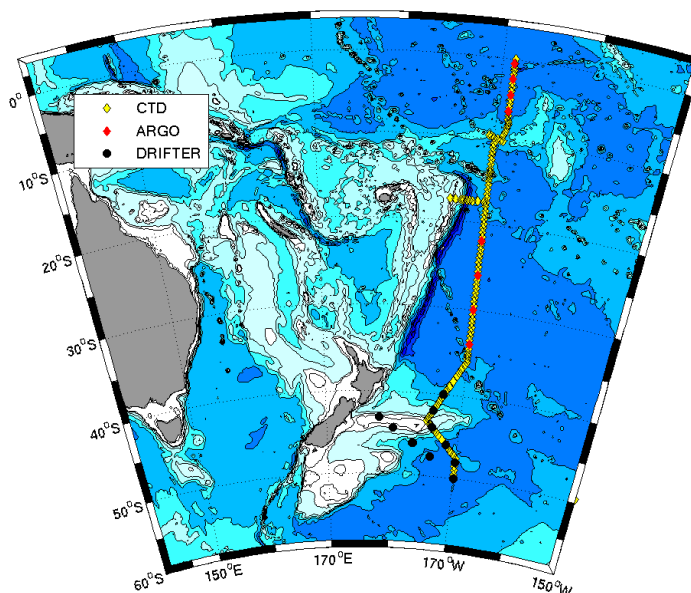


CRUISE REPORT: P15S

(Updated DEC 2009)



A. HIGHLIGHTS

A.1. CRUISE SUMMARY INFORMATION

Section designation	P15S		
Expedition designation (ExpoCode)	09SS20090203		
Chief Scientist	Dr. Bernadette M. Sloyan/CMAR		
Co-Chief Scientist	Dr. Susan Wijffels/CMAR		
Dates	2009 FEB 03 - 2009 MAR 24		
Ship	<i>R/V Southern Surveyor</i>		
Ports of call	Wellington, New Zealand Nuku'alofa, Tonga Lautoka, Fiji		
Geographic boundaries	175°0'8" E	0 50°S	168°37'50" W
Stations	128 CTD Stations		
Floats and drifters deployed	8 ARGOS floats 10 Surface Drifters		
Moorings deployed or recovered	0		

Chief Scientists Contact Information:

CSIRO Marine and Atmospheric Research • GPO 1538 • Hobart, Tasmania 7001 • Australia

Dr. Bernadette M. Sloyan email: Bernadette.Sloyan@csiro.au Ph: 03 6232 5152	Dr. Susan Wijffels Email: Susan.Wijffels@csiro.au Ph: 03 62325450 Fax: 03 62325123
--	---

LINKS TO TEXT LOCATIONS

Shaded sections are not relevant to this cruise or were not available when this report was compiled

Cruise Summary Information	Hydrographic Measurements
Description of Scientific Program	CTD Data:
Geographic Boundaries	Acquisition
Cruise Track (Figure): PI CCHDO	Processing
Description of Stations	Calibration
Description of Parameters Sampled	Temperature Pressure
Bottle Depth Distributions (Figure)	Salinities Oxygens
Floats and Drifters Deployed	Bottle Data
Moorings Deployed or Recovered	Salinity
	Oxygen
Principal Investigators	Nutrients
Cruise Participants	Carbon System Parameters
	CFCs
Problems and Goals Not Achieved	Helium / Tritium
Other Incidents of Note	Radiocarbon
Underway Data Information	References
Navigation Bathymetry	Nutrients
Acoustic Doppler Current Profiler (ADCP)	CFCs
Thermosalinograph	Carbon System Parameters
XBT and/or XCTD	
Meteorological Observations	Acknowledgments
Atmospheric Chemistry Data	
Data Processing Notes	

A.2 VOYAGE REPORT

I Introduction

The primary aims of the Deep Ocean Time Series Section (DOTSS) program are to monitor full depth ocean changes and maintain Australia's contribution to the International Repeat Hydrography and Carbon Program. We reoccupied an ocean section in the Pacific along 170°W from 50°S to the equator (P15S) with full depth, high precision hydrographic and nutrient, and carbon and tracer observations. Station spacing along the section was approximately 30nm from 50°S to the equator with close spacing over steep topography. The station positions were similar to previous 2001, and 1996 occupations of the hydrographic line.

The scientific objectives and significance of the 170°W section are:

- Maintain a time series of full-depth repeat ocean measurements capable of resolving decadal and longer time scale changes in the circulation and property storage (including heat, freshwater, oxygen and carbon) of the oceans around Australia, from Antarctica to the equator.
- Improve our understanding of basic ocean processes and fluxes through collection of full depth direct velocity measurements while conducting the repeat surveys.

Repeat full depth hydrographic and carbon sections provide data needed to detect and monitor ocean variability and changes in carbonate chemistry associated with acidification. The global network of sections is providing data on the global partitioning and evolution of carbon storage between the ocean, atmosphere and terrestrial biosphere.

Voyage Objectives

- undertake full depth CTD and Niskin bottle casts that measure salinity, temperature and pressure continuously.
- collect water samples to be analysed on board for the full suite of nutrients, dissolved inorganic carbon concentrations (DIC) and alkalinity. Through collaboration with the NOAA PMEL and the University of Washington, USA measure CFC and SF6 concentrations.
- for certain regions and where conditions allow, the CTD/Rosette will be reconfigured during the voyage to include the LADCP for full water column velocity profiles.

Principal Investigators

John Bullister	NOAA/PMEL	Chlorofluorocarbons
Bronte Tilbrook	CSIRO	Alkalinity Carbon
Rebecca Cowley	CSIRO	Salinity Nutrients Oxygen CTD

II Itinerary

Leg 1 Depart Wellington, New Zealand: 1600 Tuesday 3 February 2009. Arrive Nuku'alofa, Tonga: 0800 Thursday 26 February 2009.

Leg 2 Depart Nuku'alofa, Tonga: 1230 Friday 27 February 2009. Arrive Lautoka, Fiji: 0800 Tuesday 24 March 2009.

III Voyage Narrative

A brief narrative of voyage events for Leg 1 and 2 is presented. The cruise track and location of the CTD/Niskin stations and Argo float and drifter deployments are shown in [Figure 1](#). Section B4, [Figure 5](#) shows the bottle distribution along the section. Argo float and drifter deployment location are given in [Table 1](#) and CTD station details are provided in [Table 2](#).

Due to the limited range of the R/V Southern Surveyor the reoccupation of the P15S was broken into two legs: Leg 1 occupied stations between 50°S and 22° 09.28' S and; Leg 2 occupied stations between 21° 29.90' S and 00° 00.96'N, and completed a third crossing of the deep western boundary current at 17° 30.21S between 170° 00' W and 174° 20.02' W.

The Leg 1 science party joined the R/V Southern Surveyor in Wellington, New Zealand on 2 February 2009. Over the next two days the science party began setting up the laboratories and work spaces. The CSIRO 24 position rosette frame was used. The CSIRO 10L niskin bottle were replaced with PMEL 12L bottles to enable easier access to the petcocks for CFC sampling. The R/V Southern Surveyor departed Wellington, NZ, at 1600hrs. (All times are local, and the ship maintained GMT +1300 throughout the voyage). A test station on the Chatham Rise (41°52.42' S, 175°31.55' W) was completed at 2133. The CTD/rosette package was lowered to approximately 10m off the bottom, and then raised to 1700 dbar where all 24 bottles were fired successfully. CTD watch standers were trained in sampling methods for oxygen and carbon parameters. At the completion of the test station the R/V Southern Surveyor began its transit to the start of P15S at 50°S, 170°W.

During the transit a number of SVP drifters were deployed for the New Zealand Meteorological Agency. The first station was begun on 6 February at 2230. Winch and tension controller problems resulted in stoppages of 1.2 hours and 1 hour, on the downcast and at the beginning of the up-cast, respectively. Over the next few stations problems with the winch and tension controller were fixed and the stations were occupied as planned. After the first five stations the science party became comfortable with the watch duties. Full-depth carbon and tracer sampling was taken on odd station numbers and partial water column carbon sampling on even numbered stations.

Leg 1 continued to occupy stations on its northward track in rolling southwest to westerly swells. The last station (65) is slightly south of planned position, due time lost time over winch problems on previous station, was completed at 1045 on 24 February. After completion of station ship began transit Nuku 'Alofa to rendezvous with pilot at 0600 on 26 February.

Ten surface drifters and 4 Argo floats were deployed on leg 1.

R/V Southern Surveyor arrived in Nuku'alofa at approximately 0800, and the hand-over of CTD operations from leg 1 to leg 2 was completed by 1500hrs. Leg 2 departed Nuku'alofa at 1200 on 27 February, 20 hours behind schedule, due to air conditioning problems, in calm conditions. During the afternoon the on-coming CTD watch keepers were shown the bottle sampling route by carbon and hydrography chemists, and also CTD deployment, watch, and recovery procedures. Science personnel began watches at 1400hrs.

We reviewed the P15S 2001 CFC and Carbon sampling and determined that the best coincident station sampling will occur on leg 2 when CFC and Carbon maintain an odd stations sampling program. We arrived at the first station of leg 2 (Station 66) on 1 March at approximately 0030hrs. Both CTD watches participated in the launch of the CTD package.

After a few stations the new CTD watch standers were comfortable with their duties and settled into a good work routine. The Southern Surveyor carried approximately 6000-6500 m of wire on winch drum. Station 115 bottom depth is 6532 m and we estimate that the bottom of the station was stopped approximately ~100m off the bottom. The last CTD station of P15S (118) was completed at approximately 13:30 on 16 March. When then headed south to 17.5°S to complete 10 CTD/Rosette and LADCP stations across the deep western boundary current.

During the transit to 17.5°S the upward and downward looking ADCP units on the CTD/rosette frame were installed. This resulted in the removal of two niskin bottles. Pressure rating of LADCP units is 6000 m. Thus the lower 1500 m of Station 123, bottom depth of 7593 m, was not sampled. Four 10-litre PMEL niskin bottle were removed from rosette, and we replaced two with a General Oceanics 5-litre (rosette position 1) and 10-litre (rosette position 22) CSIRO niskin bottles. Total bottles on rosette is 22, with conservative water usage we were able to sample all properties from the 5-litre niskins. The final station (128) completed the short section across the deep western boundary current at 17.5S. The R/V Southern Surveyor arrived in Lautoka, Fiji on 24 March at 0800.

Ten surface drifters and 4 Argo floats were deployed on leg 1, and 4 Argo float were deployed on Leg 2. During both voyage legs XBT intercomparisons were preformed at a number of CTD stations.

Figure 1: DOTSS (P15S) 2009 CTD stations (yellow diamonds), deployment of surface drifters (black circles) and Argo floats (red diamond).

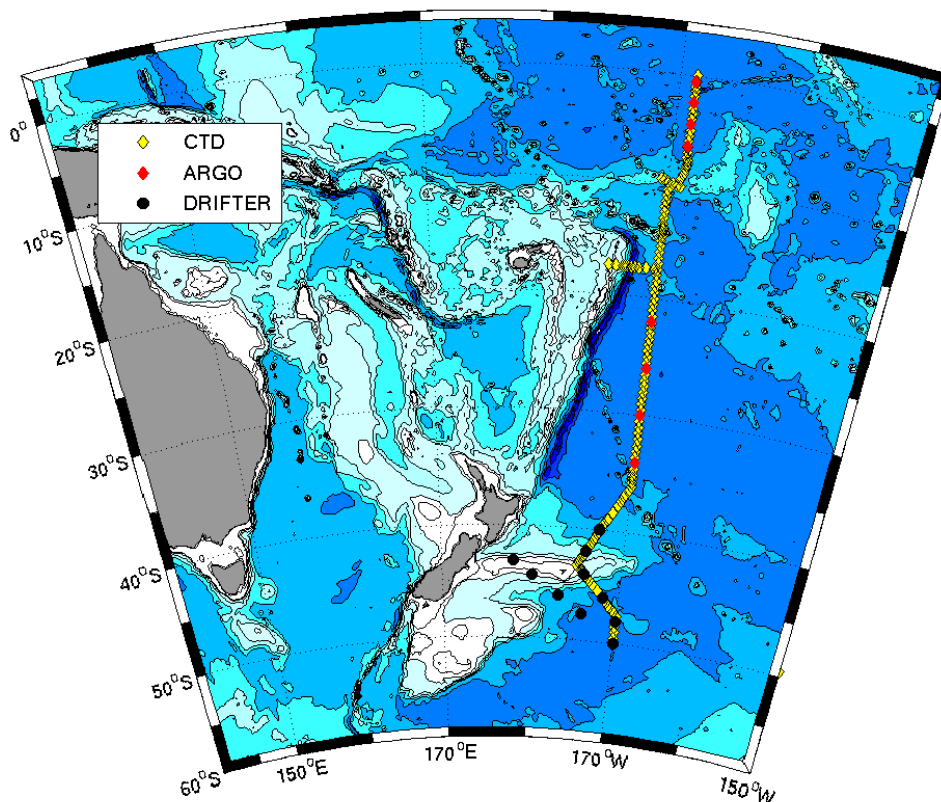


Table 1: Information of surface drifters and Argo floats deployed on the cruise

	Date/Time (GMT)	Position		other information
SVP drifter SN 83380	03/02/2009 2106	178° 0.458' W	43° 04.540' S	Transmitting ok
SVP drifter SN 83389	04/02/2009 0705	179° 59.861' W	44° 17.328' S	Transmitting ok
SVP drifter SN 83381	04/02/2009 2144	176° 59.716' W	46° 03.580' S	Transmitting ok
SVP drifter SN 83383	05/02/2009 2155	174° 00.324' W	47° 47.104' S	Transmitting ok
SVP drifter SN 83384	06/02/2009 0930	169° 59.790' W	50° 00.059' S	Transmitting ok
SVP drifter SN 83388	07/02/2009 2105	170° 02.43' W	48° 00.19' S	Transmitting ok
SVP drifter SN 83386	09/02/2009 0915	171° 40.30' W	45° 59.94' S	Transmitting ok
SVP drifter SN 83385	10/02/2009 2200	174° 7.70' W	44° 00.10' S	Transmitting ok
SVP drifter SN 83387	11/02/2009 2237	174° 08.70' W	44° 00.00' S	Transmitting ok
SVP drifter SN 83382?	13/02/2009 07:25	172° 44.82' W	39° 59.80' S	Transmitting ok
Argo Float Hull No 3668	17/02/2009 02:06	170° 00.01' W	33° 59.82' S	Transmitting ok
Argo Float Hull No 3670	19/02/2009 15:03	169° 59.35' W	29° 59.35' S	Transmitting ok
Argo Float Hull No 3672	21/02/2009 23:05	169° 59.35' W	26° 00.00' S	Transmitting ok
Argo Float Hull No 3674	24/02/2009 09:53	169° 59.85' W	22° 09.59' S	Transmitting ok

Table 2: Locations, times (UTC) and depths of CTD casts completed on Leg 1. Bottle oxygen, salinities and major nutrient samples were analysed on all casts. The last two columns indicate chlorofluorocarbon and dissolved carbon/alkalinity sampling – Y indicates the full set of bottles were sampled, P indicates on a subset of bottles were sampled.

