National Oceanography Centre, Southampton

Cruise Report No. 39

RRS *James Cook* Cruise JC031

03 FEB-03 MAR 2009

Hydrographic sections of Drake Passage

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ABSTRACT

Repeat hydrographic sections (WOCE sections SR1 AND SR1b) were occupied in Drake Passage during February - March 2009 aboard the RRS *James Cook* (JC031). 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.

A total of 84 CTD/LADCP stations were sampled across Drake Passage. 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 phytoplankton.

Some bottle and underway samples were analysed for Ar/O ratios. In addition, salinity samples were collected and analysed from the ships' underway system to calibrate and complement 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 ships' VMADCP (vessel mounted acoustic doppler current profiler) mounted on the hull. Meteorological variables were monitored using the onboard surface water and meteorological sampling system (SURFMET).

This report describes the methods used to acquire and process the data on board the ship during cruise JC031.

KEYWORDS

ADCP, Antarctic Circumpolar Current (ACC), biogeochemical budgets, carbon budgets, Carbon Tetrachloride, Carbon, CFC, *James Cook*, Circulation, climatic changes, cruise JC031 2009, CTD, Deep Western Boundary Current, Drake Passage, hydrographic section, Lowered ADCP, Meridional Overturning Circulation, nutrients, oxygen, shipboard ADCP, Southern Ocean, Sulphur Hexafluoride, Vessel Mounted ADCP.

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Contents

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NOCS = National Oceanography Centre Southampton
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Ship's Personnel

Name	Position
Antonio Gatti	Master
Philip Gauld	Chief Officer
John Mitchell	2nd Officer
Nicholas Norrish	3rd Officer
Christopher Carey	Chief Engineer
Richard Coe	2nd Engineer
Christopher Uttley	3rd Engineer
Philip Parker	ETO
Thomas Levy	Deck Engineer
Paul Lucas	Purser
Ruth McCabe	Doctor
Glenn (Tiny) Pook	CPOD
Mark Squibb	CPOS
Michael Minnock	CPOS
Andrew Maclean	POD
Steven Duncan	SG1A
David Price	SG1A
Lee Stephens	SG1A
Emlyn Gordon	ERPO
Peter Lynch	Head Chef
Wilmot (Tulip) Isby	Chef
Jacqueline Paterson	Stewardess
Amy Whalen	Catering Assistant

Background and Cruise Summary

The aim of JC031 was to occupy repeats of hydrographic sections in Drake Passage. This was funded by Oceans 2025 - Theme 1: work package 1.3, to establish regional budgets of heat, freshwater and carbon. The sections studied are as follows: Section SR1 (also known as A21), which is located in Drake Passage between the Southern tip of South America and the West Antarctic Peninsula; this has been occupied twice before, once by the *METEOR* in 1990, and again in 1999 by the RRS *James Clark Ross*. Section SR1b is located further to the east, and has been occupied every year by NOCS, except two, since 1993 (chemistry had only been measured once before). In addition to the previous section of SR1b, extra stations were sampled on the northern side of the Burdwood Bank, located south of the Falkland Islands. The data collected during JC031 comprised physical, chemical and biological measurements. There were six main scientific teams, physics, nutrients and oxygen, carbon, CFC's and transient tracers, and biology (phytoplankton).

Not only will gathering this information contribute to the current knowledge of the physical, chemical and biological properties in this region, but will also allow comparisons to be drawn with previous cruise data so that the change in water properties and transport through Drake Passage from west to east can be estimated.

In total 84 CTD (conductivity-temperature-depth) stations were occupied (see Figure 1). A 24-bottle rosette was used to take water samples at these CTD stations. Also mounted on the frame were an LADCP (lowered acoustic doppler current profiler), fluorometer, transmissometer, and a dissolved oxygen sensor. Data were collected by the VMADCP (vehicle mounted ADCP), and thermosalinograph (TSG), while the ship was underway, as well as meteorological measurements.

Itinerary and Cruise Track

Depart Punta Arenas, Chile, 3rd Feb 2009 – arrive Montevideo, Uruguay, 3rd March 2009.

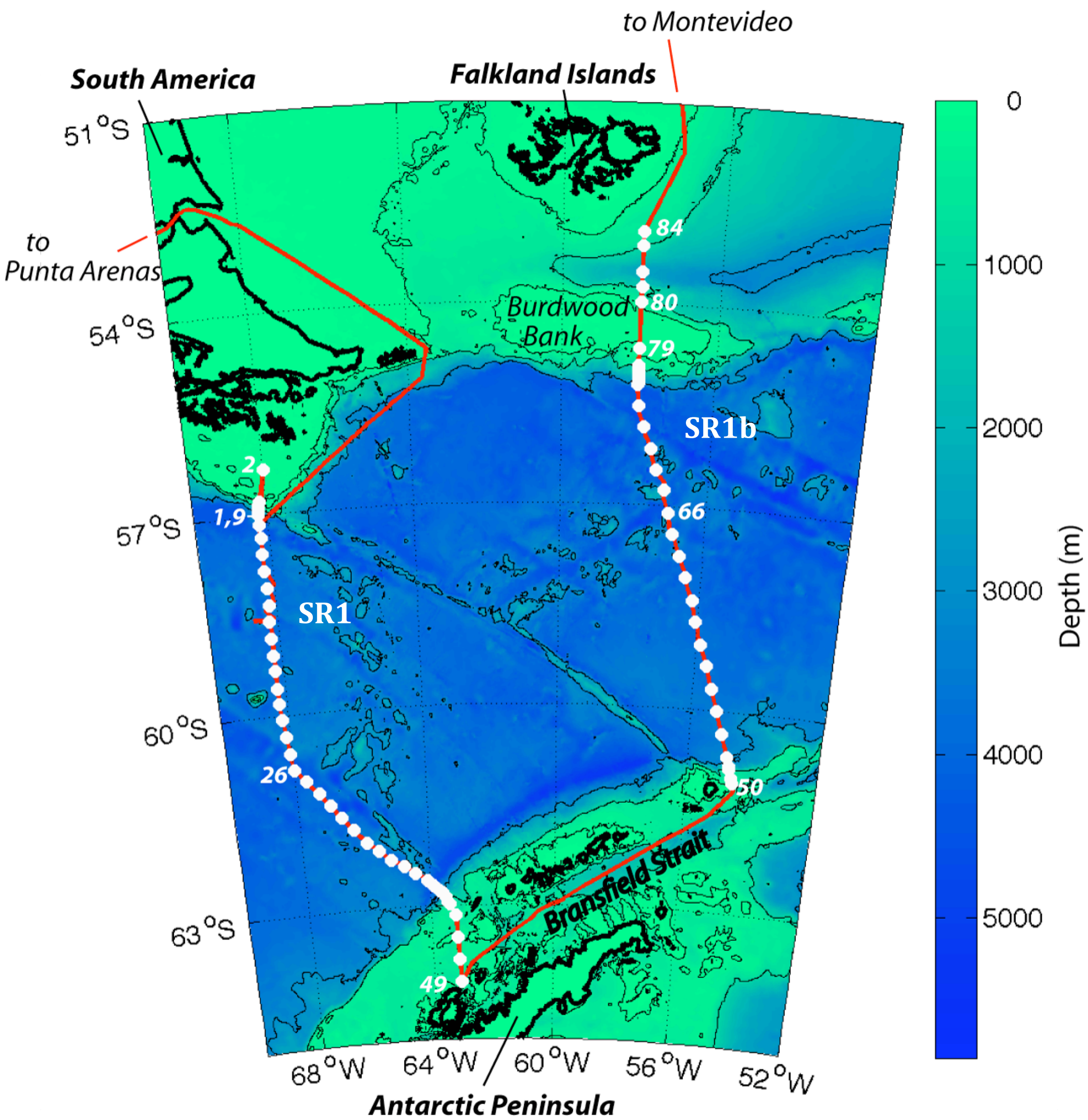

Figure 1: JC031 cruise track (red) and CTD station positions (white dots). Some CTD station numbers are marked. Bathymetry is shaded and contoured at 200m, 1000m and 3000m.

Cruise Diary

The majority of the party left the UK on the 28th Jan, arriving in Punta Arenas, Chile on the evening 29th January. The RRS *James Cook* arrived mid-afternoon on 30th January. We mobilised the cruise between 31st January and 2nd February, joining the ship on the 2nd February. Much of the equipment that we were to use was already set up as it had been used on the previous cruise, JC030, PSO Sheldon Bacon.

3rd February (J-Day 034) 1st Day of cruise
Shore leave ended at 8am on 3rd February and we left the berth at 9am local time (1200 UTC), exactly on time. We sailed to the east through the Straits of Magellan and dropped the pilot off at 2000 UTC. The sea remained calm all day and as well as enjoying the scenery in the Straits we were accompanied by dolphins, penguins, petrels and albatrosses.

4th February (J-Day 035)
Weather remains calm as we continue towards the test station – in the morning we filled some Niskin bottles on the rosette so that those who had not sampled before could practice taking samples. The ship stopped at 1200 UTC for approximately 30 minutes to make some adjustments to the starboard lifeboat and parallelogram.

5th February (J-Day 036)
We are now in a gentle swell, and the bright morning has been replaced by mist and rain. Test station successfully occupied at 1600 UTC. Drop keels put down at Station 1.

6th February (J-Day 037)
Bright sunny day. Stations were steadily occupied as we moved down a steep continental shelf. A problem with the winch hydraulics halted work after Station 5 for approx 8 hours.

7th February (J-Day 038)
More winch problem overnight delayed CTD work. Yesterday a leaking pipe that carried winch hydraulic fluid was replaced with a hose with a lower pressure rating. The reduced flow of oil caused the outlet to reach higher temperatures than the engineers were comfortable with. This part of the system was only required during deployment and recovery and so the problem was mitigated by turning the system off other than when required.

8th and 9th February (J-Day 039 and 040)
At 2.45 am (0545UTC, 8th) the package was parted from the wire and lost. Much of the rest of the day was spent rebuilding a package on the spare frame. Damage to the wire sheaths was repaired and the wire drum switched. The spooling on the new drum was tested to a depth of 500m using chains as a weight. Finally the wire was terminated and the termination load tested on the deck at 9.30pm (0030UTC, 9th). Station 13, a test for the new package went into the water at 11.17pm, (0217UTC, 9th). Station 14 was delayed due to large swell and the prospect of the winds and sea state further increasing during a CTD cast. Also during cast 13 the heating of the winch outlet became a concern again and the engineers worked to reduce the temperature of the outlet by introducing a positive flow in the system. Stations 14 and 15 were completed during the afternoon. Progress remained somewhat slowed by spooling issues, particularly at the ends of the wire drum.

10th February (J-Day 041)
Station 16 was recovered at 04:26 UTC after which work was stopped because of the large swell. We steamed to Station 17 but the sea state was still considered too bad to work. Wind was steady at 15 knots. Work began again at 2005UTC when the conditions improved sufficiently. Yueng's birthday party provided light relief.

11th February (J-Day 042)
Work continued steadily.

12th February (J-Day 043)
Calm and fair weather aided the progression of steady work. It became necessary to disconnect the wire from the package and take turns out of it after the final few casts of the day.

13th February (J-Day 044)
Weather is deteriorating – increasing winds from the east - and the sea state grew in the morning and then began to calm in the second half of the day. We continue to work steadily – approximately ten turns were taken out of the wire after Station 27 and more after Station 28.

14th February (J-Day 045)
Hydraulic oil leak in the winch room was fixed before Station 32 resulting in a 40 minute delay. We continue to take turns out of the wire after each cast.

15th February (J-Day 046)
Station 34 was deployed at 0007 – problems with comms to CTD were noted near the bottom of the downcast. Two bottles were fired and there was a complete loss of comms after the firing of the second bottle at 0138. CTD was recovered at 0306 and work began with re-terminating the CTD wire. Following the re-termination and load testing there was still an electrical failure. The electrical connection between the CTD deck unit and wire was investigated. The inboard termination was examined and found to be at fault - a corroded wire was replaced. Station 35 was deployed at 1707 and communications failed at 936m - the electrical termination had flooded. The package was recovered and the electrical termination re-made. The package was ready for deployment again at approximately 2030. Cast was aborted due to wire parting in winch room just after taking the load on deployment and the CTD frame fell on the deck. ADCP landed on a cleat and the transducer beam 1 was damaged – the LADCP passed all beam tests on deck but nevertheless the damaged unit was replaced. The electrical and mechanical terminations were remade and load tested and Station 36 (in same position as Stations 34 and 35) was deployed at 0244 on 16th February.

16th February (J-Day 047)
Work steadily progressed.

17th February (J-Day 048)
High winds and high sea state stopped work from 0900 for 11 hours. Morning began with covering of snow on deck – first view of the islands on the Antarctic Peninsula – seals and some whales breaching in the distance.

18th February (J-Day 049)
Woke to a glorious morning – the islands of the Antarctic Peninsula are shrouded in mist. CTD casts were visited by chinstrap penguins and seals. Finished the SR1 section at 19:46. The drop keels were brought up again at Station 49 (end of SR1 section) to help with passage speed along Bransfield Strait.

19th February (J-Day 050)
Spent the majority of the day steaming along the Bransfield Strait – played spot the shape in the iceberg also the odd seal and whale visit. We arrived at the SR1b section and began work moving northwards. Drop keels put down again at Station 50 for beginning of SR1b section.

20th February (J-Day 051)
We worked steadily along the section in very calm seas and sunshine and were accompanied by whales, seals and penguins.

21st February (J-Day 051)
We worked steadily throughout the day. It was noted that we were experiencing very high surface velocities.

22nd February (J-Day 052)
Work continued in relatively calm seas and sunshine, our progress was followed closely by wandering albatrosses. We reached the halfway point of the SR1b section at the end of Station 64.

23rd February (J-Day 053)
Work continued steadily, Station 67 was occupied on the ridge and we encountered 3kt currents associated with the polar front. Drop keels brought up and down while starting Station 68 at 2223 and 2230 UTC, because Tiny heard banging between 6 and 7.30pm ship's time. The source of the banging was found in the engine room.

24th February (J-Day 054)
The morning saw a beautiful sunrise, light rain and a growing swell. Station 70 was the deepest of the expedition at 4765 m – the wire was washed on the way up.

25th February (J-Day 055)
Today it was beautifully sunny and we made good progress occupying stations up the shelf and onto Burdwood Bank.

26th February (J-Day 056)
The final CTD station was completed at 00:46 on 27th February. The drop keels were brought up and we began the steam to Montevideo.

Elaine McDonagh, PSO

Table 1: Station locations and sampling regime. Bottle parameters are listed in sampling order.

Station No.	time UTC (ddd hhmm) (bottom of cast)	Latitude deg min (bottom of cast)	Longitude deg min (bottom of cast)	Water Depth (m) (from LADCP)	Bottle Sampling						
					CFC's & SF_6	O_2	O_2/Ar	Carbon	Nuts	Salt	Bio
1	036 1623	-57 7.80	-68 15.00	4392	x	x	x	x	x	x	
2	037 0114	-56 19.80	-67 59.40	99	x	x	x	x	x	x	x
3	037 0534	-56 48.00	-68 11.40	311	x	x		x	x	x	x
4	037 0732	-56 51.00	-68 12.60	527	x	x		x	x	x	x
5	037 1016	-56 52.80	-68 13.80	1398	x	x		x	x	x	x
6	037 1351	-56 53.40	-68 14.40	1924	x	x		x	x	x	x
7	037 0040	-56 54.70	-68 14.51	2603	x	x	x	x	x	x	x
8	038 0544	-56 55.20	-68 14.40	2834	x	x		x	x	x	x
9	038 1021	-56 58.80	-68 15.00	3614	x	x	x	x	x	x	x
10	038 1544	-57 7.80	-68 15.00	4393	x	x	x		x	x	x
11	038 2124	-57 19.84	-68 14.2	4376	x	x		x	x	x	x
12	039 0300	-57 34.80	-68 15.00	3749*							
13	040 0226	-57 49.83	-68 14.33	test cast to ~100 m							
14	040 1041	-57 49.94	-68 13.93	3736	x	x	x	x	x	x	x
15	040 1915	-58 5.55	-68 13.12	3709		x	x	x	x	x	x
16	041 0154	-58 20.32	-68 12.89	3606	x	x	x	x	x	x	x
17	041 2156	-58 34.80	-68 15.05	3921	x	x		x	x	x	x
18	042 0438	-58 50.48	-68 15.75	3841	x	x		x	x	x	x
19	042 1101	-59 5.45	-68 14.72	3485		x		x	x	x	x
20	042 1723	-59 19.83	-68 14.95	3655	x	x		x	x	x	x
21	042 2313	-59 35.39	-68 14.25	3667		x			x	x	x
22	043 0440	-59 49.19	-68 14.38	3657	x	x		x	x	x	x
23	043 0944	-60 4.22	-68 11.36	3502		x			x	x	x
24	043 1516	-60 19.20	-68 7.20	3782	x	x	x	x	x	x	x
25	043 2100	-60 34.80	-68 3.61	4007		x			x	x	x
26	044 0249	-60 49.73	-67 59.41	3956	x	x		x	x	x	x
27	044 0835	-61 1.18	-67 39.89	4106		x			x	x	x
28	044 1458	-61 12.59	-67 18.43	3828	x	x		x	x	x	x
29	044 2124	-61 24.58	-66 59.69	4063		x			x	x	x
30	045 0328	-61 36.00	-66 40.19	3970	x	x		x	x	x	x
31	045 0846	-61 48.00	-66 19.21	3706		x			x	x	x
32	045 1420	-61 60.00	-65 57.01	3561	x	x		x	x	x	x
33	045 1953	-62 8.40	-65 34.80	3609		x		x	x	x	x
34	046 0132	-62 16.33	65 11.52	4035		x			x	x	x
35	046 1707	n/a	n/a	cast aborted at 936 m							
36	046 0415	-62 16.80	-65 12.60	4045		x			x	x	x
37	047 0917	-62 23.33	-64 49.37	3839		x		x	x	x	x
38	047 1420	-62 30.00	-64 27.60	3751	x	x		x	x	x	x
39	047 1939	-62 36.5	-64 4.79	3479	x	x		x	x	x	x
40	047 0031	-62 41.40	-63 54.00	4473	x	x		x	x	x	x
41	048 0543	-62 46.81	-63 42.00	3289	x	x		x	x	x	x
42	048 2134	-62 48.60	-63 37.20	2654		x			x	x	x

43	049 0050	-62 51.60	-63 31.21	1743	x	x		x	x	x	x
44	049 0341	-62 56.40	-63 27.01	1011		x			x	x	x
45	049 0550	-62 58.80	-63 23.41	507	x	x		x	x	x	x
46	049 0819	-63 9.00	-63 12.01	469		x		x	x	x	x
47	049 1151	-63 28.80	-63 10.20	725	x	x		x	x	x	x
48	049 1524	-63 48.61	-63 7.20	452		x		x	x	x	x
49	049 1903	-64 8.40	-63 4.80	599	x	x		x	x	x	x
50	051 0222	-61 2.93	-54 35.33	378	x	x		x	x	x	x
51	051 0415	-60 58.85	-54 37.91	581		x		x	x	x	x
52	051 0644	-60 51.01	-54 42.67	973	x	x		x	x	x	x
53	051 0901	-60 49.99	-54 43.14	1630		x			x	x	x
54	051 1200	-60 47.97	-54 44.11	2697	x	x		x	x	x	x
55	051 1608	-60 40.20	-54 48.51	3105		x			x	x	x
56	051 2149	-60 20.00	-55 1.88	3435	x	x	x	x	x	x	x
57	052 0334	-60 0.00	-55 14.30	3497		x			x	x	x
58	052 0919	-59 40.27	-55 27.10	3674	x	x	x	x	x	x	x
59	052 1506	-59 20.44	-55 38.84	3758		x			x	x	x
60	052 2134	-59 1.55	-55 51.83	3750	x	x	x	x	x	x	x
61	053 0408	-58 41.48	-56 3.38	3746		x			x	x	x
62	053 1021	-58 22.74	-56 12.65	3820	x	x	x	x	x	x	x
63	053 1701	-58 3.00	-56 25.84	3941		x		x	x	x	x
64	053 2301	-57 44.02	-56 38.85	3480	x	x	x	x	x	x	x
65	054 0501	-57 24.62	-56 52.94	3646		x		x	x	x	x
66	054 1057	-57 6.01	-57 2.13	4193	x	x	x	x	x	x	x
67	054 1730	-56 45.94	-57 9.70	3212	x	x	x	x	x	x	x
68	054 0018	-56 28.12	-57 25.48	3885	x	x		x	x	x	x
69	055 0644	-56 9.15	-57 35.94	3497		x			x	x	x
70	055 1327	-55 50.06	-57 48.41	4754	x	x	x	x	x	x	x
71	055 2058	-55 31.01	-57 57.97	4207	x	x		x	x	x	x
72	056 0307	-55 12.86	-58 0.01	3919	x	x	x	x	x	x	x
73	056 0744	-55 10.16	-57 59.67	3101		x			x	x	x
74	056 1152	-55 7.26	-57 59.94	2801	x	x		x	x	x	x
75	056 1557	-55 4.20	-58 0.08	2317		x			x	x	x
76	056 1940	-55 0.39	-57 59.73	1649	x	x	x	x	x	x	x
77	056 2220	-54 58.6	-57 59.92	990		x			x	x	x
78	057 0038	-54 55.34	-58 0.00	741	x	x		x	x	x	x
79	057 0351	-54 40.00	-57 60.00	165		x	x	x	x	x	x
80	057 0929	-53 58.89	-58 0.00	503	x	x		x	x	x	x
81	057 1219	-53 45.16	-58 0.01	1036		x			x	x	x
82	057 1606	-53 31.20	-58 0.01	2419	x	x		x	x	x	x
83	057 2124	-53 7.99	-57 59.78	970		x		x	x	x	
84	057 0017	-52 55.74	-58 0.00	498		x			x	x	

* from CTD max pressure (converted to depth) plus altimeter height of bottom.

Comments:

Stn 12 – the package ran into the blocks and the CTD was lost. CTD data were collected but there were no water samples or LADCP data from this station.

Stn 13 – test cast with new package – max wire out ~ 100m.

Stn 34 – cast aborted due to loss of communications at the start of the upcast.

Stn 35 – cast aborted when electrical termination flooded at 936m on the downcast.

1. CTD & LADCP Systems Operation

1.1 CTD Operations

A total of 84 CTD casts were completed during the cruise. All casts used a 24-way stainless steel frame. There were no major operational issues with the CTD suite during the cruise. However, the CTD was pulled into the hydroboom block during recovery on cast CTD012 resulting in the total loss of the CTD package. The spare package was built up and subsequently used with no problems. RDI WH300 Titanium LADCP (s/n 10629) was lost with the CTD package on Station 12 hence data was not recovered for this cast. RDI WH300 Aluminium LADCP (s/n 4275) was damaged when the CTD wire parted during deployment on the repeat of Station 35. This unit passed all deck tests and remained fully functional. It is available as a spare but may be at increased risk of flooding due to the damage to the transducer face.

1.2 24-way Stainless Steel CTD Frame

The stainless steel frame configuration was as follows:

- Sea-Bird 9/11 *plus* CTD system with fin-mounted secondary sensors
- Sea-Bird SBE-32 24 way rosette pylon on NMF 24 way frame
- 24 by 20L custom OTE external spring water samplers for casts 1-12
- 20 by 10L and 4 by 20L custom OTE external spring water samplers for casts 13 onwards. The 20L bottles were fitted in rosette positions 21-24
- Sea-Bird SBE-43 oxygen Sensor
- Chelsea MKIII Aquatracka fluorometer
- Chelsea MKII Alphatracka 25cm path transmissometer
- Wetlabs BBRTD 660nm backscatter sensor
- PML 2PI PAR sensors (UWIRR and DWIRR) only used for casts <600m in daylight hours
- NMF LADCP pressure-case battery pack
- NMF BB150 pressure-case battery pack (Not used on second CTD suite)
- RD Instruments Workhorse 300 kHz lowered ADCP (Downward-looking configuration)
- Benthos 200 kHz altimeter
- NMF 10 kHz pinger (s/n B5) (Not used on second CTD suite)

For the 10L bottles, the pressure sensor was located 34 cm below the bottom of the water samplers, and 121 cm below the top of the water samplers. The 10L Niskins are 87 cm in height between end-cap seals. For the 20L bottles, the pressure sensor was located 20 cm below the bottom of the water samplers, and 131 cm below the top of the water samplers. The 20L Niskins are 111 cm in height between end-cap seals.

1.3 24-way Stainless Steel CTD Frame Instrument Configuration: Casts 1-12

The Sea-Bird CTD configuration for the stainless steel frame was as follows:

- SBE 9 *plus* Underwater unit s/n 09P-24680-0636
- Frequency 0—SBE 3P Temperature Sensor s/n 03P-4301 (primary)
- Frequency 1—SBE 4C Conductivity Sensor s/n 04C-3153(T) (primary)

• Frequency 2—Digiquartz Temperature Compensated Pressure Sensor s/n 83008
• Frequency 3—SBE 3P Temperature Sensor s/n 03P-4490 (secondary – fin mounted)
• Frequency 4—SBE 4C Conductivity Sensor s/n 04C-3160(T) (secondary – fin mounted)
• SBE 5T Submersible Pump s/n 05T-4166 (primary)
• SBE 5T Submersible Pump s/n 05T-2793 (secondary – fin mounted)
• SBE 32 Carousel 24 Position Pylon s/n 32-45661-0621
• SBE 11 *plus* Deck Unit s/n 11P-34173-0676 (CTD1 master)
• SBE 11 *plus* Deck Unit s/n 11P-24680-0589 (CTD2 slave)

The auxiliary A/D output channels were configured as below (due to incorrectly labelled Y-cables V2/3 and V6/7 usages are transposed from historically used channels):

• V0 --- SBE 43 Oxygen s/n 43-1196 (primary duct - 9+ mounted)
• V1 --- Unused – obsolete oxygen temperature
• V2 --- Chelsea MKIII Aquatracka Fluorometer s/n 088108
• V3 --- Benthos PSA-916T Altimeter s/n 1040
• V4 --- 2PI PAR (DWIRR) s/n PML10 – only fitted for casts <600m in daylight hours
• V5 --- 2PI PAR (UWIRR) s/n PML9 – only fitted for casts <600m in daylight hours
• V6 --- Wetlabs BBRTD backscatter s/n 115R
• V7 --- Chelsea MKII Alphatracka 25 cm path Transmissometer s/n 161045

The additional self-logging instruments were configured as follows:

• RDI Workhorse 300 kHz Lowered ADCP (down-looking master configuration) s/n 10629

The LADCP was powered by the NMF battery pack WH004. Battery pack BB150 s/n 02 was also fitted to the CTD frame available as a spare, but was not used.

All this equipment with the exception of the PAR sensors was lost when the CTD was pulled into the block on recovery of cast 12. All 24 20L OTE water samplers were also lost.

1.3.1 Configuration

Date: 02/04/2009

Instrument configuration file: C:\Program Files\Sea-Bird\SeasaveV7\JC031\Data\0636.CON

Configuration report for SBE 911plus/917plus CTD

Frequency channels suppressed: 0
Voltage words suppressed: 0
Computer interface: RS-232C
Scans to average: 1
NMEA position data added: Yes
NMEA depth data added: No
NMEA time added: No

NMEA device connected to: deck unit
Surface PAR voltage added: No
Scan time added: Yes

1) Frequency 0, Temperature

Serial number: 03P-4301
Calibrated on: 4 April 2008
G: 4.34599956e-003
H: 6.45265322e-004
I: 2.22833046e-005
J: 1.79962920e-006
F0: 1000.000
Slope: 1.00000000
Offset: 0.0000

2) Frequency 1, Conductivity

Serial number: 04C-3153
Calibrated on: 22 April 2008
G: -1.03208240e+001
H: 1.32137827e+000
I: -2.08417307e-004
J: 8.72309934e-005
CTcor: 3.2500e-006
CPcor: -9.57000000e-008
Slope: 1.00000000
Offset: 0.00000

3) Frequency 2, Pressure, Digiquartz with TC

Serial number: 83008
Calibrated on: 10 Sep 08
C1: -4.093335e+004
C2: -1.005887e-001
C3: 1.104120e-002
D1: 3.017600e-002
D2: 0.000000e+000
T1: 2.992572e+001
T2: -3.202788e-004
T3: 3.724670e-006
T4: 2.870340e-009
T5: 0.000000e+000
Slope: 0.99995000
Offset: -1.45830
AD590M: 1.285350e-002
AD590B: -8.337660e+000

4) Frequency 3, Temperature, 2

Serial number: 03P-4490
Calibrated on: 4 April 2008
G: 4.40563001e-003
H: 6.48330736e-004
I: 2.28666065e-005
J: 1.98942593e-006
F0: 1000.000
Slope: 1.00000000
Offset: 0.0000

5) Frequency 4, Conductivity, 2

Serial number: 04C-3160
Calibrated on: 22 April 2008
G: -1.04330266e+001
H: 1.43424090e+000
I: -1.72951215e-003
J: 2.05098967e-004
CTcor: 3.2500e-006
CPcor: -9.57000000e-008
Slope: 1.00000000
Offset: 0.00000

6) A/D voltage 0, Oxygen, SBE 43

Serial number: 43-1196
Calibrated on: 3 October 2008
Equation: Murphy-Larson
Coefficients for Owens-Millard:
Soc: 3.5000e-001
Boc: 0.0000
Offset: -0.6480
Tcor: 0.0003
Pcor: 1.35e-004
Tau: 0.0
Coefficients for Murphy-Larson:
Soc: 3.69000e-001
Offset: -5.17200e-001
A: -6.38720e-004
B: 1.72800e-004
C: -3.33020e-006
E: 3.60000e-002
Tau: 1.40000e+000

7) A/D voltage 1, Free

8) A/D voltage 2, Fluorometer, Chelsea Aqua 3

Serial number: 088108
Calibrated on: 9 January 2008
VB: 0.174500
V1: 2.092100
Vacetone: 0.198200
Scale factor: 1.000000
Slope: 1.000000
Offset: 0.000000

9) A/D voltage 3, Altimeter

Serial number: 1040
Calibrated on: March 2003
Scale factor: 15.000
Offset: 0.000

10) A/D voltage 4, PAR/Irradiance, Biospherical/Licor

Serial number: PML10
Calibrated on: 14 April 2008
M: 0.49292500
B: 1.01139400
Calibration constant: 100000000000.00000000
Multiplier: 1.00000000
Offset: 0.00000000

11) A/D voltage 5, PAR/Irradiance, Biospherical/Licor, 2

Serial number: PML09
Calibrated on: 21 June 2008
M: 0.49602600
B: 1.03304500
Calibration constant: 100000000000.00000000
Multiplier: 1.00000000
Offset: 0.00000000

12) A/D voltage 6, User Polynomial

Serial number: BBRTD-115R
Calibrated on: 13 May 2008
Sensor name: Wetlabs backscatter
A0: -0.00034810
A1: 0.00295000
A2: 0.00000000
A3: 0.00000000

13) A/D voltage 7, Transmissometer, Chelsea/Seatech/Wetlab CStar

Serial number: 161045
Calibrated on: 8 Sept 2005
M: 24.0279
B: -0.4806
Path length: 0.250

1.4 24-way Stainless Steel CTD Frame Instrument Configuration: Casts 13-84

The Sea-Bird CTD configuration for the spare stainless steel frame was as follows:

• SBE 9 *plus* Underwater unit s/n 09P-24680-0637(T)
• Frequency 0—SBE 3P Temperature Sensor s/n 03P-4592(T) (primary)
• Frequency 1—SBE 4C Conductivity Sensor s/n 04C-3272(T) (primary)
• Frequency 2—Digiquartz Temperature Compensated Pressure Sensor s/n 79501
• Frequency 3—SBE 3P Temperature Sensor s/n 03P-4782 (secondary – fin mounted)
• Frequency 4—SBE 4C Conductivity Sensor s/n 04C-3258 (secondary – fin mounted)
• SBE 5T Submersible Pump s/n 05T-3002 (primary)
• SBE 5T Submersible Pump s/n 05T-4513 (secondary – fin mounted)
• SBE 32 Carousel 24 Position Pylon s/n 32-19817-0243
• SBE 11 *plus* Deck Unit s/n 11P-34173-0676 (CTD1 master)
• SBE 11 *plus* Deck Unit s/n 11P-24680-0589 (CTD2 slave)

The auxiliary A/D output channels were configured as below (due to incorrectly labelled Y-cables V2/3 and V6/7 usages are transposed from historically used channels):

• V0 --- SBE 43 Oxygen s/n 43-0619 (primary duct - 9+ mounted)
• V1 --- Unused – obsolete oxygen temperature
• V2 --- Chelsea MKIII Aquatracka Fluorometer s/n 088244
• V3 --- Benthos PSA-916T Altimeter s/n 41302
• V4 --- 2PI PAR (DWIRR) s/n PML10 – only fitted for casts <600m in daylight hours
• V5 --- 2PI PAR (UWIRR) s/n PML9 – only fitted for casts <600m in daylight hours
• V6 --- Wetlabs BBRTD backscatter s/n 182
• V7 --- Chelsea MKII Alphatracka 25cm path Transmissometer s/n 07-6075-001

The additional self-logging instruments were configured as follows:

• RDI Workhorse 300 kHz Lowered ADCP (down-looking master configuration) s/n 4275

For casts 13 – 35 (TX1 face damaged when CTD wire parted on deployment)

• RDI Workhorse 300 kHz Lowered ADCP (down-looking master configuration) s/n 10607

For casts CTD036 – CTD084

The LADCP was powered by the NMF battery pack WH002.

1.4.1 Configuration

Date: 02/08/2009

Instrument configuration file: C:\Program Files\Sea-Bird\SeasaveV7\JC031\Data\0637.CON

Configuration report for SBE 911plus/917plus CTD

Frequency channels suppressed: 0
Voltage words suppressed: 0
Computer interface: RS-232C
Scans to average: 1
NMEA position data added: Yes
NMEA depth data added: No
NMEA time added: No
NMEA device connected to: deck unit
Surface PAR voltage added: No
Scan time added: Yes

1) Frequency 0, Temperature

Serial number: 03P-4592
Calibrated on: 28 May 2008
G: 4.38586304e-003
H: 6.39518638e-004
I: 2.13986703e-005
J: 1.79479792e-006
F0: 1000.000
Slope: 1.00000000
Offset: 0.0000

2) Frequency 1, Conductivity

Serial number: 04C-3272
Calibrated on: 13 June 2008
G: -1.01043473e+001
H: 1.31487923e+000
I: 2.82322197e-004
J: 3.51065036e-005
CTcor: 3.2500e-006
CPcor: -9.57000000e-008
Slope: 1.00000000
Offset: 0.00000

3) Frequency 2, Pressure, Digiquartz with TC

Serial number: 79501
Calibrated on: 22 September 2008

C1: -6.052595e+004
C2: -1.619787e+000
C3: 1.743190e-002
D1: 2.819600e-002
D2: 0.000000e+000
T1: 3.011561e+001
T2: -5.788717e-004
T3: 3.417040e-006
T4: 4.126500e-009
T5: 0.000000e+000
Slope: 0.99986000
Offset: -1.57600
AD590M: 1.293660e-002
AD590B: -9.522570e+000

4) Frequency 3, Temperature, 2

Serial number: 03P-4782
Calibrated on: 17 June 2008
G: 4.34975308e-003
H: 6.36202465e-004
I: 2.07170171e-005
J: 1.73012265e-006
F0: 1000.000
Slope: 1.00000000
Offset: 0.0000

5) Frequency 4, Conductivity, 2

Serial number: 04C-3258
Calibrated on: 6 June 2008
G: -1.03642856e+001
H: 1.32322147e+000
I: 1.60595502e-004
J: 4.30958271e-005
CTcor: 3.2500e-006
CPcor: -9.57000000e-008
Slope: 1.00000000
Offset: 0.00000

6) A/D voltage 0, Oxygen, SBE 43

Serial number: 43-0619
Calibrated on: 11 November 2008
Equation: Murphy-Larson
Coefficients for Owens-Millard:
Soc: 3.5000e-001
Boc: 0.0000
Offset: -0.6480
Tcor: 0.0003

Pcor: 1.35e-004
Tau: 0.0
Coefficients for Murphy-Larson:
Soc: 4.32500e-001
Offset: -4.96100e-001
A: -3.87950e-003
B: 1.54250e-004
C: -2.40370e-006
E: 3.60000e-002
Tau: 1.19000e+000

7) A/D voltage 1, Free

8) A/D voltage 2, Fluorometer, Chelsea Aqua 3

Serial number: 088244
Calibrated on: 10 June 2008
VB: 0.222400
V1: 2.140200
Vacetone: 0.320500
Scale factor: 1.000000
Slope: 1.000000
Offset: 0.000000

9) A/D voltage 3, Altimeter

Serial number: 41302
Calibrated on: 26 April 2007
Scale factor: 15.000
Offset: 0.000

10) A/D voltage 4, PAR/Irradiance, Biospherical/Licor

Serial number: PML10
Calibrated on: 14 April 2008
M: 0.49292500
B: 1.01139400
Calibration constant: 100000000000.00000000
Multiplier: 1.00000000
Offset: 0.00000000

11) A/D voltage 5, PAR/Irradiance, Biospherical/Licor, 2

Serial number: PML09
Calibrated on: 21 June 2008
M: 0.49602600
B: 1.03304500
Calibration constant: 100000000000.00000000
Multiplier: 1.00000000
Offset: 0.00000000

12) A/D voltage 6, User Polynomial

Serial number: BBRTD-182
Calibrated on: 20 June 2007
Sensor name: Wetlabs backscatter
A0: -0.00035322
A1: 0.00301900
A2: 0.00000000
A3: 0.00000000

13) A/D voltage 7, Transmissometer, Chelsea/Seatech/Wetlab CStar

Serial number: 07-6075-001
Calibrated on: 18 October 2007
M: 23.8781
B: -0.2388
Path length: 0.250

1.5 24-way Stainless Steel CTD Frame Deployment Notes

1.5.1 Wetplug Y-cables

NMF Seabird 9+ CTD systems are in the process of being converted to 'wet-pluggable' style underwater connectors. This will improve the reliability of the systems, most notably in cold water. A reduction in the frequency of sensor spiking events is expected. The conversion to wet-pluggables also makes the Break-Out Box (BOB) pressure case redundant using Y-cables instead. It is now known that the labelling of some of the Y-cable pairs is transposed. This transposes the even and odd analogue channels. The CON file was edited to swap V2 with V3. Hence the altimeter and fluorometer are not on the historically used channels, unlike the BBRTD and transmissometer. Please see the con file for clarification. Once again the wetplug connectors proved to be very reliable with no major spiking events. The fluorometer cable was replaced during the cruise due to the fluorometer dropping out. However, later in the cruise the same problem appeared so it may be a connector issue. No other connectors required pulling for servicing during the cruise.

1.5.2 Comments on CTD Deployment Duration

It should be noted that due to the nature of the winch system on RRS *James Cook* the launch and recovery of the CTD takes somewhat longer than on RRS *Discovery*. However, this is only of the order of 5-6 minutes for launch and about the same for recovery. There is also a delay of a few minutes whilst the winch system is switched from belly box control to lab control at approximately 100m of wire out. I estimate the whole cast to take about 10-15mins longer than on RRS *Discovery*. This should be set in the context of the wider operating envelope that the RRS *James Cook* has with weather compared to RRS *Discovery* – during JC031 stations were worked in 40-50kts of wind, which would not be possible on RRS *Discovery*. It should also be noted that due to the sheltered location of the CTD in the wetlab it is possible to steam straight off station whilst sampling the CTD in shelter. In higher sea states RRS *Discovery* has to remain hove-to with the sea fine on the port-bow to provide shelter whilst the CTD is sampled.

1.5.3 CTD Wire Terminations

A new mechanical termination was completed after removing less than 1m of old wire and load-tested at the start of the cruise, and a new wet-pluggable electrical splice was made. After the CTD was lost on cast 12, 46m of wire on CTD-I was removed to the inboard side of the traction winch and storage drums were swapped from CTD-I to CTD-II and new mechanical and electrical terminations were made.

During cast 34, a loss of communications with the CTD occurred and the cast was aborted. At the time there were two kinks in the wire that had started to birdcage so it was assumed that the conducting cable had been damaged. Approximately 130m of wire on CTD-II had to be removed until good continuity was restored and a new termination made. However, when the slack wire was taken up, continuity was lost once more. Continuity was dependant on the position of the storage winch. The fault was initially thought to be the slip-ring, but was eventually traced to a failure of the inboard electrical termination in the junction box of the storage winch.

After the inboard termination was made good, continuity was restored and a repeat of Station 34 started as CTD035. However, at 936m on the downcast, communications with the CTD were once again lost and the cast was aborted. It was found that the electrical sea-cable splice had flooded and the splice was remade on the existing mechanical termination. After testing good, Station 34 was once again repeated as CTD035 (renaming the previous cast as CTD035_aborted). On deployment a strange noise was heard and immediately afterwards the CTD wire parted in the winch room causing the CTD to fall back to the deck. A further 43m of damaged wire was removed from CTD-II and the fourth and final mechanical termination was made along with the fifth and final electrical splice. Station 34 was eventually completed on the fourth attempt as CTD036.

1.5.4 Sensor Problems & Failures

There were no CTD or LADCP sensor failures during the cruise. There were a few biofouling events which caused shifts in conductivity due to ingestion of marine biology. Both T/C ducts were treated with a dilute bleach solution after these events and no permanent shifts were experienced. From CTD048 onwards, there were five casts where bottle #1 did not fire. This was traced to the lever on the carousel binding. No adjustment could be made, but the lever was repeatedly cleaned and worked to minimise problems.

1.5.5 Altimetry

The Benthos altimeter worked very reliably, obtaining a good bottom return within 80m of the bottom in high acoustic reflection areas and 35m from the bottom when reflection was poor. The NMF pinger was occasionally used both as a backup and as a double check on proximity to the bottom. When the vessel was in D.P. and using large amounts of thrust the acoustic noise made bottom tracking with the pinger impossible. Due to the relatively close proximity of the azimuth thruster to the drop keels, we suspect this has the biggest effect on sounding noise. However, the old EA500 PES display from *RRS Charles Darwin* proved to be unreliable even without the use of the azimuth thruster. In calm seas the CTD was worked to around 10m from the bottom. This was increased to approximately 15m from the bottom in swell. During shelf stations in large currents, occasionally it was not possible to work the CTD close to the bottom.

1.5.6 Other Comments

In the early part of the cruise there were repeated problems with bad scrolling on the CTD storage drum. The scrolling was subsequently adjusted manually by the CPOS and the situation improved considerably. However, the winch still had to be slowed to ~20m/min at each end of the drum when hauling to ensure that the wire scrolled properly on the changeover of lay. Winch speeds had to be kept low (~15-20m/min) during near surface (<~500m) operations when in swell to minimize slack wire. The wire washer was used on casts 70 and 82. This requires a short delay at the first stop away from the bottom for installation and another at 100m for removal of the wire washer.

1.5.7 Further Documentation

A sensor information sheet 'JC031 Sensor Information.doc' and calibration & instrument history sheets were included in the main cruise archive in electronic format (Adobe Acrobat & Microsoft Word). Original copies of all log sheets were supplied to the PSO in addition to the copies that NMF will retain and also supply to BODC.

1.6 Salinometry

One Guildline Autosal 8400A and one 8400B salinometer were available for use having serial numbers 57738 and 68426. Unit s/n 68426 was used for all samples with unit s/n 57738 being reserved as a spare.

The main salinometer was located in the Constant Temperature (CT) lab and operated at 24°C bath temperature in 21-22°C ambient lab temperature. Problems with temperature stability were frequently encountered. The temperature in the CT lab was sometimes varying by 3-4°C, but the problem was eventually traced to a failed heater lamp in the Autosal. No spares were available so both lamps were changed for the lamps in the spare 8400A unit. Replacement lamps for the 8400A and additional spares have been requested for the next cruise.

The CTD and underway samples were taken and run using the OSIL PC by the science party with assistance from NMF technicians. The science party also processed the salinity data from the Autosal.

1.7 RDI Workhorse LADCP Configuration

Two main command files were used during the cruise:

Downlooking Master Workhorse 300 kHz Aluminium Pressure Case WHM_JC031.CMD	**Downlooking Master Workhorse 300 kHz Titanium Pressure Case TWHMJC031.CMD**
PS0	PS0
CR1	CR1
CF11101	CF11101
EA00000	EA00000
EB00000	EB00000
ED00000	ED00000
ES35	ES35
EX11111	EX11111
EZ0011101	EZ0011101
LW1	WM15
LD111100000	LW1
LF0500	LD111100000
LN016	LF0500
LP00001	LN016
LS1000	LP00001
LV250	LS1000
SM1	LV250
SA001	SM1
SW05000	SA001
TE00:00:01.00	SW05000
TP00:00.00	TE00:00:01.00
CK	TP00:00.00
CS	CK
	CS

1.7.1 Deployment Comments

The LADCP's were operated by NMF technicians.

Prior to each deployment the BBtalk terminal session was logged to a file named with the format CTDxxxm.txt for the down-looking master, where xxx was the CTD cast number.

Then the following commands were sent:

CB411 – to change baud rate to 9600 for sending the command file
PS0 – to provide an additional check of serial number (also in the command file)
TS? – time set, offset from GPS clock noted and time reset if greater than a few seconds.
RS? – to check flashcard space and re Erase if necessary
PA and PT200 – pre-deployment and built in self tests

A few minutes before the CTD was deployed the command files were sent and BBtalk file logging stopped. Deployment and end of pinging times were recorded on the rough log sheets.

After pinging was stopped, the number of deployments in the recorder was queried with RA? and the most recent file downloaded in the default RDI-xxx.000 name format. The file was then renamed to the form CTDxxxm.000. All filenames were noted on the rough log sheets.

The battery was fully charged at 62V until it was drawing 100mA between each cast. Every 15-20 casts the battery was vented.

During deployment of the CTD on cast 35 the CTD wire parted in the winch room. The CTD package fell back to the deck from a height of ~0.5m. Unfortunately the LADCP (s/n 4275) landed on the deck frame damaging transducer face #1. The instrument was visually inspected and then fully tested. Although it was functionally ok, the LADCP was replaced with s/n 10607 and retained as a spare to prevent possible flooding and associated additional repair costs.

Dougal Mountifield

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 header information 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
Align CTD
Wild Edit
Cell Thermal Mass

Data Conversion - turns the raw data into physical units and applies the calibration coefficients in the instrument configuration file. The input files were named *ctdnnn.hex* where *nnn* refers to the three digit station number, *ctdnnn.CON* which is the instrument configuration file and *ctdnnn.bl* which contains information regarding bottle firing. The output files were specified as *ctdnnn.cnv*, where *nnn* is the station number. Once these files had been created they were overwritten by any subsequent seabird processing.

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.

Wild Edit - The mean and standard deviation of each parameter are calculated for blocks of 500 cycles. Points that lie outside two times the standard deviation are temporarily excluded for recalculation of the standard deviation. Points outside ten times of the new standard deviation are replaced by a bad flag. It appears that, in later analysis, using a block size of 500 was too large and some 24 Hz records were excluded that should not have been.

Cell Thermal Mass - takes the .cnv files and makes corrections for the thermal mass of the cell, in an attempt to minimise salinity spiking in steep vertical gradients due to temperature/conductivity mismatches. The constants used were: thermal anomaly amplitude $\alpha = 0.03$; thermal anomaly time constant $1/\beta = 7$.

SeaPlot - provided an initial look at the data.

2.2 Mstar CTD Processing

After initial processing with the Seabird routines, all data was run through the new MEXEC processing suite of programs (based on Pstar).

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

- **SAM files:** these contain 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
- **CTD files:** contain all data from CTD sensors. There are five different CTD files: _raw, _24hz, _1hz, _psal and _2db. The suite of programs averages and interpolates the raw data until it has 2db resolution.
- **DCS files:** store information necessary for CTD downcast processing (for example start, bottom and end points of the cast). These files are also used when merging in latitude and longitude.
- **FIR files:** contains information about rosette bottle firing.

