= 1.00087E0 C2= -7.20672E-5 C3= 1.40575E-6	Near intake	Sea surface temperature
Wetlabs Fluorometer	WS3S-351P	C0=-0.8721 C1=15.3	Water sampling room	Fluorescence
Seatech Transmissometer	CST1132PR	C0=-0.01337 C1=0.2157	Water sampling room	
Nudam 6017, 6018				Voltage converters +/- 5V
SBE45 Micro TSG	0231		Water sampling room	Conductivity, temperature

9.2 Calibration of Underway Sea Surface Temperature

The sea surface temperature (SST) was measured by an FSI remote temperature module located close to the non-toxic supply intake on the hull. The SST measurements were compared to the surface temperature measurements from the primary (temp) and secondary (temp1) sensors on the CTD frame. Measurements were selected at 5db and 7db, which are the approximate depths of the remote temperature intake. Figure 59 shows that the remote temperature sensor overestimates the CTD measurements by 0.132°C (s.d. 0.07). The offset was near constant over the temperature range encountered during the cruise. The scatter in the data above temperature differences 0.2°C is believed to be from days when the top of the mixed layer was slightly stratified due to periods of low winds and strong solar heating of the surface waters.

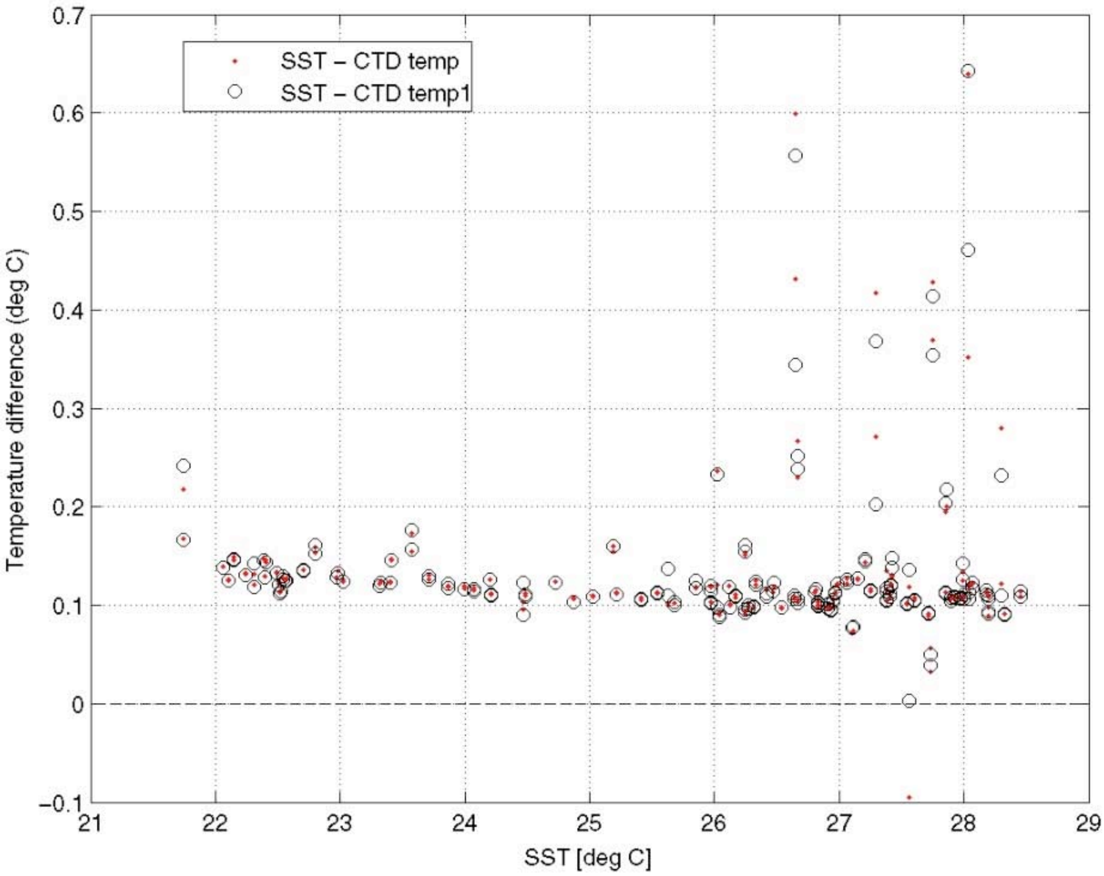

Figure 59: Comparison of CTD surface temperature measurements with the FSI remote temperature

The FSI and SBE45 systems in the water sampling room record their housing temperatures, which are used in the calculation of underway salinity. Figure 60 shows that the housing temperatures from both systems agreed with each other to within 0.018°C (s.d. 0.01) and indicates no drift between systems during the cruise.

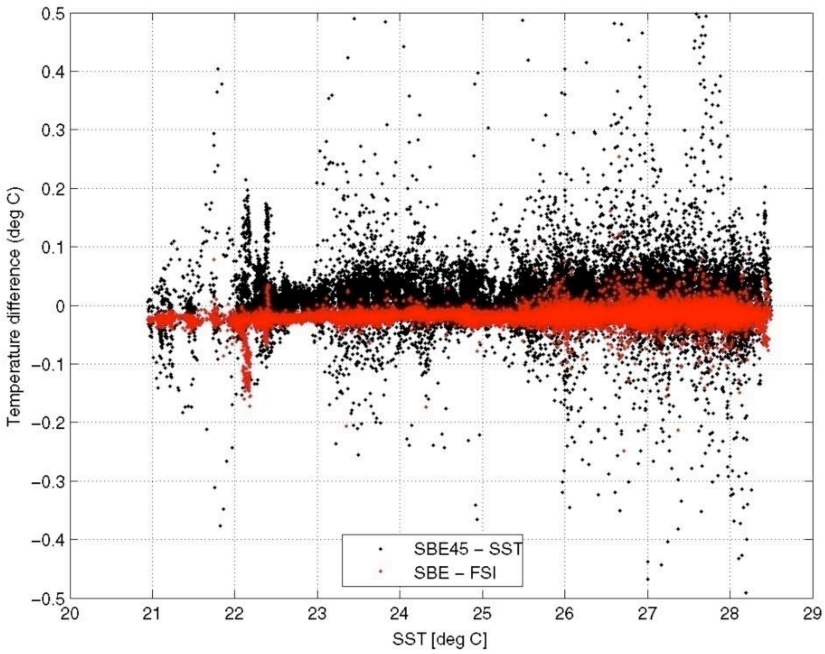

Figure 60: A comparison of the SBE45 housing temperature with the FSI housing temperature and the SST

Figure 60 shows that the SBE45 temperature agrees to within 0.007°C (s.d. 0.04) of the SST. With such a good agreement the SBE45 housing temperature may be used as a measure of the sea surface temperature. However, caution must be used if the SBE45 housing temperature was to be used as an approximation of the remote temperature outside the temperature range of this cruise. It is currently unknown how the two instruments correlate at lower sea surface temperatures.

9.3 Calibration of Underway Salinity Data

9.3.1 Introduction

Two approaches were taken towards the calibration of the underway salinity data. The salinities measured by the FSI and SBE45 were compared with; 1) salinity samples collected from the non-toxic water supply outflow, and 2) the surface salinities measured from near surface CTD.

Water samples from the TSG outflow pipe were collected in 200ml flat glass bottles every 4 hours. Before each collection, the hose connected to the outflow pipe was flushed with the sample water for several seconds (on occasions when the supply was not already running), and the sample bottles were rinsed twice with the sample water. Bottles were filled to halfway up the shoulder and the necks were wiped dry to prevent salt crystallisation at the bottle opening. The bottles were closed using airtight single-use plastic inserts and secured with the original bottle caps. The samples were stored in open crates and left beside the salinometer in the controlled temperature laboratory for a minimum of 24 hours before analysis. This allowed their temperature to adjust to the ambient temperature of the laboratory. A total of 242 TSG samples were taken over the duration of the cruise.

The conductivity ratio of each sample was measured using the salinometer, and the corresponding salinity value was calculated using the OSIL salinometer data logger software, and stored in a Microsoft Excel spreadsheet. The measured salinities of the samples were transferred to a text file, along with the date and time of collection. This file was converted to Mstar format, and the dates and times were converted into seconds since midnight on 1st January 2009.

Another method for calibrating the underway salinity is to use the surface salinity values from the near surface CTD casts. On JC032, 118 CTD casts were taken between days 66 to 109.

9.3.2 Underway Salinity Compared to Surface CTD Measurements and Bottle Samples

Figure 61 shows that the FSI salinity measurements had a strong dependence on SST, e.g. a difference of 3psu at 28°C.

$$\text{FSI offset} = (12.84-0.551)*\text{SST} \qquad R^2 = 0.99 \qquad (1)$$

The large differences in the FSI measurements with CTD and bottle samples below an SST of 23°C are produced by the FSI over-reading the salinity during the second day of the cruise. It is unknown why the FSI overestimated the SBE45 shortly after it was switched on. These data points were excluded from the FSI data to generate Eq. 1.

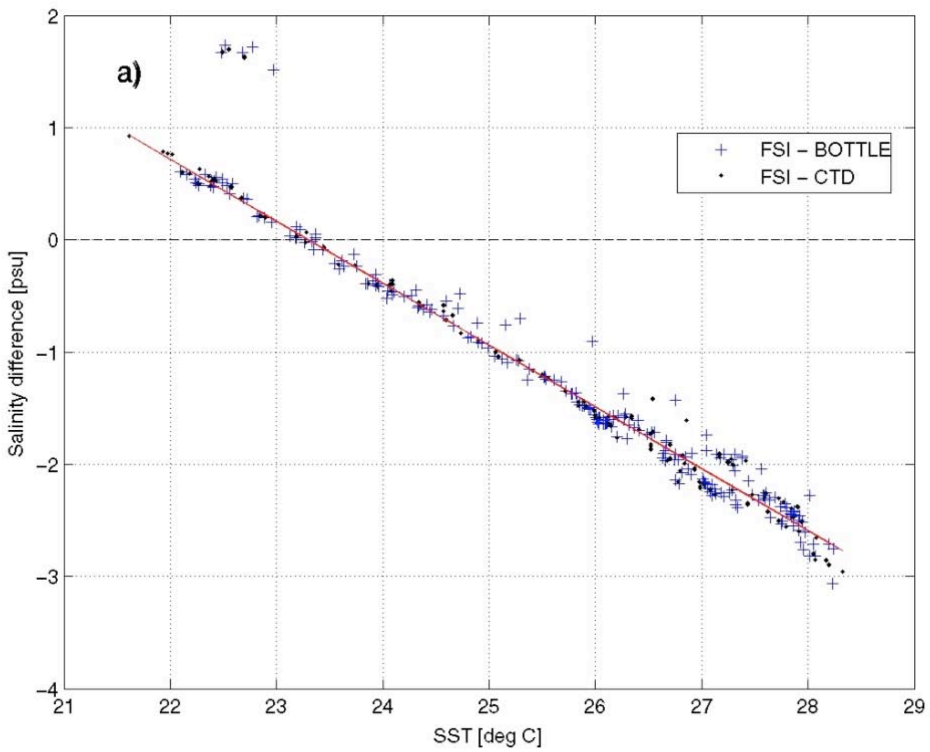

Figure 61: SBE45 and FSI underway salinity compared to bottle and CTD measurements. The SST was corrected by comparison to the CTD (Section 2).

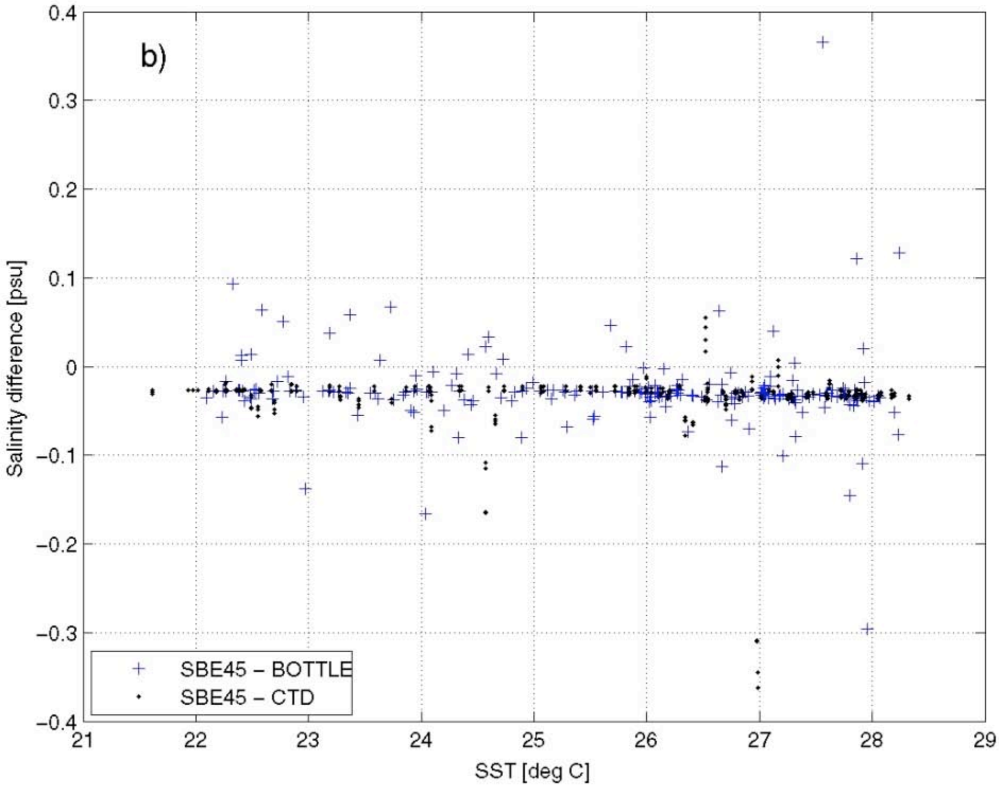

Figure 62: Calculated salinity difference between SBE45 and bottle and CTD data respectively

Figure 62 shows that the SBE45 overestimated the salinity from the combined bottle and near surface CTD measurements by 0.034psu (s.d. 0.042) and was corrected accordingly. The FSI data were not corrected as the SBE45 performed well throughout the cruise.

9.4 References

Fofonoff N. P. and Millard R. C., (1983), Algorithms for Computation of Fundamental Properties of Seawater, *UNESCO Technical Papers in Marine Science*, 44.

Lorna McLean and Ben Moat

10. Surface Meteorological Sampling System (SURFMET)

10.1 Introduction

The surface meteorological conditions were measured throughout the cruise. A brief discussion of the performance of the meteorological sensors is given in this section. Appendix A lists significant events such as periods when data logging was stopped, and Appendix B contains figures showing a time series of the meteorological data. All times refer to UTC.

10.2 Instrumentation

The RRS *James Cook* was instrumented with a variety of meteorological sensors to measure; air temperature and humidity, atmospheric pressure, short wave radiation, and wind speed and direction. These are logged as part of the SURFMET system.

The meteorological instruments were mounted on the ship's foremast (Figure 63) in order to obtain the best exposure. The heights of the instruments above the foremast platform were: Gill WindSonic anemometer, 2.3 m; Vaisala air temperature and humidity 1.85 m and the irradiance sensors 1.38 m.

10.3 Routine Processing

Files were transferred from the onboard logging system (TECHSAS) to the UNIX system on a daily basis, using the script *mday_00_get_all.m*. The raw SURFMET data files have names of the form *met_jc031_d***_raw.nc*, where *** represents the day number. These were copied to *met_jc031_d***_edit.nc* for editing.

The 1Hz SURFMET data were adjusted according to the calibration equations specific to the serial number of each instrument. This was carried out by the *mcalib_surfmet_jc032.m* script. Spikes in the data were assigned an absent data value using *mplxyed*.

True wind speed and direction were calculated using the script '*truewind1_surfmet_jc032*' as follows. Bestnav navigation data were merged on to the SURFMET data. To avoid problems associated with averaging wind direction over time, the relative wind speed, ship's heading and course made good were converted to eastward (u) and northward (v) components, using the script *muvsd.m*. The true wind direction was calculated and the data were averaged into 1-minute bins. The average directions were calculated by their respective u and v components and contained in the file (*met_jc031_d***_avg.nc*).

10.4 Sensor Performance

10.4.1 Air Temperature and Humidity

The Vaisala sensor was located on the starboard side of the foremast platform. A possible bad connection between the two sections of the sensor produced negative temperatures and very low humidity measurements on day 65. This was fixed before sailing. Unfortunately the sensor failed again on day 73 with similar problems. The wiring was checked and the connection between the sensor sections cleaned on day 77 and remained stable for the rest of the cruise.

10.4.2 Wind Speed and Direction

The Gill Windsonic was located on the foremast platform. Only data from one anemometer was logged so no comparisons with other anemometers were made. A large spotlight has been placed on the front edge of the foremast platform potentially increasing the flow distortion in that region *(Yelland et al., 1998; Moat and Yelland, 2008)*. This will bias the wind speed measurements made from foremast anemometers, especially when the anemometers are directly downwind of the spotlight.

10.4.3 TIR and PAR Sensors

The ship carried two total irradiance sensors, one (PTIR) on the port side of the foremast platform and the other (STIR) on the starboard. These measure downwelling radiation in the wavelength ranges given in Table 7. The STIR and SPAR sensor channels were logged through the wrong channels during the start of the cruise. This was corrected on day 68. A comparison of the TIR short-wave sensors showed that both sensors were in good agreement. The daily mean difference in the measured short-wave values was below 1.7W/m^2 (standard deviation 10W/m^2). In addition to the TIR sensors the ship carried two PAR sensors, which measured downwelling radiation in the wavelength ranges given in Table 7. The difference between the two PAR sensors increased linearly with increasing short wave radiation (offset = -0.039*SPAR-1.1), e.g. the starboard PAR sensor over-reads the port PAR sensor by 14.5W/m^2 at an incoming shortwave of 400W/m^2. It was not possible to check the serial numbers on the PAR sensors during the cruise so it is not clear if the correct calibrations were applied. The instrument was not replaced during the cruise.

Table 7: SURFMET instrument details

Instrument	Serial number	Calibration Y=C0+C1*X+ C2*X^2+C3*X ^3	Sensor position	Parameter (Accuracy)
Vaisala HMP45A	D1330038	C0=0 C1=1	Starboard side foremast	Air temperature and humidity Humidity ±1.0% Temperature ±0.13°C
PAR Skye energy sensor (400 – 700nm)	28563 28558	C1=0.9285 C1=0.8453	Port side Starboard side	PAR sensors 1.077mV/100W/m^2 1.049mV/100W/m^2
TIR Kipp and Zonen CMB6 (335 to 2200nm)	047462 047463	C1=0.8453 C1=0.9425	Port side Starboard side	11.83 µV/W/m^2 10.61 µV/W/m^2
Vaisala PTB100A Atmospheric pressure	RO45005	C0=4.79732E-1 C1=9.99417E-1	?	
Gill Windsonic anemometer	064537		Foremast	Wind speed and direction

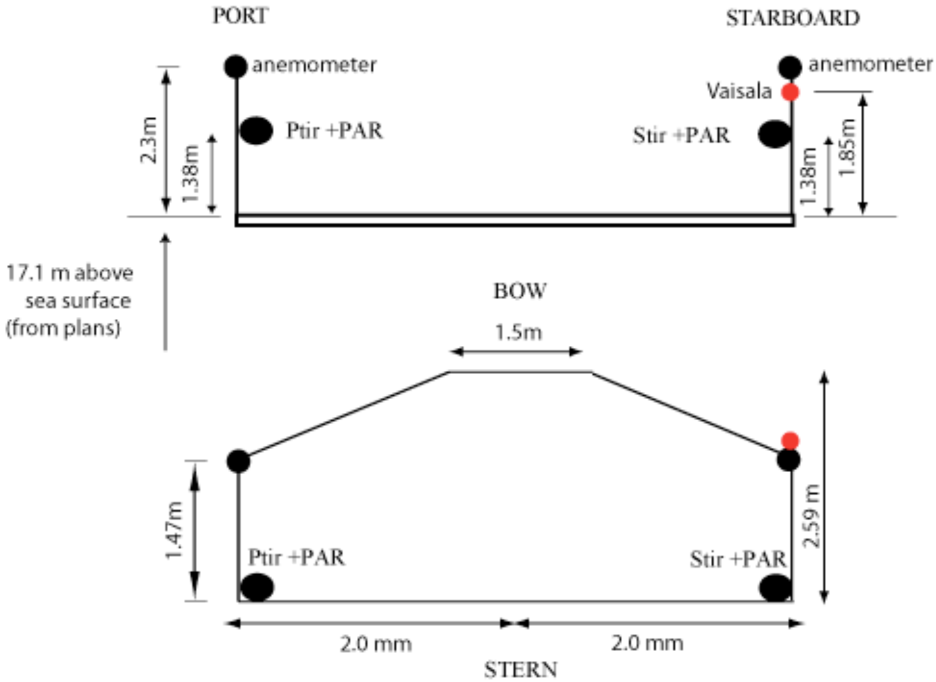

Figure 63: Schematic diagram showing the instruments on the foremast platform.

10.5 References

Moat, B. I. and M. J. Yelland, (2008), Going with the flow: state of the art marine meteorological measurements on the new NERC research vessel, *Weather*, **63**(6), 158-159.

Yelland, M. J., Moat B. I., Taylor P. K., Pascal R. W., Hutchings J. and Cornell V. C., (1998), Wind stress measurements from the open ocean corrected for airflow distortion by the ship, *Journal of Physical Oceanography*, **28**, 1511-1526.

Appendix A: List of significant events

Day 65 (in Montevideo): Intermittent Vaisala air temperature humidity sensor fault. Check connections on foremast. No reason found but sensor functioning.

Day 68: Starboard PAR/TIR radiation sensors changed to correct SURFMET logging streams.

Day 73 to 77: Vaisala air temperature humidity sensor failed. Possible loose connection. Repaired on Day 77.

Appendix B: Time series of mean meteorological data

Figures 64 - 72 show time series of 1 minute averages of the mean meteorological data. Only basic quality control criteria have been applied to these data. Each page contains five plots showing different variables over a five-day period.

Top panel - the air temperature from the Vaisala sensor plus sea surface temperature (temp_r) from the FSI thermosalinograph.

Upper middle panel - downwelling radiation from the two shortwave TIR and PAR sensors, all in W/m^2.

Central middle panel - relative wind direction (reldd = 180° for a wind on the bow) and true wind direction (TRUdir) from the starboard R3 anemometer. The ship's true heading is also shown.

Lower middle panel - relative (RELspd) and true wind (TRUspd) speeds in m/s from the anemometer. The ship's speed over the ground is also shown in m/s.

Bottom panel – Atmospheric humidity from the Vaisala sensor and the atmospheric pressure.

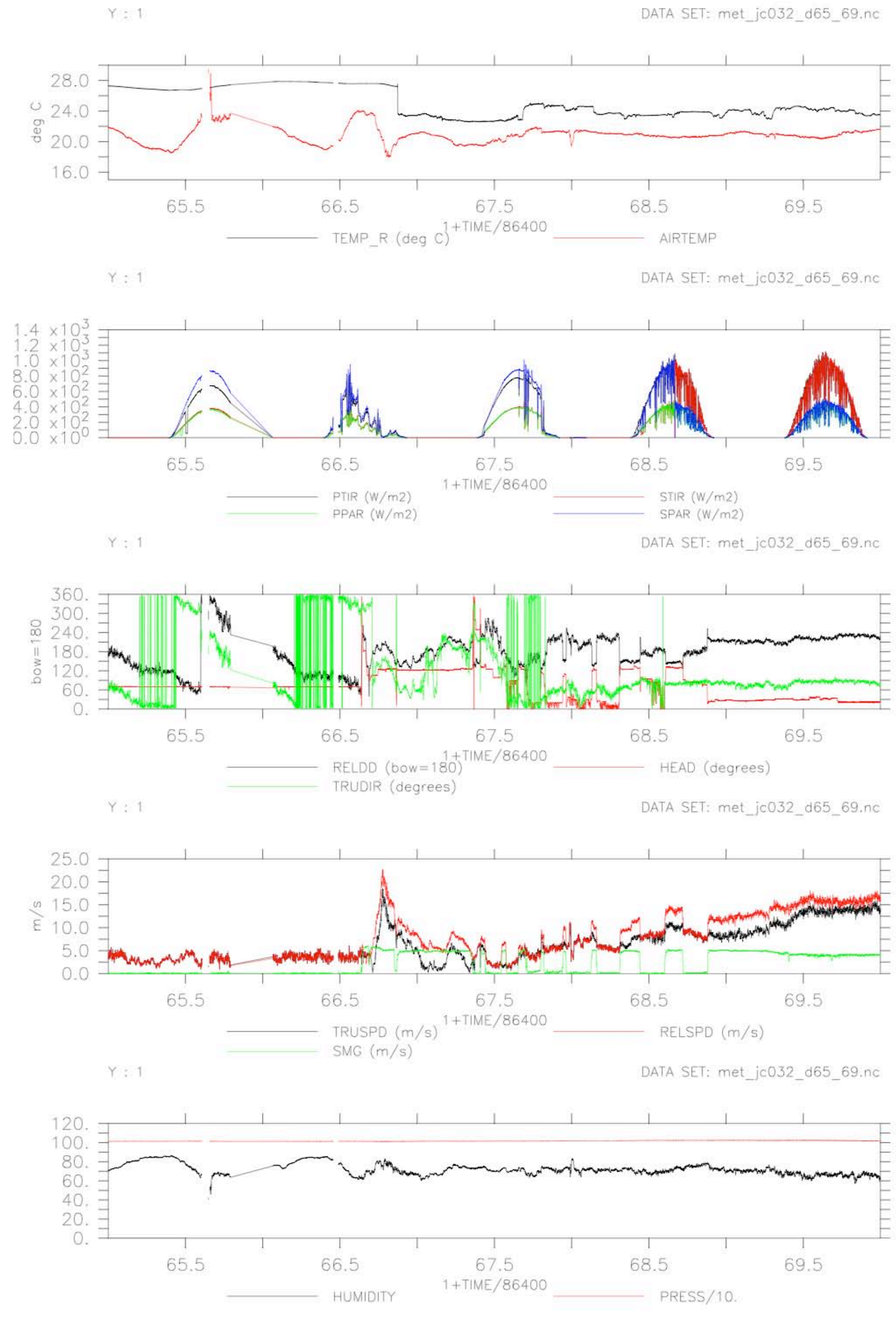

Figure 64: Meteorological data for days 65 to 70. Note the change of channels in the irradiance sensors on day 65.