No	Start Date/Time (UTC)	Latitude	Longitude	Depth (m)	Comments	CFC	DIC
1	03/02/2009 08:06	41° 52.42' S	175 °31.55' E	2406	Test Station		
2	06/02/2009 09:40	50° 00.02' S	169° 59.71' W	5347	Very long due to winch problems		Y
3	06/02/2009 23:06	49° 31.40' S	169° 59.23' W	5202		Y	
4	07/02/2009 09:07	49° 00.50' S	169° 00.51' W	5216		Y	Y
5	07/02/2009 14:45	48° 29.78' S	170° 00.13' W	5422			
6	07/02/2009 21:21	47° 59.04' S	170° 01.74' W	5294	13 XBTs dropped during cast	Y	Y
7	08/02/2009 04:21	47° 29.94' S	169° 59.40' W	5351			
8	08/02/2009 11:30	47° 06.53' S	170° 53.39' W	5356		Y	Y
9	09/02/2009 19:46	46° 43.30' S	170° 25.95' W	5279			
10	09/02/2009 02:55	46° 20.90' S	171° 21.40' W	5094			Y
11	09/02/2009 10:10	45° 56.98' S	171° 48.23' W	5137		Y	
12	09/02/2009 18:44	45° 23.34' S	172° 28.03' W	4870		Y	Y
13	09/02/2009 02:00	44° 49.73' S	173° 07.56' W	3853		Y	
14	10/02/2009 07:12	44° 31.81' S	173° 29.49' W	3417		Y	Y
15	10/02/2009 12:25	44° 19.67' S	173° 45.62' W	3110		Y	Y

16	10/02/2009 17:12	44° 09.22' S	173° 54.94' W	1938	19 bottles. Surface bottle contaminat-ed by ship' S sewage due to retrieval delay for ship repositioning	Y	Y
17	10/02/2009 21:29	43° 51.04' S	174° 17.96' W	824	17 bottles	Y	
18	11/02/2009 00:32	43° 38.86' S	174° 32.10' W	794	16 bottles. 11 XBT' S dropped during cast.		
19	11/02/2009 04:49	43° 15.14' S	175° 00.00' W	796	15 bottles.	Y	Y
20	11/02/2009 08:12	42° 55.76' S	174° 47.35' W	1067	17 bottles. No fresh nutients		
21	11/02/2009 11:11	42° 44.87' S	174° 39.60' W	1529	21 bottles.		Y
22	11/02/2009 15:03	42° 24.31' S	174° 24.08' W	2677	24 bottles.		
23	11/02/2009 19:03	42° 10.37' S	174° 17.42' W	2877		Y	Y
24	12/02/2009 00:42	41° 42.73' S	173° 58.55' W	3140			
25	12/02/2009 06:58	41° 16.19' S	173° 38.41' W	3322		Y	Y
26	12/02/2009 13:27	40° 49.47' S	173° 19.53' W	4171			
27	13/02/2009 01:27	40° 22.26' S	173° 02.06' W	4579		Y	Y
28	13/02/2009 08:06	39° 57.82' S	172° 41.89' W	4720			
29	13/02/2009 14:53	39° 30.86' S	172° 25.42' W	4758	Rosette Position 8 reserved for CFC blank test	Y	Y
30	13/02/2009 08:06	39° 05.01' S	172° 07.55' W	4840			
31	14/02/2009 05:52	38° 25.35' S	171° 38.96' W	4840	CAP crash near cast end.	Y	Y
32	14/02/2009 14:41	37° 45.90' S	171° 10.99' W	4640			
33	14/02/2009 21:14	37° 18.77' S	170° 52.57' W	5121		Y	Y
34	15/02/2009 04:06	36° 52.37' S	170° 35.72' W	5285	20mins delay due to winch problems. CAP crash – needed complete restart and bottle refires		
35	15/02/2009 11:31	36° 26.49' S	170° 52.57' W	5121		Y	Y
36	16/02/2009 18:38	36° 00.76' S	169° 59.73' W	5048			
37	16/02/2009 00:35	35° 40.62' S	170° 00.76' W	4342	12 XBTs dropped during CTD. New secondary T and C sensors fitted. Winch problems 1 hour into cast.	Y	Y
38	16/02/2009 06:14	35° 19.46' S	169° 59.25' W	4988	Changed sea-connectors between secondary T/C and main unit		
39	16/02/2009 12:06	35° 00.20' S	170° 00.12' W	5214		Y	Y
40	16/02/2009 19:20	34° 29.88' S	170° 00.38' W	5466			
41	17/02/2009 02:13	33° 59.78' S	169° 59.78' W	5516	Argo float deployment just before	Y	Y
42	17/02/2009 09:22	33° 29.82' S	169° 59.88' W	5396	No fresh nutrients		
43	17/02/2009 16:10	32° 59.43' S	169° 59.27' W	5447		Y	Y
44	17/02/2009 22:57	32° 29.95' S	170° 00.00' W	5518			P
45	18/02/2009 06:03	31° 59.94' S	169° 59.10' W	5644	Replaced bottle in RP 5.	Y	Y

46	18/02/2009 13:45	31° 29.16' S	169° 58.68' W	5560	UPS failed and crashed all acquisition systems. Downcast stopped for 1 hour at 2775db. Many underway logging systems were down for many hours it took to reboot all elements.		
47	18/02/2009 21:15	30° 59.94' S	169° 58.38' W	5592		Y	Y
48	19/02/2009 04:21	30° 29.88' S	169° 59.61' W	5518	Replaced bottle in RP 4.		P
49	19/02/2009 11:19	29° 59.43' S	169° 59.43' W	5399	Argo float deployment leaving the station	Y	Y
50	19/02/2009 18:28	28° 29.93' S	169° 58.81' W	5025			P
51	19/02/2009 01:19	29° 00.01' S	170° 00.27' W	5564	12 XBTs dropped during cast	Y	Y
52	20/02/2009 18:16	28° 30.51' S	169° 58.28' W	5432	Replaced bottle in RP 24.		P
53	20/02/2009 15:14	28° 00.30' S	169° 59.48' W	4829		Y	Y
54	20/02/2009 21:53	27° 29.96' S	169° 59.10' W	5367	12 XBTs dropped during cast		P
55	21/02/2009 05:11	26° 59.65' S	169° 59.09' W	5146		Y	Y
56	21/02/2009 12:06	26° 29.30' S	169° 59.7' W	5599			P
57	21/02/2009 19:30	26° 00.15' S	169° 59.59' W	5574	20 XBTs dropped during cast. Argo float deployed on leaving station	Y	Y
58	21/02/2009 19:30	26° 00.15' S	169° 59.59' W	5574	12 XBTs dropped during cast.No water samples. Rosette valves left open.		
59	22/02/2009 09:46	25° 00.47' S	170° 00.05' W	5618	Slow upcast due to poor lay on CTD winch	Y	Y
60	22/02/2009 17:11	24° 30.47' S	170° 00.01' W	5619	12 XBTs dropped during cast. Lanyards show severe wear on frame – many replaced		P
61	23/02/2009 00:52	23° 58.90' S	170° 00.29' W	5628	Winch spooling knife changed	Y	Y
62	23/02/2009 08:10	23° 29.93' S	170° 00.03' W	5642			P
63	23/02/2009 14:28	22° 59.80' S	170° 00.29' W	5408	Slow upcast due to care needed to spool wire on correctly. Loud bang from winch – and brief free spool -reason unknown	Y	Y
64	23/02/2009 23:58	22° 29.28' S	169° 59.94' W	5672	23 XBTs dropped during cast. Changed to aft CTD winch.		P
65	24/02/2009 0X:58	22° 09.28' S	169° 59.94' W	5	Last CTD on Leg 1..	Y	Y

Table 3: Leg 1 scientific party participants

Person	Watch	Duty
Wijffels	7am-9pm	Cruise leader
Ann Thresher	2am-2pm	Watch leader
Kail Stewart	2am-2pm	CTD watch/salts analysis
Hiski Kippo	2am-2pm	CTD watch/computer
Kate Berry	2am-2pm	Carbon analysis
Alicia Navidad	2am-2pm	Nutrients
Fred Menzia	midnight midday	CFCs
Catia Domingues	2pm-2am	Watch leader
Don McKenzie	2pm-2am	CTD watch/voyage mangr
Peter Dunn	2pm-2am	CTD watch/elec tech
Bronte Tilbrook	2pm-2am	Carbon analysis
Peter Hughes	2pm-2am	Oxygens
Dave Terhell	2pm-2am	Nutrients
Nancy Williams	midday to midnight	CFCs

Table 4: Leg 1 ships crew:

1.	MASTER	LES MORROW
2.	CHIEF OFFICER	JOHN BARR
3.	2 ND OFFICER	ROB FERRIES
4.	CHIEF ENGINEER	ROGER THOMAS
5.	1 ST ENGINEER	ROB CAVE
6.	2 ND ENGINEER	SEAMUS ELDER
7.	BOSUN	TONY HEARNE
8.	I.R.	JOHN HOWARD
9.	I.R.	GARETH GUNN
10.	I.R.	KEL LEWIS
11.	I.R.	PAUL O'NEILL
12.	CHIEF STEWARD	JOHN FABICS
13.	CHIEF COOK	ANDY GOSS
14.	2 ND COOK	LUKE RILEY

Table 5: Information of Argo floats deployed on SS200901-leg2

Argo Float	Date/Time (GMT)	Position	other information
Hull No 2855	11/03/2009 03:00	168° 45'98' W 06° 29.28' S	Transmitting ok
Hull No 2856	12/03/2009 07:40	168° 45.71' W 04° 29.24' S	Transmitting ok
Hull No 2857	13/03/2009 1104	168° 46.37' W 02° 28.82' S	Transmitting ok
Hull No 2861	14/03/2009 16:17	168° 44.41' W 00° 28.79' S	Transmitting ok

Table 8: Locations, times (UTC) and depths of CTD casts completed on Leg 2. Bottle oxygen, and major nutrient samples were analysed on all casts. The last two columns indicate chlorofluorocarbon and dissolved carbon/alkalinity sampling – Y indicates the full set of bottles were sampled, P indicates on a subset of bottles were sampled.

No	Start Date/Time (UTC)	Latitude	Longitude	Depth (m)	Comments	CFC	DIC
66	28/02/2009 15:16	21° 29.90' S	170° 00.00' W	5397	First Station of Leg 2.		P
67	28/02/2009 22:25	20° 58.46' S	169° 59.47' W	5650		Y	Y
68	01/03/2009 05:28	20° 29.44' S	170° 00.03' W	5584			P
69	01/03/2009 12:43	19° 59.79' S	170° 00.15' W	5315	Replaced secondary CTD cable prior to stations	Y	Y
70	01/03/2009 19:11	19° 29.90' S	170° 00.36' W	4899			P
71	02/03/2009 00:50	18° 59.74' S	170° 03.33' W	2942	8 XBTs dropped during cast.	Y	Y
72	02/03/2009 07:40	18° 30.02' S	170° 00.52' W	5247			P
73	02/03/2009 14:37	17° 59.10' S	170° 00.66' W	4971		Y	Y
74	02/03/2009 21:08	17° 30.54' S	170° 01.54' W	5092			P
75	03/03/2009 03:57	16° 59.31' S	170° 00.22' W	4949		Y	Y
76	03/03/2009 10:38	16° 29.04' S	170° 00.69' W	5057			P
77	03/03/2009 17:??	15° 59.04' S	170° 00.78' W	5122		Y	Y
78	04/03/2009 00:08	15° 30.04' S	170° 01.23' W	5068			P
79	04/03/2009 06:45	15° 00.21' S	170° 00.40' W	4809	12 XBT dropped during cast	Y	Y
80	04/03/2009 11:53	14° 39.09' S	169° 59.90' W	3150			P
81	04/03/2009 16:48	14° 17.11' S	170° 00.46' W	3546		Y	Y
82	04/03/2009 21:30	13° 58.19' S	170° 00.62' W	2738	CAP crashed during cast, restart via append		P
83	05/03/2009 01:21	13° 49.28' S	170° 00.69' W	4299		Y	Y
84	05/03/2009 06:49	13° 30.07' S	170° 00.52' W	4868			P
85	05/03/2009 13:26	12° 58.92' S	170° 00.80' W	4958		Y	Y
86	05/03/2009 19:45	12° 28.93' S	169° 59.66' W	4915			P
87	06/03/2009 02:14	11° 59.72' S	170° 01.08' W	5081	12 XBT dropped during cast	Y	Y
88	06/03/2009 0857	11° 29.56' S	170° 01.44' W	5039	Primary conductivity calibration coefficient change to Seabird cal report 18/01/07. Primary conductivity malfunctioned on approach to bottom. Use secondary sensors		P
89	06/03/2009 15:35	10° 59.74' S	170° 01.32' W	5106	Change primary conductivity sensor to serial no: 3311. Cal from Seabird report 18/01/07	Y	Y
90	06/03/2009 22:27	10° 29.83' S	170° 01.24' W	4982			P
91	07/03/2009 08:36	10° 08.13' S	168° 59.28' W	4617		Y	Y
92	07/03/2009 13:49	10° 02.96' S	169° 12.67' W	5193	Bottle 2 leaked – lanyard from bottle 1. Bottle 16 high temperature possible mistrip.		P
93	07/03/2009 20:01	09° 55.07' S	169° 38.49' W	5192	Bottle accidentally fired at 250dbar	Y	Y
94	08/03/2009 02:10	09° 46.00' S	170° 03.91' W	4550	Bottle 18 leaking. Replaced prior to next cast.		P
95	08/03/2009 07:07	09° 41.41' S	170° 19.56' W	4298	Bottle 18a -12035	Y	Y
96	08/03/2009 12:04	09° 35.16' S	170° 36.25' W	4042			P

97	09/03/2009 00:56	09° 27.74' S	169° 00.47' W	5279	IR and bosun checked sheaf at beginning of cast. CAP crashed after firing bottle 24	Y	Y
98	09/03/2009 07:22	08° 59.16' S	168° 53.12' W	4771	Bottle 22 fired on the fly		P
99	09/03/2009 14:06	08° 28.73' S	168° 46.76' W	5156	Started CTD data acquisition just as CTD entered water. Bottle 22 fired between 170 and 110m	Y	Y
100	09/03/2009 18:54	08° 14.46' S	168° 42.76' W	4876			P
101	09/03/2009 23:59	07° 59.60' S	168° 37.79' W	4550		Y	Y
102	10/03/2009 05:11	07° 45.10' S	168° 41.04' W	4988	Secondary conductivity calibration change to CMAR 03/9/2007. Off-se tot primary larger than previous stations.		P
103	10/03/2009 10:45	07° 29.16' S	168° 45.45' W	5288		Y	Y
104	10/03/2009 17:38	06° 45.94' S	168° 45.92' W	5476	Changed secondary calibration coefficients to seabird 08/03/2006. Primary conductivity failed at 5500 on up-cast		P
105	11/03/2009 02:45	06° 29.72' S	168° 46.22' W	5670	First two attempts at cast aborted due to CTD and mechanical problems, respectively (see daily report)	Y	Y
106	11/03/2009 10:41	05° 59.38' S	168° 45.47' W	5634	Six pairs of XBT launched within 1n.m. of stations. Argo float -SIO SOLO 2855 deployed		P
107	11/03/2009 17:27	05° 29.87' S	168° 46.14' W	4988		Y	Y
108	12/03/2009 00:35	04° 59.97' S	168° 45.99' W	5543	Argo float -SIO SOLO 2856 deployed		P
109	12/03/2009 07:32	04° 29.72' S	168° 45.84' W	5485		Y	Y
110	12/03/2009 14:16	03° 59.16' S	168° 45.76' W	4987			P
111	12/03/2009 20:36	03° 29.06' S	168° 45.42' W	4981		Y	Y
112	13/03/2009 03:52	02° 59.50' S	168° 44.98' W	5341	6 pairs of XBT launched on station prior to CTD deployment		P
113	13/03/2009 10:54	02° 29.10' S	168° 46.39' W	5341	Argo float -SIO SOLO 2857 deployed	Y	Y
114	13/03/2009 18:46	01° 50.84' S	168° 44.85' W	5056			P
115	14/03/2009 02:33	01° 24.34' S	168° 44.66' W	6532	Stopped descent with 3 turn on 3rd layer of wire. Estimate less than 100m off bottom	Y	Y
116	14/03/2009 09:30	00° 58.54' S	168° 44.67' W	5672?	Hit bottom. No steady altimeter reading. EA500 not providing reliable depth.		P
117	14/03/2009 16:06	00° 29.15' S	168° 44.26' W	5428	Argo float – SIO SOLO 2861 deployed	Y	Y
118	14/03/2009 23:41	00° 00.96' N	168° 43.86' W	6532	6 pairs of XBT launched on station prior to CTD deployment. Last Station of P15S	Y	Y
119	19/03/2009 01:37	17° 30.05' S	170° 19.95' W	5232	Bottle 21 leaking, replaced. LADCP on rosette	Y	Y
120	19/03/2009 08:57	17° 30.43' S	171° 00:01' W	5084			P
121	19/03/2009 15:56	17° 29.02' S	171° 39:15' W	4902		Y	Y
122	19/03/2009 21:56	17° 29.52' S	172° 00:13' W	5698	Winch knife replaced at end of station	P	P
123	20/03/2009 03:52	17° 29.96' S	172° 19:50' W	7593	No LADCP interference on altimeter below approx. 5500m. LADCP stopped binging?	Y	Y
124	20/03/2009 09:30	17° 29.41 S	172° 41.34' W	4718		P	P
125	20/03/2009 14:24	17° 29.75 S	172° 50.27' W	4242		Y	Y
126	20/03/2009 17:29	17° 29.41 S	173° 00.60' W	2534		P	P
127	20/03/2009 23:12	17° 30.21 S	173° 40.92' W	1362		Y	Y
128	21/03/2009 04:28	17° 24.84 S	174° 20.02' W	1489	Last stations of 17.5 S across western boundary		P

Table 10: Leg 2 scientific party participants

Person	Watch	Duty
Bernadette Sloyan	8am-9pm	Cruise leader
Mark Rosenberg	2am-2pm	Watch leader
Clothilde Langlais	2am-2pm	CTD watch/salts analysis
Bernadette Heaney	2am-2pm	CTD watch/computer
John Akl	2am-2pm	Carbon analysis
Alicia Navidad	2am-2pm	Nutrients
Fred Menzia	midnight midday	CFCs
Rebecca Crowley	2pm-2am	Watch leader
Max Gonzalez	2pm-2am	CTD watch
Drew Mills	2pm-2am	CTD watch/electronics tech/voyage manger
Kate Berry	2pm-2am	Carbon analysis
Peter Hughes	2pm-2am	Oxygen
Dave Terhell	2pm-2am	Nutrients
Nancy Williams	midday to midnight	CFCs

Table 11: Leg 2 ships crew:

15. MASTER	LES MORROW
16. CHIEF OFFICER	MICHAEL TUCK
17. 2 ND OFFICER	JOHN BOYES
18. CHIEF ENGINEER	JOHN MORTON
19. 1 ST ENGINEER	DAVE JONKER
20. 2 ND ENGINEER	SEAMUS ELDER
21. BOSUN	TONY HEARNE
22. I.R.	STEVE SALTER
23. I.R.	GARETH GUNN
24. I.R.	KEL LEWIS
25. I.R.	PAUL O'NEILL
26. CHIEF STEWARD	ASHLEIGH POLLOCK
27. CHIEF COOK	ANDY GOSS
28. 2 ND COOK	LUKE RILEY

Acknowledgements

Many thanks to the master and crew of the RV *Southern Surveyor* for their cooperation and hard work during the voyage. The ship's crew were good natured and very skilled in their handling of the CTD package and winches, during many long and tedious casts, and also during some very heavy sea conditions. The ship's engineers and bosun in particular are thanked for their hard work and ingenuity in keeping the CTD winches operating well and safely, despite several breakdowns.