2.3 Processing on JC031

After having converted CTD with the SBE programs, there are two files to work on: *ctd_jc031_nnn.cnv* and *ctd_jc031_nnn.bl*. The first one contains the raw CTD data including cast information and the second contains information about bottle firing.

msam_01: creates an empty .sam file to store all information about rosette bottle samples. The set of variables are available in the M_TEMPLATES directory and can be changed according to what variables are needed. This file named as *sam_jc031_nnn.nc* contains space to store data for each sample bottle, their flags and appropriate CTD data needed for bottle analysis.

mctd_01: reads the raw data (*ctd_jc031_nnn_ctm.cnv*) and stores it in a NetCDF file named *ctd_jc031_nnn_raw.nc*, which becomes write protected.

mctd_02: copies *ctd_jc031_nnn_raw.nc* into *ctd_jc031_nnn_24hz.nc* renaming SBE sensor variable names.

mctd_03: using 24Hz data salinity is calculated as well as a 1Hz averaged file (*ctd_jc031_nnn_1hz*) and also an averaged potential salinity and potential temperature file (*ctd_jc031_nnn_psal*).

mdcs_01: creates an empty file named *dcs_jc031_nnn* to store information about the start, bottom and end of the cast.

mdcs_02: populates *dcs_jc031_nnn* with deepest pressure information.

mdcs_03: selects and shows surface data < 20db (*ctd_jc031_nnn_surf*) from which the analyst chooses the positions of the start and end scan numbers for the top and bottom of the cast.

mctd_04: uses information from *dcs_jc031_nnn* to select the CTD downcast data from *ctd_jc031_nnn_24hz* file to create a 2db resolution file (*ctd_jc031_nnn_2db*).

mdcs_04: loads position from the navigation file and merge it onto the points previously defined by mdcs_03 and stores it in *dcs_jc031_nnn_pos.nc*.

mfir_01: extracts information about fired bottles from *ctd_jc031_nnn.bl* and copies into a new file named *fir_jc031_nnn_bl.nc*.

mfir_02: uses information from *fir_jc031_nnn_bl* and *ctd_jc031_nnn_1hz* to merge the time from the CTD using scan numbers and puts this into a new file (*fir_jc031_nnn_time.nc*).

mfir_03: stores the CTD data for the time each bottle was fired in *fir_jc031_nnn_ctd*. The CTD data are taken from *ctd_jc031_nnn_psal* and selected according to the firing time information stored in *fir_jc031_nnn_time*.

mfir_04: copies information of each bottle from *fir_jc031_nnn_ctd* onto *sam_jc031_nnn*.

mdcs_05: apply positions from *dcs_jc031_nnn_pos.nc* to all files.

2.4 Sample Files

Chemistry and tracer data from the various disciplines were merged with CTD data to create master sample files. The sample files *sam_jc031_nnn.nc* were created when processing each CTD station. At this stage they were filled with upcast conductivity, temperature, oxygen and pressure from both primary and secondary sensors coincident with bottle firings (up to a maximum of 24 points).

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. 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. At this stage oxygen was converted from μm/l to μm/kg. Residuals were created using the program *msam_02*.

2.5 Sensor calibration - conductivity

The CTD was lost on Station 12 so there were two separate station groupings: Stations 1-12 and Stations 13-84. The CTD was fitted with two separate conductivity and temperature sensors; one on the main frame and the other on the fin of the CTD package. The primary conductivity sensor (on the frame) for Stations 1-12 had a pressure trend while the sensor on the fin appeared stable with just a bias needing to be applied to the laboratory calibrations of -.0027mmho/cm. For stations 1-12 the frame sensor had a bias of -.0032 mmho/cm applied and a pressure slope correction of -.34 *10-6 mmho/cm per dbar. For Stations 13-84 it was decided to use the frame conductivity sensor as the main sensor since the secondary sensor on the fin showed a slight pressure trend and also the secondary sensor appeared slightly less stable with occasional 'wanderings' of less than .001 between stations. A bias of .00055 mmho/cm and a pressure slope correction of -.22*10-6mmho/cm per dbar were initially applied to the frame conductivity data. The conductivity appeared stable for the duration of the cruise, any change was within the bounds of the accuracy of the salinity bottle samples. For the sensor on the fin for stations 14 to 84 a bias of .0017 mmho/cm and a pressure slope correction of -.26*10-6 mmho/cm per dbar were applied to conductivity. (An attempt was made to fit a station trend to the conductivity fin calibrations but due to the occasional small jumps between stations it was decided to remain with one single calibration constant. Between stations 14 and 84 there is a change in the fin conductivity sensor of .002 mmho/cm).

Figure 2 shows bottle salinity minus CTD salinity after calibration versus station number (fin sensor Stations 1-11, frame sensor Stations 14-84).

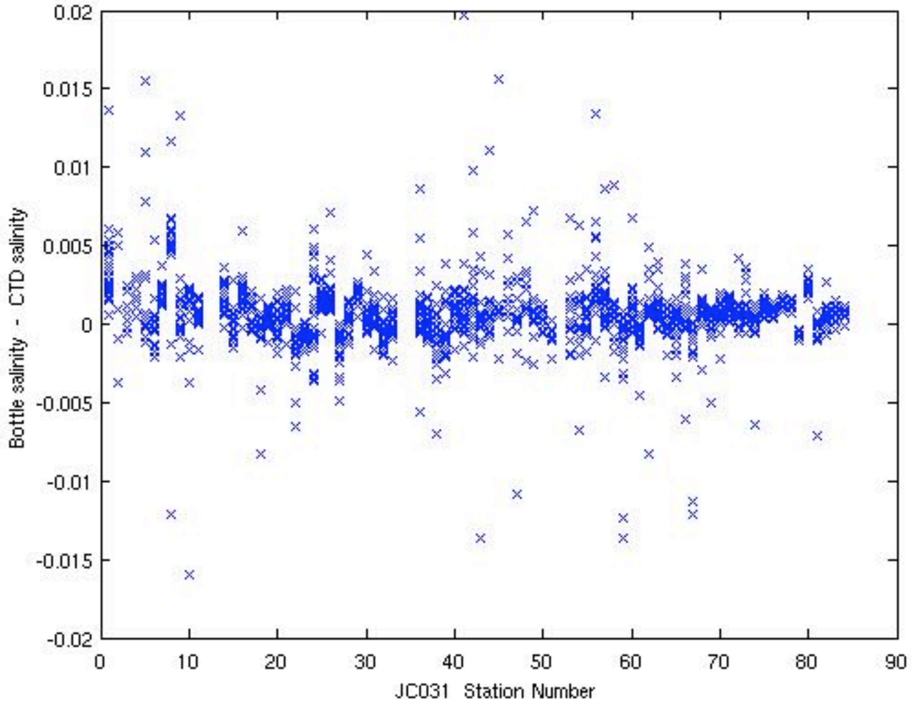

Figure 2: Salinity residuals plotted against station number

2.6 Sensor calibration – oxygen

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. 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 down and upcasts. The residuals calculated were shown to have a dependence on pressure. For Stations 1-12 the pressure adjustment from 0 to 4500db was 8.5 μm/kg, for Stations 13-84 the pressure adjustment from 0 to 4500 db was almost 14 μm/kg. As with the conductivity sensor, the oxygen sensor appeared stable throughout the length of the cruise.

2.7 Pressure Bias

No on-deck pressure bias has been applied to the data. From the time the instrument was put into recording mode until entering the water, the bias was anywhere between 0 to -0.7 db as the instruments position changed on the deck. On recovery the bias was generally between -0.6 to -1.0.

2.8 Problems created with the use of 'wild edit'

On several of the stations the use of wild edit had created small gaps in the data with some points that were rejected in conductivity and salinity which should not have been. This created the problem that when salinity was calculated at the 2db stage from the averaged temperatures and averaged conductivities there was the occasional salinity spike since averaged conductivity and temperature values were misaligned. Normally, the new Mstar suite of programs would calculate salinity from averaged 2db conductivity and temperature data. For the processing of JC031 we decided to calculate salinity at the 24Hz stage only when there were values for both conductivity and temperature and then average this consistent 24Hz salinity data directly to 2db data. Therefore if 2db conductivity and temperature data are used to calculate salinity, the resulting salinities may be slightly different. Those stations where the use of Wild Edit created a problem are shown in Table 2.

Table 2: Stations that have corresponding Wild Edit problems

CTD Number	Wild Edit Problems
9	Frame temp at 3237db Fin temp at 3237db
19	Frame temp at 2089db Fin temp at 3367db
20	Fin cond at 2187db
22	Frame cond at 1663db Fin cond at 1509db
29	Frame cond at 1819db Fin cond at 1819db
31	Frame temp at 3137db (Fin cond 47395-47398 raw removed)
32	Frame cond at 1867db (Oxygen & Frame sensor cond bad below 3583db)
33	(Fowling on Fin cond below 2143db)
40	Fin temp at 2297db
42	Fin cond at 1745db
43	Frame temp at 933db
47	Fin temp and cond 539db
51	Fin cond 468db
53	Fin temp 1329db
54	Frame temp at 1751db and 2727db Fin cond at 1377db
55	Frame temp at 1883db
59	Frame cond at 2508db and slight in both sensors at 948db
60	Frame and Fin temp at 2129db and 2783db
62	(Fin cond at 54485-54490 raw removed)
63	Frame temp at 695db and 2779db Fin cond at 1839db Fin temp 2735db
65	Frame temp 3449db
68	(Fin cond at 126069-126071raw removed)
69	Fin cond at 2975db Frame temp and cond 3460db
72	Fin cond at 2278db
75	Fin cond at 713db
76	(Fin cond at 20932-20934 raw removed)
	(Problems in parentheses not caused by use of Wild Edit)

2.9 CTD Data

Contour plots for oxygen, salinity and potential temperature have been created from data collected by the CTD sensor along each section. These can be seen in Figures 3-6.

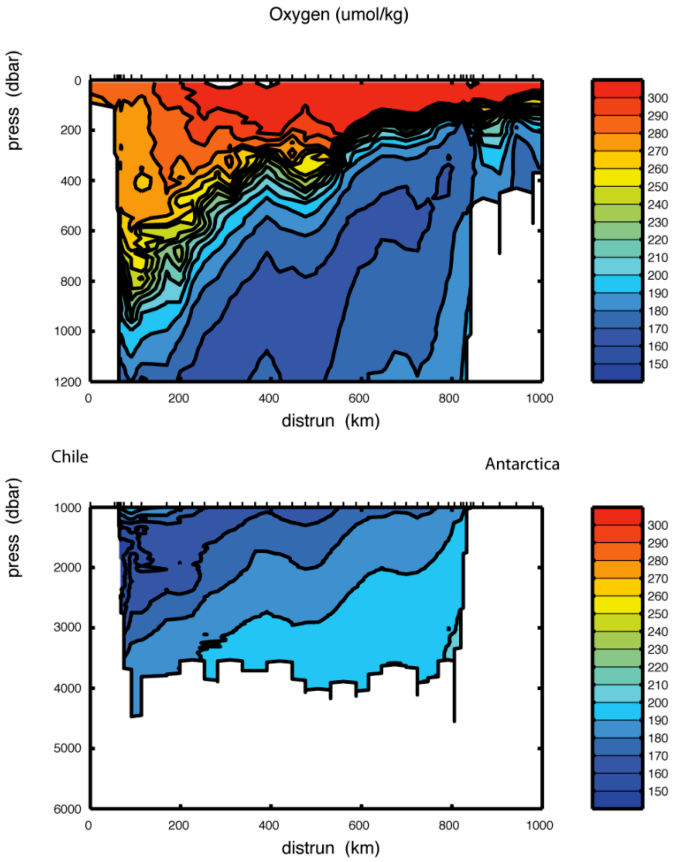

Figure 3: Contour plots for the parameters of oxygen along section SR1

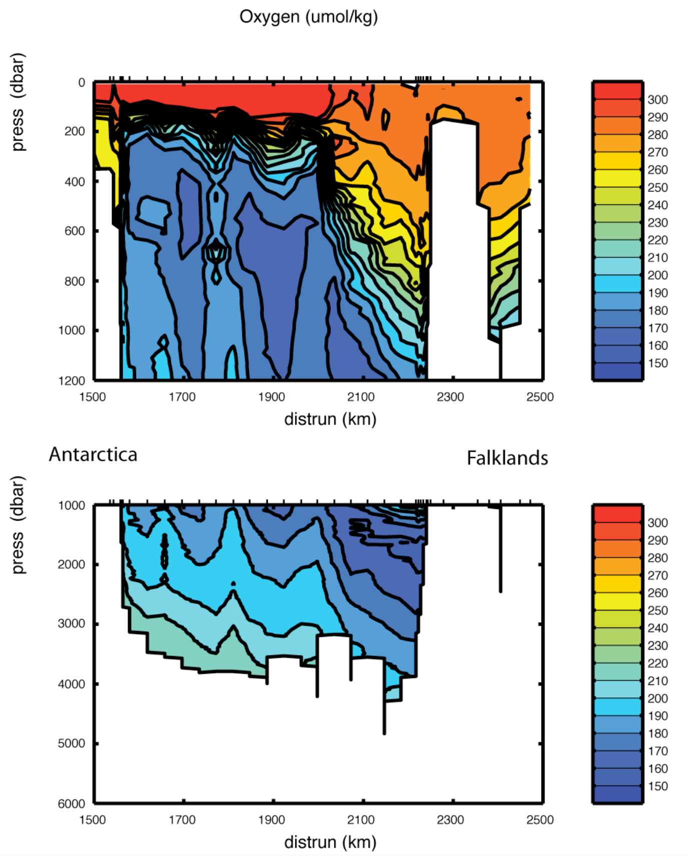

Figure 4: Contour plots for the parameters of oxygen along section SR1b

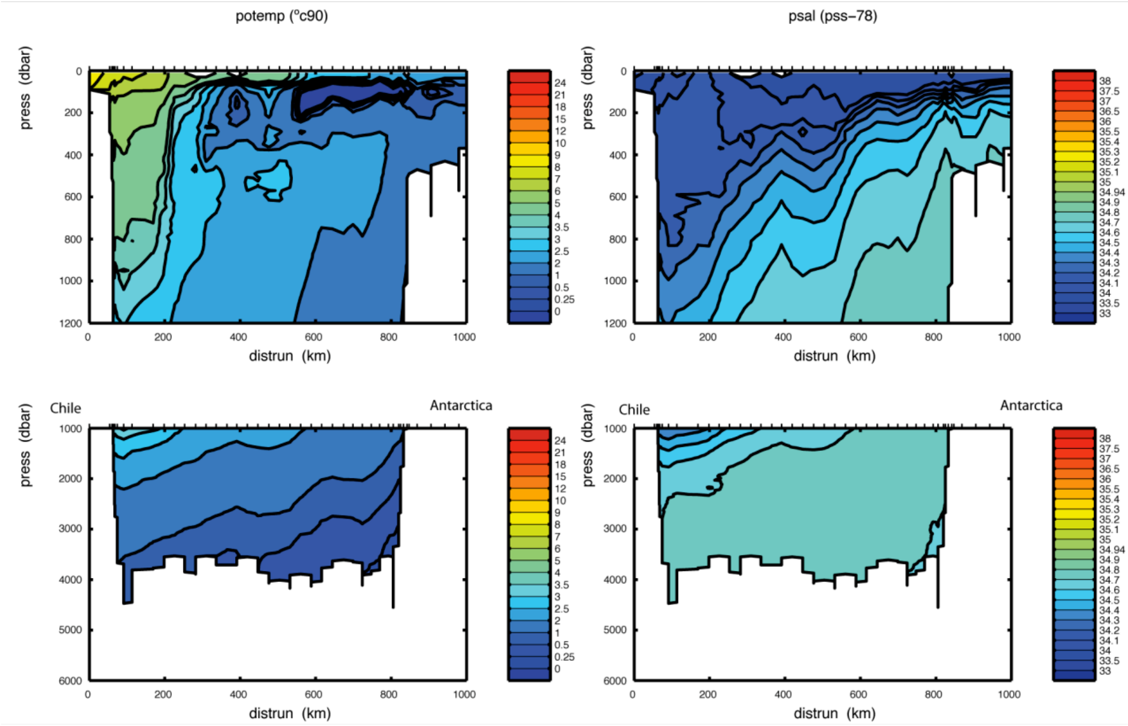

Figure 5: Contour plots for the parameters of potential temperature and salinity along section SR1

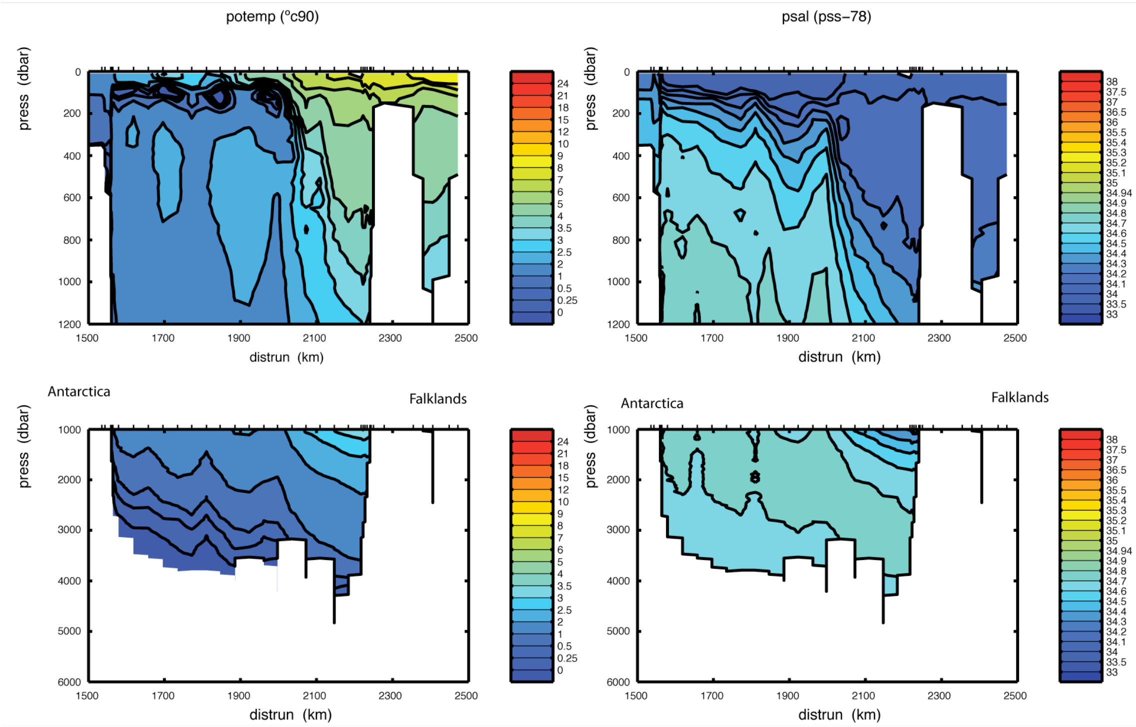

Figure 6: Contour plots for the parameters of potential temperature and salinity along section SR1b

Mary Woodgate-Jones

3. Water Sample Salinity Analysis

3.1 Sampling

Samples were taken from all unique depths on every CTD cast. The salinity samples were taken in 200ml medicine bottles. Each bottle was rinsed twice and filled to just below the neck, with the bottle screw cap also being rinsed in the water from the Niskin bottle. The sample bottles' rims were then wiped with blue tissue paper and the bottles fitted with a plastic seal insert and capped with the (wiped/dried) screw cap. After each cast, the crate of salinity bottles was moved into the CT lab and left for 24 hours to equilibrate to the ambient temperature of the laboratory.

Samples were also taken from the underway system between every station using the same method as described above for the CTD. This was done to enable calibration of the TSG system. The underway samples were stored together in a separate crate and analysed once the crate had been filled, but were otherwise treated in the same way as the CTD samples.

3.2 Laboratory Setup

The salinometer used to analyse samples on JC031 was a Guildline 8400B Autosal, serial number 68426. On 12th February both heater lamps were replaced after it was noticed that the salinometer appeared to have experienced a notable temperature drop and was constantly heating the water bath. This was found to be due to one of the heater lamps having blown, and both were therefore replaced as a precaution. Aside from this, no major technical problems were experienced with the instrument.

The salinometer was set up in the constant temperature laboratory, with the lab temperature set at 22°C and the salinometer water bath temperature set at 24°C throughout the cruise. A thermometer kept next to the salinometer was used to record lab temperature whenever an analysis was performed, and the temperature was in the range 22-23°C throughout the cruise. Ocean Scientific Instruments Ltd (OSIL) standard seawater batch P150 (conductivity 0.99978) was used for standardisation throughout.

3.3 Analysis

In total, 1612 samples were analysed. The crates were analysed in batches of two or more. At the beginning of each crate, the salinometer was standardised using OSIL P150 standard seawater and the potentiometer setting was noted. The P150 standard seawater was then measured (as a sample) following standardisation. At the end of the crate (when another crate was available to be analysed immediately afterwards), the P150 standard seawater to be used for standardising the next crate was also measured as the final sample of the prior crate. For example, for crates 1 and 2, where crate 1 contains 24 samples: readings number 1 and 26 for crate 1 would be measurements of the standard seawater, the seawater used for reading 26 would then be used to standardise the salinometer prior to the analysis of crate 2, and would finally be measured again as reading number 1 of crate 2. This enabled an extra stage of error checking of the salinometer measurements to be performed, showing offset at beginning and end and hence any drift. In addition to this, the salinometer data logging software (supplied by OSIL and used to record measurements throughout the cruise) applied the offset measured during the standardisation procedure to all readings. Further corrections were applied to readings where the initial/final values appeared to have shown significant drift, with the difference between the final and expected value being subtracted, where this was available, as it was noticed that the salinometer was generally more stable towards the end of an analysis. Stations to which corrections were applied were: 14, 17, 38, 39, 57, 64, and 65. Further details are given in Table 3 below. Bottles were removed from Stations 23, 45 and 60 due to suspected bad data quality. Further details are given in Table 4.

Table 3: Adjustments applied to station values

Station number	Correction
14	-0.0019
17	0.003
38	0.0045
39	0.001
57	0.0013
64	-0.001
65	-0.0018

Table 4: Bottles removed due to suspected bad data quality

Station number	Bottle removed
23	18
45	1
60	1

3.4 Processing

Salinity values were obtained by following standard procedure of using the conductivity ratios obtained from the Autosal analysis of the samples. The conductivity ratios are automatically recorded in Excel files which correct for offsets from standard readings.

3.5 Assessment

The 8400B Autosal was found to be a reliable piece of equipment despite requiring a certain degree of troubleshooting, in order to return the instrument to full working order. Therefore it can be stated that although this is a very useful and accurate piece of equipment, it is not foolproof and its performance requires close observation in order to identify when the accuracy is beginning to fail.

Sally Close

4. Dissolved Oxygen Analysis

4.1 Cruise Objectives

The objectives of the dissolved oxygen analysis were to provide a calibration for the oxygen sensor mounted on the frame of the CTD for cruise JC031, which undertook two transects within Drake Passage. For this, a Winkler titration was performed on a water sample taken from the Niskin bottles mounted on the CTD frame.

4.2 Methods

Dissolved oxygen samples were only taken from the CTD casts and they were the second samples to be drawn from the Niskin bottles after the CFC sampling. Every Niskin bottle that had been fired and was being sampled for other analysis was sampled for dissolved oxygen. The samples were drawn through short pieces of silicon tubing into clear, pre-calibrated, wide necked glass bottles. The temperature of the sample water at the time of sampling was measured using an electronic thermometer probe. The temperature would be used to calculate any temperature dependent changes in the sample bottle volumes. Each of these samples was fixed immediately using 1 ml of a 600g/l manganese chloride and 600g/l alkaline iodide solution. The samples were shaken thoroughly and then left to settle for 30 minutes before being shaken again. The samples were then left for a few hours before analysis.

The samples were analysed in the chemistry laboratory following the procedure outlined in Holley and Hydes (1995). The samples were acidified using 1ml of a 5M sulphuric acid solution immediately before titration and stirred using a magnetic stirrer. The Winkler whole bottle titration method with amperometric endpoint detection (Culberson and Huang, 1987), with equipment supplied by Metrohm, was used to determine the oxygen concentration. In total 1,557 samples were analysed for dissolved oxygen.

The normality of the sodium thiosulphate titrant was checked using a potassium iodate standard. This was done approximately daily throughout the cruise. Sodium thiosulphate standardisation was carried out by adding 5ml of 0.01N potassium iodate solution after the other reagents had been added to a CTD bottle water sample in reverse order. The sample was then titrated and the volume of sodium thiosulphate required was noted. This was repeated 5 times and the average amount of sodium thiosulphate required was calculated. This standardisation was then used in the calculation of the final dissolved oxygen calculation. The sodium thiosulphate was changed during the cruise. Figure 7 shows the average volume of sodium thiosulphate required to titrate the 5ml potassium iodate for both sets of sodium thiosulphate.

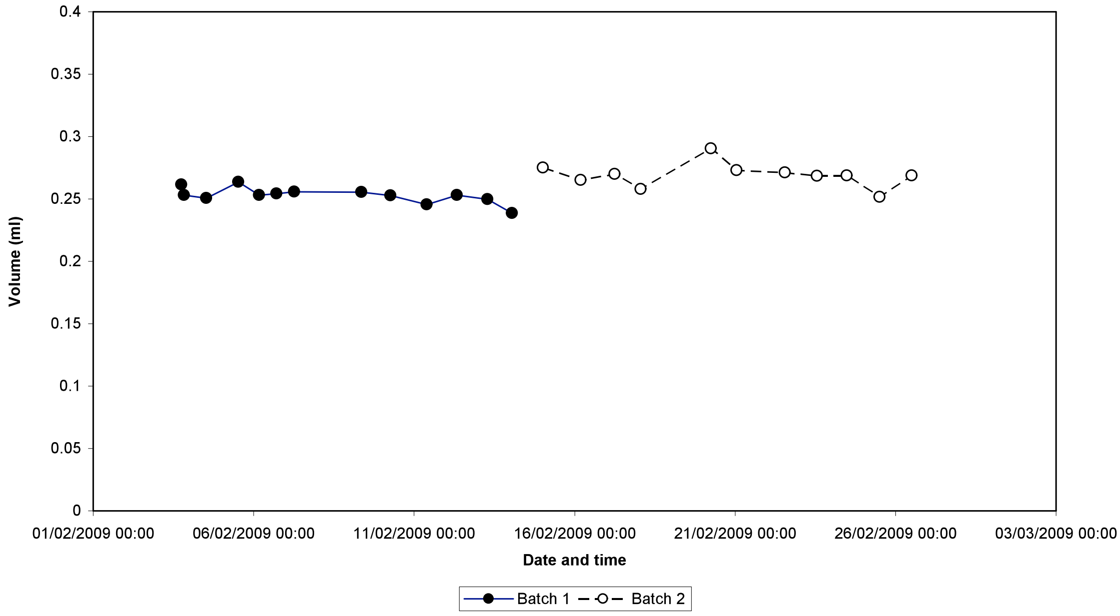

Figure 7: The volume of sodium thiosulphate required to titrate 5ml of a 0.01N potassium iodate solution. The values are relatively stable with time indicating that the sodium thiosulphate did not degrade over the course of the cruise.

A blank was also carried out to account for the oxygen in the reagents. The reagents were added in reverse order, as for the sodium thiosulphate standardisation, and then 1ml of the 0.01N potassium iodate standard was added. This was titrated and the volume of sodium thiosulphate required was noted. 1ml was again added to the same sample and it was titrated again. This was again repeated. The average of the second two volumes of sodium thiosulphate was subtracted from the first volume. This whole process was repeated three times in total and the average blank was taken and used in the calculation of the final dissolved oxygen calculation.

4.3 Dissolved oxygen measurements; further data quality control

Dissolved oxygen residuals (i.e. sensor data subtracted from measured values) plotted against station number (Figure 8) showed there was high variability between stations throughout the cruise. This prompted us to further quality control our measurements back at the NOCS.

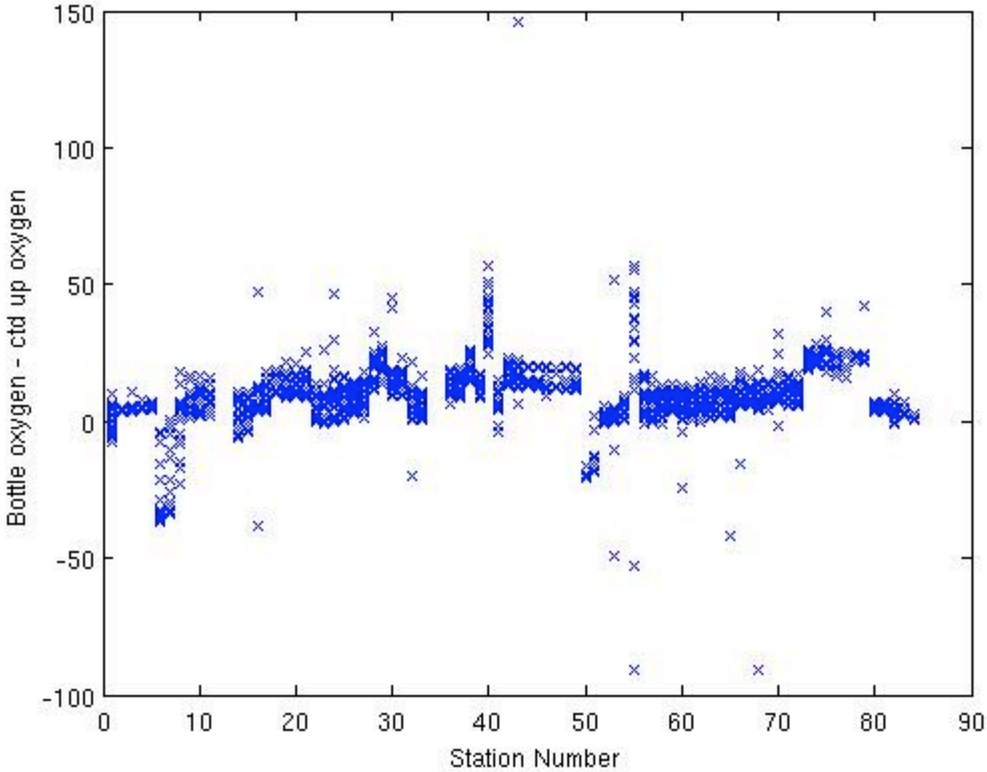

Figure 8: The oxygen residuals plotted against station number. There is no stable offset throughout the cruise. We believe this to be because of the thiosulphate and reagent calibrations undertaken during the cruise.

The first step taken was to check log sheets for consistency in the recorded titration values and calculation spreadsheets for consistency in input values. Typographic errors and outliers were found, and were corrected and removed accordingly. Dissolved oxygen concentrations were then recalculated. Variability of the residuals was reduced to some degree, but it was not satisfactory yet.

Measurements of dissolved oxygen involves addition of chemical reagents at different steps, most of which are controlled by means of automatic dispensers and automated titration burettes. However, the standardisation of the method involves manual additions using pipettes and this step is the most prone to introducing errors.

After further reviewing all log sheets, it became apparent the standardisation values were highly variable during the early stages of the cruise, but improved as the cruise progressed. We think the reason for this is that during this first set of calibrations, there were three different people doing the pipetting and two of them were new to oxygen analysis. Then measurements improved as they became more familiarised and confident with the technique. We thus decided the best way to proceed was to average out all standardisations for each batch of thiosulphate solution used during the cruise. Doing this very much improved the residuals consistency between stations. However, given that there were three different thiosulphate solutions used during the cruise, there were now three groups of data, with the residuals between stations being consistent within each group. Having compared the residuals for these three thiosulphate solutions, dissolved oxygen concentrations for Stations 32 to 84, which were titrated with our third thiosulphate solution, produced the most consistent and minimum residuals and these were used to correct Stations 1-29.

All standardisation data for Stations 1-29 produced an average of 0.2528ml with a standard deviation of 0.0081. Due to the variability caused by the three operators the true standardisation value was considered to be within this range. By comparing the residuals values for Stations 32-84 with Stations 1-29, the standardisation volume required to negate the offset was 0.2555ml. This was well within the range of values obtained for the first batch of thiosulphate and this value was used to calculate oxygen concentrations for Stations 1-29. The residuals were again plotted and showed a much more stable offset, as would be expected (Figure 9).

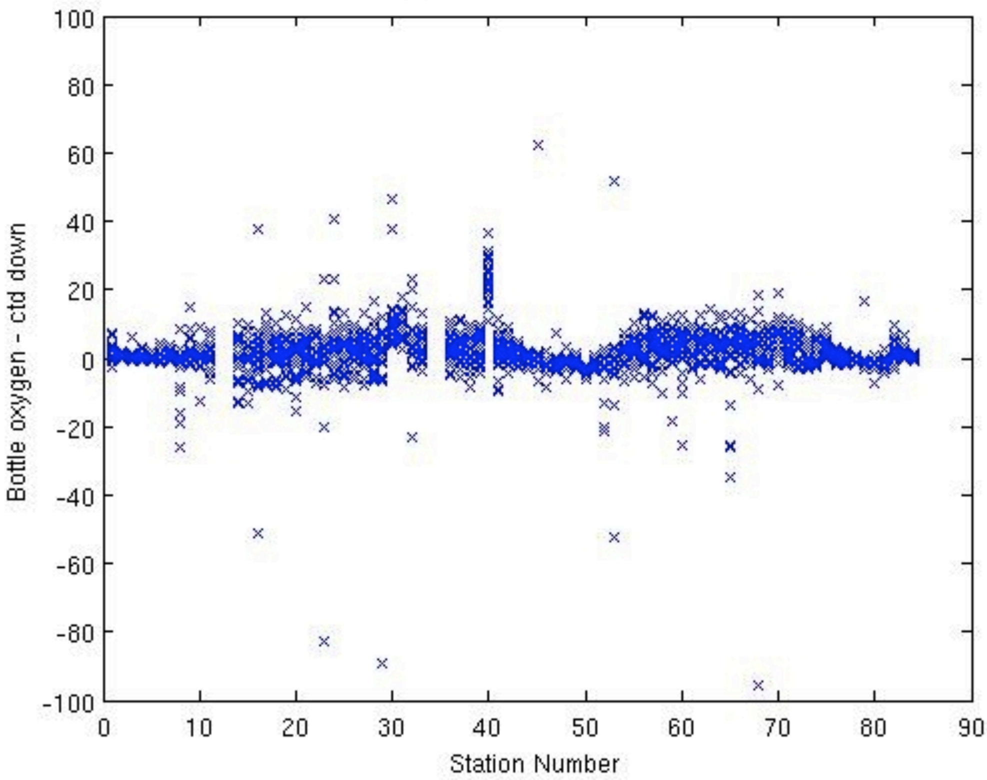

Figure 9: The oxygen residuals plotted against station number. There is now a stable offset across the cruise. The majority of data points are within a range of -5 and +10 but this plot does include all data points, even those that had been flagged as suspicious.

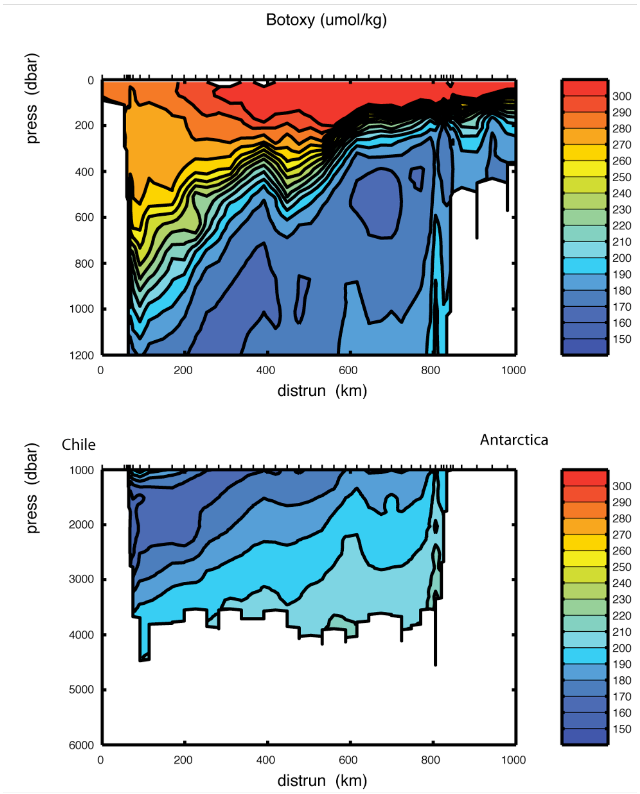

Figure 10: Contour plots for the parameters of bottle oxygen along section SR1

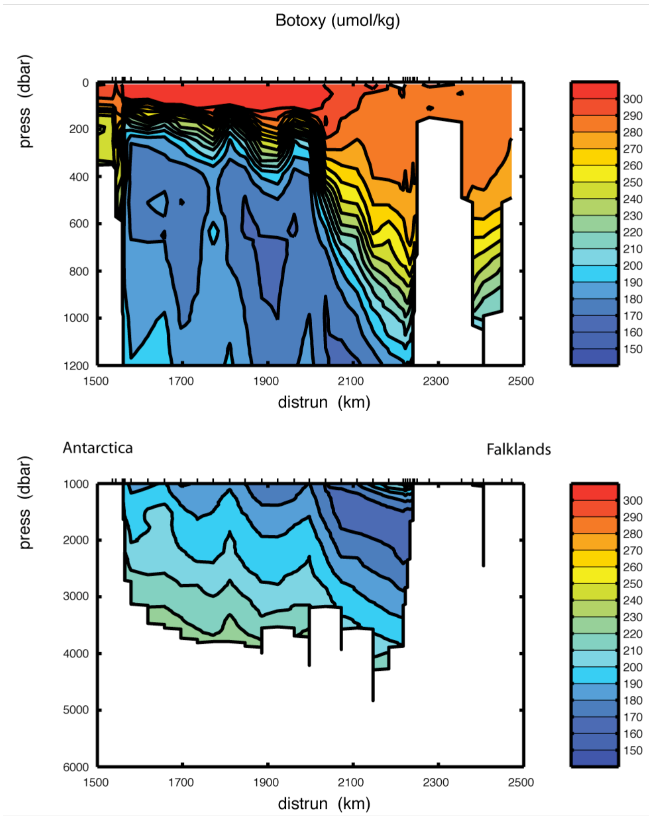

Figure 11: Contour plots for the parameters of bottle oxygen along section SR1b

4.4 References

Holley, S. E. and D. J. Hydes (1994). Procedures for the determination of dissolved oxygen in seawater, James Rennell Centre for Ocean Circulation**:** 1-38.

Culberson, C. H. and S. Huang (1987). "AUTOMATED AMPEROMETRIC OXYGEN TITRATION." Deep-Sea Research Part a-Oceanographic Research Papers **34**(5-6): 875-880.

Mark Stinchcombe, Maria Salta, Glaucia Berbel, Sinhue Torres-Valdez and Mark Moore

5. Inorganic Nutrients Analysis

5.1 Cruise Objectives

Our objectives for cruise JC031 to Drake Passage in the Southern Ocean were to measure the levels of the inorganic nutrients: nitrate, silicate and phosphate using segmented flow analysis.

5.2 Method

Analysis for micro-molar concentrations of nitrate and nitrite (hereinafter nitrate), phosphate and silicate was undertaken on a Scalar San Plus Autoanalyser following methods described by Kirkwood (1996) with the exception that the pump rates through the phosphate line were increased by a factor of 1.5, to improve reproducibility and peak shape. Samples were drawn from Niskin bottles on the CTD into 25ml sterilin coulter counter vials and kept refrigerated at approximately 4^{o}C until analysis, which commenced within 12 hours. Stations were run in batches of 1 to 4 with most runs containing just 1 station. Overall 68 runs were undertaken with 1567 samples being analysed in total from the CTD, 36 from the underway and 17 incubation samples. An artificial seawater matrix (ASW) of 40g/L sodium chloride was used as the inter-sample wash and standard matrix. The nutrient-free status of this solution was checked by running Ocean Scientific Instruments Ltd. (OSIL) nutrient-free seawater on every run. A single set of mixed standards were made up by diluting 5mM solutions made from weighed dried salts in 1L of ASW into plastic 1L volumetric flasks that had been cleaned by soaking in MQ water. Data processing was undertaken using Skalar proprietary software and was done within 24 hours of the run being finished. The wash time and sample time were 90 seconds; the lines were washed daily with 0.5M sodium hydroxide and 10% Decon. Time series of baseline, instrument sensitivity, calibration curve correlation coefficient, nitrate reduction efficiency and duplicate difference was compiled to check the performance of the auto-analyser over the course of the cruise.

5.3 Performance of the Analyser

The auto-analyser performed very well during JC031. The noise level of all three chemistries appeared lower than has been noted on a few previous cruises. Only two problems presented themselves during JC031. The first was a problem with the software. There would be an ‘unknown filename’ error and as a result we had to reinstall the software. This occurred three times over the course of JC031. This is a fault that has also occurred on previous cruises so we were aware that a re-install was the quickest way to deal with this error. The second problem was a contamination of our artificial seawater matrix. These contaminations are detected using the low nutrient seawater and so when these are shown to be below the baseline we knew the artificial seawater matrix was contaminated. This was easily corrected by making a fresh batch. The results during these contamination periods need to be corrected. This will be done back at NOCS.

The general performance of the analyser is monitored via the following parameters: sensitivity, baseline value, regression coefficient of the calibration curve, nitrate reduction efficiency and the error in duplicate samples. Time series of these parameters are shown in Figures 10 to 11.

The sensitivity of the analyser stayed relatively constant throughout the cruise (Figure 12). There was only one run that had a large difference in sensitivity in comparison to the other analyses; run number 37 for phosphate. The sensitivity of the nitrate line also seemed to decrease slightly throughout the cruise. This was due to a slight decrease in the efficiency of the cadmium column, from around 100% down to 95%. The column was thoroughly cleaned which bought the efficiency back up to 100%. This also greatly improved the sensitivity of the nitrate chemistry.

The regression coefficients of the calibration curves for all three chemistries were all higher than 0.998 (Figure 13). The vast majority (greater than 99%) were greater than 0.999. The reduction efficiency of the cadmium column never got below 94%. There was a slight decrease in efficiency over the cruise, but this was improved by cleaning the cadmium column.

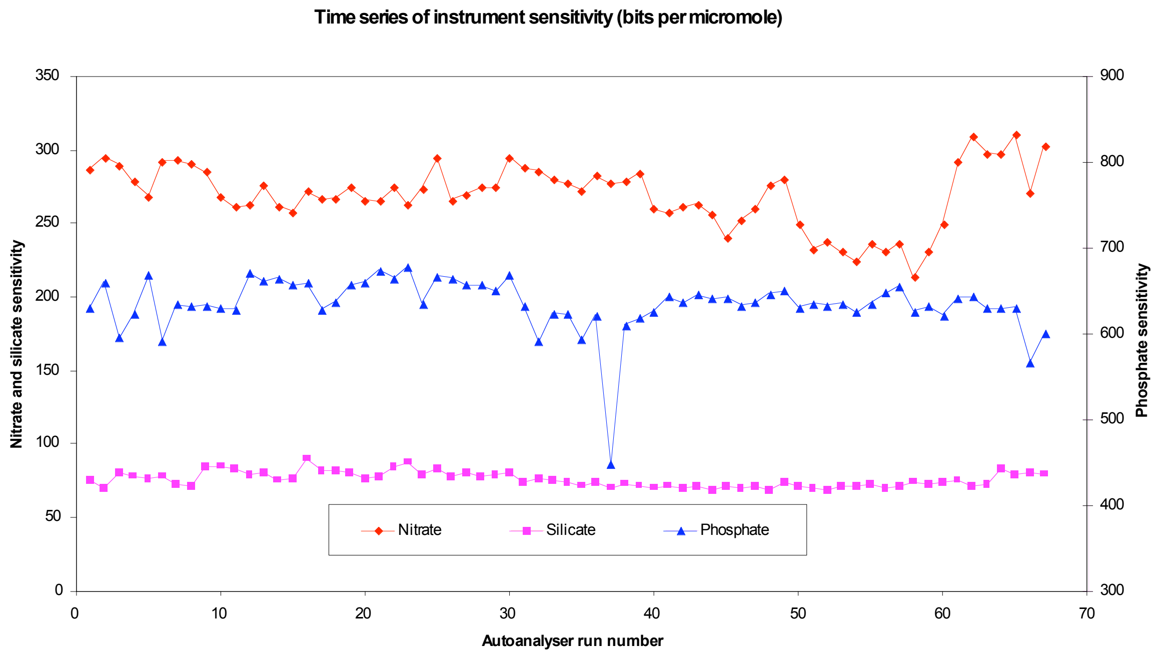

Figure 12: The sensitivity of the analyzer in bits per micromole.

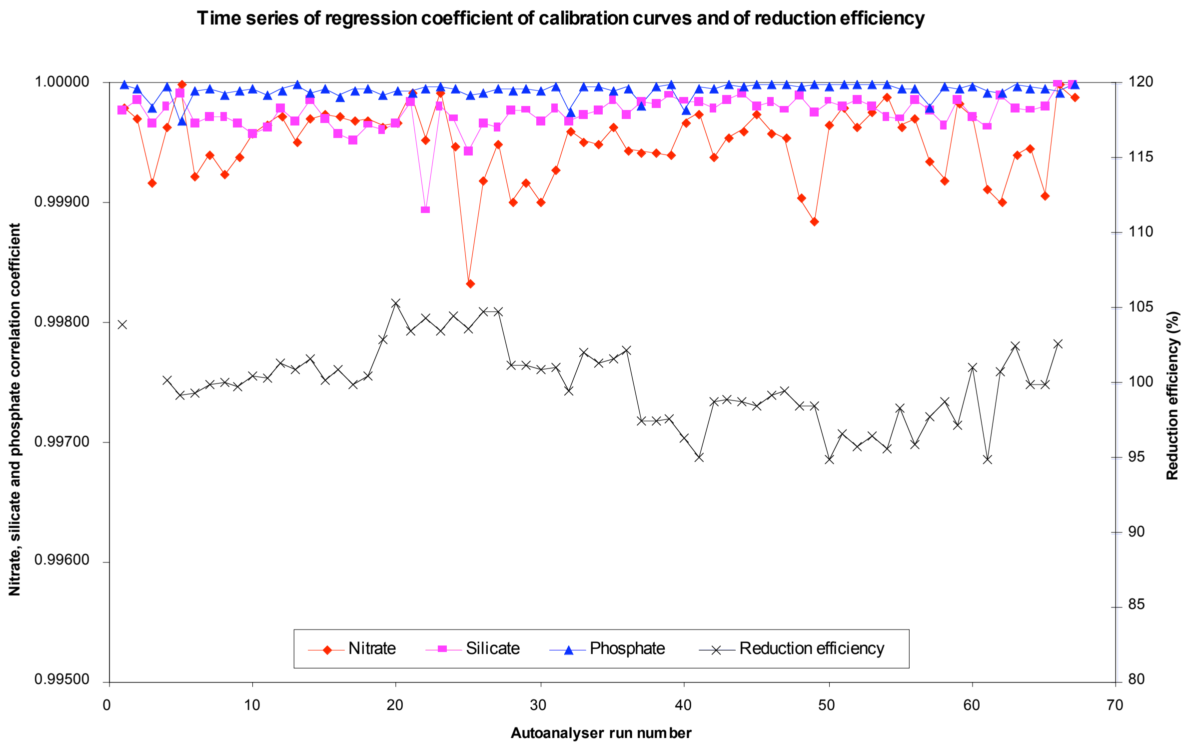

Figure 13: The regression coefficients of the calibration curves for all three chemistries and the efficiency of the cadmium column in the nitrate line.

The time series of the baseline values shows that there was a large jump in the baseline values for nitrate after run 19 (Figure 14). This coincided with a new artificial seawater solution being made up. The new batch of artificial seawater was contaminated. Due to time constraints this contaminated batch was used for a series of runs before it was changed. The nitrate values for these runs will be processed again at NOCS to ensure this contamination issue is resolved.

The time series in percentage error between duplicates was calculated by comparing the values of the first two drift samples analysed on each run for each chemistry. All except six runs came in below a 3% error margin. The silicate chemistry was always below 3%, whilst nitrate had four runs that were above 3% (the highest being 4.51%) and phosphate had two runs above 3% (the highest being about 4.22%).