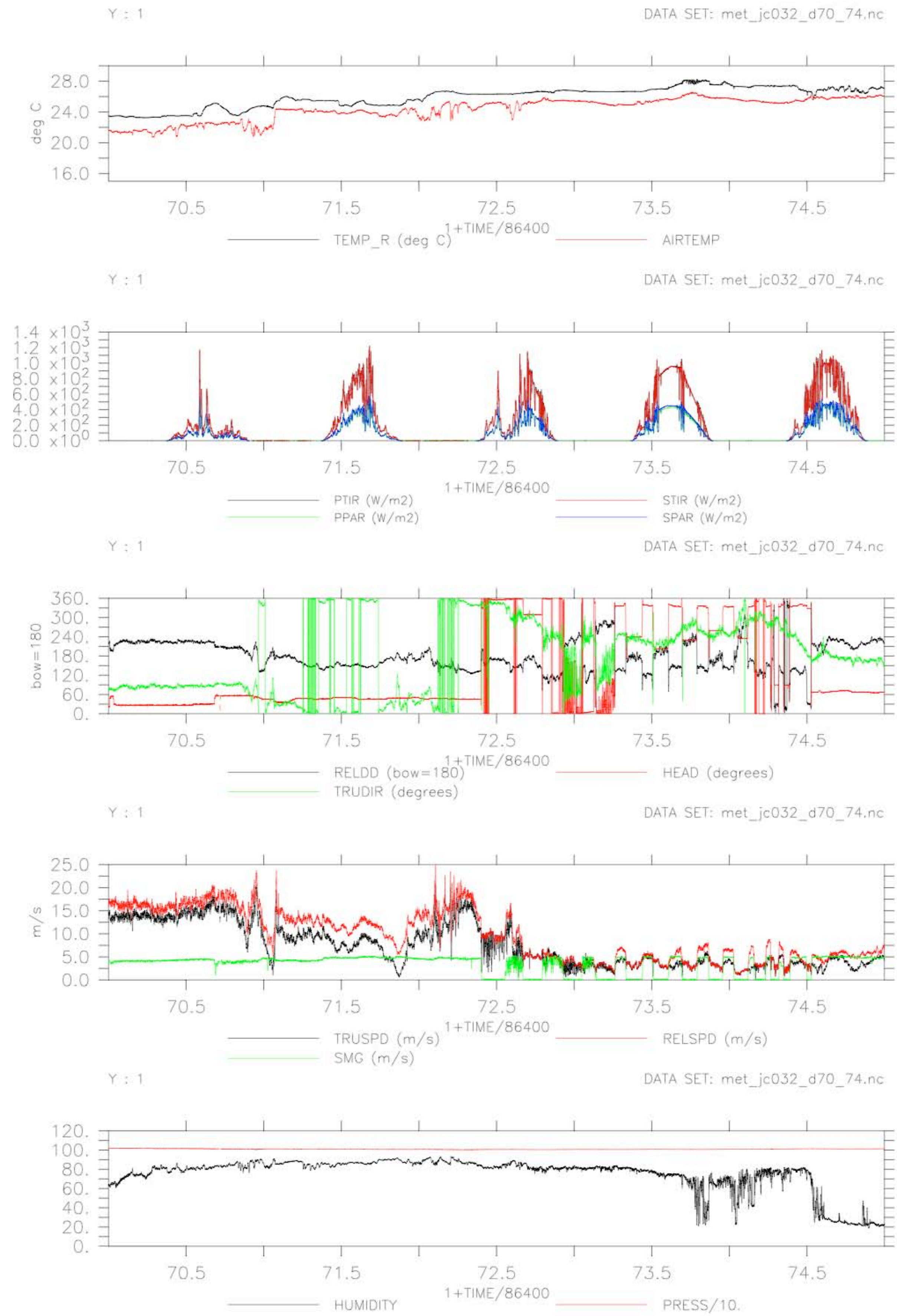

Figure 65: Meteorological data for days 70 to 75

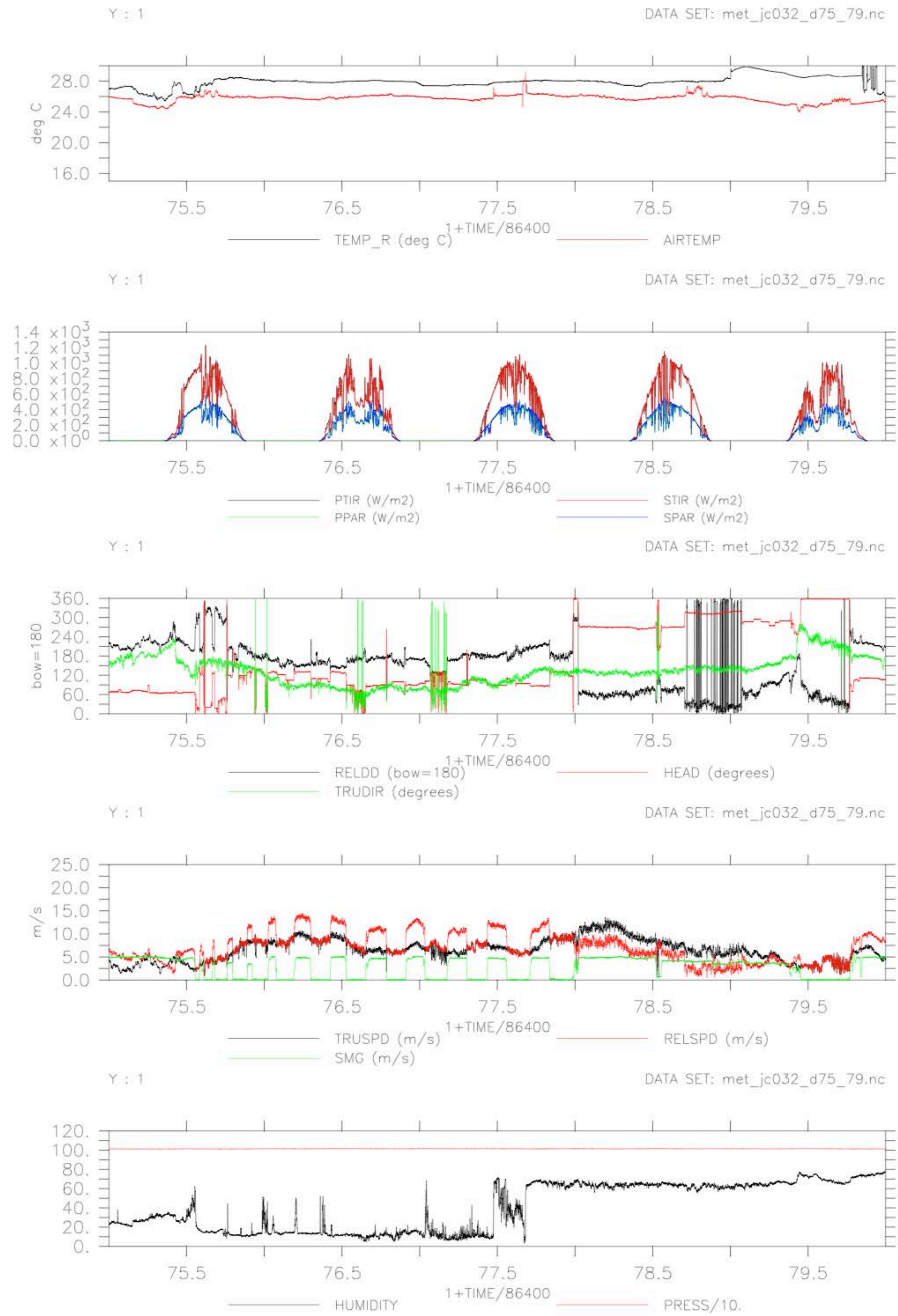

Figure 66: Meteorological data for days 75 to 80

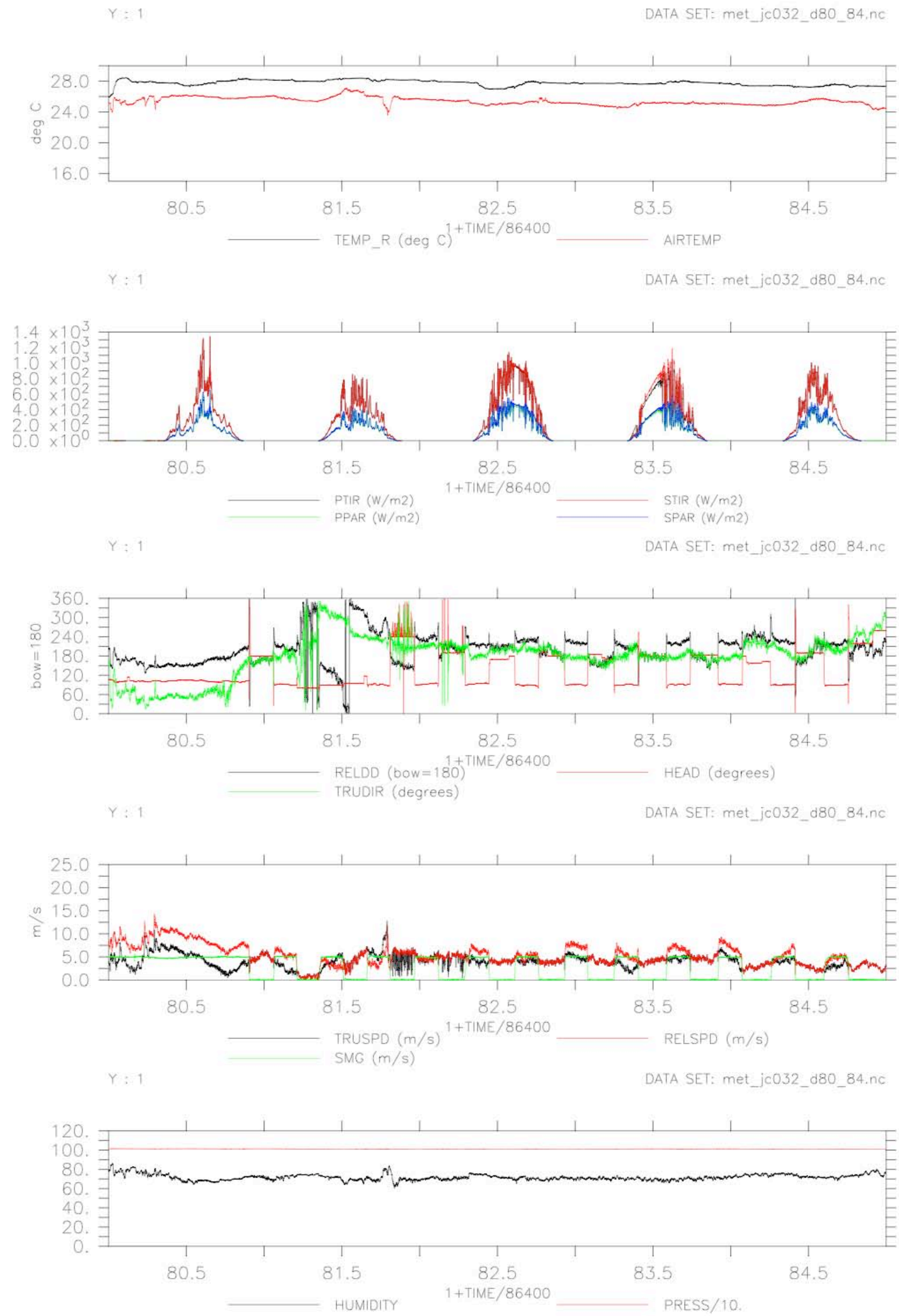

Figure 67: Meteorological data for days 80 to 85

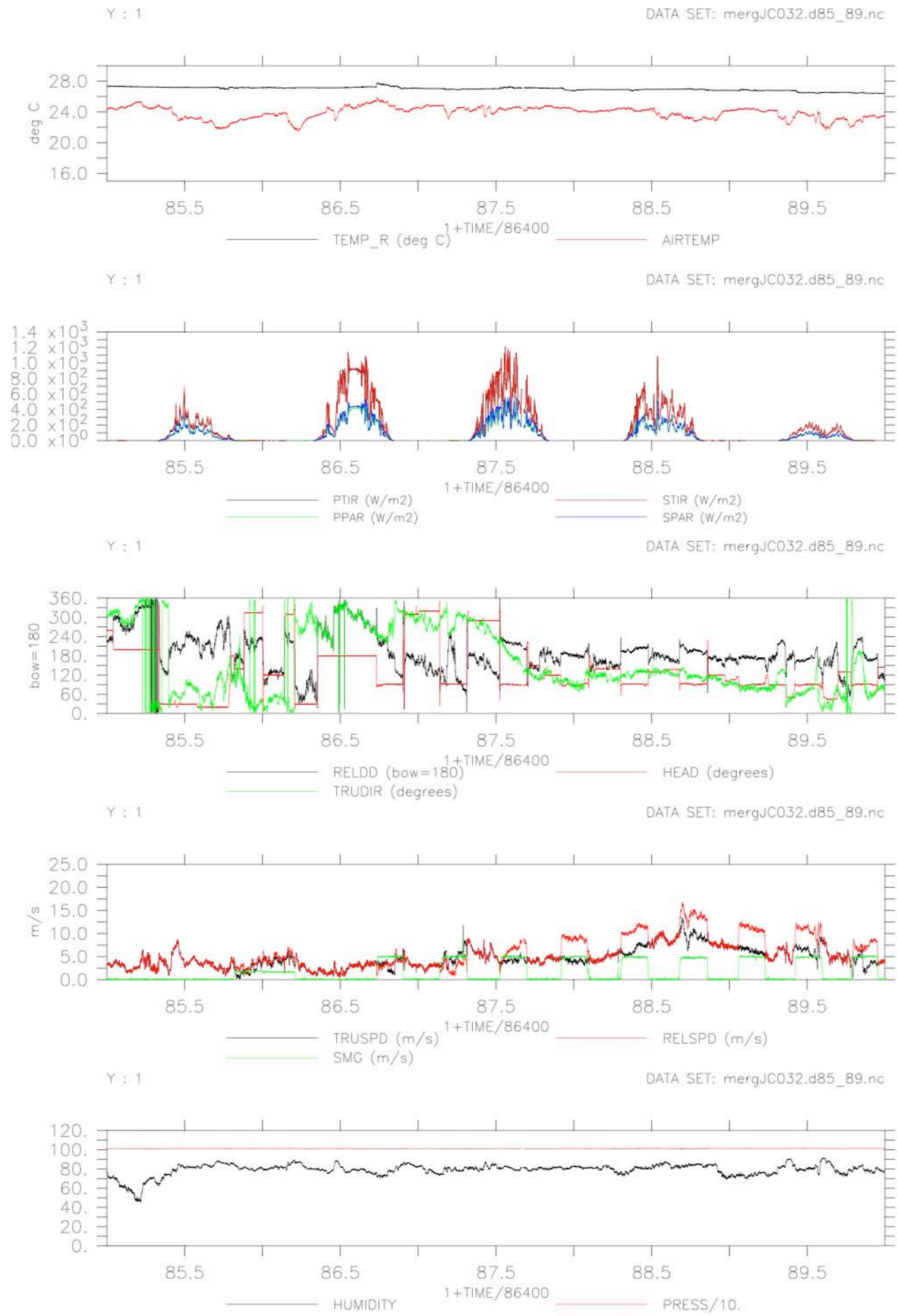

Figure 68: Meteorological data for days 85 to 90

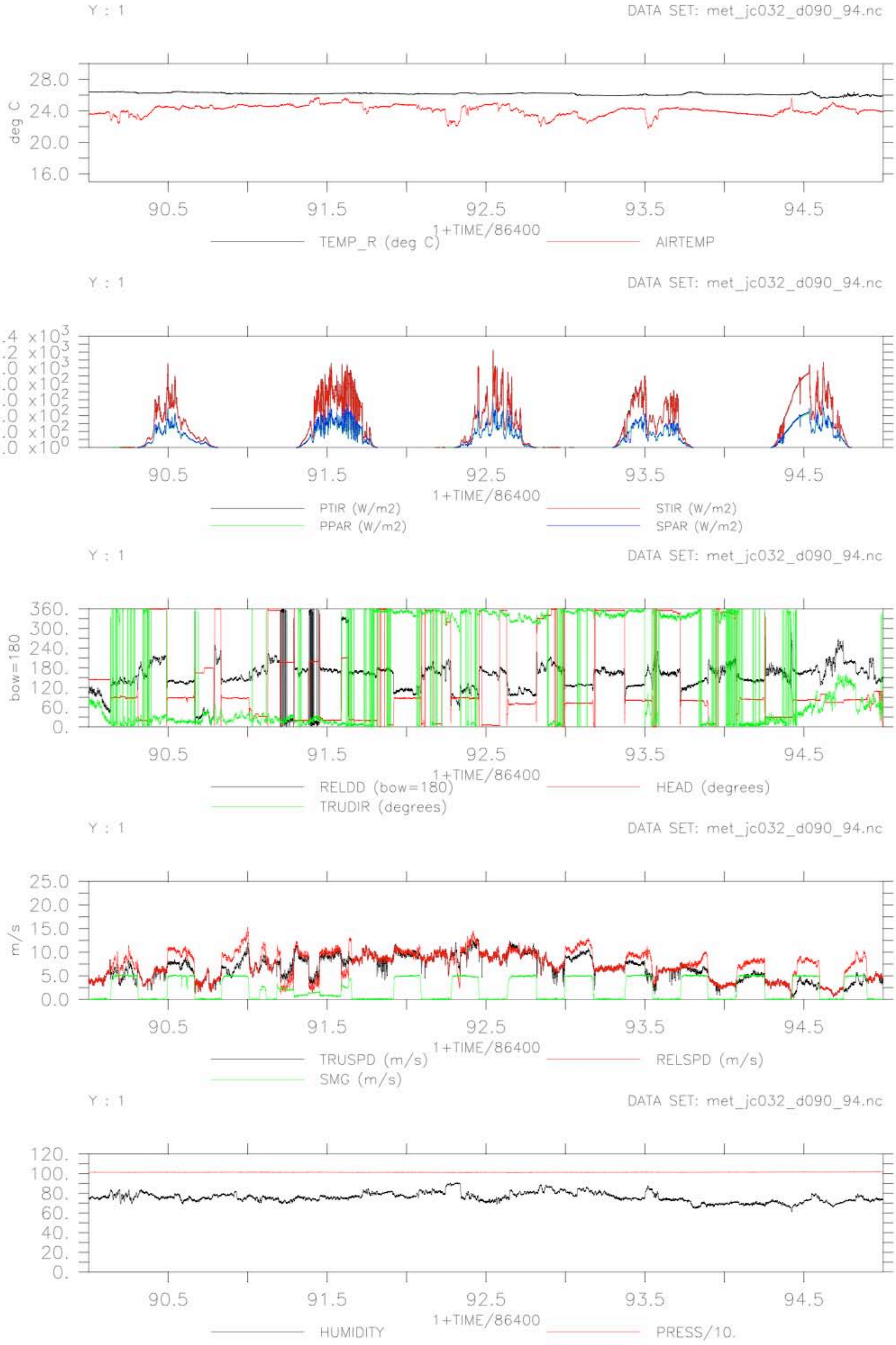

Figure 69: Meteorological data for days 90 to 95

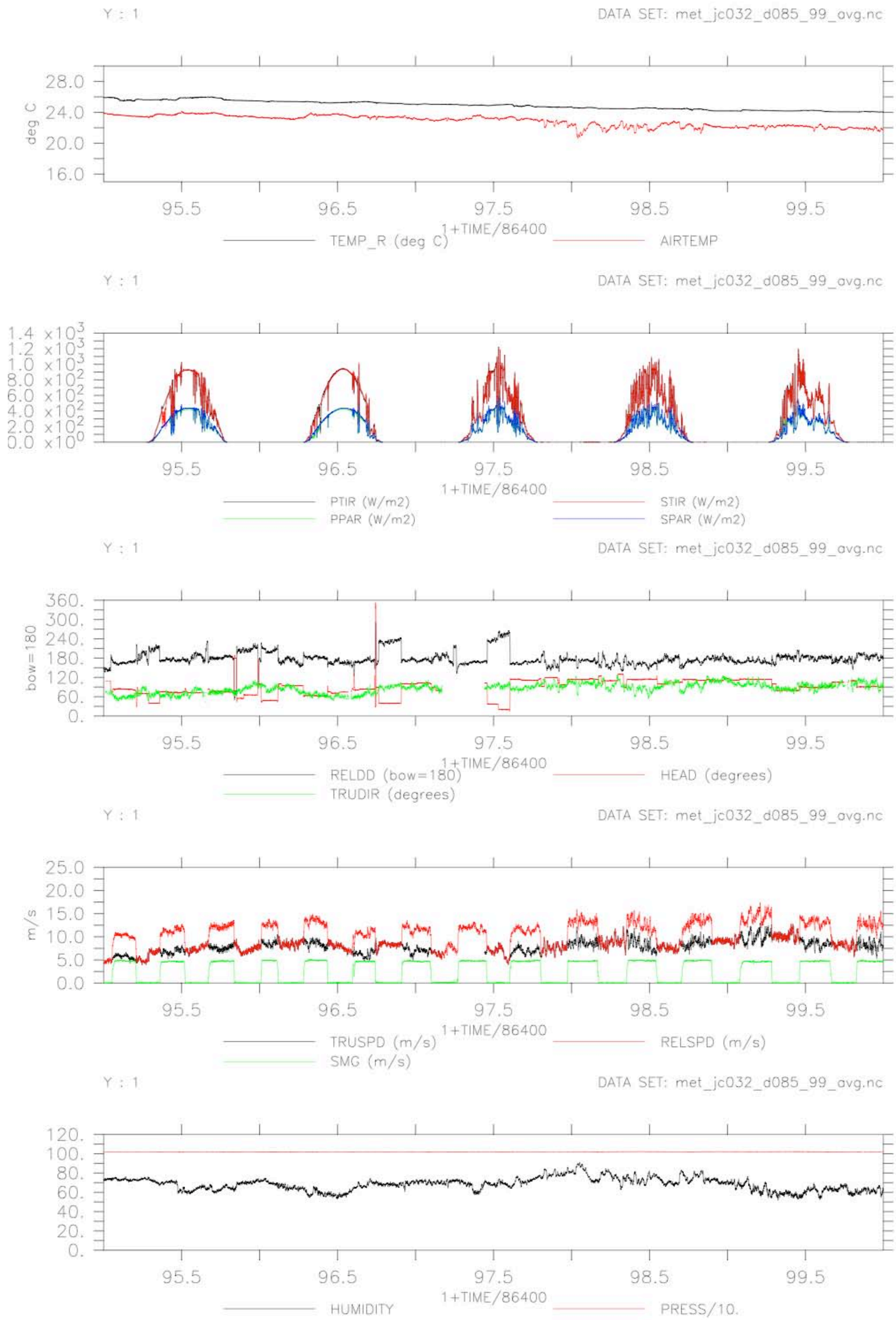

Figure 70: Meteorological data for days 95 to 100

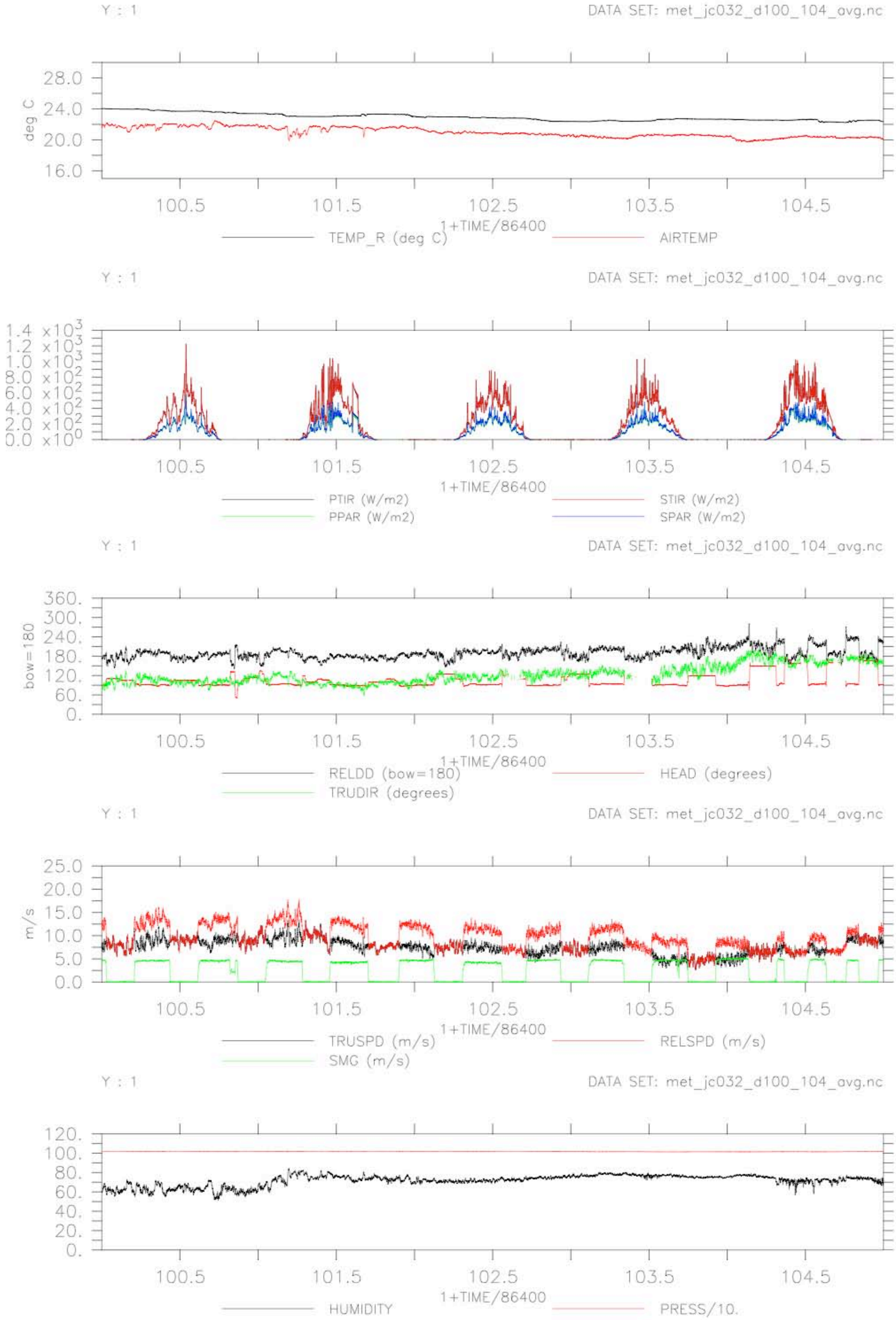

Figure 71: Meteorological data for days 100 to 105

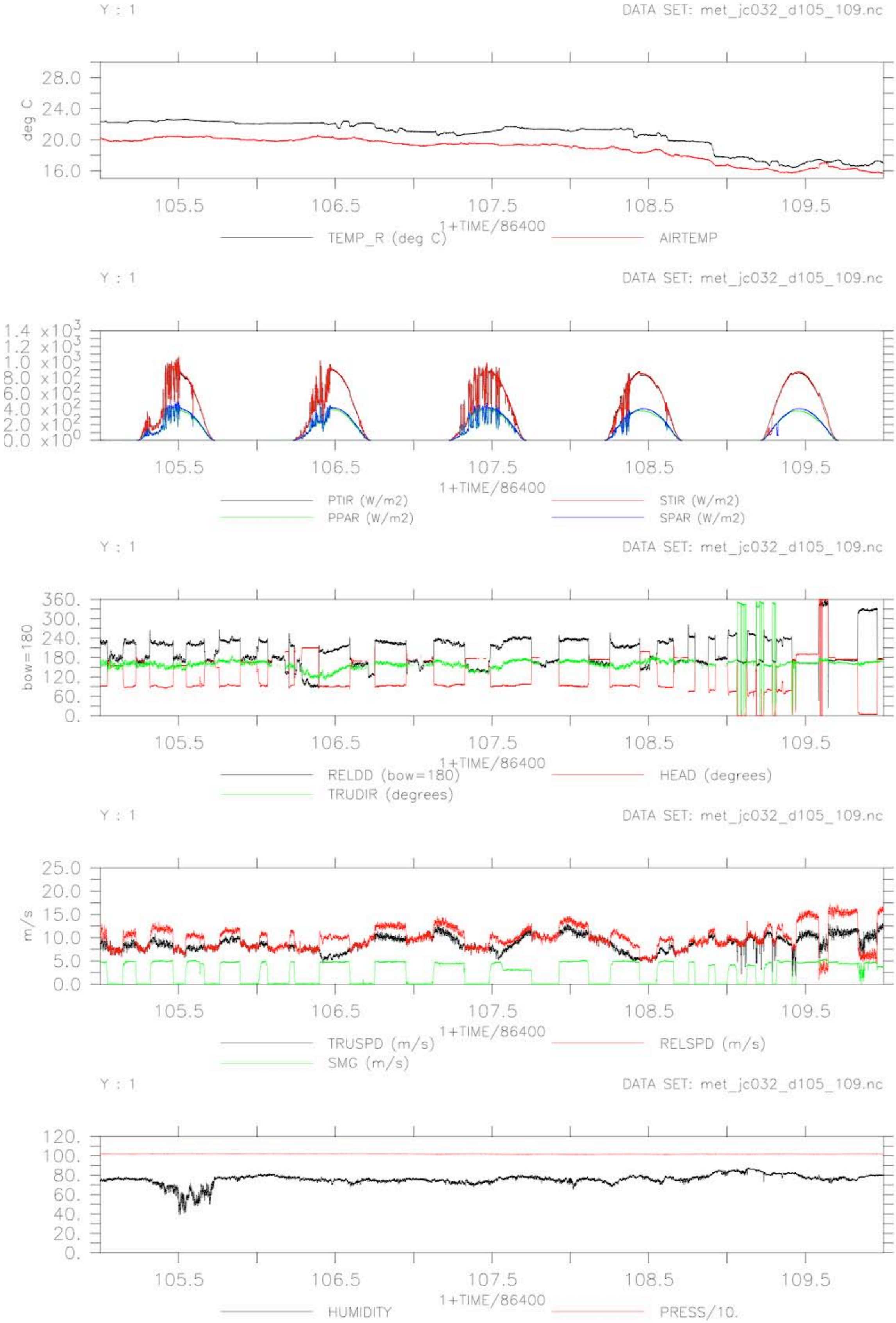

Figure 72: Meteorological data for days 105 to 109

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11. Navigation

11.1 Instrumentation

11.1.1 POSMV

The Applanix POSMV is the primary GPS system used for science. Three data streams are output by the RVS system at 1Hz. ‘posmvpos’ contains the ships position whilst the ‘posmvtss’ contained heading information. The ‘gyropmv’ data stream contains the posmvtss heading information rounded to 1 decimal place and is not analysed in this report. Occasional dropouts of the DGPS would happen, particularly towards the centre of the basin. The *posmvpos* data were used in the LADCP processing and as a position in the bathymetry and SBE45 data files.

11.1.2 Seapath systems

Two Seapath systems are used on the ship. The Seapath dps116 is the primary GPS unit for the ship’s dynamic positioning system and is believed to be very accurate. The data are logged via the ‘dps116’ rvs data stream. In addition the ship possesses a Seapath 200 system as a secondary unit for the dynamic positioning system. The Seapath 200 data are not made available via the rvs data stream and are only available via the TECHSAS system. Even though the systems are classed as primary and secondary the ship’s dynamic positioning system takes input from both systems.

11.1.3 Ashtech

On previous ships, the Ashtech used to be the primary system for obtaining the most accurate measurement of the ship’s heading, but has been replaced by the posmv system. Accurate heading is required by the ship’s ADCP systems. The Ashtech heading will be compared to the headings from other systems in Section 4. The Ashtech heading defaulted to 0 on day 070 and was not reset until day 087. The data stream was then checked daily as occasional dropouts to zero were observed during the remainder of the cruise.

11.1.4 Ship’s Gyro

The ships gyro on the bridge was logged via the rvs data stream as ‘gyros’. The data were used to remove any large outliers in the Ashtech system.

11.2 Routine processing

All data streams were processed in a similar manner. Data were transferred daily from the TECHSAS system using the script *mday_00_get_all.m*. Raw data files were copied to files with the suffix ‘edit’ and manually despiked using the *mplxyed* function. Data were averaged into 1 minute bins and appended into final files named*_jc032_01.nc’*. Before averaging, the headings were split into east and north components to prevent errors arising from averaging a direction.