B. Measurement Techniques

B.1 CTD/O₂ processing

The new CTD Acquisition Program (CAP) (Pender, L. and Beattie, R. D., 2009:CAP User' S Guide, in prep) was used to acquire the CTD/O₂ data. The CAP software provided a very convenient and reliable method to display down-and-up cast temperature, salinity and oxygen concentrations.

CTD primary and secondary conductivity sensors and SBE 43 oxygen sensor were calibrated with bottle salinity and oxygen data using procCTD (Beattie, R. D., 2009: procCTD CTD Processing Procedures Manual, rev June 2009, <http://www.marine.csiro.au/~dpg/opsDocs/procCTD.pdf>).

B.2 Bottle Salts -- Summary of conductivity measurements for stations 1 – 18 (Kial Stewart, Australian National University)

The operating temperature of the AutoSal water bath temperature and laboratory were in of order 1-2°C different during the analysis of salt samples for stations 1-20. Therefore, bottle salts are not reliable for stations 1-17.

It was found that the laboratory temperature exhibited a ~2°C oscillation with a 15 – 20 minute period. The setting of the laboratory temperature was adjusted to ensure the maximum of the laboratory temperature did not exceed the setting of the AutoSal water bath. This procedure was applied after station 17.

Bottle salt analysis is reliable, apart from outliers, from station 18 onwards.

On Leg 2, the salinometer became unstable during the analysis of Station 110. It was replaced with spare unit after unsuccessfully trying to determine the problem.

B.3 Bottle Oxygen (Peter Hughes, CMAR)

The oxygen analysis was performed on a photometric analysis system designed and built by Scripps Oceanographic Institute. The computer driving the system died part way through the voyage and was replaced by a laptop but no data was lost. Some of the original LST files were lost as they hadn't been backed up to the ship's server when the computer died. However, I had copies of the edited LST (lost) files used for uploading the results into hydro. The edited files do not contain the samples that were overshot during their titration; no endpoint was measured.

Bottle oxygen analysis is reliable and was periodically checked against external standards in addition to normal standardization and blank determination daily.

B.4 Nutrient Processing, 24th to 28th April, 2009 (Rebecca Cowley, CMAR)

Nutrient data analysed by Dave Terhell and Alicia Navidad using the Lachat on the R/V Southern Surveyor voyage 2009/01 was mostly processed on board. However, there were still some issues with the data and the processing methods that required further work after the voyage. This document summarises the steps taken to finalise the data.

General

With the help of Lindsay Pender, a matlab routine was developed to process the nutrient data prior to the voyage. The data was:

- 1 collected on the Lachat,
- 2 screened by the analyst,
- 3 exported to a csv file,
- 4 imported into matlab and processed using the matlab routine
- 5 exported by the matlab program to an .xls format,
6. imported into Hydro

After step 4, the data was plotted up using matlab. The most useful plots were:

- nutrient vs. potential temperature with the DISCOVERY data plotted in the background,
- QC plots of calibrant, blank and QC peak heights and concentrations
- Calibration plots and plots of the errors in the calibration.

Where there were noise issues with the Lachat, these were clearly seen in the calibration plots. The nitrate analysis was problematic for the first 50 stations, after which analysis was improved. As a result, the first 50 stations were repeated for nitrate (and some for phosphate) near the end of the second leg.

Steps for each run – matlab processing

- 1 When a run was processed, the calibration was looked at. Sometimes calibrants were removed to improve the fit.
- 2 Obviously bad data was hashed from the run in the .csv file.
- 3 Plots of nutrient vs. potential temperature were made. These were good for determining leakers or if there was an issue with the calibration that caused an offset in the data from the historical values.

After the initial processing of station nutrient data was completed, a systematic examination of the station data was undertaken. This included comparison with DISCOVERY nutrient data, and completed nutrient data from this voyage. Many varied plots of the data were completed and from these a decision of data quality was made and whether there was a need to re-run the station analysis from stored samples

Silicate and Nitrate

Silicate results were straightforward, and only a few runs needed revisiting. Nitrate was more complex and many bad data flags assigned the leg 1 data. These stations were repeated near the end of the voyage using the stored bottle samples. Generally the calibrations didn't require too much work.

Phosphate

Some of the phosphate results required correction for silicate interference, which was demonstrated in one run (run 43). This run was completed at the end of leg 1. Silicate in high concentrations contributes to about 1.4% (about 0.04uM phosphate at 3uM levels) of the phosphate concentration, according to this test.

The chemistry of the phosphate analysis is designed to eliminate silicate interference by keeping the acidity of molybdate reagent very low. I suspect that at the start and end of the voyage, the

silicate interference was minimal, but for some reason, in the middle of the voyage, the chemistry wasn't quite right, and silicate was interfering with the results. Hence the need to correct the results from runs 53 to 100. Originally, I corrected from run 44, but it appeared that runs 44 to 52 weren't affected by the silicate interference, yet run 43 was when the test for the interference was run. Maybe it is more variable than I have accounted for here.

The QC results were very important in diagnosing the above issues. It was obvious from the QC results that the bias in the sample results was an instrument problem, as the QC followed the same pattern as the sample offsets from historical results.

The blank correction (refractive index and milli-q) was assessed and throughout the voyage, the blank correction essentially equated to the LNSW value, as the correction is calculated as follows:

Corrected peak area = peak area – blank;

Where:

blank = (LNSWbg – MQbg) + MQcol;

The MQbg and MQcol values were mostly equivalent, and cancelled each other out. The correction of LNSWbg equated to about 0.02% of the Cal 5 peak height. A mean of each section's (see [figure 4](#)) results was used to correct the data, as in some runs there were outliers and bad blank concentrations that offset that stations results. The blank correction has a minor effect on the overall results.

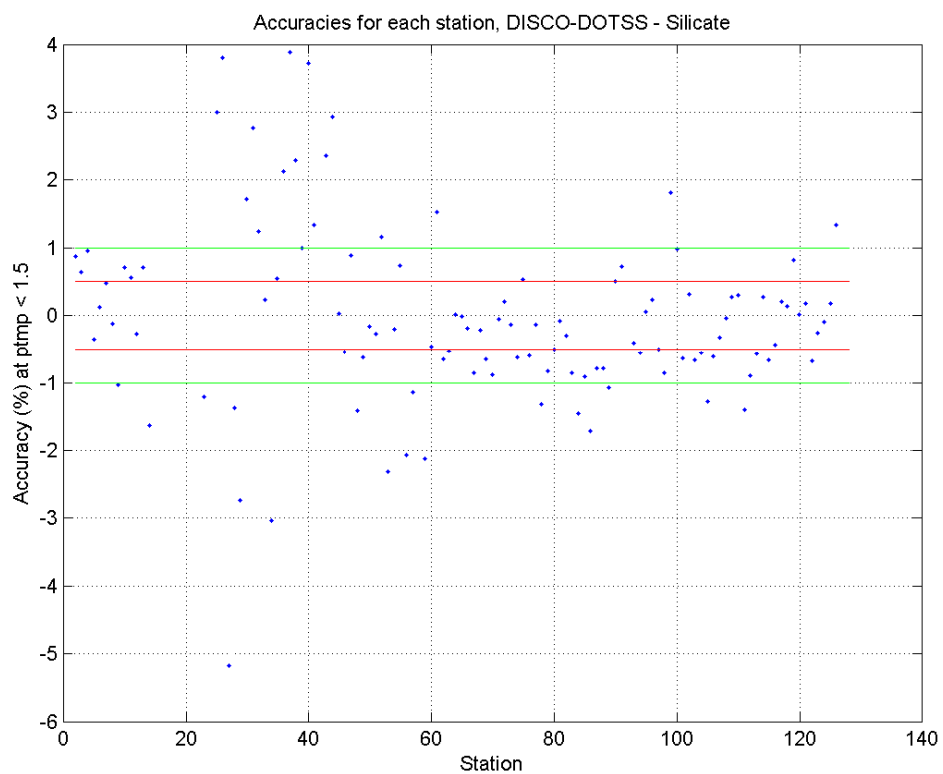
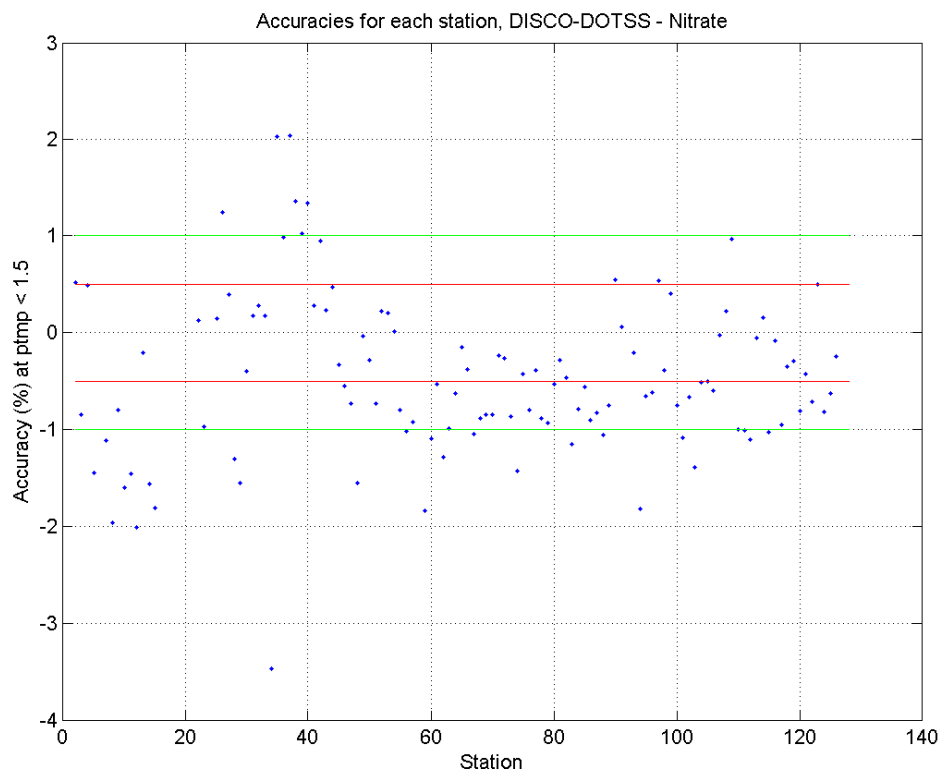
In many runs, the calibration results required adjustment to improve the results. Removal of some calibrants had a marked effect in some instances. In some runs, I had to use calibrant results from adjacent runs in order to get accurate results. This is not a desirable method of correcting results, but was the best I could come up with and proved to be successful.

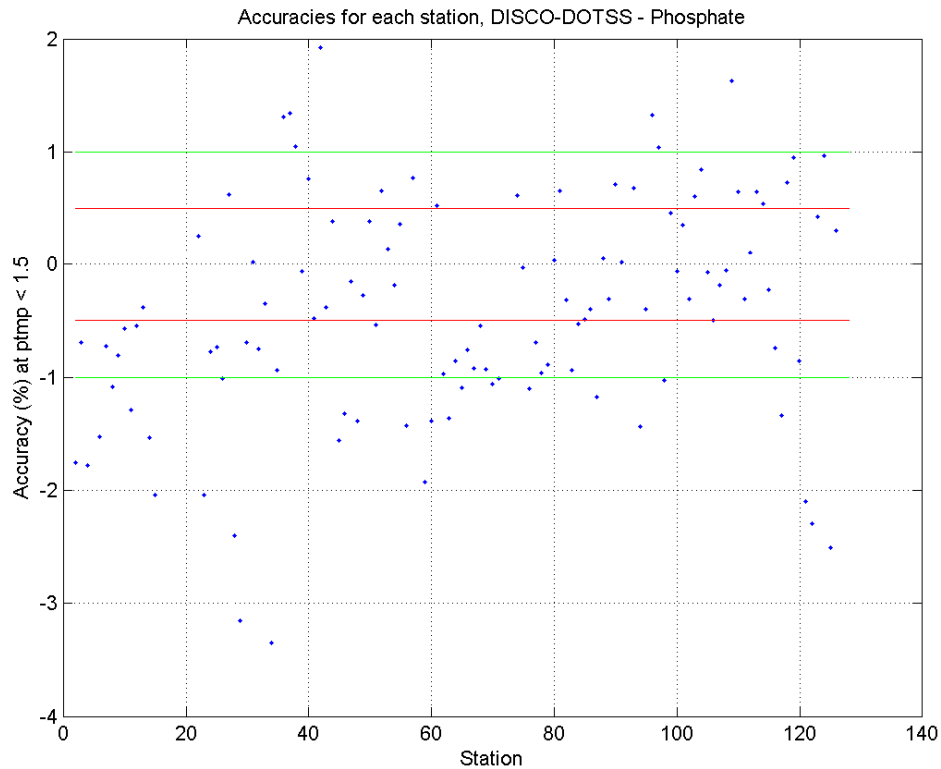
Accuracies and precisions

The accuracy of the results against the DISCOVERY results was determined by putting the data onto a potential temperature grid. Only data between a potential temperature of 1.2 and 2 was used. The DISCO data was subtracted from the Southern Surveyor data and then divided by the DISCO data. The mean error was then plotted against station number. The following figures show the results, with 0.5% and 1% error bars included.

Accuracy = ((SouthernSurveyor – DISCO)/DISCO)*100%

Towards the end of the voyage, accuracies of +/-1% for all nutrients were being achieved. Most were within +/-0.5%.