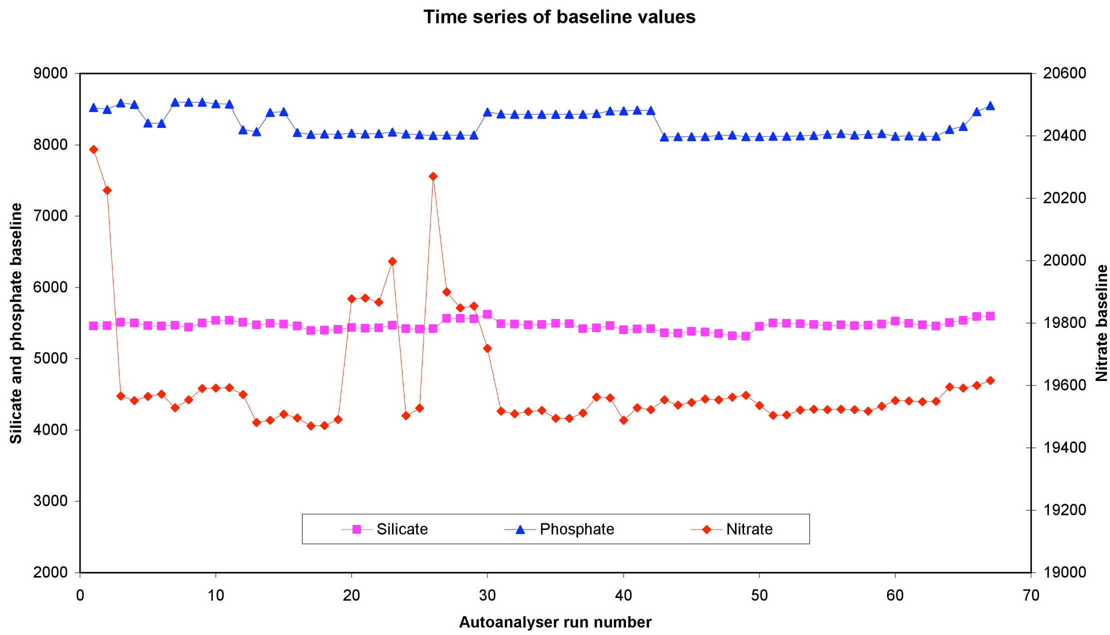

Figure 14: The baseline values for all three chemistries.

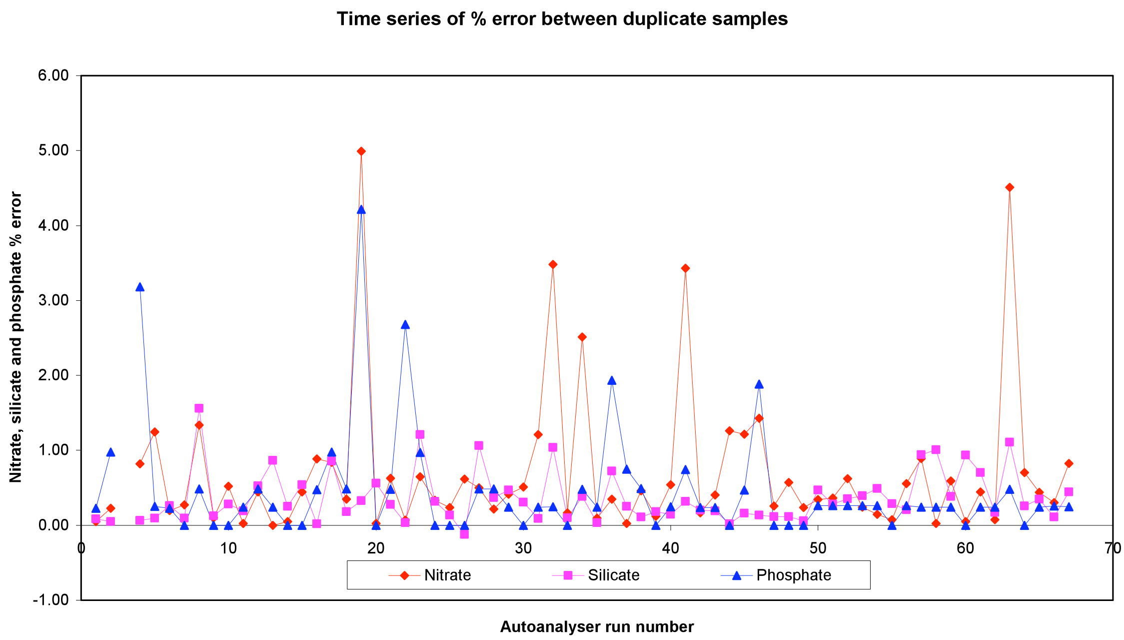

Figure 15: The time series of % error for each chemistry calculated from duplicate drift samples

In almost every run, a couple of bulk standard samples were analysed. These samples were from a large volume water sample taken on a previous cruise in a carboy. All biological life was killed using mercuric chloride. The sample is a deep-water sample and so is relatively high in nutrients. This sample was run just to check the performance of the analyzer from run to run. As can be seen in Figure 16 the bulk nutrient value showed little change throughout the cruise. There is a slight change in the silicate values from run 30 which coincides with when the artificial seawater contamination was resolved and so may be a by-product of this. Further analysis will take place back at NOCS.

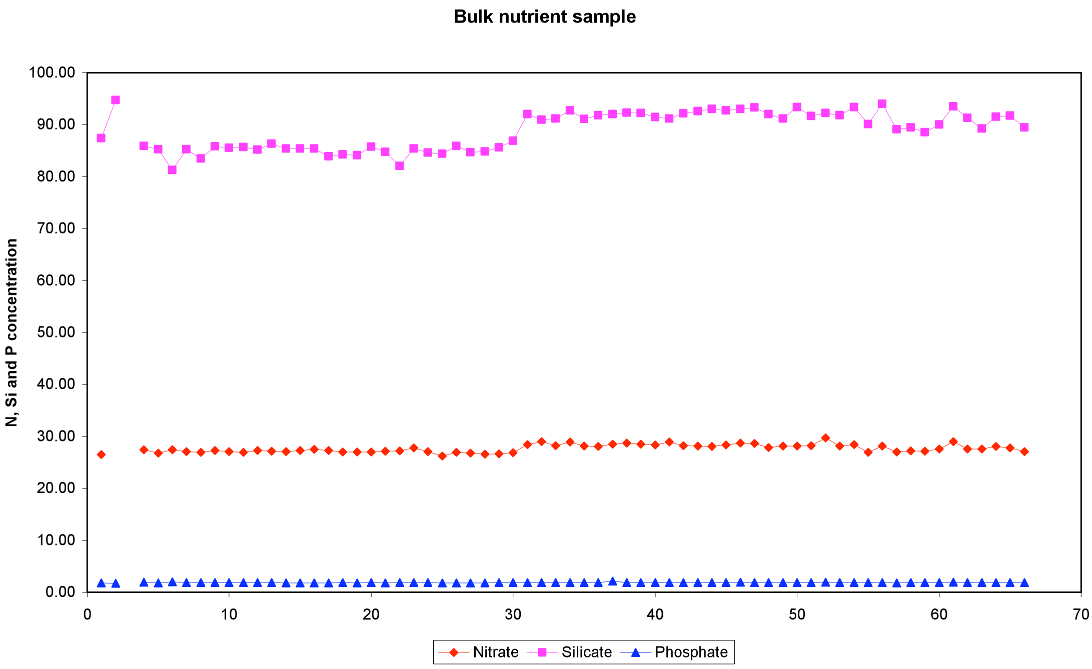

Figure 16: Time-series of the bulk nutrient sample that was analysed on almost every run.

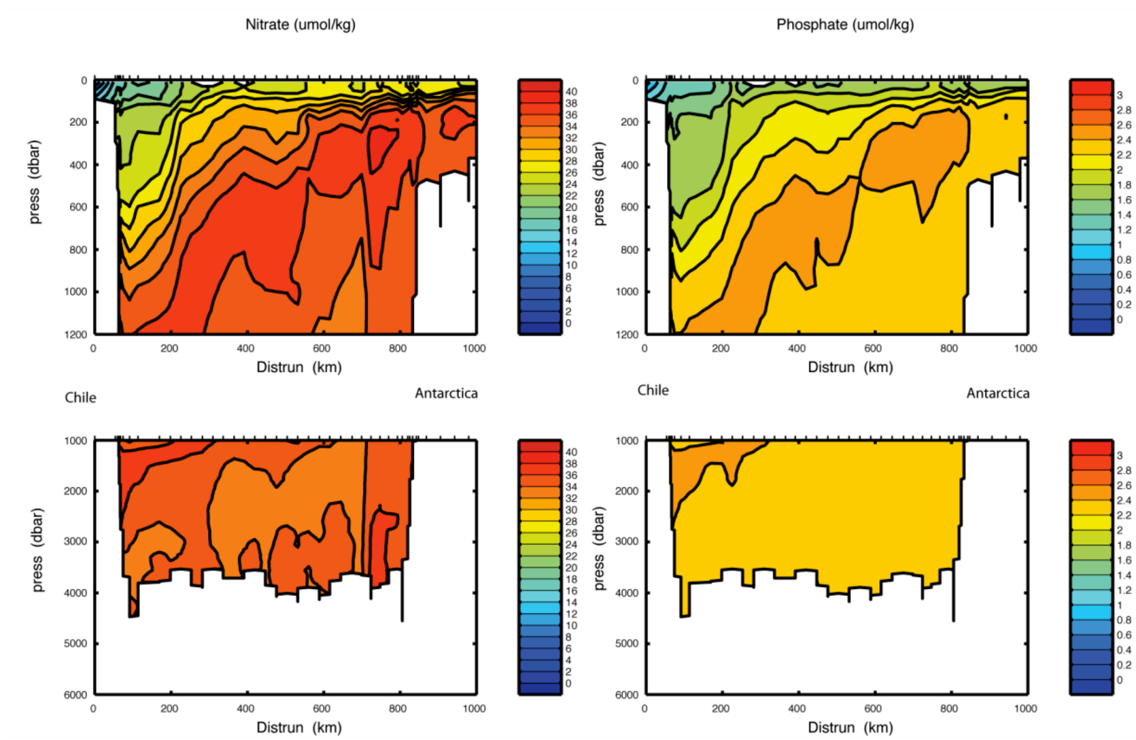

Figure 17: Contour plots for the parameters of nitrate and phosphate along section SR1

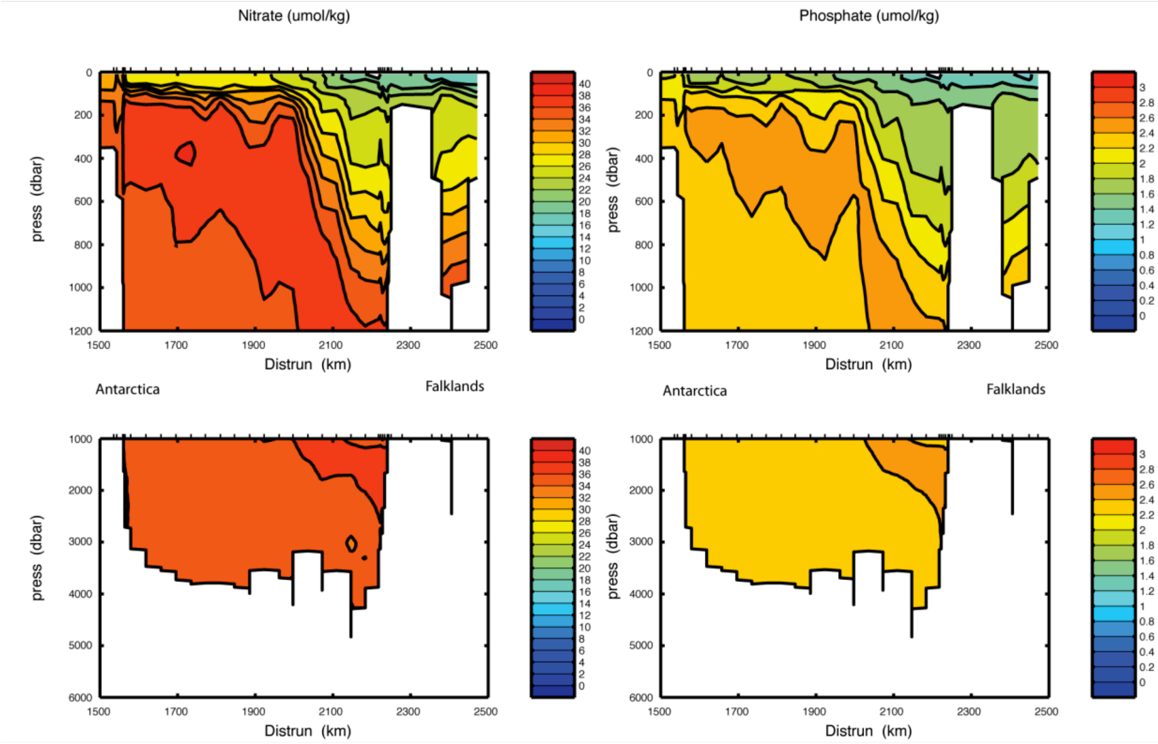

Figure 18: Contour plots for the parameters of total nitrate and phosphate along section SR1b

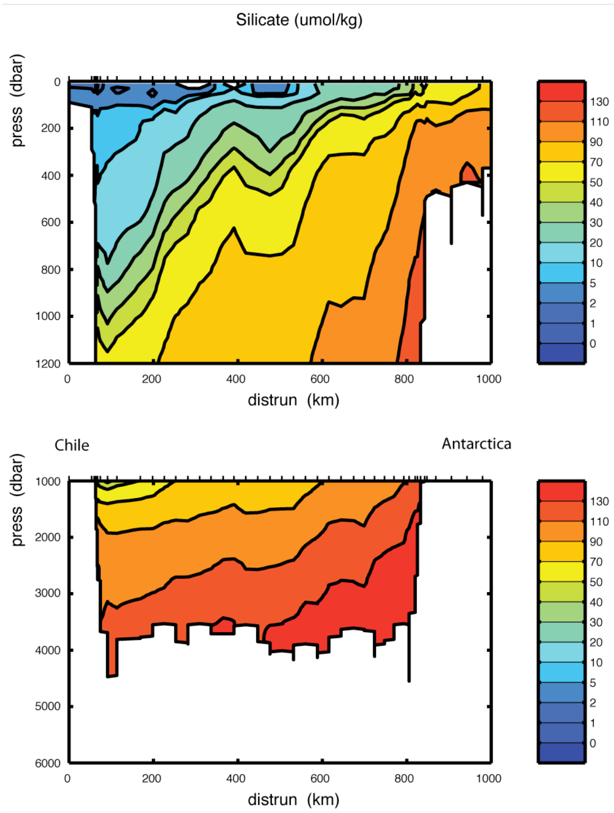

Figure 19: Contour plots for the parameter of silicate along section SR1

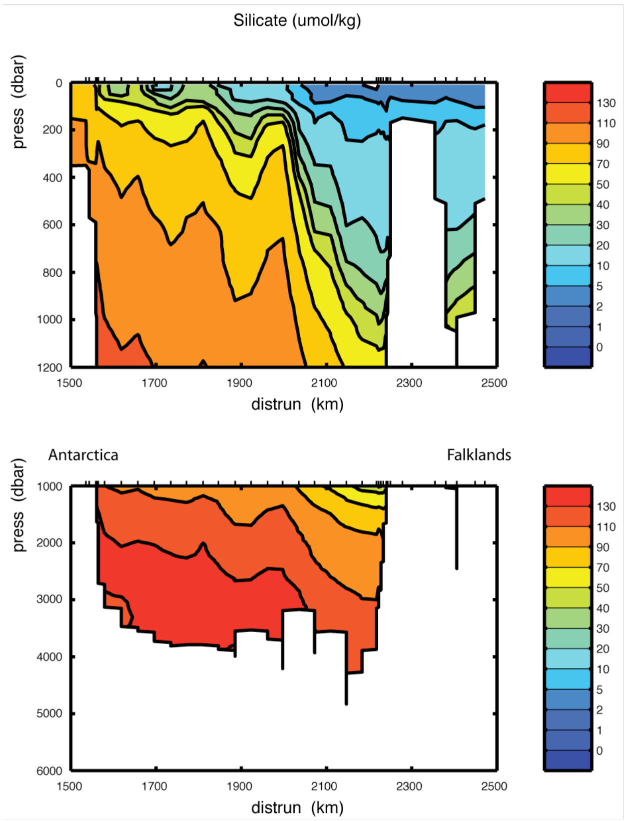

Figure 20: Contour plots for the parameter of silicate along section SR1b

5.4 References

Kirkwood, D. (1996). Nutrients: Practical notes on their determinations in sea water. ICES Techniques in marine environmental sciences. Copenhagen, International Council for the Exploration of the Sea**:** 25.

Mark Stinchcombe, Maria Salta and Glaucia Berbel

6. Carbon Parameters

6.1 Rationale

The Southern Ocean is an important region for ventilation of the deep ocean. Deep water upwelling to the surface leads to exchanges of heat, carbon dioxide (CO_2), and other gases with the atmosphere. Most of the anthropogenic CO_2 taken up by the Southern Ocean is transported north and downward along equal density surfaces (Caldeira and Duffy, 2000), presumably in Antarctic Intermediate Water and Sub-Antarctic Mode Water. A reduction of the vertical mixing and upwelling in the Southern Ocean would probably increase the atmospheric CO_2 level (Sarmiento et al., 1998; Matear and Hirst, 1999). Global warming might provoke such changes in the circulation of the Southern Ocean (Sarmiento et al., 1998).

The UEA carbon and tracer work on JC031 is part of a SOFI (Strategic Ocean Funding Initiative) bid to the Oceans 2025 program. A focus of Theme 1 in Oceans 2025 is the overturning circulation of the Atlantic and the Southern Oceans. A major aim is to estimate new property budgets and transports of heat, freshwater, and carbon. The Drake Passage sections are part of a series of oceanographic sections in the Atlantic and Southern Oceans, which will be carried out by the National Oceanography Centre (NOC) and collaborators in the years 2008-2010. UEA contributes to this program with measurements of the inorganic carbon system and the chlorofluorocarbon (CFC) family of transient tracers along these hydrographic sections.

6.2 SOFI Objectives for JC031

1. Quantification of the distribution and transports of natural and anthropogenic inorganic carbon across sections WOCE A21 (also called SR1) and SR1b in Drake Passage.
2. Determination of long-term variation in carbon and tracer properties across the SR1 WOCE section by comparison to data from 1990.
3. Quantification of a carbon budget for Drake Passage between both sections.
4. Quantification of a carbon budget for the South Atlantic by combining the cruise data with results from other oceanographic sections.

Additional objectives:

5. A comparison of the UEA and CASIX systems for underway pCO_2 in surface water and marine air (PhD project Elizabeth Jones).
6. A better understanding of the processes governing CO_2 air-sea gas transfer and inorganic carbon chemistry in different regions of the Antarctic Circumpolar Current, including effects of biological activity, sea ice and calcification (PhD projects Elizabeth Jones, and Anastasia Charalampopoulou).

6.3 Methods

6.3.1 Underway pCO_2 and Oxygen

6.3.1.1 Seawater Supply and Seawater Temperature

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. Unfortunately, the inlet temperature had a large offset (far beyond the 0.1°C accuracy needed for pCO_2 analysis) on JC030 and JC031. Consequently, a full comparison will be made between CTD temperatures and onboard temperature sensors, notably the TSG temperature, the SBE45 temperature, located close to the TSG, and temperature sensors on the CASIX and UEA pCO_2 systems. 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. The bypass was incidentally used for discrete sampling of seawater for dissolved inorganic carbon (DIC) and alkalinity.

6.3.1.2 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 above the bridge (monkey island) at about 16 m height. Seawater from the ship's surface water supply was introduced at a rate of 2-3 l 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 not dried. The standards bought from BOC amounting to mixing ratios of 248.44 +/- 0.03 (25-B18), 350 (35-B04) and 455.59 +/- 0.08 μ mol CO_2 mol^{-1} (45-B18) had been calibrated against certified NOAA standards. The analyses were carried out for a flow speed of 100 ml 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 the pressure had been corrected for. 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 1 μatm, as determined during previous cruises (e.g., Bakker et al., 2001).

6.3.1.3 Oxygen Concentration of Surface Water

In many oceanic processes oxygen (O_2) is complementary to CO_2. Therefore, it is useful to measure oxygen in combination with CO_2. The O_2 concentration and water temperature were measured with an optode, (model 3930) from Aanderaa. The instrument was contained in a cylindrical titanium housing, 160mm in length and 40mm in diameter. Purpose built titanium housing positioned the optode in the seawater flow. The optical window of the optode was in the wider part of the housing and in the centre of the flow. The external housing was positioned vertically. The optical window of the optode was put in the direction of the flow, in order to minimize any effects from air bubbles. The temperature sensor just entered the wider part of the external housing. The data from the optode were logged on the data logger, model 3660 (Aanderaa), and passed on every minute to the PC of the online pCO_2 system.

The optode had a measuring range of 0-500mM, with a resolution better than 1mM and an accuracy better than 8mM or 5%, whichever is greater (Aanderaa, 2003). The optode was valid for a salinity range of 33-37. Software in the data logger calculates the oxygen concentration (mM) from the raw data and the calibration coefficients of the oxygen sensor. The oxygen optode had its own internal thermometer for the calculation of the oxygen concentration in addition to the external temperature sensor. The O_2 data will be checked against oxygen concentrations determined by the precise Winkler method in surface samples at CTD stations (Mark Stinchcombe and colleagues).

6.3.2 Vertical Profiles of DIC and Alkalinity

6.3.2.1 Rosette Sampling

Water samples for the determination of DIC and alkalinity were drawn from the 20 and 10L Niskin bottles on the CTD rosette and collected in 500ml glass bottles in the usual way to avoid gas exchange with the air. In total, 63 of the 79 CTD stations during the cruise were sampled. Depths were distributed evenly over the water column with a bias towards the upper 1000m. A total of 1380 rosette samples were analysed twice for DIC and alkalinity. Samples were kept cold and stored in the dark. Samples from the upper 500m were analysed within 6 hours of collection, with other samples following within 20 hours of collection. If such rapid analysis was not possible, the samples were poisoned with mercuric chloride (100µl per 500ml sample).

6.3.2.2 Dissolved Inorganic Carbon Measurements

Water samples were first analysed for Dissolved Inorganic Carbon (DIC) also denoted as Total CO_2 (TCO_2). Two different instruments were used for this analysis. The first instrument uses an extractor unit built after the design by Robinson and Williams (1992). For the first instrument samples were measured at about 4°C to prevent bubble formation in the extractor tubing. The second instrument is a Vindta combined DIC/alkalinity instrument (#7, version 3C) and operates at 25°C (Mintrop, 2004). Two replicate analyses were made on each sample bottle. Replicate samples were also drawn from the rosette. The DIC concentration was determined by the coulometric method after the method of Johnson et al. (1987). Generally all samples from one station were run using the same coulometer cell. At least two CRMs (batches 90 and 92) were used per coulometric cell and station. The data await further processing, merging and analysis.

6.3.2.3 Titration Alkalinity Measurements

The alkalinity measurements were made by potentiometric titration with two VINDTA instruments (#4 and #7, version 3C, Mintrop, 2004). The acid consumption up to the second endpoint is equal to titration alkalinity. 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 100 ml), and the analysis cell have a water jacket around them. The titrant (0.1 M hydrochloric acid, HCl) was made in the home laboratory. Samples on one Vindta (#4) were run, after analysis on the stand-along DIC extractor and warming to 25°C. Samples on the second Vindta (#7) were run for both DIC and alkalinity at 25°C. Replicate analyses were run for all samples on the Vindta #7 and for most samples on the Vindta #4. At least two CRMs of batch 92 or 90 were run per station. The alkalinity data need calculation for seawater density and nutrient concentrations. The data await further processing, merging and analysis.

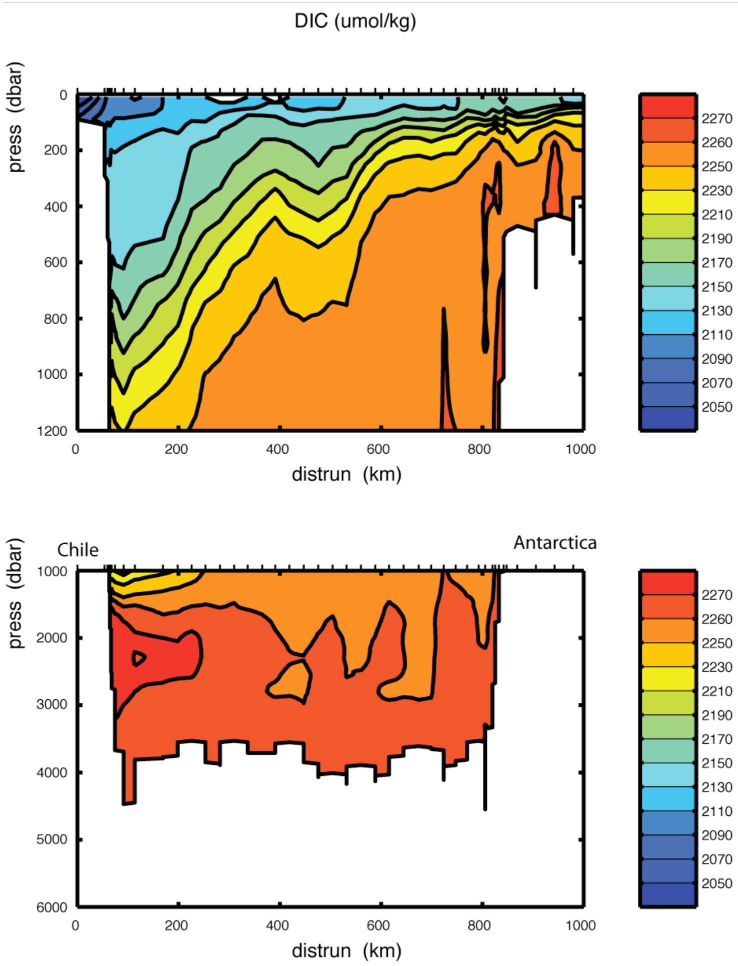

Figure 21: Contour plots for the parameter of dissolved inorganic carbon along section SR1

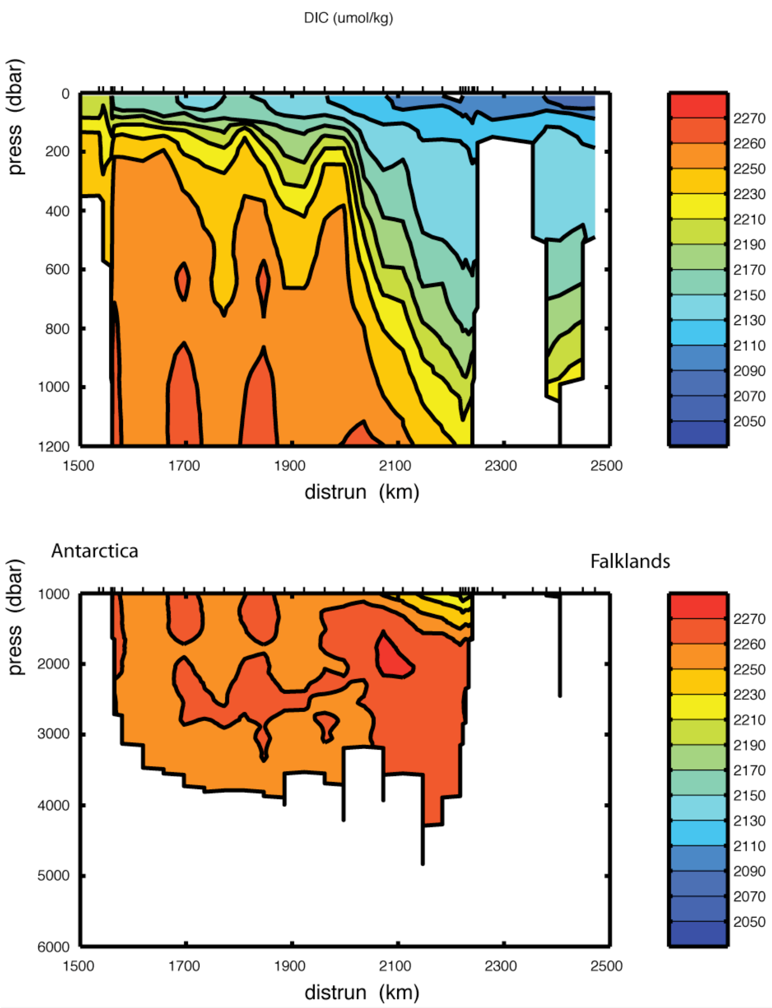

Figure 22: Contour plots for the parameter of dissolved inorganic carbon along section SR1b

6.4 Data Availability

The final pCO_2, DIC, alkalinity, and O_2 data will be stored with other cruise data at the British Oceanographic Data Centre (http://www.bodc.ac.uk/). The data will become publicly accessible once the results have been published. The data will also be submitted to the international, publicly accessible surface water CO_2 database at the U.S. Carbon Dioxide Information Analysis Centre (http://cdiac.esd.ornl.gov/oceans/).

6.5 Recommendation

Stable and calibrated sensors for sea surface salinity and temperature with at least 0.1°C accuracy for temperature for underway of measurements pCO_2 and other parameters.

6.6 References

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Dorothee Bakker, Elizabeth Jones, Jennifer Riley and Sophie Seeyave

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

7.1 Sample Collection and Analysis Techniques

Water samples for CFCs (F11, F12, F113 and CCl_4) and SF_6 were collected from 20 litre or 10 litre Niskin bottles attached to the CTD sampling rosette. The samples were analysed on board 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, pers com.) and the Plymouth Marine Laboratory (PML) SF_6 method (Law et al., 1994, *Mar. Chem.* 48, pp 57-69) 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. During JC031, particular effort was made to replicate station locations previously occupied during WOCE cruises, sampling predominantly from every second cast.

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. 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 on a Porapak Q trap immersed on the headspace of liquid nitrogen. Then the traps were headed 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 CFCs 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 23. 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.

Blank corrections 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 JC031, 13 duplicate samples and 2 triplicate samples were analysed, from which we calculate the following precision, expressed as the ratio of standard deviation to mean concentration:

SF_6	F12	F11	F113	CCl_4
1.76%	0.74%	0.76%	1.56%	3.22%

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 was 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 dataset comprises the second part of three consecutive South Atlantic cruises on the *RRS James Cook* by the UEA CFC/SF_6 team. A total of 1221 samples were analysed during JC031 along the two Drake Passage transects. 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.

The surface water data are plotted in Figure 24 according to station number. The data from both transects show a similar gradient, with concentrations of all compounds increasing from north to south, with discontinuities at the polar front.

Contour plots for F11, F12, F113, CCl_4 and SF_6 are shown in Figures 25-27 (first transect: SR1) and 28-30 (second transect: SR1b). The distributions of the freons and SF_6 seen here are largely consistent with previous studies, showing a broad near surface maximum, and deep water minimum. We also observe a deepening of the contours to the north. A bottom water signal is also evident, which is most pronounced close to the Antarctic shelf. This signal is strongest in the eastern transect (Figures 28-30). The effect of upwelling at the polar front can also be seen in the plots, with low CFC water causing a shallowing of the contours. The final analysis of this data set will involve additional filtering for instrumental problems, correction for standard drift, refined blank correction and assessment of sparging efficiency.

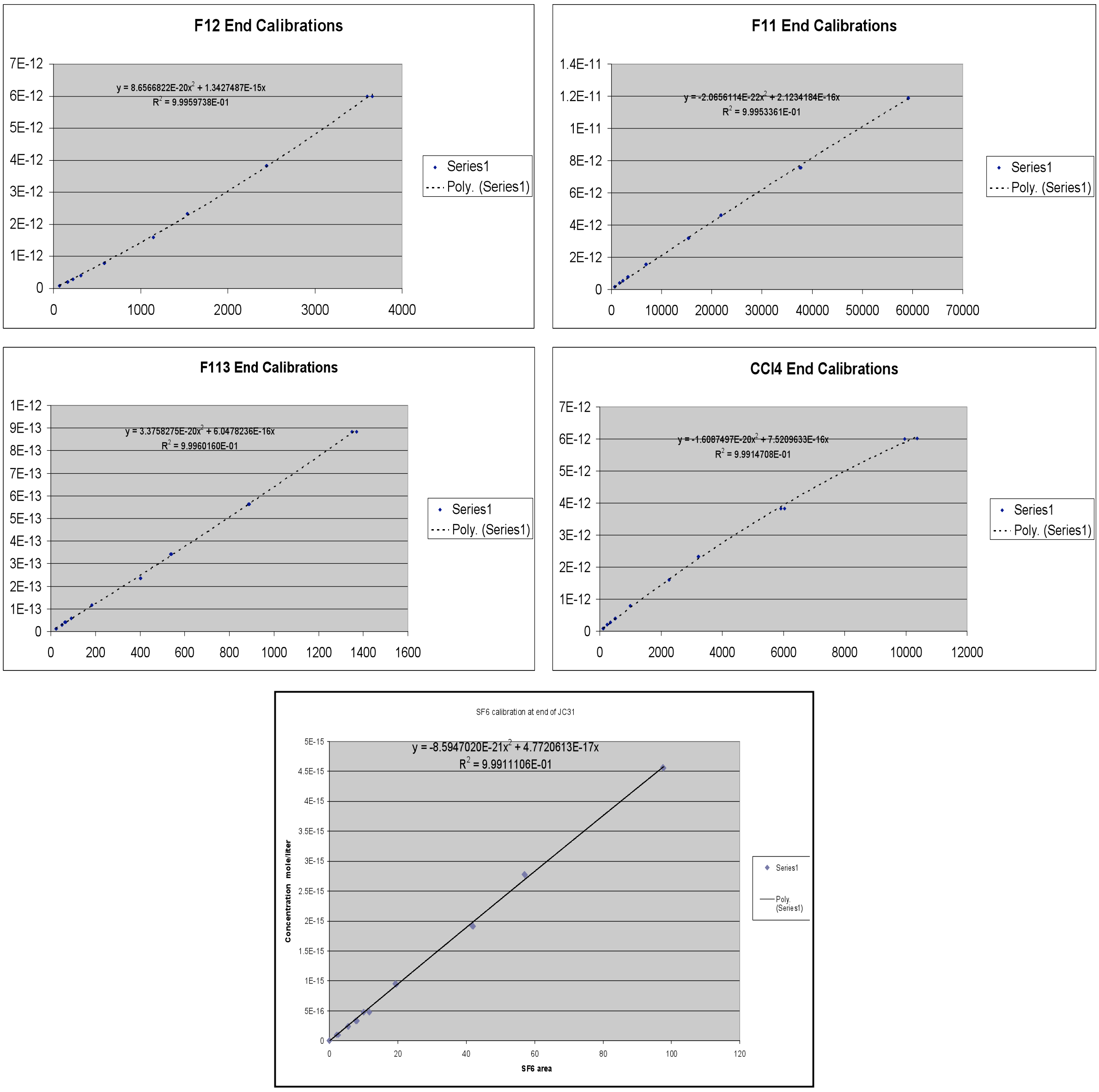


Figure 23: Calibration data from JC031. Units are shown as mol/litre equivalent in seawater. The fits are second-degree polynomials, as used in the onboard calculations.

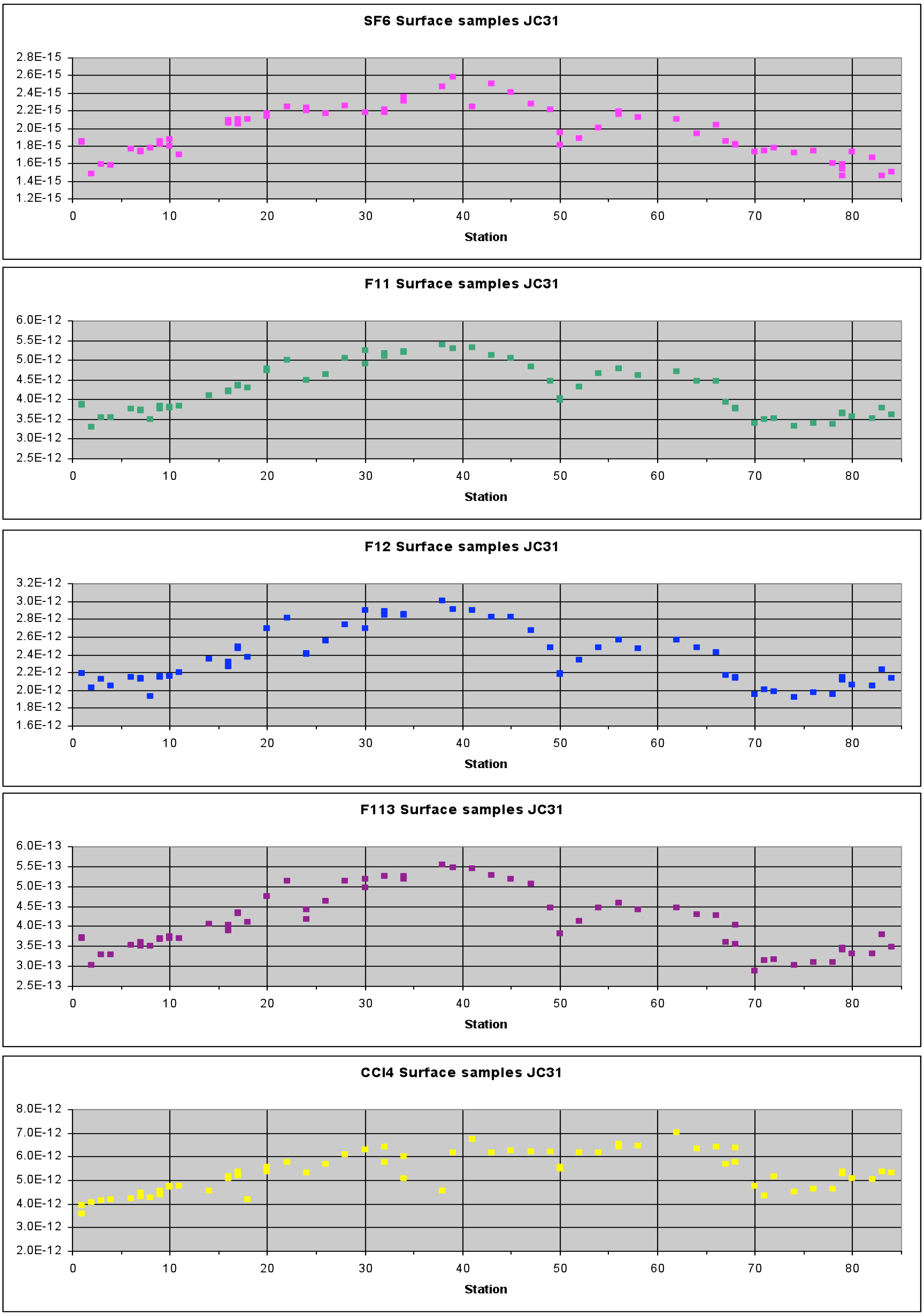


Figure 24: Combined surface seawater data from the two JC031 transects. Stations 1-49 make up section 1 (SR1) (southbound) and Stations 50-83 make up section 2 (SR1b) (northbound).

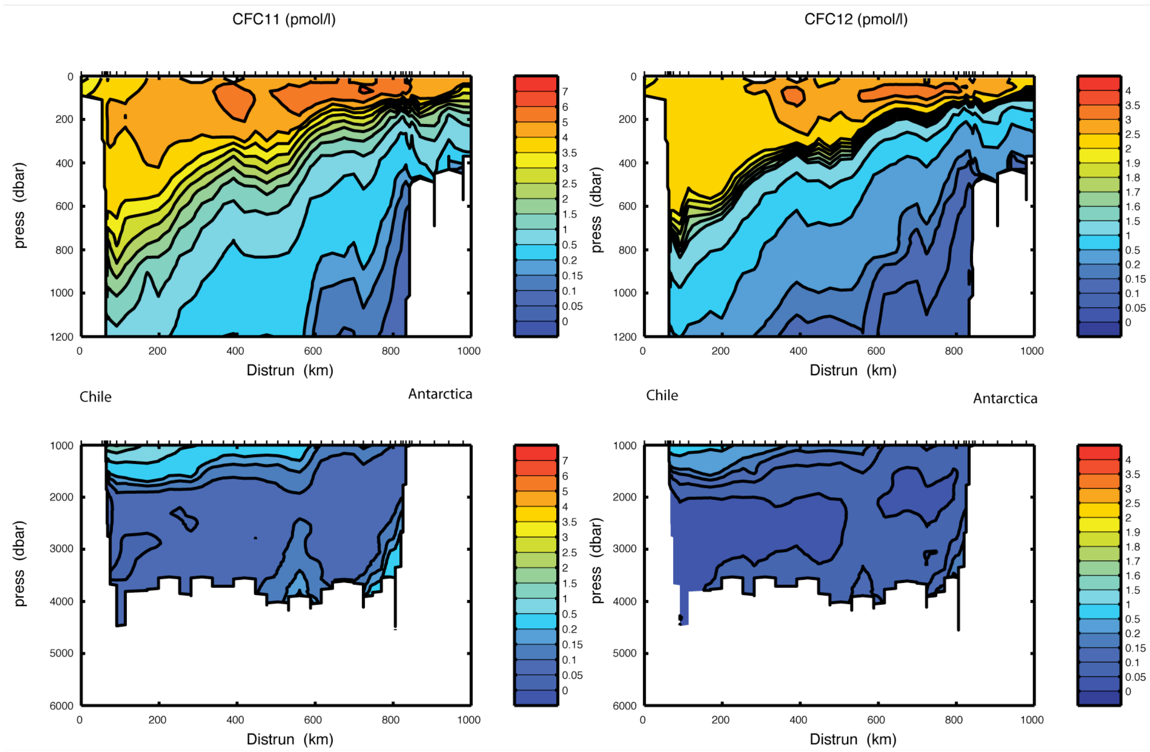


Figure 25: Contour plots of F11 and F12 data from section SR1

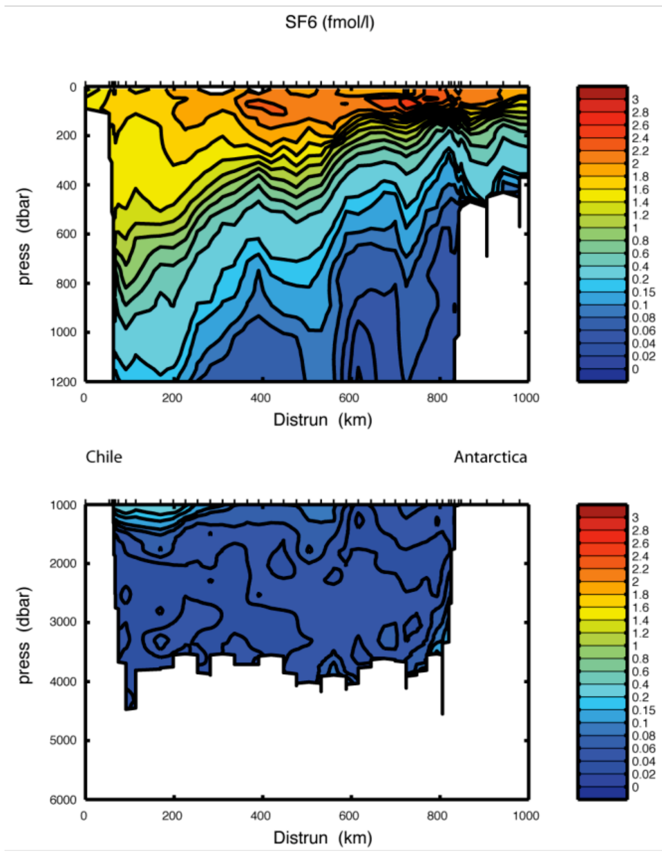


Figure 26: Contour plots of SF_6 data from section SR1

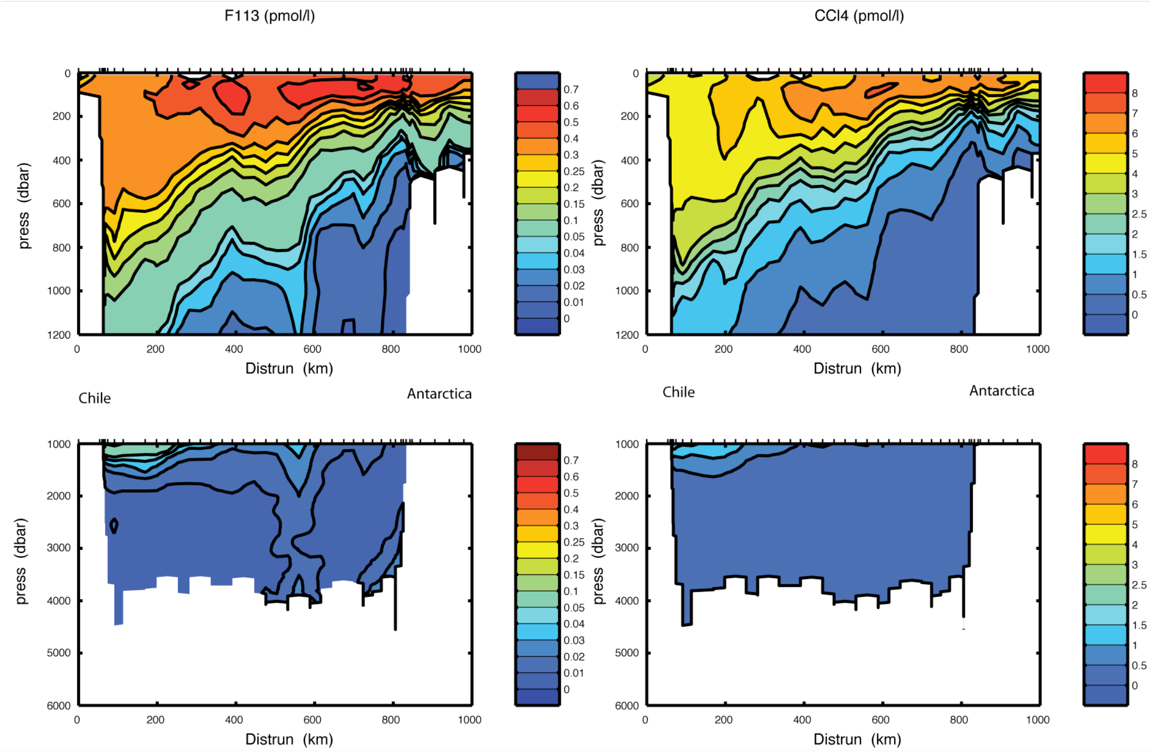


Figure 27: Contour plots of F113 and $CC1_4$ data for section SR1

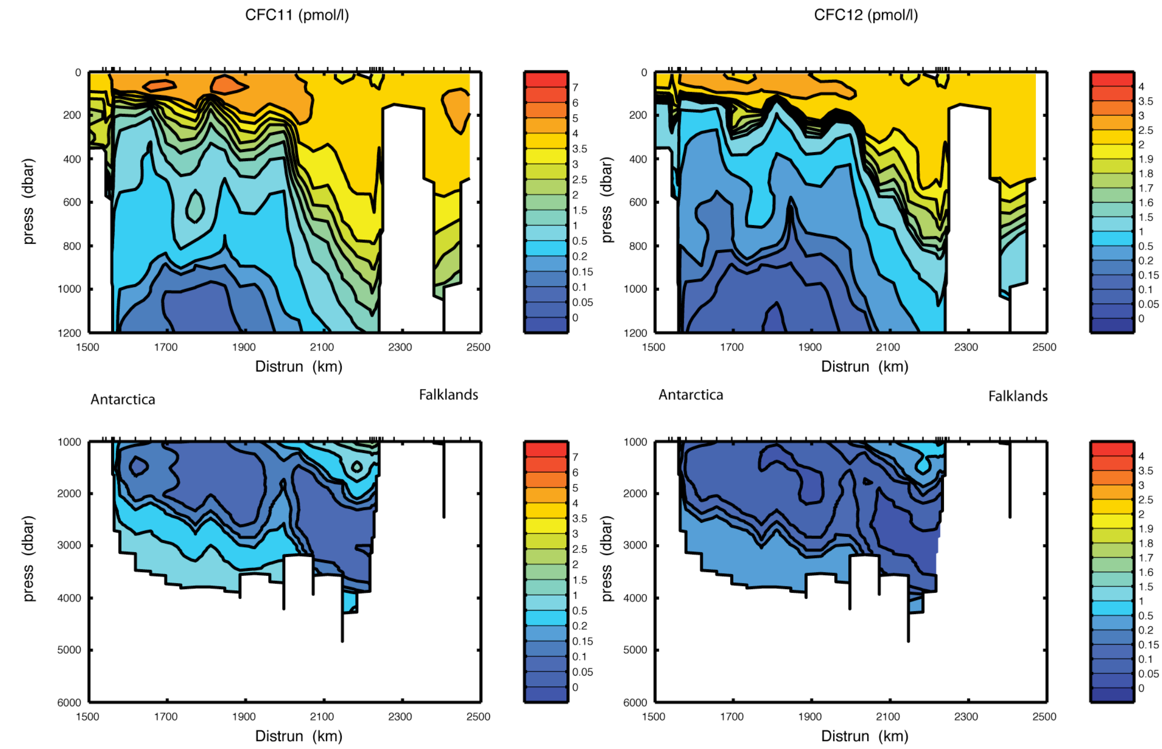


Figure 28: Contour plots of F11 and F12 data from section SR1b

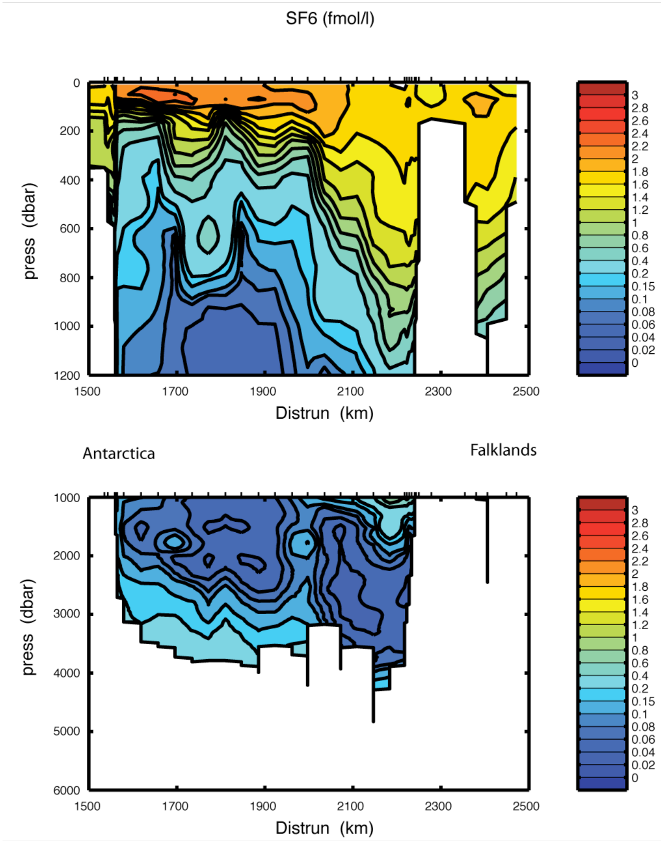


Figure 29: Contour plots of SF_6 data from section SR1b

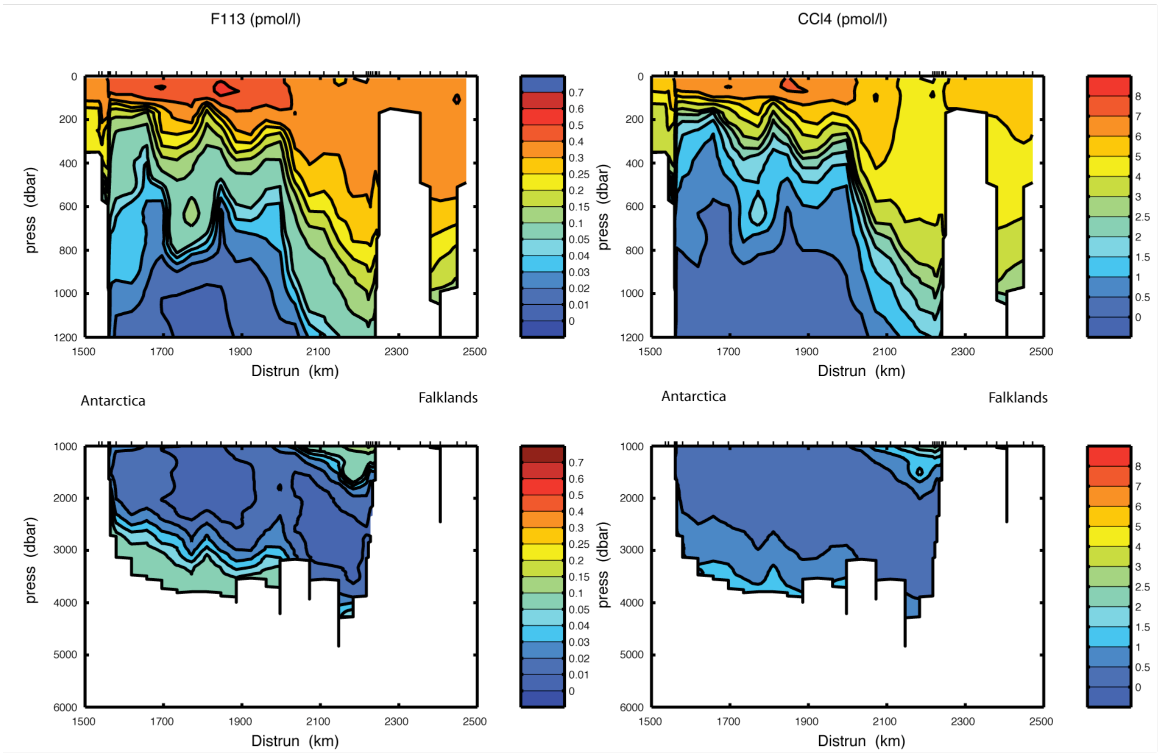


Figure 30: Contour plots of F113 and CCl_4 for section SR1b

David Cooper, John Brindle and Andrew Brousseau

8. Instrumentation

8.1 Ship Fitted Mechanical Equipment Report

8.1.1 CTD Wire No. 1

Initially used, scrolling problems occurred which were eventually overcome by manually scrolling the wire onto the drum, further advice from ODIM is expected on this issue. CTD 1 wire then suffered a wire break resulting in loss of the CTD and the decision was made to switch to CTD 2.

