COOPERATIVE RESEARCH CENTRE FOR THE ANTARCTIC AND SOUTHERN OCEAN ENVIRONMENT (ANTARCTIC CRC)

Aurora Australis Marine Science Cruise AU9309/AU9391 - Oceanographic Field Measurements and Analysis

MARK ROSENBERG
Antarctic CRC, GPO Box 252-80, Hobart, Australia

RUTH ERIKSEN
Antarctic CRC, GPO Box 252-80, Hobart, Australia

STEVE RINTOUL
Antarctic CRC, GPO Box 252-80, Hobart, Australia
CSIRO Division of Marine Research, Hobart, Australia

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MARK ROSENBERG

Antarctic CRC, GPO Box 252-80, Hobart, Australia

RUTH ERIKSEN

Antarctic CRC, GPO Box 252-80, Hobart, Australia

STEVE RINTOUL

Antarctic CRC, GPO Box 252-80, Hobart, Australia;
CSIRO Division of Marine Research, Hobart, Australia

ABSTRACT

Oceanographic measurements were conducted along WOCE Southern Ocean meridional sections SR3 and P11 between Tasmania and Antarctica, from March to May, 1993. A total of 128 CTD vertical profile stations were taken, most to near bottom. Over 2500 Niskin bottle water samples were collected for the measurement of salinity, dissolved oxygen, nutrients, dissolved inorganic carbon, carbon isotopes, barium, and biological parameters, using 24 and 12 bottle rosette samplers. Measurement and data processing techniques are described, and a summary of the data is presented in graphical and tabular form.

1 INTRODUCTION

From March to May 1993, the first marine science cruise of the Cooperative Research Centre for the Antarctic and Southern Ocean Environment (Antarctic CRC) was conducted aboard the Australian Antarctic Division vessel RSV Aurora Australis. The major constituent of the cruise was oceanographic measurements relevant to the Australian Southern Ocean WOCE Hydrographic Program. The primary scientific objectives of this program are:

1. to estimate the interbasin exchange of heat, freshwater and other properties south of Australia, and the seasonal and interannual variability of this exchange;

2. to investigate the mechanisms responsible for the formation of deep and intermediate water masses in the Southern Ocean, and to identify the ventilation pathways that newly formed water masses follow into the ocean interior;

3. in conjunction with current meter data, to determine the importance of eddy heat and momentum fluxes in the dynamics and thermodynamics of the Antarctic Circumpolar Current south of Australia.

The cruise discussed in this report is the first in a series of Southern Ocean marine science cruises, scheduled to take place over the period 1993 to 1997, adding to the data set presented here.

Two Southern Ocean CTD transects, along WOCE sections SR3 and P11, were completed during the cruise, both traversed from north to south. Section SR3 was occupied once previously, in the spring of 1991 (Rintoul and Bullister, in prep.). This report describes the collection of oceanographic data from the two transects, and the chemical analysis and data processing methods employed. Brief comparisons are also made with existing historical data. All information required for use of the data set is presented in tabular and graphical form.

2 CRUISE ITINERARY

The original cruise plan was to sample along section SR3 from north to south, conduct supplementary sea ice and biology programs in the sea ice zone, and then to sample along section P11 from south to north on the return to Hobart. Following the completion of section SR3, the ship was forced to return to Hobart with a sick crew member. Work for the remainder of the cruise was then rescheduled, beginning with a north to south traverse of section P11, and followed by sea ice and biology experiments in and around the sea ice zone. The cruise was thus divided into two distinct legs (Table 1), with cruise designations AU9309 and AU9391 for the SR3 and P11 sections respectively.

Table 1: Summary of cruise itinerary.

Expedition Designation

Leg 1: Cruise AU9309 (cruise acronym WOES), encompassing WOCE section SR3
Leg 2: Cruise AU9391 (cruise acronym WORSE), encompassing WOCE section P11, plus additional measurements at sea ice stations

Chief Scientist

Steve Rintoul, CSIRO

Ship

RSV Aurora Australis

Ports of Call

Leg 1: Hobart to Antarctic Ice Edge (return to Hobart)
Leg 2: Hobart to Antarctic Ice Edge (return to Hobart)