11.3 GPS positional accuracy

Figure 73 shows the difference in position between the different systems. It is clear that the posmv and the dps116 positions drift more than the other systems. The posmv exhibits excursions of up to 200m off position (top panels in figure). The drift in the dps116 position was smaller than the posmv. A major feature can be seen in Figure 73c and d as a circular track. This is seen in Figure 73a in the top right quadrant. The difference between the Ashtech and Seapos positions is small and exhibits little drift (Figure 73e).

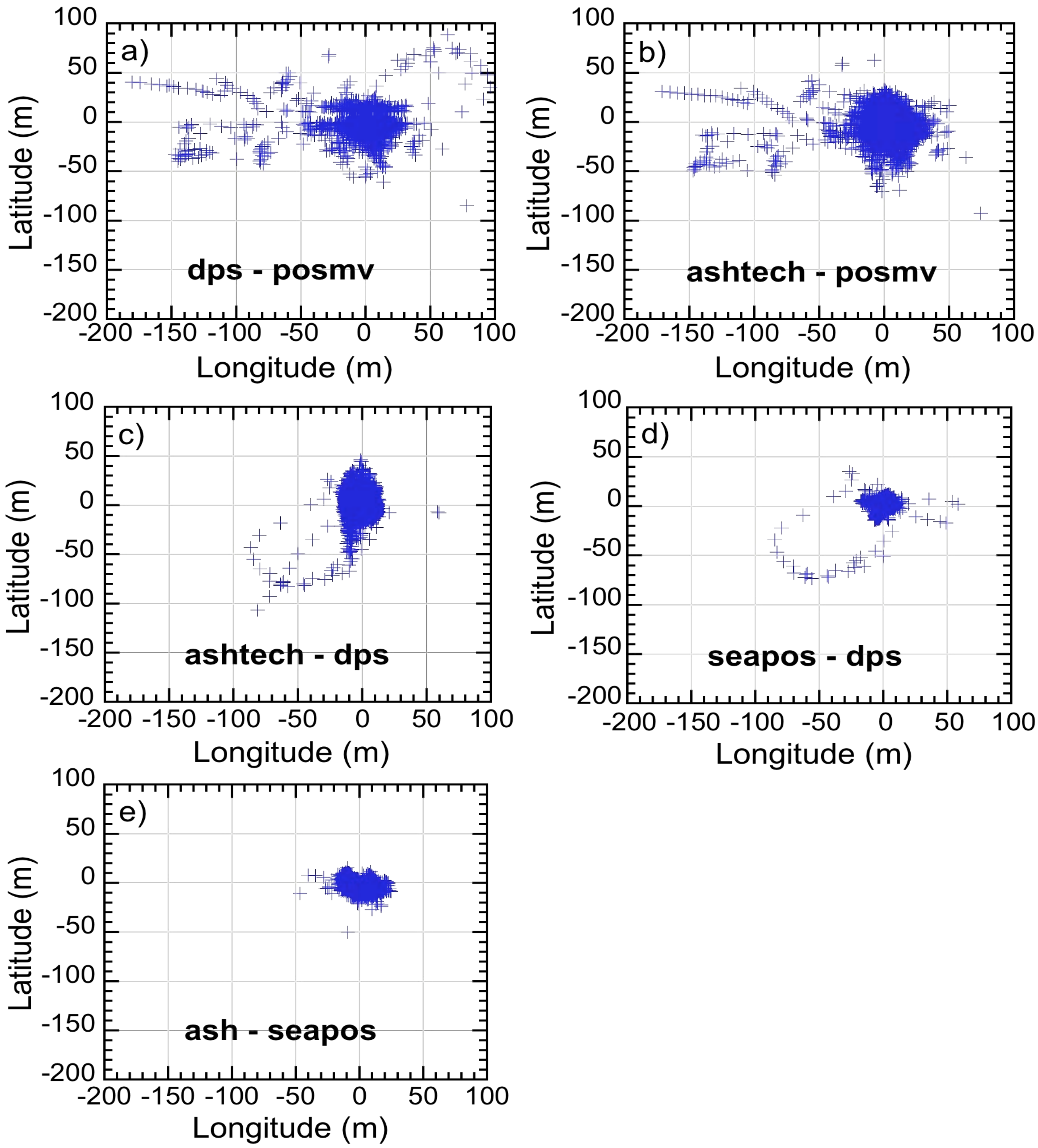

Figure 73: Differences between latitude and longitude measured from different GPS systems.

11.4 Heading accuracy

Ashtech data were subject to more detailed editing. The 1Hz data were merged with the ship's gyro and edited using the following criteria:

Heading	0<heading<360
Pitch	-5<pitch<5
Roll	-7<roll<7
Measurment RMS error	10^{-8} < mrms < 0.01,
Baseline RMS error	10^{-8} < brms < 0.01
Astech-Gyro heading	-7<a-g<7

The posmv and gyro heading was merged onto the Ashtech data and averaged in 2 minute bins. Figure 74 shows that the three systems generally agree with each other to within about ±1°.

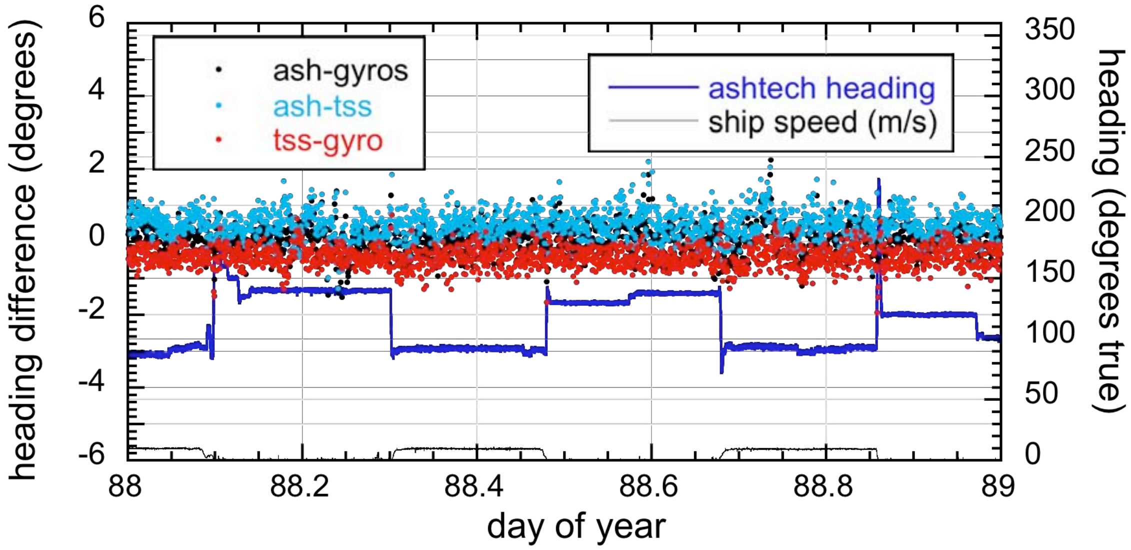

Figure 74: Comparison of GPS headings during dayofyear 80.

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12. Bathymetry

12.1 Kongsberg EA600 Single Beam Echo Sounder

Bathymetry data are measured at 1Hz by an EA600 echo sounder and are processed daily.

The raw data were initially copied into a file named *sim_jc032_d???_edit.nc* (where *???* refers to the 3 digit Julian day number) using *medit_sim_jc032*. During the cruise the EA600 often lost the bottom and either reported zeros or inaccurate depths. These spurious depths were removed by manual despiking using the *mplxyed* function. This process was helped enormously by a hard copy screen dump of the 4-hour depth trace from the EA600.

The position data from the *posmvpos* system were merged on the bathymetry data and the corrected depths calculated from the carter tables using *mmerge_sim_nav_jc032*. A file named *sim_jc032_d???_merged.nc* was created.

There was still noise at depths close to the bottom, which biases the mean towards a shallower value. Therefore the median average over a period of 5 minutes was calculated using *mavg_sim_jc032* and gave a better representation of the data. On occasions where the instrument could not locate the bottom, gaps are present in the data (Figure 75). Each day the averaged files (*sim_jc032_d???_avg.nc*) are appended using *mday_02* and creates a final appended file named *sim_jc032_01.nc*. 'Distance run' was calculated from the navigation files and this was merged onto the bathymetry file. The data were then averaged over 5km to create the file *sim_jc032_01_dist_5km.nc.*

12.2 Kongsberg EM120 Swath System

The EM120 swath system was running throughout the cruise. It is known that the flow of water over the ship's hull produces bubbles that are detrimental to the swath depth measurements. However, the instrument was reliable in calm seas or on station when the number of bubbles passing over the hull was reduced. The instrument was generally more constant in measuring the actual station depth than the single beam EA600 when the sea floor was steeply sloped or the CTD was flown into narrow valleys, e.g. the EA600 depth measurements were occasionally 400m shallower than the actual bottom depth.

It would be useful for future cruises to record the centre beam depth directly beneath the hull via the TECHSAS system.

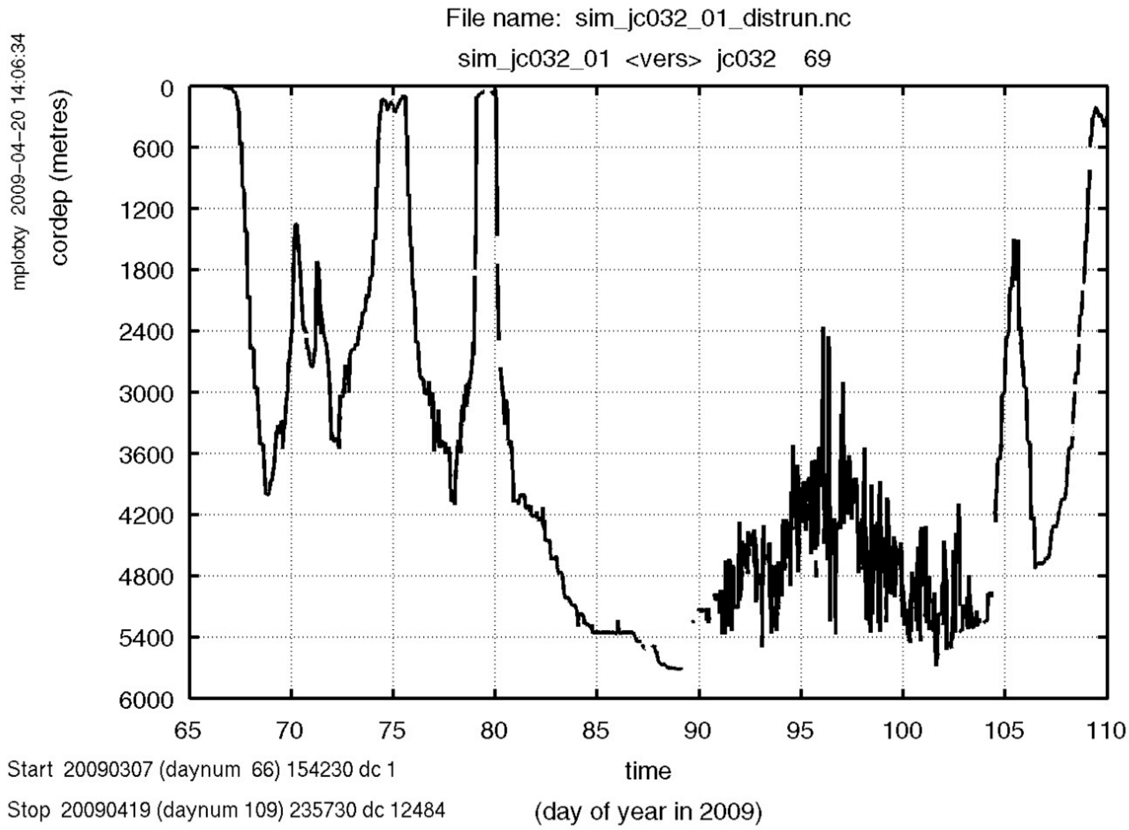

Figure 75: Five minute averaged bathymetry data for the duration of the cruise

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13. Lowered Acoustic Doppler Current Profiler (LADCP)

13.1 Instrument Setup

Following incidents on the previous cruise only one LADCP was available for use on JC032. The instrument in question was a downward looking titanium casing RDI 300kHz Workhorse ADCP (serial number 10607) and this was mounted just off-centre at the bottom of the CTD frame. The LADCP was configured to have a standard 16 x 10m bins, with one water track and one bottom track ping in a two second ensemble. There was also a 5m blank at the surface.

Prior to each station the ADCP was connected to a laptop in the deck lab (via a serial port – USB adapter) for pre-deployment tests and the instrument was programmed. After each station the instrument was reconnected to the laptop for the retrieval of the data. The battery package was charged between stations.

13.2 Instrument Performance

The LADCP exceeded expectations with respect to beam failure. It is believed that over 160 'deep' casts have now been completed in the past two months and this far exceeds aluminium pressure cased units. Although on a few stations a weak beam signal was detected (Figure 76), the correlation between the 4 beams remained tight and the beam strength always returned to normal strength at the following station.

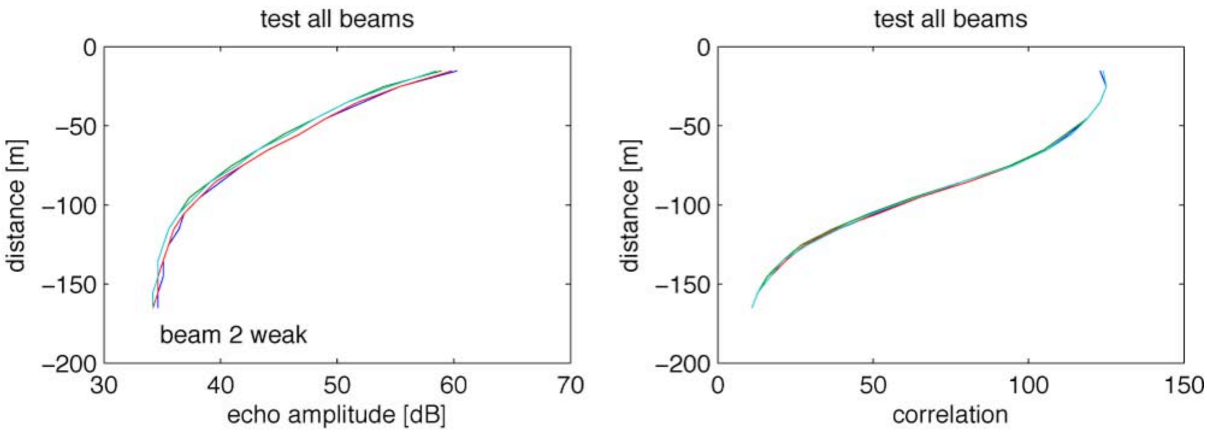


Figure 76: Example plot of echo amplitude with depth from Station 40 indicating a weak beam on the LADCP and the corresponding plot showing the correlation of all 4 beams.

The main issue regarding the technical performance of the LADCP occurred in the downloading of the data. On a number of stations it required numerous attempts to download the data, as the instrument was not communicating with the laptop. On three of these Stations (46, 48 and 50) the retrieval of the data had to be abandoned which led to incomplete upcast profiles (Figure 77). A number of actions were taken to try to solve the problem. Originally the LADCP was connected to this laptop via a USB – serial port adapter that was replaced by a PCMCIA – serial adapter to improve the data transfer but the download problems persisted. On day 87 after Station 51 the original laptop was replaced with a newer machine and the LADCP was plugged directly into the COM1 serial port. Subsequently, there were fewer problems with downloading the data.

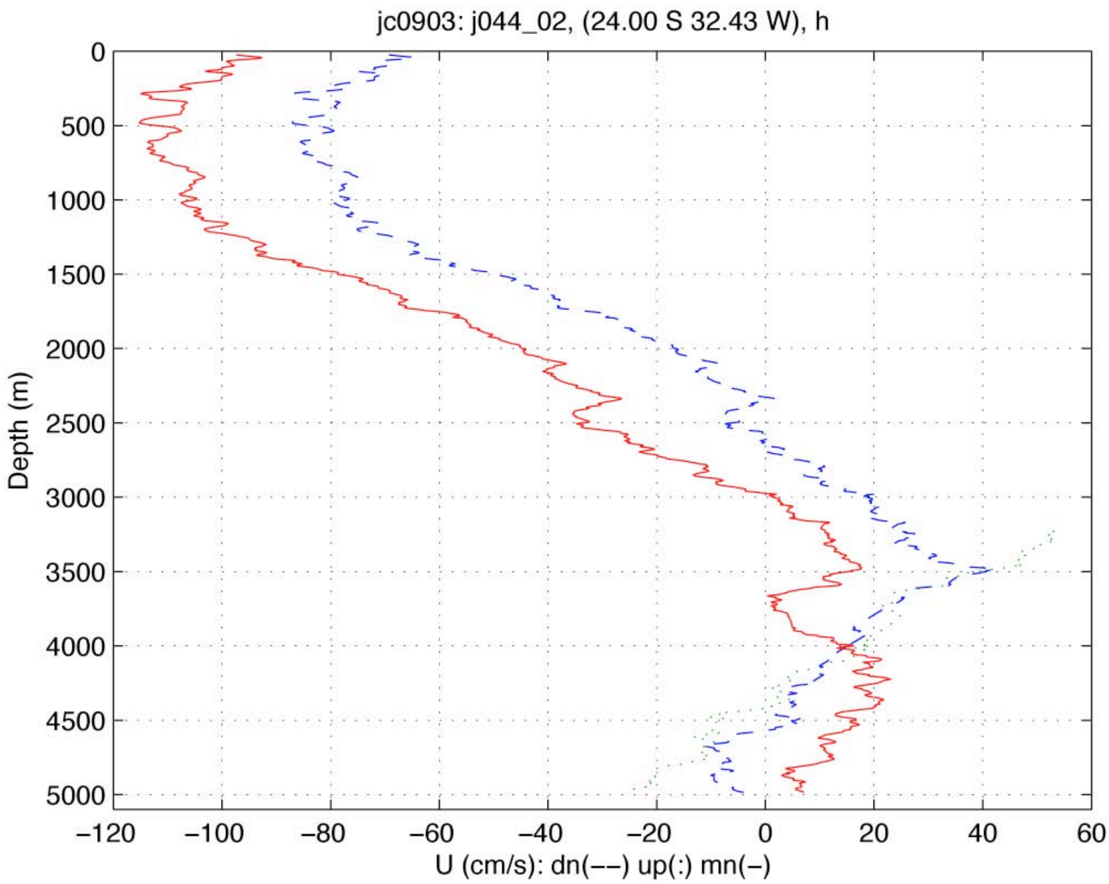


Figure 77: A plot of the *u* component of the flow on Station 44 measured in the downcast (dashed blue line) and the upcast (dotted green line). The mean is shown by the solid red line. Note that the upcast ends at approximately 3250 m.

On day 84 during Station 48, problems with the winch left the CTD at 3000m for a period of approximately 10 hours. Whilst at depth the LADCP continued to log data and this was downloaded on recovery to see if any evidence of internal waves could be detected.

On day 91 the CTD was dropped on the deck due to another failure of the winch mechanism as it was being deployed for Station 61. The LADCP was removed from the frame to check for damage but the instrument was not opened up as it was thought that this would increase the risk of flooding when put back into the water. The face of the instrument was checked visually for signs of damage and only a small chip on the powder coating of the transducer head was noticed. It was not clear when this happened but was thought to have been present before the dropping of the CTD. The chip was touched up with nail varnish and no other damage to the instrument was found and therefore considered suitable for redeployment. The instrument was also connected up to the laptop to run tests to ensure it was operating well. The technicians were happy with the performance of the LADCP and so it was reattached to the frame ready to be redeployed.

The performance of the LADCP deteriorated with depth as can be seen from plots of the sample number and shear standard deviation (Figure 78). Below a depth of 1500m sample numbers reduced to significantly low levels and the shear standard deviation became highly variable between bins. This is thought to be due to the lack of scatterers at depth. Therefore data recorded by the LADCP below 1500m may be considered unreliable.

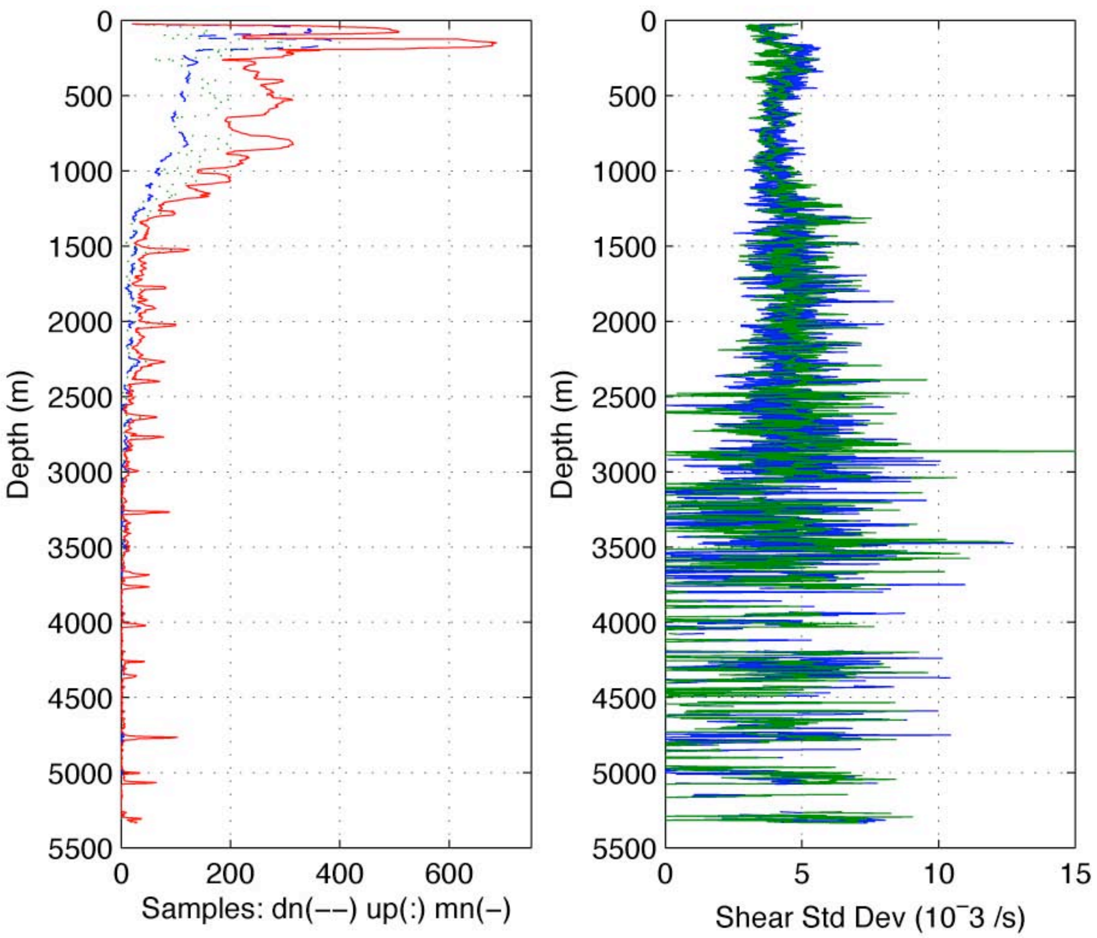


Figure 78: Plots from Station 51 displaying the number of pings with depth and the corresponding shear standard deviation

13.3 Data Processing

The data collected by the instrument were downloaded after each cast and stored as RDI binary files and corresponding text files in the directory */data32/JC032/LADCP/WHMaster*. Both the binary (*ctd*.000*) file and the text file were copied into the directory */data32/cruise/pstar/data/ladcp/uh/raw/jc0903/*ladcp where the text file was then moved into the directory txtfiles and the binary file was renamed using the format *jc032???m.000* (where ??? represents the 3 digit station number).

The data were then processed using two different tools. Primarily a software package from the University of Hawaii (UH) was used to calculate the current velocities and provide information about the heading and tilt of the CTD package. The second piece of software originates from Lamont-Doherty Earth Observatory (LDEO) and was used for obtaining bottom track profiles and to monitor the beams of the instrument.

All the processing for the LADCP was carried out on the RAPID terminal and therefore used Solaris rather than Linux versions of the software.

The sequence of the routine processing for the LADCP data is outlined below.

13.3.1 UH Processing

The initial stages of processing allow the user to examine the quality of the data and to calculate relative velocity profiles in the absence of CTD data.

1. After navigating to the directory */data32/cruise/pstar/data/ladcp/uh,* type *source LADall* to set up the paths required for the processing.

2. Type *cd proc/Rlad* and *linkscript* to create symbolic links from the binary *.000 files to the real raw file.

3. Navigating back up to the directory *~/data/ladcp/proc* type *perl –S scan.prl ???_02* to scan the raw data and create a station specific directory in the proc/casts directory. Data printed to screen should be checked to ensure the details of the cast (i.e. depth, downcast/upcast times) agree approximately with the CTD log sheet.

4. Station position and the magnetic variation correction are entered by typing *putpos2 ??? 02*. This updates *stations.asc* and *magvar.tab* using Matlab.

5. *perl –S load.prl ???_02* loads the raw data, correcting for *magvar.tab* to start processing. It is very important that this step is only carried out once. If it needs to be repeated the database files (*~/proc/casts/j???_02/scdb*) must be deleted first.

6. Next type *perl –S domerge.prl –c0 ???_02* to merge the velocity shear profiles from individual pings into full upcast and downcast profiles. The option *–c0* refers to the fact that CTD data has not yet been included.

7. Enter the *Rnav* directory and run *updatesm.exec* to update the navigation file. Then backup one level to the *proc* directory.

8. Open a Matlab session in this directory and set the variable *plist = ???.02* and run *do_abs* to calculate relative velocity profiles. Check that these plots look sensible, i.e. reasonable agreement between downcast and upcast and that the vertical velocity changes sign between downcast and upcast (it may be necessary to rescale some of the plots). Also check the plot on Figure 78 to monitor the number of pings throughout the profile.

Once the CTD data has been processed this can be incorporated into the LADCP processing to make more accurate estimates of depth and sound velocity and to obtain a final absolute velocity profile.

9. The inclusion of CTD data requires an ASCII file containing 1Hz CTD data for the station created in Matlab. If this is present navigate to *~/proc/Rctd* and open a Matlab session. Run the script *mk_ctdfile* entering the station number when prompted. *ctd_in(???,02)* will read the 1Hz CTD data in. Set *plist=???.02* and run *fd* to align the LADCP and CTD data sets in time.

10. Exit Matlab and navigate back to *~/ladcp/proc*. Type *perl –S add_ctd.prl ???_02* to add the CTD data to the **.blk* LADCP files in the *scdb* directory.

11. Merge the single pings into corrected shear profiles by running *perl –S domerge.prl -c1 ???_02* where the *-c1* option now states that we have included CTD data.

12. Finally in Matlab, once again set *plist = ???.02* and run do_abs to produce the final absolute velocity profiles.

13.3.2 LDEO Processing

As with the UH processing the LDEO processing can first be carried out without the CTD data to monitor the results and performance of the beams.

1. Navigate to */data32/cruise/pstar/data/ladcp/ldeo/jc0903* and start a Matlab session.

2. Type *sp* and when prompted enter the station number and the run letter (*'noctd'* for no ctd data and *'wctd'* when CTD data are included).

3. Next type *lp* and this will run the processing scripts.

4. Print required plots.

The steps above should then be repeated to include the CTD data after it has been processed. The format of the CTD data required is the same for both LDEO and UH processing and when CTD data are available the processing will automatically use it.

13.3.2.1 Inclusion of True Depths

During the LDEO processing with CTD data, a corrected bottom depth was recorded. This was found by typing *grep found */*wctd.log | grep bottom* in the *~ladcp/ldeo/jc0903* directory. The second depth for the station in question was then noted along with its error and the *proc.dat* file located in *~ladcp/proc* was edited to include these values. The original depths were left in place but commented out so they were not used when the file was read. The *perl –S domerge.prl –c1 ???* step was repeated to incorporate the new depth and in Matlab *plist = ???.02* and *do_abs* was re-run. The plots produced then show the corrected depth and may be printed.

13.4 Comparison of LADCP (UH and LDEO) with VMADCP

The opportunity to compare the velocity data from the two different types of LADCP processing and also the VMADCP (75Hz) was presented on this cruise, as was the case on JC031. There were four different components plotted in these graphs; UH velocities, LDEO velocities, bottom track velocities (calculated by the LDEO software), and the VMADCP velocities. The 75Hz VMADCP is capable of penetrating to a depth of approximately 800m and from the majority of the plots comparing velocities, it can be observed that the VMADCP plots are more consistent with those created by the LDEO processing. However, it must be stated that this is not always the case, because for certain stations the UH processing appears to have better agreement with the VMADCP. In all stations affected greatly by shear, the VMADCP is generally the most reliable reading, and this is complimented by the fact that the bottom track is well aligned with these velocities. This is a good indication that the outputs from the UH and LDEO processing should not strictly be taken at face value. The UH processing is particularly severe with the editing of 'bad' data points and may reject data that would be found perfectly acceptable by the LDEO software. As one might expect, the bottom track velocities are generally in best agreement with the LDEO velocities, since they are both processed by the same program. However, as was the case with comparison of the LADCP and the VMADCP velocities, that bottom track is not consistently in best agreement with the LDEO software. Again, shear plays a large role in heightening the ambiguity of any agreements that may exist between the bottom track and the UH and LDEO velocities. Bottom velocity is a reliable reading because it has a reference point with a reference velocity (the sea bed), which can be used to achieve more accurate velocities. No bottom track data is available for Stations 4 or 51. Reasons for this have not been firmly deduced, but it is possible that the slope of the seabed is such that it did not scatter the pings back to the instrument.