8.1.2 CTD Wire No. 2

More scrolling problems encountered, these were again overcome by manually setting up the scrolling, at which point a "flat spot" was noted, this was at first thought to be caused by a fault in the slip-ring assembly, however, investigation revealed that the termination in the junction box at the wire end had failed, a repair has been affected however this JB should be removed at the earliest opportunity and re-terminated, the box also needs to be re-machined such that correct size cable glands for the CTD wire fit it. The FO core has not been re-connected due to time constraints. CTD 1 termination was also checked at this time and found to be good – see separate report completed by DM (attached).

8.2 Mechanical Portable Equipment Reports

8.2.1 Equipment name: LN2 generator (Orange one)

Faults rectified in use: New fan fitted to heat exchanger unit in CP415 refrigeration plant. On removal of the fan the heat exchanger grill was found to be almost completely choked with dust/dirt. The grill was wire brushed clean and blown through with an air line.
The Dewar was cleaned inside thoroughly by removing the cold heat unit and extraction line. Large quantities of ice were found on the cold head and in the Dewar. The Dewar was left for several days to warm up, but a heat gun was also used to accelerate the warming operation. The Dewar was ragged out as best it could be. An air leak in the delivery line from the air dryer was repaired.

The main capacitor for the cold head motor circuit was replaced when the hold head was found to be no longer making its usual thumping noise, and not receiving the 15V supply.
Charcoal filter replaced with spare (both spare filters found to be years outside there use by dates)

Comments:

The Generator worked reasonably well for the first two weeks of the cruise, and then it stopped producing LN. The Dewar was left open to atmosphere to allow it to warm up and for any ice to melt and moisture to evaporate.

It was left off for two days, and then the system was purged for several hours before putting back on line. It took over thirty hours before liquid nitrogen was produced again.

The system was not producing as much LN as it had been during the pre-seeding weeks, but it struggled on for another week, until it was shut down again after the science had finished. This was only made possible by the fact that the scientists had sent out from the UK 2 x 50L Dewar's which were filled locally in Punta. So we had an excess stock to draw from while the generator was offline.

The generator has run over 8600 hours of total running and I feel that the cold heat needs to be serviced fully with all internal parts checked for excessive wear and all seals replaced.

The generator had been moved down to the hold on JC030, during our time on the ship the hold was not much warmer than the Hangar only just staying above freezing on occasion. The ambient temperature in the hold was less than the manufacturer's specified operating limit of $10^{o}C$.

As of 02/03/09 the generator is again running and has just started producing liquid nitrogen again.

The generator was critical to the CFC work being carried out during the three cruises JC030, 31 and 32.

My personal feelings are that either a second generator should have been provided for a spare or that additional 50L Dewar's should be provided with the Generator. Then possibly the Generator could be left on the vessel during prior cruises to allow for a stock of LN to be built up. If the generator fails the surplus stock can be used. When possible the additional Dewar's could be sent ashore during Mob/Demob's and filled locally.

8.4 Instrumentation Report

8.4.1 Sea Surface Monitoring System

Both FSI temperature sensors were replaced at the start of the cruise. WS3S-351P was replaced after the first scientific section was complete. FSI OTM sn 1334 failed on day 059. This sensor was being used as the remote temperature sensor (Surface Seawater Temperature). It was replaced by FSI OTM 1370 which was due to be sent back to NOCS for recalibration.

8.6 Computing Report

8.6.1 (Vsat Systems) Vigor 5500 Firewall + Verso + Comtech + Orbit dish controller + Telephone Exchange

The spare motor/gearbox unit was not delivered in time for the PA port call and therefore problems with this system continued throughout the cruise. Initial investigations showed that the system would work in point-to-sat mode and after entering the dome to verify that this was not placing undue workload on the faulty unit it was decided to continue to operate the satellite in this mode for as long as possible. After 2 weeks however, this mode started to have difficulty tracking the satellite effectively and the EbNo and BER were seen to fluctuate quite widely. This was initially thought to be due to the very low angle of elevation but as we headed north and the angle increased the situation did not improve. For the remainder of the cruise the system has been used solely in manual mode which necessitates fine adjustment of the satellite every couple of hours and renders it virtually useless in rough seas. It is hoped that the new motor/gearbox will remedy this, although some setting up of the system will also be required. Two faulty telephones found onboard during routine maintenance, awaiting spare 3 way cables to rectify.

Dougal Mountifield, Martin Bridger, Jeff Benson, Mick Myers and Darren Young (TLO)

9. Underway Salinity Samples and SURFMET

9.1 System Description

SURFMET is the onboard surface water and meteorological sampling system for the RRS *James Cook*. The data from the set of sensors are logged by the ship system, TECHSAS. In addition to the standard SURFMET instruments, a new TSG system (SBE45 microTSG) provides another source of underway salinity data. Table 5 gives a summary of the instruments used by the SURFMET system. The surface water instruments are located along the underway system that pumps surface seawater into the laboratories. The meteorological instruments are located above the ship's bridge (Monkey Island).

Table 5: SURFMET instrument details

Instrument	Manufacturer/Type	Serial number	Variable name	Comments
Thermosalinograph – housing temperature	FSI OTM	1374	temp_h	
Thermosalinograph – conductivity	FSI OCM	1333	Cond	
Sea surface temperature	FSI OTM	1334 1370	temp_r	Until JDay 59 After JDay 59
Fluorometer	Wetlabs	WS3S-246 WS3S-351P	Fluo	Until JDay 50 After JDay 50
Air temperature and humidity	Vaisala HMP45A	D1330038	airtemp humidity	
PAR sensors	Skye	28563 28558	ppar spar	Port side Starboard side
TIR sensors	Kipp and Zonen CMB6	047462 047463	ptir stir	Port side Starboard side
Barometer	Vaisala PTB100A	RO45005	Press	
Wind speed and direction	Gill Windsonic anemometer option 3	064537	speed direct	
Transmissometer	Seatech	CST1132PR	Trans	
Voltage converters	Nudam 6017, 6018			+/- 5V
SBE45 Micro TSG	Seabird	0231	salin, cond, temp	Stored in tsg files, rather than SURFMET

9.2 Routine Processing

Files were transferred from the onboard logging system (TECHSAS) to the UNIX system (data32) 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 Julian day number. These were copied to met_jc031_d***_edit.nc for editing.

The data were adjusted according to the calibration equations specific to the serial number of each instrument. This was carried out by the mcalib_surfmet.m script. The variables which did not require calibration in this way are: conductivity (cond), air temperature, humidity, and wind speed and direction. Spikes in the data were removed by eye, and converted to missing data values (NaN) using the mplxyed.m script.

The data is logged every second, and is averaged into 1-minute bins using the script mavg_surfmet.m. To avoid problems associated with averaging wind direction over time, the speed and direction are first converted to eastward (u) and northward (v) components, using the script muvsd.m. These are averaged in time, and then are converted back to obtain the average direction. The u and v components are kept in the new minute-averaged file (met_jc031_d***_avg.nc) in addition to the speed and direction.

Salinity is calculated from the conductivity variable (cond) using the script mcalc_sal.m. First, conductivity ratio is calculated by the seawater routine 'sw_condr.m', which divides cond by the conductivity at S=35psu, T=15°C, p=0db. Salinity is calculated from the conductivity ratio using 'sw_salt.m', which uses the UNESCO algorithm from Fofonoff and Millard, (1983). Pressure is set to zero for this calculation. The housing temperature (temp_r) is used for temperature, since this is the temperature at which the conductivity is measured by the instrument.

The daily navigation files (nav/posmvpos/pos_jc031_d***_raw.nc) were also copied before editing (pos_jc031_d***_edit.nc). They were then averaged into 1-minute bins using mavg_nav.m. Latitude and longitude were merged from the navigation files into the SURFMET files using mmerge_surfmet_nav.m. The files from each day were then appended together using mapend.m.

9.3 Calibration of Underway Salinity Data

Two approaches were taken towards the calibration of the underway salinity data. The first involved measuring the salinity of samples collected from the thermosalinograph (TSG) outflow, and the second used surface salinities from the CTD casts.

9.3.1 TSG (Thermosalinograph) Bottle Samples

Water samples from the TSG outflow pipe were collected in 200ml flat glass bottles, roughly every 4-6 hours (see Table 6 for the times of collection). 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 in the controlled temperature laboratory for a minimum of 24 hours before analysis, to allow their temperature to adjust to the ambient temperature of the laboratory. A total of 88 TSG samples were taken over the duration of the cruise.

The conductivity ratio of each sample was measured by the Guildline 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 for 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. The FSI salinity data were then merged into this file, using the mmerge Mstar tool. This method interpolated the FSI salinity values onto the time levels at which salinity samples were taken from the TSG outflow.

The offset between the FSI salinity and the bottle sample salinity was calculated and found to have a mean value of 2.9psu. It was found that the second method of calibration (using surface CTD salinity) gave a better fit than the bottle salinities, and so the calibration was completed this way (see next section).

9.3.2 Surface CTD Salinity

Another method for the calibration of the underway salinity is to use the surface salinity values from the CTD casts. On JC031, 80 CTD casts were taken between Julian days 36 and 58. The salinity values interpolated onto the 5.5db level (which corresponds to the depth of the TSG water intake) were merged with the FSI salinity time series, according to time.

Figure 31 shows the salinity values from the CTD, along with the salinities from the FSI sensor interpolated onto the time points of the CTD salinity values. There is a large offset between the two data sets, with the FSI salinity consistently higher than the CTD salinity. The mean offset is 2.9psu.

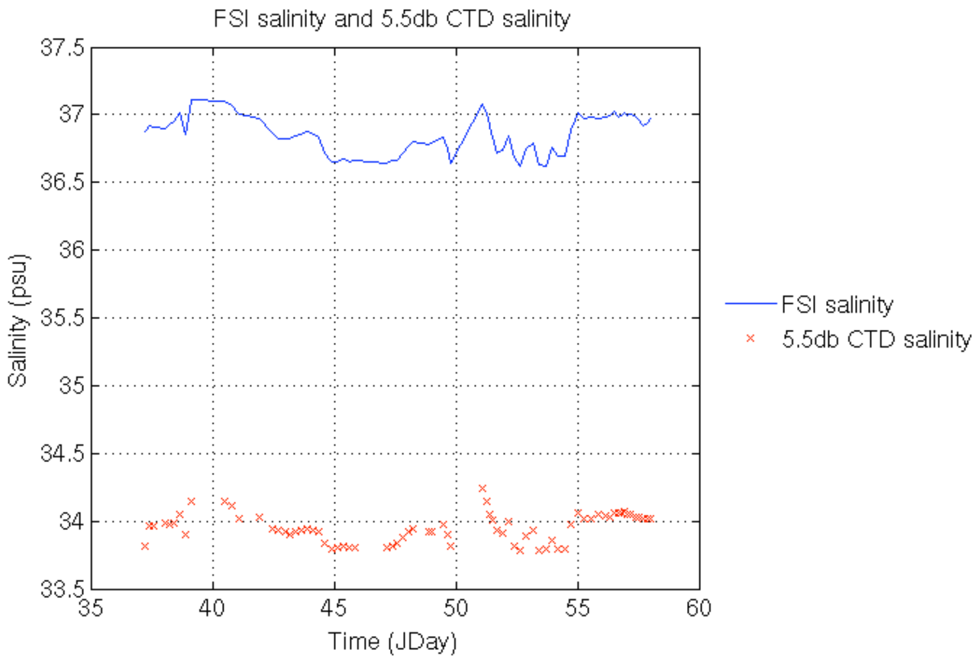


Figure 31: FSI (blue curve) and CTD (red points) salinity with time. The FSI salinity has been interpolated onto the time points at which the CTD measurements were taken.

Figure 32 shows the offset between the FSI and CTD salinities, as a function of salinity (a) and as a function of temperature (b). Three outlying points have been removed from the data. The salinity offset has a linear dependence on both salinity and temperature. Also shown in Figure 32 are the least-squares fit lines for each relationship, with r-squared values of 0.5212 and 0.7171 for salinity and temperature respectively.

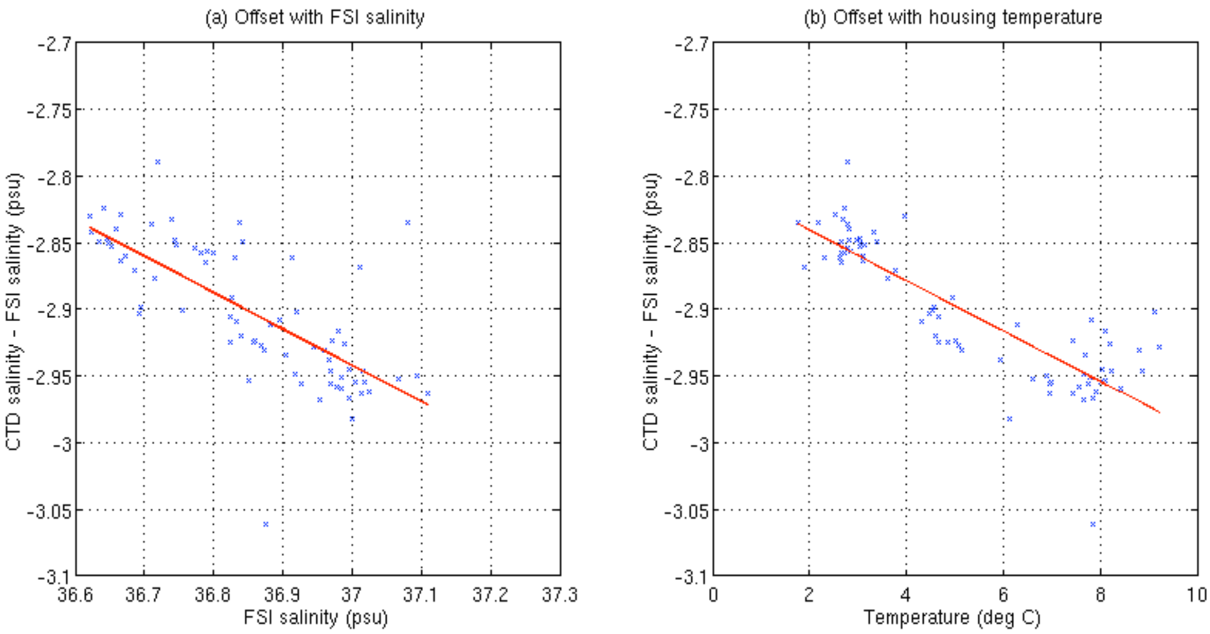


Figure 32: Offset between FSI and CTD salinity (CTD-FSI), as a function of salinity (a), and as a function of temperature (b), with least-squares regression lines.

The equation of the least-squares fit line for the temperature dependence is,

$$\text{offset} = -0.0189\ T - 2.8028, \qquad (1)$$

When this linear temperature-dependent offset is added to the FSI salinity, the mean difference between the corrected FSI salinity and the CTD salinity is less than 10^{-4}psu, with no significant salinity dependence. Figure 33 shows the corrected FSI salinity, along with the CTD salinity.

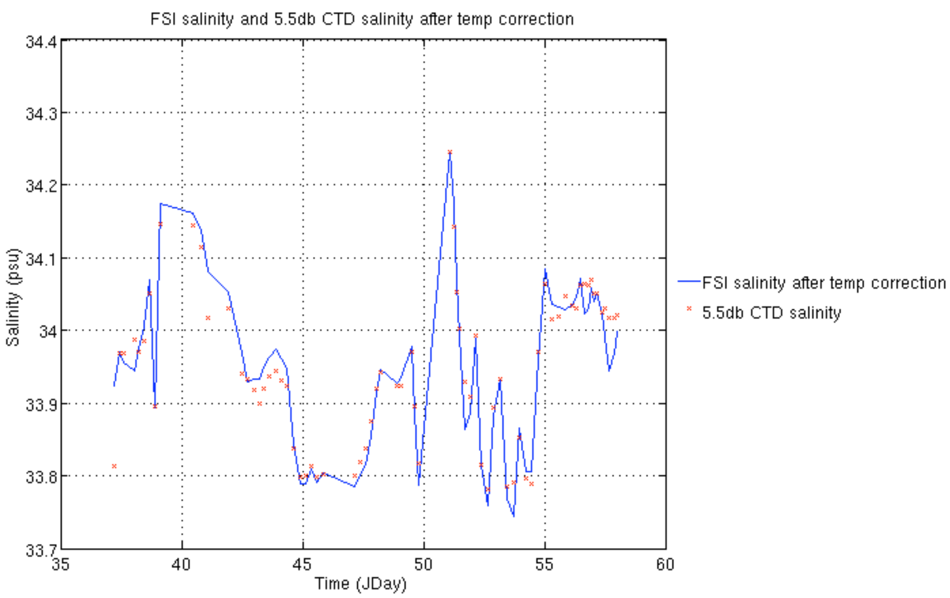


Figure 33: FSI (blue curve) and CTD (red points) salinity with time, after the temperature dependence has been removed from the FSI data.

The full SURFMET time series for the duration of JC031, with the routine data processing applied, is given in the file:

/data32/cruise/pstar/data/surfmet/met_jc031_d033-61.nc

The linear offset given by equation 1 was applied to the salinity data this file, using msal_correct_surfmet.m. The resulting salinity-corrected version is:

/data32/cruise/pstar/data/surfmet/met_jc031_d033-61_sal_corrected.nc

9.4 SBE45 Salinity Sensor

In addition to the FSI salinity sensor, the SURFMET system includes an SBE45 micro TSG instrument. The salinity measurements from this instrument are stored in the TSG files. These files were processed daily in much the same way as the SURFMET files (copied for editing, de-spiked using mplxyed, averaged into 1-minute bins, merged with navigation, and appended).

The salinity from the SBE sensor is shown in Figure 34, along with the salinity from the surface CTD data (described in the last section). Three outlying points have been removed from the CTD salinity data.

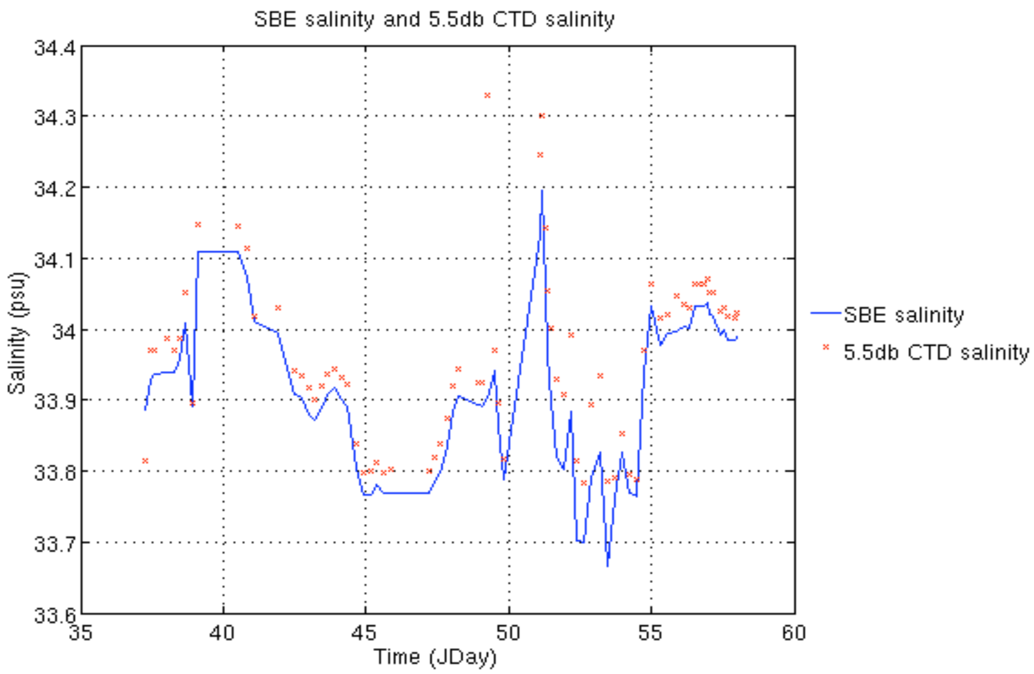


Figure 34: SBE (blue curve) and CTD (red points) salinity with time. The SBE salinity has been interpolated onto time points at which CTD measurements were taken.

The offset between CTD salinity and SBE salinity is shown in Figure 35 as a function of salinity (a) and temperature (b). With the exception of a small cluster of points, there is a near-constant offset between the SBE and CTD salinities with a mean value of 0.03psu. The histogram in Figure 36 shows that the majority of points fall within the 0.03psu bin, justifying the use of a constant offset correction. To correct the SBE salinity data, a correction of +0.03psu should be applied.

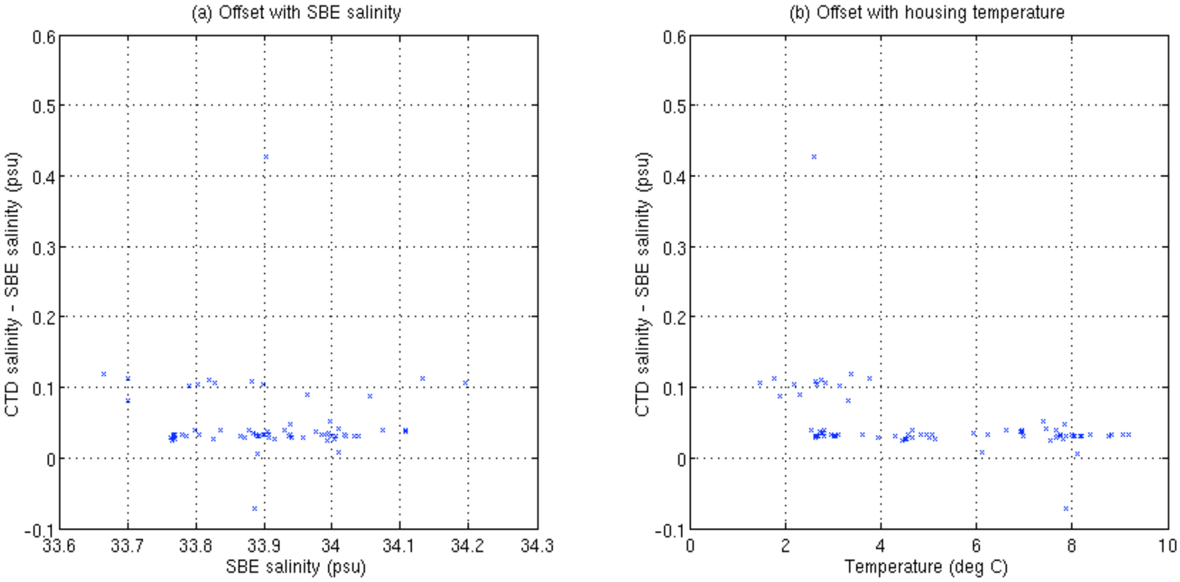


Figure 35: Offset between SBE and CTD salinity (CTD-SBE), as a function of salinity (a), and as a function of temperature (b).

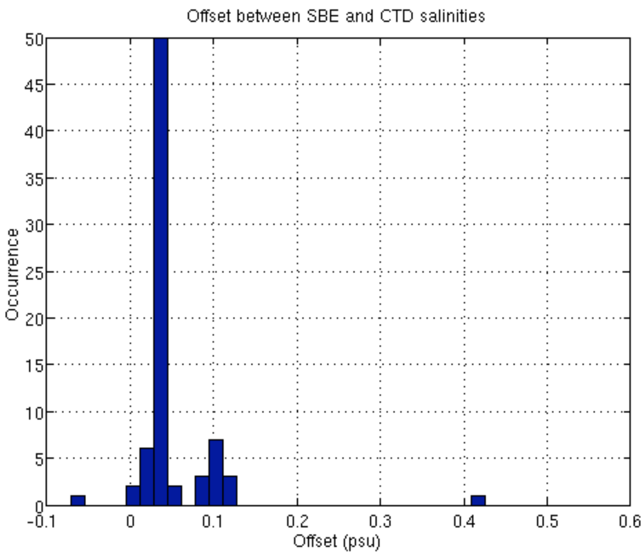


Figure 36: Histogram showing the incidence of each offset value between SBE and CTD salinities.

The full time series for the SBE microTSG, with the routine data processing applied, is given in the file:

/data32/cruise/pstar/data/tsg/tsg_jc031_d036-61.nc

The constant offset of +0.03psu was applied to the salinity data this file, using msal_correct_tsg.m. The resulting salinity-corrected version is:

/data32/cruise/pstar/data/tsg/tsg_jc031_d036-61_sal_corrected.nc

9.5 Sea Surface Temperature

The sea surface temperature data is stored in the temp_r variable in the SURFMET files. Figure 37 shows this plotted against time, along with the TSG housing temperature (temp_h). The sea surface temperature appears to be warmer than the housing temperature for most of the time, suggesting that temp_r is not calibrated correctly. This problem was highlighted on JC030. Time did not allow for the correction of sea surface temperature data during JC031, but it is suggested that the CTD temperature at a depth of 5m may be used to determine any offset.

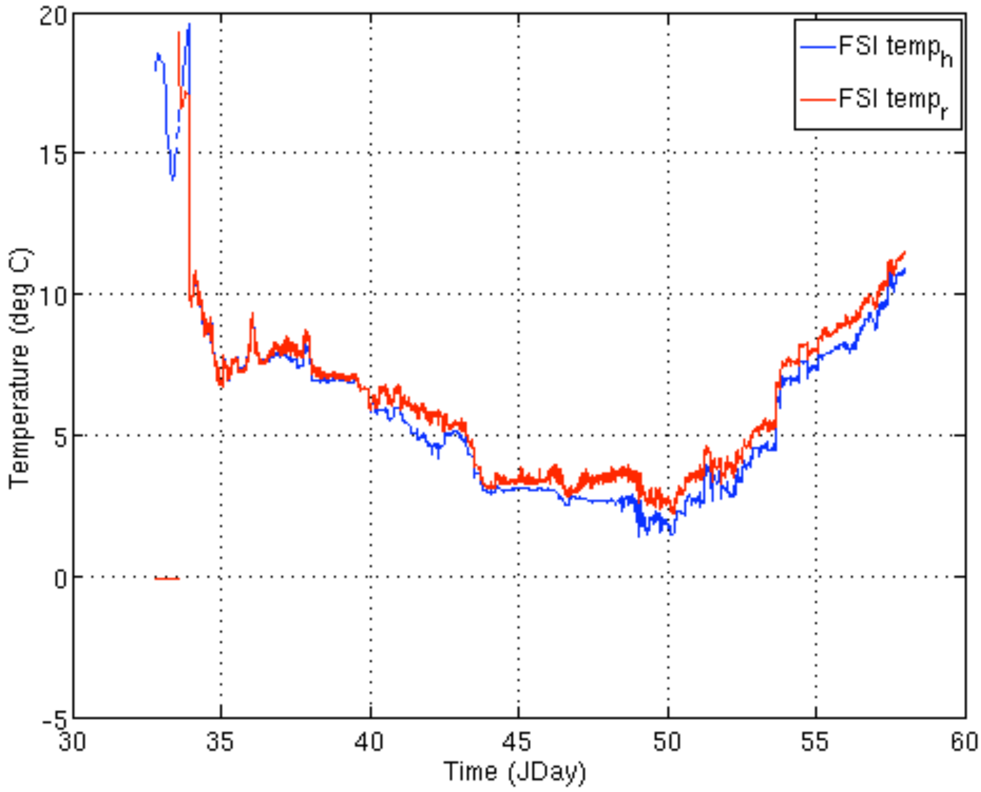


Figure 37: Sea surface temperature (temp_r) (red) and TSG housing temperature (temp_h) (blue) with time, from the start of JC031 until Julian day 59, when a new instrument was installed for temp_r.

9.6 Underway Maps

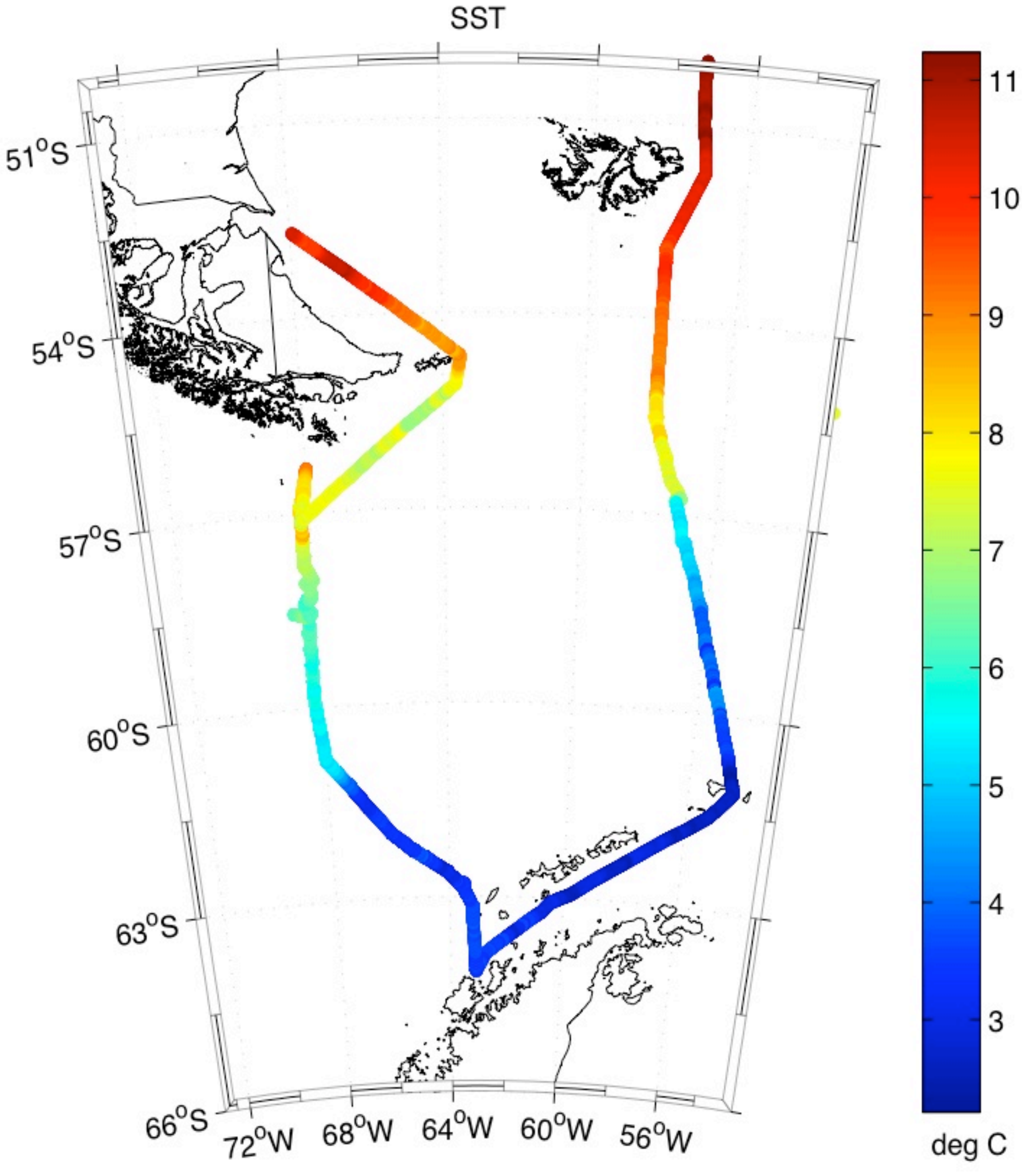


Figure 38: Sea surface temperature (temp_r variable in SURFMET file) along the ship track of JC031.

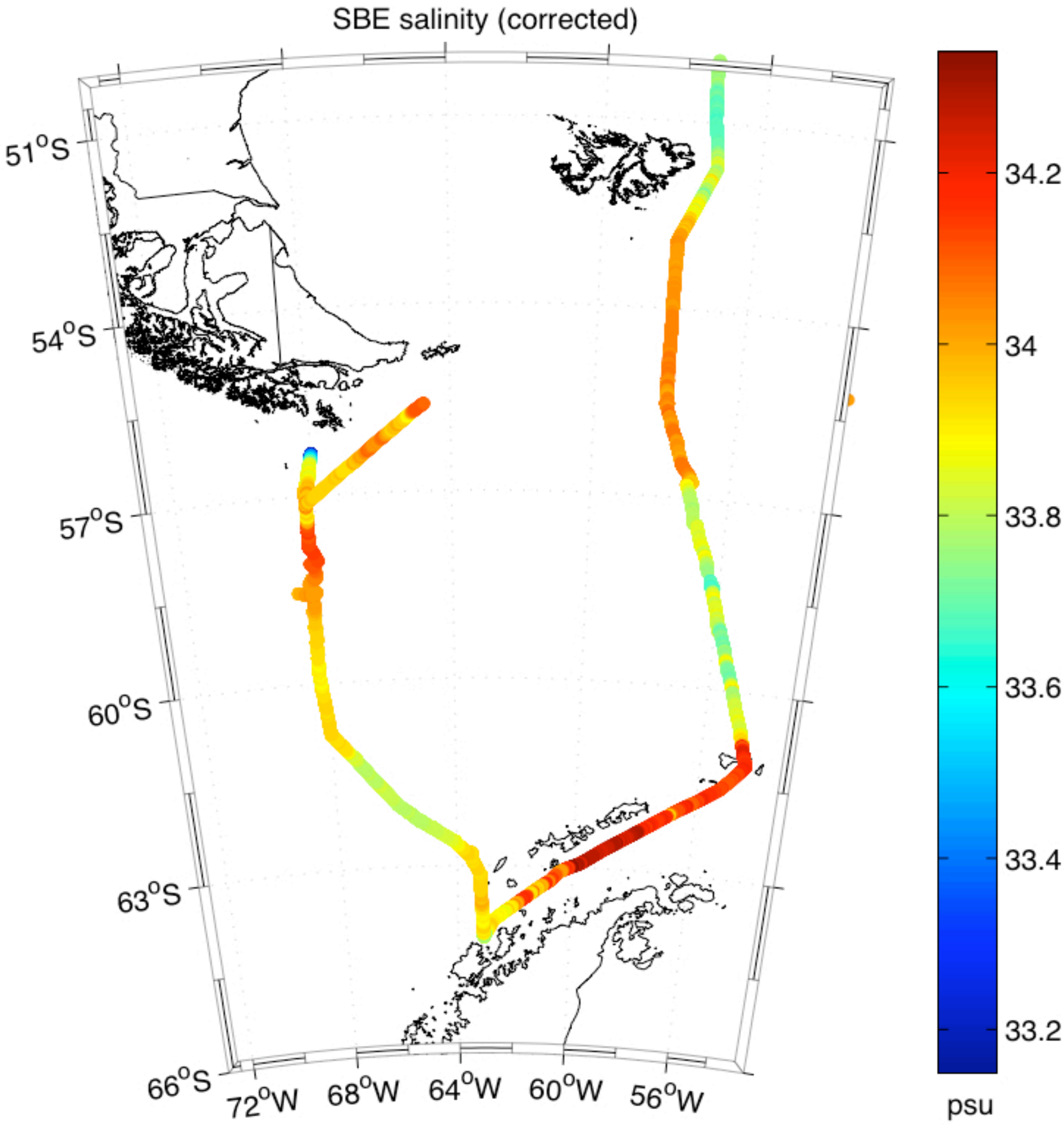


Figure 39: Sea surface salinity, corrected for offset using surface CTD measurements (salin_corrected variable in tsg file) along the ship track of JC031.

Table 6: Times at which TSG bottle samples were collected

JDay	Time (GMT)	JDay	Time (GMT)
35	1835	47	1732
35	2129	47	2240
36	0023	48	0141
36	0357	48	0344
36	0910	48	2347
36	1340	49	0229
36	2141	49	0650
37	0000	49	0930
37	0217	49	1316
37	0526	49	1633
38	0425	50	0125
38	0815	50	0505
38	1020	50	1553
38	1359	50	1935
38	1914	51	0153
39	0109	51	0531
39	1247	51	1429
39	1915	51	1837
40	0629	52	0623
40	0930	52	1154
40	1514	52	1808
41	0534	53	0024
41	1108	53	0654
41	1923	53	1426
42	0745	53	1954
42	1208	54	0152
42	1423	54	0808
43	0000	54	1421
43	0732	54	2018
43	1238	55	0317
43	1842	55	0955
44	0057	55	1725
44	0558	56	0014
44	1210	56	0551
44	1827	56	0959
45	0032	56	1809
45	0629	56	2125
45	1156	56	2339
45	1702	57	0152
45	2242	57	0437
46	0453	57	1329
46	0836	57	1839
47	0707	57	2249
47	1200	58	1633

Lesley Allison and Steven Alderson

10. Bathymetry

Bathymetry data were collected by an EA600 echo sounder and processed daily. This model is a single beam echosounder that operates at the industry standard frequency of 12kHz, which allows full ocean depth sounding. This particular model also has a multipulse function that allows a higher pinger rate and thus better accuracy than normally possible. The transducers for the EA600 are mounted on the extendable drop keels to allow them to be positioned in clear water away from disturbances caused by the ships hull.

The data was logged by the TECHSAS system and further processing was undertaken using the Mstar suite as follows.

Edit - 1Hz data were edited – initially data were discarded outside of the range 5m to 10000m. data were also manually de-spiked using ‘mplxyed’.

Average - Data were binned into one minute averages using ‘mavrge’.

Navigation - Position data from posmvpos files were merged on time onto the depth data.

Correction - Uncorrected depths were corrected using carter tables.

Section profiles - Bathymetry profiles for each of the SR1 and SR1b sections were constructed by extracting appropriate data cycles and then binning onto a 1 minute latitude grid.

Elaine McDonagh

11. Lowered Acoustic Doppler Current Profiler (LADCP)

11.1 Instrument Setup

The JC031 Drake Passage cruise began in Punta Arenas equipped with a compliment of 3 fully functioning LADCP's, all the same model (RDI Workhorse Monitor 300 kHz), two of which were comprised of a titanium casing and the other had an aluminium casing. The original LADCP was ready installed from the previous cruise (JC030), and was bolted securely to the CTD frame on the opposite side to the CTD fin. The battery life of the LADCP only held up deployment on the shallow stations, but disruption due to charging time was minimal. Between a deep station and a shallow station where the steaming time was only an hour the disruption caused by charging the LADCP was reported as approximately 15 minutes. The data was downloaded from the instrument by the CTD technicians. As with other NOCS cruises the LADCP's were configured to have a standard 10x16m bins, with one water track and one bottom track ping in a two second ensemble. There was also a 500cm blank at the surface.

11.2 LADCP Performance

Following the JC030 cruise the LADCP's were considered to be in good working order. On the test station that was performed at the beginning of the trip, the CTD along with the LADCP was lowered to a depth of 4409m to test the performance. The graphs produced from the processed data at this station demonstrated that the instrument was working correctly, and all the beams were shown to be aligned in terms of signal strength. No messages warning about weak or broken beams were produced.

Physical loss and damage forced the use of each of the spare instruments on board. The LADCP that had been attached since Punta Arenas was lost when an incident with the winch caused the whole package to be lost at Station 12. The other incident occurred between Stations 35 and 36 when the wire slipped on the traction winch causing the CTD frame to fall from a height (a few inches). Unfortunately the LADCP bore the brunt of the impact with the metal fastening on the deck in the wetlab. The instrument was removed, tested and found to be functioning properly. As can be seen from Figure 40, the damage was localised to one area of the instrument. However, it was decided that continuing to use it would be unwise as the instrument could likely flood when submerged again, especially as the instrument would be subject to large pressures when lowered to depth. Consequently, the instrument was taken out of action and the final spare was deployed. In addition to these major impedances, several minor technical issues occurred throughout the cruise, but not of any real significance that affected the data collected. For example, on Station 24 the memory was erased because the LADCP ping could not be heard. Station 50 did not yield any LADCP data because the deploy command was not sent. Station 75 presented problems with downloading the data because a diode failed. This was replaced and there did not appear to be any problems with downloading data at subsequent stations.

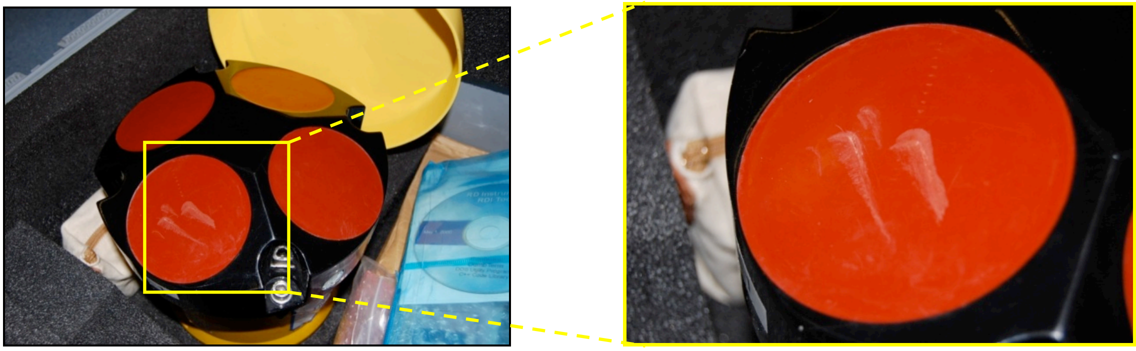


Figure 40: Damage to the LADCP

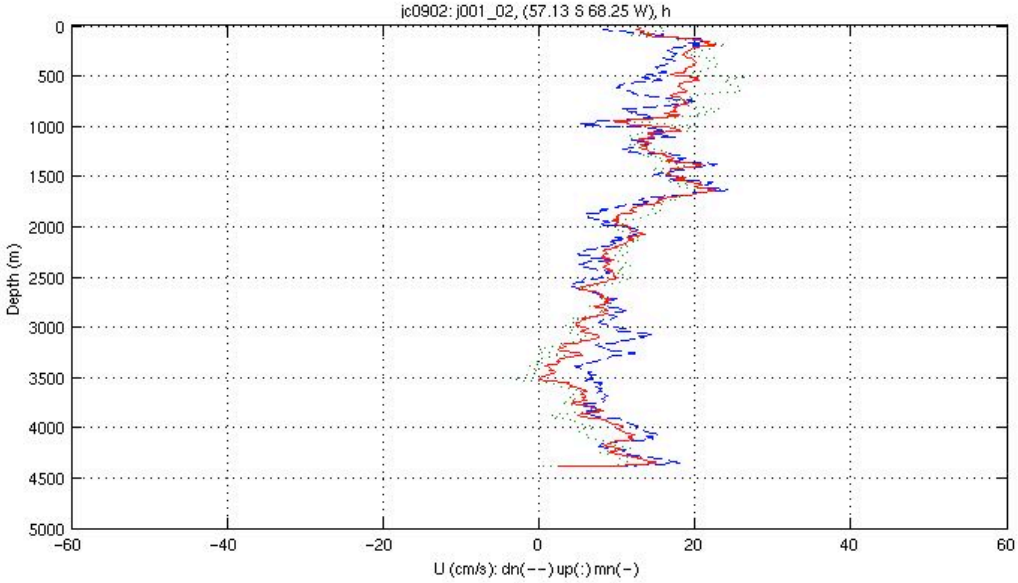
11.3 Data Processing

Data collected by the instrument was downloaded after each cast by the technician on watch. This data comprised of RDI binary .000 files and corresponding .txt files.