Cruise Dates

Leg 1: March 11 to April 3, 1993
Leg 2: April 4 to May 9, 1993

3 CRUISE SUMMARY

3.1 CTD casts

In the course of the cruise, 128 CTD casts were completed at 113 different sites along the WOCE Southern Ocean sections SR3 and P11 (Figure 1), at an average spacing between sites of 30 nm, and with most casts reaching to within 15 m of the bed (Table 2). The southern extent of both sections was restricted by sea ice conditions, and by time lost due to the medical evacuation. However the base of the continental slope was reached in both cases. Additional surface and deep

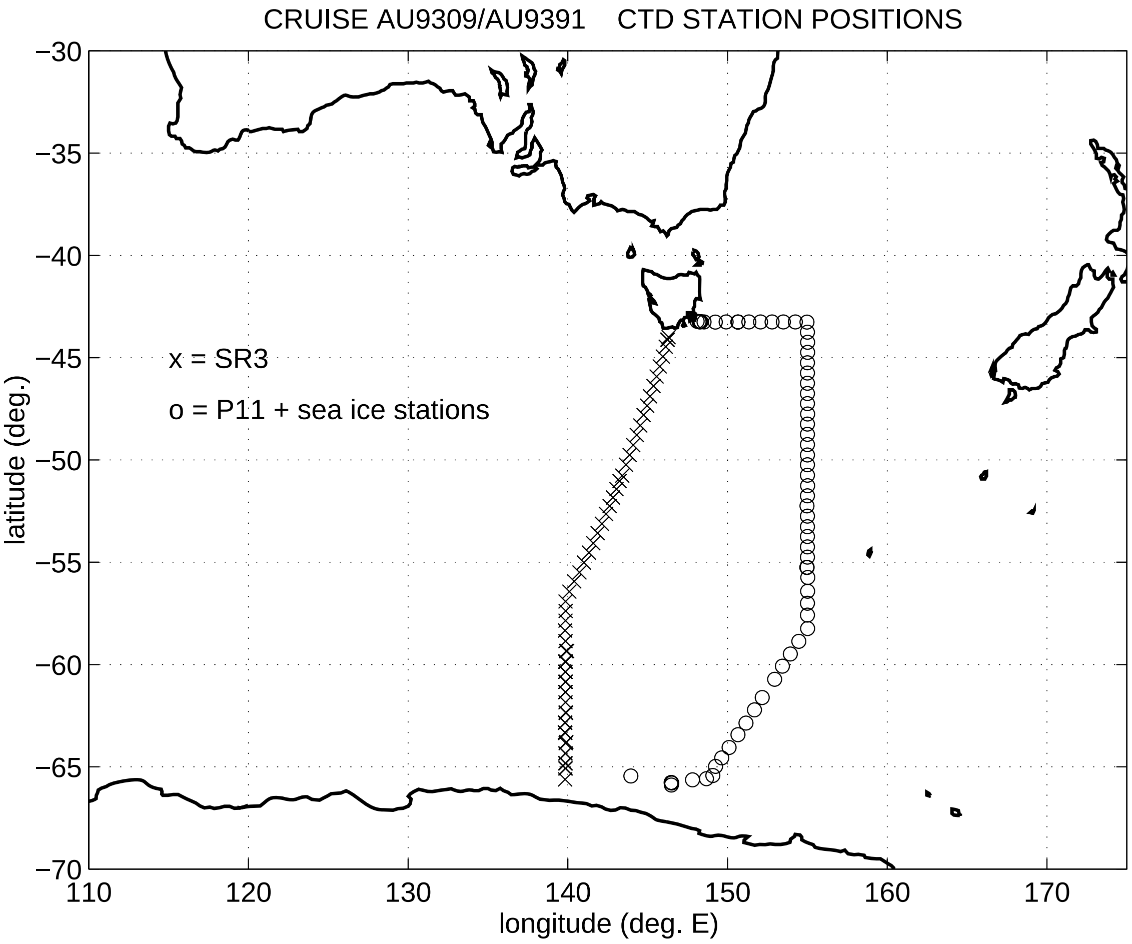


Figure 1: CTD station positions for RSV Aurora Australis cruise AU9309/AU9391 along WOCE transects SR3 and P11.

CTD casts were taken within the sea ice zone at designated sea ice measurement stations following the P11 transect (Tables 2 and 3).