There was a minor problem during the processing which meant that all of the VMADCP data had the wrong time series applied to it, but this was corrected after investigation by Alex Brearley, who found that the time series was out by approximately 24hrs from Station 52 onwards. The velocity comparisons were re-plotted for these stations. It is possible to observe from the plots that, in deeper stations, below approximately 1500m the ability of the programs to process the data in a reliable manner is reduced by the significant lack of scatterers in the water, such as zooplankton. Due to these conditions, the pings made by the LADCP are not scattered back to the instrument, thus the number of samples collected can be negligible. However, the number of samples is increased on the upcast due to the time spent at each of the bottle firing stops, which allows the instrument to collect more samples. Comparison is not possible for Station 48 as this was an incomplete cast and was abandoned due to winch failure.

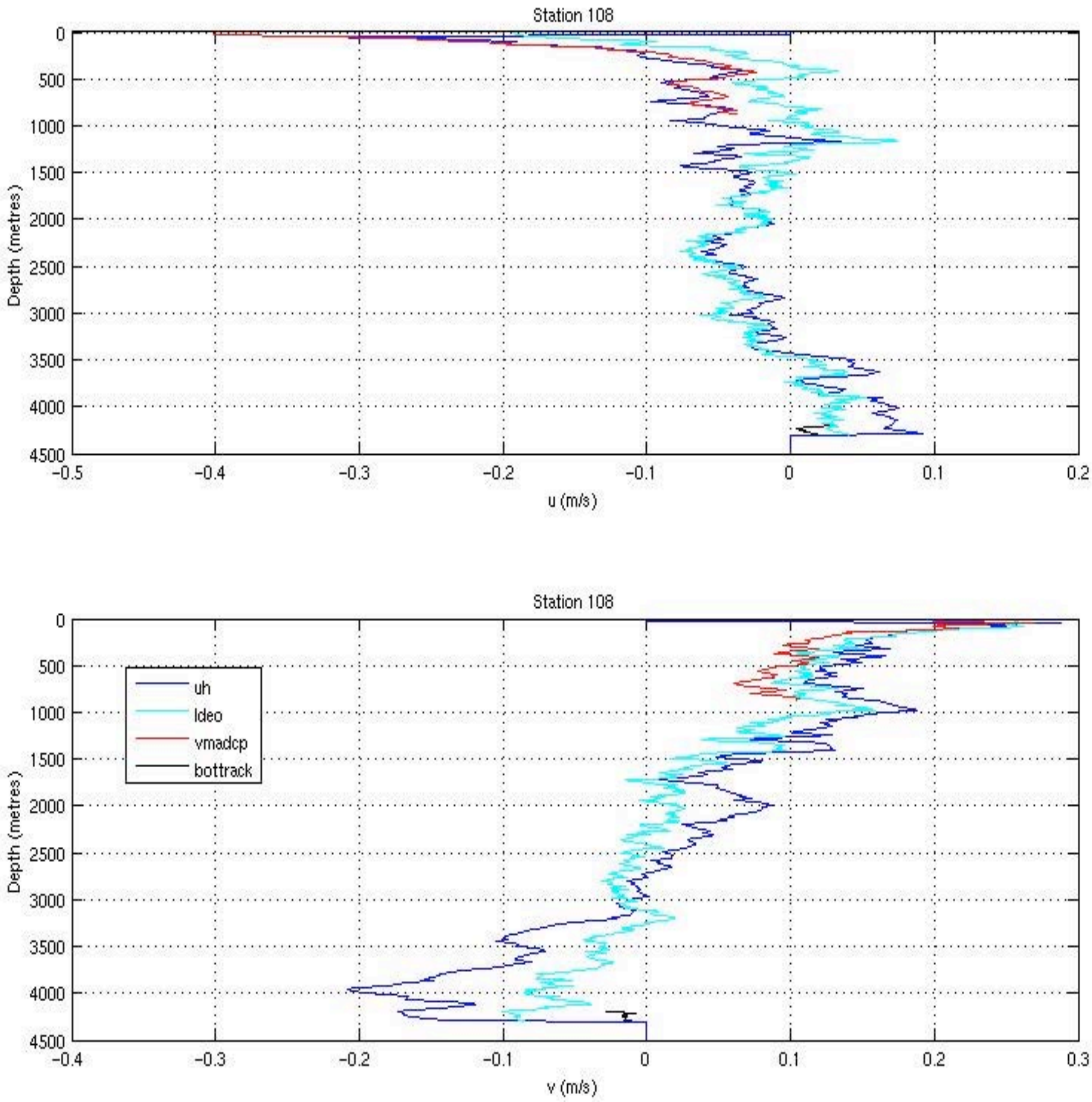
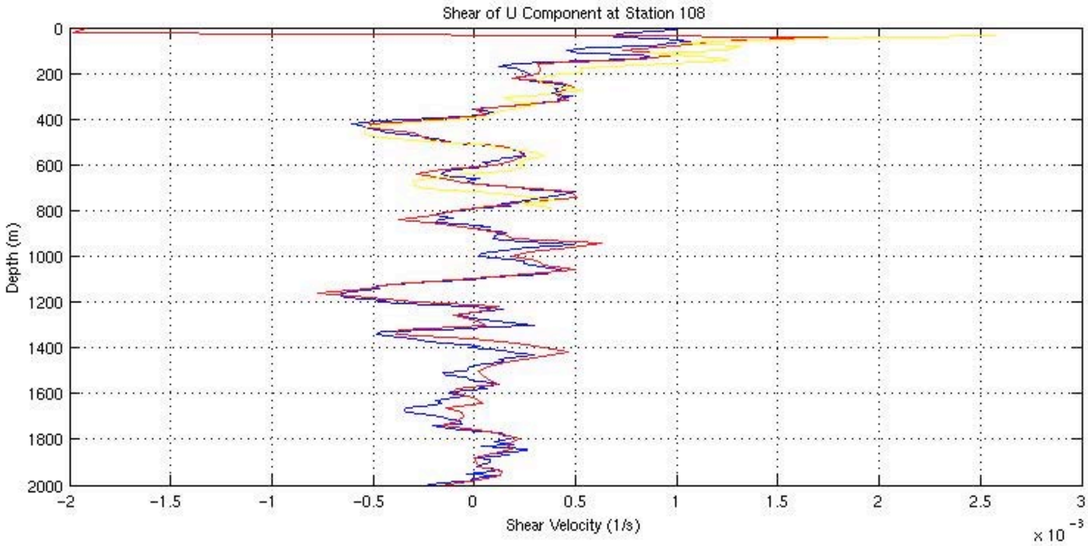


Figure 79: An example of the ADCP comparison plots produced.

13.5 Shear

As can be observed from the graph below, the shear velocities agree very well in the range of comparison. It should be noted that in the deeper ocean, the agreement was not as good, but this was largely due to the fact that there was little good data below 1500m depth. There does not appear to be any great difference between the agreements of the shear velocities in the *u* and *v* components. This shear was calculated using a filtering method in Matlab, which allowed the data to be made as smooth as desired. This comparison will be improved later on by using polyfit linear regression on different sections of the shear.



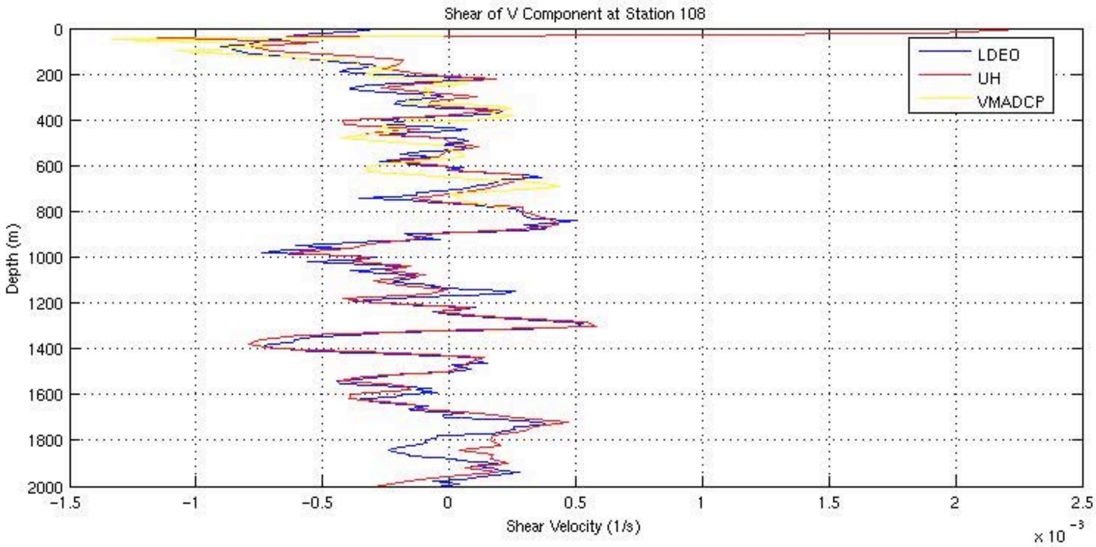


Figure 80: An example of the plots produced for ADCP shear velocities

13.6 Accumulation of Turns

The LADCP programming was used to keep track of the number of turns that were being put into the wire on each station. This was made possible because of the log of the heading that was recorded due to the need for the LADCP to know its orientation. Although the number of turns could be counted from the LDEO and UH processing of the LADCP data, additional scripts were constructed by Brian King to provide an 'unwrapped' station by station view and also a cumulative view of all the stations.

Assuming the number of turns on the winch cable to be zero at the start of the cruise, it can be seen from the cumulative graph produced that the number of turns on the cable started to increase from approximately Station 5 onwards. There was a brief reprieve between Stations 19 and 24 where there was no change in the number of turns (+10 turns, where a positive value indicates a clockwise motion). After this station the twists in the wire increased to +37 by Station 42. Due to the winch failure on Station 48, the winch drum and thus the wire was switched and the wire was re-terminated, therefore effectively resetting the number of turns in the wire to zero. The new wire is represented on the graph by the red line. The trend visible after Station 48 is a progressive increase in the number of decreasing turns (turning of the package in an anticlockwise direction). This appeared to show some signs of improvement after Station 84 but the increase in anticlockwise turns resurfaced after Station 95. Consequently, after Station 108 was completed, the wire had accumulated approximately -100 turns at which point the wire developed a kink and therefore required a re-termination. However, after discussing this matter with Brian King it was decided that this number of turns in the wire was likely to have been insufficient to be the cause of the kink. Each break between the different coloured lines on the graph represents the point where a re-termination had to be carried out. By the end of the cruise the wire had accumulated a total of 79 turns in the anticlockwise direction.

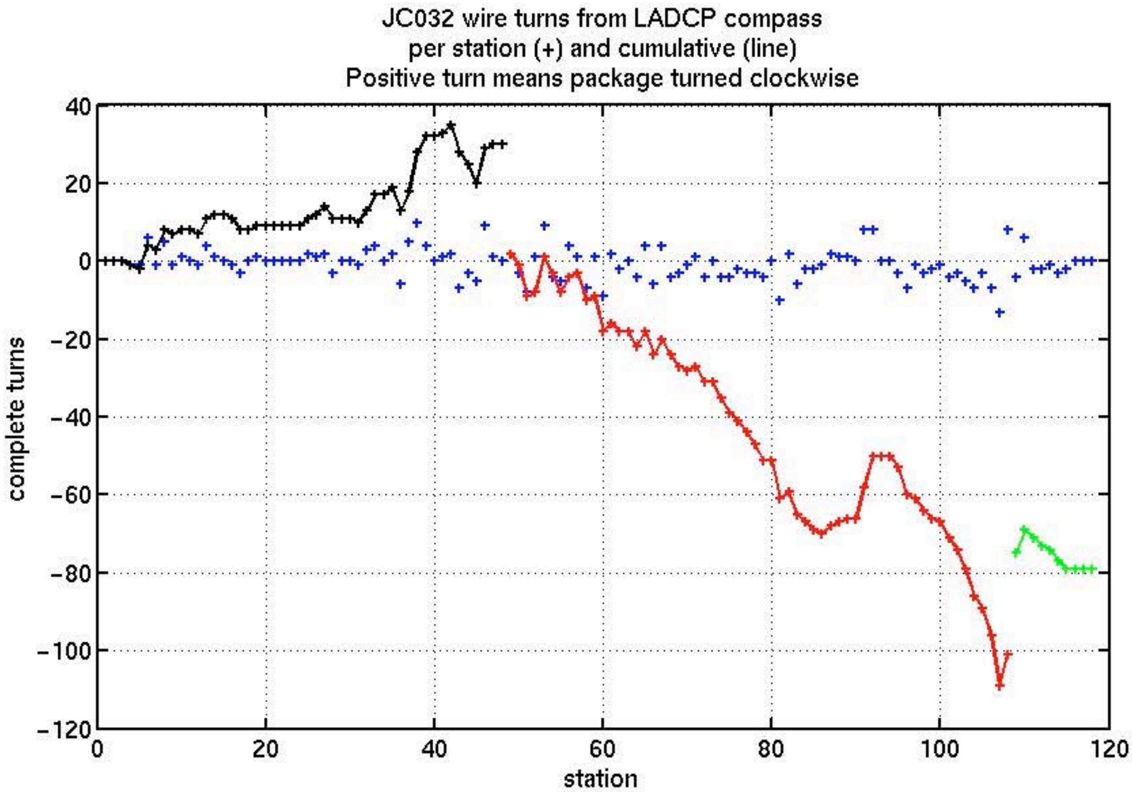


Figure 81: Representation of the cumulative number of turns on the CTD. A break between the different coloured lines on the graph represents a re-termination of the wire. Black line = Stations 1 to 47, red line = 48 to 108, green line = 109 to 118.

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14. Vessel Mounted ADCP Instruments

14.1 Introduction

The two vessel-mounted Acoustic Doppler Current Profilers (ADCPs) onboard *RRS James Cook* were used throughout the cruise to estimate the horizontal velocity field. These instruments, installed on the port drop keel of the ship, are 75kHz and 150kHz Ocean Surveyor (OS) instruments supplied by Teledyne RD Instruments, Poway, California. The instruments can be operated with the keel either retracted or lowered (hereafter known as 'keel up' and 'keel down' respectively). The keel up position allows greater ship speed, as the vessel is limited to 10 knots with the keel down, but also exposes the instrument to more bubbles, which significantly reduces its profiling range. By contrast, in the keel down position, the keel extends 2.8m below the hull, which itself has a draft of 6.9 m. Thus when the keel is lowered, the depth of the transducer is 9.7 m. We chose to run the instruments with the keel down throughout the cruise, except for short periods entering and leaving port.

The different frequencies of the two instruments affect both their depth range and resolution. The 150kHz allows smaller depth bins and consequently higher vertical resolution, but the signal is more rapidly attenuated and typically only penetrates to ~500m. The 75kHz lacks such good vertical resolution but penetrates to ~1000m.

14.2 Real Time Data Acquisition

The data from the two instruments were acquired using the RD Instruments VmDas software package version 1.42. This software is installed on two PCs in the main laboratory, which control the 75kHz and 150kHz Ocean Surveyor instruments respectively. The software allows data acquisition in a number of configurable formats and performs preliminary screening and transformation of the data from beam to Earth coordinates.

In order to collect data in VmDas:

1. Open VmDas from the Start Menu and click on "Collect Data" in the File Menu.
2. Under Options, click "Edit Data Options" and then set the configurable parameters to the values outlined in the JC029 cruise report *(Section 9.3.2)*. Under the ADCP setup tab, specify the relevant control file in Table 8. It is important each time the ADCP is restarted to increase the number in the recording tab by 1; otherwise VmDas may overwrite previously written files.
3. Recording commences by clicking the blue record button in the top left of the screen.
4. Collection stops by pressing the blue stop recording button in the top left of the screen. Data collection was typically stopped and restarted with a new ensemble number every 1-3 days during the cruise. Leaving it on the same file for more than three days allows the files to become too large and post-processing in CODAS becomes slow.

14.2.1 Files Produced by VmDas

The files we produced have names of the form *OS<inst>_JC032<nnn>_<filenumber>. <ext>*, where *<inst>* is the instrument name (75 or 150), *<nnn>* is the file sequence number, *<filenumber>* is the number of the file in the sequence and *<ext>* is the extension. We set a new *<filenumber>* to occur every time a file size of 10Mb was reached.

The list of files produced is given below:

- .ENR files are the binary raw data files.
- .ENS files are binary ADCP data after being screened for RSSI and correlation and with navigation data included.
- .ENX files are ADCP single ping data and navigation data after having been bin-mapped, transformed to Earth coordinates and screened for error velocity and false targets.
- .STA files are binary files of short-term average ADCP data (120s, user-specified in VmDas).
- .LTA files are binary files of long-term average ADCP data (600s, user-specified in VmDas).
- .N1R files are ASCII text files of raw NMEA navigation data from the NMEA1 stream.
- .N2R files are ASCII text files of raw NMEA navigation data from the NMEA2 stream.
- .NMS files are binary files of navigation data after screening.
- .VMO files are ASCII text files specifying the option settings used for the data collection.
- .LOG files are ASCII text files logging all output and error messages.

These files were stored in the *C:\ADCP\Data\JC032* directory.

14.2.2 Real Time Data Monitoring

The 'R', 'S' and 'L' tabs on the VmDas menu bar allow you to swap between graphical output from the .ENR, .STA and .LTA files. When in 'R' mode, the default upper left hand display in VmDas is the raw velocity parallel to each beam, but this can be difficult to interpret as it is shown in beam coordinates. A more useful plot can be made in either the 'S' or the 'L' mode, displaying the current at a specified depth level as a stick plot in Earth coordinates. To produce these plots, ensure 'Ship Track 1' and/or 'Ship Track 2' is ticked in the Chart menu. The bins used in the stick plot are specified within "Options", "Edit Display Options". We used the NAV as the ship's position source throughout.

The data can also be inspected in real-time using the WinADCP software, which loads the .ENX, .STA or .LTA files and displays the output as contour plots. The Monitor Option should be switched on with a suitable time interval (120s), meaning the contour plot is regularly updated. Plots of *u* and *v* were routinely examined throughout the cruise to check the data stream and to inform the bridge of ADCP measurements as required on station.

Several other things were also regularly checked whilst the ADCPs were recording:

1. We made sure the ensemble number in the real time display of VmDas was increasing and that the size of the files in the *C:\ADCP\Data\JC032* directory was increasing. The ensemble number check routinely took place every 4 hours as part of the watchkeeping log.
2. We checked the deviation of the PC clock from the ship's clock. This synchronisation occurs through the "Meinberg Network Time Protocol", a piece of software installed on the hardware of each PC. The deviation is recorded as the last entry on each $PADCP line of the N2R file. Although the deviation was generally small (~0.10 s) throughout the cruise, a short period of larger deviations did occur in *OS75_JC032028_000000.N2R* and *OS75_JC032029_000000.N2R* (~5 s). Upon further investigation, it was found that this occurred when the instrument was started immediately after restarting the PC. It generally takes a few minutes after Windows starts for the synchronisation to be fully correct.
3. We ensured that records of the files created are kept up-to-date. A full list of filenames can be found in Appendix II.
4. The .LOG file records any problems such as timeouts and navigation problems and was occasionally inspected. A frequent error regarding the source of heading did occur, as discussed in the JC029 cruise report. However, this once again did not appear to affect the data.

14.2.3 Alignment

As outlined in the JC029 cruise report, it is known that the OS75 instrument is roughly 9° out of alignment, in spite of the installation report stating that both ADCPs are perfectly aligned with the ship's axis. We once again used the EA00900 command setting in the control file to enable real time monitoring of the currents and for internal VmDas processing.

14.2.4 General Settings

During JC032, we ran both instruments in narrowband single-ping mode, with transducer depth adjustments made in the control file when the drop keel was lowered (9.7m compared to 6.9m). Where depth permitted, we ran both instruments in bottom track mode to obtain the most accurate phase and amplitude calibrations. Typically, the instruments were switched between bottom tracking and water tracking close to 1000 m. A table of the filenames and configurations used is given below:

Table 8: Configurations of individual control files used on JC032. Bottom and water tracked files are denoted in the filename by 'BTon' and 'BToff' respectively.

Control file name	Time between ensembles (s)	Bin Depth (m)	Time between bottom and water pings (s)	Coarse transducer misalignment	Max bottom search depth (m)
OS75NB_BTon_JC32_down.txt	3	16	1.5	9°	1200
OS75NB_BToff_JC32_down.txt	3	16	1.5	9°	1200
OS75NB_BTon_JC32_up.txt	3	16	1.5	9°	1200
OS150NB_BTon_JC32_down.txt	2	8	1	0°	800
OS150NB_BToff_JC32_down.txt	1	8	1	0°	800
OS150NB_BTon_JC32_up.txt	2	8	1	0°	800

On both instruments, 60 bins were used, with a bin size of 16m for the OS75 and 8m for the OS150. A blanking distance of 8m was used for the OS75 and 6m for the OS150, in order to avoid ringing from the transmit pulse. During JC031, both instruments had been run with a 2s 'time between ensembles' and a 1s 'time between BT and WT pings' whilst in water track mode. We were unsure why this had been done and so chose to test identical times (1s) using the OS150. It was found that the data did not appear to be compromised and so the instrument remained in this configuration for the rest of the cruise. We did not, however, alter the water track control file for the OS75. The control files in full are printed in Appendix I.

14.2.6 Sound Speed Considerations

There was initial concern at the start of the cruise about the effect on inaccurate sound speed estimates on the quality of the data. It was known that the temperature at the transducer face is measured for each ping, as water temperature is the largest variable in the calculation of sound speed, but we were worried that there was no accounting for salinity changes. Using the simple *sw_svel* Matlab routine (part of the Seawater package), it was found that a salinity change of 1 at 20°C produced a 1.1 m/s change in sound speed, whilst a temperature change of 1°C at S = 35 produced a 2.7 m/s change. Our fears were compounded when it was found that the temperatures of the OS75 and OS150 instruments disagreed with each other by up to 1°C and with CTD temperatures by up to 2°C.

However, close inspection of the ADCP Principles of Operation Primer, supplied by Teledyne with the instrument, revealed that the measurement of x and y velocities is independent of sound speed for a phased array instrument (page 46). Each of the Ocean Surveyor ADCPs on *RRS James Cook* is of the phased array type, comprising a single ceramic assembly that produces 4 acoustic beams simultaneously from the same aperture. Each element in the array is driven with the same signal except for a phase shift, which is constant for a given frequency and element spacing. If the speed of sound changes, the angle of the beam will consequently change. Fortunately, this beam angle change occurs in the same ratio as the Doppler shift equation, meaning that a change in the Doppler frequency shift of a particle moving parallel to the face is compensated entirely by the corresponding beam angle shift, rendering the horizontal velocity component independent of sound speed (although the vertical component is *more* sensitive than in a conventional transducer). As a result of these findings, accuracy of the sound speed measurements did not require further consideration.

14.3 Post-Processing

The final processing of the data was done using the CODAS (Common Ocean Data Access System) suite of software provided by the University of Hawaii. This suite of Unix and Matlab programs allows manual inspection and removal of bad profiles and provides best estimates of the required rotation of the data, either from water profiling or bottom tracking.

14.3.1 Transferring the Data

CODAS was run on the *nosea1* terminal, so the files had to be transferred from the ADCP PCs to this Linux box. This was done using the *psftp* application on the desktop of both PCs. At the command window within sftp, the local directory was changed to *C:\ADCP\Data\JC032* using the *lcd* command, and we logged into *cook3* using *open cook3.cook.local*. The raw data were moved into either the */data32/JC032/cruise/pstar/data/vmadcp/jc032_os75/rawdata* directory or the */data32/JC032/cruise/pstar/data/vmadcp/jc032_os150/rawdata* directory, depending on the instrument.

14.3.2 Setting Up the Directories and Using quick_adcp

Once loaded into the *rawdata* directory, the following steps were followed:

1. *movescript* was typed in the Unix command window. This short script creates a new directory called *rawdata <nnn>* (*nnn* denotes the file sequence) and moves the data loaded into the *rawdata* directory to the appropriate *rawdata<nnn>* directory.

2. The command *adcptree.py jc032<nnn>nbenx –datatype enx* was typed at the command window. This command sets up a directory tree for the codas dataset and an extensive collection of configuration files, text files and m files.

3. The directory was then changed to *jc032<nnn>nbenx* using the *cd* command, and the control files *q-py.cnt*, *q_pyedit.cnt* and *q_pyrot.cnt* were copied into that directory. We then used the command: '*quick_adcp.py –cntfile q_py.cnt*', which loads the data into the directory tree, performs routine editing and processing and makes estimates of both water track and (if available) bottom track calibrations. The raw ping files are also averaged into 5 minute periods. The calibration values are stored in the *adcpcal.out* and *btcaluv.out* files found in the *cal/watertrk* and *cal/botmtrk* directory and are appended each time *quick_adcp.py* is run.

14.3.3 Gautoedit

The gautoedit package within CODAS allows the user to review closely the data collected by VmDas and flag any data that is deemed to be bad. These flags can then be passed forward and, using the *q_pyedit.cnt* control file, the data removed. Typically, the data were reviewed as follows:

1. Matlab was opened in the *jc032<nnn>nbenx* directory (for the portion of data we wished to process). In the command window, typing:

codaspaths
cd edit
gautoedit

This started up an editing GUI, shown in Figure 82. The editing was done from here.

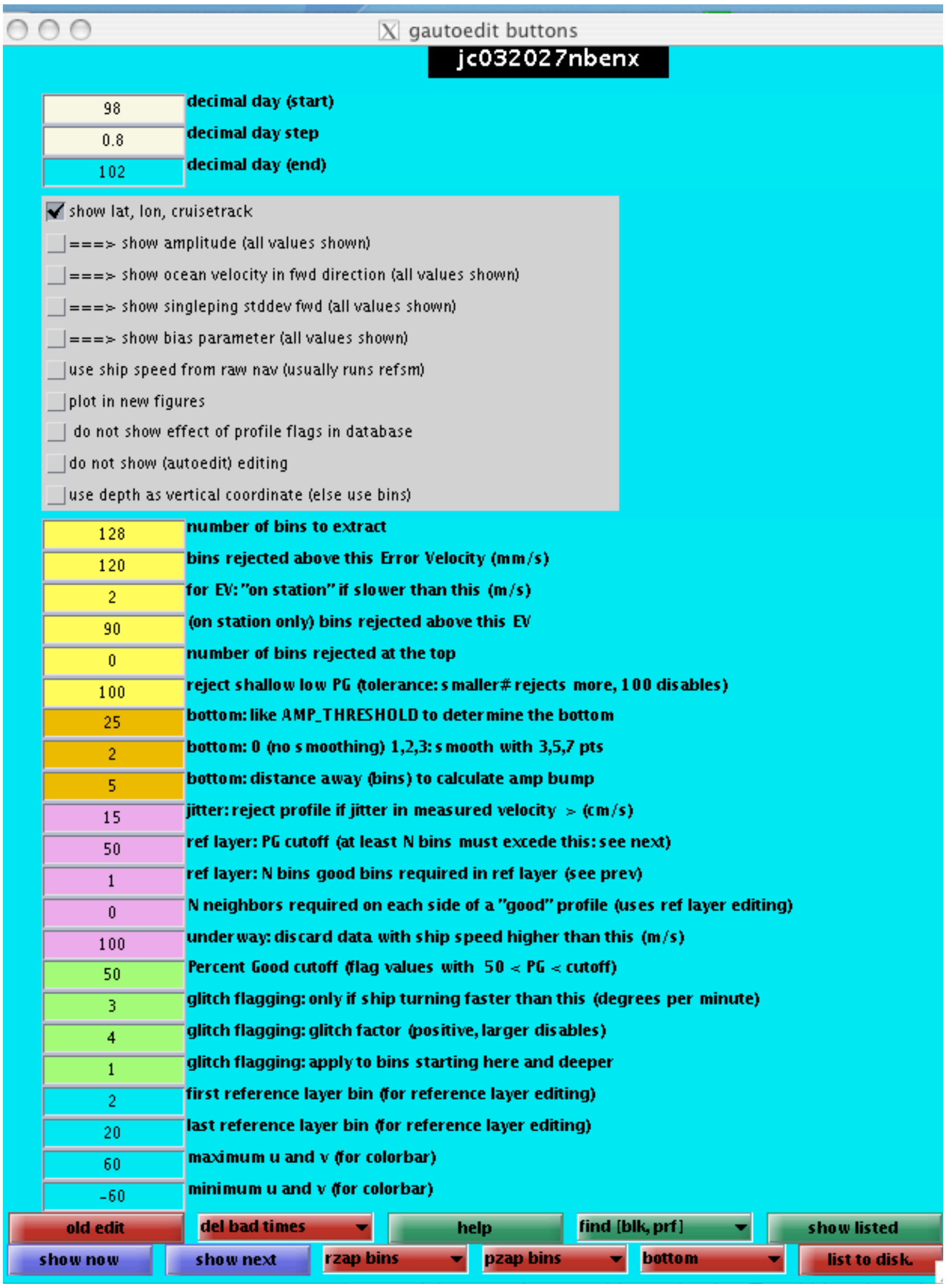

Figure 82: The gautoedit editing window within the CODAS suite of programs in Matlab.