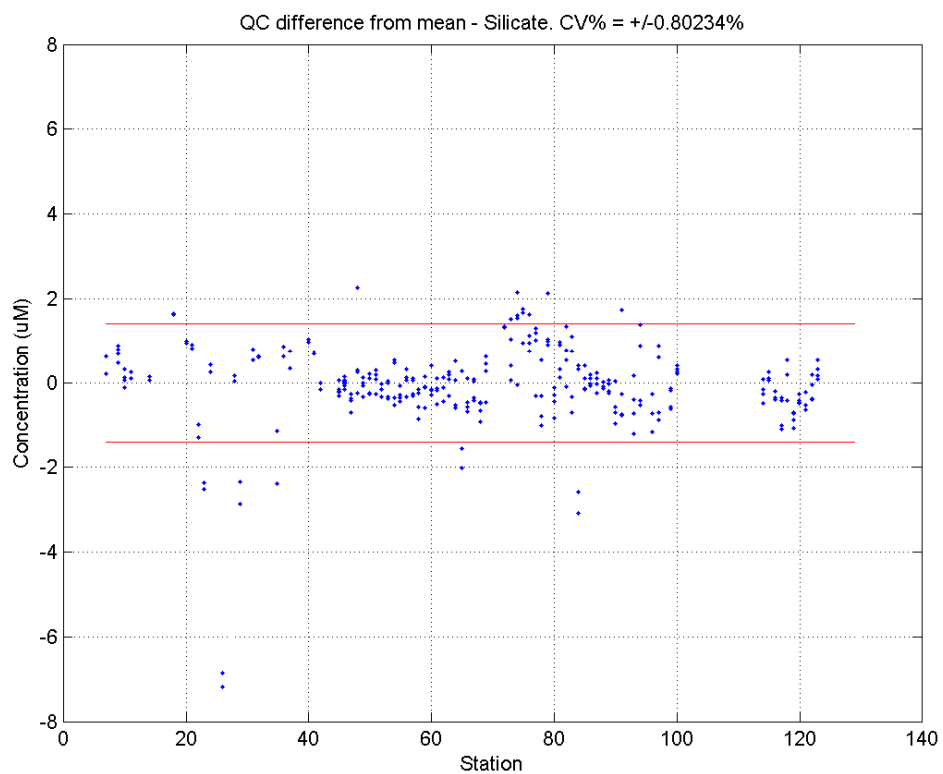
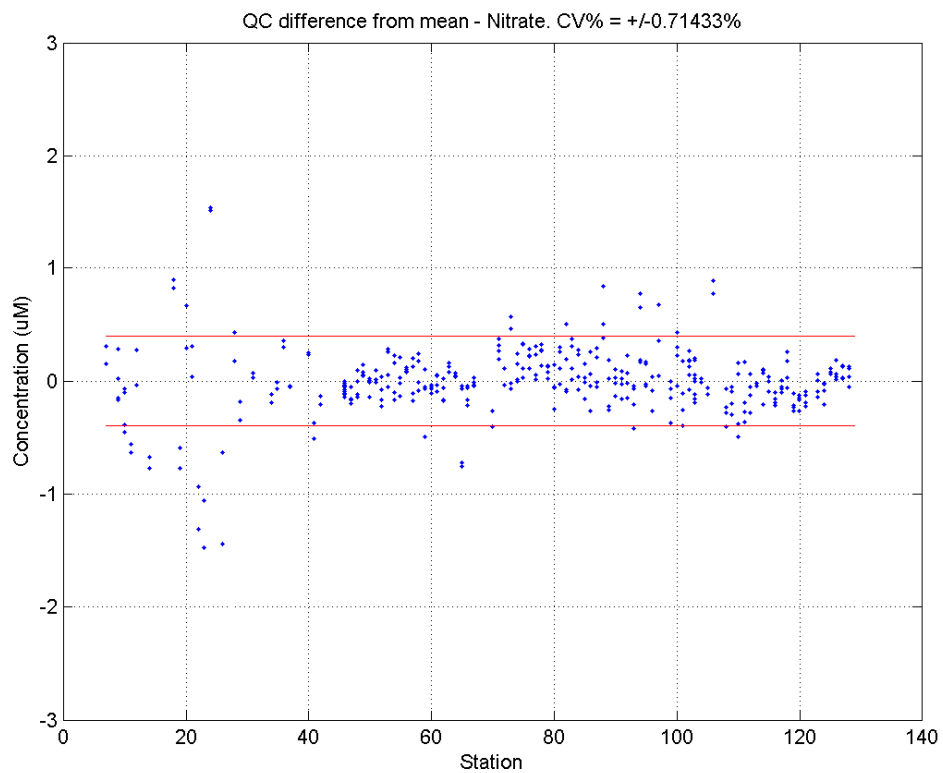


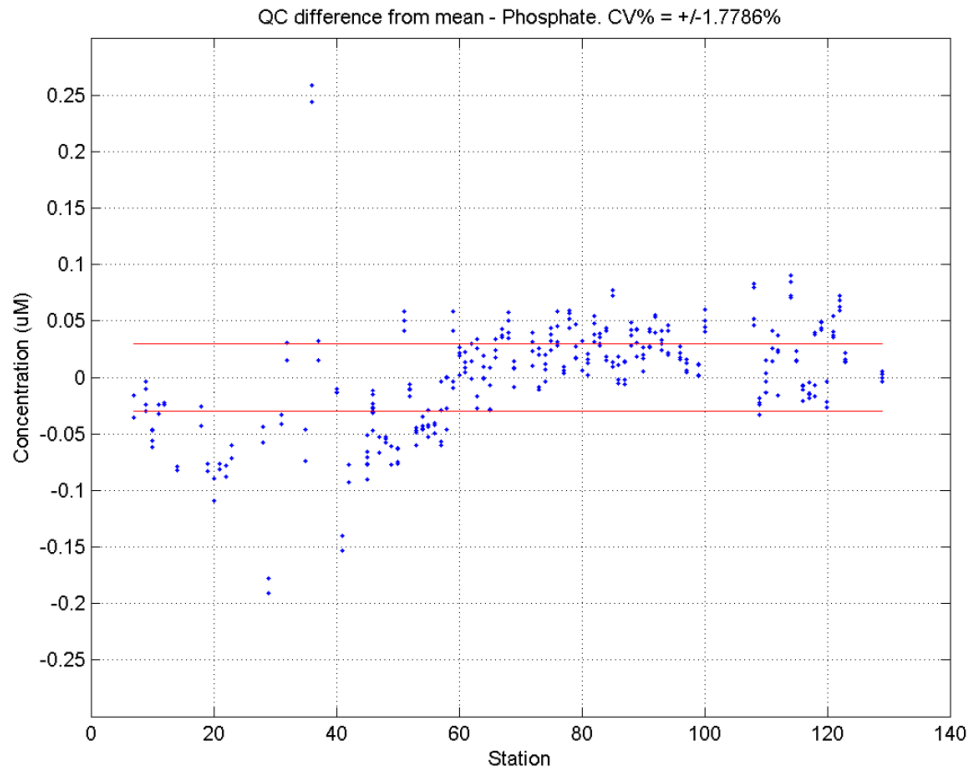


The coefficient of variation of the results is shown below, with the QC sample residuals plotted with error bars of 1%. Both nitrate and silicate had a coefficient of variation of less than 1% in most cases, but phosphate's precision is 1.7% overall.

$$CV\% = \text{stdev}(QC)/\text{mean}(QC)*100\%$$

The QC results for phosphate show a lot of variation early on and are higher in the second half of the voyage. The noise in the first leg is probably due to the long runs, combined with other issues, such as the topping up of calibrants during a run, which appeared to cause a lot of noise in a run. This practice was stopped during the second leg and the runs were shortened significantly with improved the calibrations.





Plots:

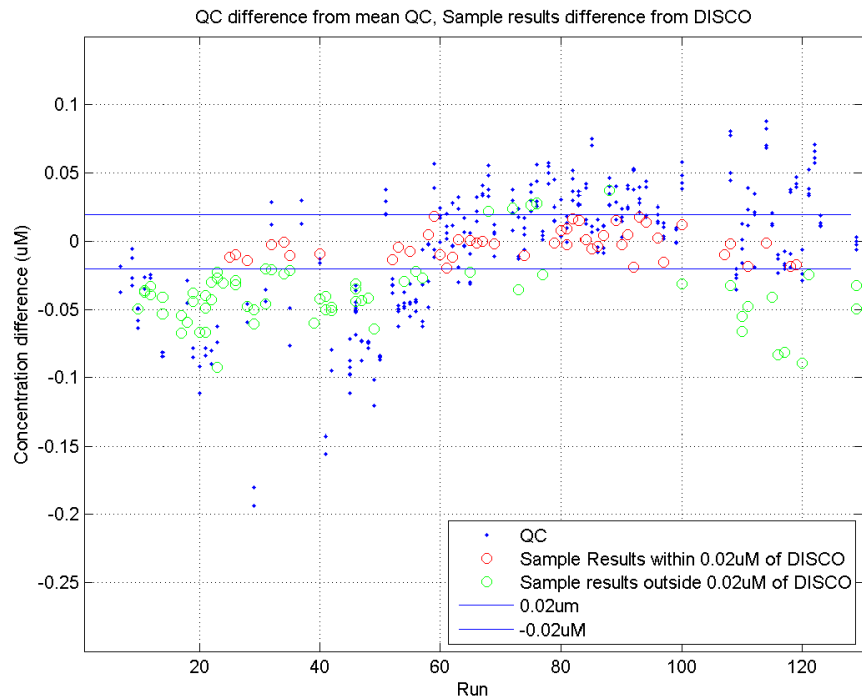


Figure 1: Shows the QC results for the phosphate channel, overlaid with the sample offset from the Discovery voyage results. These results are after ALL runs were corrected for silicate interference. Runs 1 to 52 are low (first leg) as are some runs at the end. These runs were not affected by Si interference, so the correction was removed for these runs (see [figure 2](#)).

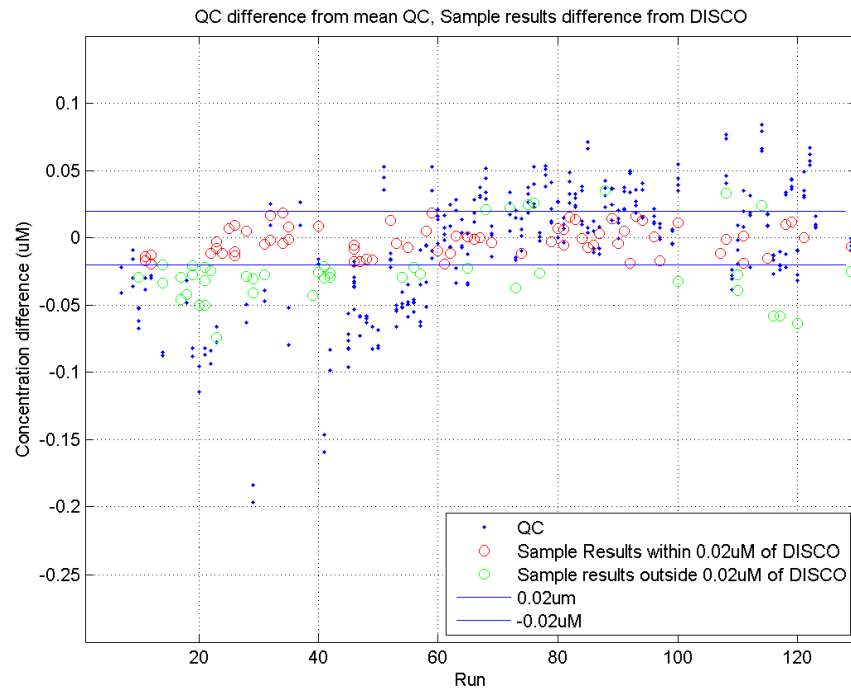


Figure 2: Shows the QC results for the phosphate channel, overlaid with the sample offset from the Discovery voyage results. These results are after just runs 43 to 100 were corrected for silicate interference.

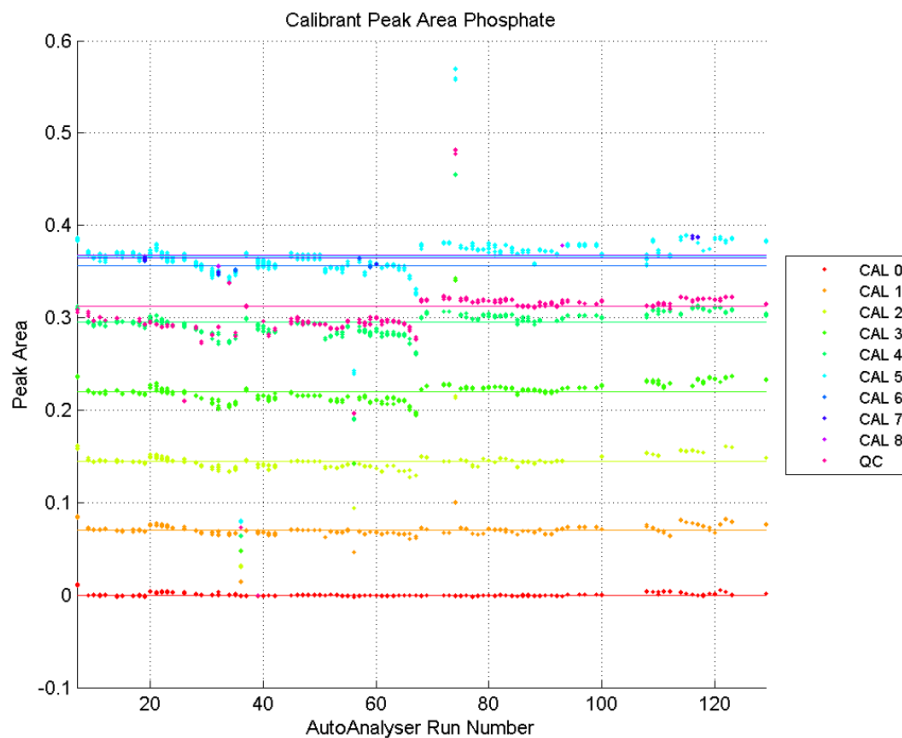


Figure 3: Calibrant and QC Peak areas for phosphate for each run. There is some variation in the sensitivity of the instrument between runs.

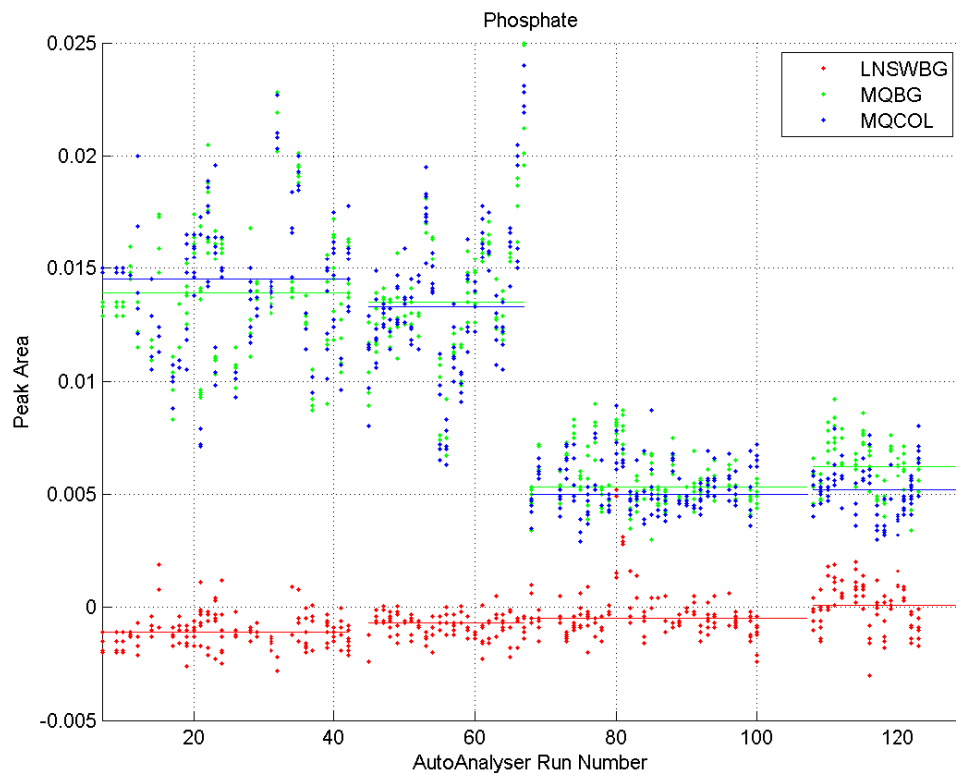


Figure 4: Blank correction values for phosphate for each run. The net result for the blank correction makes a very small difference to the results. A mean for each section was used to correct the results.