3.2 Water samples from CTD casts

Over 2500 Niskin bottle water samples were collected for the measurement of salinity, dissolved oxygen, nutrients, dissolved inorganic carbon, carbon isotopes, barium, and biological parameters, using 24 and 12 bottle rosette samplers. Table 3 provides a summary of samples drawn at each station. For all stations, the different samples were drawn in a fixed sequence, as discussed in section 4.1.3. The methods for drawing the salinity, dissolved oxygen and nutrient samples are discussed in section 4.1.4.

Salinity, dissolved oxygen and nutrients: Samples were drawn from most stations for salinity, dissolved oxygen and nutrient analyses. Salinity and dissolved oxygen hydrology data was further used for the calibration of CTD salinity and dissolved oxygen data; nutrient samples were analysed for concentration of orthophosphate, nitrate plus nitrite, and reactive silicate.

Dissolved inorganic carbon: Samples were drawn for total dissolved inorganic carbon analysis approximately every second station. In general, salinity and oxygen properties determined the Niskin sampling strategy, thus the sampling depths were not always best suited to the resolution of dissolved inorganic carbon gradients in the top 300 m of the water column. Results from these analyses are reported elsewhere (Tilbrook, pers. comm.), and are not discussed further in this report.

Carbon isotopes and barium: Samples were drawn for barium analysis on the SR3 transect; samples for carbon isotope analyses (^{13}C and ^{14}C) were drawn on section P11. These sample sets are not discussed further in this report.

Primary productivity: For casts taken during daylight hours, samples were drawn for analysis of primary productivity and suspended particle size. These samples were taken from the shallowest four Niskin bottles. At most primary productivity sites, a Seabird "Seacat" CTD was deployed to obtain vertical profiles of photosynthetically active radiation and fluorescence from the top part of the water column. These data are not discussed further in this report.

Biological sampling: Four different analyses were performed on the biological water samples, as follows:

(i) pigments
(ii) cyanobacteria counts
(iii) algal counts (lugols iodine fixed)
(iv) protist identification (osmium/glutaraldehyde fixed)

Biological samples were usually drawn from the shallowest four or five Niskin bottles. The data are not discussed further in this report.

3.3 Additional drifters and moorings deployed/recovered

An array of four current meter moorings was deployed (Table 4) and a single mooring recovered, along the SR3 transect line. Six ALACE floats were deployed at various positions along both the SR3 and P11 transects (Table 5). These floats drift at 900 m below the surface, and periodically return to the surface to telemeter their positions.

3.4 XBT/XCTD deployments

A total of 19 new model Sippican XCTD and "Fast Deep" XBT deployments were made, chiefly to test the new units. Results are not reported here.

Table 2 (following 4 pages): **Summary of station information for RSV Aurora Australis cruise AU9309/AU9391. The information shown includes time, date and position for the start of the cast, at the bottom of the cast, and for the end of the cast; “d” refers to the ocean depth; maximum pressure (“max P”) reached for each cast, and the altimeter reading (“alt”) at the bottom of each cast (i.e. elevation above the bed) are also included. The altimeter value at each station is recorded manually from the CTD data stream display at the bottom of each CTD downcast. Motion of the ship due to waves can cause an error in these manually recorded altimeter values of up to ±3 m. Missing ocean depth values are due to noise from the ship’s bow thrusters, as discussed in Appendix 2, section A2.3. For casts which do not reach to within 100 m of the bed (i.e. the altimeter range), there is no altimeter value. Note that all times are UTC (i.e. GMT). CTD unit 4 (serial no. 1197) was used for SR3 stations 1 to 35. CTD unit 1 (serial no. 1073) was used thereafter.**