The data from the lowered Doppler was subject to two processing types; UH (University of Hawaii) and LDEO (Lamont-Doherty Earth Observation). Principally, the current velocities were calculated without the CTD data in order to gauge how the instrument was operating and also to identify what was happening in terms of current velocities. Once the CTD data had been processed by Mary Woodgate-Jones, the speed of sound corrections could be made to the LADCP data, giving a more accurate interpretation of the current velocities at each station. To accomplish this, an ascii version of the CTD 1Hz file was created using Matlab. Another program then checked that the vertical velocities for the CTD and LADCP agree. The CTD data is then incorporated into the LADCP soundings and the single pings are merged into corrected shear profiles.

11.3.1 UH Processing

The following graphs demonstrate the findings from the UH processing of the data from the test Station (001). The data used in these graphs has had the speed of sound corrections applied. By using the UH processing technique, information regarding the current velocities, CTD rotation and tilt, and shear are extracted.



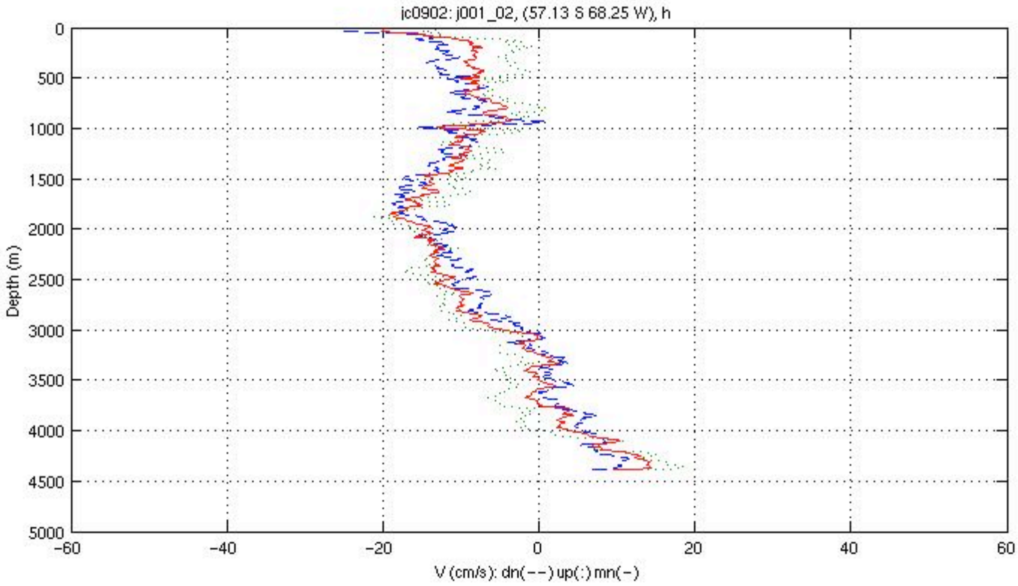


Figure 41: Example of a UH processing output of a U and V velocity profile.

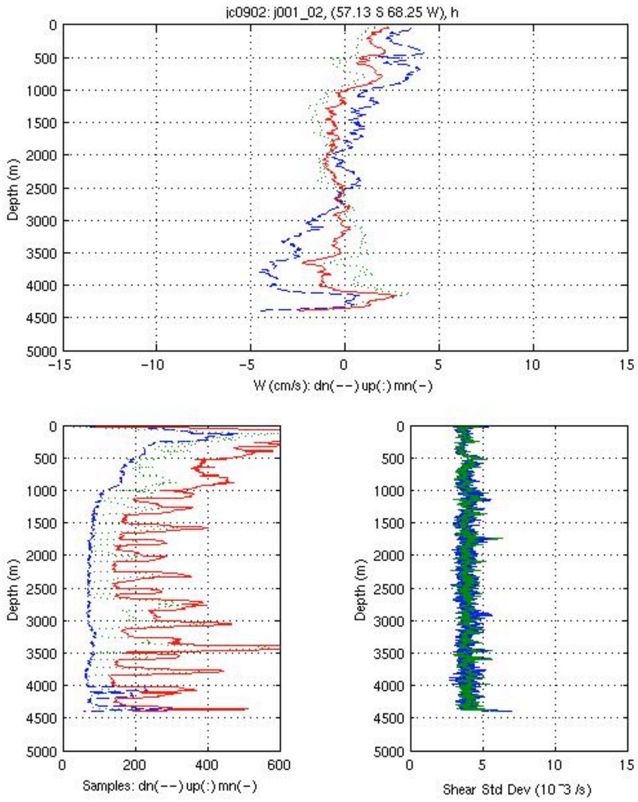


Figure 42: Example of UH processing output of processing velocity and also number of samples taken. Shear standard deviation is also taken.

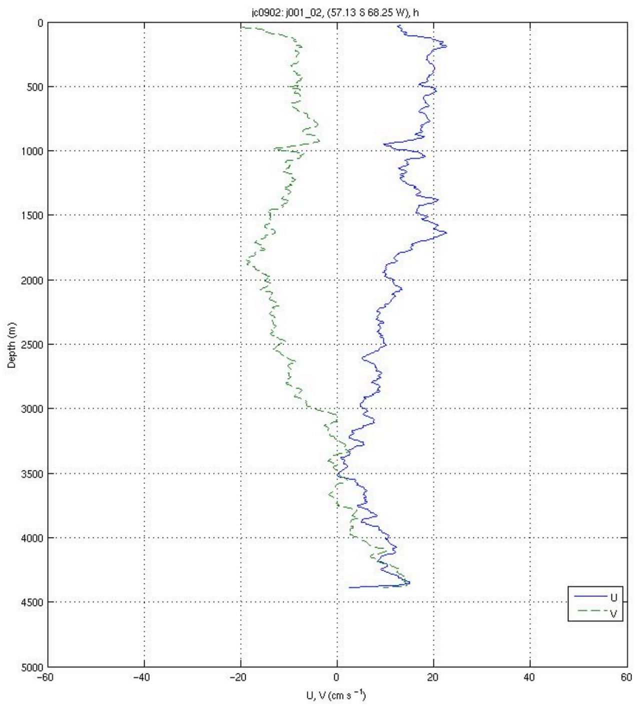


Figure 43: The mean values of the *U* and *V* components from the UH processing.

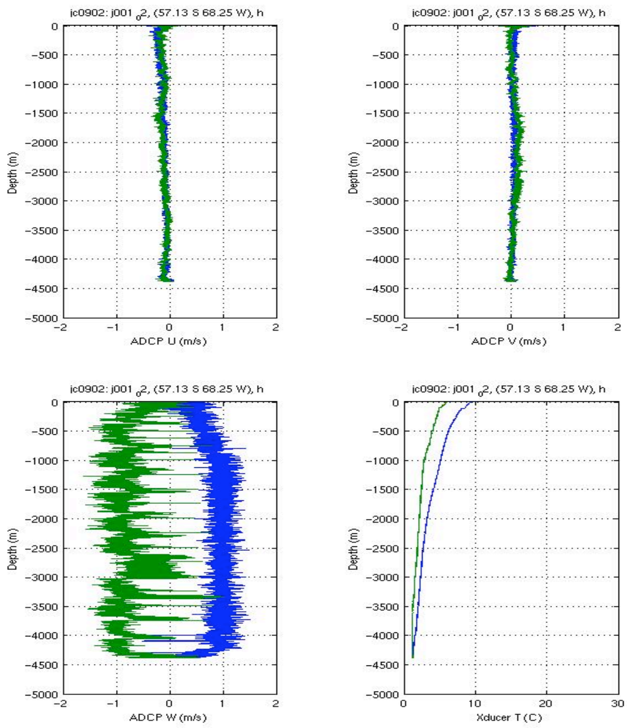


Figure 44: Example of Shear in the *U* and *V* components from the UH processing

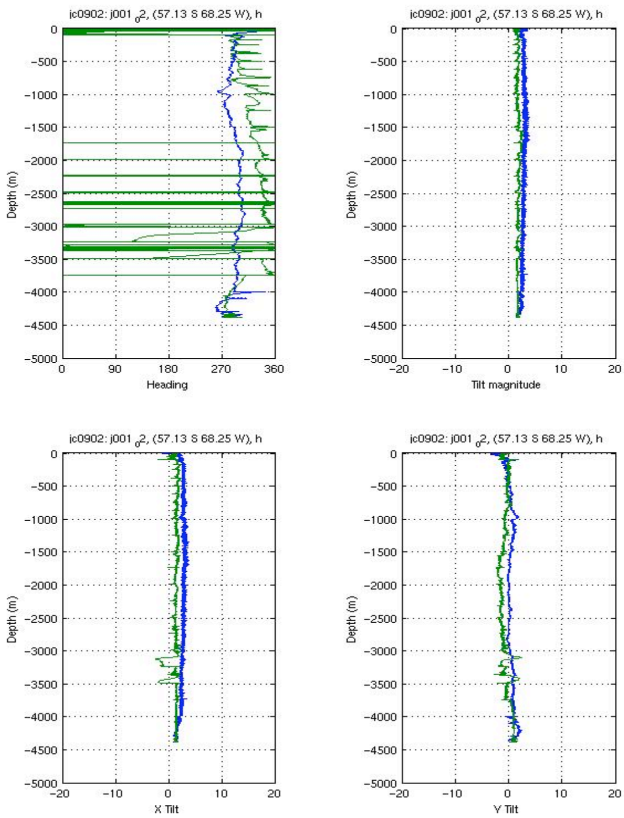


Figure 45: Example of the UH processing calculating the numbers of turns on the CTD wire.

At certain points during the cruise, especially around Station 67, the current velocities sensed by the LADCP were found to be in the order of 120-130 m/s near the surface, and accounted for the amount of drift experienced by the CTD package and the ship. It was considered that these strong currents were the result of an eddy that we encountered a few stations after Elephant Island whilst steaming northwards.

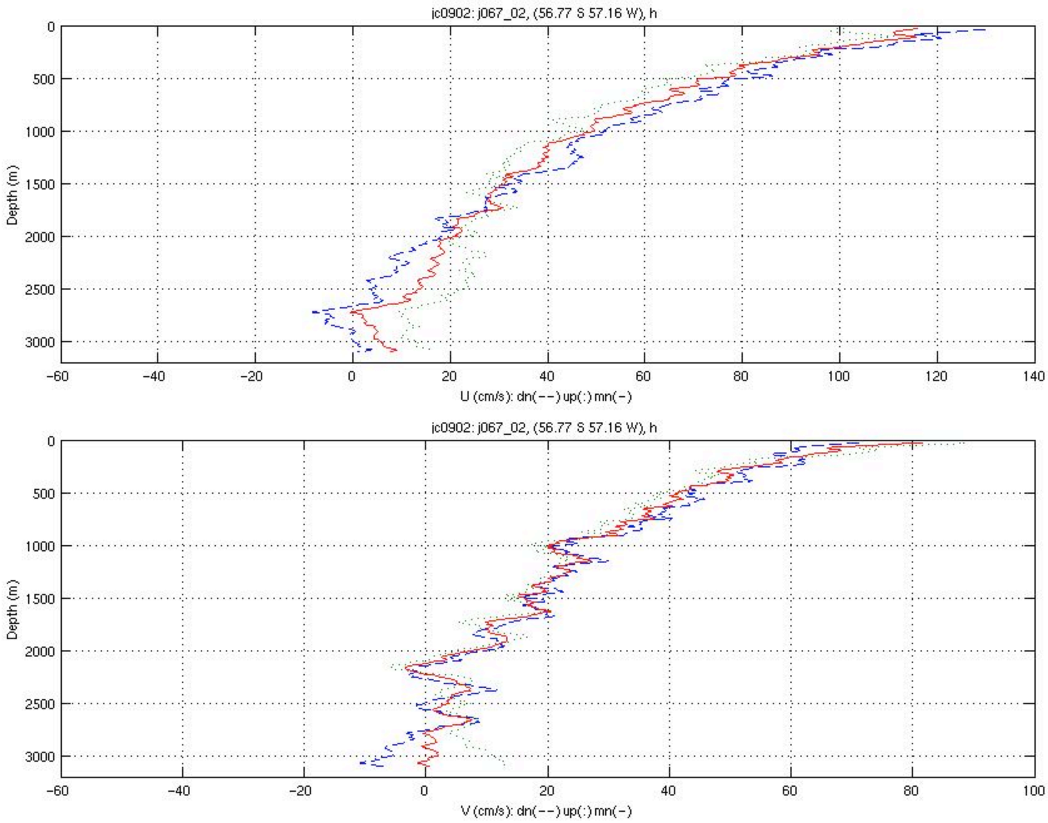


Figure 46: UH processing of Station 67

11.3.2 LDEO Processing

The LDEO processing technique offers similar current velocity plots to the UH processing technique, but one of the main reasons for doing this processing was to observe and monitor the condition of the beams. Very occasionally a weak beam signal was detected on the LADCP, but this seemed to improve and return to normal beam strength at the following station. This processing technique also offers the ability to observe the relative movements of the ship and the CTD package by connecting the two paths of movement with points of identical time.

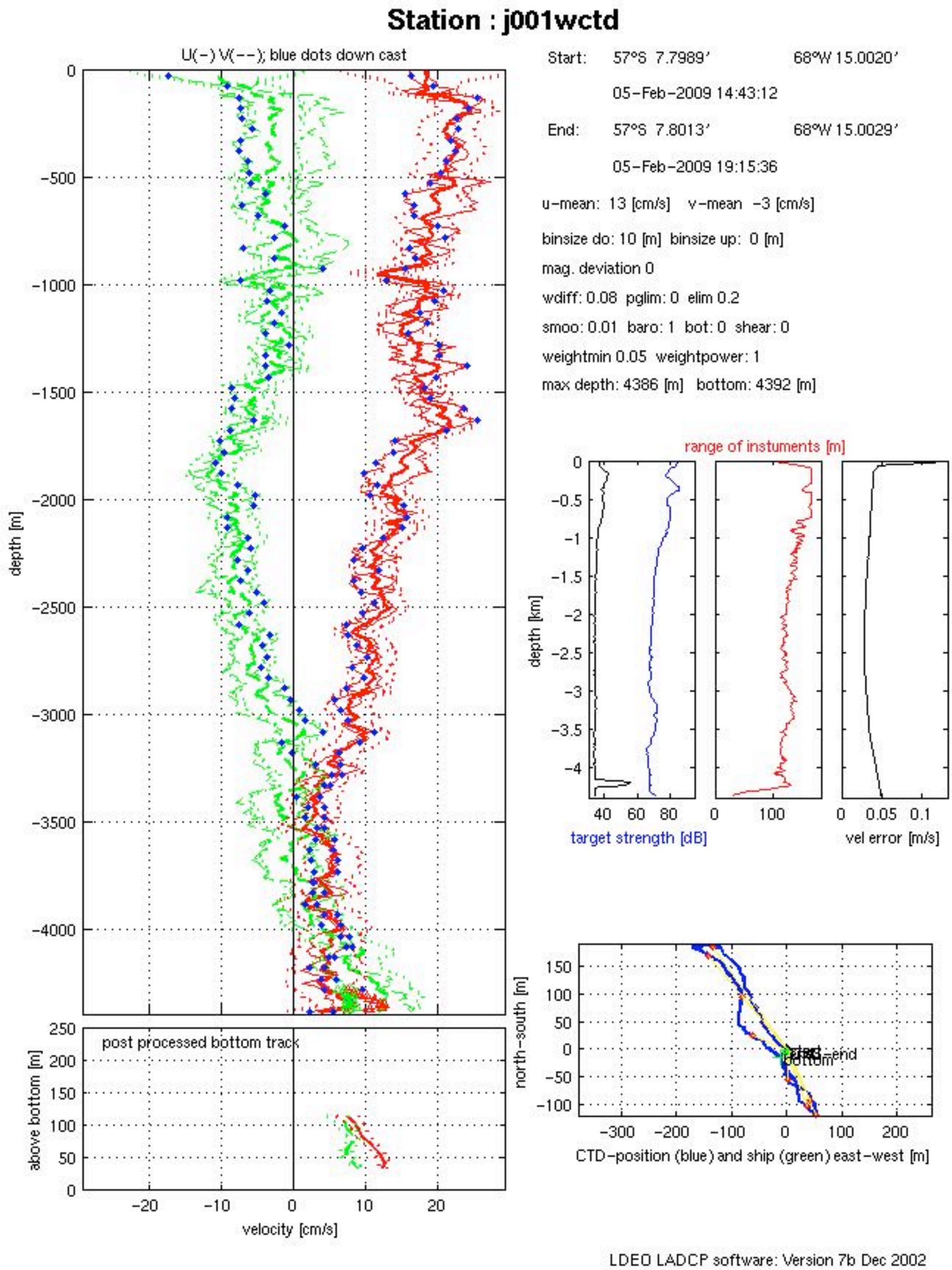


Figure 47: Example of LDEO processing

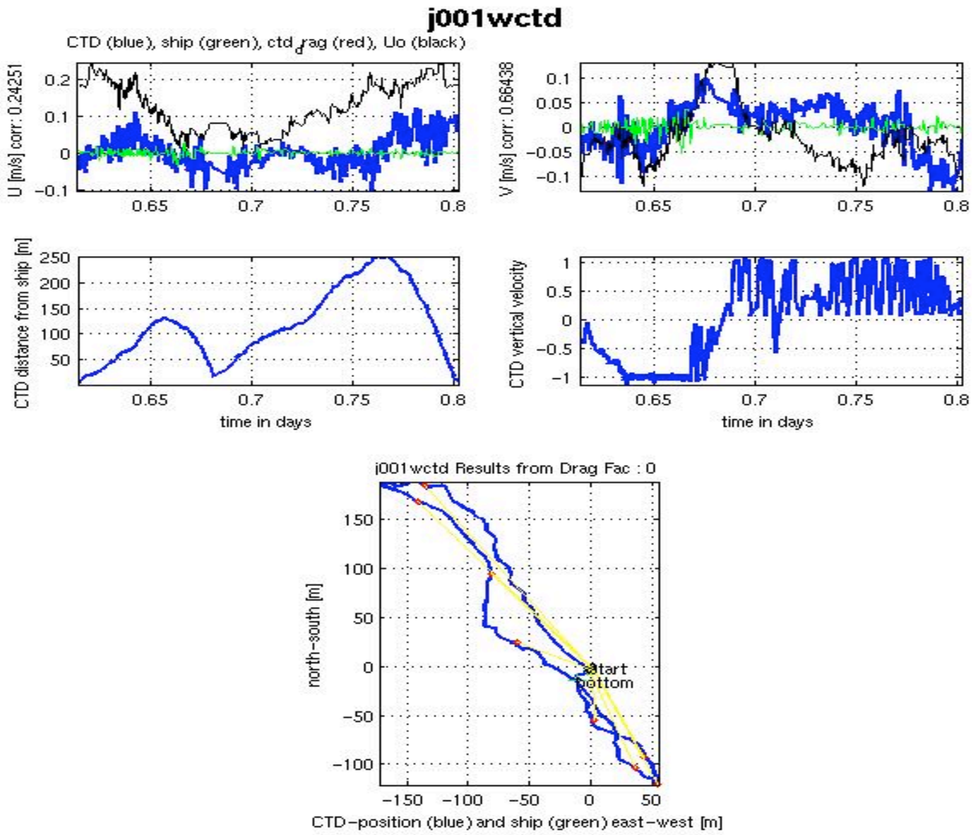


Figure 48: LDEO processing showing the CTD package motion relative to the ship

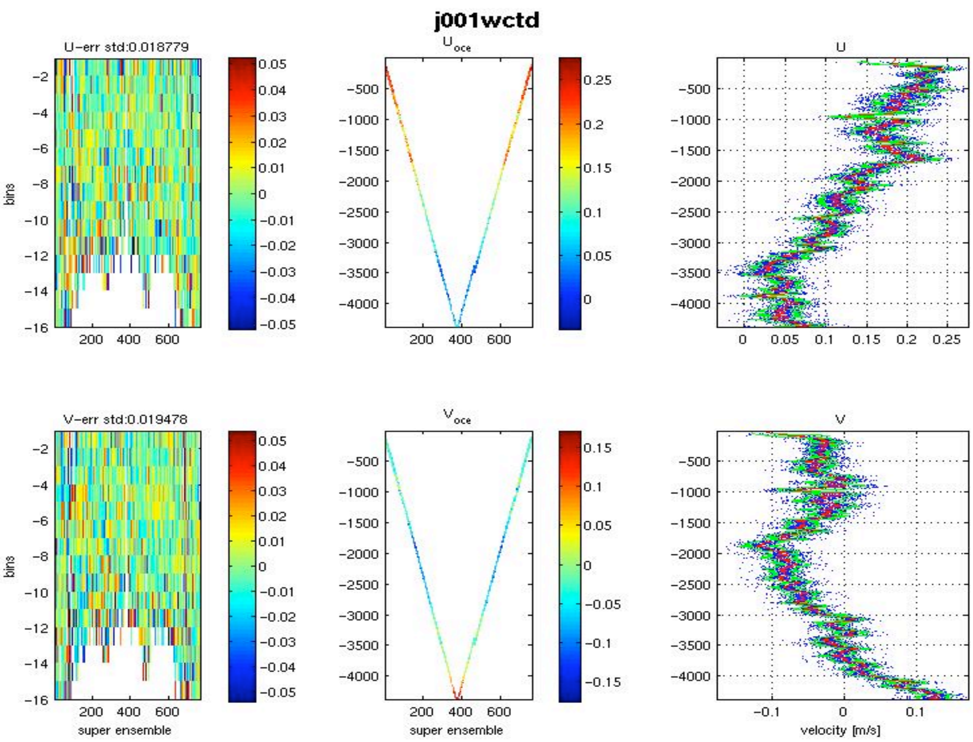


Figure 49: Super-ensemble grid

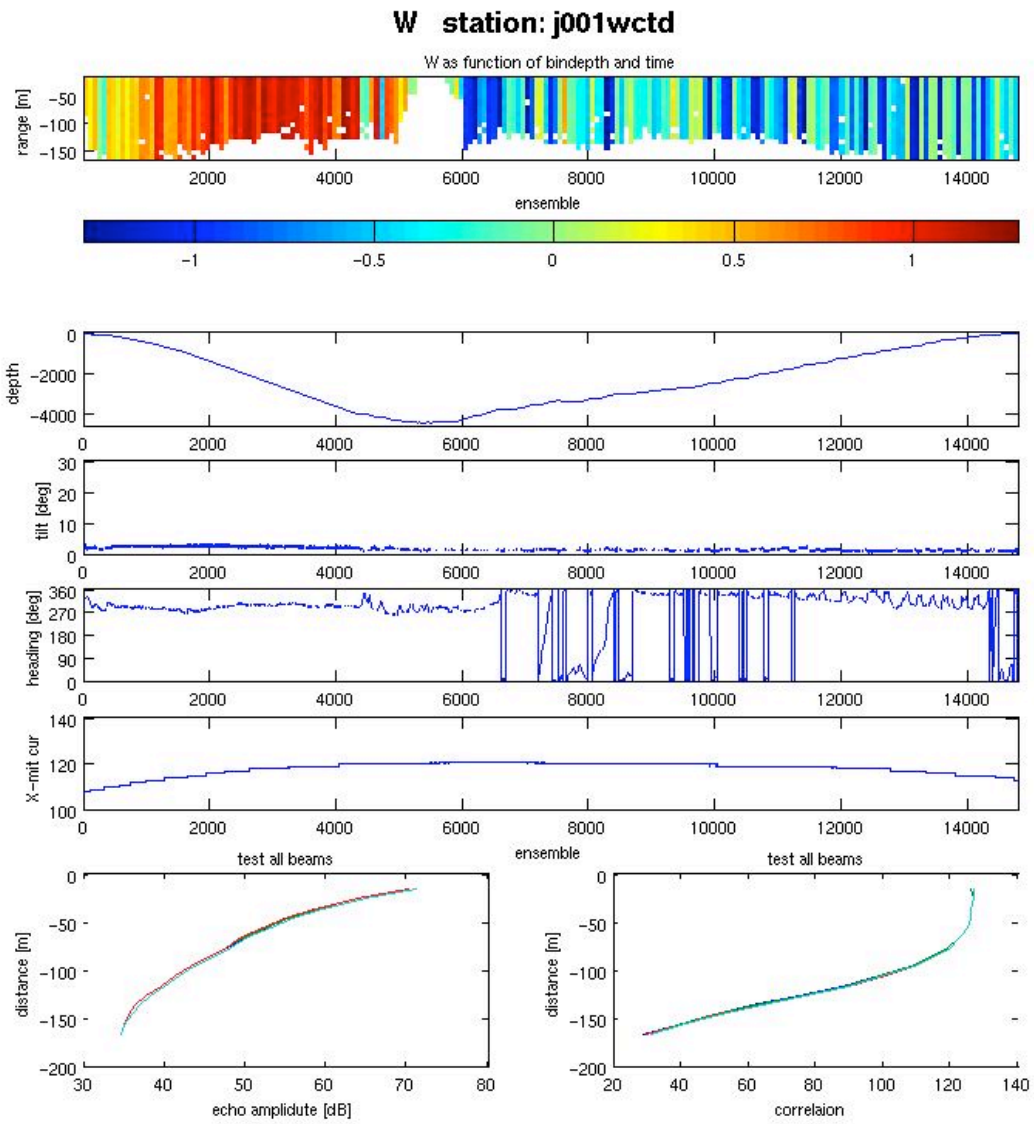


Figure 50: LDEO processing showing beam strength and sample collection with depth.

11.4 Data Comparison

The use of two different techniques to process identical data yielded the opportunity to observe how the interpretation of the data would vary. The *U* and *V* velocity profiles for each station were compared in the following ways; comparison between UH and LDEO, comparison between LDEO and bottom track data, comparison between UH and bottom track data and comparison between the LADCP and VMADCP. In order to do this a number of scripts were written in Matlab because it was necessary for the data to be put on the same depth grid. For each of the station comparisons the mean offset and the standard deviation was calculated and appended to the respective graph. Comparisons with bottom track data are particularly useful, because the bottom track is likely to be more accurate and reliable due to a fixed reference point.

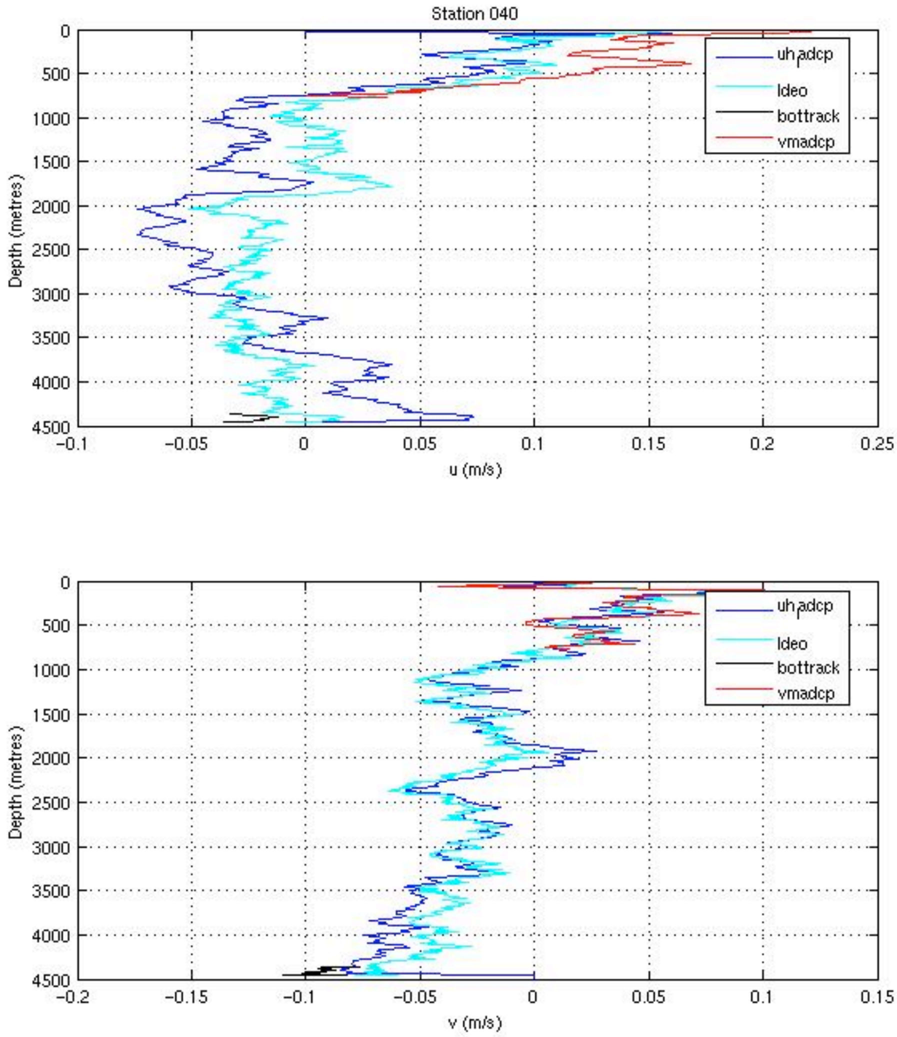


Figure 51: Velocity comparison of different instruments and processing types

Here is an example of one of the graphs that were created principally at the beginning of the data comparison exercise. For each station the UH, LDEO, bottom track and VMADCP data was plotted so as to achieve a simple visual comparison of the *U* and *V* components. As can be observed in this example there is a general agreement between the different techniques and data sources.

Below is one of the plots created from the calculation of velocity difference. It is evident from this plot that the difference in velocity between the LADCP and VMADCP and also the different processing techniques, is not stable with depth. In this particular graph (Figure 52), the velocity difference is minimal, but it must be noted that on some stations, a much higher degree of variation is found.

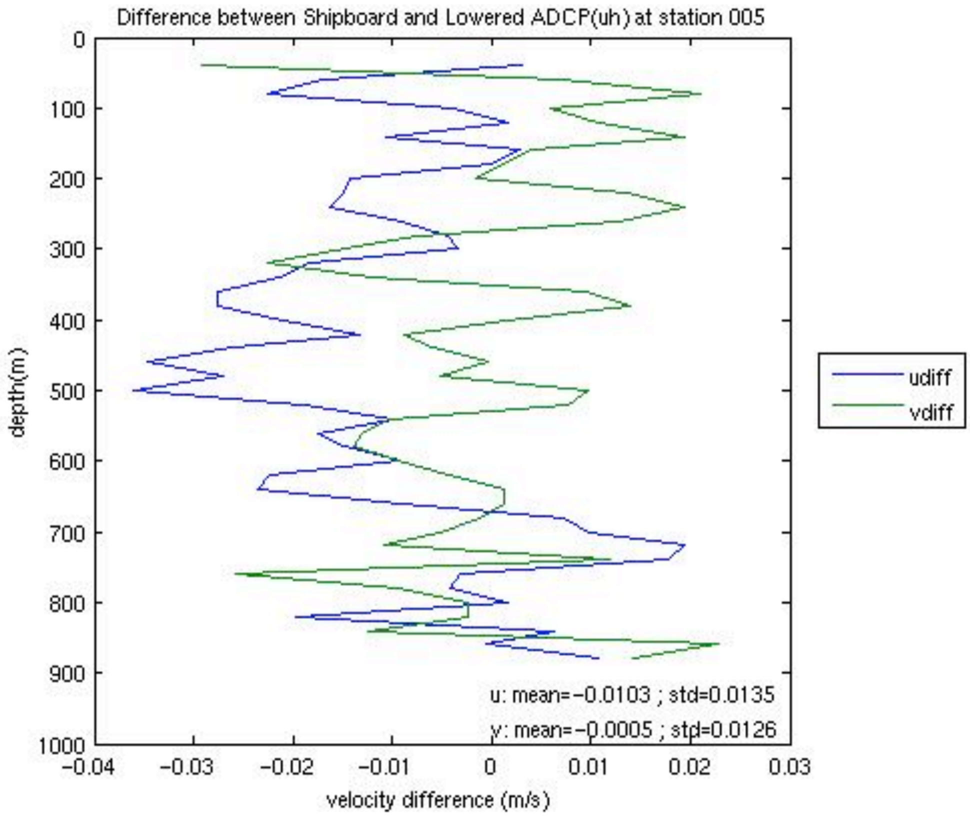


Figure 52: Calculated difference between different processing types. In this case the VMADCP and LADCP with UH processing.

11.5 Summary

- LADCP use was perturbed mainly by physical damage or loss.
- Any technical problems that were experienced were mostly minor, apart from at Stations 50 and 75.
- Two different processing techniques for the same data allowed the opportunity to observe how the different techniques interpreted the raw data.
- Additional comparisons were made between LADCP and bottom track data were the data sets overlapped.
- The damaged LADCP needs to be sent back to NOCS for repair.
- At the end of JC031 there is only one working LADCP remaining.

The LADCP beams were generally very stable in terms of amplitude. There were some decreases in beam strength at certain stations but these changes appeared to be anomalous each time as the beam strength would be shown to have improved at the next station.

David Hamersley

12. Navigation

Underway data (including navigation) were transferred from the onboard logging system (TECHSAS) to the user UNIX system on a daily basis using the script mday_00_get_all.m. This master script requires two parameters: a name key to the dataset required and a Julian day number. The name key is present to translate a meaningful word from the user into the correct stream name on the TECHSAS side.

Key names and their equivalences are:

Key name	Stream name
tsg	SBE45
ash	adu5pat
sim	ea600m
gyr	gyro_s
gyp	gyropmv
pos	posmvpos
tss	posmvtss
met	surfmet

The script then runs other scripts in turn mday_00.m and mday_01.m with the correct information for each individual stream. Script mday_01.m does the work, connects to remote machines, converts between data formats and finally creates Mstar format NetCDF files.

Navigation data is then available to be merged into all other streams. See individual Sections for procedures used.

Steven Alderson

13. Vessel Mounted Acoustic Doppler Current Profiler (VMADCP)

13.1 Acoustic Doppler Current Profiler Measurements

The RRS *James Cook* has two RDI ship mounted Acoustic Doppler Current Profilers (ADCP) located on one of the two retractable drop keels. Previous cruises have noted that the data quality is severely degraded when the keel is retracted possibly because of air bubbles flowing under the ship which interfere with the sound transmission.

When extended, the forward end of the keel rests in a curved locking plate and is pushed home with a clamping mechanism at the aft end. This is likely to result in slightly different orientations for the transducers each time the keel is lifted and then re-deployed. It is therefore important that this does not happen too often and that there is sufficient good calibration data in the periods when the keel is deployed to produce a correction independently of any other period.

The ADCP's are controlled from deck unit PC's located in the main laboratory. They both ran continuously throughout the cruise without problems.

Both ADCP's were run in narrow beam mode only. Although WinADCP was run and used as a front end for the ADCP's to provide a real time display of data, the binary ADCP data and raw navigation message files were used in the UH_ADCP processing suite to calculate absolute velocities.

The VMDAS configuration files used are listed in Appendix A. The 150 kHz instrument was run with 8 metre bins whilst the 75 kHz had 16 metre bins. The 75 kHz provides deeper coverage (700-800m in good conditions) than the 150 kHz instrument (300-400m). However in shallow water (< 50m) the 75 kHz often returns no good data because of boundary problems. As noted on JC029, the 75 kHz ADCP seems to be aligned at an angle of about 9° to the axis of the ship and this correction has been made in the configuration files (EA00900). The depth of the transducers is also set in these files with the ED command. The WinADCP configuration files are shown in Appendix B.

At irregular intervals data logging was briefly stopped in order to force the deck units to close a dataset so that it could be transferred onto another system for processing. Care had to be taken at this stage to increment the file number (menu Option: Edit Data Options: Recording), since there was the danger of overwriting existing data files. This was usually done whilst approaching or leaving a CTD station or when moving between bottom tracking and no bottom tracking modes.

Table 7a summarises the ENX data files obtained during the cruise and the parameter sets used. The data files corresponding to the parts of the cruise when the keel was retracted have not been analysed. These are: the passage leg to the first (test) CTD site (sequence number 001); the passage leg from the end of the first section to the start of the second (sequence number 010); and the passage to Montevideo after leaving the second section after Burdwood Bank (sequence number 017 and following). Note that in these sections there was no adjustment to the ED parameter in the VMDAS configuration files for a retracted keel.

Table 7a: Data files logged by OS150 ADCP during cruise JC031 with start and end times and number of ensembles. Filenames take the form OS150_JC31002_000000.ENX which is identified in the table as a sequence number of 002 and an ENX file number of 000000. BT is bottom track mode, WT is water track (i.e. bottom track off)

Sequence number	**ENX file numbers**	**Start date**	**Start time**	**End ensemble**	**End date**	**End time**	**Notes**
002	000000 to 000002	05/02/2009	14:54:18	18060	06/02/2009	00:56:16	WT
003	000000 to 000002	06/02/2009	00:58:11	14334	06/02/2009	12:48:03	BT
004	000000 to 000010	06/02/2009	12:48:48	75569	08/02/2009	06:47:44	WT
005	000000 to 000021	08/02/2009	06:48:47	152687	11/02/2009	19:38:18	WT
006	000000 to 000012	11/02/2009	19:39:38	86515	13/02/2009	19:43:25	WT
007	000000 to 000019	13/02/2009	19:45:15	133324	16/02/2009	21:49:20	WT
008	000000 to 000007	16/02/2009	21:50:54	55523	18/02/2009	04:41:38	WT
009	000000 to 000002	18/02/2009	04:43:14	14885	18/02/2009	19:54:37	BT
010	000000 to 000005	18/02/2009	19:56:06	34552	20/02/2009	01:59:50	BT, Keel up
011	000000	20/02/2009	02:00:28	5660	20/02/2009	07:24:37	BT
012	000000 to 000016	20/02/2009	07:26:23	117908	23/02/2009	00:56:36	WT
013	000000 to 000005	23/02/2009	00:58:15	39546	23/02/2009	22:56:25	WT, Keel up 22:27-22:30
014	000000 to 000012	23/02/2009	22:57:55	84089	25/02/2009	21:40:50	WT
015	000000 to 000001	25/02/2009	21:42:31	12137	26/02/2009	07:20:20	BT
016	000000 to 000003	26/02/2009	07:22:14	20235	27/02/2009	00:46:25	BT

On day 054 between 22:23 and 22:30, the keel had to be retracted to investigate a rattling noise that had been heard from inside the ship earlier that day. This split the SR1b section into two halves which had to be calibrated separately using shelf bottom track data at each end of the transect.

Table 7b: Data files logged by OS75 ADCP during cruise JC031 with start and end times and number of ensembles. Filenames take the form OS75_JC31002_000000.ENX which is identified in the table as a sequence number of 002 and an ENX file number of 000000. BT is bottom track mode, WT is water track (i.e. bottom track off)

Sequence number	**ENX file numbers**	**Start date**	**Start time**	**End ensemble**	**End date**	**End time**	**Notes**
002	000000 to 000001	05/02/2009	14:54:23	13863	06/02/2009	00:56:06	WT
003	000000 to 000001	06/02/2009	00:57:21	9233	06/02/2009	12:48:45	BT
004	000000 to 000008	06/02/2009	12:49:57	57994	08/02/2009	06:47:36	WT
005	000000 to 000016	08/02/2009	06:48:54	117265	11/02/2009	19:38:25	WT
006	000000 to 000009	11/02/2009	19:40:00	66407	13/02/2009	19:43:19	WT
007	000000 to 000014	13/02/2009	19:44:47	102214	16/02/2009	21:49:14	WT
008	000000 to 000006	16/02/2009	21:50:27	42617	18/02/2009	04:40:45	WT
009	000000 to 000001	18/02/2009	04:42:49	10546	18/02/2009	19:54:30	BT
010	000000 to 000003	18/02/2009	19:55:49	21030	20/02/2009	02:00:00	BT, Keel up
011	000000	20/02/2009	02:00:48	3613	20/02/2009	07:25:12	BT
012	000000 to 000012	20/02/2009	07:26:28	90522	23/02/2009	00:57:24	WT
013	000000 to 000004	23/02/2009	00:58:35	30363	23/02/2009	22:56:31	WT, Keel up 22:23-22:30
014	000000 to 000009	23/02/2009	22:58:37	64559	25/02/2009	21:40:56	WT
015	000000 to 000001	25/02/2009	21:43:01	7219	26/02/2009	07:20:32	BT
016	000000 to 000001	26/02/2009	07:21:51	12267	27/02/2009	00:48:01	BT

13.2 Data Processing

13.2.1 Processing

The UH software consists of a CODAS database and a suite of programs either written in C or as Matlab m-files which are controlled and run by a few higher level routines coded in python. The latter are controlled either by options on the command line or using files of settings (cnt files). On JC031, cnt-files were used. These were stored in directories os75_cnts and os150_cnts and copied to the relevant directories when required.

Three basic cnt files were used (here for the OS 75 dataset):
q_py.cnt:

```
# q_py.cnt is
## comments follow hash marks; this is a comment line
--yearbase 2009
--dbname jc031001nnx
--datadir /data32/cruise/pstar/data/vmadcp/jc031_os75/rawdata001
#--datafile_glob "*.LTA"
--datafile_glob *.ENX
--instname os75
--instclass os
--datatype enx
--auto
--rotate_angle 0.0
--rotate_amp 1.0
--pingtype nb
--ducer_depth 5
#--verbose
# end of q_py.cnt
```

Before use, the file sequence number (here 001) was changed appropriately.

q_pyrot.cnt:

```
# q_pyrot.cnt is
## comments follow hash marks; this is a comment line
--yearbase 2009
--rotate_angle 0.0
--rotate_amp 1.0
--steps2rerun rotate:navsteps:calib
--auto
# end of q_pyrot.cnt
```

Before use, the rotate_angle and rotate_amp parameters were set to their calibration values.

q_pyedit:

```
# q_pyrot.cnt is
## comments follow hash marks; this is a comment line
--yearbase 2009
--steps2rerun apply_edit:navsteps:calib:matfiles
```

--instname os75
--auto
end of q_pyrot.cnt

In order to process a dataset an initial directory structure was created (files in italics, sub-directories indented):

jc031_os75
    rawdata
jc031_os150
    rawdata
movescript
mstar
os150_cnts
os75_cnts

The processing was performed in a number of steps, which are described here.

1. Data was transferred from the two logging PC's to the UNIX system by USB memory stick. It was copied into one of the two directories called 'rawdata' under either jc031_os75 or jc031_os150.

2. Running script 'movescript' from inside either directory jc031_os75 or jc031_os150, then separated the data files from the rawdata directory into parallel directories named rawdata<nnn> where <nnn> is the sequence number from the PC.

3. adcptree.py jc031<nnn>nbenx --datatype enx

   This python script creates the directory tree for the CODAS dataset, which at the top level looks:

   jc031<nnn>nbenx
       adcpdb
       adcp_processing.html
       cal
       contour
       edit
       grid
       load
       nav
       ping
       quality
       scan
       stick
       template_rpt.txt
       vector

   Below these directories adcptree.py creates an extensive collection of configuration files, text files and m-files. On JC031, it was not found necessary to alter any of these.

4. Change directory to jc031<nnn>nbenx and copy in file 'q_py.cnt' and edit for the PC sequence number in two lines. Then run

   quick_adcp.py --cntfile q_py.cnt

   This loads the data into the codas tree, performs standard editing and processing and makes estimates of both water track calibrations and when available, bottom track calibrations.

   To examine these calibrations, type:

   more cal/*/*.out

   Note that these files accumulate estimates of the calibration. Each time a quick_adcp.py is run involving the 'calib' parameter in the cnt-file another will be appended, but based on the sequence of angular and amplitude corrections already applied.

   Extensive documentation comes with the UH software and should be consulted for more details about the processing steps made by the quick_adcp.py utility.

5. Perform editing with gautoedit inside Matlab (see next section).

6. To actually apply the edits made in 5 to the dataset, copy q_pyedit.cnt into the jc031<nnn>nbenx directory and run:

   quick_adcp.py --cntfile q_pyedit.cnt

7. Calibration data can be applied at this stage. Copy q_pyrot.cnt into the current directory, edit in the relevant parameters and then run

   quick_adcp.py --cntfile q_pyrot.cnt

   Note that these rotations are cumulative so care must be taken to record the values used and on what dataset. If unsure, delete the whole of the jc031<nnn>nbenx directory, start again from step 3 above and apply a single total calibration in this step (7). Unfortunately this means that the editing has to be repeated as well.

13.2.2 Editing

A deliberate choice was made to only edit the data within the CODAS database, rather than to move it into Mstar format and despike and calibrate there. This should allow for a consistent product between cruises and makes use of the extensive expertise already built into the UH software. However, it also makes the processing path somewhat unwieldy, since problems in the final data necessitate going right back to the start of the procedure although it may have been possible to simply fix them with MEXEC programs.

Start up Matlab in the jc031<nnn>nbenx directory.

In the Matlab command window, type:

codaspaths
cd edit
gautoedit

This starts an editing GUI, which looks like:

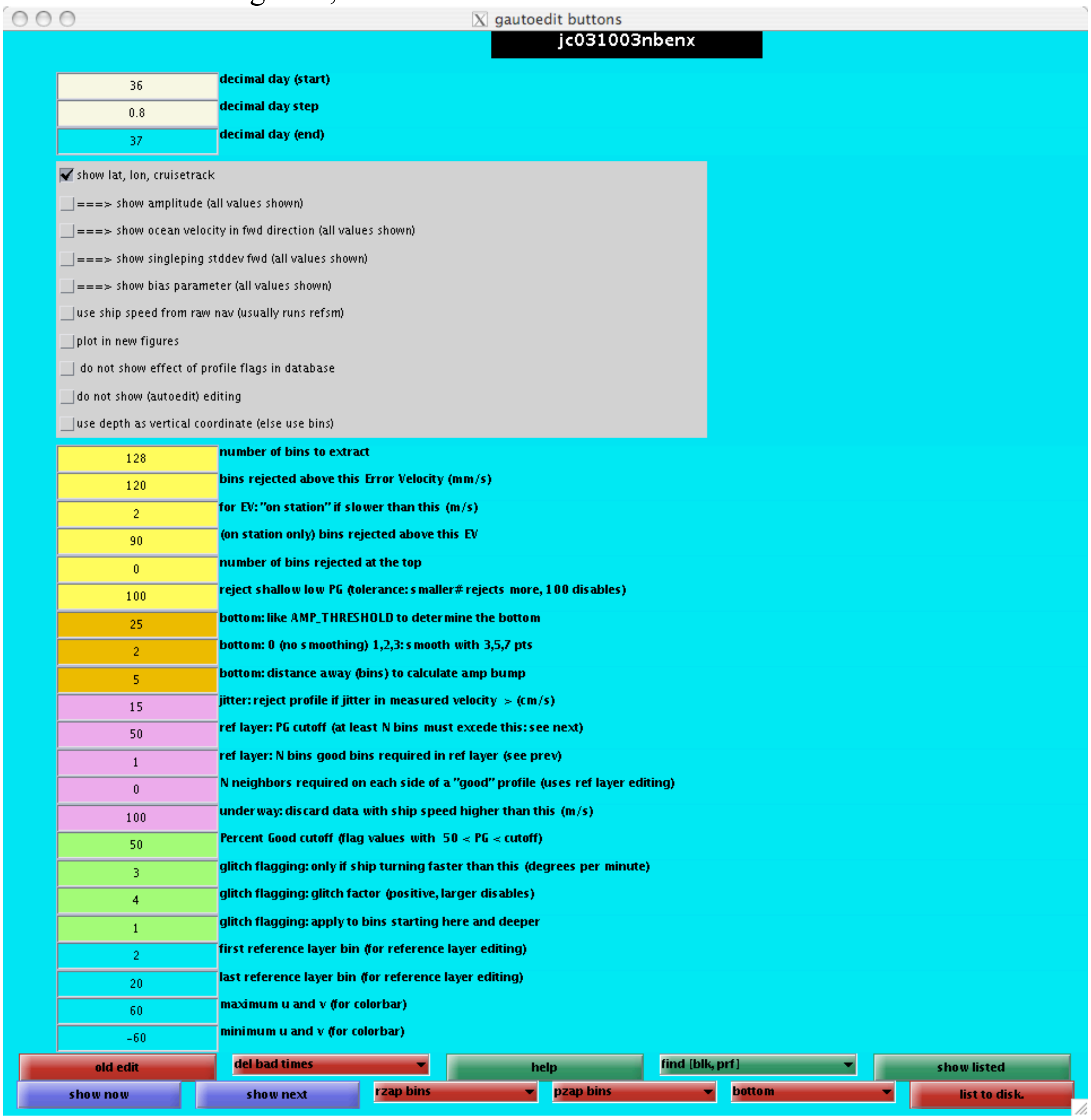


Figure 53: Screen shot of editing GUI

Show Now: this button produces two plots based on the start, stop and range selected at the top left: one shows four subplots with the absolute east-west velocity component, the absolute north-south component, the percent good parameter and an editing parameter called jitter. The other plot has subplots displaying the ship's track over the ground and mean absolute velocity vectors. An error will occur if the selected range does not include data, in this case change the start day and interval accordingly and try again. If any of the parameters in the selection boxes are changed, simply press the "Show Now" button to see the effect. This should always be the first button pressed when starting a new edit session.

del bad times: click on this button to delete a whole column of data; choose a subplot to use as a basis for editing from the pop-up sub-menu. A separate modal menu window appears as well as a separate plot window with a single copy of the plot of the variable selected. Choose one of the two options first: the easiest to use is labelled "click on profile to be deleted" and is the one that will be described here. When the mouse is moved over the data in the plot window a cursor appears: click in the centre of a column of cells to delete it; repeat as many times as necessary and then press the return button to finish.

rzap bins: click on this button and then choose a subplot to use as a basis for editing from the pop-up sub-menu. A new separate plot window will appear with a single copy of the plot of the variable selected. Make this large enough so that individual bins are distinguishable. Select a rectangular group of bins to remove by clicking on a point with the mouse and dragging to the opposite corner. Note that the top left corner of each bin cell is the active point, so to delete a single cell, click in the cell to the top right of it and drag into the cell in question and then release the mouse button. Only one rectangular area can be edited at a time.

list to disk: this creates files of edits which can then be later applied to the codas database. It should be pressed before each press of "Show Next".

do not show effect of profile flags in database: this tickbox allows the user to see the rawdata before any editing by the first run of quick_adcp.py

Show Next: this moves onto the next selection of data (default is to add 0.8 to the start day of the plot)

Gautoedit does not apply the edits to the CODAS database (see step 6 in section 12.2.1 above), but writes them into text files in the edit directory.