2. To get an initial feel for the data, the start time of the ENX file was entered in the *decimal day (start)* box and the length of the dataset (in days) was entered in the *decimal day step* box. Upon pressing *Show Now*, two plots are displayed. One contains four subplots: the first displays the absolute east-west velocity component, the second shows the absolute north-south component, the third shows the percentage good parameter and the fourth shows the ship speed (in m/s) and an editing parameter called jitter. The second figure contains subplots of the ship's track and mean absolute velocity vectors at the reference layer. By default, this reference layer is set at bin 2 using the *First Reference Layer Bin* command. An error command will appear if there are no data in the selected time range. This initial review of the data allows the user to confirm the direction of steaming, identify the position of on-station and off-station parts of the file and spot any areas with low percentage good. It is also

useful to identify the maximum and minimum values of *u* and *v* to allow a suitable colour bar to be used when examining the data more closely (by default -60 to +60 is used). To change this, use the *maximum u* and *v* and *minimum u* and *v* boxes.

3. To inspect the data more closely and to start applying edits, the data must be inspected in shorter time sections. Typically, we worked from the start of the data in 0.4 day portions as this allowed us to see the individual 5-minute bins. Once the edits were finished on one portion, the *List to Disk* option was selected to save the flags before using *Show Next* to advance onto the next 0.4 day section. Routine editing for each section included:

- (i) looking for bad profiles (i.e. those in which the *u* and/or *v* had a systematic offset over all depth levels). These were flagged using the *del bad times* command.
- (ii) looking for bad levels. This is common at the bottom of profiles where the amplitude return is small and the profiles commonly have a low percentage good. These bad 'tails' are removed most easily using the *rzap bins* command, which allows the user to flag all data within a defined rectangular box.
- (iii) looking at the jitter parameter in the bottom subplot. A high level of jitter either indicates noise in the navigation and/or rapidly changing velocities. Generally, the default jitter threshold (set in the *Jitter: reject profile if jitter in measured velocity*) of 15 cm/s seemed to be a reasonable value for flagging potentially bad profiles and did not need to be changed.

4. More specialised editing was required for some parts of the dataset where we suspected velocity biases were present. In particular, the presence of either enhanced scattering layers in the profiles or bubbles directly beneath the ship are known to bias the underway velocities in the affected layers in the direction of steaming. These biases are discussed at more length in Section 4, but the typical steps taken to remove them were:

- (i) inspecting the echo amplitude plot, which shows the magnitude of the return at each depth. Enhanced scattering layers can be distinguished clearly in this plot.
- (ii) inspecting the bias parameter plot. This shows the vertical gradient in the demeaned amplitude, multiplied by the ship velocity. The demeaning removes the mean amplitude at the particular depth level, so the plot is really the vertical derivative of the amplitude anomaly multiplied by velocity. In an enhanced scattering layer (e.g. due to zooplankton) the bias parameter tends to have positive (red) values towards the top of the layer (as the anomaly increases with depth) and negative values below (as the anomaly decreases), though the sizes of these anomalies need not be symmetric. On station the parameter, by definition, has a value of zero. Positive values in the top two or three bins often indicate bubbling. The bias parameter thus indicates the *potential* for velocity bias, but does not show bias in itself.
- (iii) inspecting the alongtrack velocities on steaming sections. For most of the cruise (along 24°S), this was the *u* velocity component. Regions of potential bias highlighted with the bias parameter were then examined for

underway bias in the velocity. If bias in the direction of travel whilst the ship was steaming could be found, the bad bins were flagged using *rzap bins*. In the presence of anomalous scattering, it was common to find a layer of positive velocity bias above a layer of negative bias. In these cases, both layers were removed.

Although it is possible to edit data using other thresholds (e.g. percentage good and number of neighbours), this was not found to be necessary during JC032. Further details of *gautoedit* capabilities can be found at:

http://currents.soest.hawaii.edu/docs/adcp_doc/edit_doc/index.html

5. Once satisfied with the changes made, the *List to Disk* option is selected which creates and updates *a*.asc* files in the *jc032<nnn>nbenx/edit* directory.

14.3.4 Applying the Edits

Once the *a*.asc* files have been created, the edits are applied using the following command at the Unix terminal prompt from within the *jc032<nnn>nbenx* directory:

quick_adcp.py –cntfile q_pyedit.cnt

The *q_pyedit.cnt* file has to have the correct *instname* command line (i.e. OS75 or OS150).

14.3.5 Calibration

In order to obtain accurate horizontal velocities, it is vital to correct for heading errors. These can either occur as a result of transducer misalignment with respect to the hull, or from errors in navigation. Fortunately, the navigation is fed directly into VmDas from the Applanix POSMV, which incorporates a GPS heading source that is not sensitive to many of the heading errors that occur when gyrocompasses are used in isolation (e.g. Schuler Oscillations).

The best calibration estimates are obtained when the velocity data are referenced to the bottom. However, bottom track calibration estimates are only obtainable when the water depth is within 1.5 times the depth of the ADCP profiling range. We were able to obtain five separate periods of bottom tracking during the cruise, four on the Brazil/Uruguay shelf and one on the Namibian shelf. Unfortunately, the need to raise the drop keel for our unscheduled stop in Arraial do Cabo meant that two separate calibrations were required for each instrument (one for Stations 1-35 and one for Stations 36-118). We examined both bottom track and water track calibrations for consistency on each section before deciding on best amplitude and phase corrections for each instrument.

The *quick_adcp.py* script estimates amplitude and phase corrections for each set of data. The values for these are presented in Appendices III and IV. By default, the water track estimates have an ensemble length of 7, meaning that seven individual five-minute ensembles bracket each turn or acceleration. The bottom track estimates have a default step size of 1, meaning that the individual ensembles are used to evaluate the calibration. Step sizes of 2 and 3 are also permissible, meaning that adjacent profiles of length 2 or 3 are averaged to obtain the amplitude and phase. By changing the control file *timslip.tmp* using the vi editor and the Matlab file *calladcpcal_tmp.m,* water track ensembles of length 5, 7 and 9 were evaluated for each section. It was found that varying the choice of ensemble length did not substantially change the values of amplitude and phase obtained. By modifying the Matlab file *callbtcaluv_tmp.m,* the sensitivity of each bottom track calibration was also tested by altering the step size to 2 and 3. Once again, it was found that no substantial changes occurred, and as a result we chose to study the water track estimates based on ensemble length 7 and the bottom track estimates based on ensemble length 1.

14.3.5.1 First Calibration: Montevideo to Arraial do Cabo

OS75: The individual bottom track calibrations for file sequence numbers 002, 010 and 014 were compared with the water track calibrations from file sequences 002, 003, 004, 008, 009, 010, 012 and 013. It was found useful to have all the water track calibrations plotted together on the same axes to allow us to inspect for any large outliers and/or drift over time. To do this, a script was created called *watertrack_all.m* (Appendix V), which loads the individual estimates of phase and amplitude from each file sequence and then plots the estimates together on the same axes along with the time differences between the navigation and PC. The single best estimate water track calibration was then derived, given in Table 9 (bold figures). The best estimate for bottom track was based on a mean value of the three individual estimates from 002, 010 and 014, weighted by the number of ensembles used. The result is also given in Table 9.

Both estimates agree closely as the difference between them only gives very small velocity differences. The maximum possible error in water velocity caused by employing one estimate of amplitude instead of the other (assuming a ship speed of 500 cm/s) is only 0.8 cm/s. The associated error for phase is only 0.45 cm/s. Given the larger number of ensembles and better quality of bottom tracking estimates, we choose the median values of bottom tracked amplitude and phase for as our final calibration. The total error in velocities obtained should not exceed 2 cm/s.

Table 9: Best estimates of OS75 calibration for the section from Montevideo to Arraial do Cabo for water tracking and bottom tracking. The bold figures are the final calibration applied.

Calibration Method	**Number of ensembles**	**Amplitude**			**Phase (deg)**		
		Median	***Mean***	***Std Dev.***	***Median***	***Mean***	***Std Dev.***
Water track	59	1.0040	1.0044	0.0083	-0.0880	-0.1191	0.5080
Bottom track	474	**1.0024**	1.0025	0.0035	**-0.1392**	-0.1329	0.1963

OS150: The individual bottom track calibrations for file sequence numbers 002, 009 and 013 were compared with water track calibrations from file sequences 002, 003, 007, 008, 009, 011 and 012. Using the same methodology as for the OS75, the results are given in Table 10. The maximum error resulting from the difference in amplitude of the calibrations is 1.1 cm/s and for the phase difference is 0.56 cm/s. Once again, the expected total error is less than 2 cm/s.

Table 10: Best estimates of OS150 calibration for the section from Montevideo to Arraial do Cabo for water tracking and bottom tracking. The bold figures are the final calibration applied.

Calibration Method	**Number of ensembles**	**Amplitude**			**Phase (deg)**		
		Median	***Mean***	***Std Dev.***	***Median***	***Mean***	***Std Dev.***
Water track	63	1.0060	1.0057	0.0070	-0.6290	-0.6315	0.6013
Bottom track	478	**1.0038**	1.0040	0.0034	**-0.5644**	-0.5652	0.2321

14.3.5.2 Second Calibration: Arraial do Cabo to Walvis Bay

OS75: This time, the periods of bottom tracked data were confined to file sequence numbers 016 on the steam-out from Arraial do Cabo and 033 on the steam into Walvis Bay. Water track calibrations were available across the entire 24°S section. Initially, we used the bottom tracked section leaving Arraial do Cabo and the water tracked sections 017-024 up to Station 78 to estimate the calibrations (Table 11). It was found that there was a more noticeable difference between the bottom track and water track estimates of amplitude than for the period between Montevideo and Arraial do Cabo. As a result, we chose to use values mid-way between the water track and bottom track calibrations for our final calibration. These values were reviewed after a 27-hour period of bottom tracking on the continental shelf of Namibia. This was started after Station 115 and included the last three stations followed by three six-hour periods steaming at 10 knots, 9 knots and 8 knots respectively. The keel was finally raised at 0815GMT on 21st April 2009.

Table 11: Best estimates of OS75 calibration for the section from Arraial do Cabo to Walvis Bay for water tracking and bottom tracking. The bold figures are the final calibration applied.

Calibration Method	**Number of ensembles**	**Amplitude**			**Phase (deg)**		
		Median	***Mean***	***Std Dev.***	***Median***	***Mean***	***Std Dev.***
Water track	65	1.0060	1.0071	0.0073	-0.1520	-0.1163	0.3450
Bottom track (Arraial)	80	1.0016	1.0015	0.0029	-0.0906	-0.0913	0.2375
Bottom track (Namibia)	256	1.1037	1.1203	0.0986	-0.1631	-0.1667	-0.2226
Final choice	-	**1.004**	-	-	**-0.12**	-	-

The long section of bottom tracking on the continental slope of Namibia gave an unrealistic amplitude calibration, which differed markedly from the water track calibration of the same period. Furthermore, the standard deviation of the bottom-tracked amplitude estimates was very large. Inspection of the individual plots (Figure 83) suggests that the period between decimal days 108.35 and 108.52 (either side of Station 118) gave realistic values close to zero, but elsewhere the estimates are generally bad. We suspect that there may have been a problem in the navigation given the noisy speed and heading estimates in the second part of the period (third and fourth panels), but this has not been confirmed. In light of these concerns, we decided not to use this section to estimate our final calibration and hence the values of the final calibration remained unchanged.

On the 20th April 2009, the port keel was raised and the ADCP was run for the final day using the control file for BT on and keel up (file sequences 034 and 035). The bottom track calibration from file sequence 34 was applied to both sequences (1.0043, -0.1796). These values are only slightly different from the keel down values used on the rest of the section (1.004, -0.12), suggesting the orientation of the transducer face did not change dramatically during the keel raising process.

OS150: The same procedure was used for the OS150, with the bottom tracked file sequences being 015 and 031 respectively. The water tracked file sequences used were 016-023. The final calibration was once again reviewed after the collection of data on the continental shelf of Namibia (Table 12). This time, the bottom tracking on the Namibian shelf gave reasonable estimates of amplitude, but a large negative phase correction. Had we chosen to apply this to the rest of the data, on and off-station striping would have occurred. Once again, we chose not to use this period of bottom tracking when making our final calibration estimate. It remains to be determined why this period of bottom tracking gave such poor estimates.

After the keel was raised on the 20th April 2009, two further file sequences were written (032 and 033). The bottom track calibration from sequence 032 was applied to both sequences (1.0071, -0.6693). Once again, these do not differ by a large amount from the keel down values used on the rest of the section. The phase estimate of sequence 033 (-4.24) is clearly bad, but the reason for such a bad value is unclear and warrants further investigation.

Table 12: Best estimates of OS150 calibration for the section from Arraial do Cabo to Walvis Bay for water tracking and bottom tracking. The bold figures are the final calibration applied.

Calibration Method	**Number of ensembles**	**Amplitude**			**Phase (deg)**		
		Median	***Mean***	***Std Dev.***	***Median***	***Mean***	***Std Dev.***
Water track	60	1.0075	1.0076	0.0073	-0.5265	-0.6018	0.3287
Bottom track (Arraial)	80	1.0024	1.0022	0.0037	-0.4308	-0.4298	0.2118
Bottom track (Namibia)	252	1.0056	1.0062	0.0059	-1.5443	-1.5258	0.7115
Final choice	-	**1.005**			**-0.48**		

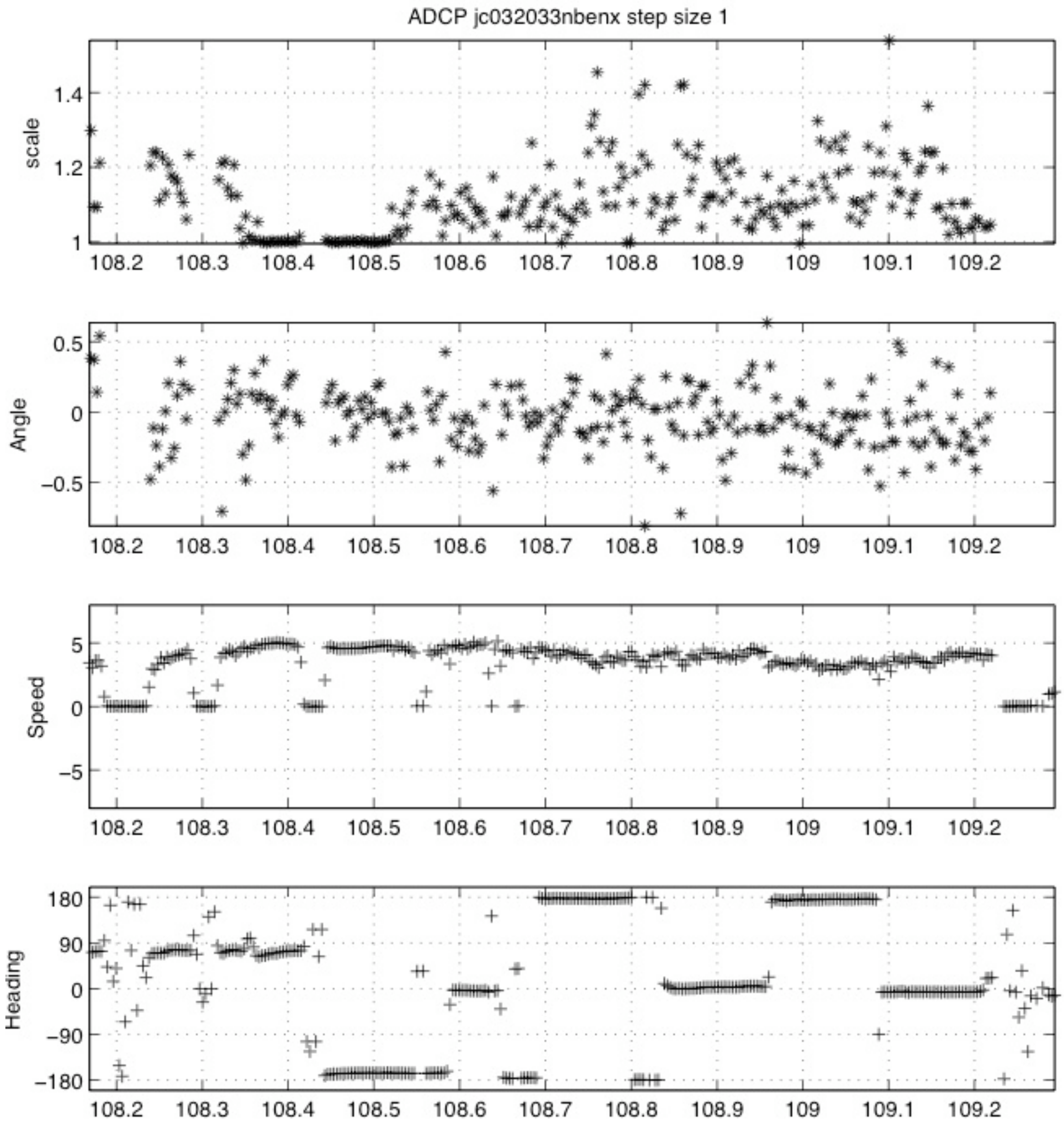

Figure 83: Amplitude scale and phase calibrations for OS75 instrument for the period of bottom tracking on the continental shelf of Namibia. Speed and heading (from nav) are given in the lower panels.

14.3.5.3 Applying the Rotation

The final calibrations discussed above were applied to each file sequence using:

quick_adcp.py –cntfile q_pyrot.cnt

in the *jc032<nnn>nbenx* directory in the Unix terminal window. This rotates the data by the phase and amplitude specified by the user in the control file *q_pyrot.cnt*. A recalculated calibration (after taking the first calibration into account) is printed to the **.out* file(s). The data were then double checked in gautoedit to ensure that any vertical striping associated with on/off station differences had been removed by application of the calibration.

14.3.6 Creating the Output Files

Once the editing and rotation was complete, the final velocities were collated into Mstar files (*.nc) using the following commands in the *jc032<nnn>nbenx* directory of a Matlab command window:

m_setup
m_addpath
mcod_01jc32
mcod_02jc32 (type *os75_jc032<nnn>nnx* or *os150_jc032<nnn>nnx* as the input file when prompted).

The first two commands set up the Mstar suite of programs and the relevant paths. The other two commands (derivatives of *mcod_01* and *mcod_02* respectively) load in the final data for the file sequence and save it as two Mstar files. The first command produces a file of the form *os75_jc032<nnn>nnx.nc* that includes the variables:

time - (in seconds since [2009 1 1 0 0 0])
lon - (0 to 360)
lat - (-90 to 90)
depth - (of bin)
uabs - (absolute *u* velocity in cm/s)
vabs - (absolute *v* velocity in cm/s)
uship - (*u* velocity of ship over ground)
vship - (*v* velocity of ship over ground)
decday - (decimal day of year)

The second file is of the form *os75_jc032<nnn>nnx.nc* and includes, in addition to the above variables:

speed - (scalar water speed in cm/s)
shipspd - (scalar ship speed over ground in cm/s).

The individual *os75_jc032<nnn>nnx.nc* and *os150_jc032<nnn>nnx.nc* files are then appended together into a single output file for the cruise using the *mapend* command. This command relies on an input file containing the paths of all the individual files to be merged. These are to be found in the */jc032_os75* and */jc032_os150* directories and are named *merge_days.dat*. The final output files are *os75_jc032_apended.nc* and *os150_jc032_apended.nc*.

In order to compare the vessel-mounted ADCP velocities on station with those derived from the lowered ADCP, the command *mcod_03* was run using the appended file as the input. A loop was written to automate this process, named *mcod_03rep* (Appendix V), which is stored in both the */jc032_os75* and */jc032_os150* directories. The *mcod_03* routine relies on an input file *stations.dat*, which contains the start and end times (in seconds since start of year) for each station. This *.dat* file is found in the */data32/JC032/cruise/pstar/data/mexec_processing_scripts_0902021711* directory and is created using the *stations.m* script. The output files from *mcod_03* are of the form *os75_jc032_<sta>.nc* where *<sta>* denotes the station number.

14.4 Data Quality Issues

Whilst carrying out *gautoedit* editing, several quality control issues were identified that warrant discussion.

14.4.1 Bubble Contamination and Bias

Two potential issues arise from the presence of bubbles immediately below the transducer face. The first is that bubbles can prevent penetration of the transmit pulse and lead to truncated or bad quality profiles. This was not widely observed on our cruise. The second is the problem of bubble bias. It is known that the high amplitude return from bubbles can cause anomalous velocities in the direction of ship steaming (i.e. towards the east on the main 24°S section). It is commonly identified by a relatively low percentage good in the top few bins, and a red surface stripe in the along-track bias parameter *(see Section 14.4.2)*. It typically does not affect lower bins of the profile, which remain good.

Bubble contamination was not a frequent problem when the keel was down on either instrument, but occasional periods of strong velocities in the surface associated with anomalously high returns were observed and the top few bins were discarded as a result (Figure 85).

14.4.2 Anomalous Scattering Bias

A more extensive problem is the presence of anomalous scattering layers leading to along-track velocity bias. The presence of layers of scatterers such as zooplankton in the water can cause severe bias in the direction of travel whilst the ship is steaming. This is observed as horizontal stripes in the velocity field, which disappear when the vessel is on station. If the layers are very strong, a layer of negative bias will also appear immediately below the scattering layer. Such features have been observed on previous subtropical cruises, such as Cruise 324 on *RRS Discovery*.

On this cruise, a large anomalous scattering layer was found on the OS75 instruments for bins 28-40 (460-660 m) across much of the section (Figure 84). This resulted in extensive red-over-blue striping in the along track bias parameter. The affected bins were removed using *rzap bins* within gautoedit. For much of JC032, there was no obvious evidence for a diurnal cycle in the depth of this layer, as is commonly found in zooplankton layers. However, close examination of some days (e.g. decimal days 71 and 93) show an enhanced amplitude layer moving downwards during the day from 150m to 500m, before returning to its original level in the evening (Figure 86). On some days (e.g. decimal day 93), there is an abrupt cut-off in percentage good below this depth (Figure 87), which does not occur for the deeper scattering layer at 500m. Whilst it is likely to be caused by the diurnal vertical migration of zooplankton, further investigation is required to find out why the percentage of good bins below this layer sometimes drops as low as 50%.

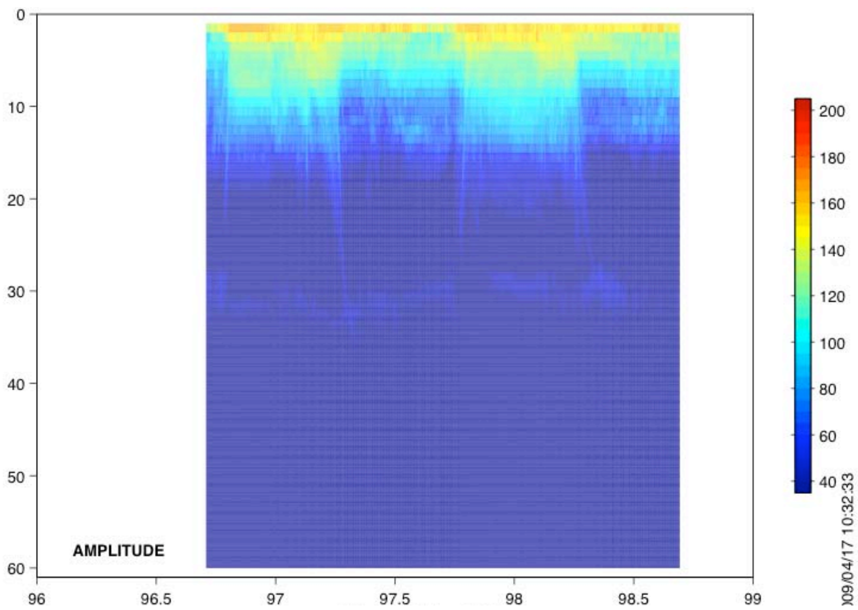

Figure 84: Amplitude return for the OS75 for file sequence 025. The anomalously high scattering layer can be seen close to Layer 30.

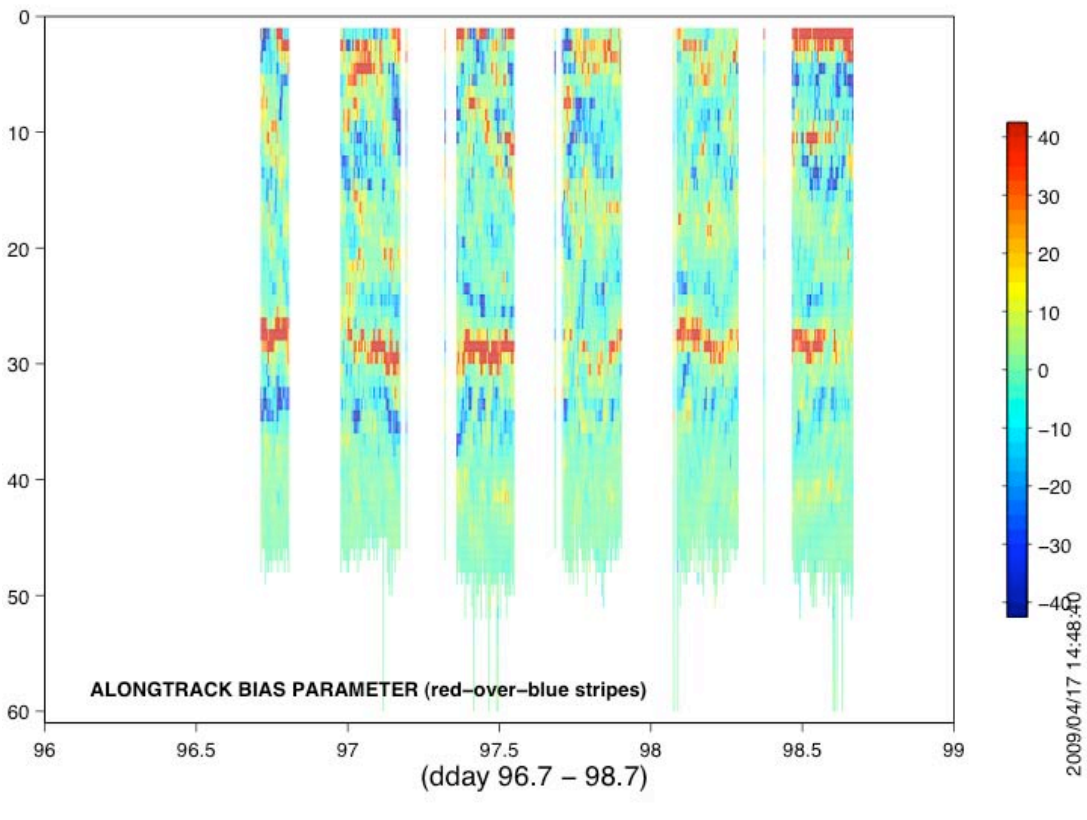

Figure 85: Bias parameter for the same period. Note the strong red-over-blue striping during the steaming periods at the depth of the anomalous scattering layer. Note also the enhanced near-surface amplitude return after day 98.5, most likely the result of bubbles below the ship.

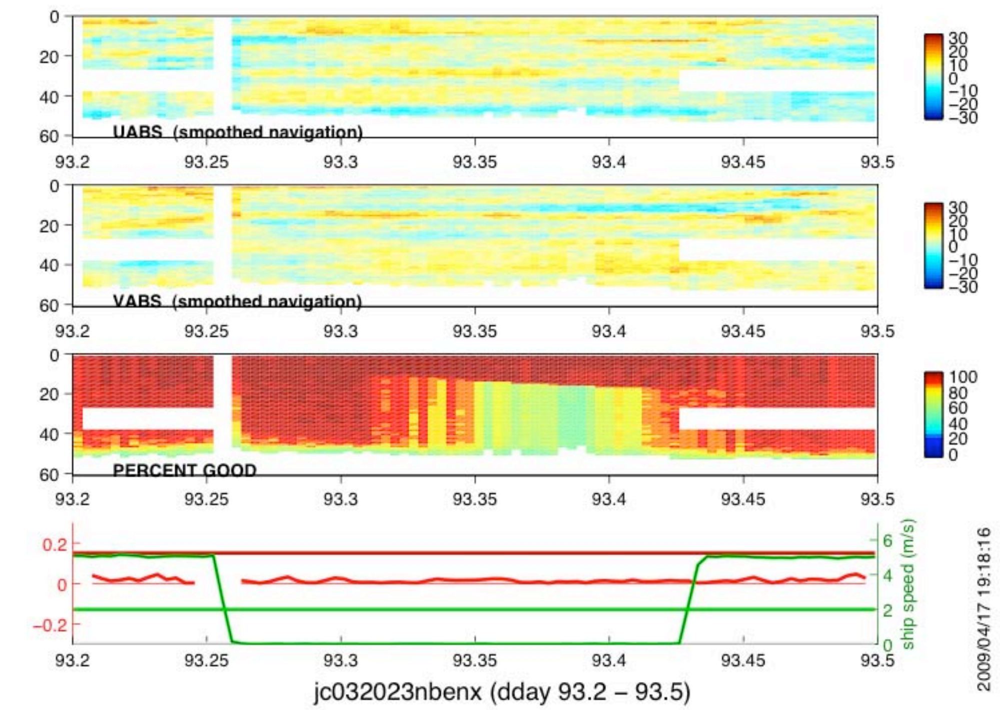

Figure 86: Anomalous region of low percentage good below bins 15-20 on decimal day 93. This is thought to be caused by a diurnally migrating zooplankton scattering layer.