Table 2: **(continued)**

stn no.	SR3 time	date	start latitude	longitude	d (m)	max P (dbar)	SR3 time	bottom latitude	longitude	alt (m)	d (m)	SR3 time	end latitude	longitude	d (m)
1	2032	11-MAR-93	44:06.73S	146:14.35E	1000	956	2118	44:06.37S	146:14.35E	46.8	-	2154	44:06.19S	146:14.60E	990
2	0027	12-MAR-93	44:00.06S	146:18.61E	300	289	0042	44:00.03S	146:18.77E	9.0	-	0115	43:59.97S	146:18.64E	313
3	0513	12-MAR-93	44:07.51S	146:14.89E	1100	1115	0549	44:07.48S	146:15.06E	9.9	1110	0632	44:07.39S	146:15.23E	1120
4	0854	12-MAR-93	44:27.89S	146:07.94E	2340	2335	0938	44:27.52S	146:07.30E	5.0	2318	1028	44:27.32S	146:07.51E	-
5	1437	12-MAR-93	44:56.71S	145:56.67E	3380	3465	1606	44:56.10S	145:56.52E	15.0	3390	1727	44:55.56S	145:56.36E	3490
6	2033	12-MAR-93	45:25.97S	145:45.16E	2475	2429	2121	45:25.86S	145:44.79E	10.0	2350	2228	45:25.73S	145:44.71E	2350
7	0149	13-MAR-93	45:55.44S	145:33.61E	2550	2491	0245	45:56.09S	145:33.54E	11.6	2470	0343	45:56.25S	145:34.87E	-
8	0650	13-MAR-93	46:23.31S	145:22.13E	3360	3351	0756	46:22.85S	145:22.97E	11.6	3330	0921	46:22.45S	145:23.67E	3300
9	1253	13-MAR-93	46:53.05S	145:08.92E	3520	3555	1400	46:52.38S	145:08.95E	15.0	3550	1522	46:51.70S	145:09.35E	3550
10	1824	13-MAR-93	47:20.97S	144:58.14E	3970	4038	1942	47:20.50S	144:58.31E	11.0	3940	2124	47:19.56S	144:58.60E	3850
11	0122	14-MAR-93	47:48.16S	144:44.53E	3970	4028	0231	47:48.20S	144:44.57E	12.5	3970	0355	47:48.21S	144:44.80E	3960
12	0653	14-MAR-93	48:18.91S	144:32.00E	4130	4169	0811	48:19.11S	144:33.46E	10.3	4150	0942	48:19.32S	144:34.39E	-
13	1259	14-MAR-93	48:46.95S	144:19.20E	4150	4165	1411	48:47.57S	144:19.56E	8.3	4125	1533	48:48.47S	144:20.16E	4100
14	1852	14-MAR-93	49:16.18S	144:05.26E	4320	4361	2013	49:16.33S	144:05.67E	30.0	4350	2147	49:16.11S	144:06.16E	4330
15	0130	15-MAR-93	49:45.09S	143:52.12E	3940	3876	0238	49:44.45S	143:52.35E	11.0	3870	0353	49:44.05S	143:52.60E	-