13.2.3 MEXEC

Data from the CODAS database was dumped into Matlab files and then imported into Mstar format for further examination using the MEXEC suite of Matlab programs (functionally based on the old PEXEC suite written in FORTRAN).

mcod_01 - extract data from CODAS and write into Mstar file
mcod_02 - force variables in a file to use the same grid
mcod_03 - average data onto a single profile on station
mcod_04 - average data onto a single profile between stations
m_info_var - utility to get information from an Mstar file into a Matlab variable
Station_range - given a station number, return the start and end time in seconds relative to the beginning of the year. This uses a file called 'stations.dat' held in the same directory as the script itself, which contains lines of the form:
stn start_jday start_hour start_min end_jday end_hour end_min
(Listings for these scripts are given in Appendix C).

13.3 Calibration

On each of the two sections bottom track data was available at the beginning and end as the ship crossed the shelf. The UH_ADCP software provides an automated means of calculating both water track and bottom track calibration values. No consistent water track calibrations were obtained from the separate datasets (see Table 8a & b), so the SR1b section data were initially calibrated with the first shelf bottom track data. The parameters obtained for the 150 kHz ADCP were consistent between the start and end values, while the 75 kHz had slightly different answers for the two segments of bottom track data. The data were divided into on and off station data and then each averaged into one column of data. 150 kHz and 75 kHz profiles were then over-plotted. On-station profiles produced consistently good agreement. Off-station profiles were still reasonably good. Later recalibration of the 75 kHz using shelf bottom track data at the southern end of the SR1 section made this agreement deteriorate, so the first calibration was reinstated. Table 9 shows the calibrations applied to each section of data. The on- and off-station averages for the OS150 and OS75 are compared for each profile in Table 10. Here an rms difference has been calculated, defined as $1/2\sqrt{U_{150} - U_{75}}$.

Agreement on station is good, with rms values typically less than one. Off-station differences are rather larger as would be expected, generally in the region of 1-2 cm/s on the SR1 section (Stations 2-49) and rather larger on the second section (SR1b), in the range 1-4 cm/s. This reflects the better calibration available for the first section. The OS150 in particular has two independent bottom track calibrations that agree well on S1. Even the OS75 has calibrations that differ by less than 0.2°. When the ship is travelling at 10 knots (the maximum speed allowed on the RRS *James Cook* when the keel is down), this angle would result in a spurious cross track velocity of 0.2x3.142x5/180 = 0.017 m/s, which is in line with the differences found between the two instruments.

Table 8a: Calibration data calculated by quick_adcp.py for the OS150 ADCP from separate dataset sequences and amalgamated datasets. Only those from when the keel was down are shown.

Dataset	Water track							Notes
	N	Amplitude			Phase			
		Median	Mean	Std dev	Median	Mean	Std dev	
1								Keel up
2	1	0.998	0.998	0	-0.517	-0.517	0	
3	4	1.018	1.012	0.0231	-0.3445	-0.1933	0.5683	
4	8	1.0055	1.0047	0.0049	-0.4305	-0.4884	0.3354	
5	14	1.022	1.0222	0.0153	-0.296	-0.1708	0.8463	
6	16	1.0085	1.0121	0.012	-0.004	-0.0188	0.6274	
7	16	1.011	1.0101	0.0091	-0.401	-0.5918	0.7269	
8	7	1.007	1.011	0.0117	-0.349	-0.356	0.4776	
9	8	1.011	1.0086	0.0087	-0.583	-0.5003	0.3958	
003-009	78	1.009	1.0117	0.0137	-0.377	-0.3049	0.6674	
10								Keel up
11	4	1.0045	1.0085	0.0219	0.4835	0.1333	1.001	
12	22	1.003	1.0052	0.0095	-0.448	-0.4151	0.8648	
13	6	1.002	1.0032	0.0088	-0.733	-1.068	1.0776	
011-013	33	1.003	1.0053	0.0113	-0.454	-0.4547	0.9539	
14	13	1.017	1.0148	0.0131	-0.995	-0.8255	1.1189	
15	5	1.018	1.0144	0.0099	-0.963	-0.7898	0.5522	
16	9	1.01	1.0099	0.0085	-0.821	-0.7581	0.3156	
17								Keel up

Dataset	Bottom track							Notes
	N	Amplitude			Phase			
		Median	Mean	Std dev	Median	Mean	Std dev	
1								Keel up
2								
3	127	1.0025	1.0032	0.0027	-0.4529	-0.4884	0.1214	
4								
5								
6								
7								
8								
9	259	1.0039	1.0042	0.0046	-0.4696	-0.497	0.2288	
003-009	390	1.0032	1.0039	0.0042	-0.4689	-0.4926	0.1941	
10								Keel up
11	60	1.006	1.0092	0.0141	-0.5326	-0.4969	0.2831	
12								
13								
011-013	60	1.006	1.0092	0.0141	-0.5326	-0.4969	0.2831	
14								
15	133	1.0043	1.0043	0.0049	-0.7584	-0.7178	0.2483	
16	97	1.0081	1.0089	0.0063	-0.5619	-0.6183	0.3671	
17								Keel up

Table 8b: Calibration data calculated by quick_adcp.py for the OS75 ADCP from separate dataset sequences and amalgamated datasets. Only those from when the keel was down are shown.

Dataset	Water track							Notes
	N	Amplitude			Phase			
		Median	Mean	Std dev	Median	Mean	Std dev	
1								Keel up
2	1	1	1	0	0.334	0.334	0	
3	3	1.01	1.01	0.0141	0.888	0.888	0.0665	
4	8	1.0065	1.006	0.0042	-0.094	-0.1816	0.4068	
5	14	1.011	1.0154	0.0112	0.3085	0.3076	0.642	
6	16	1.0095	1.0155	0.0156	0.4185	0.2864	0.567	
7	16	1.0095	1.0094	0.0097	-0.05	0.0427	0.5013	
8	7	1.011	1.0099	0.0052	0.124	0.1869	0.5455	
9	8	1.0065	1.0076	0.0047	0.0475	0.1165	0.5189	
003-009	78	1.009	1.0118	0.0109	0.1	0.1681	0.5502	
10								Keel up
11	4	0.9875	0.9955	0.0212	0.5625	0.6537	0.9389	
12	22	1.005	1.0078	0.0106	-0.035	-0.1075	0.5726	
13	5	1.01	1.009	0.0051	-0.197	-0.5116	0.7872	
011-013	32	1.005	1.0064	0.0121	-0.063	-0.0744	0.7097	
14	13	1.01	1.0113	0.011	-0.457	-0.2293	0.914	
15	5	1.016	1.0156	0.0063	-0.705	-0.5412	0.5096	
16	9	1.008	1.0093	0.0083	-0.309	-0.2433	0.3623	
17								Keel up

Dataset	Bottom track							Notes
	N	Amplitude			Phase			
		Median	Mean	Std dev	Median	Mean	Std dev	
1								Keel up
2								
3	145	1.0042	1.0173	0.0461	-0.1325	-0.1274	0.1887	
4								
5								
6								
7								
8								
9	263	1.0226	1.0476	0.0617	-0.2344	-0.2157	0.3146	
003-009	414	1.0089	1.046	0.072	-0.1955	-0.1999	0.2952	
10								Keel up
11	78	1.0153	1.0259	0.0269	-0.0493	-0.0818	0.3262	
12								
13								
011-013	78	1.0153	1.0259	0.0269	-0.0493	-0.0818	0.3262	
14								
15	168	1.0063	1.0143	0.0234	-0.3717	-0.3654	0.3295	
16	184	1.0469	1.0749	0.0803	-0.199	-0.299	0.6088	
17								Keel up

Table 9: Calibration data used for each of the processed sections of data for the two instruments.

Sequence number	**OS150**		**OS75**	
	Angular correction	**Amplitude correction**	**Angular correction**	**Amplitude correction**
002	-0.4525	1.0025	-0.1325	1.0042
003	-0.4525	1.0025	-0.1325	1.0042
004	-0.4525	1.0025	-0.1325	1.0042
005	-0.4525	1.0025	-0.1325	1.0042
006	-0.4525	1.0025	-0.1325	1.0042
007	-0.4525	1.0025	-0.1325	1.0042
008	-0.4525	1.0025	-0.1325	1.0042
009	-0.4525	1.0025	-0.1325	1.0042
011	-0.5326	1.0060	-0.0493	1.0153
012	-0.5326	1.0060	-0.0493	1.0153
013	-0.5326	1.0060	-0.0493	1.0153
014	-0.7584	1.0043	-0.3717	1.0063
015	-0.7584	1.0043	-0.3717	1.0063
016	-0.7584	1.0043	-0.3717	1.0063

Table 10: Comparison of OS150 and OS75 ADCP data shown as a table of RMS differences calculated for on-station and off-station data. Profiles collected over the relevant time periods have been averaged together into one profile and then the OS75 mean profile merged onto the OS150 depths. The RMS is defined as $1/2\sqrt{U_{150} - U_{75}}$.

Stn	**Rms**	**Stns**	**Rms**	**Stn**	**Rms**	**Stns**	**Rms**	**Stn**	**Rms**	**Stns**	**Rms**
3	0.8659	003-004	1.9065	31	0.9428	031-032	2.2662	59	1.8091	059-060	4.0762
4	0.996	004-005	1.6815	32	0.7437	032-033	1.8668	60	0.3833	060-061	3.232
5	0.7196			33	1.9785	033-034	1.2741	61	0.4462	061-062	4.2669
6	0.6922			34	0.5991			62	0.7255	062-063	2.7296
7	0.6332	007-008	1.6295	35	0.9175			63	0.9173	063-064	2.6461
8	0.4319	008-009	1.5899	36	0.6435	036-037	1.1146	64	0.9921	064-065	3.5017
9	0.5751	009-010	1.3852	37	0.6093	037-038	2.0543	65	0.8886	065-066	3.6624
10	0.813	010-011	1.7361	38	0.792	038-039	1.6002	66	1.2062	066-067	3.5547
11	0.8575	011-012	1.244	39	0.4414	039-040	1.7166	67	0.9584	067-068	2.0984
12	0.526	012-013	2.1207	40	0.5202	040-041	1.5518	68	0.9863	068-069	2.0351
13	0.9388			41	0.5854	041-042	1.2962	69	0.6519	069-070	1.9393
14	1.0812	014-015	2.0743	42	0.8944	042-043	2.5296	70	0.544	070-071	1.8477
15	0.7547	015-016	1.5288	43	0.664	043-044	1.1754	71	0.5208	071-072	1.7324
16	0.8478	016-017	0.6423	44	0.9365	044-045	2.6509	72	0.6411	072-073	1.3956
17	0.4553	017-018	1.1524	45	1.1169	045-046	1.6325	73	0.7486	073-074	2.0218
18	0.9631	018-019	1.2206	46	1.0616	046-047	1.1352	74	0.9189	074-075	2.0372
19	1.7232	019-020	1.2195	47	1.1366	047-048	3.2638	75	1.0094	075-076	2.4225
20	0.6165	020-021	0.7576	48	0.8749	048-049	2.1324	76	0.8975		
21	1.2704	021-022	1.6145	49	0.895			77	0.9575	077-078	1.4935
22	0.5698	022-023	1.6505	50	0.8486	050-051	3.6545	78	0.9925	078-079	1.6183
23	0.7301	023-024	1.528	51	1.6851	051-052	4.0077	79	0.8434	079-080	2.2149
24	0.6124	024-025	1.6025	52	2.0707	052-053	1.8538	80	0.8362	080-081	0.7308
25	0.7206	025-026	1.2103	53	0.8463	053-054	1.9903	81	0.8321	081-082	1.2879
26	0.6243	026-027	1.7323	54	0.4815	054-055	1.7063	82	0.4767	082-083	4.4554
27	0.9633	027-028	1.5961	55	1.0833	055-056	3.5079	83	0.9389	083-084	0.8844
28	0.8211	028-029	2.3328	56	0.6369	056-057	1.987	84	0.9976		
29	0.962	029-030	1.4284	57	0.9187	057-058	4.8923				
30	0.5657	030-031	1.4175	58	0.631	058-059	2.8887				

Appendix A

1. VMDAS OS 150 Bottom track configuration file

```
;--------------------------------------------------------------------------\
; ADCP Command File for use with VmDas software.
;
; ADCP type:     150 kHz Ocean Surveyor
; Setup name:    default
; Setup type:    Low resolution, long range profile(narrowband)
;
; NOTE:  Any line beginning with a semicolon in the first
;        column is treated as a comment and is ignored by
;        the VmDas software.
;
; NOTE:  This file is best viewed with a fixed-point font (e.g. courier).
; Modified Last: 01November2008 for JC029 (SOFINE)
;--------------------------------------------------------------------------/
; Restore factory default settings in the ADCP
cr1

; set the data collection baud rate to 38400 bps,
; no parity, one stop bit, 8 data bits
; NOTE:  VmDas sends baud rate change command after all other commands in
; this file, so that it is not made permanent by a CK command.
cb611

; Set for narrowband single-ping profile mode (NP), sixty (NN) 8 meter bins (NS),
; 6 meter blanking distance (NF)
WP0
NN060
NP00001
NS0800
NF0600

; Enable single-ping bottom track (BP),
; Set maximum bottom search depth to 800 meters (BX)
BP001
BX08000

; output velocity, correlation, echo intensity, percent good
ND111100000

; 1 seconds between bottom and water pings
TP000100

; Two seconds between ensembles
; Since VmDas uses manual pinging, TE is ignored by the ADCP.
; You must set the time between ensemble in the VmDas Communication options
TE00000200
```

```
; Set to calculate speed-of-sound, no depth sensor, external synchro heading
; sensor, no pitch or roll being used, no salinity sensor, use internal transducer
; temperature sensor
EZ1020001

; Output beam data (rotations are done in software)
EX00000

; Set transducer misalignment (hundredths of degrees)
EA00000

; Set transducer depth (decimeters)
ED00096

; Set Salinity (ppt)
ES35

; save this setup to non-volatile memory in the ADCP
CK
```

2. VMDAS OS 75 Bottom track configuration file

```
;---------------------------------------------------------------------------\
; ADCP Command File for use with VmDas software.
;
; ADCP type:     75 kHz Ocean Surveyor
; Setup name:    NB, BT on
; Setup type:    Low resolution, long range profile(narrowband)
;
; NOTE:  Any line beginning with a semicolon in the first
;        column is treated as a comment and is ignored by
;        the VmDas software.
;
; NOTE:  This file is best viewed with a fixed-point font (e.g. courier).
; --------------------------------------------------------------------------/

; Restore factory default settings in the ADCP
cr1

; set the data collection baud rate to 38400 bps,
; no parity, one stop bit, 8 data bits
; NOTE:  VmDas sends baud rate change command after all other commands in
; this file, so that it is not made permanent by a CK command.
cb611

; Set for narrowband single-ping profile mode (NP), sixty (NN) 16 meter bins (NS),
; 8 meter blanking distance (NF)
WP0
NN060
```

NP00001
NS1600
NF0800

; Enable single-ping bottom track (BP),
; Set maximum bottom search depth to 1200 meters (BX)
BP001
BX12000

; output velocity, correlation, echo intensity, percent good
ND111100000

; One and a half seconds between bottom and water pings
TP000150

; Three seconds between ensembles
; Since VmDas uses manual pinging, TE is ignored by the ADCP.
; You must set the time between ensemble in the VmDas Communication options
TE00000300

; Set to calculate speed-of-sound, no depth sensor, external synchro heading
; sensor, no pitch or roll being used, no salinity sensor, use internal transducer
; temperature sensor
EZ1020001

; Output beam data (rotations are done in software)
EX00000

; Set transducer misalignment (hundredths of degrees)
EA00900

; Set transducer depth (decimeters)
ED00097

; Set Salinity (ppt)
ES35
; save this setup to non-volatile memory in the ADCP
CK

Appendix B

1. WINADCP OS 150 configuration file

```
[Version Info]
VmDasVersion=Version 1.43.16
Option Table Version=1
[Expert only options]
SaveOnlyChangedOptions=TRUE
TurnedOffBeam=0
PashrImuFlagUseNormalInterpretation=TRUE
[ADCP Port Setup]
AdcpComPortName=COM1
AdcpComBaudRate=9600
AdcpComParity=NOPARITY
AdcpComStopBits=1
AdcpComDataBits=8
AdcpConfigFilename=C:\Program Files\RD
Instruments\VmDas\OS150NB_BTon_JC31.txt
TimeoutNoRespCmd=1000
TimeoutHaveCharCmd=100
TimeoutNoRespSlowCmd=10000
TimeoutHaveCharSlowCmd=10000
TimeoutNoRespBreak=3000
TimeoutHaveCharBreak=2000
TimeoutNoEns=0
[NMEA Port Setup]
NMEANavComEnable=TRUE
NmeaNavComPortName=COM3
NmeaNavComBaudRate=4800
NmeaNavComParity=NOPARITY
NmeaNavComStopBits=1
NmeaNavComDataBits=8
NMEARPHComEnable=TRUE
NmeaRPHComPortName=COM4
NmeaRPHComBaudRate=19200
NmeaRPHComParity=NOPARITY
NmeaRPHComStopBits=1
NmeaRPHComDataBits=8
NMEA3ComEnable=FALSE
Nmea3ComPortName=None
Nmea3ComBaudRate=4800
Nmea3ComParity=NOPARITY
Nmea3ComStopBits=1
Nmea3ComDataBits=8
[NMEA Comm window]
NoDataTimeout(ms)=5000
AutoOpen=TRUE
NumNmeaDisplayedOnErrRecovery=10
[Serial Port for Binary Ensemble Data Output]
```

BinaryEnsembleOutputComEnable=FALSE
BinaryEnsembleOutputComPortName=None
BinaryEnsembleOutputComBaudRate=9600
BinaryEnsembleOutputComParity=NOPARITY
BinaryEnsembleOutputComStopBits=1
BinaryEnsembleOutputComDataBits=8
BinaryEnsembleOutputDataType(0:none;1:enr;2:enx;3:sta;4:lta)=0
BinaryEnsembleOutputRefVelType(0:none;1:Bottom;2:Mean)=0
BinaryEnsembleOutputStartBin=1
BinaryEnsembleOutputEndBin=4
BinaryEnsembleOutputMeanStartBin=1
BinaryEnsembleOutputMeanEndBin=4
BinaryEnsembleOutputLeader(0:no;1:yes)=FALSE
BinaryEnsembleOutputBottomTrack(0:no;1:yes)=FALSE
BinaryEnsembleOutputNavigation(0:no;1:yes)=TRUE
BinaryEnsembleOutputVelocity(0:no;1:yes)=TRUE
BinaryEnsembleOutputIntensity(0:no;1:yes)=TRUE
BinaryEnsembleOutputCorrelation(0:no;1:yes)=TRUE
BinaryEnsembleOutputPercentGood(0:no;1:yes)=TRUE
BinaryEnsembleOutputStatus(0:no;1:yes)=TRUE
[Serial Port for ASCII Ensemble Data Output]
AsciiEnsembleOutputComEnable=FALSE
AsciiEnsembleOutputComPortName=None
AsciiEnsembleOutputComBaudRate=9600
AsciiEnsembleOutputComParity=NOPARITY
AsciiEnsembleOutputComStopBits=1
AsciiEnsembleOutputComDataBits=8
AsciiEnsembleOutputDataType(0:none;1:enr;2:enx;3:sta;4:lta)=0
AsciiEnsembleOutputRefVelType(0:none;1:Bottom;2:Mean)=0
AsciiEnsembleOutputStartBin=1
AsciiEnsembleOutputEndBin=4
AsciiEnsembleOutputStoreToDisk(0:no;1:yes)=FALSE
AsciiEnsembleOutMeanStartBin=1
AsciiEnsembleOutputMeanEndBin=4
AsciiEnsembleOutputLeader(0:no;1:yes)=TRUE
AsciiEnsembleOutputBottomTrack(0:no;1:yes)=TRUE
AsciiEnsembleOutputNavigation(0:no;1:yes)=TRUE
AsciiEnsembleOutputVelocity(0:no;1:yes)=TRUE
AsciiEnsembleOutputIntensity(0:no;1:yes)=TRUE
AsciiEnsembleOutputCorrelation(0:no,1:yes)=TRUE
AsciiEnsembleOutputPercentGood(0:no;1:yes)=TRUE
AsciiEnsembleOutputStatus(0:no;1:yes)=TRUE
[Serial Port for Speed Log Output]
SpeedLogComEnable=FALSE
Speed Log ComPortName=None
Speed Log ComBaudRate=9600
Speed Log ComParity=NOPARITY
Speed Log ComStopBits=1
Speed Log ComDataBits=8
SpeedLogDataSource=STA

SpeedLogWLSource=WP
SpeedLogWLStartBin=3
SpeedLogWLEndBin=5
[IP Port for Binary Ensemble Data Output]
BinaryEnsembleOutputNetEnable=FALSE
BinaryEnsembleOutputIPPortNumber=5433
[IP Port for ASCII Ensemble Data Output]
AsciiEnsembleOutputNetEnable=FALSE
AsciiEnsembleOutputIPPortNumber=5433
[IP Port for Speed Log Output]
SpeedLogNetEnable=FALSE
SpeedLogHostName/IPAddress=5434
[Fake Data Options]
AdcpSimInAirEnable=FALSE
AdcpFakeDataEnable=FALSE
AdcpFakeDataFilename=SimAdcp.enr
FakeDataTimeBetweenEnsembles=2
NMEAFakeDataEnable=FALSE
NMEAFakeDataFilename=SimNav.nmr
[File Name Components]
EnableDualRecordDir=FALSE
FileRecordPath=C:\ADCP\Data\JC031\
FileRecordBackupPath=C:\RDI\ADCP\
DeploymentName=OS150_JC31
DeploymentNumber=1
MaximumFileSize=10
[Bottom Track Data Screening Options]
BTAmpScreenEnable=FALSE
BTCorScreenEnable=FALSE
BTErrScreenEnable=FALSE
BTVertScreenEnable=FALSE
BTFishScreenEnable=FALSE
BTPctGoodScreenEnable=FALSE
BTAmplitudeThreshold=30
BTCorrelationThreshold=220
BTErrorVelThreshold=1000
BTVerticalVelThreshold=1000
BTFishThreshold=50
BTPctGoodThreshold=50
[Water Track Data Screening Options]
WTAmpScreenEnable=FALSE
WTCorScreenEnable=FALSE
WTErrScreenEnable=FALSE
WTVertScreenEnable=FALSE
WTFishScreenEnable=FALSE
WTPctGoodScreenEnable=FALSE
WTAmplitudeThreshold=30
WTCorrelationThreshold=180
WTErrorVelThreshold=1000
WTVerticalVelThreshold=1000

WTFishThreshold=50
WTPctGoodThreshold=50
[Profile Data Screening Options]
PRAmpScreenEnable=FALSE
PRCorScreenEnable=FALSE
PRErrScreenEnable=FALSE
PRVertScreenEnable=FALSE
PRFishScreenEnable=FALSE
PRPctGoodScreenEnable=FALSE
PRMarkBadBelowBottom=FALSE
PRAmplitudeThreshold=30
PRCorrelationThreshold=180
PRErrorVelThreshold=1000
PRVerticalVelThreshold=1000
PRFishThreshold=50
PRPctGoodThreshold=50
[2nd Band Profile Data Screening Options]
PRAmpScreenEnable=FALSE
PRCorScreenEnable=FALSE
PRErrScreenEnable=FALSE
PRVertScreenEnable=FALSE
PRFishScreenEnable=FALSE
PRPctGoodScreenEnable=FALSE
PRAmplitudeThreshold=30
PRCorrelationThreshold=180
PRErrorVelThreshold=1000
PRVerticalVelThreshold=1000
PRFishThreshold=50
PRPctGoodThreshold=50
[Transformation Options]
XformToEarth=TRUE
Allow3Beam=TRUE
BinMap=TRUE
BeamAngleSrc(0:auto,1:man)=0
ManualBeamAngle=30
HeadingSource(0:adcp,1:navHDT,2:navHDG,3:navPRDID,4:manual)=3
NMEAPortForHeadingSource=2
ManualHeading=0
TiltSource(0:adcp,1:nav,2:man)=2
NMEAPortForTiltSource=2
ManualPitch=0
ManualRoll=0
SensorConfigSrc(0:PRfixed,1:Pfixed,2:auto)=2
ConcavitySource(0:convex,1:concave,2:auto)=2
UpDownSource(0:dn,1:up,2:auto)=2
EnableHeadingCorrections=FALSE
SinCorrectionAmplitudeCoefficient=0
SinCorrectionPhaseCoefficient=0
MagneticOffsetEV=0
BackupMagneticOffsetEV=0

AlignmentOffsetEA=0
EnableVelocityScaling=FALSE
VelocityScaleFactorForBTVelocities(unitless)=1
VelocityScaleFactorForProfileAndWTVelocities(unitless)=1
EnableTiltAlignmentErrorCorrection=FALSE
TiltAlignmentHeadingCorr(deg)=0
EAOptionSource=FALSE
TiltAlignmentPitchCorr(deg)=0
TiltAlignmentRollCorr(deg)=0
[2nd Band Transformation Options]
EnableVelocityScaling=FALSE
VelocityScaleFactorForProfileVelocities(unitless)=1
[Backup HPR NMEA Source Options]
EnableBackupHeadingSource=FALSE
BackupHeadingSource(0:adcp,1:navHDT,2:navHDG,3:navPRDID,4:manual,5:PASHR,6:PASHR,ATT,7:PASHR,AT2)=0
NMEAPortForBackupHeadingSource=-1
BackupManualHeading=0
EnableBackupTiltSource=FALSE
BackupTiltSource(0:adcp,1:nav,2:man,3:PASHR,4:PASHR,ATT,5:PASHR,AT2)=0
NMEAPortForBackupTiltSource=-1
BackupManualPitch=0
BackupManualRoll=0
[Ship Pos Vel NMEA Source Options]
EnableGGASource=TRUE
NmeaPortForGGASource=2
EnableGGABackupSource=FALSE
NmeaPortForGGABackupSource=-1
EnableVTGSource=FALSE
NmeaPortForVTGSource=2
EnableTVGBackupSource=FALSE
NmeaPortForVTGBackupSource=-1
[Averaging Options]
AvgMethod(0:time,1:dist)=0
FirstAvgTime=120
SecondAvgTime=600
FirstAvgDistance=500
SecondAvgDistance=5000
EnableRefLayerAvg=TRUE
RefLayerStartBin=3
RefLayerEndBin=10
[Reference Velocity Options]
RefVelSelect(0:none,1:BT,2:WT,3:LYR,4:NDP,5:NAP,6:NSPD)=1
VelRefLayerStartBin=3
VelRefLayerEndBin=5
RefVelUnitVel(0:mm/s,1:m/s,2:knots,3:ft/s)=1
RefVelUnitDepth(0:m,1:cm,2:ft)=0
[User Exit Options]
UserWinAdcpEnable=FALSE
UserWinAdcpPath=C:\Program Files\RD Instruments\WinAdcp\WinAdcp.exe

UserWinAdcpUpdateInterval(sec)=60
UserWinAdcpFileType(0:enr,1:enx,2:sta,3:lta)=3
UserAdcpScreening=FALSE
UserNavScreening=FALSE
UserTransform=FALSE
[Shiptrack Options]
ShipTrack1Source(0:Nav;1:BT;2:WT;3:Layer)=0
ShipTrack2Source(0:Nav;1:BT;2:WT;3:Layer)=1
ShipTrack1RedStickEnable=TRUE
ShipTrack1GreenStickEnable=FALSE
ShipTrack1BlueStickEnable=FALSE
ShipTrack2RedStickEnable=TRUE
ShipTrack2GreenStickEnable=FALSE
ShipTrack2BlueStickEnable=FALSE
ShipTrack1RedBin=1
ShipTrack1GreenBin=2
ShipTrack1BlueBin=3
ShipTrack2RedBin=1
ShipTrack2GreenBin=2
ShipTrack2BlueBin=3
ShipTrack1DisplaySelect(0:Lat/Lon;1:Distance)=0
ShipTrack2DisplaySelect(0:Lat/Lon;1:Distance)=0
ShipTrack1WaterLayerStartBin=3
ShipTrack1WaterLayerEndBin=5
ShipTrack2WaterLayerStartBin=3
ShipTrack2WaterLayerEndBin=5
ShipTrackDistanceUnit=0
[Narrow Band Shiptrack Options]
RadioBtnSelForShipPosition1DataType=0
RadioBtnSelForShipPosition2DataType=0
ShipTrack1RedStickEnable=FALSE
ShipTrack1GreenStickEnable=FALSE
ShipTrack1BlueStickEnable=FALSE
ShipTrack2RedStickEnable=FALSE
ShipTrack2GreenStickEnable=FALSE
ShipTrack2BlueStickEnable=FALSE
ShipTrack1RedBin=1
ShipTrack1GreenBin=2
ShipTrack1BlueBin=3
ShipTrack2RedBin=1
ShipTrack2GreenBin=2
ShipTrack2BlueBin=3
[ADCP Setup Options]
SetProfileParameters=TRUE
NumberOfBins=50
BinSize(meters)=4
BlankDistance(meters)=4
TransducerDepth(meters)=6
SetBTEnable(0:SendBPCmd,1:Don'tSendBPCmd)=TRUE
ADCPSetupMethod(0:Options,1:CommandFile)=1

BtmTrkEnable(0:SendBP0,1:SendBP1)=1
MaxRange(meters)=400
SetHdgSensorType=FALSE
HdgSensorType(0:internal,1:external)=-1
SetTiltSensorType=FALSE
TiltSensorType(0:internal,1:external)=-1
SetProcessingMode=TRUE
BandwidthType(0:Wide,1:Narrow)=0
ADCPTimeBetweenEnsemblesSel=1
ADCPTimeBetweenEnsembles=2

2. WINADCP OS75 configuration file

[Version Info]
VmDasVersion=Version 1.43.16
Option Table Version=1
[Expert only options]
SaveOnlyChangedOptions=TRUE
TurnedOffBeam=0
PashrImuFlagUseNormalInterpretation=TRUE
[ADCP Port Setup]
AdcpComPortName=COM1
AdcpComBaudRate=9600
AdcpComParity=NOPARITY
AdcpComStopBits=1
AdcpComDataBits=8
AdcpConfigFilename=C:\Program Files\RD Instruments\VmDas\OS75NB_BTon_JC31.txt
TimeoutNoRespCmd=1000
TimeoutHaveCharCmd=100
TimeoutNoRespSlowCmd=10000
TimeoutHaveCharSlowCmd=10000
TimeoutNoRespBreak=3000
TimeoutHaveCharBreak=2000
TimeoutNoEns=0
[NMEA Port Setup]
NMEANavComEnable=TRUE
NmeaNavComPortName=COM3
NmeaNavComBaudRate=4800
NmeaNavComParity=NOPARITY
NmeaNavComStopBits=1
NmeaNavComDataBits=8
NMEARPHComEnable=TRUE
NmeaRPHComPortName=COM4
NmeaRPHComBaudRate=19200
NmeaRPHComParity=NOPARITY
NmeaRPHComStopBits=1
NmeaRPHComDataBits=8
NMEA3ComEnable=FALSE
Nmea3ComPortName=None

Nmea3ComBaudRate=4800
Nmea3ComParity=NOPARITY
Nmea3ComStopBits=1
Nmea3ComDataBits=8
[NMEA Comm window]
NoDataTimeout(ms)=5000
AutoOpen=TRUE
NumNmeaDisplayedOnErrRecovery=10
[Serial Port for Binary Ensemble Data Output]
BinaryEnsembleOutputComEnable=FALSE
BinaryEnsembleOutputComPortName=None
BinaryEnsembleOutputComBaudRate=9600
BinaryEnsembleOutputComParity=NOPARITY
BinaryEnsembleOutputComStopBits=1
BinaryEnsembleOutputComDataBits=8
BinaryEnsembleOutputDataType(0:none;1:enr;2:enx;3:sta;4:lta)=0
BinaryEnsembleOutputRefVelType(0:none;1:Bottom;2:Mean)=0
BinaryEnsembleOutputStartBin=1
BinaryEnsembleOutputEndBin=4
BinaryEnsembleOutputMeanStartBin=1
BinaryEnsembleOutputMeanEndBin=4
BinaryEnsembleOutputLeader(0:no;1:yes)=FALSE
BinaryEnsembleOutputBottomTrack(0:no;1:yes)=FALSE
BinaryEnsembleOutputNavigation(0:no;1:yes)=TRUE
BinaryEnsembleOutputVelocity(0:no;1:yes)=TRUE
BinaryEnsembleOutputIntensity(0:no;1:yes)=TRUE
BinaryEnsembleOutputCorrelation(0:no;1:yes)=TRUE
BinaryEnsembleOutputPercentGood(0:no;1:yes)=TRUE
BinaryEnsembleOutputStatus(0:no;1:yes)=TRUE
[Serial Port for ASCII Ensemble Data Output]
AsciiEnsembleOutputComEnable=FALSE
AsciiEnsembleOutputComPortName=None
AsciiEnsembleOutputComBaudRate=9600
AsciiEnsembleOutputComParity=NOPARITY
AsciiEnsembleOutputComStopBits=1
AsciiEnsembleOutputComDataBits=8
AsciiEnsembleOutputDataType(0:none;1:enr;2:enx;3:sta;4:lta)=0
AsciiEnsembleOutputRefVelType(0:none;1:Bottom;2:Mean)=0
AsciiEnsembleOutputStartBin=1
AsciiEnsembleOutputEndBin=4
AsciiEnsembleOutputStoreToDisk(0:no;1:yes)=FALSE
AsciiEnsembleOutMeanStartBin=1
AsciiEnsembleOutputMeanEndBin=4
AsciiEnsembleOutputLeader(0:no;1:yes)=TRUE
AsciiEnsembleOutputBottomTrack(0:no;1:yes)=TRUE
AsciiEnsembleOutputNavigation(0:no;1:yes)=TRUE
AsciiEnsembleOutputVelocity(0:no;1:yes)=TRUE
AsciiEnsembleOutputIntensity(0:no;1:yes)=TRUE
AsciiEnsembleOutputCorrelation(0:no,1:yes)=TRUE
AsciiEnsembleOutputPercentGood(0:no;1:yes)=TRUE

AsciiEnsembleOutputStatus(0:no;1:yes)=TRUE
[Serial Port for Speed Log Output]
SpeedLogComEnable=FALSE
Speed Log ComPortName=None
Speed Log ComBaudRate=9600
Speed Log ComParity=NOPARITY
Speed Log ComStopBits=1
Speed Log ComDataBits=8
SpeedLogDataSource=STA
SpeedLogWLSource=WP
SpeedLogWLStartBin=3
SpeedLogWLEndBin=5
[IP Port for Binary Ensemble Data Output]
BinaryEnsembleOutputNetEnable=FALSE
BinaryEnsembleOutputIPPortNumber=5433
[IP Port for ASCII Ensemble Data Output]
AsciiEnsembleOutputNetEnable=FALSE
AsciiEnsembleOutputIPPortNumber=5433
[IP Port for Speed Log Output]
SpeedLogNetEnable=FALSE
SpeedLogHostName/IPAddress=5434
[Fake Data Options]
AdcpSimInAirEnable=FALSE
AdcpFakeDataEnable=FALSE
AdcpFakeDataFilename=SimAdcp.enr
FakeDataTimeBetweenEnsembles=2
NMEAFakeDataEnable=FALSE
NMEAFakeDataFilename=SimNav.nmr
[File Name Components]
EnableDualRecordDir=FALSE
FileRecordPath=C:\ADCP\Data\JC031\
FileRecordBackupPath=C:\RDI\ADCP\
DeploymentName=OS75_JC31
DeploymentNumber=1
MaximumFileSize=10
[Bottom Track Data Screening Options]
BTAmpScreenEnable=FALSE
BTCorScreenEnable=FALSE
BTErrScreenEnable=FALSE
BTVertScreenEnable=FALSE
BTFishScreenEnable=FALSE
BTPctGoodScreenEnable=FALSE
BTAmplitudeThreshold=30
BTCorrelationThreshold=220
BTErrorVelThreshold=1000
BTVerticalVelThreshold=1000
BTFishThreshold=50
BTPctGoodThreshold=50
[Water Track Data Screening Options]
WTAmpScreenEnable=FALSE

WTCorScreenEnable=FALSE
WTErrScreenEnable=FALSE
WTVertScreenEnable=FALSE
WTFishScreenEnable=FALSE
WTPctGoodScreenEnable=FALSE
WTAmplitudeThreshold=30
WTCorrelationThreshold=180
WTErrorVelThreshold=1000
WTVerticalVelThreshold=1000
WTFishThreshold=50
WTPctGoodThreshold=50
[Profile Data Screening Options]
PRAmpScreenEnable=FALSE
PRCorScreenEnable=FALSE
PRErrScreenEnable=FALSE
PRVertScreenEnable=FALSE
PRFishScreenEnable=FALSE
PRPctGoodScreenEnable=FALSE
PRMarkBadBelowBottom=FALSE
PRAmplitudeThreshold=30
PRCorrelationThreshold=180
PRErrorVelThreshold=1000
PRVerticalVelThreshold=1000
PRFishThreshold=50
PRPctGoodThreshold=50
[2nd Band Profile Data Screening Options]
PRAmpScreenEnable=FALSE
PRCorScreenEnable=FALSE
PRErrScreenEnable=FALSE
PRVertScreenEnable=FALSE
PRFishScreenEnable=FALSE
PRPctGoodScreenEnable=FALSE
PRAmplitudeThreshold=30
PRCorrelationThreshold=180
PRErrorVelThreshold=1000
PRVerticalVelThreshold=1000
PRFishThreshold=50
PRPctGoodThreshold=50
[Transformation Options]
XformToEarth=TRUE
Allow3Beam=TRUE
BinMap=TRUE
BeamAngleSrc(0:auto,1:man)=0
ManualBeamAngle=30
HeadingSource(0:adcp,1:navHDT,2:navHDG,3:navPRDID,4:manual)=3
NMEAPortForHeadingSource=2
ManualHeading=0
TiltSource(0:adcp,1:nav,2:man)=2
NMEAPortForTiltSource=2
ManualPitch=0

ManualRoll=0
SensorConfigSrc(0:PRfixed,1:Pfixed,2:auto)=2
ConcavitySource(0:convex,1:concave,2:auto)=2
UpDownSource(0:dn,1:up,2:auto)=2
EnableHeadingCorrections=FALSE
SinCorrectionAmplitudeCoefficient=0
SinCorrectionPhaseCoefficient=0
MagneticOffsetEV=0
BackupMagneticOffsetEV=0
AlignmentOffsetEA=0
EnableVelocityScaling=FALSE
VelocityScaleFactorForBTVelocities(unitless)=1
VelocityScaleFactorForProfileAndWTVelocities(unitless)=1
EnableTiltAlignmentErrorCorrection=FALSE
TiltAlignmentHeadingCorr(deg)=0
EAOptionSource=FALSE
TiltAlignmentPitchCorr(deg)=0
TiltAlignmentRollCorr(deg)=0
[2nd Band Transformation Options]
EnableVelocityScaling=FALSE
VelocityScaleFactorForProfileVelocities(unitless)=1
[Backup HPR NMEA Source Options]
EnableBackupHeadingSource=FALSE
BackupHeadingSource(0:adcp,1:navHDT,2:navHDG,3:navPRDID,4:manual,5:PASH
R,6:PASHR,ATT,7:PASHR,AT2)=1
NMEAPortForBackupHeadingSource=2
BackupManualHeading=0
EnableBackupTiltSource=FALSE
BackupTiltSource(0:adcp,1:nav,2:man,3:PASHR,4:PASHR,ATT,5:PASHR,AT2)=0
NMEAPortForBackupTiltSource=-1
BackupManualPitch=0
BackupManualRoll=0
[Ship Pos Vel NMEA Source Options]
EnableGGASource=TRUE
NmeaPortForGGASource=2
EnableGGABackupSource=FALSE
NmeaPortForGGABackupSource=-1
EnableVTGSource=FALSE
NmeaPortForVTGSource=2
EnableTVGBackupSource=FALSE
NmeaPortForVTGBackupSource=-1
[Averaging Options]
AvgMethod(0:time,1:dist)=0
FirstAvgTime=120
SecondAvgTime=600
FirstAvgDistance=500
SecondAvgDistance=5000
EnableRefLayerAvg=TRUE
RefLayerStartBin=3
RefLayerEndBin=10

```
[Reference Velocity Options]
RefVelSelect(0:none,1:BT,2:WT,3:LYR,4:NDP,5:NAP,6:NSPD)=1
VelRefLayerStartBin=3
VelRefLayerEndBin=5
RefVelUnitVel(0:mm/s,1:m/s,2:knots,3:ft/s)=1
RefVelUnitDepth(0:m,1:cm,2:ft)=0
[User Exit Options]
UserWinAdcpEnable=FALSE
UserWinAdcpPath=C:\Program Files\RD Instruments\WinAdcp\WinAdcp.exe
UserWinAdcpUpdateInterval(sec)=60
UserWinAdcpFileType(0:enr,1:enx,2:sta,3:lta)=3
UserAdcpScreening=FALSE
UserNavScreening=FALSE
UserTransform=FALSE
[Shiptrack Options]
ShipTrack1Source(0:Nav;1:BT;2:WT;3:Layer)=0
ShipTrack2Source(0:Nav;1:BT;2:WT;3:Layer)=1
ShipTrack1RedStickEnable=FALSE
ShipTrack1GreenStickEnable=FALSE
ShipTrack1BlueStickEnable=FALSE
ShipTrack2RedStickEnable=FALSE
ShipTrack2GreenStickEnable=FALSE
ShipTrack2BlueStickEnable=FALSE
ShipTrack1RedBin=1
ShipTrack1GreenBin=2
ShipTrack1BlueBin=3
ShipTrack2RedBin=1
ShipTrack2GreenBin=2
ShipTrack2BlueBin=3
ShipTrack1DisplaySelect(0:Lat/Lon;1:Distance)=0
ShipTrack2DisplaySelect(0:Lat/Lon;1:Distance)=1
ShipTrack1WaterLayerStartBin=3
ShipTrack1WaterLayerEndBin=5
ShipTrack2WaterLayerStartBin=3
ShipTrack2WaterLayerEndBin=5
ShipTrackDistanceUnit=0
[Narrow Band Shiptrack Options]
RadioBtnSelForShipPosition1DataType=1
RadioBtnSelForShipPosition2DataType=1
ShipTrack1RedStickEnable=FALSE
ShipTrack1GreenStickEnable=FALSE
ShipTrack1BlueStickEnable=FALSE
ShipTrack2RedStickEnable=FALSE
ShipTrack2GreenStickEnable=FALSE
ShipTrack2BlueStickEnable=FALSE
ShipTrack1RedBin=1
ShipTrack1GreenBin=2
ShipTrack1BlueBin=3
ShipTrack2RedBin=1
ShipTrack2GreenBin=2
```

ShipTrack2BlueBin=3
[ADCP Setup Options]
SetProfileParameters=FALSE
NumberOfBins=25
BinSize(meters)=8
BlankDistance(meters)=8
TransducerDepth(meters)=6
SetBTEnable(0:SendBPCmd,1:Don'tSendBPCmd)=TRUE
ADCPSetupMethod(0:Options,1:CommandFile)=1
BtmTrkEnable(0:SendBP0,1:SendBP1)=0
MaxRange(meters)=2000
SetHdgSensorType=FALSE
HdgSensorType(0:internal,1:external)=-1
SetTiltSensorType=FALSE
TiltSensorType(0:internal,1:external)=-1
SetProcessingMode=TRUE
BandwidthType(0:Wide,1:Narrow)=0
ADCPTimeBetweenEnsemblesSel=1
ADCPTimeBetweenEnsembles=2

Appendix C - MEXEC scripts used in VMADCP processing

mcod_01.m

```
% get current adcp data from codas database and create Mstar file
% for this to work currently, you have to be in the directory containing
% adcpdb for the chunk of data concerned

here = pwd;
if length(findstr(here,'os150')) > 0
  inst = 'os150';
else
  inst = 'os75';
end

[alldata,config]= run_agetmat('ddrange', [-10 400], 'editdir', 'edit');
data = apply_flags(alldata, alldata.pflag); %edit bad points

sec0 = datenum(MDEFAULT_DATA_TIME_ORIGIN);
secs = datenum(data.time) - sec0;
time = 86400 .* secs;
lon = data.lon;
lat = data.lat;
depth = data.depth;
uabs = data.uabs_sm;
vabs = data.vabs_sm;
uship = data.uship_sm;
vship = data.vship_sm;
time = reshape(time,size(lon));

dataname = [inst '_' config.dbname];
timestring = ['[' sprintf('%d %d %d %d %d
%d',MDEFAULT_DATA_TIME_ORIGIN) ']'];
otfile = dataname;

MARGS_IN = {
otfile
'time'
'lon'
'lat'
'depth'
'uabs'
'vabs'
'uship'
'vship'
' '
' '
'1'
dataname
'/'
```

```
'2'
PLATFORM_TYPE
PLATFORM_IDENTIFIER
PLATFORM_NUMBER
'/'
'4'
timestring
'/'
'8'
'time'
'/'
'seconds'
'lon'
'/'
'degrees'
'lat'
'/'
'degrees'
'depth'
'/'
'metres'
'uabs'
'/'
'cm/s'
'vabs'
'/'
'cm/s'
'uship'
'/'
'm/s'
'vship'
'/'
'm/s'
'-1'
'-1'
};
msave
```

mcod_02.m

```
% script to calculate ships speed
% and expand 1D arrays into 2D

infile = input('Enter name of input file ','s');
wkfile = ['wk_' datestr(now,30)]
otfile = [infile '_spd'];
%--------------------------------

MARGS_IN = {
infile
wkfile
```

```
'uabs vabs/'
'time uabs'
'y=repmat(x1(1,1:end),size(x2,1),1)'
' '
' '
'lon uabs'
'y=repmat(x1(1,1:end),size(x2,1),1)'
' '
' '
'lat uabs'
'y=repmat(x1(1,1:end),size(x2,1),1)'
' '
' '
'uship uabs'
'y=repmat(x1(1,1:end),size(x2,1),1)'
' '
' '
'vship uabs'
'y=repmat(x1(1,1:end),size(x2,1),1)'
' '
' '
'depth uabs'
'y=repmat(x1(1:end,1),1,size(x2,2))'
' '
' '
' '
};
mcalc
%--------------------------------

MARGS_IN = {
wkfile
otfile
'/'
'uabs vabs'
'y=sqrt(x1.*x1+x2.*x2)'
'speed'
' '
'uship vship'
'y=sqrt(x1.*x1+x2.*x2)'
'shipspd'
' '
' '
};
mcalc
%--------------------------------
```

mcod_03.m

```
function mcod_03(infile, istn)

% high level function to split out on station data

m_common
m_margslocal
m_varargs

if nargin < 1
  stn = input('Enter station number ','s');
  istn = str2num(stn);
end
if nargin < 2
  infile = input('Enter name of input file ','s');
end
wkfile = ['wk_' datestr(now,30)];

% construct output filename by removing last token
% delimited by '_'
otfile = fliplr(infile);
[atok,otfile] = strtok(otfile,'_');
otfile = fliplr(otfile);
otfile = [otfile sprintf('%3.3d',istn)];
%--------------------------------

[d1,d2] = station_range(istn);
[b1,b2] = m_info_var(infile,'time','range');
fmt1 = 'datafile: %12.2f to %12.2f\n';
fmt2 = 'station : %12.2f to %12.2f\n';
fprintf([fmt1 fmt2],b1,b2,d1,d2);

if d1 < b1 | d2 > b2
  m = 'station not wholly contained in data file';
  error(m);
end
[r1,c1] = m_info_var(infile,'time',{'first-greater' d1});
[r2,c2] = m_info_var(infile,'time',{'last-less' d2});

grange = [num2str(c1) ' ' num2str(c2)];
%--------------------------------

MARGS_IN = {
infile
otfile
'/'
' '
' '
grange
```

```
' '
' '
};
mcopya
%-------------------------------
```

mcod_04.m

```
function mcod_04(infile, istn1, istn2)

% top level function to split file into underway parts

uway = 1.0

m_common
m_margslocal
m_varargs

if nargin < 1
  infile = input('Enter name of input file ','s');
end
if nargin < 2
  stn = input('Enter 1st station number ','s');
  istn1 = str2num(stn);
end
if nargin < 3
  istn2 = istn1 + 1;
end
wkfile = ['wk_' datestr(now,30)];

% construct output filename by removing last token
% delimited by '_'
otfile = fliplr(infile);
[atok,otfile] = strtok(otfile,'_');
otfile = fliplr(otfile);
otfile = [otfile sprintf('%3.3d-%3.3d',istn1,istn2)];
%-------------------------------

[d1,d2] = station_range(istn1);
[e1,e2] = station_range(istn2);
[b1,b2] = m_info_var(infile,'time','range');
fmt1 = 'datafile: %12.2f to %12.2f\n';
fmt2 = 'passage : %12.2f to %12.2f\n';
fprintf([fmt1 fmt2],b1,b2,d2,e1);

if d2 < b1 | e1 > b2
  m = 'station not wholly contained in data file';
  error(m);
end
[r1,c1] = m_info_var(infile,'time',{'first-greater' d2});
```

```
[r2,c2] = m_info_var(infile,'time',{'last-less' e1});

grange = [num2str(c1) ' ' num2str(c2)]
%--------------------------------
% copy out part between the two stations in time

MARGS_IN = {
infile
wkfile
'/'
' '
' '
grange
' '
' '
};
mcopya
%--------------------------------

[r1,c1] = m_info_var(wkfile,'shipspd',{'first-greater' uway});
[r2,c2] = m_info_var(wkfile,'shipspd',{'last-greater' uway});

grange = [num2str(c1) ' ' num2str(c2)];
%--------------------------------
% copy out central part where shipspeed is greater than uway

MARGS_IN = {
wkfile
otfile
'/'
' '
' '
grange
' '
' '
};
mcopya
%--------------------------------
```

Station_range.m

```
function [s1,s2] = station_range(nstn)

% read station file and calculate time in seconds
stnpath = which('station_range')';
stnpath = strrep(stnpath','station_range.m','stations.dat');
eval(['load ',stnpath]);

% a line assumed to be 'stn doy hour min sec doy hour min sec'
```

```
stns = stations(:,1);
sec1 = 86400*(stations(:,2)-1) + 3600*stations(:,3) + 60*stations(:,4);
sec2 = 86400*(stations(:,5)-1) + 3600*stations(:,6) + 60*stations(:,7);

istn = fix(find(stns == nstn));
s1 = fix(sec1(istn));
s2 = fix(sec2(istn));

clear stations;
```

m_info_var.m

```
function [varargout] = m_info_var(fname,vname,question)

% ask for specific information about a variable
% available questions:
%       shape                - give back [rows,columns]
%       minimum              - give back minimum
%       maximum              - give back maximum
%       range                - give back minimum and maximum
%       ["first-greater",value] - row and column number where var first exceeds value
%       ["last-greater",value]  - row and column number where var last exceeds value
%       ["first-less",value]    - row and column number where var is first less than
value
%       ["last-less",value]     - row and column number where var is last less than
value

m_common
m_margslocal
m_varargs

Mprog = 'm_ask_var';
m_proghd;

ncfile.name = fname;
ncfile = m_ismstar(ncfile);

h = m_read_header(ncfile);
k = m_findvarnum(vname,h);

if ischar(question)
  word = question;
  value = NaN;
else
  if iscell(question)
    word = cell2mat(question(1));
    value = cell2mat(question(2));
  end
end
```

```
switch word

  case 'shape'
    rows = h.dimrows(k);
    cols = h.dimcols(k);
    varargout{1} = rows;
    varargout{2} = cols;
    return

  case 'minimum'
    varargout{1} = h.alrlim(k);
    return

  case 'maximum'
    varargout{1} = h.uprlim(k);
    return

  case 'range'
    varargout{1} = h.alrlim(k);
    varargout{2} = h.uprlim(k);
    return

  case 'first-greater'
    dv = nc_varget(ncfile.name,vname);
    ids = find(dv > value);
    [row,col] = m_index_to_rowcol(ids(1),h,k);
    varargout{1} = row;
    varargout{2} = col;
    return

  case 'last-greater'
    dv = nc_varget(ncfile.name,vname);
    ids = find(dv > value);
    [row,col] = m_index_to_rowcol(ids(end),h,k);
    varargout{1} = row;
    varargout{2} = col;
    return

  case 'first-less'
    dv = nc_varget(ncfile.name,vname);
    ids = find(dv < value);
    [row,col] = m_index_to_rowcol(ids(1),h,k);
    varargout{1} = row;
    varargout{2} = col;
    return

  case 'last-less'
    dv = nc_varget(ncfile.name,vname);
    ids = find(dv < value);
    [row,col] = m_index_to_rowcol(ids(end),h,k);
```

```
    varargout{1} = row;
    varargout{2} = col;
    return
  otherwise
    return
end
```

Steven Alderson

14. Primary Production, Calcification, Coccolithophores and the Carbonate System

14.1 Background and Cruise Objectives

Ocean acidification is the result of increasing carbon dioxide in the atmosphere being absorbed by the ocean. This shifts the carbonate system towards more CO_2 and H^+ and less carbonate ion (CO_3^{2-}), which in turn decreases calcite saturation state in the seawater. Experiments imply that ocean acidification and the subsequent decline in calcite saturation state will have a negative impact on marine calcifiers such as corals, mussels, sea urchins, pteropods and coccolithophores. Coccolithophores are of particular importance as they comprise a great proportion of biogenic calcification (50-80%). Moreover, calcite is considered to be an important ballast material for organic carbon transport from the surface to the deep ocean and is therefore playing an important role in the global carbon cycle.