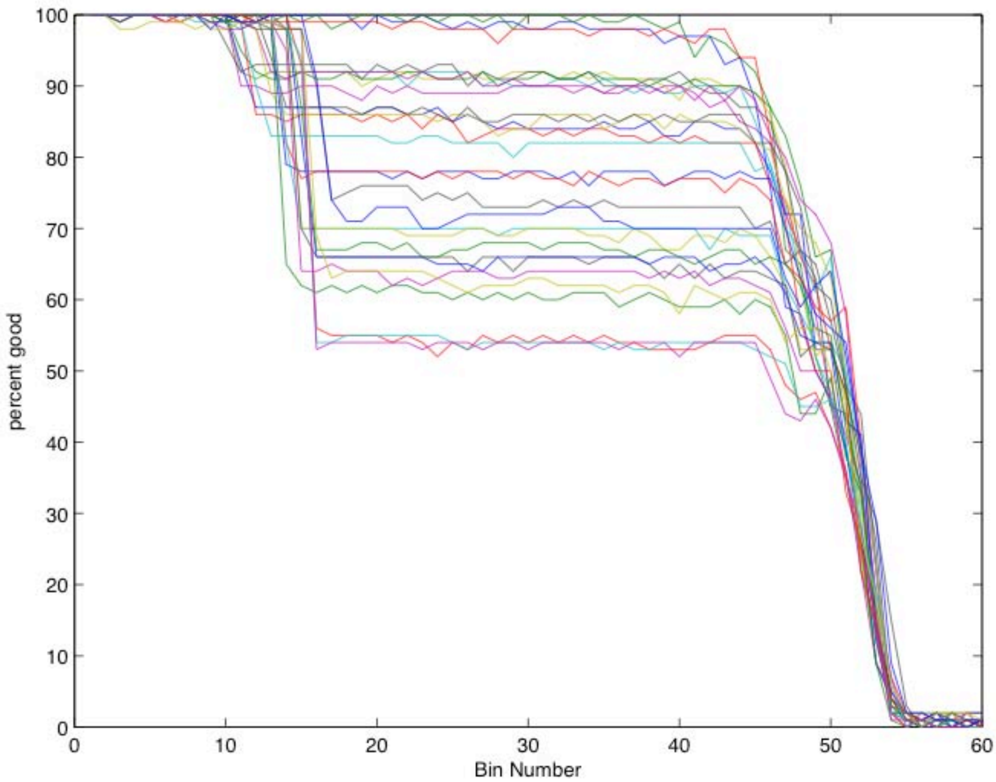

Figure 87: Abrupt cut-off in percentage good around bin 16 for profiles collected between decimal day 93.3 and 93.4 using the OS75.

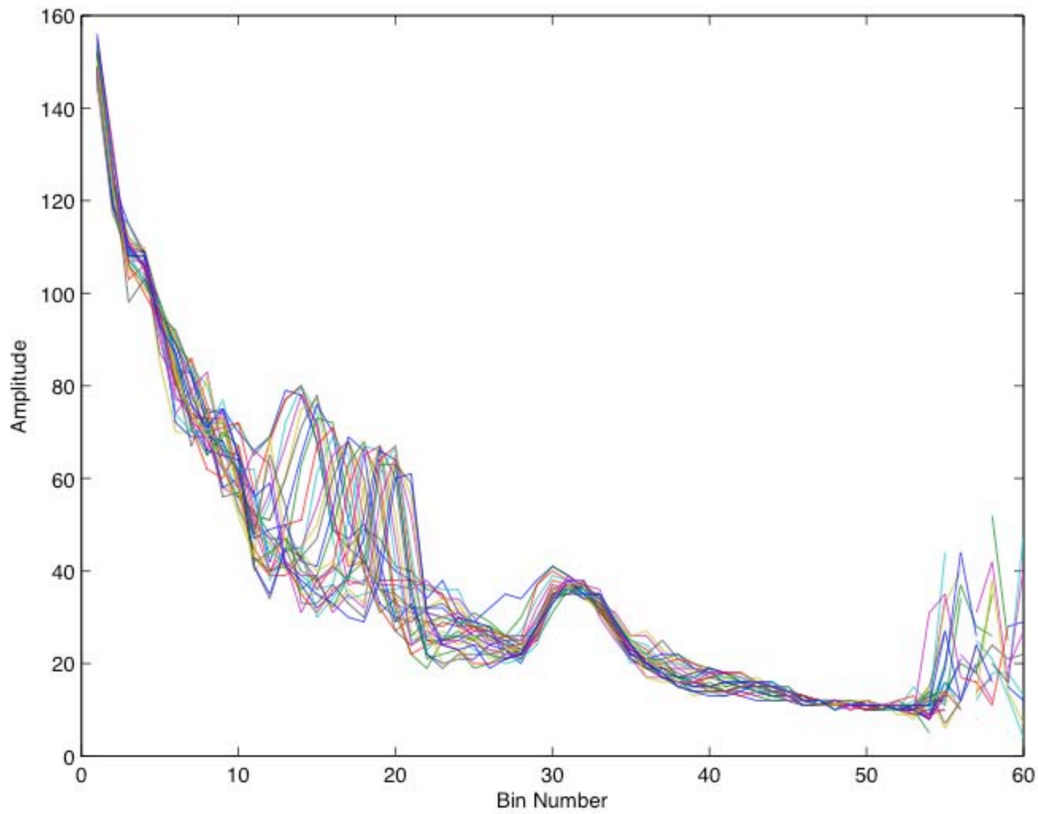

Figure 88: Amplitude return for beam 1 for decimal day 93.3 to 93.4. Two scattering layers are seen: one coincident with the sharp drop off in percentage good and the deeper layer around bin 30.

Strong scattering layers are seen less frequently with the OS150. This is most likely because the beam does not penetrate as deep as the OS75 and the zooplankton are too large to act as strong scatterers on this instrument.

14.4.3 Interference Issues

No obvious evidence of interference with other instruments was seen in the amplitude returns during the cruise, despite the use of other acoustic instruments (e.g. the EM120 and EA600 echo sounders). There was some concern at the start of the cruise that the two ADCPs may be interfering with one another, as the amplitude returns of the raw .ENX files did show some periodic green blocks in certain pings. However, these appeared to be removed by CODAS processing and we thus chose not to change any of the settings. CTD wire interference, which generally results in enhanced error velocities on station, was not observed during JC032.

14.5 Results

14.5.1 Brazil Current Crossings

The median on-station velocities at 98m (bin 5) are displayed for the three Brazil Current crossings in Figures 89, 90 and 91 respectively. In each case, the core of the Brazil Current is found close to the 1500m isobath, although the maximum velocity and alignment with respect to the topography varies between the sections. The strongest velocities were recorded in the first section off the coast of Uruguay (Figure 89), with values exceeding 40cm/s found at Stations 3-7. The flow is generally parallel to the topography.

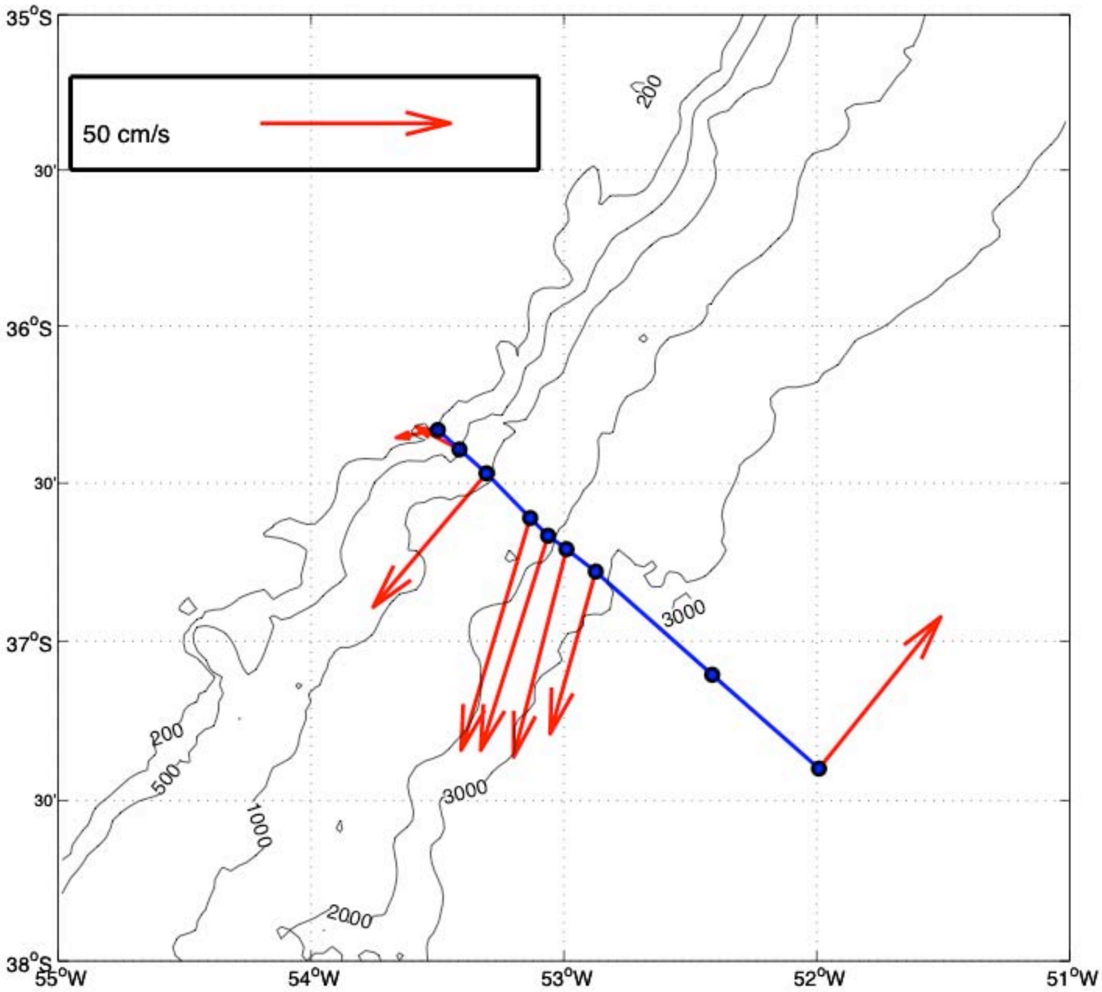

Figure 89: Median on-station VMADCP velocities from the OS75 at 98m for the first Brazil Current Crossing. The Brazil Current is seen flowing towards the southwest, with a north-eastward recirculation offshore.

The two northern crossings of the Brazil Current have a more complex structure. The second crossing (Figure 90), to the west of the Santos Plateau, has smaller absolute velocities in the Brazil Current (20cm/s), with the flow directed offshore at 45° to the topography. On the final crossing to the east of the Santos Plateau, the Brazil Current is stronger (40cm/s), but the direction is highly variable across the shelf (Figure 91). Northward recirculation offshore of the main current is observed on all three sections.

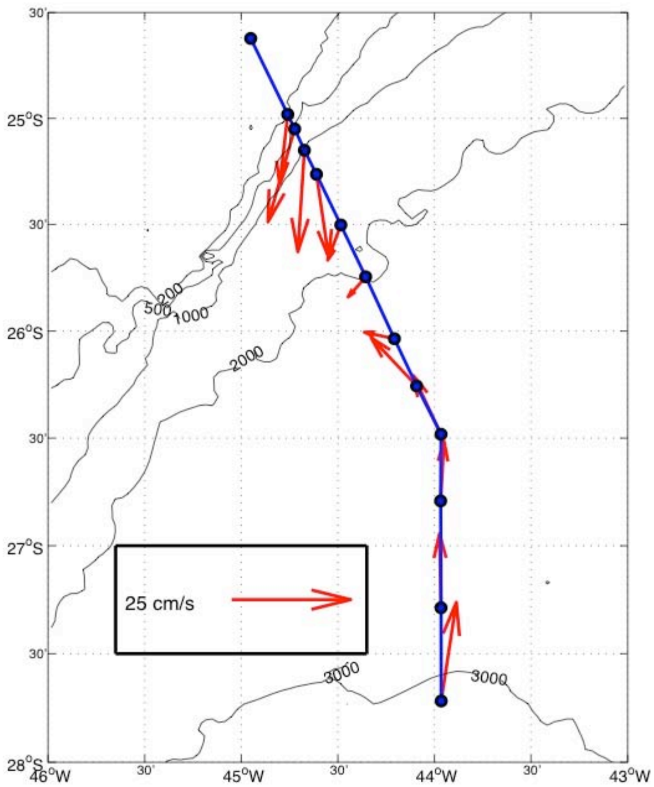

Figure 90: Median on-station VMADCP velocities from OS75 at 98m for the second Brazil Current crossing. Note the different arrow size to that used in Figure 89.

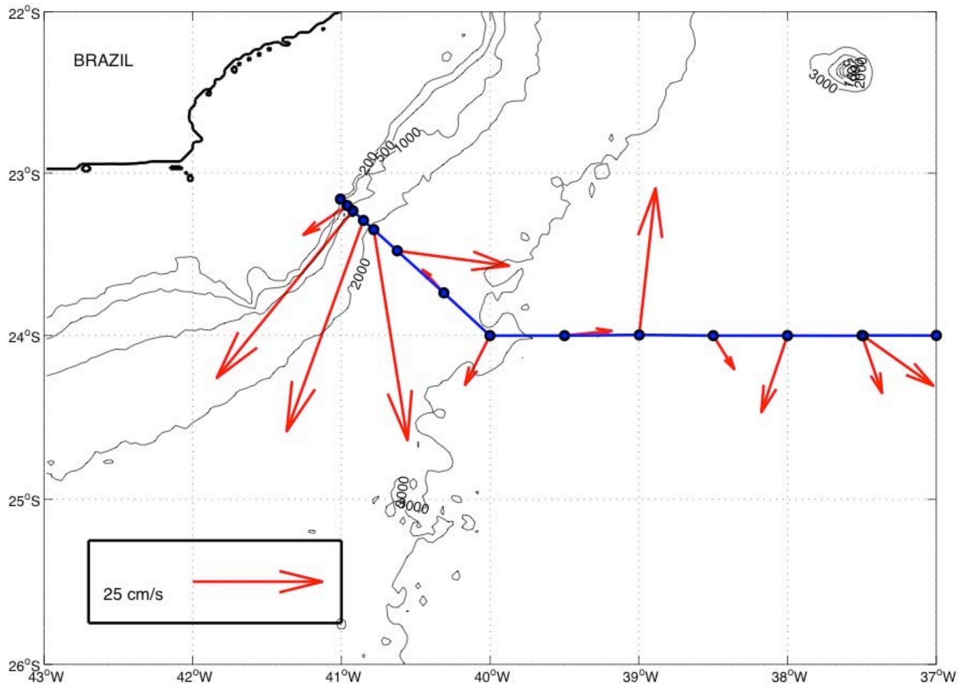

Figure 91: Median on-station VMADCP velocities from OS75 at 98m for the third Brazil Current crossing. The Brazil Current closely follows the isobaths above 1000m but becomes perpendicular to them at around 2500m.

14.5.2 24°S Mid-Ocean Section

The 98m velocities for the mid-ocean section are shown in Figure 92. Relatively weak northward flows are generally observed across the section, with the exception of the Mid-Atlantic Ridge near 15°W and the Walvis Ridge near 5°E.

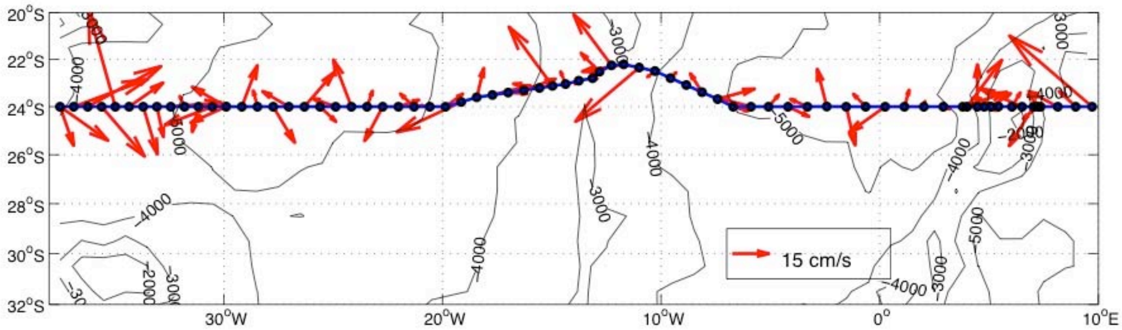

Figure 92: Median on-station VMADCP velocities from OS75 at 98m for the 24°S section.

14.5.3 The Continental Slope of Namibia

The north-south component of velocity at the eastern boundary (using the off-station OS75 data) is shown in Figure 93. The northward flowing Benguela Current is seen in the upper 250m between Stations 111 and 112, with peak velocities of around 30cm/s and a width of around 100km. However, several reversals in flow direction are seen on the rest of the slope, with southward flow both inshore and offshore of the main boundary current.

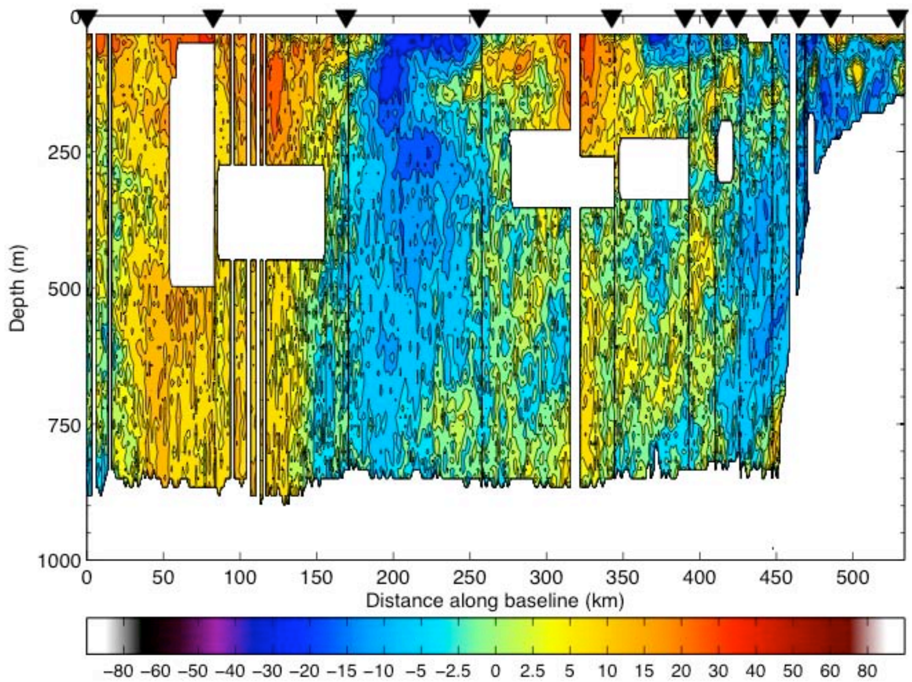

Figure 93: Off-station VMADCP *v* velocity in cm/s at the eastern boundary of the 24°S section. Triangles show station position (107 to 118), with distances calculated relative to Station 107. The blank regions are areas where bad data were removed using gautoedit.

14.6 Conclusions

We have successfully used two Ocean Surveyor phased array VMADCPs to obtain absolute velocities in the upper 1000m during JC032. The velocity errors associated with the calibration are less than 2cm/s. A comparison between the vessel-mounted and lowered ADCPs is given in David Hamersley's LADCP section of the cruise report (*Section 13*).

J Alexander Brearley

15. Biological and Additional Nutrient Biogeochemistry Sampling

15.1 Introduction

Oceanic productivity is ultimately constrained by the availability of nutrients at both local and global scales. Simultaneously, the activity of microorganisms in the ocean exerts a fundamental control on the biogeochemical cycles of the nutrient elements involved. Within different regions of the ocean the elements nitrogen (N), phosphorous (P) and iron (Fe) are thought to play the most important role in limiting productivity. However, there remain many gaps in our understanding of the interactions between the linked biogeochemical cycles of these elements, as well as the response of organisms and communities to shifts in nutrient abundance. An important example concerns the oceanic fixed nitrogen cycle. At global and potentially local scales, *(Deutsch et al. 2007)* the fixed nitrogen, which is lost from the oceans as a result of denitrification/anammox in anoxic regions, must be replenished by the activity of nitrogen-fixing organisms (diazotrophs). This balance between nitrogen inputs and losses is crucial for maintaining productivity in the predominantly N-limited oceans. However, fundamental questions remain concerning both the spatial and temporal scales, as well as the mechanism, by which this process operates *(Deutsch et al. 2007)*. In particular, the relative influence of P and/or Fe availability in controlling of nitrogen fixation and hence the coupling of the N to P is still debated *(Falkowski, 1997; Deutsch et al. 2007; Moore et al. submitted)*.

Cruise JC032 crossed the sub-tropical South Atlantic along a nominal latitude of 24°S. In marked contrast to the Northern sub-tropical gyres in the Atlantic and Pacific the southern sub-tropical gyres are highly under-sampled and in particular very little work has been performed in the South Atlantic. Consequently, JC032 represented an ideal opportunity to collect samples for the investigation of upper ocean and deep-water nutrient biogeochemistry and consequent influences on biological productivity in an under sampled region. Moreover, the cruise track crosses from west to east along a known marked gradient in upper ocean phosphorus availability which we hypothesise to result from the fixed nitrogen removal within anoxic regions of the Benguela current system on the eastern side, not being replaced by the action of diazotrophs until the waters have been transported around the gyre circulation to the western boundary where atmospheric Fe inputs are thought to be higher. Simultaneously, we wished to investigate what influence this gradient in P availability has on the upper ocean biota.

Samples were collected for a number of different analyses, most of which will be performed on return to the laboratory in Southampton.

15.2 Overall Sampling Strategy

Given the available manpower and the volumes of water available, compared to the high requirements for some of the desired measurements it was never going to be possible to collect samples for every parameter at each CTD station. A decision was thus taken to concentrate efforts on acquiring samples for the analysis of as many parameters as possible at one CTD station per day. To supplement the volumes of water available, samples were also collected from the ships underway (UW) non-toxic seawater supply at each station sampled. Additional sampling was also undertaken with a surface bucket in order to estimate the abundance of the nitrogen fixing colonial cyanobacterium *Trichodesmium* and using a General Oceanics Go-Flo bottle for collection of trace metal samples.

15.2.1 Total Chlorophyll a

Water samples (250ml) were collected from CTD bottles and the underway (UW) surface water supply and were filtered onto 25mm glass fibre filters (Fisherbrand, equivalent to Whatman GF/F). Filters were then placed in vials and extracted in 8ml 90% acetone for 24 hours in a darkened fridge. Total chlorophyll *a* was then measured with a TD-700 Turner Designs fluorometer following the procedure of *Welschmeyer (1994)* which minimises interference by chlorophyll *b*. The fluorometer was calibrated with dilutions of a solution of pure chlorophyll *a* (Sigma, UK) in 90% acetone before JC031. Blanks of 90% acetone were analysed daily. Additionally, 2 bulk samples with differing concentrations of chlorophyll were filtered onto multiple filters then stored at -80°C. Sub-sets of these samples were then thawed and analysed throughout the cruise at 1-2 week intervals to check for drift in the instrument response. A number of these filters, alongside duplicate profiles from a selection of stations will also be returned to the lab (frozen at -80°C) for analysis, as a second overall check on the accuracy of the calibration. The limit of detection calculated as 3 standard deviations of the blank was 0.003mg m^{-3} and differences measured between duplicate samples were <0.001mg m^{-3} in all cases, both of which were satisfactory, given the measured chlorophyll concentrations ranging from 0.006 and 3.09mg m^{-3}. A total of 140 samples were collected at 34 stations (Table 13). The upper water column chlorophyll concentration is mapped in Figure 94.

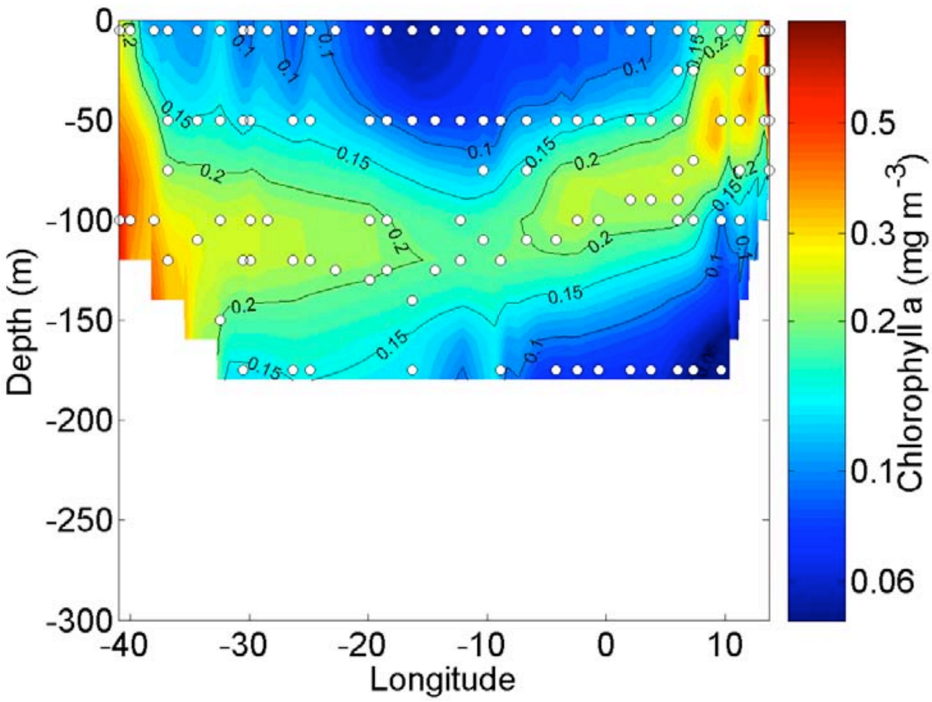

Figure 94: Preliminary contoured section of chlorophyll a measured on discrete samples collected across the 24°S section.

15.2.2 Samples for $^{\delta 15}$N PON

Particulate organic material (POM) was collected from the ships UW supply for the measurement of the natural abundance ratio of ^{15}N:^{14}N. Replicate 4.5L water samples were collected on station and filtered onto pre-ashed Whatman GF/F filters under gentle vacuum (<200 mbar). Filters were then placed in plastic vials and dried for 24-48 hours at 50-60°C before being stored for transport back to NOCS. On return samples will be analysed by isotope ratio mass spectrometry (IRMS) and used for the calculation of the $^{\delta 15}N$ ($^{0}/_{00}$) (=1000 x (^{15}N:$^{14}N_{sample}$/^{15}N:$^{14}N_{standard}$ – 1), where the standard is N_2 gas) of particulate organic nitrogen (PON). This data will in turn be used as a tracer of nitrogen cycling and the initial condition for direct incubation based rate measurements of nitrogen fixation.

15.2.3 Nitrogen Fixation Rate Measurements

Samples for water column nitrogen fixation rate measurements were collected from the CTD. Typically the top 3-4 Niskins were sampled corresponding to depths within the surface layer and within and above the DCM. Occasionally samples from the first bottle below the DCM were also incubated. Rate measurements were performed according to the methods detailed elsewhere *(Montoya et al. 1996; Mills et al. 2004)*. Briefly, samples were drawn into 4.5L Nalgene polycarbonate bottles and sealed ensuring that no air bubbles were present with a silicone septum lid. Bottles were then injected with either 3ml or 4ml of 99% $^{15}N_2$ gas, sealed in clear plastic zip-loc bags and then transferred to an on-deck incubator cooled with flowing surface seawater. The incubator and individual bottles were shaded so as to approximate the irradiance at the sampling depth. After 24 hours, the incubations were terminated by gentle filtration (<200 mbar) onto precombusted GF/F filters, and the samples dried (24 hours at 50-60°C) and once again stored for IRMS analysis. A total of 36 stations were sampled (Table 13).

15.2.4 Samples for Intact Polar Lipids

Samples for intact polar lipids were drawn from Niskin bottles corresponding to both the near surface (~5m) and the DCM. Intact polar lipids are very labile and the goal was to have samples frozen within ~1 hour of collection. Due to the time taken to sample the CTD it was typically only possible to filter 1L of sample from Niskins within a reasonable time frame. Consequently samples were also collected from the ships UW supply on station, such that a surface sample of 2L could be filtered and frozen within 1 hour. Samples were filtered onto anodized aluminium disks under gentle vacuum (<200 mbar). As soon as the filtrations were finished, discs were quickly taken and placed onto ashed foil which was then folded into an envelope, labelled and placed in the -80°C freezer for transport back to NOCS. Samples will be analysed by Patrick Martin (PhD student) during his participation in the Woods Hole exchange programme where he will be visiting the laboratory of Dr. Ben Van Mooy. In total 86 samples were collected from 33 stations (Table 13).

15.2.5 Samples for Protein Analysis

Samples were also collected for quantification of major metabolic proteins (including the photosystems, nitrogenase and Rubisco) via quantitative immunoblotting using global antibodies. Water samples were drawn from Niskin bottles (1 L) or the ships UW system (2 L) and gently filtered (<200 mbar) onto Advantec glass fibre filters. Filters were then quickly transferred to a -80°C freezer for return to NOCS where they will be analysed by a PhD student (Miss Anna Macey) under the supervision of Dr. Tom Bibby and Dr. Mark Moore (NOCS). In total, 86 samples were collected from 33 stations (Table 13).

15.2.6 Samples for the Enumeration of Trichodesmium

At each station sampled for nitrogen fixation rate measurements a surface bucket sample was collected for the enumeration of *Trichodesmium*. This organism forms large (~10,000 cell) colonies, which can be a significant component of the nitrogen fixing community even at relatively low abundance, frequently (<1 colony l^{-1}). Consequently, a large volume must be filtered. 10L samples from the surface collected with a bucket were gently filtered through a 10μm mesh, then re-suspended in filtered seawater and preserved in 2% lugols iodine solution for return to NOCS and enumeration by light microscopy *(Tyrrell et al. 2003)*. A total of 34 samples were collected (Table 13).