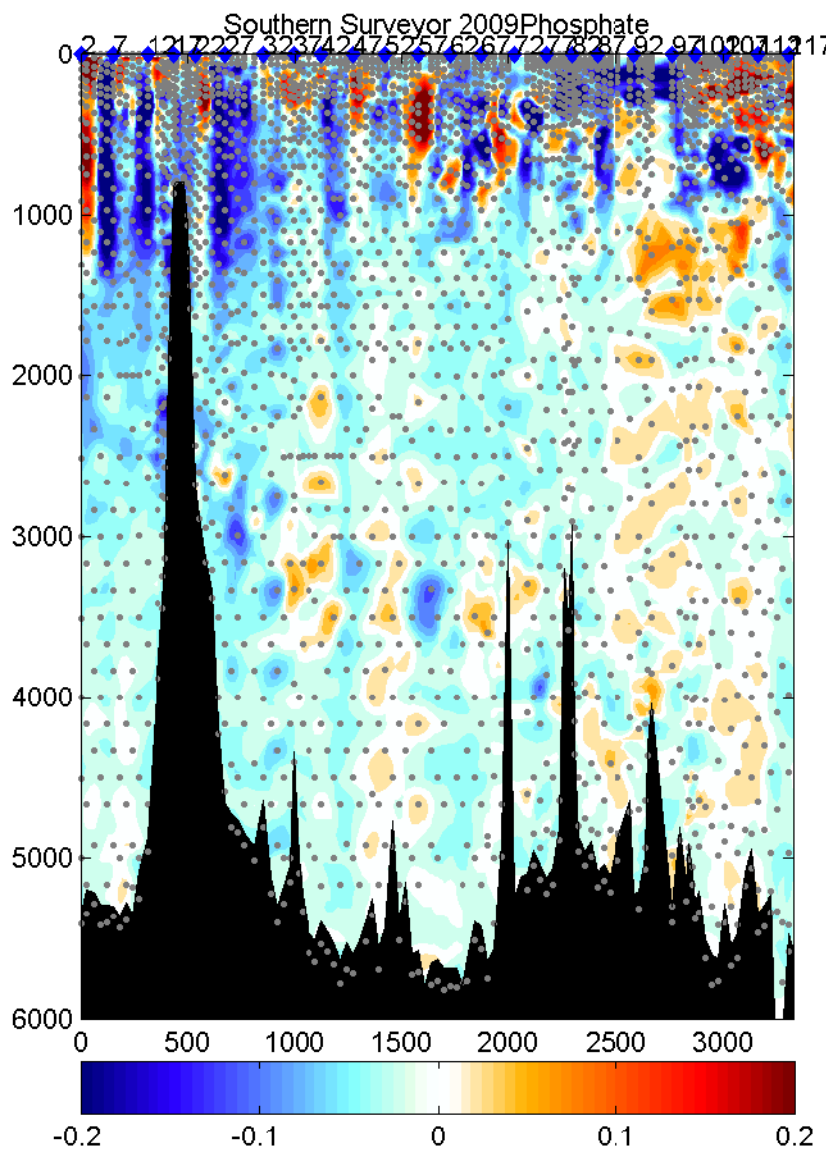


Figure 5: Difference between the Southern Surveyor voyage and DISCO phosphate results with runs 53 to 100 corrected for silicate interference, results plotted on a depth grid.

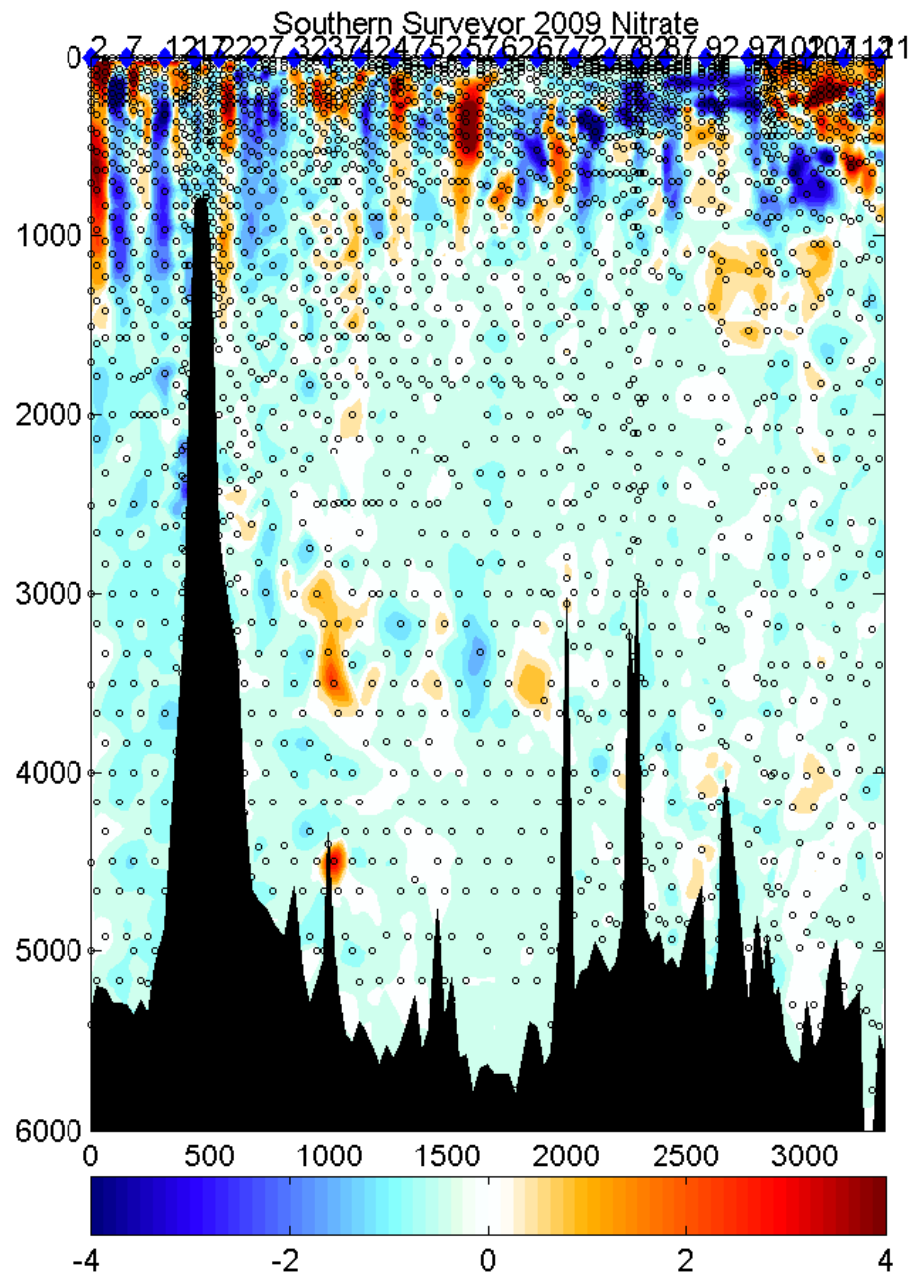


Figure 6: Difference between the Southern Surveyor voyage and DISCO for Nitrate, results plotted on a depth grid.

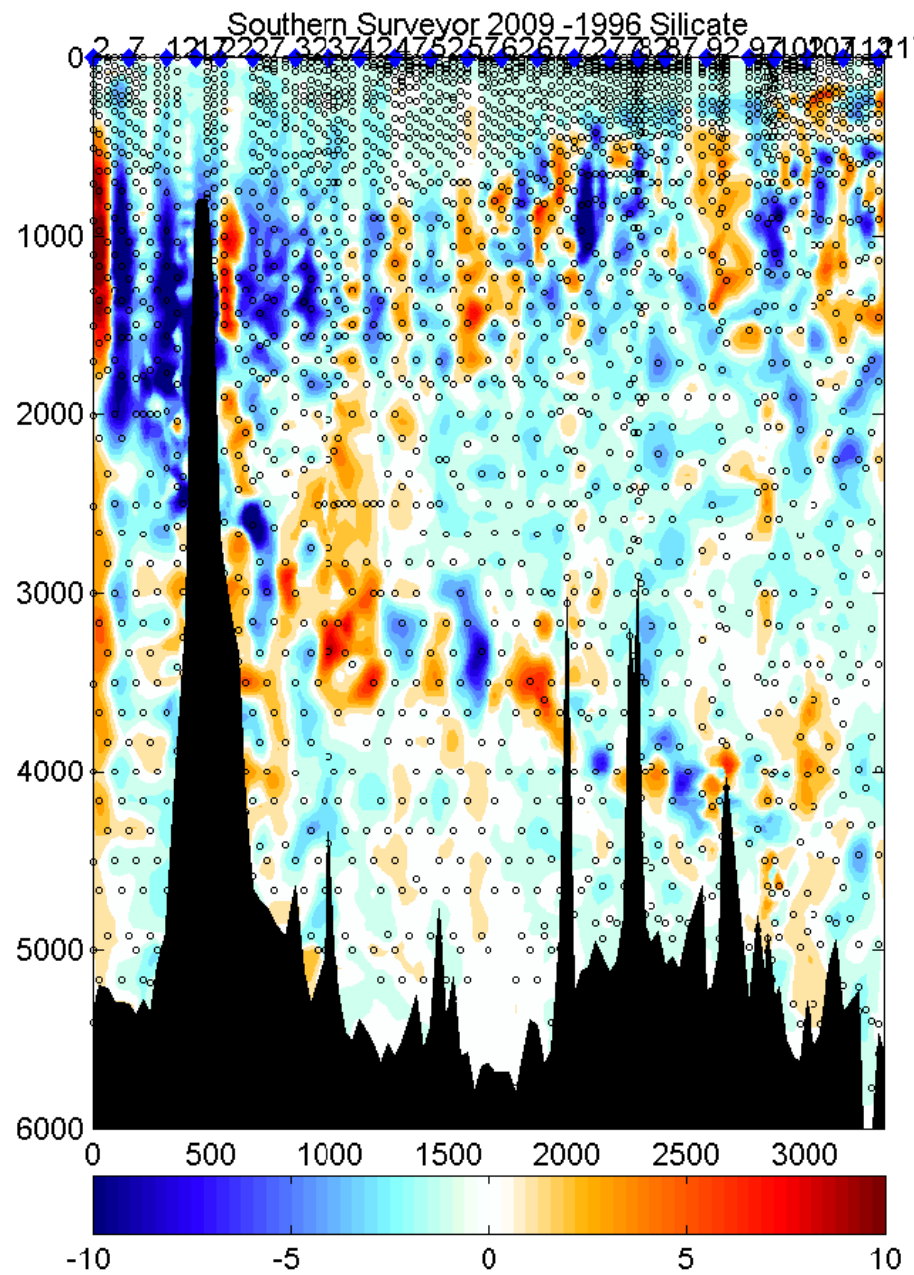


Figure 7: Difference between the Southern Surveyor voyage and DISCO for Silicate, results plotted on a depth grid.

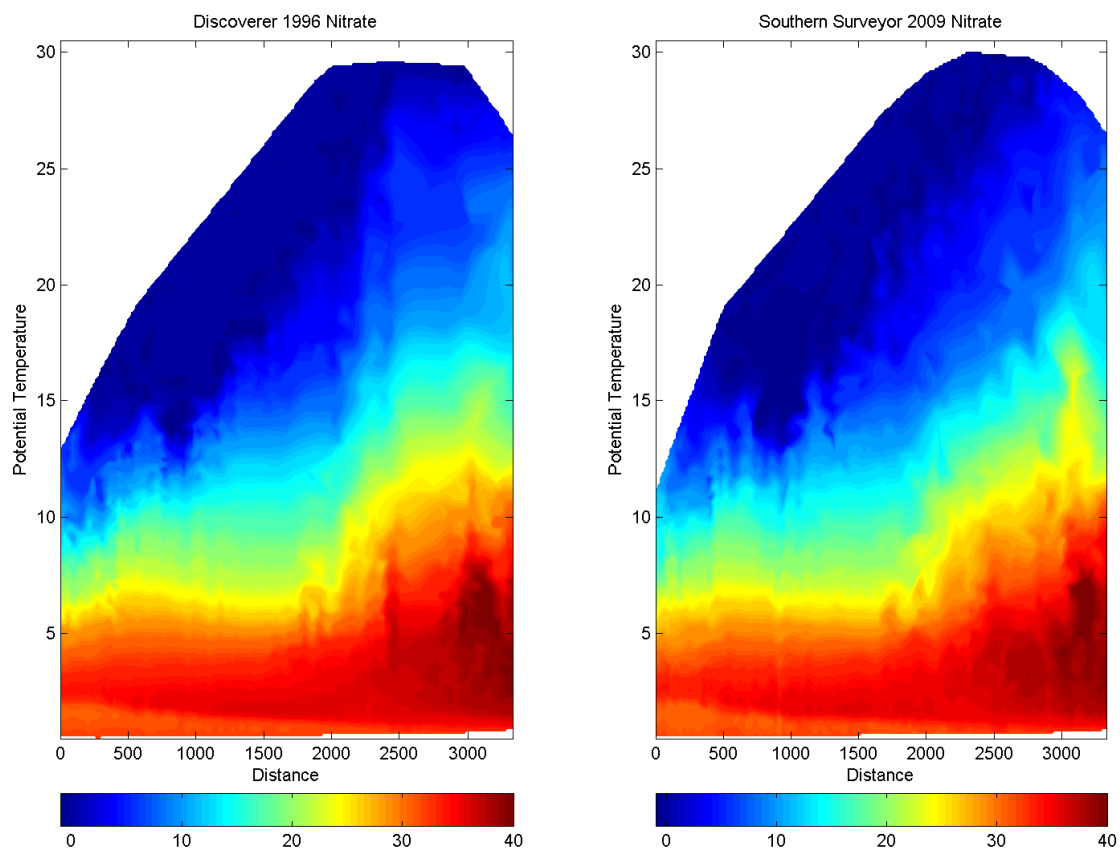


Figure 8: Nitrate concentrations on a potential temperature grid.

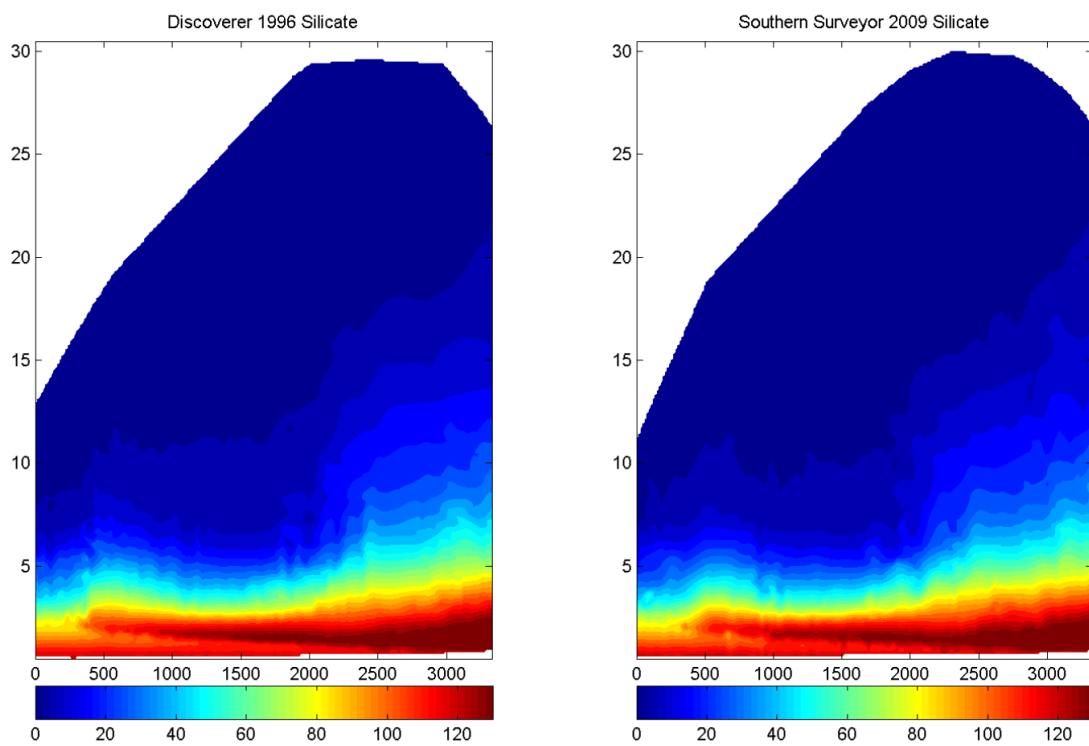


Figure 9: Silicate concentrations on a potential temperature grid.