Extensive lab experiments have been done on coccolithophore responses to ocean acidification and some of them show contradictory results, but studies on natural populations are limited. The cruise track crossed a natural gradient of calcite saturation state; from high values at high latitudes to very low values in Antarctic waters. Thus, a "natural lab" was provided in order to investigate how *in-situ* assemblages of coccolithophores might respond to ocean acidification, in a natural system were parameters like temperature, nutrients, mixing etc. are not controlled but have a joint effect on biological processes.

14.2 Sampling and Methods

We sampled for coccolithophores *(SEM)*, particulate inorganic carbon *(PIC)*, particulate organic carbon and particulate organic nitrogen *(POC/N)*, *chl-a, cells counts, primary production, calcification,* ^{15}N *and* ^{13}C *uptake,* dissolved inorganic carbon *(DIC)* and alkalinity *(Alk)*. Samples were collected at 79 CTD stations from 3-6 light depths (see Table 11). Underway samples (35 in total, see Table 12) were also collected during the first leg and last leg of the cruise.

14.2.1 SEM

Samples for coccolithophore analysis were taken at 59 CTD stations and from the underway supply. Exactly 1000ml of seawater were filtered on 1.2µm Isopore membrane filters under low vacuum. The filters were rinsed with analytical grade trace ammonium solution (pH ~ 9.7) to prevent the formation of salt crystals that makes analysis under the SEM difficult. Filters were dried at ~30ºC, placed in sealed Petri dishes, wrapped in tin foil and kept in a cool and dry place until analysis at NOCS using a Leo 1450VP Carl Zeiss scanning electron microscope. Analysis will involve identification, enumeration and morphometric analysis of coccospheres and loose coccoliths.

14.2.2 PIC

Samples for PIC were taken at 59 CTD stations and from the underway supply. Up to 500ml of seawater were filtered on 0.2µm or 0.8µm polycarbonate filters. The filters were rinsed with analytical grade trace ammonium solution (pH ~ 9.7) in order to dissolve salt that would otherwise contaminate the sample, placed in centrifuge tubes and kept at 4ºC until analysis at NOCS using a Perkin Elmer Optima 4300 DV inductively coupled plasma-optical emission spectrometer (ICP-OES).

14.2.3 POC/N

Samples for POC/N were taken at 59 CTD stations and from the underway supply. Up to 1500ml of seawater were filtered on pre-ashed GF/F filters. The filters were placed in Petri dishes and kept at -20ºC. Further analysis will be done using a Thermo Finnigan flash EA1112 elemental analyzer at NOCS.

14.2.4 Chl-a

Chlorophyll-*a* samples were taken at all CTD stations and from the underway supply. Exactly 200-250ml of seawater were filtered on GF/F filters. Filters were wrapped in tin foil and kept at -20ºC. Analysis at NOCS will be done following the Welschmeyer protocol using a Turner fluorometer calibrated against a spectrophotometrically determined calibration curve of commercial grade (SIGMA) chl-*a* using the SCOR / UNESCO tri-chromatic equations.

14.2.5 Cell Counts

Exactly 500ml of seawater were filtered on 0.45µm cellulose nitrate filters under low vacuum. The filters were rinsed with analytical grade trace ammonium solution (pH ~ 9.7) to prevent the formation of salt crystals. Filters were dried at ~30ºC, placed in sealed Petri dishes, wrapped in tin foil and kept in a cool and dry place until analysis at NOCS using a cross-polarised microscope.

14.2.6 Primary Production and Calcification

Daily rates of primary production and calcification were determined at 20 CTD stations following the 'micro-diffusion' technique of Paasche and Brubak 1994 (as modified by Balch *et al*., 2000). Water samples (150ml, 3 incubated, 1 formalin-killed) were collected from 3-6 light depths (around 80, 50, 20, 9, 6, 1% incident light) spiked with 100µCi of ^{14}C-labelled sodium bicarbonate and incubated in on-deck incubators. Light depths were replicated through the use of a mixture of misty blue and neutral density filters and continuous flow of water from the underway supply in the incubators kept samples at sea surface temperature. Incubations were terminated by filtration through 25mm 0.2µm polycarbonate filters, and extensive rinsing with filtered seawater to remove any labelled ^{14}C-DIC. Filters were then placed in a glass vial with gas-tight septum and a bucket containing a GFA filter soaked with phenylethylamine (PEA) attached to the lid. Phosphoric acid (1ml, 1%) was then injected through the septum into the bottom of the vial to convert any labelled ^{14}C-PIC to ^{14}C-CO_2, which was then captured in the PEA-soaked filter. After 24 hours, GFA filters were removed and placed in a fresh vial and liquid scintillation cocktail was added to both vials: one containing the polycarbonate filter (non-acid labile production, organic or primary production) and the other containing the GFA filter (acid labile production, inorganic production or calcification). Activity in both filters was then determined on a liquid scintillation counter and counts converted to uptake rates using standard methodology. Daily uptake rates per cell will also be calculated using the data from the SEM and cell count samples.

14.2.7 ^{15}N and ^{13}C Uptake Measurements

14.2.7.1 Objectives

1. To measure phytoplankton new production using ^{15}N-NO_3 and ^{13}C tracers relative to calcification rates.
2. To assess phytoplankton new production in response to ambient light gradients and relative to FRRf underway measurements.
3. To assess Redfield C:N fixation rates from dual-labelling (^{13}C, ^{15}N) experiments.

14.2.7.2 General Approach & Methods

Uptake measurements were made at every station and depth where calcification rate measurements were made.

14.2.8.1 New Production, Nitrate Uptake and Carbon Fixation

Dual-labelled (^{15}-NO_3, ^{13}C-bicarbonate) incubations were conducted at up to 6 light depths in 2.0L polycarbonate bottles for 24 hours. Light bottles were inoculated with both ^{15}N (0.1µmol $K^{15}NO3$ / 100µl) and ^{13}C spikes (4.2507g sodium bicarbonate / 100ml artificial sea water) to achieve ^{15}N-NO_3 and ^{13}C enrichments of ~10% and ~5% respectively of ambient concentrations. The light treatments were the same for primary production and calcification. After incubation, samples were filtered onto pre-ashed GF/F filters (25mm) and dried overnight in an oven at ~30°C. The dried filters will be measured for isotopic abundance on a mass spectrometer in the University of Cape Town.

14.2.8.2 Underway FRRf

Underway FRRf (Chelsea Instruments) was plumbed to the non-toxic seawater supply in the main bio lab and logged continuously. FRRf measurements will provide an indicator of the physiological status of phytoplankton assemblages in the Drake Passage region. It is anticipated that the active fluorescence response of Fv/Fm will be low, indicating Fe stress that typifies phytoplankton in Fe limited HNLC waters. Since Fe stress impacts on the ability of phytoplankton to take up and reduce nitrate to ammonium in the cells because of the iron dependency of nitrate reductase, the Fv/Fm response ought to correlate well with the ^{15}-NO_3 uptake measurements. The combination of both data sets will add to our understanding of Fe-limited nitrogen metabolism by Southern Ocean phytoplankton.

14.2.8.3 DIC and Alkalinity

Sampling procedure was according to DOE (U.S. Department of Energy) 1994. Samples were taken as soon as the Niskin bottle was opened to prevent any gas exchange. Silicone tubing and borosilicate glass bottles (250ml) were used for sampling and care was taken to prevent any air bubbles being trapped in the bottle. A headspace of 1% (2.5ml) was allowed for water expansion. Each sample was then poisoned with mercuric chloride in order to prevent any biological activity and the bottle was airtight sealed with a glass stopper. Samples were stored in a cool and dark place until analysis at NOCS. Analysis will be done using the VINDTA (Versatile INstrument for Determination of Total Alkalinity) connected with a UIC coulometer. DIC will be measured using a coulometric titration and alkalinity by titrating the sample with hydrochloric acid. Certified Reference Materials (CRMs) from A.G. Dickson (Scripps Institute of Oceanography) will be used to calibrate the instrument before sample analysis. DIC and alkalinity values will then be used to calculate the rest of the carbonate system parameters; carbon dioxide, bicarbonate and carbonate ion, pH and finally calcite and aragonite saturation state.

14.2.8.4 Continuous pCO_2 and Satellite Images

In order to support our data, continuous pCO_2 measurements (courtesy of PML) were also made and chl-*a* and true-colour and reflectance (in which coccolithophore blooms can be identified) satellite images were sent daily to the ship.

Table 11: CTD stations and depths at which samples were collected

CTD Cast	CTD bottle no.	Depth (m)	DIC/Alk	Chl-a	POC/N	PIC	SEM	Cell counts	PP	Calcifica -tion	$^{15}N/^{13}C$ uptake
2	22	5		x	x	x	x				
	18	25		x							
	14	50		x							
	5	75		x							
	1	93		x							
3	24	5		x	x	x	x	x	x	x	x
	21	25		x							
	19	50		x	x	x	x	x	x	x	x
	12	75		x							
	9	100		x	x	x	x	x	x	x	x
	6	175		x							
4	22	5		x	x	x	x	x			
	19	25		x							
	16	50		x							
	13	75		x							
	10	100		x							
	8	175		x							
5	24	5		x	x	x	x	x	x	x	x
	22	25		x							
	20	50		x	x	x	x	x	x	x	x
	18	75		x							
	14	100		x	x	x	x	x	x	x	x
	12	175		x							
6	24	5		x	x	x	x				
	22	25		x							
	20	50		x							
	18	75		x							
	16	100		x							
	14	175		x							

CTD Cast	CTD bottle no.	Depth (m)	DIC/Alk	Chl-a	POC/N	PIC	SEM	Cell counts	PP	Calcifica-tion	$^{15}N/^{13}C$ uptake
7	23-24	5		x	x	x	x				
	22	25		x							
	21	50		x							
	20	75		x							
	16	100		x							
	15	175		x							
8	24	5		x	x	x	x				
	22	25		x							
	21	50		x							
	19-20	75		x							
	18	100		x							
	17	175		x							
9	24	5		x	x	x	x				
	23	50		x							
	22	101		x							
	21	175		x							
10	24	5	x	x	x	x	x				
	23	50		x							
	22	100		x							
	21	175		x							
11	24	5		x	x	x	x	x	x	x	x
	23	50		x							
	22	100		x							
	21	175		x							
14	24	5		x		x	x	x	x	x	x
	23	50		x		x	x	x	x	x	x
	22	75		x		x	x	x	x	x	x
	21	100		x		x	x	x	x	x	x
	20	175		x							
15	Underway	5	x	x	x		x				
	23	50		x							
	22	75		x							
	21	100		x							
	20	175		x							

CTD Cast	CTD bottle no.	Depth (m)	DIC/Alk	Chl-a	POC/N	PIC	SEM	Cell counts	PP	Calcifica-tion	$^{15}N/^{13}C$ uptake
16	23-24	5		x	x	x	x				
	22	50		x							
	21	75		x							
	20	100		x							
	19	175		x							
17	24	5		x	x	x	x	x			
	23	50		x							
	22	75		x							
	21	100		x							
	20	175		x							
18	24	5		x	x	x	x	x	x	x	x
	23	50		x	x	x	x	x	x	x	x
	22	75		x	x	x	x	x	x	x	x
	21	100		x	x	x	x	x	x	x	x
	20	175		x							
19	24	5		x	x	x	x	x			
	23	50		x							
	22	75		x							
	21	100		x							
	20	175		x							
20	24	10		x	x	x	x				
	23	25		x							
	22	50		x							
	21	100		x							
	20	175		x							
21	24	5		x	x	x	x				
	23	50		x							
	22	75		x							
	21	100		x							
	20	175		x							
22	24	5		x	x	x	x	x	x	x	x
	23	50		x	x	x	x	x	x	x	x
	22	75		x	x	x	x	x	x	x	x
	21	100		x	x	x	x	x	x	x	x
	20	175		x							

CTD Cast	CTD bottle no.	Depth (m)	DIC/Alk	Chl-a	POC/N	PIC	SEM	Cell counts	PP	Calcifica-tion	$^{15}N/^{13}C$ uptake
23	24	5	x	x	x	x	x				
	23	25		x							
	22	50		x							
	21	75		x							
	20	100		x							
	19	175		x							
24	24	5		x	x	x	x				
	23	50		x							
	22	75		x							
	21	100		x							
	20	175		x							
25	24	5	x	x	x	x	x				
	23	50		x							
	22	100		x							
	21	175		x							
26	24	5		x	x	x	x		x	x	x
	23	50		x	x	x	x		x	x	x
	22	100		x	x	x	x		x	x	x
	21	175		x	x	x	x				
27	24	5		x	x	x	x	x	x	x	x
	23	50		x	x	x	x	x	x	x	x
	22	75		x	x	x	x	x	x	x	x
	21	100		x	x	x	x	x	x	x	x
28	24	5		x	x	x	x				
	23	50		x							
	22	75		x							
	21	100		x							
	20	175		x							
29	24	5	x	x	x	x	x				
	23	50		x							
	22	75		x							
	21	130		x							

CTD Cast	CTD bottle no.	Depth (m)	DIC/Alk	Chl-a	POC/N	PIC	SEM	Cell counts	PP	Calcifica-tion	$^{15}N/^{13}C$ uptake
30	24	5		x	x	x	x				
	23	65		x							
	22	100		x							
	21	175		x							
31	24	5		x	x	x	x				
	23	50		x							
	22	75		x							
	21	100		x							
	20	175		x							
32	24	5		x	x	x	x				
	23	50		x							
	22	75		x							
	21	100		x							
	20	125		x							
	19	175		x							
33	24	5		x							
	23	50		x							
	22	75		x							
	21	100		x							
	20	175		x							
36	24	5		x	x	x	x	x	x	x	x
	23	50		x	x	x	x	x	x	x	x
	22	100		x	x	x	x	x	x	x	x
	21	175		x							
37	24	5		x							
	23	50		x							
	22	75		x							
	21	100		x							
	20	175		x							
38	24	5		x	x	x	x				
	23	50		x							
	22	75		x							
	21	100		x							
	20	175		x							

CTD Cast	CTD bottle no.	Depth (m)	DIC/Alk	Chl-a	POC/N	PIC	SEM	Cell counts	PP	Calcifica-tion	$^{15}N/^{13}C$ uptake
39	24	5		x							
	23	25		x							
	22	50		x							
	21	75		x							
	20	100		x							
	19	175		x							
40	24	5		x	x	x	x				
	23	50		x							
	22	100		x							
	21	175		x							
41	24	5		x	x	x	x	x	x	x	x
	23	25		x	x	x	x	x	x	x	x
	22	50		x	x	x	x	x	x	x	x
	21	75		x	x	x	x	x	x	x	x
	20	101		x							
	19	126		x							
42	24	15		x							
	23	20		x							
	22	50		x							
	21	75		x							
	20	100		x							
	18	125		x							
43	24	15		x	x	x	x				
	23	20		x							
	22	50		x							
	21	75		x							
	20	100		x							
	19	125		x							
44	24	5	x	x	x	x	x				
	23	10		x							
	21	25		x							
	19	50		x							
	17	75		x							
	15	125		x							

CTD Cast	CTD bottle no.	Depth (m)	DIC/Alk	Chl-a	POC/N	PIC	SEM	Cell counts	PP	Calcifica -tion	$^{15}N/^{13}C$ uptake
45	23	5		x	x	x	x				
	21	25		x							
	19	50		x							
	17	75		x							
	14	100		x							
	11	175		x							
46	24	5		x							
	22	25		x							
	20	51		x							
	17	76		x							
	12	101		x							
	11	176		x							
47	24	5		x							
	22	25		x							
	20	50		x							
	17	75		x							
	13	100		x							
	11	175		x							
48	24	5		x	x	x	x				
	22	25		x							
	20	50		x							
	18	75		x							
	16	100		x							
	14	125		x							
49	24	5		x							
	22	25		x							
	18	50		x							
	16	75		x							
	14	100		x							
	12	125		x							

CTD Cast	CTD bottle no.	Depth (m)	DIC/Alk	Chl-a	POC/N	PIC	SEM	Cell counts	PP	Calcifica-tion	$^{15}N/^{13}C$ uptake
50	24	5		x							
	22	25		x							
	20	50		x							
	17	75		x							
	14	100		x							
	11	125		x							
51	20	5		x							
	19	25		x							
	18	50		x							
	17	75		x							
	12	100		x							
	11	125		x							
52	24	5		x							
	23	25		x							
	22	50		x							
	21	75		x							
	20	100		x							
	16	125		x							
53	24	5		x							
	23	25		x							
	22	50		x							
	21	75		x							
	20	100		x							
	16	125		x							
54	24	5		x	x	x	x	x	x	x	x
	23	50		x	x	x	x	x	x	x	x
	21	100		x	x	x	x	x	x	x	x
	20	175		x	x	x	x	x	x	x	x
55	24	5		x							
	23	50		x							
	21	100		x							
	20	175		x							

CTD Cast	CTD bottle no.	Depth (m)	DIC/Alk	Chl-a	POC/N	PIC	SEM	Cell counts	PP	Calcification	$^{15}N/^{13}C$ uptake
56	24	5		x	x	x	x				
	23	50		x							
	21	100		x							
	20	175		x							
58	24	5		x	x	x	x	x	x	x	x
	23	50		x	x						
	22	75		x	x	x	x	x	x	x	x
	21	99		x	x	x	x	x	x	x	x
	20	174		x							
59	24	5		x							
	23	50		x							
	21	100		x							
	20	175		x							
	19	250		x							
60	24	5		x	x	x	x				
	23	50		x							
	21	100		x							
	20	175		x							
	19	250		x							
61	24	5		x							
	23	50		x							
	21	100		x							
	20	175		x							
62	24	5		x	x	x	x	x	x	x	x
	23	50		x	x	x	x	x	x	x	x
	21	100		x	x	x	x	x	x	x	x
	20	175		x							
63	24	5		x	x	x	x				
	23	50		x							
	22	100		x							
	21	175		x							
64	24	5		x	x	x	x				
	23	50		x							
	20	100		x							
	19	175		x							

CTD Cast	CTD bottle no.	Depth (m)	DIC/Alk	Chl-a	POC/N	PIC	SEM	Cell counts	PP	Calcifica-tion	$^{15}N/^{13}C$ uptake
65	24	5		x	x	x	x	x	x	x	x
	23	50		x	x	x	x	x	x	x	x
	20	100		x	x	x	x	x	x	x	x
	19	165		x							
66	24	5		x	x	x	x				
	23	50		x							
	22	100		x							
	21	175		x							
67	24	5		x	x	x	x				
	23	50		x							
	22	100		x							
	21	175		x							
68	24	5		x	x	x	x				
	23	50		x							
	22	100		x							
	21	175		x							
69	24	5	x	x	x	x	x	x	x	x	x
	23	50	x	x	x	x	x	x	x	x	x
	20	100	x	x	x	x	x	x	x	x	x
	19	175		x							
70	24	5		x	x	x	x				
	23	50		x							
	22	100		x							
	20	175		x							
71	24	5		x	x	x	x				
	23	50		x							
	22	100		x							
	20	175		x							
72	24	5		x	x	x	x	x	x	x	x
	23	50		x	x	x	x	x	x	x	x
	22	100		x	x	x	x	x	x	x	x
	21	175		x							

CTD Cast	CTD bottle no.	Depth (m)	DIC/Alk	Chl-a	POC/N	PIC	SEM	Cell counts	PP	Calcifica-tion	$^{15}N/^{13}C$ uptake
73	24	5		x	x	x	x				
	23	25		x							
	22	50		x							
	20	75		x							
	19	100		x							
	18	175		x							
74	24	5		x	x	x	x				
	22	50		x							
	20	100		x							
	19	175		x							
75	24	5		x	x	x	x				
	16	50		x							
	15	100		x							
	14	175		x							
76	24	5		x	x	x	x				
	23	50		x							
	13	100		x							
	12	175		x							
77	24	5		x	x	x	x				
	11	50		x							
	10	100		x							
	9	175		x							
78	24	5		x	x	x	x				
	11	50		x							
	10	100		x							
	9	175		x							
79	20	5		x							
	16	25		x							
	12	50		x							
	8	75		x							
	4	110		x							
	1	160		x							

CTD Cast	CTD bottle no.	Depth (m)	DIC/Alk	Chl-a	POC/N	PIC	SEM	Cell counts	PP	Calcification	$^{15}N/^{13}C$ uptake
80	23	5		x	x	x	x				
	22	30		x							
	21	50		x							
	19	75		x							
	15	101		x							
	13	176		x							
81	24	5	x	x	x	x	x				
	23	50		x							
	21	100		x							
	18	175		x							
82	20	5		x	x	x	x	x	x	x	x
	16	25		x	x	x	x	x	x	x	x
	12	50		x	x	x	x	x	x	x	x
	8	75		x	x	x	x	x	x	x	x
	4	100		x	x	x	x	x	x	x	x
	1	125		x							

Table 12: Dates, times and positions of underway sampling

Event no.	Date	Time (BST)	Lat (N) Deg/Min	Long (E) Deg/Min	DIC/ Alk	Chl-a	POC/ N	PIC	SEM
1	04/02/09	01:04	52 58.70	68 18.83	x	x	x	x	x
2	04/02/09	03:00	53 12.20	66 48.64	x	x	x	x	x
3	04/02/09	05:00	53 24.65	66 21.30	x	x	x	x	x
4	04/02/09	07:57	53 44.21	65 37.29	x	x	x	x	x
5	04/02/09	09:00	53 51.03	65 20.84	x	x	x	x	x
6	04/02/09	11:02	54 07.71	64 43.79	x	x	x	x	x
7	04/02/09	12:58	54 18.14	64 18.94	x	x	x	x	x
8	04/02/09	15:05	54 31.84	63 48.80	x	x	x	x	x
9	04/02/09	17:03	54 45.47	63 31.79	x	x	x	x	x
10	04/02/09	19:02	55 06.77	63 39.90	x	x	x	x	x
11	04/02/09	21:09	55 20.12	64 08.52	x	x	x	x	x
12	04/02/09	22:56	55 29.79	64 30.34	x	x	x	x	x
13	05/02/09	00:59	55 41.73	64 58.21	x	x	x	x	x
14	05/02/09	02:57	55 53.76	65 24.86	x	x	x	x	x
15	05/02/09	04:59	55 06.38	65 53.11	x	x	x	x	x
16	05/02/09	06:57	56 18.72	66 20.88	x	x	x	x	x
17	05/02/09	08:55	56 30.99	66 48.54	x	x	x	x	x
18	05/02/09	11:03	56 44.56	67 21.70	x	x	x	x	x
19	05/02/09	12:56	56 57.36	67 50.38	x	x	x	x	x
20	08/02/09	08:00	57 34.81	68 14.64	x	x	x	x	x
21	27/02/09	11:59	51 01.46	57 13.64	x	x	x	x	x
22	27/02/09	13:57	50 41.19	57 15.62	x	x	x	x	x
23	27/02/09	18:53	49 50.98	57 15.14	x	x	x	x	x
24	27/02/09	23:03	49 12.75	57 14.24	x	x	x	x	x
25	28/02/09	02:52	48 35.88	57 09.77	x	x	x	x	x
26	28/02/09	04:57	48 17.70	57 09.05	x	x	x	x	x
27	28/02/09	08:56	47 43.70	57 04.71	x	x	x	x	x
28	28/02/09	13:01	47 07.52	57 02.64	x	x	x	x	x
29	28/02/09	16:57	46 30.91	56 59.99	x	x	x	x	x
30	28/02/09	20:52	45 53.45	56 37.58	x	x	x	x	x
31	29/02/09	01:00	45 11.30	56 54.29	x	x	x	x	x
32	29/02/09	03:58	44 51.56	56 52.08	x	x	x	x	x
33	01/03/09	08:58	43 53.71	56 48.00	x	x	x	x	x
34	01/03/09	11:57	43 26.29	56 46.22	x	x	x	x	x
35	01/03/09	16:37	42 58.86	56 43.86	x	x	x	x	x

14.3 References

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15. Continuous O_2 concentration measurements from the uncontaminated seawater supply

15.1 Objectives

- To measure the continuous O_2 concentration from the uncontaminated seawater supply (USW) using an underway oxygen optode (*Aanderaa* Model No. 3835, Serial No. 329).
- To calibrate the continuous O_2 concentration from the optode by collecting discrete samples from the USW and analyzing for the total O_2 content using the Winkler method.

We measured continuously the O_2 concentration from the sea surface water pumped by the uncontaminated system supply of seawater (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. To measure the continuous dissolved O_2 concentration in the USW we used an *Aanderaa* Oxygen optode **(AOO, Model No. 3835, Serial No. 329)**, which is based on the ability of selected substances to act as dynamic fluorescence quenchers. The fluorescent indicator is a special platinum porphyrin complex embedded in a gas permeable foil that 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 linearizing 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, determined by the Winkler method (Dickson, 1996).

15.2 Setup

15.2.1 Uncontaminated System Supply of Sea Surface Water, RRS James Cook

The USW pumping system in the RRS *James Cook* consists of two screw pumps with a capacity of 10-20m^3 h^{-1} at a pressure of 2.5bar, and a maximum rotation speed of 2350 rpm. Each pump works over a period of 12 hours, alternating its functioning with an automated switchover.

The pumps are located in the lower deck on the starboard side of the ship. The pipes distribute the water towards the centre of the ship and then up two levels until reaching the laboratories in the upper deck. The pipe splits four ways, which distributes the water to the different taps in the laboratories. The taps in the laboratories consist of a pipe design of three outlets for each sink, with an internal diameter in a gradient that allows the same outflow in case the three taps are open at the same time. Approximately 90% of the pipe system is insulated.

15.2.2 Underway Oxygen Measurements by an Aanderaa optode

The optode was kept in a 1L dark bucket that was continuously filled with the USW flow from the backward starboard sink in the controlled temperature laboratory (CTL) (deck level) of the RRS *James Cook*. Constant temperature, non-calibrated dissolved O_2 and O_2 saturation was recorded giving a dataset of more than 250,000 individual readings at 10 seconds resolution.

Stability on the optode signal is achieved unless external perturbations are detected due to the high sensitivity of the optical sensor. In general, the readings from the sensor proved to be stable throughout the cruise. The USW onboard the RRS *James Cook* also proved to be a very stable system with constant flow over time without a significant entrance of bubbles into the pipes, keeping good measurements along the transit while steaming between stations and during stations. Every 12 hours the USW pump switchover was performed and a spike in the signal was easily identified (Figure 56) with perturbation over the measurement during 5 minutes on average, followed by a very stable signal. The USW was kept on at all times except when leaving and arriving in port. During a few short periods of time, the optode signal was not stable; these events occurred when the ship was rolling and pitching due to high wind speeds and large swell. Therefore, we deduced that the ships speed was not a cause of bubbles entering the system.

In total, 28 days worth of data were recorded between Julian days 34 - 61 (3rd of February to 2nd of March, 2009).

15.2.3 Calibration of the Underway Oxygen optode

The oxygen concentration sensed by the optode represents the partial pressure of dissolved oxygen. Since the foil is only permeable to gas and not water, the optode cannot sense the effect of salt dissolved in the water, hence the optode always measures as if immersed in fresh water. Post compensation must be performed using the true salinity on site to achieve a more accurate correction.

To calibrate the optode, 102 samples (including duplicates) were collected from the uncontaminated seawater system, using the same sampling point as the optode O_2 measurements (i.e. backward starboard sink in the CTL, deck level). The discrete samples were collected into pre-calibrated glass bottles and the total dissolved O_2 was quantified on the base of the Winkler method published by the WOCE procedures (Dickson, 1996) using a Winkler Ω-Metrohm titration unit (716 DMS Titrino) with amperometric end-point detection.

Chemical reagents and standards, as well as Winkler equipment was provided by the nutrients and oxygen team from the National Oceanography Centre, Southampton. The same equipment was used for the CTD discrete samples for the O_2 sensor calibration.

The USW samples were analyzed over the time of the cruise within 5 sessions. A corresponding pickling chemicals calibration, consisting of 5 blanks with MilliQ water, and 5 analysis of KIO_3 standard (1.667mM certified, *OSIL*) for the $Na_2S_2O_3$

calibration were performed before the seawater sample analysis for each session. The Winkler bottle number for each sample was corrected to the uncalibrated optode temperature. The typical standard deviation of a duplicate analysis was 0.51μmolkg^{-1}. In the next table the reagent blanks, KIO_3 standard volumes for the $Na_2S_2O_3$ calibration and final $Na_2S_2O_3$ concentration for each session are shown.

Table 13 – Reagent blanks and KIO_3 standard titration results for the calibration of the sodium thiosulphate ($Na_2S_2O_3$) solution.

Session	Date	$Na_2S_2O_3$ volume for blank reagents (ml) [1]	$Na_2S_2O_3$ volume for KIO_3 standard titration (ml) [1]	$Na_2S_2O_3$ concentration (mol dm^{-3}) [2]
1	03/02/09	0.0012±0.0003	0.4985±0.0014	0.3300
2	10/02/09	0.0003±0.0004	0.4977±0.0018	0.3305
3	14/02/09	0.0007±0.0012	0.5373±0.0009	0.3063
4	21/02/09	0.0002±0.0003	0.5340±0.0021	0.3078
5	27/02/09	0.0013±0.0008	0.5293±0.0007	0.3113

[1] Results show the average ± 1 standard deviation for the 5 blanks and standard measurements, respectively.

[2] Sessions 1 and 2 were for the thiosulphate labelled "A", while sessions 3, 4 and 5 were using thiosulphate "B".

Using the temperature-dependent fourth-order calibration polynomial stored in the optode, the Winkler measurements were converted to phase values, as measured by the optode. These "inverted" phase values (solved d-phase) were regressed linearly against the phase values measured by the optode (raw d-phase) closest to the sampling time of the discrete sample (Figure 54). The resulting calibration function will be used to compute the calibrated optode data. Differences are originated both from uncertainties in the optode and in the Winkler measurements. Figure 55 shows the comparison between the raw and solved d-phase for the samples collected.

15.2.4 Dissolved O_2 Concentration from USW and CTD Surface Niskin Bottle

To evaluate the effect of the pipes on the O_2 concentration in the surface seawater, discrete samples from the USW from about 54% of the total number of CTD casts (45 out of a total of 84) were collected at the firing time of the sea surface Niskin bottle. A preliminary comparison between the O_2 discrete results determined by the Winkler method on the USW and Niskin bottles samples (Figure 55) showed on average a difference of 2.93 ±13.48 μmol kg^{-1}. This value represents a removal of O_2 over the sea surface water due to the pipes in the USW system.

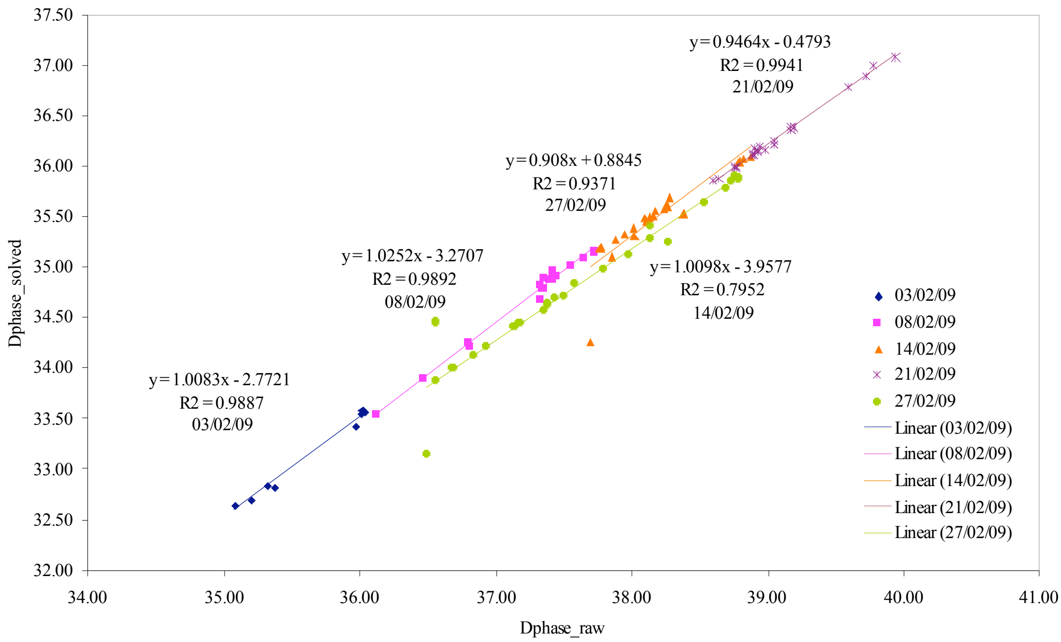

Figure 54: Optode D-phase raw against D-phase solved for the discrete USW samples collected for O_2 continuous calibration.

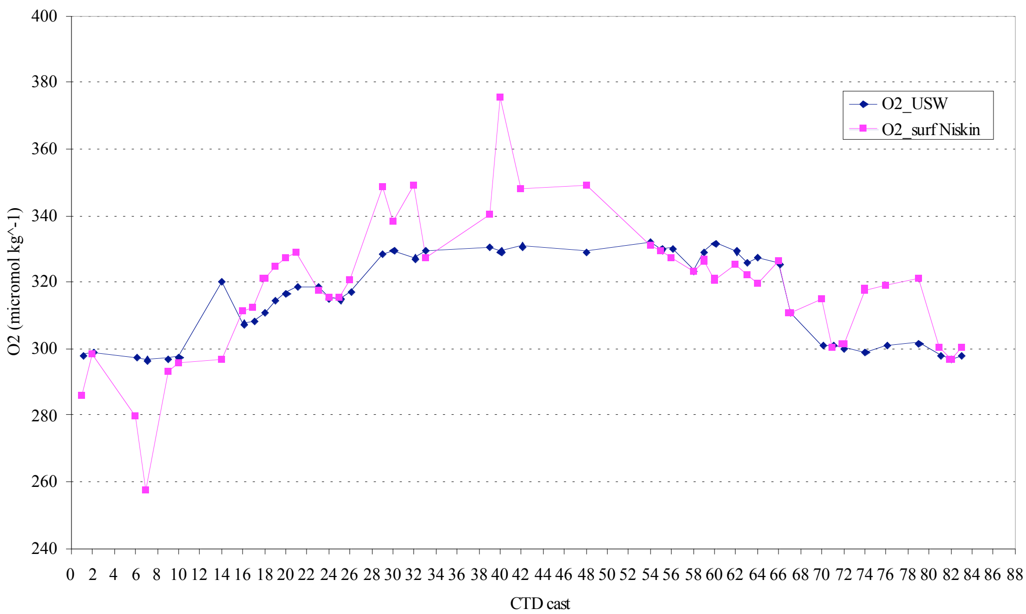

Figure 55: Comparison between O_2 concentration from surface Niskin bottles and discrete samples from the USW at the firing Niskin time.

It is important to note that the temperature of the sample considered at O_2 fixing time (i.e. when the pickling reagents were added) corresponded to the optode uncalibrated temperature and the temperature recorded by a digital thermometer at the time of sample collection, both for the USW and surface Niskin bottle respectively. A consistent lower temperature was obtained from the optode compared with the one recorded by the digital thermometer at sampling time.

A final correction of data using a common calibrated sea surface temperature should be considered to account for the correct effect on the O_2 concentration due to the pipes.

In the Figure 56, continuous 10-second resolution data of temperature and oxygen from the *Aanderaa* optode corresponding to Julian day 54 (23 Feburary, 2009) are shown. The values plotted are not calibrated. The O_2 concentration determined by the Winkler method from the discrete samples collected along the day, are displayed as red dots.

During Julian day 54, we steamed northwards in the Drake Passage along the second transect. A gradient of temperature and oxygen was observed (from 4.40 to 6.14ºC and 358 to 335 μmol kg^{-1}, respectively) between the 15:24 hrs to 15:40 hrs, proof of the cross over the PF (polar front) (Julian day 54.64 to 54.65) (Figure 56).

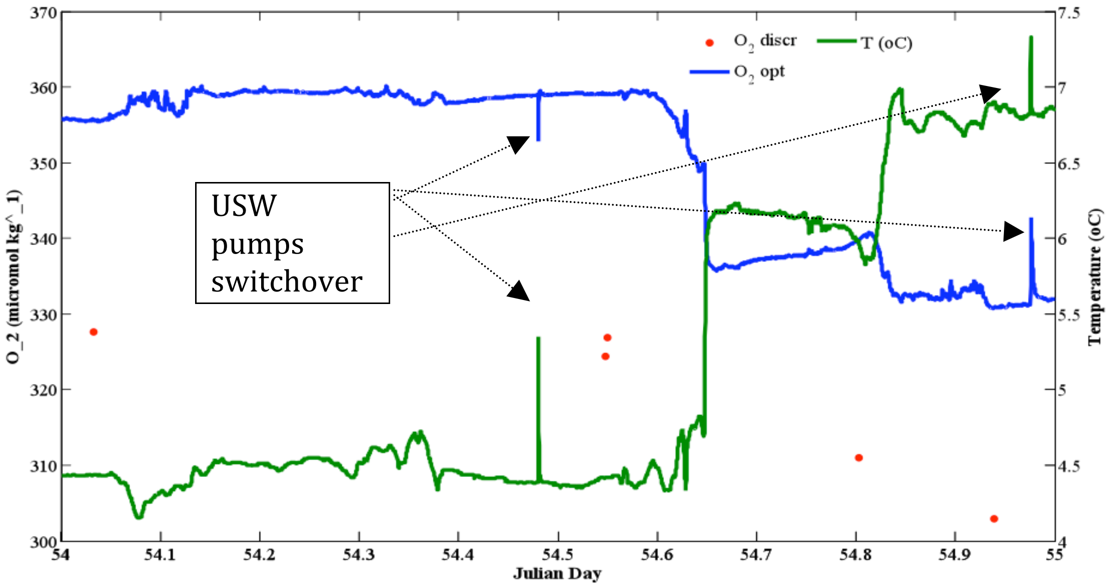

Figure 56: Raw dissolved O_2 concentration (not corrected by salinity and calibrated sea surface temperature (SST)) and temperature from the USW recorded by the *Aanderaa* optode corresponding at Julian day 54 (23 February, 2009). Red dots show the O_2 concentration obtained by Winkler method from the discrete samples collected from the USW along the day. Arrows indicate the location of the USW pumps switchover signal, identified as a spike in the continuous signal.

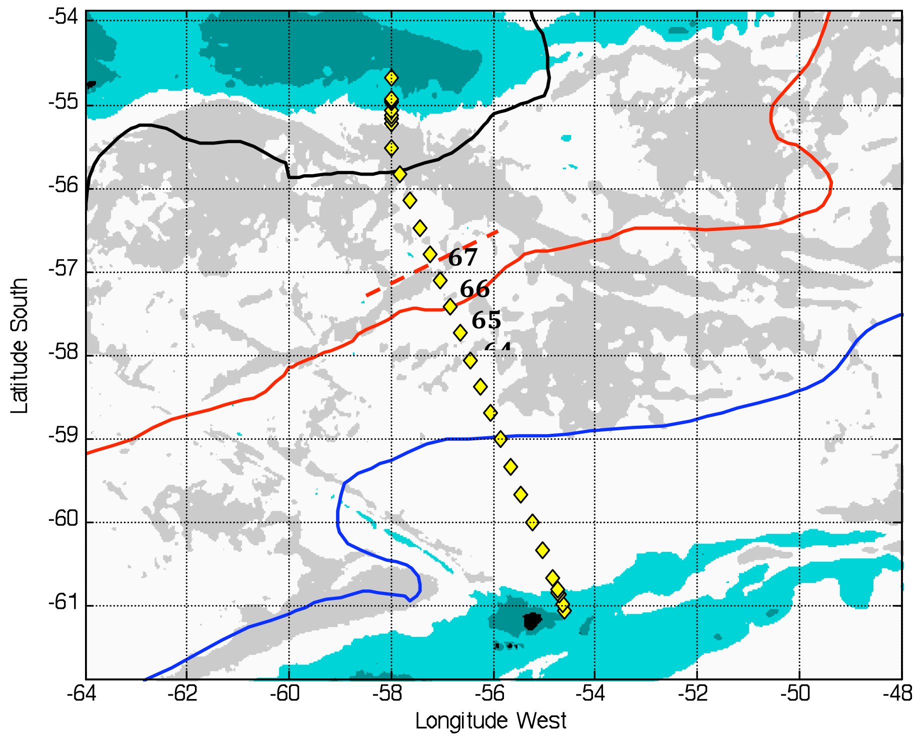

Figure 57: Location of CTD casts for the second section during JC031. Red continuous line shows the PF location climatologically obtained; Red dotted line shows the location of the PF by the identification of the temperature gradient in the optode data during the present cruise.

15.2.5 Sea Surface Temperature Optode Sensor (SST-opt)

The temperature recorded by the optode should be corrected due to a possible warming effect on the sea surface water travelling from the intake at the bow of the ship through the pipes to the tap in the CTL sink. To calibrate the optode temperature, comparison with available continuous sea surface temperature from the ship sensors should be performed. The RRS *James Cook* has three sensors to record the continuous SST from the USW.

The SST recorded by SURFMET is known as the remote sensor (sst-r) and is located at the intake of the USW being the first temperature sensor to record a value every second. The second SST is recorded where the USW flow travels through the thermosalinograph (TSG) equipment and is known as the housing sensor (sst-h). This sensor is located in the wet laboratory. The continuous flow of USW passes through a de-bubbler and then enters to the TSG.

Next to this equipment, is located a high precision temperature sensor (SeaBird45). Finally, the USW flow travels towards the CTL with the optode being the last sensor to record SST from the continuous surface seawater flow. A comparison with the available calibrated SST from these sensors, with a stable signal along the time, will be used to correct the continuous O_2 concentrations obtained from the *Aanderaa* optode.