15.2.7 Samples for Trace Metal Analysis

Clean samples for the analysis of trace metals were collected at a total of 20 stations using a General Oceanics Go-Flo sampler deployed using a handheld Kevlar line. The Go-Flo is deployed closed and empty (air filled). A hydrostatic release then triggers at a depth of ~10m, flooding the bottle. The sampler was then lowered on down to 20m and a messenger sent down the line to close the bottle. On recovery the bottle was taken to a dedicated clean laboratory environment (the isotope container which had been loaded for JC031). Samples were then drawn from the Go-Flo into pre acid-washed 125ml LDPE bottles for both total dissolvable (i.e. unfiltered) and dissolved (filtered) trace metal analysis. Filtered samples were collected by gravity filtering ~100ml through Sarbortan™ filter cartridges. Both filtered and non-filtered samples were then acidified by adding 60μl of ultra clean HNO_3. Sample filtration and acidification were performed within glove bags flushed with air passed through an in-line HEPA filter.

15.2.8 Samples for Scanning Electron Microscopy Analysis

Samples were collected on behalf of Dr. Alex Poulton for the identification and enumeration of coccolithophores. Around 1-2L of water were collected either from the CTD or the UW system and gently filtered (<200 mbar vacuum) onto 0.4μm polycarbonate filters. Filters were subsequently dried for 12-24 hours at 50-60°C, then stored for return to NOCS where they will be analysed by scanning electron microscopy (SEM).

15.2.9 Samples for $^{\delta15}N\ NO_3^-$

In addition to the $^{\delta15}N$ of PON, the $^{\delta15}N$ of NO_3^- can also be used as a tracer of the relative influence of nitrogen fixation and denitrification within a water body. We are currently investigating setting up methods for the analysis $^{\delta15}N$ of NO_3^- at NOCS along with collaborators elsewhere. Consequently, given the ideal location of the JC032 transect for studying nitrogen dynamics it was prudent to collect frozen samples for potential future isotopic analysis. Water was collected directly from Niskin bottles into acid-washed and Milli-Q rinsed 125ml or 250ml plastic bottles following 3 sample rinses. These samples were then frozen at -20°C for return to NOCS. A total of 162 samples for the potential assessment of $^{\delta15}NO_3^-$ were collected at 15 stations. Where possible, sampling depths and stations were chosen to coincide with those sampled for DOM (see below) and where a CFC sample was also taken. The latter may eventually allow assessment of changes in $^{\delta15}NO_3^-$ as a function of tracer age.

15.2.10 Samples for DOM

Samples were also drawn from a limited set of CTDs for the analysis of dissolved organic matter (DOM). Water was drawn directly from the CTD into Sterilin pots which were first rinsed 3 times with sample. Samples were then frozen for the return to NOCS. Samples will be stored with the intention of analysis at some future date for dissolved organic nitrogen and phosphorus by Dr. Sinhue Torres. One station a day was typically sampled. DON and DOP gradients are strongest in surface waters and due to a limited supply of sampling pots, on alternate days sampling concentrated on the upper water column, with a full (24 bottle) profile taken every other day. A total of 445 samples were taken at 26 stations.

Table 13: Simple overview of sampling giving listings of stations sampled for each parameter. A more detailed spreadsheet has been saved within the cruise data directory or can be requested directly from C. M. Moore (e-mail: cmm297@noc.soton.ac.uk).

Parameter	***Stations sampled***	***No. stations***	***Total samples***
N_2 fixation	8,10,15,25,29,30,34,37,38,41,44,47,49,51,54,56,59,63,65,68,71,75,78,80,83,86,88,90,93,95,101,105,108,110,117,118	36	132
$^{\delta15}$PON	8,10,15,25,30,34,37,41,44,47,49,51,54,56,59,63,65,68,71,75,78,80,83,86,88,90,93,95,101,105,108,110,118	33	33
Protein	8,10,15,25,30,34,37,41,44,47,49,51,54,56,59,63,65,68,71,75,78,80,83,86,88,90,93,95,101,105,108,110,118	33	86
Lipids	8,10,15,25,30,34,37,41,44,47,49,51,54,56,59,63,65,68,71,75,78,80,83,86,88,90,93,95,101,105,108,110,118	33	86
Chlorophyll a	8,10,15,25,30,34,37,41,44,47,49,51,54,56,59,63,65,68,71,75,78,80,83,86,88,90,93,95,101,105,108,110,117,118	34	140
SEM	10,15,25,37,44,49,51,54,56,59,63,65,68,71,75,78,80,83,86,88,90,93,95,105,108,110,118	27	44
Trichodesmium	10,15,25,29,30,34,37,38,41,44,47,49,51,54,56,59,63,65,68,71,75,78,80,83,86,88,90,93,95,101,105,108,110,118	34	34
Trace metals	30,34,38,41,44,47,49,54,59,63,68,75,78,83,86,88,93,101,108,118	20	20
$^{\delta15}NO_3^-$	25,30,37,43,46,53,59,65,77,88,93,100,108,115,118	15	162
DOM	37,43,46,51,53,56,59,62,65,68,71,74,77,80,83,85,88,90,93,95,100,104,108,110,115,118	26	445

15.3 References

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***Acknowledgments* -** Mark would particularly like to thank the principal scientist of JC032 (Dr. Brian King) for allowing me to participate in what has been an enjoyable cruise and being supportive in the collection of what will hopefully prove to be a very interesting dataset. I was also hugely impressed with the overall professionalism of the core science team that made the cruise run so smoothly. As ever Mark would like to thank all the crew of the *RRS James Cook* and the NMF technical staff for the co-operation and assistance.

Mark Moore and Sinhue Torres

16. Continuous O_2 Concentration Measurements from the Uncontaminated Seawater Supply

16.1 Objectives

- To measure the O_2 concentration continuously from the uncontaminated seawater supply (USW) using an oxygen optode sensor (*Aanderaa* Model No. 3835).
- To calibrate the optode data with discrete samples collected from the USW.

Dissolved O_2 concentrations are measured from the sea surface water. Surface seawater is pumped to the laboratory by the uncontaminated system supply (USW) on board the *RRS James Cook*. The intake of the surface seawater (SS) is located at the bow of the ship at a nominal depth of 5m. Continuous dissolved O_2 measurements were done using an *Aanderaa* Oxygen optode sensor (AOO, Model No. 3835, Serial No. 329).

The optode sensor measurements are based on the ability of selected substances to act as dynamic fluorescence quenchers. A fluorescent indicator with a special platinum porphyrin complex embedded in a gas permeable foil is exposed to the surrounding water. The foil is excited by modulated blue light, and the phase of a returned red light is measured. By linearising and temperature compensating with an incorporated temperature sensor, the absolute O_2 concentration can be determined.

The continuous O_2 concentration data from the optode was calibrated against the total O_2 concentration from USW discrete samples. These were determined by the Winkler titration method *(Dickson, 1996)*, using a Winkler Ω -Metrohm titration unit (716 DMS Titrino).

16.2 Underway Oxygen Measurements By an Aanderaa Optode.

The optode sensor was kept in a 1L dark bucket fed by the continuous USW flow in the controlled temperature laboratory (CTL) of the *RRS James Cook*. The USW was kept on at all times, except when approaching and leaving port.

Continuous temperature, not calibrated dissolved O_2 and O_2 saturation were recorded at a rate of 1 reading every 10 seconds. This produced a data set of more than 250,000 measurements for the whole of the cruise, comprising 42 days between Julian days 67 to 110 (8^{th} of March to 20^{th} of April, 2009).

In general the optode sensor was stable; however, it may have been affected by external perturbations such as the presence of bubbles in the USW. Bubbles in the system were mainly produced by the ship pitching during bad weather (Figure 95).

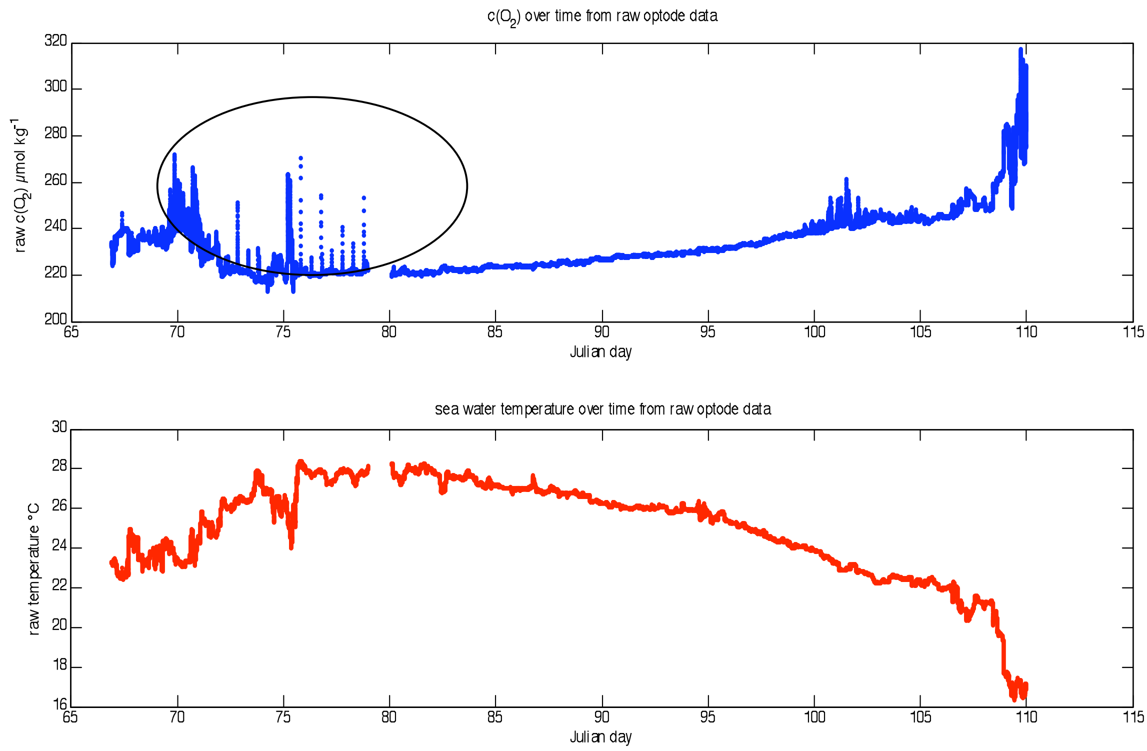

Figure 95: Optode O_2 concentration and temperature over time. The circle is showing periods with bubbles.

16.3 Calibration of the Underway Oxygen Optode

The oxygen concentration measured by the optode represents the partial pressure of the dissolved oxygen. Since the foil is only permeable to gas, the optode sensor is not affected by dissolved salts. This is comparable to if the optode measurement is made in fresh water. Salinity corrections must be performed to obtain more accurate values.

Measurements of discrete samples were taken from the same supply feeding the sensor. These were collected directly into pre-calibrated glass bottles. The total dissolved O_2 concentration was quantified following the Winkler titration method described by *Dickson (1996)*, using a Winkler Ω-Metrohm titration unit (716 DMS Titrino) with amperometric end point detection.

A total of 326 samples were taken during the cruise. In general 4 samples were taken in duplicate per day, and were analysed after a crate of 28 samples were accumulated. This represented 13 measurement sessions. Standards and blanks were prepared with the nutrients and oxygen team in 11 sessions (see methods in oxygen and nutrients report). The typical standard deviation of a duplicate analysis was 0.31µmol kg^{-1}.

The calibration was carried out using a temperature-dependent fourth-order calibration polynomial called “DPhase”, which is stored in the optode. In order to compare the sensor data with the discrete samples, these were transformed to a solved “DPhase”. The resulting calibration function will be used to compute ‘calibrated’ optode data. Figure 96 shows the comparison between the sensor raw data and the solved “Dphase” for the samples collected.

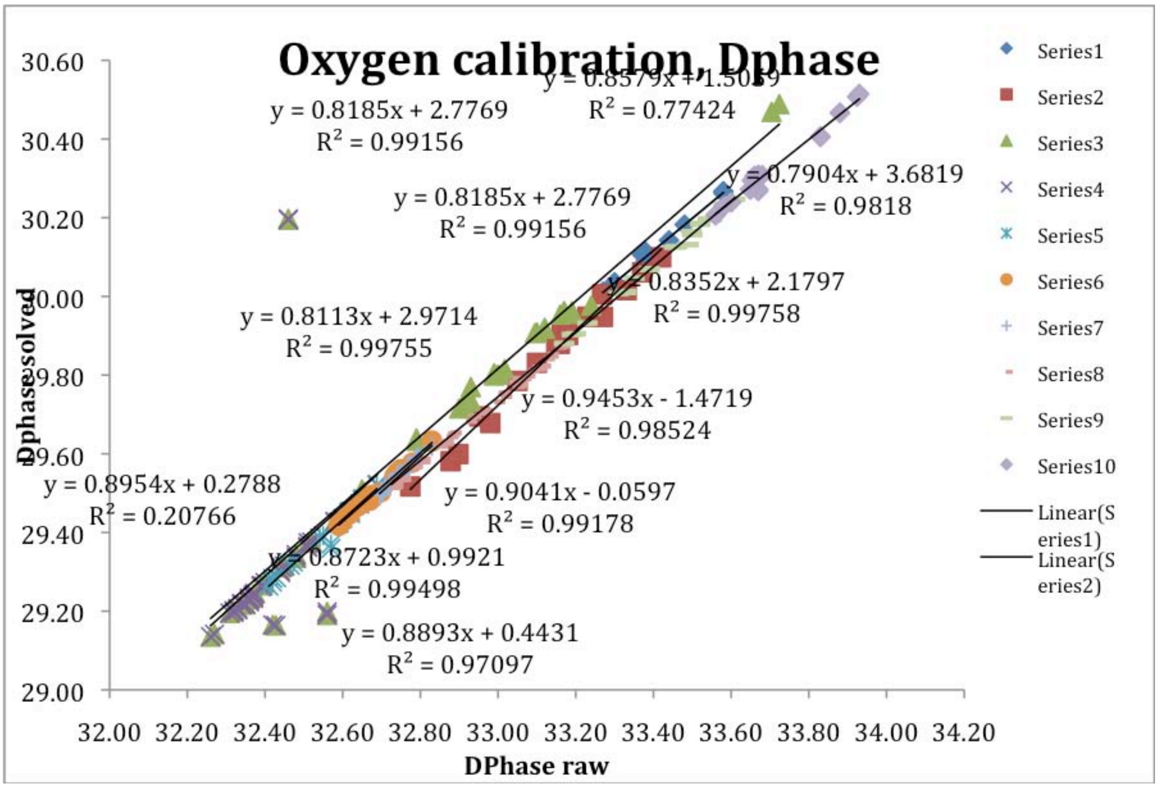

Figure 96: Optode Dphase raw against Dphase solved for the discrete USW samples collected for O_2 continuous calibration. The worst data comparison (Series 3 and 4) comes from the periods were there were bubbles in the USW.

Differences are originated both from uncertainties in the optode and in the Winkler measurements.

16.4 Dissolved O_2 Concentration From USW and CTD Surface Niskin Bottle

To evaluate the effect of the pipes over the O_2 concentration in the surface seawater, a comparison between surface Niskin bottles and the laboratory USW will be done when USW oxygen concentration is completely calibrated.

Acknowledgements **-** I am grateful to the crew, officers and scientific party of *RRS James Cook* during cruise JC032. I am also grateful to Niki Silveira and Sinhué Torres for helping with the collection of the discrete O_2 samples. Many thanks to the chemistry team for allowing me to use the Winkler titration unit and reagents.

16.5 References

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Alba Gonzalez-Posada

17. Net Community Production Estimates From Dissolved Oxygen/Argon Ratios Measured By Membrane Inlet Mass Spectrometry (MIMS)

Gross Productivity Estimates From $^{17}O/^{16}O$ and $^{18}O/^{16}O$ Isotope Ratios of Dissolved Oxygen

17.1 Rationale and Objectives

The dissolved oxygen (O_2) concentration of seawater is affected by fundamental physical and biological processes. These include; photosynthesis (*P*) and respiration (*R*), diffusive and bubble-mediated gas exchange with the atmosphere, temperature and pressure changes, lateral mixing and vertical diffusion. In the absence of physical effects, dissolved O_2 constrains the difference between *P* and *R*, i.e. net community production (*N*). Thus, O_2 can be used as a geochemical tracer that reflects carbon fluxes integrated over characteristic response times. Warming and bubble injection lead to O_2 supersaturation, posing a challenge to this approach.

Craig and Hayward (1987), Dickson (1995) used oxygen/argon (O_2/Ar) ratios to separate O_2 supersaturations into a biological and physical component. This method is based on the similar solubility characteristics of O_2 and Ar with respect to temperature and pressure changes as well as bubble injection. One can define an O_2/Ar supersaturation, ΔO_2/Ar, as:

$$\Delta O_2/\mathrm{Ar} = \frac{c(\mathrm{O_2})}{c(\mathrm{Ar})} \bigg/ \frac{c_{\mathrm{sat}}(\mathrm{O_2})}{c_{\mathrm{sat}}(\mathrm{Ar})} - 1$$

ΔO_2/Ar essentially records the difference between photosynthetic O_2 production and respiration. c is the dissolved gas concentration (in mol m^{-3}) and c_{sat} is the saturation concentration. c_{sat} is a function of temperature, pressure and salinity. This method, in which discrete samples are collected at sea, stored, and analyzed in the lab, has been widely used in subsequent work *(Spitzer and Jenkins 1989; Quay, Emerson et al. 1993; Luz and Barkan 2000; Hendricks, Bender et al. 2004).*

Recently presented was an advance of this method for continuous underway measurements of O_2/Ar by membrane-inlet mass spectrometry (MIMS) *(Kaiser, Reuer et al. 2005)*, extending earlier oceanographic MIMS applications *(Kana, Darkangelo et al. 1994; Tortell 2005)*. The measured ΔO_2/Ar values can be used in conjunction with suitable wind-speed gas-exchange parameterizations to calculate biologically induced air-sea O_2 fluxes and, where conditions are appropriate, *N*. The inferred *N* values represent rates integrated over the characteristic mixed layer gas exchange times (ratio of mixed layer thickness and piston velocity), typically between 2 and 4 weeks.

The O_2/Ar method has the advantage not to involve potential biases associated with incubating water samples in a bottle. The *N* estimates from the JC032 cruise will be used to quantitatively study the autotrophic or heterotrophic nature of different marine ecosystems in the South Atlantic subtropical gyre.

In addition to the continuous underway measurements, discrete samples from the same source of water were taken for calibration purposes and to measure the $^{17}O/^{16}O$ and $^{18}O/^{16}O$ isotope ratio analysis of dissolved oxygen. Triple oxygen isotope measurements combined with O_2/Ar data can be used to estimate the ratio of net community production (*N*) to gross production (*P*) and the ratio of gas exchange to gross production. Again, in combination with suitable wind-speed gas-exchange parameterizations this can be used to estimate gross production over large regional scales at timescales of weeks to months.

17.2 Methodology

Continuous measurements of dissolved N_2, O_2, Ar and CO_2 were made by MIMS on board *RRS James Cook*. The ship's uncontaminated system supply of seawater (USW) was used to pump water through an exchange chamber with a tubular Teflon AF membrane (*Random Technologies*) mounted on the inside. The membrane was connected to the vacuum of a quadrupole mass spectrometer (*Pfeiffer Vacuum* Prisma). The intake of the USW is located at the bow of the ship at a nominal depth of 5m. The water first passed through a 50µm filter to remove macroscopic particles that can obstruct the flow in the degassing membrane. The inlet of seawater to the MIMS was kept in a 1L dark bucket that was filled up with the continuous USW flow from the aft starboard sink in the control temperature laboratory (CTL) (deck level) of the *RRS James Cook*. A flow of about 60ml/min was continuously pumped from the bucket through the membrane chamber, using a gear pump (*Micropump*). In order to reduce O_2/Ar variations due to temperature effects and water vapour pressure variations, the exchange chamber with the membrane was held at a constant temperature of 15ºC. The flight tube was in a thermally insulated box maintained initially at 70ºC.

The O_2/Ar ratio measurements will be calibrated with discrete water samples taken from the same seawater outlet as used for the MIMS measurements. 200–300cm^3 samples were drawn into pre-evacuated glass flasks poisoned with 7mg $HgCl_2$ *(Quay, Emerson et al. 1993).* These samples will be later analyzed with an isotope ratio mass spectrometer at the School of Environmental Sciences, University of East Anglia, for their dissolved O_2/Ar ratios and the oxygen triple isotope composition relative to air *(Hendricks, Bender et al. 2004).* Raw O_2/Ar ion current ratio measurements were made every 10 s and had a short-term stability of 0.05%. Absolute Ar supersaturation will be calculated from the absolute O_2 supersaturations measured by Winkler titration and the O_2/Ar ratios measured by MIMS.

17.3 Results

In total 77 discrete water samples were collected for calibration purposes and to analyze oxygen triple isotopes, 60 of them were taken from the USW and 17 from the CTD. The water was sampled into evacuated bottles with compression o-ring valves (*Glass Expansion*). From Jan Kaiser's experience, this type of valve is more watertight than previously used high-vacuum valves (*Louwers Hapert*). These samples will be analyzed at the University of East Anglia after our return.

Membrane inlet mass spectrometry (MIMS) was used to analyze dissolved gases continuously, namely oxygen (O_2), nitrogen (N_2), argon (Ar), and carbon dioxide

(CO_2). The general performance of the instrument was good. However there are some unstable periods due to the contamination of the membrane with air usually after running discrete samples on station.

Acknowledgements **-** Many thanks to crew, officers and scientific party of the *RRS James Cook* during JC032, particularly to David Cooper for helping with the collection of samples.

17.4 References

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18. Fast Repetition Rate Fluorometry (FRRF) From the Uncontaminated System Supply

A Fast Repetition Rate Fluorometer (FRRF) (Chelsea Instruments Ltd.) was used to measure active fluorometry from the uncontaminated system supply (USW) onboard the *RRS James Cook.* The fast repetition rate fluorometry (FRR) is based on variable fluorescence characteristics of the phytoplankton (*chlorophyll a*). The FRRF has been introduced as a potential tool to evaluate the primary productivity in aquatic systems. Active *chlorophyll a* fluorometry provides a non-destructive and minimally intrusive method for probing oxygenic photosynthesis, in general, and the functioning of photosystem II in particular (*Raateoja, 2004*).

The FRRF was fitted to a protective rack in one of the sinks of the deck laboratory on the deck level onboard the *RRS James Cook.* A constant flow of surface water from the USW was kept acquiring data for the duration of the JC031 oceanographic cruise (JD 34 to 61) including the transits before and after the CTD casts. The USW pumps sea surface water from a nominal depth of 5m. The intake is located at the bow of the ship.

The acquisition of discrete samples (data resolution) was every 10 seconds operating in a bench-top mode. A single file per 24 hours of data was created in .txt format.

The variables of interest from the FRRF data are Fo and Fm that corresponds to the initial and maximal in vivo fluorescence yield (relative) in the dark-adapted state in the absence of non-photochemical quenching. Since there are non-homogeneous regions with high variation in phytoplankton concentration, a photomultiplier (PMT) variable is also considered. This variable was set to auto-ranging mode in the protocol (see below) set for the USW analysis.

A copy of the boot protocol followed is shown below.

FRRF boot protocol:

Boot Protocol = 9

6.	65535	Acquisitions
7.	16	Flash sequences per acquisition (averaged)
8.	100	Saturation flashes per sequence
9.	4	Saturation flash duration
A.	0	Saturation interflash delay
B.	ENABLED	Decay flashes
C.	20	Decay flashes per sequence
D.	4	Decay flash duration
E.	120	Decay interflash delay
F.	10000	Sleep-time between acquisition sequence (mS)
G.	16	PMT Gain in Autoranging mode
H.	DISABLED	Analogue output
I.	ENABLED	Desktop (verbose) Mode
J.	INACTIVE	Light Chamber
K.	ACTIVE	Dark Chamber
L.	ENABLED	Logging mode to internal flashcard
M.	95	Upper Limit Autoranging Threshold value
N.	5	Lower Limit Autoranging Threshold value

18.1 References

Raateoja, M.P. (2004), Fast repetition rate fluorometry (FRRF) measuring phytoplankton productivity: A case study at the entrance to the Gulf of Finland, Baltic Sea, *Boreal Environment Research*, 9: 263-276.

Acknowledgements **-** I am very grateful to Mark Moore for his advice and help with the FRRF system and also for providing me with a script to process the data.

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19. Aerosol Sampling

Aerosol samples were collected throughout the cruise using a high volume ($1m^3min^{-1}$) collector, with each sample collected over a period of approximately 24 hours.

The apparatus for the collection of this data was situated on Monkey Island at the very top of the *RRS James Cook*. It was necessary to consult the bridge crew every time access was required to Monkey Island due to the operation of the large radar dish, which was a source of ionizing radiation. The bridge crew would not only ensure that the access to Monkey Island was safe, but also would keep an eye on the weather and provide notification of when the conditions such as the wind direction changed, or if it was likely to start raining.

Aerosol samples collected will be analysed at UEA for their major ion content, with the main focus being the estimation of atmospheric nutrient (N and P) fluxes into the South Atlantic. Rainwater samples were also collected whenever possible using a 40cm diameter polypropylene funnel. These samples will also be analysed at UEA for their major ion/nutrient content.

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20. Argo Floats

20.1 Introduction

One of the operations that the physics team was involved with on JCO32 was the preparation and launch of APEX type Argo floats (provided by the MET Office). APEX stands for Autonomous Profiling EXplorer, and this particular float is equipped with an array of sensors, which measure parameters such as salinity/conductivity, temperature, and pressure, whilst tracking the position of the float via the contingent of ARGOS satellites orbiting the Earth. The data collected by the floats is automatically transmitted to these satellites when the float surfaces. The floats manoeuvre vertically through the water column by means of pumping fluid into and out of an external bladder. This particular type of float is designed to be neutrally buoyant at a depth of 1000m (park pressure). The float then descends to a depth of 2000m and then rises back up to the surface. The process of inflating and deflating the bladder is repeated over and over, resulting in a continuous cycle from which high quality data of the ocean profile from 2000m depth to the surface can be recorded. The cycle length is programmable, but these particular floats have a cycle that carries out 1 profile every 10 days.

20.2 Objectives

During this cruise, 16 Argo floats were launched at different locations along the 24°S transect in the South Atlantic. The principal aim of this venture was to increase the population of Argo floats in the South Atlantic, in order to augment the quantity and quality of ocean profile data in this location. The launch positions largely depended on the positions of floats that were currently active near the 24°S transect. Out of the 16 Argo floats that were launched during the cruise, 4 of these were designed for near-surface temperature monitoring.

20.3 Float Identification

Each float had its own unique serial number on the hull. All the information for each of the floats, including pre-deployment tests and also when the float was actually launched was recorded in a log. The main information has been compiled in the following table.

Table 14: Key Argo Float Information

Deployment	Crate	Type	Hull Serial	WMO ID	Station	Activation Time (JDay/hhmm)	Expected Dive Time (JDay/hhmm)	Deployment time (JDay/hhmm)	Latitude	Longitude
1	1	Norm	4364	1901228	36	080 / 23:46	080 / 05:46	080 / 01:31	23°S 59.96'	037°W 29.85'
2	1	Norm	4439	1901229	40	082 / 04:40	082 / 10:40	082 / 06:55	23°S 59.92'	034°W 57.95'
3	2	Norm	4440	1901230	46	084 / 04:35	084 / 10:35	084 / 06:12	23°S 59.98'	031°W 10.13'
4	A	Surf. Temp	4480	1901240	51	087 / 11:07	087 / 17:07	087 / 12:38	23°S 59.92'	028°W 27.90'
5	2	Norm	4469	1901231	59	090 / 09:51	090 / 15:51	090 / 11:51	24°S 00.07'	022°W 43.93'
6	3	Norm	4471	1901233	63	092 / 13:32	092 / 19:32	092 / 15:12	24°S 00.03'	019°W 52.13'
7	A	Surf. Temp	4481	1901241	67	094 / 00:14	094 / 06:14	094 / 01:49	23°S 24.59'	017°W 00.03'
8	3	Norm	4470	1901232	72	095 / 14:19	095 / 20:19	095 / 16:07	22°S 54.41'	013°W 46.00'
9	4	Norm	4473	1901235	77	097 / 05:00	097 / 11:00	097 / 06:25	22°S 21.09'	011°W 00.53'
10	B	Surf. Temp	4482	1901242	82	099 / 00:25	099 / 06:25	099 / 01:50	23°S 41.01'	007°W 25.05'
11	4	Norm	4472	1901234	86	100 / 13:31	100 / 19:31	100 / 14:43	23°S 59.95'	004°W 11.78'
12	5	Norm	4475	1901237	89	101 / 20:08	102 / 02:08	101 / 21:35	24°S 00.08'	001°W 53.13'
13	B	Surf. Temp	4483	1901243	95	104 / 06:05	104 / 12:05	104 / 07:25	23°S 59.98'	003°E 48.01'
14	5	Norm	4474	1901236	103	105 / 22:48	105 / 04:48	106 / 00:21	23°S 59.91'	007°E 02.52'
15	6	Norm	4477	1901239	107	107 / 11:02	107 / 17:02	107 / 11:35	24°S 00.00'	009°E 42.00'
16	6	Norm	4476	1901238	111	108 / 11:51	108 / 17:51	108 / 13:13	24°S 00.00'	012°E 04.00'

20.4 Launch Positions

This map shows the positions where the Argo floats were deployed, and it also highlights the positions of older floats in the vicinity.