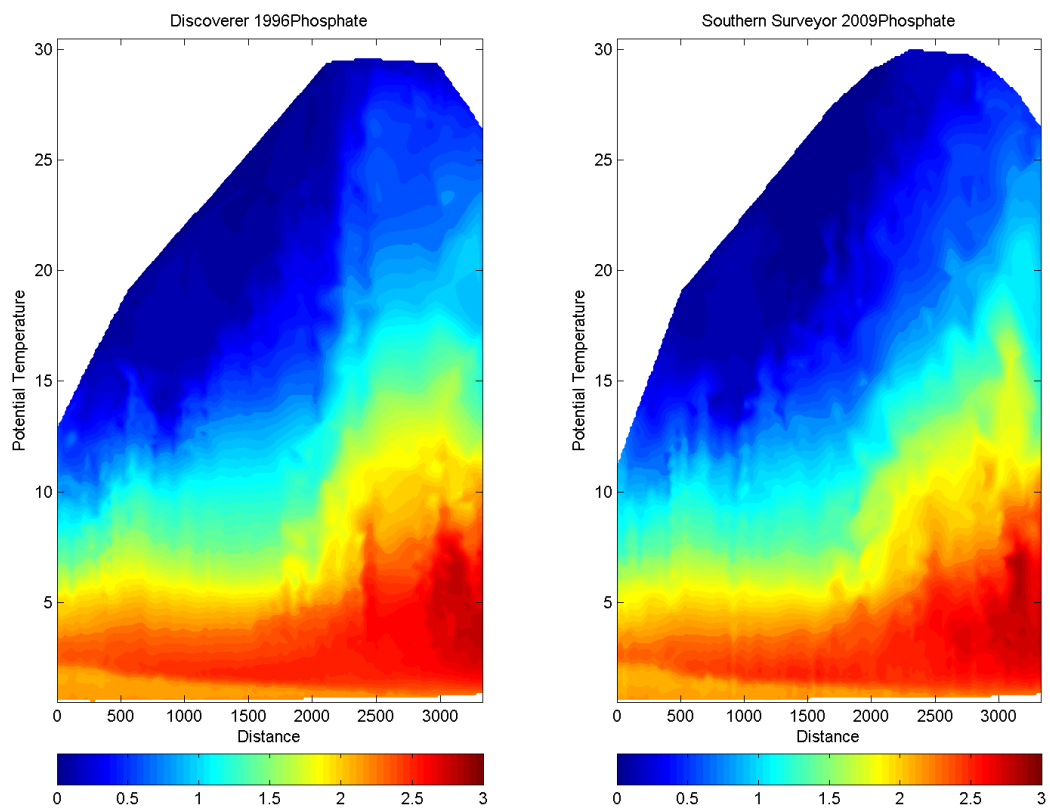


Figure 10: Phosphate concentrations on a potential temperature grid.

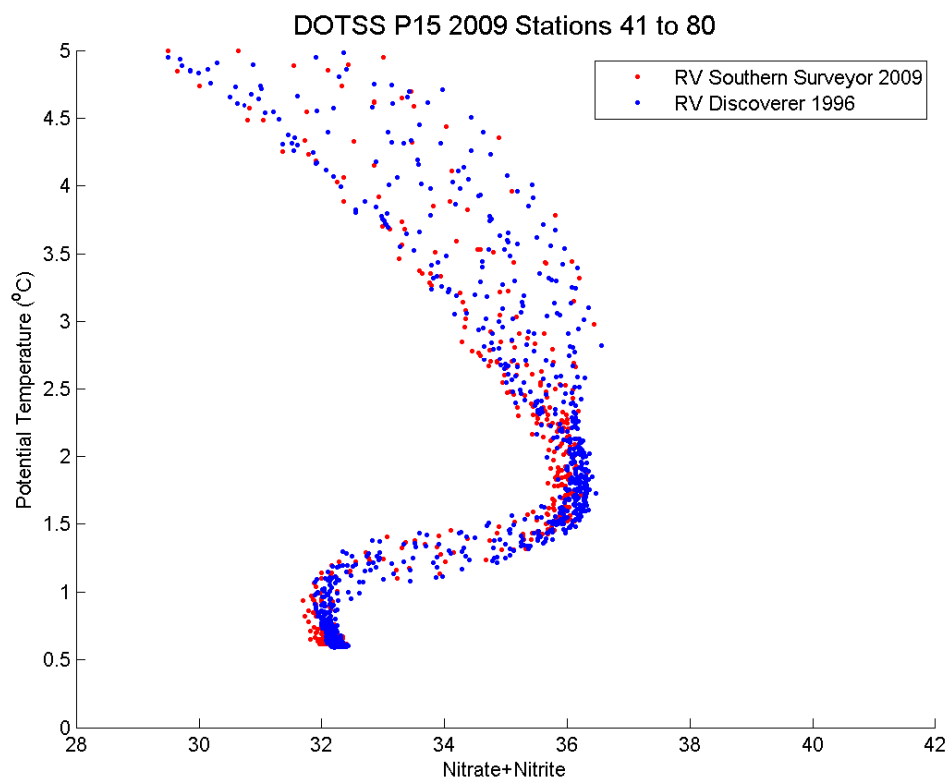
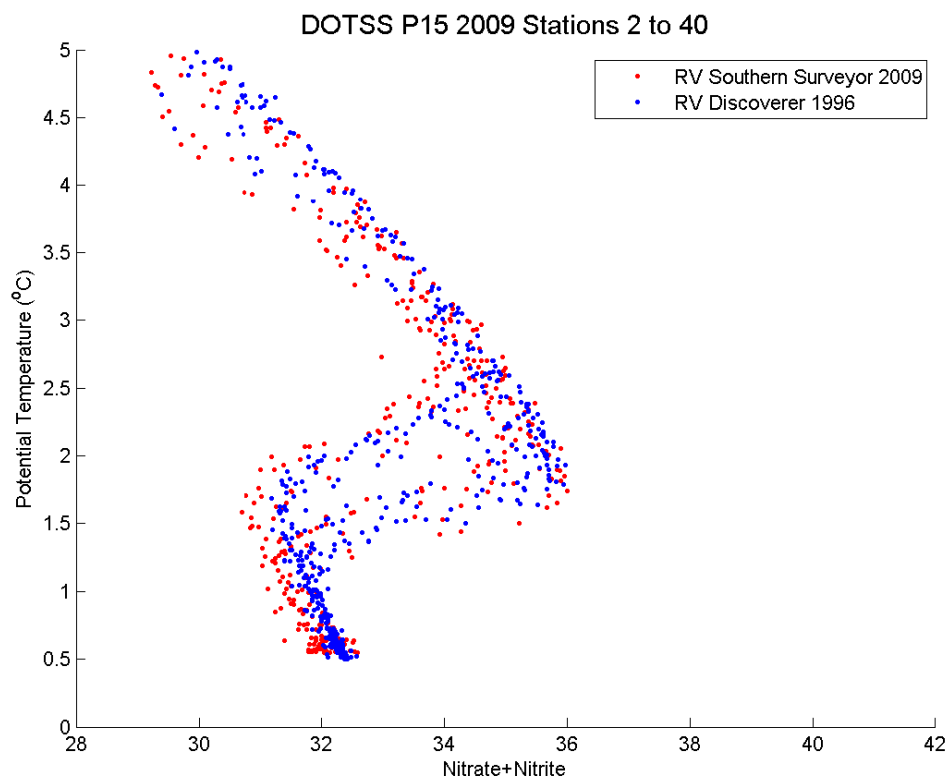


Figure 11: Plots of nitrate/nitrite against potential temperature in station groups.

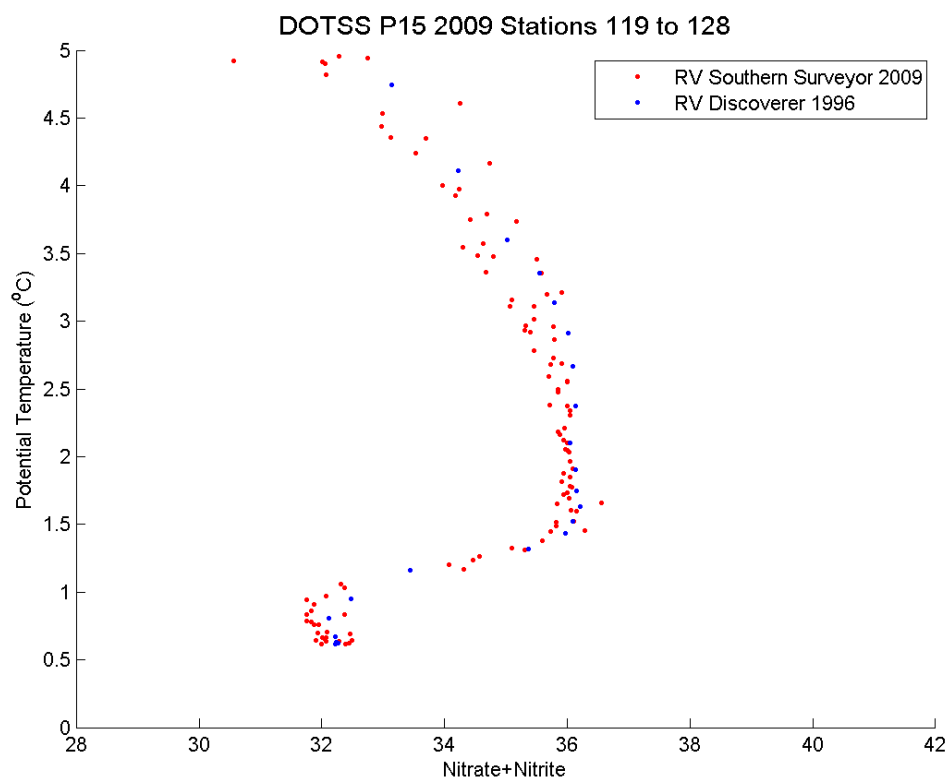
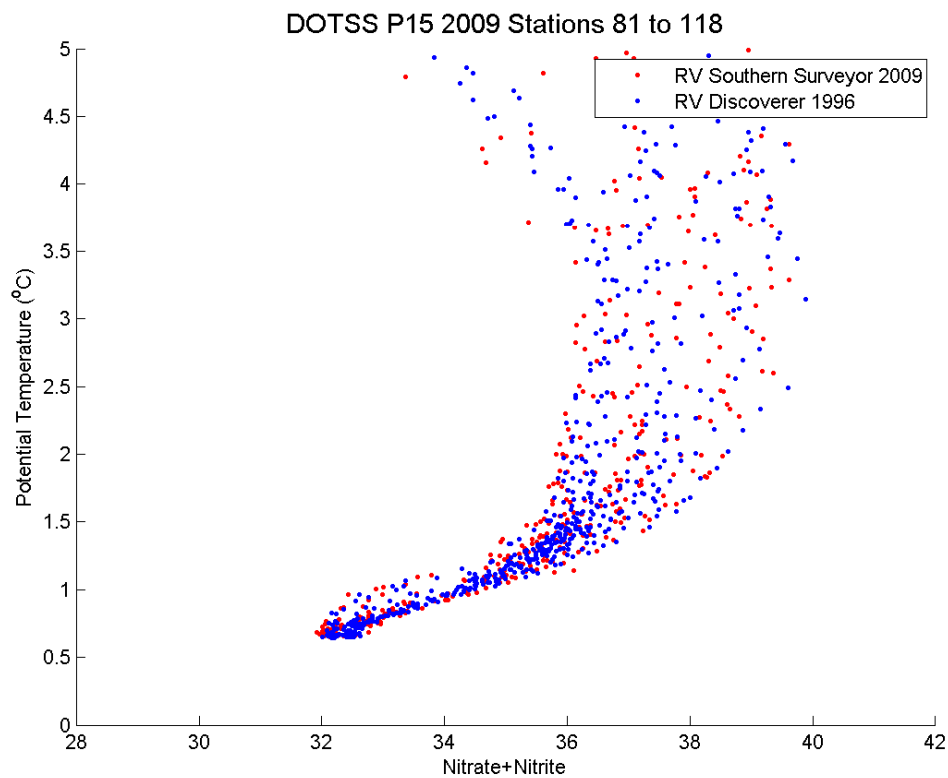


Figure 11: Plots of nitrate/nitrite against potential temperature in station groups.

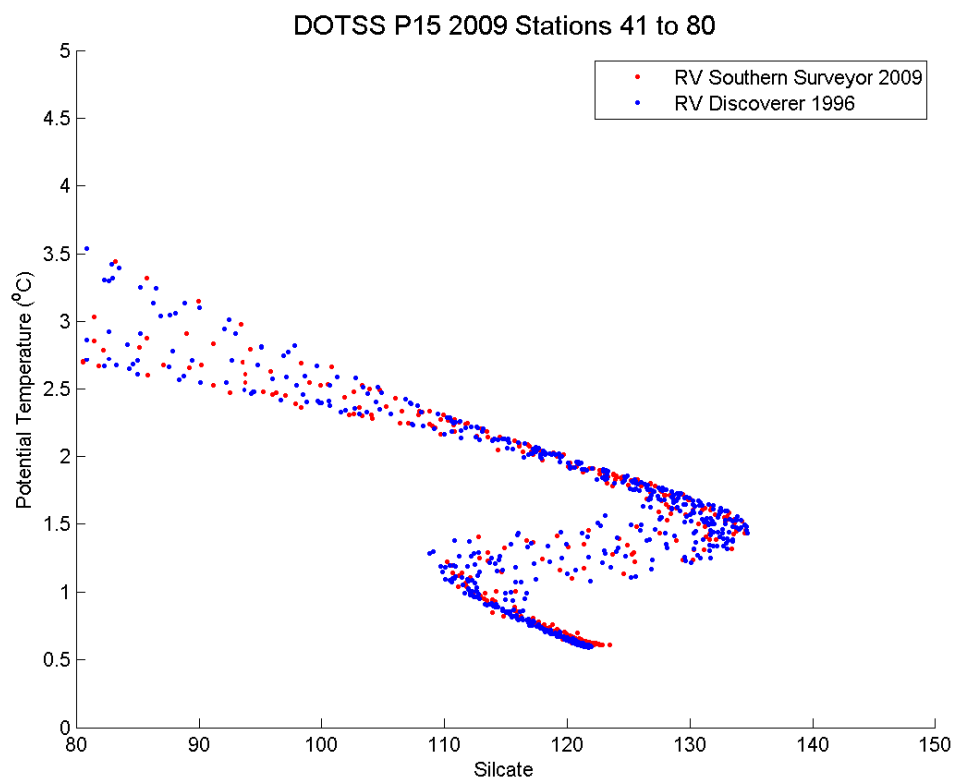
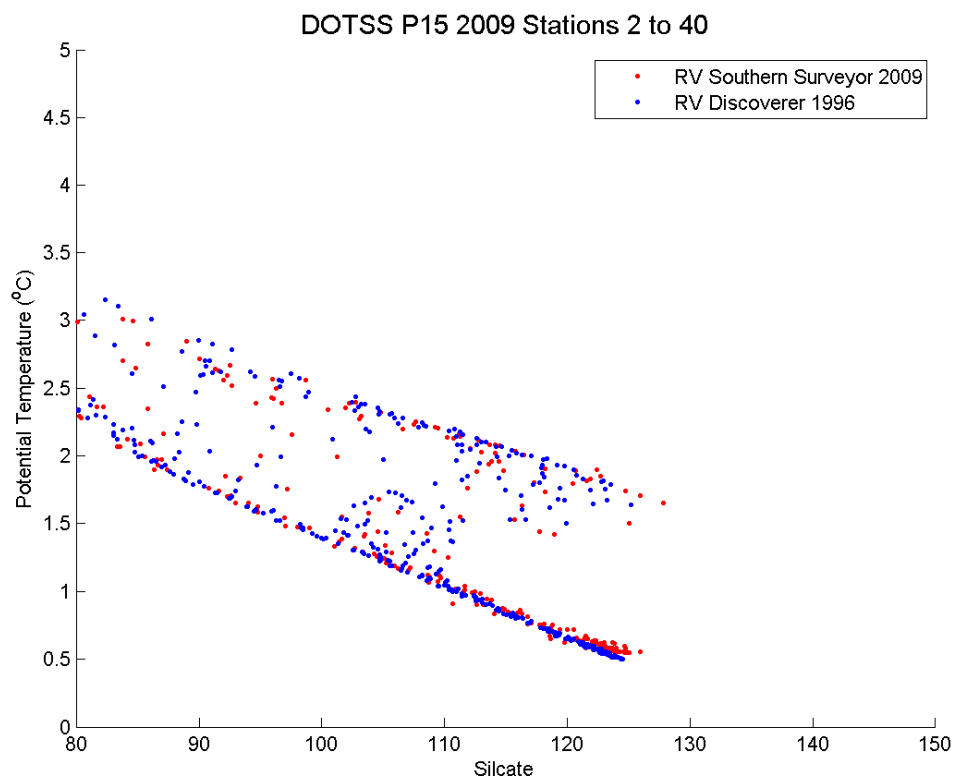


Figure 12: Plots of silicate against potential temperature in station groups.