16	0721	15-MAR-93	50:13.96S	143:38.14E	3720	3701	0831	50:13.76S	143:39.59E	15.5	-	0951	50:13.80S	143:40.45E	-
17	0707	16-MAR-93	50:45.72S	143:24.75E	3900	4048	0836	50:46.25S	143:26.20E	15.4	3940	0958	50:46.37S	143:27.03E	3940
18	1601	16-MAR-93	51:01.80S	143:14.11E	3800	3902	1710	51:01.59S	143:14.72E	11.0	3800	1845	51:01.60S	143:15.55E	3800
19	1229	17-MAR-93	51:25.80S	143:02.42E	3700	3771	1331	51:26.08S	143:03.28E	7.6	3750	1450	51:26.38S	143:03.78E	3700
20	1809	17-MAR-93	51:50.35S	142:49.46E	3575	3683	1928	51:50.47S	142:49.40E	15.3	3550	2106	51:50.77S	142:49.48E	3525
21	0005	18-MAR-93	52:15.27S	142:37.50E	3500	3451	0050	52:15.73S	142:37.68E	14.0	3450	0159	52:16.04S	142:38.02E	3490
22	0448	18-MAR-93	52:38.18S	142:23.56E	3470	3447	0559	52:38.55S	142:23.46E	14.2	-	0730	52:39.05S	142:23.45E	3450
23	1015	18-MAR-93	53:07.33S	142:08.10E	3120	3115	1110	53:07.61S	142:07.92E	10.4	3120	1220	53:07.80S	142:07.66E	3130
24	1551	18-MAR-93	53:34.91S	141:52.03E	2525	2489	1636	53:34.68S	141:52.32E	9.6	-	1749	53:34.34S	141:52.89E	2375
25	2048	18-MAR-93	54:04.00S	141:35.73E	2580	2682	2155	54:03.74S	141:36.41E	23.3	2600	2257	54:03.40S	141:36.79E	2650
26	0332	19-MAR-93	54:32.09S	141:19.20E	2800	2844	0440	54:31.47S	141:19.99E	16.7	2850	0606	54:31.06S	141:20.29E	2950
27	0957	19-MAR-93	55:01.15S	141:00.75E	3250	3335	1058	55:01.04S	141:00.64E	15.4	3270	1203	55:00.57S	141:00.82E	3200
28	0524	20-MAR-93	55:29.97S	140:43.33E	4000	4261	0701	55:29.50S	140:42.59E	15.0	4200	0853	55:29.36S	140:42.87E	-
29	1639	20-MAR-93	55:55.89S	140:24.35E	3650	3621	1813	55:55.44S	140:24.11E	11.8	3600	1951	55:55.60S	140:23.20E	3550
30	2343	20-MAR-93	56:26.22S	140:06.15E	3940	4014	0104	56:26.07S	140:06.15E	-	3950	0219	56:26.10S	140:05.84E	3950
31	0721	21-MAR-93	56:55.04S	139:51.45E	4070	4140	0857	56:54.75S	139:52.49E	16.0	4100	1016	56:54.70S	139:53.10E	4100
32	1447	21-MAR-93	57:23.08S	139:51.65E	4050	4082	1557	57:23.29S	139:50.97E	11.9	-	1708	57:23.40S	139:50.26E	-