15.3 References

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***Acknowledgements* -** Many thanks to the crew, officers and scientific party of RRS *James Cook* cruise JC031 Drake Passage.

Karel Castro-Morales

16. 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

16.1 Rationale and Objectives

Dissolved oxygen (O_2) concentrations of seawater are 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 affects, 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 super-saturation, posing a challenge to this approach.

Craig and Hayward (1987) used oxygen/argon (O_2/Ar) ratios to separate O_2 super-saturations into a biological and a 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 super-saturation, ΔO_2/Ar, as:

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

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 (Hendricks et al., 2004; Luz and Barkan, 2000; Quay et al., 1993; Spitzer and Jenkins, 1989). Recently an advancement of the method was presented for continuous underway measurements of O_2/Ar by membrane-inlet mass spectrometry (MIMS) (Kaiser et al., 2005), extending earlier oceanographic MIMS applications (Kana 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 of not involving potential biases associated with incubating water samples in a bottle. The *N* estimates from the JC031 cruise will be used to quantitatively study the autotrophic or heterotrophic nature of different marine ecosystems in the Southern Ocean.

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 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.

16.2 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 quadruple 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 controlled 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 -2ºC. The flight tube was in a thermally insulated box maintained initially at 70 ºC.

The O_2/Ar ratio measurements were 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 et al., 1993). These samples will be later analyzed using an isotope ratio mass spectrometer at the School of Environmental Sciences, University of East Anglia, to determine dissolved O_2/Ar ratios and the oxygen triple isotope composition relative to air (Hendricks et al., 2004). Raw O_2/Ar ion current ratio measurements were made every 5 seconds 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.

16.3 Results

52 discrete water samples were collected for calibration purposes and to analyze oxygen triple isotopes. 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 from the South.

Membrane inlet mass spectrometry (MIMS) was used to analyse 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 during Julian days 38 to 48 (7 to 17th of February, 2009) the equipment was unstable due to the contamination of the membrane box with air. Therefore, during this time discrete sample collection was still performed.

Figure 58 is an illustration of the O_2/Ar ratio data from MIMS during the Julian day 54 (23rd February, 2009) when the crossing of the Polar Front occurred. The uncalibrated O_2 saturation (%) from the optode is also plotted. Both signals are interpolated at 10-second resolution over the same time vector. The gradient in seawater properties (i.e. temperature and salinity) characterizing the PF cross was registered between JD 54.64 and 54.65 (15:24 to 15:40 hrs) and as can be seen, the O_2 saturation decreased by 2.5% (representing about 20μmol kg^{-1} of O_2 concentration in a change of 1.75ºC of surface seawater temperature).

The variation observed at the time of the PF crossing, in terms of the O_2/Ar ratio, does not show a noticeable decrease in a gradient as for the O_2 super-saturation. This could reflect a biological O_2 super-saturation in the area. This is an example of the O_2/Ar ratio as a useful proxy to detect the O_2 saturation due to biological processes removing the physical factors in the gas solubility.

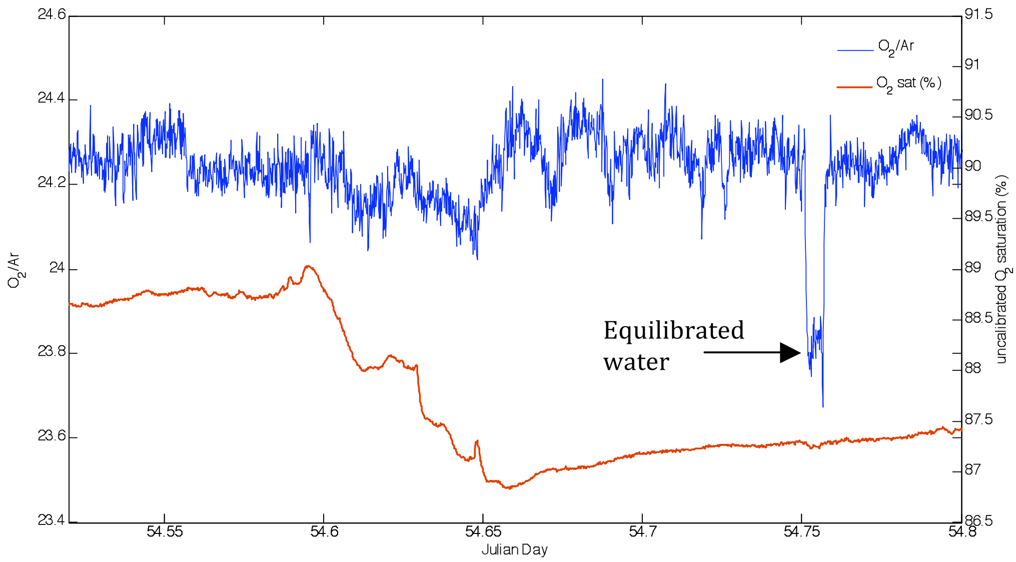

Figure 58: Raw (uncalibrated) O_2/Ar from MIMS and uncalibrated O_2 saturation from Optode for the USW measurement during JD 54.5 to 54.8. A reading of standard equilibrated water in the MIMS is also shown.

Since the O_2/Ar ratio in the air is more or less constant over the time, it is a good standard to evaluate the performance of the MIMS over the time. For this purpose, filtered seawater was kept under constant sea air bubbling to equilibrate its gas content and use it as standard. In Figure 58, a period of 8 minutes shows the equilibrated water reading that is activated by switching the gear pump, allowing the flow of the equilibrated water to pass into the MIMS for a manually selected period of time. As can be seen, the signal before and after the standard reading shows a gas super-saturation with respect to the gas content in equilibrium with the atmosphere.

The O_2/Ar data are not affected as much by bubbles, because the O_2/Ar ratio in seawater (about 20.5) is similar to the ratio in air (about 22). Therefore, the influence of bubbles entrained through the USW can be detected by the N_2/Ar ratios. For N_2/Ar, the corresponding ratios are about 40 to 80.

16.3.1 O_2/Ar Ratio Distribution in the Vertical Water Column

Since the MIMS is continuously recording the O_2/Ar ratio in the surface seawater representing the mixed layer, an attempt to measure the distribution in the water column was performed in this cruise. From selected CTD casts and depths (see Table 14) characterizing the vertical profile, seawater was sampled in 500ml glass bottles. The analysis of the samples was performed while on the next station after the one sampled to keep recording the continuous signal from the transits between stations.

Figure 59, shows the analysis of the samples corresponding to Station 64 of the second transect, south of the PF, at 10 depths distributed along the profile (5, 50, 100, 250, 500, 875, 1000, 2000, 3000 and 3500m). Two samples from the USW were collected from the outlet where the MIMS is connected to the TCL at the firing time of Niskin surface bottle; these are to compare the effect of the pipes over the O_2/Ar in the USW.

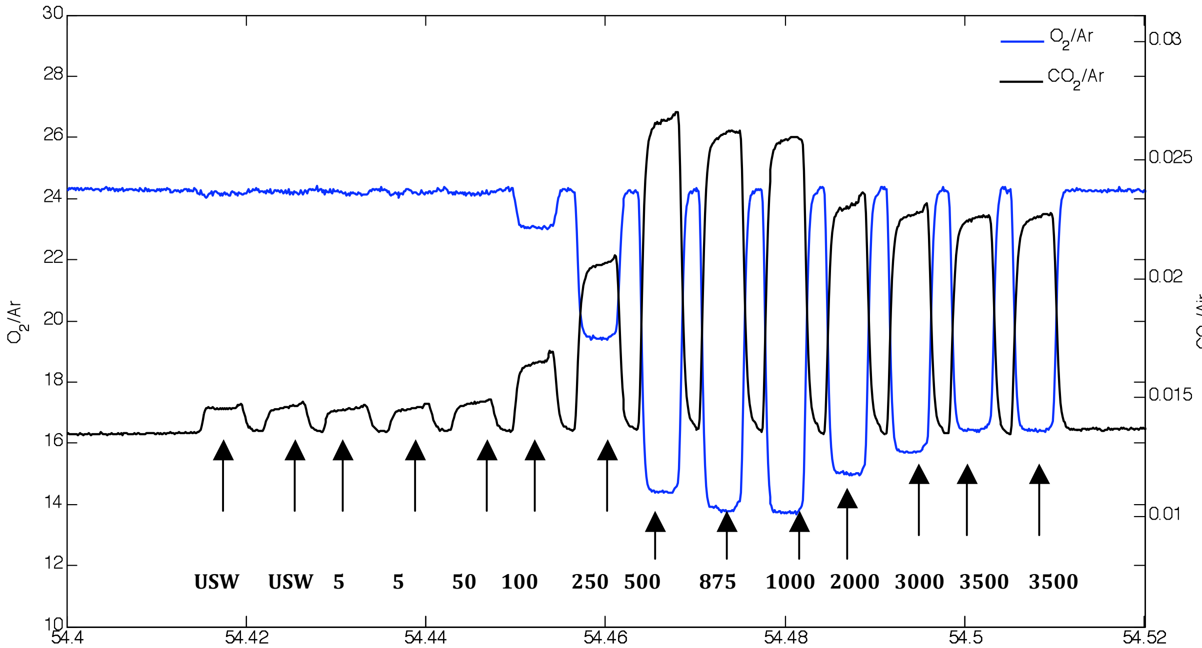

Figure 59: Raw (uncalibrated) O_2/Ar and CO_2/air ratio from MIMS data using Channeltron detector for the seawater samples from the vertical profile at selected depths in Station 64, transect 2, JC031. The measurement was performed while occupying Station 65.

For some selected depths, duplicate samples were collected in order to evaluate the reproducibility of the sampling and equipment. As can be observed in Figure 59, the variation in the O_2 content along the vertical profile is reflected in the O_2/Ar ratio. With this information we can derive the Ar total concentration and estimate the amount of O_2 biological super-saturation.

For the first time these measurements are performed, allowing a realistic contribution of Ar concentration to gas transport models. In Figure 59, the O_2/Ar signal is compared with the CO_2/air signal.

Table 14: Selected stations and depths along the transect 2 of the JC031 oceanographic campaign, for the measurements of O_2/Ar by MIMS.

CTD cast	Source (Niskin bottle)	Depth (m)
1	USW	5
	USW	5
	24	5
	22	100
	20	250
	18	500
	16	750
	16	750
	14	1000
	12	1500
	12	1500
	10	2000
	6	3000
	1	4390
2	USW	5
	USW	5
	24	5
	1	89
7	USW	5
	USW	5
	23	5
	23	5
	21	50
	16	100
	14	250
	12	500
	10	750
	8	1000
	6	1500
	4	2000
	2	2410
	2	2410
14	USW	5
	USW	5
	24	5
	24	5
	20	175
	17	500
	15	750
	15	750
	13	1000
	11	1500
	9	2000
	6	2750
	1	3730
	1	3730
16	USW	5
	USW	5
	24	5
24	USW	5
	USW	5
	24	5
	24	5
	23	50
	19	250
	17	500
	13	1000
	13	1000
	5	3000
	9	2000
	3	3500
	1	3775
	1	3775
56	USW	5
	USW	5
	24	5
	21	100
	17	500
	17	500
	13	1000
	11	1500
	9	2000
	9	2000
	7	2500
	5	3000
	2	3425
	2	3425
58	USW	5
	USW	5
	24	5
	24	5
	21	100
	21	100
	17	500
	13	1000
	11	1500
	11	1500
	9	2000
	5	3000
	1	3660
	1	3660
60	USW	5
	USW	5
	24	5
	23	50
	22	100
	22	100
	17	500
	17	500
	13	1000
	9	2000
	5	3000
	3	3500
	1	3730
	1	3730
62	USW	5
	USW	5
	24	5
	24	5
	23	50
	21	100
	19	250
	17	500
	15	750
	13	1000
	9	2000
	5	3000
	1	3810
	1	3810
64	USW	5
	USW	5
	24	5
	24	5
	22	50
	21	100
	18	250
	16	500
	13	875
	12	1000
	8	2000
	4	3000
	1	3500
	1	3500

Table 14 continued.

CTD cast	Source (Niskin bottle)	Depth (m)
66	USW	5
	USW	5
	24	5
	24	5
	23	50
	22	100
	20	250
	17	625
	14	1000
	10	2000
	10	2000
	10	2000
	5	3250
	1	4130
	1	4130
67	24	5
	21	100
	18	175
	13	750
	8	1763
	1	3116
70	USW	5
	USW	5
	24	5
	23	50
	22	100
	17	625
	14	1000
	13	1250
	11	1750
	7	2960
	5	3600
	3	4200
	1	4700
	1	4700
72	USW	5
	USW	5
	24	5
	24	5
	22	100
	18	500
	16	750
	14	1000
	12	1500
	12	1500
	10	2000
	6	3000
	1	3812
	1	3812
76	USW	5
	USW	5
	24	5
	24	5
	23	50
	13	100
	9	500
	7	750
	7	750
	5	1000
	3	1500
	1	1635
	1	1635
79	USW	5
	USW	5
	22	5
	20	5
	16	25
	12	50
	8	75
	4	110
	2	160
	1	160

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Karel Castro-Morales

17. FRRF - Fast Repetition Rate Fluorometry from the Uncontaminated Supply

A Fast Repetition Rate Fluorometer (FRRF) (*Chelsea Instruments Ltd.*) was used to measure active fluorometry from the uncontaminated system supply (USW) on board 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 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 surface seawater from a nominal depth of 5m where 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 F_o and F_m 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 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.

Extraction of the variables mentioned above was performed from each file using a Matlab script, to finally construct a matrix of the FRRF parameters along the time per Julian day. Data processing and comparisons against chlorophyll a measurements from the USW will be performed in the University of East Anglia (Dr. Jan Kaiser) and in the National Oceanographic Centre, Southampton (Dr. Mike Lucas).

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

17.1 References

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Karel Castro-Morales

18. Natural Products as Marine Antifoulants: Observing Biofouling Activity in the Drake Passage

18.1 Background Information and Objectives

Biofouling (the attachment of organisms on either manmade or natural surfaces) has recently received increased attention since marine fouling organisms attached on ship hulls affect many aspects of the shipping industry; the attachment of marine organisms, such as barnacles and algae, increase moving vessel's drag resulting in considerably higher fuel consumption. Additionally, biofouling has been shown to affect the native marine biodiversity since alien fouling species have been reported to be transported across the world's harbours and thus invade and affect the dynamics of the local biodiversity. Although the incorporation of tributyl tin (TBT) into coating systems has been widely used for its anti-fouling property, recently, in September 2008 the use of TBT has been banned due to its toxic affects in the wider marine environment. Therefore, the need for a new, effective and environmentally friendly coating system has been the focus and challenge for the scientific community. Commercial marine paint technologies including foul release coatings (FRC) have been found to be effective only for scheduled ships (e.g. ferries) while self-polishing co-polymers (SPC) and controlled depletion polymers (CDP) often contain substances deemed to be toxic to the marine environment (e.g. copper and zinc) and have high residence times in aquatic sediments.

Thus, the current research project aims to design and assess the performance of environmentally acceptable marine antifoulants by exploiting natural chemical defence mechanisms of non-fouled organisms.

For the JC031 cruise, two different seaweed extracts were incorporated into a marine experimental polymeric coating system and submerged into sea water from the Drake Passage transects. The main objectives of the experiment were: (*i*) to observe bio-film activity over a 28-day interval (temporal) beginning 05/02/2009 and (*ii*) to test the efficacy of the anti-fouling coating, as well as the binder integrity with time.

18.2 Sampling and Methods

Two marine extracts were incorporated into a coating system and applied on steel panels in order to be submerged in a container supplied by oceanic water from the Drake Passage and observe the fouling formation over a 28 day period. Specifically, 4 mild steel panels (Q panel 50 x 90 mm) were:

- Steel blasted, cleaned and degreased
- Primed at dry film thickness (dft) 50μm
- Experimental topcoat: Incorporated into a primer at dft 150 μm

Experimental panels:

- 2.5 % natural product 1 (*Chondrus crispus*)
- 2.5 % natural product 2
- Blank 1 (steel)
- Blank 2 (primer)

Two sets of panels (8 in total) were introduced into a natural seawater incubator covered with blue film in order to simulate the surface water irradiance levels. A continuous flow-through (non toxic) system was supplying the incubator with surface water throughout the incubations.

18.3 Measurements

18.3.1 Flow Cytometry

In order to quantify the bacterial community present in the incubator, measurements for flow cytometry were taken on a daily basis. Duplicates of 2ml of seawater were added in 2ml eppendorf tubes containing 100μl of paraformaldehyde. They were then left at room temperature for 30 min and stored at -80^{o}C. Flow cytometry analysis will be conducted at the National Oceanography Centre, Southampton (NOCS).

18.3.2 Nutrients

Water from the incubator was collected for nutrient analysis (30ml) on a daily basis and immediately analysed on a SAN^{plus} segmented flow autoanalyser.

18.3.3 Temperature

Temperature measurements were taken using a digital thermometer on a daily basis.

18.3.4 Images

Images of the panels were taken using an Olympus camera (model No: C-5050ZOOM) to record visual changes in biofouling formation on the panels' surface over time.

18.3.5 Scanning Electron Microscopy (SEM)

The panels were stored at -80^{o}C at the end of the experiment for SEM analysis at the School of Engineering Sciences (SES), Southampton.

Maria Salta

19. Organic Geochemical Biomarker Analysis

19.1 Sample Retrieval

Particulate organic matter (POM) from seawater was obtained on board the RRS *James Cook* on the "JC031" cruise from 03.02.09 to the 03.03.09 through the Drake Passage and the South Atlantic Ocean.

Seawater was collected in 50-Litre Carboys from the non-toxic underway seawater supply and from Niskin-bottles from a few CTD casts. Depending on the amount of suspended material in the seawater, between 40 and 200 litres of seawater were filtered per sample through Whatman 47mm GF/F glass fibre filters (pre-cleaned by heating them at 450 ˚C for 4 hours in a furnace). The filtered samples were placed in Aluminium foil (pre-cleaned by heating them at 450 ˚C for 12 hours in a furnace) and dried at 30 ˚C. When the filters were dry, the filters inside the Aluminium foil were placed in Whirl-packs and stored in a fridge at 4˚C.

19.2 Sample Analysis

The samples collected (Table 15) during JC031 will be analysed by the organic geochemistry group (Leader: Dr. J. Bendle) at the University of Glasgow. First the POM will be extracted using organic solvents. The total organic extract will undergo a separation procedure (similar to silica-gel column chromatography) in which the different components will be separated from each other depending on their polarity.

The analysis of the different fractions will be done by GC-FID (Gas-chromatography – Flame Ionisation Detection), GC-MS (Gas-chromatography – Mass Spectrometry) and HPLC-APCI-MS (High Pressure Liquid Chromatography – Atmospheric Pressure Chemical Ionisation – Mass Spectrometry).

19.3 Aim

The primary aim of the study is to analyse biomarkers, specific to Coccolithophorids. Special emphasis will be put upon alkenones, which are produced by the calcite forming algae. The relative abundance of alkenones (with different amounts of double bonds) produced by Coccoliths, changes with variations in SST. Thus alkenones are useful for reconstructing past SST changes.

The alkenone unsaturation index ($U^{K'}_{37} = \frac{[C_{37:2}]}{[C_{37:2}] + [C_{37:3}]}$) is used to correlate SST to the relative abundance of the different alkenones. We will use the $U^{K'}_{37}$ to calibrate the relative abundance of alkenones to the SSTs at the sample locations during the time of sampling. During the cruise, SST was recorded by placing a thermometer into the carboys containing the samples. However, for the sake of post-cruise analysis CTD temperature data will be used due to its greater degree of accuracy. We aim to improve the use of $U^{K'}_{37}$ as a palaeoclimate reconstruction tool and further our understanding of phytoplankton-derived biomarkers, especially coccolithophorides.

Table 15: Samples acquired during JC031 aboard the RRS *James Cook*

		Location		Time	
Sample ID	Date	Latitude (S)	Longitude (W)	GMT	Water filtered (L)
JC31_UW_1	04.02.09	54˚ 07.71	064˚ 43.74	11:00	50
JC31_UW_2	04.02.09	54˚ 30.63	063˚ 51.61	14:54	100
JC31_UW_3	05.02.09	56˚ 44.57	067˚ 21.47	11:00	100
JC31_UW_4	05.02.09	57˚ 07.79	068˚ 15.00	14:57	100
JC31_UW_5	06.02.09	56˚ 19.79	067˚ 59.40	01:13	100
JC31_UW_6	06.02.09	56˚ 47.94	068˚ 11.33	05:07	100
JC31_UW_7	06.02.09	56˚ 54.60	068˚ 14.40	18:11	100
JC31_UW_8	07.02.09	56˚ 58.80	068˚ 14.99	12:19	150
JC31_UW_9	07.02.09	57˚ 07.80	068˚ 15.00	16:15	150
JC31_UW_10	09.02.09	57˚ 49.98	068˚ 13.68	11:25	150
JC31_UW_11	09.02.09	58˚ 05.00	068˚ 15.05	18:05	150
JC31_UW_12	10.02.09	58˚ 34.77	068˚ 15.08	21:47	150
JC31_UW_13	11.02.09	59˚ 05.51	068˚ 14.04	12:47	150
JC31_UW_14	11.02.09	59˚ 35.37	068˚ 14.78	21:50	150
JC31_UW_15	12.02.09	60˚ 04.28	068˚ 11.84	11:15	150
JC31_UW_16	12.02.09	60˚ 34.80	068˚ 03.60	21:06	150
JC31_UW_17	13.02.09	61˚ 01.17	067˚ 39.73	10:47	150
JC31_UW_18	13.02.09	61˚ 24.58	066˚ 59.64	21:31	150
JC31_UW_19	14.02.09	61˚ 48.00	066˚ 19.20	10:58	200
JC31_UW_20	15.02.09	62˚ 16.80	065˚ 12.59	15:18	200
JC31_UW_21	16.02.09	62˚ 30.00	064˚ 27.60	15:15	200
JC31_UW_22	17.02.09	62˚ 48.60	063˚ 37.19	09:15	200
JC31_UW_23	18.02.09	63˚ 28.79	063˚ 10.19	12:01	150
JC31_UW_24	18.02.09	64˚ 08.40	063˚ 04.80	18:30	40
JC31_UW_25	20.02.09	60˚ 49.99	054˚ 43.31	10:15	100
JC31_UW_26	20.02.09	60˚ 20.00	055˚ 01.88	21:51	150
JC31_UW_27	21.02.09	59˚ 40.63	055˚ 27.72	10:40	150
JC31_UW_28	21.02.09	59˚ 01.38	055˚ 51.69	21:25	150
JC31_UW_29	22.02.09	58˚ 22.98	056˚ 11.83	11:03	150
JC31_UW_30	22.02.09	57˚ 43.99	056˚ 38.57	22:05	150
JC31_UW_31	23.02.09	57˚ 06.00	057˚ 02.12	11:00	150
JC31_UW_32	23.02.09	56˚ 45.93	057˚ 09.59	17:32	100
JC31_UW_33	23.02.09	56˚ 28.12	057˚ 25.46	23:37	100
JC31_UW_34	24.02.09	55˚ 50.05	057˚ 48.40	15:21	100
JC31_UW_35	24.02.09	55˚ 31.00	057˚ 57.32	21:48	100
JC31_UW_36	24.02.09	55˚ 12.86	058˚ 00.00	02:03	100
JC31_UW_37	25.02.09	55˚ 07.26	057˚ 59.95	13:19	100
JC31_UW_38	26.02.09	53˚ 45.15	058˚ 00.00	12:32	100
JC31_UW_39	26.02.09	53˚ 31.19	058˚ 00.00	17:20	100
JC31_UW_40	26.02.09	53˚ 07.77	058˚ 00.00	22:14	100
JC31_UW_41	27.02.09	49˚ 50.27	057˚ 15.07	18:58	50
JC31_UW_42	28.02.09	48˚ 35.00	057˚ 09.00	03:00	100
JC31_UW_43	28.02.09	47˚ 25.30	057˚ 03.71	11:00	100
JC31_UW_44	28.02.09	45˚ 52.58	056˚ 57.41	21:00	45
JC31_UW_45	01.03.09	43˚ 35.55	056˚ 46.88	11:00	50
CTD_2_75m	05.02.09	56˚ 19.79	067˚ 59.40	02:10	50
CTD_3_75m	06.02.09	56˚ 47.79	067˚ 59.40	06:30	50
CTD_75_50m	25.02.09	55˚ 04.18	058˚ 00.00	17:30	80
CTD_77_50m	25.02.09	54˚ 58.66	057˚ 59.92	23:30	90

Heiko Moossen

20. Geostrophic Velocities and Volume Transports

Geostrophic transports were calculated using the calibrated CTD data. The data were gridded to a 2db pressure grid using linear interpolation. Geopotential anomaly was calculated using the CSIRO seawater routines for Matlab. Geostrophic velocity was then calculated, again using the CSIRO seawater routine. Volume transports were calculated both for data collected on JC031 and for previous sections.

20.1 Section SR1

Taking zero velocity at 3000db, a transport of 98Sv is estimated for JC031. For comparison, both the ALBATROSS section taken in 1999 and the original section taken by Roether in 1990 (RO90) have an estimated transport of 102Sv. Taking zero velocity at the bottom yields larger transports, with a value of 128Sv being obtained for JC031, compared with 129Sv for RO90 and 131Sv for ALBATROSS.

20.2 Section SR1b

Using the same method as above, the SR1b volume transport for JC031 is calculated to be approximately 124Sv assuming zero velocity at base (or 105Sv assuming zero velocity at 3000db). For comparison, for historical sections taken by BAS/NOCS between 1993 and 2005, the highest transport values were: 1997, u=0 at 3000db: 111.4034Sv, u=0 at bottom: 139.6707Sv. The lowest transport values were: 1995, u=0 at 3000db: 92.7627Sv, u=0 at bottom: 119.2563Sv.

Compared to the values calculated by Adam Williams using historical sections taken by BAS/NOCS, the mean of the values calculated here are 4.25Sv lower than the mean obtained for the same sections. This results in the corrected values (all increased by 4.25Sv) given below:

Table 16: Corrected Geostrophic values

Section name (SR1)	Transport (u=0 at 3000db) / Sv	Transport (u=0 at deepest common level) / Sv
RO90 (1990)	106	134
ALBATROSS (1999)	106	135
JC031 (2009)	104	132

Section name (SR1b)	Transport (u=0 at 3000db) / Sv	Transport (u=0 at deepest common level) / Sv
SR1b (1995)	97	124
SR1b (1997)	116	145
SR1b (2009)	109	128

Sally Close

21. Mixing and Wind-driven Inertial Currents

21.1 Research Objectives

I was invited to join the JC031 cruise by Principle Scientist Elaine McDonagh. In order to complement the main objectives of the cruise and maximise the potential of the hydrography and biochemical observations, I have focused on two goals:

1. Quantify the diapycnal mixing rates by estimating Thorpe scales of overturning.
2. Quantify the availability of wind energy for mixing by investigating the propagation of inertial waves through the base of the mixed layer.

21.2 Observations

The Thorpe scale analysis incorporates 47 stations on the first section occupied across the western Drake Passage (SR1 repeat); and another 30 stations on the second section occupied downstream of Drake Passage (SR1b repeat). Two Seabird instruments collected the CTD data; one attached to the fin of the instrument package and a second instrument was attached inside the base of the Niskin bottle rosette. The data from the fin-mounted Seabird proved to be less affected by the local disturbances to the water column due to the closing of the Niskin bottles. The CTD data was processed and calibrated to bottle salts and nutrients by Mary Woodgate-Jones using a combination of Seabird software and Mstar routines written by Brian King. The 2db CTD data from the fin-mounted instrument was used in this analysis.

The shipboard ADCP velocities were measured with two different instruments an RDI 150 kHz and a 75 kHz Ocean Surveyor. During the Drake Passage transects, the ship's drop keel was lowered to reduce bubble noise in the ADCP data. The 150 kHz instrument typically had a range of 300-400m depth and was configured to bin-average velocities in 8m bins with the shallowest bin centred at 24m depth. The Ocean Surveyor typically returned data to a depth of 800m and was configured to bin-average velocities in 16m bins with the shallowest bin centred at 34m depth.

Inertial currents are expected to be smaller and much more strongly sheared than the geostrophic currents that dominate the total currents observed. Therefore, data from the 75 kHz instrument with a greater depth resolution across the base of the mixed layer was employed in the hunt for the inertial currents.

21.3 Preliminary Results

The analyses presented here are not final and should be treated as such.

21.3.1 Thorpe Scale Estimates

In a turbulent fluid, velocity and scalar parameters vary more slowly in time than space. At small spatial scales, extremely large shear and rates of strain coincide with the acute damping of fluid motion by viscosity. As the kinetic energy cascades to ever-smaller scales until all fluid motion ceases and the residual kinetic energy is dissipated irreversibly as heat. The turbulent mixing occurring as a result of this process is dependent on the turbulent kinetic energy dissipation ε that is related to the velocity fluctuations of energy-containing eddies (i.e. $u' \approx (\varepsilon l)^{\frac{1}{3}}$). In stratified flows, the eddy length scale l is set by the Ozmidov scale, $L_O = (\varepsilon/N^3)^{\frac{1}{2}}$(N = buoyancy frequency, $L_O = 0.1 - 20$m in the ocean). When the fluid turbulence is isotropic, the dissipation rate is typically assumed to be balanced by the spatial average of shear or strain variance, $\epsilon = \frac{15}{2}\nu\overline{\left(\frac{\partial w}{\partial x}\right)^2} = \frac{15}{2}\nu\overline{\left(\frac{\partial u}{\partial x}\right)^2}$ where $\frac{\partial w}{\partial x}$ is any component of shear and $\frac{\partial u}{\partial x}$ is any component of strain.

In the absence of microstructure shear velocity data, less-highly-resolved CTD potential density (*sigma*) profiles can be used to determine a related parameter known as the Thorpe scale L_T Thorpe, (1977); Dillon, (1982). This length scale characterizes the vertical extent of the density overturns in an otherwise stably stratified fluid. Thorpe displacements *d* are the vertical distances gravity instabilities have to be moved in order to re-organise a σ profile so that it is perfectly stably stratified (i.e. density increases monotonically with depth). An overturning region is defined as the region over which *d* sums to zero. The Thorpe scale is then given as the root mean square displacement within the overturn, $L_T = \sqrt{(d^2)}$.

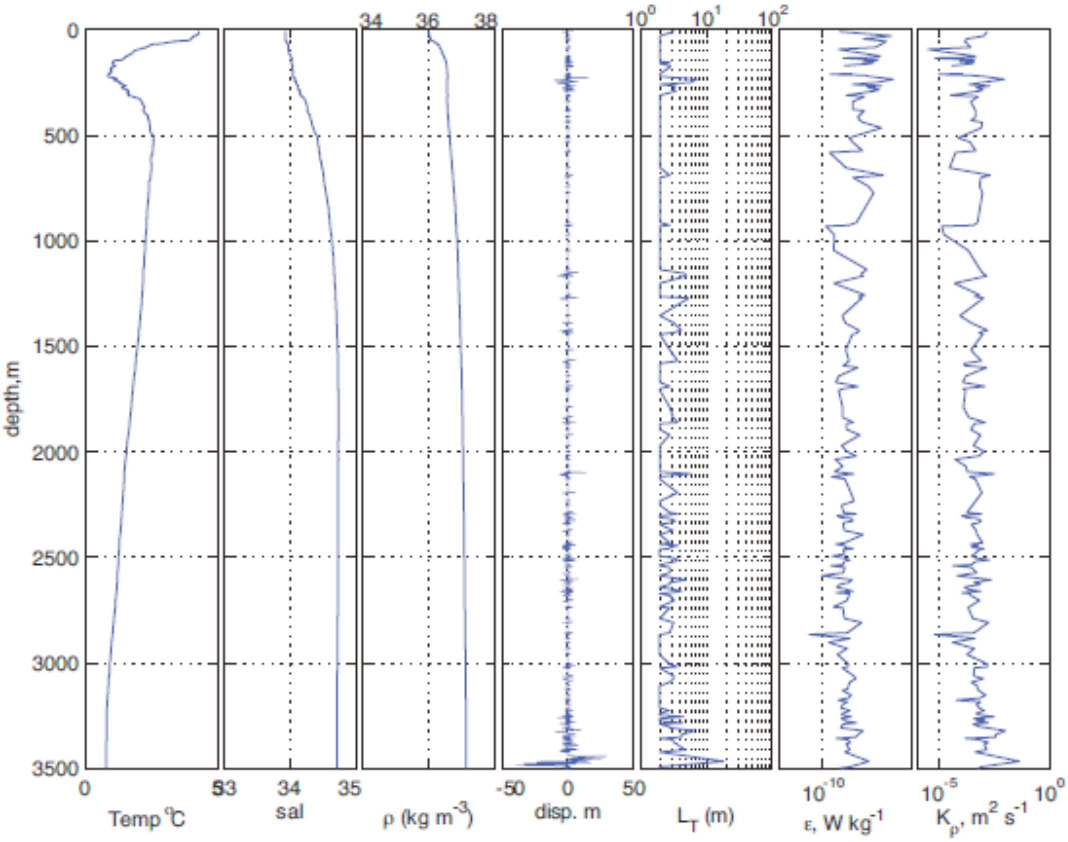

Figure 60: Data from Station 23 on the SR1 repeat. Panels from left to right show temperature (^{o}C), salinity, potential density σ2000 (kg m^{-3}), Thorpe displacements (m), Thorpe scales L_T, turbulent kinetic energy dissipation ε (W kg^{-1}) and eddy diffusivity K_ρ (m^2 s^{-1}).

As pointed out by Thompson et al. (2007), in the Southern Ocean where mean horizontal gradients are much smaller than vertical gradients, L_T are a fair representation of overturn size. In the preliminary analysis for JC031, I have adopted the methods outlined by Thompson et al. (2007), in assuming a linear relationship between L_T and L_O based on Dillon [1982] results, such that the dissipation within an individual overturn is $\varepsilon_i = 0.64L^2_T\,(N)^3_i$. The calculation is then taken a step further and converted to a diapycnal eddy diffusivity $K_\rho = \Gamma\varepsilon N^{-2}$ following Osborn (1980), where the mixing efficiency Γ is typically assumed to be 0.2. One has to be careful to distinguish between the mean buoyancy frequency within the re-organized overturn $(N)_i$ when calculating ε, and the background buoyancy frequency N^2 when calculating $K_{\rho.}$

Analysis of a typical hydrographic cast, Station 23 in the middle of the first Drake Passage section, shows that the Thorpe displacements and consequently L_T are larger near the bottom of the profile where the potential density is less well stratified (Figure 60). This station was south of the Polar Front and the subsurface temperature minimum associated with the winter water can be seen in the temperature profile. There appear to be higher *d* and L_T at the base of this layer was well. Turbulent kinetic energy dissipations ε range from 10^{-9} to 10^{-7} W kg^{-1}, which are not uncommon for open ocean values and appear to be higher near the surface. Once the background N has been taken into account, the high stratification in the upper ocean dampens down the eddy diffusivities, such that K_ρ appears to be O (10^{-4} m^2 s^{-1}) in most of the water column and is slightly elevated near the bottom. In the initial calculations, these patterns are repeated across both sections (Figure 61).

21.3.2 Inertial Currents

It is usually difficult to distinguish variably-phased inertial currents from spatial variability in the geostrophic signal in an underway dataset. However, on the first transect of Drake Passage, usual deployment of the CTD package was delayed on three occasions due to necessary repairs to the winch system, package loss and rebuilding of the replacement package and weather stoppages. These resulted in at least two 'on-station' time-series of ADCP data of 8 hours or more, when the ship became a virtual mooring. These longer time series, the longest of which was 20 hours, provided an ideal opportunity to attempt to isolate the inertial current signal.

A time series of currents from the 20-hour delay were obtained at Stations 13-14 (Figure 62). Station 13 was a test cast for the full-depth profile obtained at the same position known as Station 14. During this time the ship maintained position within a 4km box. The current persisted toward the southeast, but were modulated by an oscillatory signal that suggested the presence of inertial currents. Shear amplitudes were enhanced above 100m depth, within the mixed-layer, particularly towards the latter half of the time series. An examination of the phase or direction of the shear vector in the mean 60-70m depth layer shows that the shear vector is rotating at near-inertial frequencies (Figure 63).

An examination of the progressive vector trajectories in two layers within and below the mixed-layer show that although there is a marked drift due to the mean geostrophic current, there is also an easily perceptible rotary component in the currents. The illustration of the inertial oscillation is clearest in the progressive vector trajectory computed from the time-series currents with the time-mean current subtracted (Figure 63, bottom right). The trajectories clearly track in an anti-clockwise sense with time, as expected for inertial currents, and have a period similar to the inertial period.

There is a marked change in phase in the rotary currents across the base of the mixed layer, and the trajectories are not nearly circular, but exhibit a noticeable elongation along different axes at different depths. These results confirm the presence of near-inertial currents and will form the basis of on-going investigation into the transmission of wind energy to the deep ocean via inertial currents.

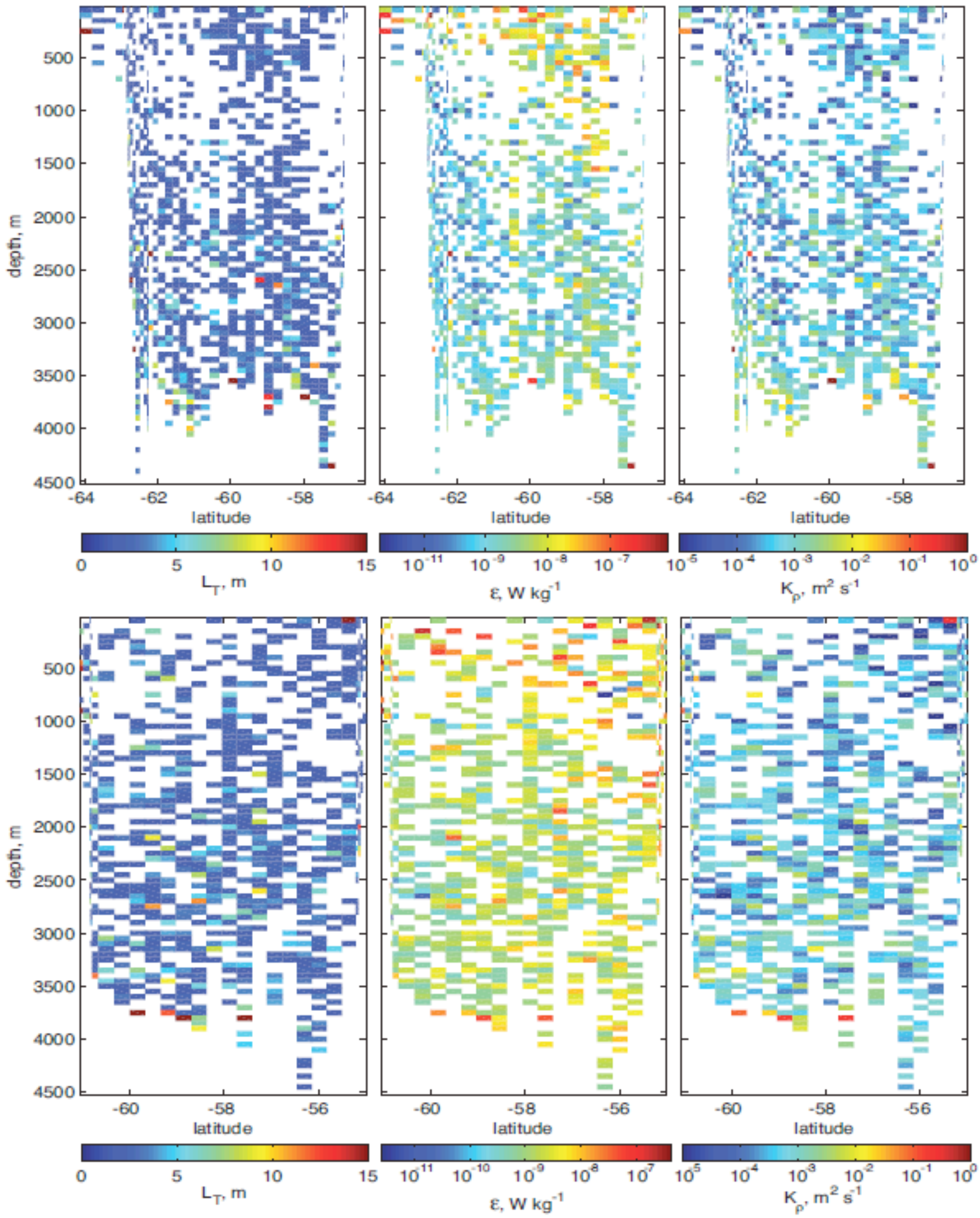

Figure 61: Preliminary Thorpe-scale mixing estimates for the JC031-A21 section (top panel) and JC031-SR1b section (bottom panel). Panels from left to right show: Thorpe scales L_T, turbulent kinetic energy dissipation ε (W kg^{-1}) and eddy diffusivity K_ρ (m^2 s^{-1}), plotted against depth and latitude.

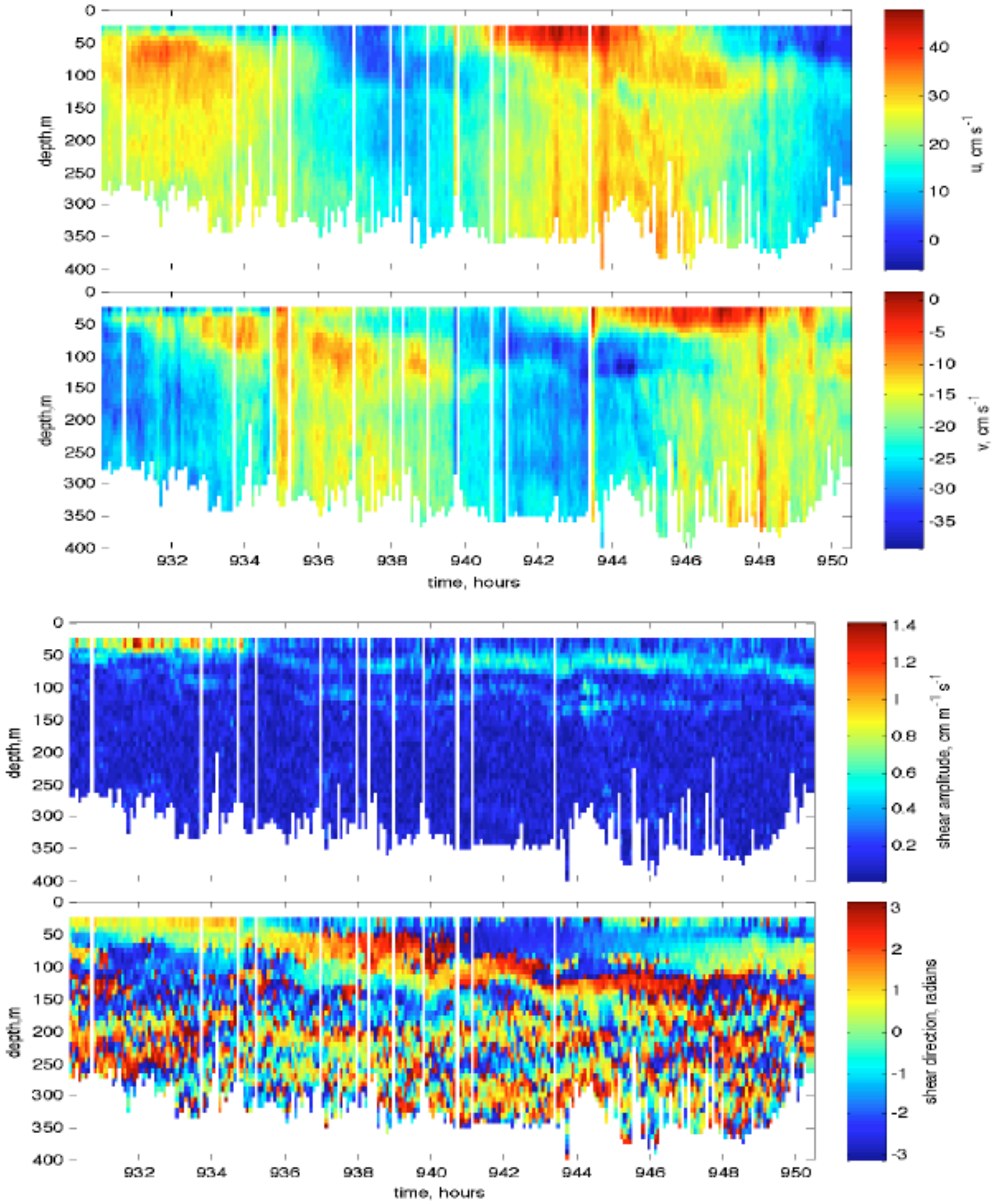

Figure 62: Station 13/14 time-series, panels from top to bottom: zonal and meridional currents (cm s^{-1}), shear (cm m^{-1} s^{-1}) and the direction of the shear vector (degrees from true east).

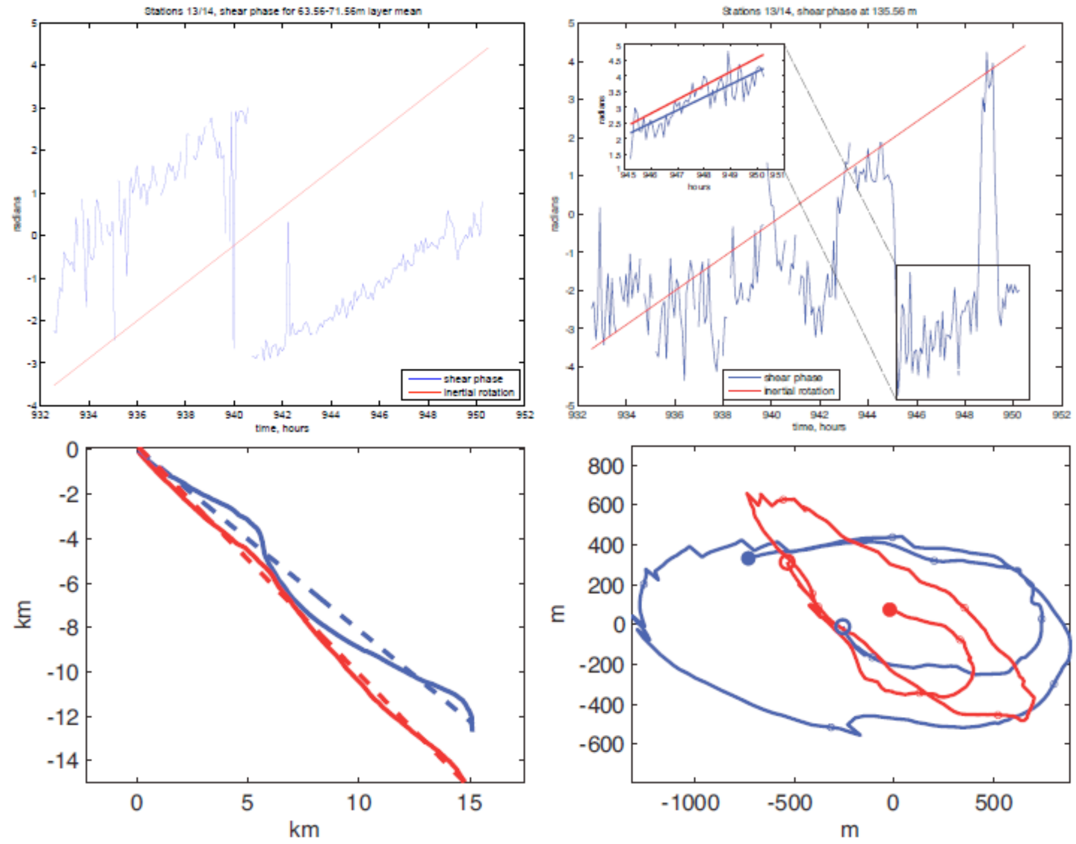

Figure 63: Direction of the shear vector in the 60-70m layer (top left panel), and at 135m deep (top right panel). The inset in the right panel shows the end of the phase-wrapped time series. The red lines in the top panels represent the rate of inertial rotation. Progressive vector trajectories are shown for the total currents (bottom left) and residual currents (bottom right). In the bottom panels the mean 30-70m layer trajectories are plotted in blue and the mean 120-160m layer trajectories are plotted in red. The inertial period at this location is 14.14 hours. Large open circles indicate the start of the trajectory and the solid circles mark the end of the trajectories; small open circles mark 3-hourly intervals.

21.4 References

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