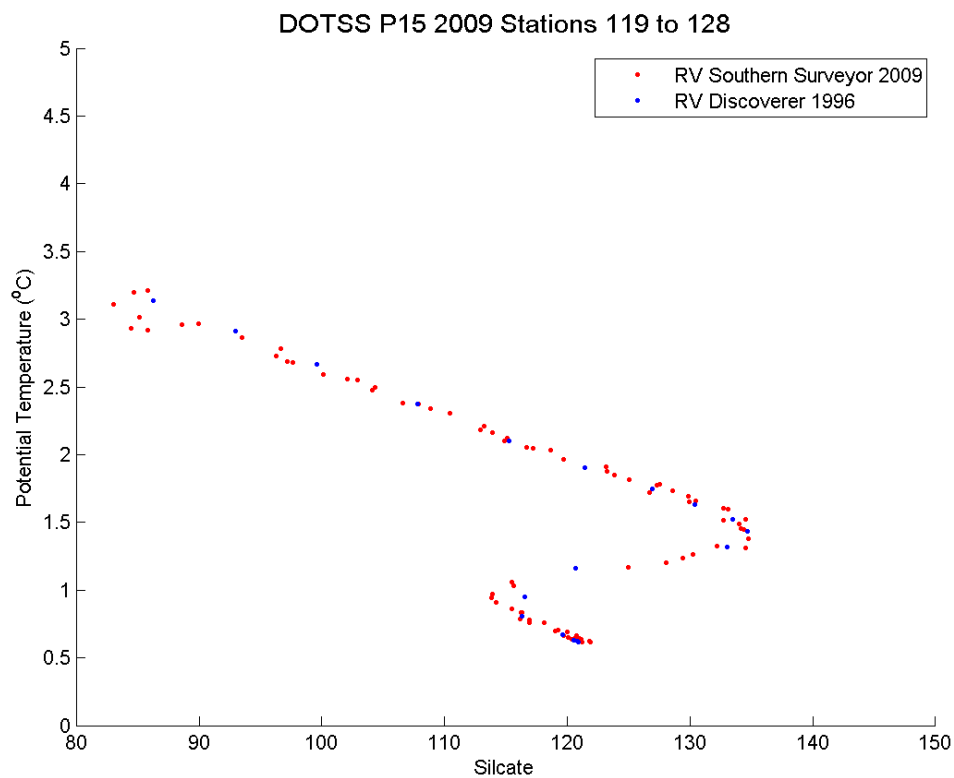
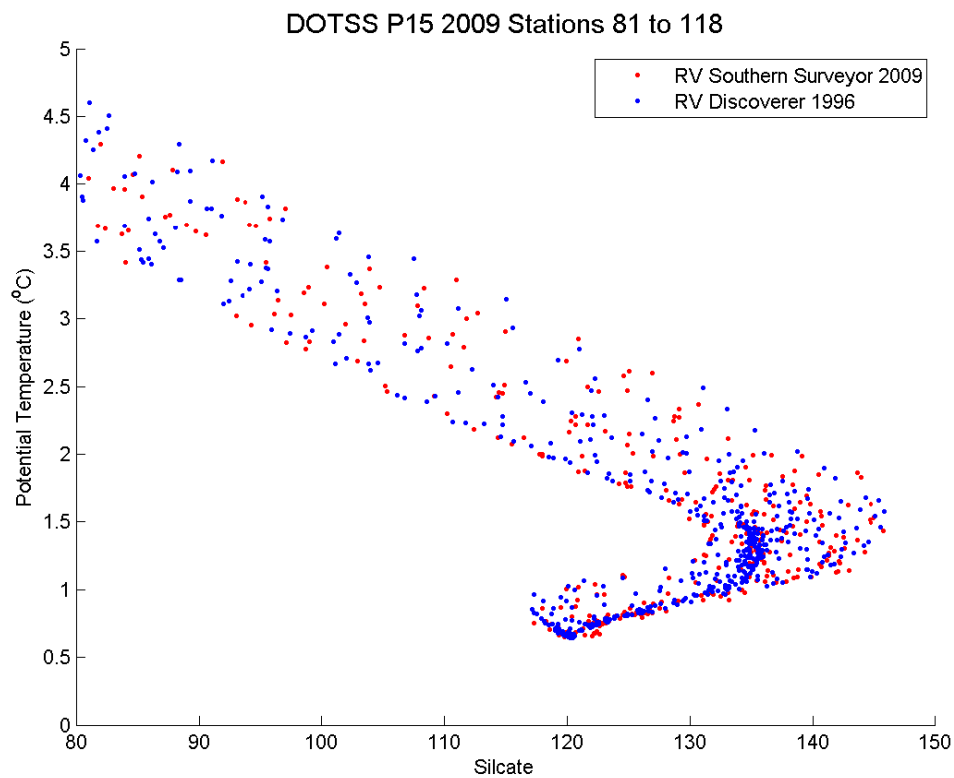


Figure 12: Plots of silicate against potential temperature in station groups.

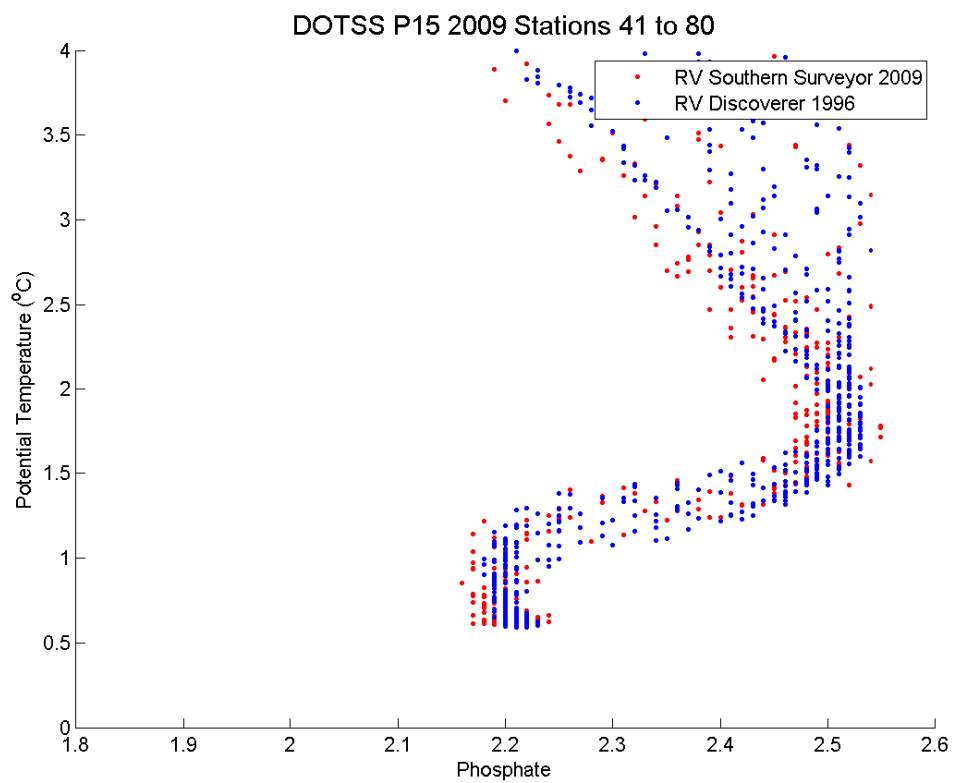
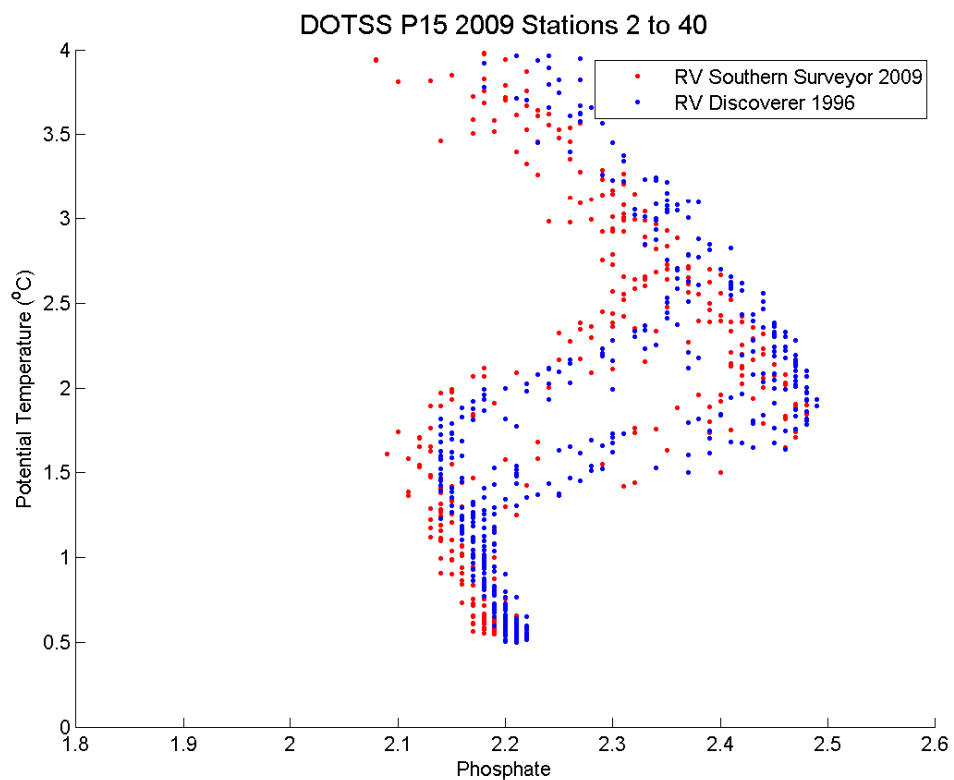


Figure 13: Plots of phosphate against potential temperature in station groups.

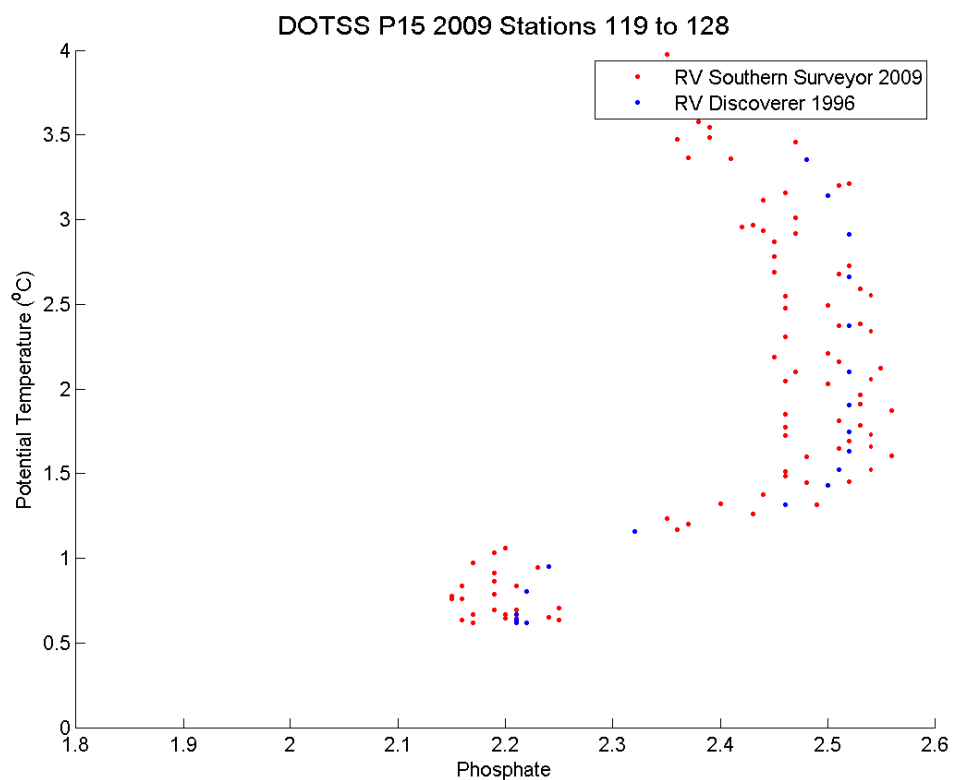
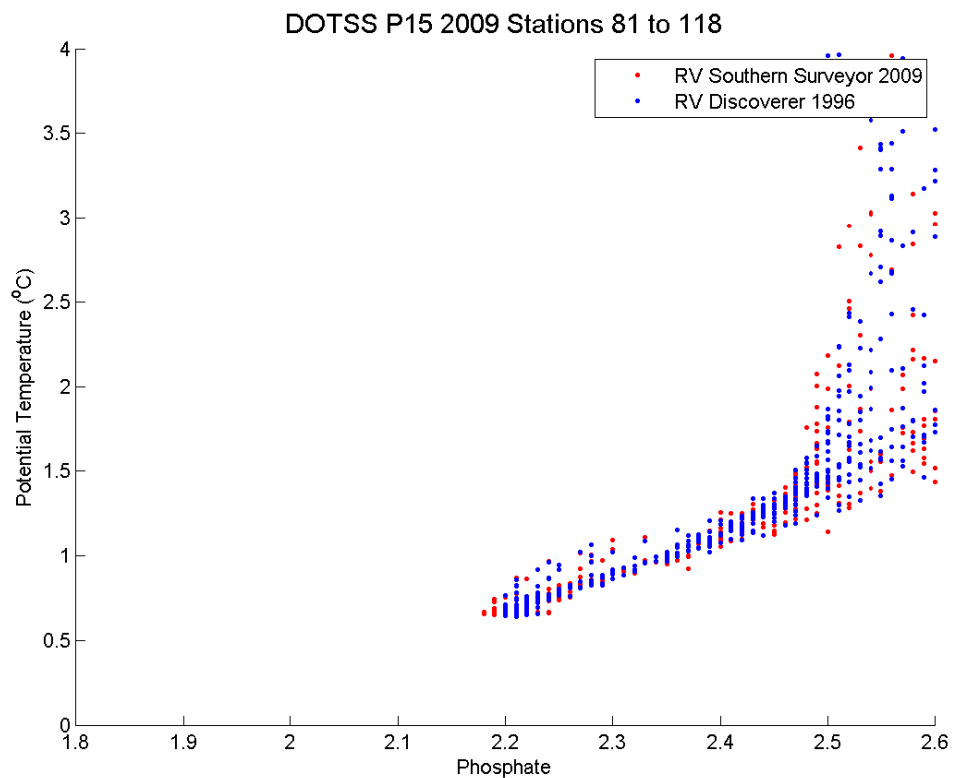


Figure 13: Plots of phosphate against potential temperature in station groups.

B.5 ADCP

The ADCP, 75kHz Ocean Surveyor phased array, lost beam 2 on 2 March 2009. Data from this date is unusable unless a 3-beam solution can be achieved. ADCP data till 2 March 2009 has been processed.

B.6 Chlorofluorocarbon (CFC) Measurements

Analysts: Fred Menzia (University of Washington/JISAO)
Nancy Williams (University of Washington/JISAO)

PIs: John Bullister (NOAA-PMEL)
Mark Warner (University of Washington)

A PMEL analytical system was used for CFC-11, CFC-12 and sulfur hexafluoride (SF₆) analyses on the 2009 P15S expedition. Samples for the analyses of dissolved CFC-11, CFC-12 and SF₆ ('CFC/SF₆') were drawn from ~1330 of the ~3070 water samples collected during the expedition. Analysis of CFC-11, CFC-12, and SF₆ were made on the same ~200 cc water sample. All CFC/SF₆ samples were analysed on board ship in a 20' CFC laboratory van.

Water samples on the 2009 P15S cruise were collected in 12 liter bottles designed at PMEL that use a modified end-cap design to minimize the contact of the water sample with the end-cap O-rings after closing. Stainless steel springs covered with a nylon powder coat were substituted for the internal elastic tubing provided with standard Niskin bottles. When taken, water samples collected for dissolved CFC-11, CFC-12 and SF₆ analysis were the first samples drawn from the bottles. Care was taken to coordinate the sampling of CFC/SF₆ with other samples to minimize the time between the initial opening of each bottle and the completion of sample drawing. Samples easily impacted by gas exchange (dissolved oxygen and DIC) were collected within several minutes of the initial opening of each bottle. To minimize contact with air, the CFC/SF₆ samples were drawn directly through the stopcocks of the bottles into 250 ml precision glass syringes equipped with three-way plastic stopcocks. The syringes were immersed in a holding tank of clean surface seawater held at ~5°C until ~30 minutes before being analyzed. At that time, the syringe was placed in a bath of surface seawater heated to ~30°C.