Table 2: **(continued)**

stn	SR3		start			max P	SR3	bottom				SR3	end		
no.	time	date	latitude	longitude	d (m)	(dbar)	time	latitude	longitude	alt (m)	d (m)	time	latitude	longitude	d (m)
33	2021	21-MAR-93	57:51.18S	139:50.99E	4020	4152	2140	57:51.65S	139:51.03E	9.1	-	2336	57:51.67S	139:51.09E	-
34	0334	22-MAR-93	58:20.43S	139:50.01E	3980	4006	0524	58:20.42S	139:50.01E	15.6	4050	0640	58:20.39S	139:49.68E	-
35	1022	22-MAR-93	58:51.32S	139:51.32E	3990	4070	1139	58:51.03S	139:51.83E	13.0	-	1318	58:50.77S	139:53.03E	-
36	2330	22-MAR-93	59:20.63S	139:53.74E	4150	1005	0009	59:20.61S	139:53.75E	-	-	0045	59:20.59S	139:54.03E	-
37	0127	23-MAR-93	59:20.68S	139:54.55E	4150	1847	0200	59:20.67S	139:54.82E	-	-	0258	59:20.58S	139:55.44E	-
38	0435	23-MAR-93	59:20.61S	139:57.43E	4380	3864	0606	59:20.37S	139:58.20E	-	-	0709	59:20.12S	139:58.57E	4380
39	1021	23-MAR-93	59:51.28S	139:50.95E	4490	705	1049	59:51.39S	139:50.73E	-	-	1112	59:51.54S	139:50.87E	-
40	1142	23-MAR-93	59:51.60S	139:50.64E	4490	3846	1314	59:51.92S	139:50.79E	-	-	1415	59:51.91S	139:51.13E	-
41	1457	23-MAR-93	59:52.01S	139:51.83E	4490	1005	1515	59:52.00S	139:51.95E	-	-	1541	59:52.07S	139:52.24E	-
42	1949	23-MAR-93	60:21.22S	139:50.86E	4400	3846	2042	60:21.08S	139:51.00E	-	-	2209	60:21.12S	139:51.18E	4400
43	2246	23-MAR-93	60:21.34S	139:50.91E	4400	1003	2311	60:21.35S	139:51.00E	-	-	2342	60:21.43S	139:50.72E	-
44	2235	25-MAR-93	60:51.03S	139:50.70E	4400	4456	0028	60:50.72S	139:51.35E	9.6	4400	0146	60:50.43S	139:51.76E	-
45	0222	26-MAR-93	60:50.32S	139:51.78E	4400	1003	0237	60:50.28S	139:51.70E	-	-	0309	60:50.28S	139:51.50E	4400
46	0606	26-MAR-93	61:20.96S	139:51.09E	4350	4394	0719	61:20.74S	139:50.61E	8.5	-	0847	61:20.86S	139:50.67E	4350
47	0918	26-MAR-93	61:21.11S	139:50.35E	4350	1003	0941	61:21.14S	139:50.75E	-	-	1015	61:21.07S	139:50.58E	4350
48	1425	26-MAR-93	61:50.76S	139:51.22E	4285	4348	1537	61:50.86S	139:51.41E	4.0	4290	1645	61:51.00S	139:51.52E	-
49	1725	26-MAR-93	61:51.06S	139:51.58E	4285	1003	1742	61:51.16S	139:51.54E	-	-	1806	61:51.39S	139:51.43E	-
50	2112	26-MAR-93	62:21.14S	139:51.44E	3975	3990	2237	62:21.25S	139:52.38E	8.2	-	0001	62:21.45S	139:53.13E	-
51	0039	27-MAR-93	62:21.58S	139:53.58E	3975	1006	0058	62:21.64S	139:54.05E	-	-	0128	62:21.57S	139:54.28E	-
52	0408	27-MAR-93	62:50.91S	139:50.59E	3220	3226	0516	62:50.79S	139:49.62E	6.7	-	0618	62:50.74S	139:49.49E	-
53	0652	27-MAR-93	62:50.71S	139:49.17E	3220	1005	0709	62:50.70S	139:49.09E	-	-	0743	62:50.74S	139:48.96E	-
54	1255	27-MAR-93	63:21.04S	139:50.31E	3815	3834	1404	63:20.71S	139:50.20E	9.7	-	1503	63:20.09S	139:49.95E	-
55	1723	27-MAR-93	63:19.29S	139:49.21E	3815	1009	1744	63:19.15S	139:48.86E	-	-	1815	63:18.99S	139:48.67E	3815
56	2152	27-MAR-93	63:50.89S	139:51.75E	3750	3772	2306	63:49.76S	139:53.41E	10.6	3750	0039	63:48.18S	139:54.48E	-
57	0121	28-MAR-93	63:47.35S	139:54.20E	3750	1003	0144	63:46.76S	139:54.54E	-	-	0214	63:45.91S	139:54.81E	3760
58	0645	28-MAR-93	64:21.11S	139:51.50E	3400	1003	0708	64:21.10S	139:51.23E	-	-	0741	64:21.01S	139:50.95E	-
59	0818	28-MAR-93	64:20.87S	139:50.74E	3400	3408	0923	64:20.32S	139:50.27E	8.5	-	1038	64:20.01S	139:50.21E	3400
60	1441	28-MAR-93	64:49.27S	139:50.31E	2600	2575	1534	64:49.67S	139:50.65E	8.7	-	1622	64:50.07S	139:50.83E	-
61	1704	28-MAR-93	64:50.43S	139:51.27E	2600	1005	1728	64:50.62S	139:51.63E	-	-	1804	64:50.75S	139:51.95E	2580
62	2012	28-MAR-93	65:05.06S	139:51.08E	2800	2791	2109	65:05.05S	139:51.37E	10.7	2815	2209	65:05.10S	139:51.28E	-
63	2246	28-MAR-93	65:04.89S	139:51.27E	2780	1005	2306	65:04.84S	139:51.23E	-	-	2343	65:04.84S	139:51.22E	2720
64	0630	29-MAR-93	65:37.29S	139:49.65E	375	343	0643	65:37.32S	139:49.13E	-	-	0656	65:37.33S	139:48.68E	375