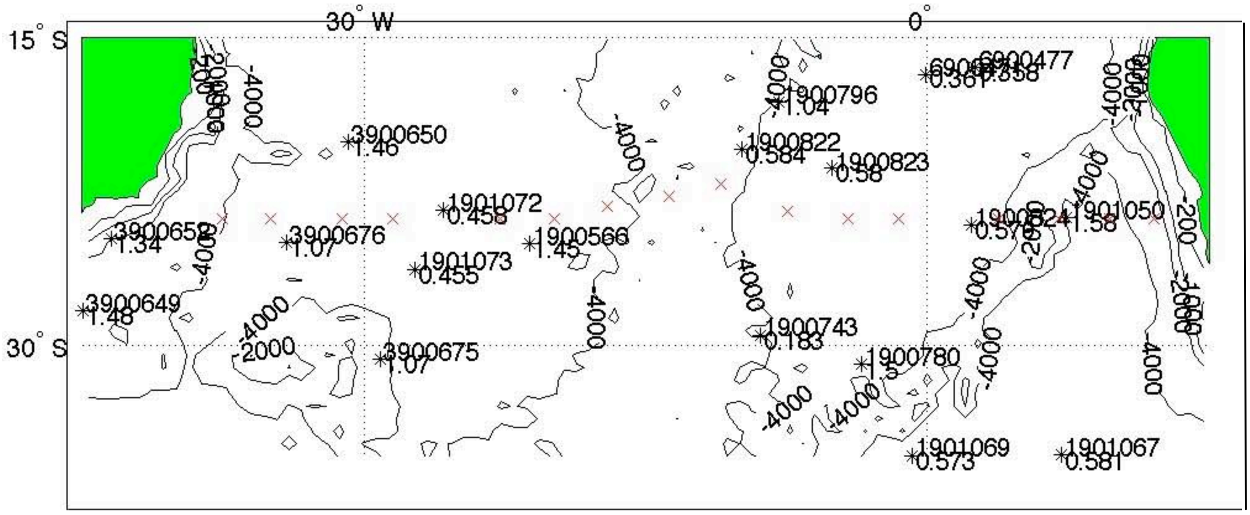

Figure 97: Map of the South Atlantic Ocean with locations of old floats (*) and the launch positions of floats on JC032 (x)

20.5 Pre-deployment checks

Tests were run on each float in advance of each deployment to ensure that the float was functioning as expected. These checks were performed using a laptop computer with a COM1 port to which the cables could be connected. It was necessary to ensure that the clamps were touching only the terminals protruding from the float and not the hull of the float itself otherwise random symbols would be generated in the terminal window on the screen. The program used for talking to the float was Hyper-terminal, saved under the alias 'apex_talk'.

Firstly, the parameters for communication with the float had to be selected, such as the terminal parity (none), transfer rate (9600 bits). Gerard McCarthy created log sheets and instructions for the pre-deployment checks. To start the program recording information, the capture text → start function in the menu toolbar was selected.

The list of values for the parameters of the float e.g. park pressure, Argos repetition period, up-time, down-time, etc. were displayed by typing L into the terminal, and the values were checked off, and were also noted if different to those displayed on the sheet.

Typing P displayed the pressure table of the float. There was a difference in the pressure tables between the normal and surface floats, as the near surface floats had an additional pressure level (58) to the normal floats.

The time offset (GMT – float was recorded), and it was generally found that the offset was in the order of 5-9 seconds. To test if the float was able to transmit data, a transmit command was sent to the float which would generate a beep from a receiver in confirmation.

The high pressure pumps were tested by monitoring the original positions of the pistons (should be 100 counts for shipping), and then the pump was extended and retracted by 4 counts. The battery voltage was checked, and was supposed to be higher than 15.2V. The internal vacuum was checked for a value between 78-87 counts.

The pneumatic system test was run in two stages due to the need to wait for five minutes before the second stage. Firstly the pumps were run for 6 seconds and the vacuum counts were observed to check that they had risen by 20-30 counts. The pumping continued until the vacuum had reached 120 counts, and once this value was reached the time was recorded concluding the first stage of the pneumatic system test. The second stage of the pneumatic system test consisted of checking that the vacuum counts had held at a relatively constant level (1-2 counts).

During the 5-minute wait, it was found to be an efficient use of time to carry out the CTD check where the current values of temperature, salinity and pressure were displayed just to check that they were sensible. All that was left after this was to run a self-test, which passed for every float. The float could then be made to hibernate and the text capture could be stopped.

20.6 Pre-deployment Issues

Several issues arose during the pre-deployment tests that are worth noting. These issues are listed below:

- The transmission beep was very faint on floats 4473 and 4475
- Float 4482 was given five minutes extra time to check vacuum counts
- The CTD pressure test had to be retaken on 4483; first reading = 0.00db; second reading = 0.02db
- Floats 4439 and 4469 had higher test salinities (0.03 psu) than the other floats.
- Floats 4470 and 4474 had 226 piston full extension 4481 had 225 piston full extension as opposed to the prescribed 227 counts.

20.7 Deployment

Several hours before deployment (usually when the CTD package had reached maximum depth) the float was activated by rubbing a magnet across the reset panel of the Argo float, which tripped a reed switch inside. This started the float transmitting, which could be audible from the beep of the cat's meow receiver. The activation time was recorded in the log sheet. By the time the CTD had been brought back up to approximately 1000m depth, the float was checked again just to ensure that the receiver was beeping every 2 minutes.

The procedure of deployment would occur immediately after a station had surfaced and the ship had begun steaming slowly. Usually about three people were required to be present for a launch, two scientific staff to deploy the instrument and one of the deck crew to communicate the progress of the deployment with the bridge. The float was prepared on deck by removing the sensor covers and threading a rope through the plastic damper plate with one end of the rope attached securely to the ship with a bowline. Two people from the physics watch would lift the float over the side, keeping it upright, and then one person would take the weight of the float on the rope and start lowering it slowly into the water. When the float was in the water, it was allowed to stream out behind the ship and the rope was released to let the float go. When the rope was recovered an announcement would be made to the bridge to say all lines were clear. The time and coordinates of the float deployment were recorded.

On at least two occasions the floats deployed were not observed to float in the upright position, but were seen to remain horizontal in the water. It is likely that they managed to right themselves. Conditions during float launches on this cruise have been favourable, with minimal swell and a fair head wind to carry the float away from the ship.

20.8 Additional Notes

Upon investigation of the crates containing the Argo floats in Montevideo, it was found that none of them had cat meow receivers in them (receivers used to sound the beep during the transmission test). Luckily a spare receiver was brought by Brian King and has subsequently been used during the tests of all the floats.

So far we are aware of at least one APEX float that has failed to transmit its location 24 hrs after deployment. This is float, hull serial number 4439, (WMO ID 1901229). It will not be known if the remaining floats are successfully transmitting until at least 10 days after the final float has been deployed.

David Hamersley and Gerard McCarthy

Appendix: Details of Stations sampled during Cruise JC032

Station Number	Date	Time	Latitude (Deg Min)	Longitude(Deg Min)	Water Dep Corr (m)	Max CTD Dep (m)	Min Ht Off Bot (m)	Max CTD Press (dbar)	Number of Bottle Samples: Dep	Sal	Oxy	Nut	CO_2	CFC	Comments
1	08/03/2009	09:06													Start of 1st Brazil Current section
	08/03/2009	09:18	036 19.85 S	053 29.90 W	246	241	7	243	7	7	7	7	7	7	
	08/03/2009	09:41													
2	08/03/2009	12:02													
	08/03/2009	12:20	036 23.54 S	053 24.75 W	553	546	8	551	9	8	9	9	9	10	
	08/03/2009	12:58													
3	08/03/2009	14:08													
	08/03/2009	14:41	036 28.12 S	053 18.33 W	981	975	8	984	14	13	13	13	13	12	
	08/03/2009	15:30													
4	08/03/2009	17:17													
	08/03/2009	17:53	036 35.98 S	053 07.71 W	1412	1405	9	1421	15	15	14	15	15	15	
	08/03/2009	18:58													
5	08/03/2009	20:20													
	08/03/2009	21:07	036 39.89 S	053 03.71 W	2067	2059	6	2084	18	18	18	18	18	18	
	08/03/2009	22:29													
6	08/03/2009	23:58													
	09/03/2009	01:09	036 42.53 S	052 59.35 W	2596	2545	14	2580	20	20	20	20	20	20	
	09/03/2009	02:46													
7	09/03/2009	04:30													
	09/03/2009	05:34	036 46.74 S	052 52.38 W	2961	2952	8	2996	22	21	21	21	21	21	
	09/03/2009	07:14													
8	09/03/2009	10:54													
	09/03/2009	12:14	037 06.30 S	052 24.80 W	3513	3508	6	3564	24	24	24	24	24	24	
	09/03/2009	14:16													
9	09/03/2009	17:33													End of 1st Brazil current section
	09/03/2009	18:54	037 24.01 S	051 59.56 W	3993	3986	7	4054	24	24	23	24	24	7	
	09/03/2009	20:53													
10	13/03/2009	10:21													Start of 2nd Brazil current section
	13/03/2009	11:33	027 43.07 S	043 57.90 W	3037	3031	7	3074	21	20	20	20	19	20	
	13/03/2009	13:09													
11	13/03/2009	16:17													
	13/03/2009	17:27	027 17.24 S	043 57.96 W	2852	2846	7	2885	21	21	22	24	21	20	
	13/03/2009	18:55													
12	13/03/2009	22:33													
	13/03/2009	23:33	026 47.54 S	043 58.06 W	2584	2573	11	2606	20	20	20	24	11	11	
	14/03/2009	00:59													
13	14/03/2009	03:35													
	14/03/2009	04:31	026 28.93 S	043 57.95 W	2533	2521	10	2553	20	20	20	20	15	12	
	14/03/2009	05:59													
14	14/03/2009	08:16													
	14/03/2009	09:11	026 15.37 S	044 05.50 W	2354	2349	6	2378	19	19	19	19	10	10	

	14/03/2009	10:25													
	14/03/2009	12:20													
15	14/03/2009	13:11	026 02.11 S	044 12.44 W	2211	2202	8	2229	18	18	18	18	10	9	
	14/03/2009	14:25													
	14/03/2009	16:53													
16	14/03/2009	17:42	025 44.74 S	044 21.35 W	2064	2055	8	2079	18	18	18	18	9	9	
	14/03/2009	18:51													
	14/03/2009	20:59													
17	14/03/2009	21:44	025 30.14 S	044 29.09 W	1863	1857	6	1877	18	18	17	17	9	10	
	14/03/2009	22:52													
	15/03/2009	00:54													
18	15/03/2009	01:34	025 15.81 S	044 36.64 W	1501	1496	6	1511	16	16	16	16	8	10	
	15/03/2009	02:39													
	15/03/2009	04:09													
19	15/03/2009	04:41	025 09.04 S	044 40.35 W	996	993	5	1002	13	13	13	13	8	8	
	15/03/2009	05:25													
	15/03/2009	06:39													
20	15/03/2009	06:56	025 02.98 S	044 43.41 W	504	496	8	500	10	10	10	10	7	7	
	15/03/2009	07:25													
	15/03/2009	08:36													
21	15/03/2009	08:47	024 58.87 S	044 45.55 W	253	247	8	248	8	8	8	8	5	5	
	15/03/2009	09:07													
	15/03/2009	12:13													
22	15/03/2009	12:19	024 37.32 S	044 57.04 W	126	120	7	121	6	6	0	0	0	0	End of 2nd Brazil current section
	15/03/2009	12:31													
	16/03/2009	13:35													
23	16/03/2009	13:41	023 09.64 S	041 00.38 W	110	102	7	102	5	5	5	6	5	5	Start of 3rd Brazil Current section
	16/03/2009	13:56													
	16/03/2009	14:50													
24	16/03/2009	15:14	023 12.07 S	040 57.63 W	485	450	6	453	11	9	9	9	9	9	
	16/03/2009	15:49													
	16/03/2009	16:39													
25	16/03/2009	17:11	023 13.95 S	040 55.39 W	1069	1061	7	1071	14	14	14	14	9	9	
	16/03/2009	18:07													
	16/03/2009	19:29													
26	16/03/2009	20:14	023 17.61 S	040 51.13 W	1565	1556	9	1571	16	15	15	15	9	9	
	16/03/2009	21:11													
	16/03/2009	22:28													
27	16/03/2009	23:18	023 20.98 S	040 46.91 W	1997	1989	9	2011	19	18	18	18	11	11	
	17/03/2009	00:28													
	17/03/2009	02:06													
28	17/03/2009	03:03	023 28.79 S	040 37.46 W	2505	2498	9	2530	20	20	20	18	12	12	
	17/03/2009	04:26													
	17/03/2009	07:25													
29	17/03/2009	08:32	023 44.33 S	040 18.66 W	2857	2846	10	2884	21	21	21	21	12	12	
	17/03/2009	10:06													
	17/03/2009	12:51													
30	17/03/2009	13:53	024 00.02 S	040 00.05 W	3011	3006	6	3047	20	20	20	21	12	12	
	17/03/2009	15:31													
	17/03/2009	19:08													
31	17/03/2009	20:16	024 00.01 S	039 29.98 W	3017	3012	7	3053	22	20	20	20	12	12	
	17/03/2009	21:43													

	18/03/2009	01:03													
32	18/03/2009	02:19	024 59.78 S	038 59.88 W	3400	3391	10	3440	23	22	22	22	13	12	
	18/03/2009	04:02													
	18/03/2009	07:33													
33	18/03/2009	08:46	024 00.01 S	038 29.94 W	3484	3472	12	3523	24	24	24	24	13	14	
	18/03/2009	10:20													
	18/03/2009	13:39													
34	18/03/2009	15:03	024 00.03 S	038 00.06 W	3587	3581	8	3635	24	23	23	23	14	14	
	18/03/2009	16:56													
	18/03/2009	20:15													End of 3rd Brazil Current section
35	18/03/2009	21:41	024 00.07 S	037 29.47 W	4063	4056	7	4122	24	23	23	24	14	13	
	18/03/2009	23:31													
	21/03/2009	22:00													Repeat of Station 35. Start of main section
36	21/03/2009	23:21	024 59.94 S	037 29.92 W	4062	4054	9	4120	22	24	24	24	18	18	
	22/03/2009	01:14													
	22/03/2009	05:17													
37	22/03/2009	06:39	024 00.01 S	036 52.01 W	4001	3993	10	4057	22	22	22	22	14	16	
	22/03/2009	08:21													
	22/03/2009	12:27													
38	22/03/2009	13:49	024 00.05 S	036 13.78 W	4114	4108	8	4175	22	24	24	24	16	16	
	22/03/2009	15:41													
	22/03/2009	19:42													
39	22/03/2009	21:09	024 00.12 S	035 35.86 W	4204	4197	8	4266	22	24	24	24	16	15	
	22/03/2009	23:06													
	23/03/2009	03:08													
40	23/03/2009	04:34	023 59.93 S	034 57.96 W	4243	4237	6	4308	22	24	24	24	16	16	
	23/03/2009	06:36													
	23/03/2009	10:58													
41	23/03/2009	12:27	024 00.01 S	034 20.10 W	4439	4431	7	4507	22	24	24	24	16	16	
	23/03/2009	14:27													
	23/03/2009	18:39													
42	23/03/2009	20:12	024 00.08 S	033 41.88 W	4628	4625	2	4706	23	24	24	24	16	16	
	23/03/2009	22:18													
	24/03/2009	02:10													
43	24/03/2009	03:44	023 59.97 S	033 04.11 W	4766	4759	5	4844	23	24	24	24	15	17	
	24/03/2009	05:51													
	24/03/2009	09:57													
44	24/03/2009	11:39	024 00.12 S	032 25.98 W	5013	5005	7	5097	23	24	24	24	16	16	
	24/03/2009	13:54													
	24/03/2009	18:01													
45	24/03/2009	19:46	023 59.99 S	031 47.94 W	5084	5077	8	5171	24	23	24	24	16	17	
	24/03/2009	21:57													
	25/03/2009	02:02													
46	25/03/2009	03:44	023 59.97 S	031 10.15 W	5166	5159	9	5255	24	24	24	24	16	16	
	25/03/2009	05:59													
	25/03/2009	10:10													
47	25/03/2009	11:58	023 59.88 S	030 31.97 W	5268	5260	9	5360	24	24	24	24	17	18	
	25/03/2009	14:14													
	27/03/2009	12:40													Station 48 aborted. CTD002 winch failed.
49	27/03/2009	14:23	023 00.04 S	029 53.99 W	5350	5340	10	5442	24	24	24	24	16	18	
	27/03/2009	17:26													

	27/03/2009	22:01													
50	27/03/2009	23:46	024 00.08 S	029 10.91 W	5437	5427	9	5532	24	24	24	24	16	19	
	28/03/2009	03:10													
	28/03/2009	07:54													
51	28/03/2009	09:50	023 59.94 S	028 27.97 W	5443	5306	61	5407	23	23	24	24	17	18	
	28/03/2009	12:27													
	28/03/2009	17:06													
52	28/03/2009	19:01	023 59.99 S	027 44.88 W	5555	5473	6	5580	24	24	24	24	17	18	
	28/03/2009	21:55													
	29/03/2009	02:37													
53	29/03/2009	04:35	024 00.04 S	027 02.05 W	5664	5657	8	5769	24	24	24	24	18	18	
	29/03/2009	07:05													
	29/03/2009	11:48													
54	29/03/2009	13:36	023 59.97 S	026 19.23 W	5698	5688	10	5802	24	24	24	24	17	17	
	29/03/2009	16:08													
	29/03/2009	20:54													
55	29/03/2009	22:46	023 59.95 S	025 36.15 W	5712	5703	8	5818	24	24	24	24	17	17	
	30/03/2009	01:16													
	30/03/2009	05:46													
56	30/03/2009	07:44	023 59.98 S	024 52.99 W	5198	5186	11	5284	24	24	24	24	17	17	
	30/03/2009	09:59													
	30/03/2009	14:34													
57	30/03/2009	16:19	024 00.02 S	024 10.03 W	5256	5245	11	5344	24	24	24	24	17	17	
	30/03/2009	18:40													
	30/03/2009	23:06													
58	31/03/2009	00:47	023 59.95 S	023 26.97 W	5144	5134	9	5230	24	23	23	23	17	17	
	31/03/2009	03:14													
	31/03/2009	07:41													
59	31/03/2009	09:20	024 00.12 S	022 44.01 W	5127	5121	6	5216	24	23	23	23	17	15	
	31/03/2009	11:43													
	31/03/2009	16:12													
60	31/03/2009	17:49	024 00.00 S	022 00.96 W	4978	4971	6	5062	24	24	24	24	17	17	
	31/03/2009	19:56													
	01/04/2009	17:56													Winch emergancy stop failed.
61	01/04/2009	19:40	024 00.03 S	021 18.02 W	5110	5101	9	5196	23	24	24	24	17	18	
	01/04/2009	21:54													
	02/04/2009	02:26													
62	02/04/2009	04:01	024 00.03 S	020 34.98 W	4796	4786	9	4871	24	23	23	23	16	17	
	02/04/2009	06:21													
	02/04/2009	11:12													
63	02/04/2009	12:46	024 00.03 S	019 52.13 W	4457	4447	10	4523	23	23	23	23	16	16	
	02/04/2009	15:01													
	02/04/2009	19:52													
64	02/04/2009	21:32	023 48.00 S	019 08.77 W	4819	4810	9	4896	24	24	24	24	17	19	
	02/04/2009	23:47													
	03/04/2009	04:27													
65	03/04/2009	06:07	023 36.29 S	018 25.99 W	4686	4678	9	4761	24	24	24	24	16	16	
	03/04/2009	08:49													
	03/04/2009	13:22													
66	03/04/2009	14:56	023 30.43 S	017 42.99 W	4732	4720	11	4804	23	23	23	23	17	16	
	03/04/2009	17:14													
67	03/04/2009	21:45													

	03/04/2009	23:19	023 24.59 S	017 00.04 W	4981	4971	9	5061	24	24	24	24	16	16	
	04/04/2009	01:37													
	04/04/2009	06:23													
68	04/04/2009	07:54	023 18.66 S	016 16.80 W	4617	4608	10	4688	24	24	24	24	4	17	
	04/04/2009	10:09													
	04/04/2009	14:34													
69	04/04/2009	15:59	023 12.82 S	015 34.00 W	3918	3907	11	3968	22	24	24	24	15	16	
	04/04/2009	17:52													
	04/04/2009	21:47													
70	04/04/2009	23:10	023 07.70 S	014 58.02 W	4212	4202	10	4272	24	22	23	22	15	18	
	05/04/2009	01:12													
	05/04/2009	05:17													
71	05/04/2009	06:41	023 02.97 S	014 22.03 W	4064	4058	8	4124	23	22	22	22	17	17	
	05/04/2009	08:32													
	05/04/2009	12:42													
72	05/04/2009	14:12	022 54.41 S	013 46.01 W	3824	3820	8	3880	22	23	24	24	16	16	
	05/04/2009	15:54													
	05/04/2009	20:30													
73	05/04/2009	22:17	022 48.20 S	013 07.91 W	3988	3981	10	4044	24	24	24	24	16	16	
	06/04/2009	00:25													
	06/04/2009	03:06													
74	06/04/2009	04:38	022 31.60 S	012 49.03 W	4433	4418	9	4493	23	24	24	24	10	16	
	06/04/2009	06:38													
	06/04/2009	10:40													
75	06/04/2009	12:04	022 15.42 S	012 16.08 W	4397	4386	12	4459	20	19	19	23	16	16	
	06/04/2009	14:11													
	06/04/2009	18:03													
76	06/04/2009	19:43	022 12.79 S	011 43.21 W	4369	4361	9	4434	23	23	23	23	16	16	
	06/04/2009	21:42													
	07/04/2009	02:42													
77	07/04/2009	04:13	022 21.17 S	011 00.31 W	4155	4147	9	4214	23	24	24	24	16	17	
	07/04/2009	06:09													
	07/04/2009	11:12													
78	07/04/2009	12:33	022 30.07 S	010 17.11 W	4074	4062	11	4128	22	23	23	23	17	16	
	07/04/2009	14:25													
	07/04/2009	19:31													
79	07/04/2009	21:08	022 47.89 S	009 34.00 W	4636	4627	9	4708	24	24	24	24	4	16	
	07/04/2009	23:17													
	08/04/2009	04:20													
80	08/04/2009	06:03	023 05.54 S	008 51.03 W	5243	5235	9	5333	24	24	24	24	17	17	
	08/04/200	08:22													
	08/04/2008	13:20													
81	08/04/2009	14:51	023 23.29 S	008 08.08 W	4457	4450	9	4526	24	24	24	24	16	16	
	08/04/2009	16:51													
	08/04/2009	21:47													
82	08/04/200	23:34	023 41.01 S	007 25.05 W	4902	4890	9	4979	24	23	23	23	16	16	
	09/04/2009	01:46													
	09/04/2009	07:08													
83	09/04/2009	08:46	023 59.88 S	006 42.11 W	4882	4875	7	4963	24	24	23	24	16	16	
	09/04/2009	10:58													
84	09/04/2009	16:09													
	09/04/2009	17:39	023 59.99 S	005 53.55 W	4614	4607	8	4688	23	23	23	23	16	16	

	09/04/2009	19:39													
	10/04/2009	00:54													
85	10/04/2009	02:37	023 59.98 S	005 05.07 W	5234	5226	8	5325	24	24	24	24	17	17	
	10/04/2009	04:54													
	10/04/2009	10:39													
86	10/04/2009	12:25	023 59.95 S	004 11.78 W	5151	5138	12	5234	23	24	24	24	16	15	
	10/04/2009	14:37													
	10/04/2009	21:11													
87	10/04/2009	22:48	024 00.00 S	003 18.48 W	4840	4828	11	4915	23	24	24	24	16	14	
	11/04/2009	01:00													
	11/04/2009	07:01													
88	11/04/2009	08:44	023 59.83 S	002 25.27 W	5032	5023	9	5116	23	24	24	24	16	15	
	11/04/2009	10:54													
	11/04/2009	17:04													
89	11/04/2009	19:11	024 00.08 S	001 32.14 W	5283	5274	6	5375	24	23	23	23	16	15	Deck unit restarted near bottom
	11/04/2009	21:29													
	12/04/2009	03:14													
90	12/04/2009	04:59	024 00.00 S	000 38.58 W	5476	5469	8	5576	24	24	24	24	17	17	
	12/04/2009	07:13													
	12/04/2009	13:36													
91	12/04/2009	15:08	023 59.98 S	000 14.73 E	4463	4452	10	4528	24	23	24	24	16	16	
	12/04/2009	17:03													
	12/04/2009	22:37													
92	13/04/2009	00:18	023 59.97 S	001 07.97 E	5201	5189	11	5287	24	24	24	24	17	17	
	13/04/2009	02:32													
	13/04/2009	08:20													
93	13/04/2009	10:05	023 59.98 S	002 01.26 E	5288	5276	12	5376	24	19	22	22	17	17	Primary cond. sensor failed
	13/04/2009	12:17													
	13/04/2009	18:08													
94	13/04/2009	19:51	023 59.96 S	002 54.60 E	5167	5157	10	5253	24	23	24	24	17	17	
	13/04/2009	22:07													
	14/04/2009	03:36													
95	14/04/2009	05:10	023 59.99 S	003 48.02 E	5002	4992	8	5084	24	24	24	24	16	16	
	14/04/2009	07:16													
	14/04/2009	09:04													
96	14/04/2009	10:25	023 59.93 S	003 59.88 E	4182	4173	10	4241	22	22	22	22	17	16	
	14/04/2009	12:14													
	14/04/2009	15:21													
97	14/04/2009	16:31	023 59.98 S	004 28.05 E	3643	3634	10	3689	24	23	24	24	14	13	
	14/04/2009	18:08													
	14/04/2009	20:25													
98	14/04/2009	21:30	024 00.00 S	004 47.05 E	3005	2998	9	3039	23	23	23	23	13	13	
	14/04/2009	23:03													
	15/04/2009	01:18													
99	15/04/2009	02:08	023 59.92 S	005 05.87 E	2459	2452	9	2483	21	23	23	23	12	11	
	15/04/2009	03:22													
	15/04/2009	05:45													
100	15/04/2009	06:29	023 59.73 S	005 25.83 E	1978	1971	9	1993	18	19	20	20	11	11	
	15/04/2009	07:30													
	15/04/2009	11:24													
101	15/04/2009	12:02	023 59.99 S	006 02.73 E	1872	1865	9	1886	20	24	24	24	11	11	
	15/04/2009	13:00													

	15/04/2009	16:09													
102	15/04/2009	17:01	024 00.00 S	006 30.85 E	2375	2368	6	2397	20	24	24	24	13	12	
	15/04/2009	18:10													
	15/04/2009	21:39													
103	15/04/2009	22:43	023 59.99 S	007 02.27 E	2948	2943	6	2983	22	24	24	24	12	12	
	16/04/2009	00:14													
	16/04/2009	01:54													
104	16/04/2009	03:08	024 00.03 S	007 14.27 E	3495	3486	9	3537	24	22	22	22	2	14	
	16/04/2009	04:45													
	16/04/2009	06:02													
105	16/04/2009	07:30	024 00.09 S	007 21.75 E	4248	4240	9	4310	24	24	24	24	15	15	
	16/04/2009	09:24													
	16/04/2009	14:22													
106	16/04/2009	15:57	024 00.01 S	008 08.98 E	4672	4664	9	4746	24	23	23	23	16	16	
	16/04/2009	17:55													
	16/04/2009	23:14													
107	17/04/2009	00:45	024 00.01 S	008 58.12 E	4621	4615	8	4695	23	24	24	24	2	15	
	17/04/2009	02:46													
	17/04/2009	08:03													
108	17/04/2009	09:28	023 59.94 S	009 42.82 E	4305	4297	10	4368	23	23	23	23	16	16	
	17/04/2009	11:25													
	17/04/2009	18:52													
109	17/04/2009	20:13	024 00.10 S	010 29.85 E	4038	4031	9	4096	23	24	24	24	14	14	
	17/04/2009	22:07													
	18/04/2009	03:00													
110	18/04/2009	04:16	023 59.99 S	011 17.06 E	3544	3536	8	3588	24	24	24	24	13	14	
	18/04/2009	05:57													
	18/04/2009	10:49													
111	18/04/2009	11:45	024 00.02 S	012 03.91 E	2806	2797	9	2834	21	23	23	23	12	11	
	18/04/2009	13:07													
	18/04/2009	16:06													
112	18/04/2009	16:51	023 59.97 S	012 29.85 E	2237	2229	8	2256	18	18	20	24	11	11	
	18/04/2009	17:58													
	18/04/2009	19:13													
113	18/04/2009	19:54	023 57.58 S	012 38.99 E	1912	1907	9	1928	18	18	20	24	10	10	
	18/04/2009	21:02													
	18/04/2009	22:22													
114	18/04/2009	23:00	023 55.37 S	012 47.42 E	1518	1511	6	1526	16	16	16	16	9	10	
	18/04/2009	23:55													
	19/04/2009	01:46													
115	19/04/2009	02:12	023 52.49 S	012 58.33 E	1000	995	7	1004	14	14	17	17	8	8	
	19/04/2009	02:54													
	19/04/2009	04:42													
116	19/04/2009	04:59	023 49.54 S	013 08.87 E	498	492	8	496	10	10	10	10	6	7	
	19/04/2009	05:28													
	19/04/2009	07:04													
117	19/04/2009	07:14	023 46.69 S	013 19.72 E	302	293	9	295	12	8	8	8	5	5	
	19/04/2009	07:28													
118	19/04/2009	10:06													End of main section
	19/04/2009	10:15	023 40.64 S	013 42.78 E	202	193	9	195	7	7	7	7	4	4	
	19/04/2009	10:31													