For atmospheric sampling, a ~75 m length of 3/8" OD Dekaron tubing was run from the CFC lab van to the bow of the ship. A flow of air was drawn through this line into the main laboratory using an Air Cadet pump. The air was compressed in the pump, with the downstream pressure held at ~1.5 atm. using a backpressure regulator. A tee allowed a flow of ~100 ml min⁻¹ of the compressed air to be directed to the gas sample valves of the CFC/SF₆ analytical systems, while the bulk flow of the air (>7 l min⁻¹) was vented through the back-pressure regulator. Air samples were analyzed only when the relative wind direction was within 60 degrees of the bow of the ship to reduce the possibility of shipboard contamination. Analysis of bow air was performed at ~19 locations along the cruise track. At each location, ~5 air measurements were made to increase the precision of the measurements. Concentrations of CFC-11, CFC-12 and SF₆ in air samples, seawater, and gas standards were measured by shipboard electron capture gas chromatography (EC-GC) using techniques modified from those described by Bullister and Weiss (1988) and Bullister and Wisegarver (2008), as outlined below. For seawater analyses, water was transferred from a glass syringe to a glass-sparging chamber (volume ~200 ml). The dissolved gases in the seawater sample were

extracted by passing a supply of CFC/SF₆ free purge gas through the sparging chamber for a period of 5 minutes at ~150 ml min⁻¹. Water vapor was removed from the purge gas during passage through an 18 cm long, 3/8" diameter glass tube packed with the desiccant magnesium perchlorate. The sample gases were concentrated on a cold-trap consisting of a 1/16" OD stainless steel tube with a 5 cm section packed tightly with Porapak Q (60-80 mesh) and a 22 cm section packed with Carboxen 1000. A Neslab Cryocool CC-100 was used to cool the trap to ~70°C. After 5 minutes of purging, the trap was isolated, and then heated electrically to ~175°C. The sample gases held in the trap were then injected onto a precolumn (~60 cm of 1/8" O.D. stainless steel tubing packed with 80-100 mesh Porasil B, held at 80°C) for the initial separation of CFC-12, CFC-11, and SF₆ from later eluting peaks. After the SF₆ and CFC-12 had passed from the pre-column and into the second precolumn (5 cm of 1/8" O.D. stainless steel tubing packed with MS5A, 80°C) and into the analytical column #1 (240 cm of 1/8" OD stainless steel tubing packed with MS5A and held at 80°C), the outflow from the first precolumn was diverted to the second analytical column (150 cm 1/8" OD stainless steel tubing packed with Carbograph 1AC, 80-100 mesh, held at 90°C). Late eluting gases in the first pre-column were backflushed from the pre-column and vented. Column #1 and both pre-columns were mounted in a Shimadzu GC8 gas chromatograph with an electron capture detector (ECD) held at 340°C. Column #2 was in another Shimadzu GC8 gas chromatograph with ECD held at 250°C.

The analytical system was calibrated frequently using a standard gas of known CFC/SF₆ composition. Gas sample loops of known volume were thoroughly flushed with standard gas and injected into the system. The temperature and pressure was recorded so that the amount of gas injected could be calculated. The procedures used to transfer the standard gas to the trap, precolumn, main chromatographic column, and ECD were similar to those used for analyzing water samples. Four sizes of gas sample loops were used. Multiple injections of these loop volumes could be made to allow the system to be calibrated over a relatively wide range of concentrations. Air samples and system blanks (injections of loops of CFC/SF₆ free gas) were injected and analyzed in a similar manner. The typical analysis time for seawater, air, standard or blank samples was ~11 minutes. Concentrations of the CFC-11 and CFC-12 in air, seawater samples, and gas standards are reported relative to the SIO98 calibration scale (Cunnold et al., 2000). Concentrations of SF₆ in air, seawater samples, and gas standards are reported relative to the CMDL calibration scale (Bullister et al., 2006). Concentrations in air and standard gas are reported in units of mole fraction CFC in dry gas, and are typically in the parts per trillion (ppt) range. Dissolved CFC concentrations are given in units of picomoles per kilogram seawater (pmol kg⁻¹) and SF₆ concentrations in fmol kg⁻¹. CFC/SF₆ concentrations in air and seawater samples were determined by fitting their chromatographic peak areas to multi-point calibration curves, generated by injecting multiple sample loops of gas from a working standard (PMEL cylinder 45189 of water samples and PMEL standard 38415 for air samples) into the analytical instrument. The response of the detector to the range of moles of CFC/SF₆ passing through the detector remained relatively constant during the cruise. Full-range calibration curves were run at intervals of 4-5 days during the cruise. Single injections of a fixed volume of standard gas at one atmosphere were run much more frequently (at intervals of ~90 minutes) to monitor short-term changes in detector sensitivity.

The purging efficiency was estimated by re-purging a high-concentration water sample and measuring this residual signal. At a flow rate of 150 cc min⁻¹ for 5 minutes, the purging efficiency for CFC-11 was >99.5% and ~100% for CFC-12. Corrections for these has been applied to the reported water concentration values.

A severe problem was encountered with the SF₆ analysis during the cruise, in part due to a chromatographic peak which eluted near to that of SF₆ on the chromatograms. Adjusting the backflush times and lengthening the second pre-column later in the cruise somewhat reduced this interference, but overall the quality of the SF₆ data on the 2009 P15S cruise is poor and all samples are flagged either '3' (questionable) or '4' (bad).

On this expedition, based on the analysis of ~340 pairs of duplicate samples, we estimate precisions (1 standard deviation) of about 1% or 0.005 pmol kg⁻¹ (whichever is greater) for both dissolved CFC-11 and CFC-12 measurements.

Overall accuracy of the measurements (a function of the absolute accuracy of the calibration gases, volumetric calibrations of the sample gas loops and purge chamber, errors in fits to the calibration curves and other factors) is estimated to be about 2% or 0.010 pmol kg⁻¹ for CFC11 and CFC-12.

Based on the earlier occupation of the P15S section in 1994 and crossings of this section by other WOCE-era sections, the region of the water column between 20°S and the equator and between 2000m and 3000 m depth is thought to have near zero levels of CFCs the time of the 2009 P15S section. The means of measured values in this region on the 2009 P15S expedition was 0.005 pmol kg⁻¹ for CFC-11 and 0.002 pmol kg⁻¹ for CFC-12. Based on previous experiments showing a slow grow-in of CFCs in water held in the sample bottles, and the scatter in measured concentrations of these deep samples, we estimate a total sampling and analytical blank of 0.003 pmol kg⁻¹ for CFC-11 and 0.001 pmol kg⁻¹ for CFC-12. The final water concentration data reported here have had these blank corrections applied.

A small number of water samples had anomalously high CFC-11 and CFC-12 concentrations relative to adjacent samples. These samples occurred sporadically during the cruise and were not clearly associated with other features in the water column (e.g., anomalous dissolved oxygen, salinity, or temperature features). This suggests that these samples were probably contaminated with CFCs during the sampling or analysis processes. Measured concentrations for these anomalous samples are included in the data file, but are given a quality flag value of either 3 (questionable measurement) or 4 (bad measurement). Approximately 98 CFC-11 samples and 81 CFC-12 samples were assigned quality flags of 3 and approximately 17 CFC-11 samples and 18 CFC-12 samples were assigned quality flags of 4. A quality flag of 5 was assigned to samples which were drawn from the rosette but never analyzed due to a variety of reasons (e.g., leaking stopcock, plunger jammed in syringe barrel, etc).

References

- Bullister, J.L., and R.F. Weiss, 1988: Determination of CC13F and CC12F2 in seawater and air. *Deep-Sea Res.*, v. 25, pp. 839-853.
- Bullister, J.L., and D.P. Wisegarver (2008): The shipboard analysis of trace levels of sulfur hexafluoride, chlorofluorocarbon-11 and chlorofluorocarbon-12 in seawater. *Deep-Sea Res. I*, 55, 1063–1074. [[PDF Version](#)]
- Prinn, R.G., R.F. Weiss, P.J. Fraser, P.G. Simmonds, D.M. Cunnold, F.N. Alyea, S. O'Doherty, P. Salameh, B.R. Miller, J. Huang, R.H.J. Wang, D.E. Hartley, C. Harth, L.P. Steele, G. Sturrock, P.M. Midgley, and A. McCulloch, 2000: A history of chemically and radiatively important gases in air deduced from ALE/GAGE/AGAGE. *J. Geophys. Res.*, v. 105, pp. 17,751-17,792.

B.7 Carbon Parameters

Bronte Tilbrook, CMAR

- Total dissolved inorganic carbon (TCO₂)
Precision and accuracy estimate: $\pm 1 \mu\text{mol kg}^{-1}$
- Total (titration) alkalinity (TA)
Precision and accuracy estimate: $\pm 2 \mu\text{mol kg}^{-1}$

Total dissolved inorganic carbon:

Total dissolved carbon dioxide in seawater is:

$$\text{TCO}_2 = [\text{CO}_2] + [\text{HCO}_3^-] + [\text{CO}_3^{2-}]$$

Carbon dioxide dissolved in seawater is analysed by acidifying the seawater to convert bicarbonate and carbonate to CO₂, extracting the CO₂ from the solution by bubbling with high purity nitrogen (>99.995%), and trapping and quantifying the amount of CO₂ using a UIC model 5011 coulometer.

A SOMMA system is used to extract the CO₂ and follows the procedure described in detail by Johnson et al (1993) and Dickson et al (2007). The SOMMA loads seawater from a sample bottle into a calibrated pipette that is thermostated at a constant temperature of 20°C. The sample in the pipette is then dispensed into a stripping chamber to which 1 ml of a 10% (v/v) solution of phosphoric acid has been added. The stripping chamber has a glass frit at the base and this is used to bubble nitrogen carrier gas through the sample and strip the CO₂ from the sample. The CO₂ in the carrier gas stream flows into the cathode compartment of a coulometer cell where it is quantitatively trapped in an ethanolamine solution. The absorbed CO₂ reacts to form hydroxyethylcarbamic acid, causing a change in the colour of the cell solution due to the presence of a thymolphthalein pH indicator in the solution. Base is generated at the cell cathode, until the solution colour returns to its starting point. The efficiency of the coulometric method is determined by injecting known amounts of pure CO₂ (>99.99%). A combination of measurements of certified reference seawater, from the Scripps Institution of Oceanography, and of duplicate water samples collected from the CTD Niskin bottles is used to check accuracy and precision of the analyses.

Total alkalinity:

An automated open-cell potentiometric titration is used to measure total alkalinity. Samples stored in sealed glass bottles are placed in a thermostated water bath and brought to a temperature of 20°C prior to analysis. A 100ml volume of sample is pipetted into a water-jacketed (20°C) glass beaker and the sample mixed with a stir bar. A 0.1N solution of hydrochloric acid (HCl) titrant is added to the sample to adjust the pH of the seawater to about 3.5. The sample is then stirred to degas CO₂. After 10 minutes of stirring, the titration proceeds by adding small increments of the hydrochloric acid titrant until the pH reaches about 3.0. The amounts of acid added and the associated change in e.m.f. of a pH electrode (Metrohm Aquatrode) used to monitor the progress of the titration are recorded.

The 0.1N HCl titrant contains 0.6 mol/kg sodium chloride to approximate the ionic strength of seawater. The normality of each batch of titrant is measured by coulometry and is known to better than $\pm 0.03\%$. The density of the titrant, which is used to calculate the total alkalinity, is measured with an Anton Parr density meter over a range of temperatures near 20°C and is known to better than $\pm 0.01\%$.

The volumes delivered by the burettes are calibrated every six to twelve months by weighing volumes of deionised water dispensed by the burettes at 20° and applying an air buoyancy correction (Dickson et al 2007). The pH electrode responses are checked by comparison with Tris and Aminopyridine buffers in synthetic seawater (Dickson et al 2007). Electrodes with responses within $100 \pm 0.3\%$ of the Nernst slope of the electrode are used for titrations. The e.m.f. of the electrodes is recorded to $\pm 0.1\text{mV}$.

A non-linear fitting routine, written in Interactive Data Language (IDL), is used to calculate TA. This is similar to the computations described in Johannsson and Wedborg (1982) and Dickson et al. (2007). The pK of the acids used in the routine are taken from Dickson (1990) for HSO₄⁻ and Dickson and Riley (1979) for HF. Comparison of the routine used here was compared to a TA result for data published in Dickson et al (2007) using a different non-linear fitting procedure and both agree within $\pm 0.01\%$. A combination of measurements of certified reference seawater, from the Scripps Institution of Oceanography, and of duplicate water samples collected from the CTD Niskin bottles is used to check accuracy and precision of the analyses.

References

- Dickson, A.G. (1990) Standard potential of the reaction: $\text{AgCl(s)} + \frac{1}{2}\text{H}_2\text{(g)} = \text{Ag(s)} + \text{HCl(aq)}$, and the standard acidity constant of the ion HSO₄⁻ in synthetic sea water from 273.15 to 318.15 K. *Journal Chemical Thermodynamics* 22: 113–127.
- Dickson, A.G. and Riley, J.P. (1979) The estimation of acid dissociation constants in seawater media from potentiometric titrations with strong base. I. The ionic product of water (KW). *Marine Chemistry* 7: 89–99.
- Dickson, A. G., Sabine, C. L. and Christian, J. R. (2007) Guide for best practices in ocean CO₂ measurements. PICES Special Publication 3, 191pp.
- Johansson, O. and Wedborg, M., (1982) On the evaluation of potentiometric titrations of seawater with hydrochloric acid, *Oceanologica Acta* 5:209–218
- Johnson, K.M., Wills, K.D., Butler, D.B., Johnson, W.K. and Wong, C.S. (1993) Coulometric total carbon dioxide analysis for marine studies: maximizing the performance of an automated continuous gas extraction system and coulometric detector. *Marine Chemistry* 44: 167–187.

Data Processing Notes

2009-10-19	<i>Cowley, Rebecca</i>	CTD/DOC	Submitted	submitted CTD+DOCs (pdf)
2009-10-20	<i>Sloyan, Bernadette</i>	CTD	Data are Public	CTD are public now
	This data is an Australian contribution to the International Repeat Hydrography program. As such the (CTD) data can be made publicly available as of now. We will get the bottle data to you when it has passed final QA/QC checks at CMAR. Hopefully this will be completed in November.			
2009-10-22	<i>Diggs, Steve</i>	CTD/DOCs	Corrected CTD data format / DOCs and CTD data online	
	Corrected NaN values for flags in station 1 CTD data and filenames put in Exchange format. Corrected ExpoCodes in all files to use 09SS20090230. Made NetCDF CTD files and all zip archives. Checked through normal QC procedures, made cruise maps from CTD positions. Placed all versions of CTD data, station maps and CSIRO-supplied PDF documentation online. All data histories for this cruise updated.			
2009-11-05	<i>Cowley, Rebecca</i>	CTD	Submitted	Updated missing values
	This is the updated CTD data from the voyage, with some missing surface values included. For the first leg, almost none of the data is shallower than 4 db & a number start at 6 db. For the second leg, all of the deployments start at 4 db, or shallower, and one has data in the surface (0 db) bin.			
2009-11-11	<i>Cowley, Rebecca</i>	CTD	Submitted	correct surface values
	Update missing values: Sent the incorrect file last time. This file has the latest CTD data with correct surface values.			
2009-11-30	<i>Cowley, Rebecca</i>	Bottle	Submitted	Submitted by S. Diggs for R. Cowley
	In email from Rebecca Cowley to Steve Diggs: 2009.11.30 --> "I tried to upload the bottle data for the 09SS20090203 voyage, but had a server error. So here it is. This file doesn't contain the carbon or alkalinity results or the CFC results yet. These will be updated soon."			
2009-12-03	<i>Cowley, Rebecca</i>	CFC	Submitted	Exchange format, put online
	This is the latest bottle file in exchange format and contains the CFC data in addition to the bottle data already submitted. The Carbon and Alkalinity results are still not available and will probably be submitted during the first half of 2010.			