Table 2: **(continued)**

stn	P11		start			max P	P11	bottom				P11	end		
no.	time	date	latitude	longitude	d (m)	(dbar)	time	latitude	longitude	alt (m)	d (m)	time	latitude	longitude	d (m)
1	0902	4-APR-93	43:13.14S	148:05.85E	170	151	0906	43:13.14S	148:05.79E	12.9	-	0919	43:13.27S	148:05.74E	160
2	1028	4-APR-93	43:14.60S	148:13.31E	650	609	1050	43:14.38S	148:13.37E	13.4	616	1122	43:13.98S	148:13.30E	582
3	1220	4-APR-93	43:14.99S	148:15.81E	1160	1159	1258	43:14.74S	148:15.78E	12.9	1140	1339	43:14.48S	148:15.85E	1150
4	1437	4-APR-93	43:14.71S	148:20.41E	2150	2426	1553	43:14.20S	148:20.82E	15.2	2400	1710	43:13.38S	148:21.23E	2300
5	1827	4-APR-93	43:14.85S	148:32.08E	2920	2954	1924	43:14.43S	148:32.53E	12.2	2950	2031	43:14.04S	148:32.82E	3000
6	0120	5-APR-93	43:15.61S	149:14.26E	3275	3322	0306	43:16.67S	149:14.31E	12.8	3300	0447	43:17.51S	149:14.67E	3275
7	0820	5-APR-93	43:14.86S	149:55.23E	3080	3100	0926	43:15.17S	149:55.42E	13.0	3070	1106	43:15.43S	149:55.47E	3070
8	1434	5-APR-93	43:15.50S	150:39.52E	3180	2424	1553	43:15.87S	150:39.07E	-	3150	1632	43:16.14S	150:40.31E	3160
9	1743	5-APR-93	43:15.22S	150:39.58E	3200	3232	1910	43:15.39S	150:39.75E	6.8	3200	2041	43:15.48S	150:40.28E	3150
10	2330	5-APR-93	43:15.09S	151:20.29E	4030	4069	0116	43:14.92S	151:19.62E	10.1	4030	0306	43:14.65S	151:18.99E	-
11	0633	6-APR-93	43:15.33S	152:03.83E	4490	4559	0828	43:14.90S	152:03.65E	10.6	4490	1028	43:14.40S	152:03.55E	4490
12	1743	6-APR-93	43:14.82S	152:47.43E	4625	4702	1933	43:14.43S	152:47.73E	11.1	4630	2130	43:14.11S	152:47.73E	4625
13	0042	7-APR-93	43:15.00S	153:29.99E	4650	4732	0238	43:15.37S	153:29.75E	10.7	4650	0440	43:16.07S	153:29.83E	4650
14	0757	7-APR-93	43:14.84S	154:14.65E	4650	4722	0953	43:14.56S	154:15.39E	11.6	4650	1146	43:14.42S	154:15.58E	4650
15	2309	8-APR-93	43:15.38S	154:58.76E	4470	4579	0110	43:15.13S	154:58.57E	12.0	4500	0308	43:14.88S	154:57.60E	4550
16	0939	9-APR-93	43:44.91S	155:00.10E	4610	4688	1128	43:45.00S	154:59.90E	14.9	4610	1318	43:45.27S	154:59.89E	4610
17	1650	9-APR-93	44:14.73S	155:00.58E	4750	4847	1832	44:14.31S	155:00.81E	11.1	-	2046	44:13.98S	155:01.56E	-
18	0037	10-APR-93	44:44.23S	155:00.40E	4875	4977	0243	44:44.16S	155:00.32E	11.0	4875	0503	44:44.20S	154:59.70E	4870
19	0801	10-APR-93	45:15.07S	155:00.07E	4720	4845	0955	45:14.49S	155:00.27E	13.1	4760	1157	45:13.91S	155:00.62E	4850
20	1500	10-APR-93	45:45.06S	154:59.91E	4780	4900	1646	45:44.61S	154:59.72E	10.4	4810	1859	45:44.15S	154:59.86E	4775
21	2151	10-APR-93	46:15.01S	155:00.11E	4550	4637	2346	46:15.25S	154:59.91E	12.4	4550	0141	46:15.74S	155:00.37E	4570
22	0435	11-APR-93	46:45.16S	155:00.30E	4600	4678	0618	46:45.18S	155:00.88E	10.0	4600	0812	46:45.19S	155:01.26E	4600
23	1102	11-APR-93	47:14.98S	154:59.68E	4675	4756	1254	47:15.04S	154:59.50E	13.1	4675	1500	47:14.86S	154:59.53E	4675
24	1735	11-APR-93	47:45.15S	155:00.39E	4850	4919	1925	47:45.05S	155:00.34E	11.0	4860	2142	47:44.88S	154:59.65E	-
25	0036	12-APR-93	48:14.87S	154:59.91E	4740	4825	0229	48:15.09S	154:59.50E	12.7	4740	0436	48:15.60S	154:59.20E	4730
26	0717	12-APR-93	48:44.98S	154:59.91E	4500	4581	0859	48:45.23S	154:59.55E	14.4	4505	1100	48:45.42S	154:59.94E	4500
27	1351	12-APR-93	49:15.18S	154:59.68E	4575	4621	1541	49:15.47S	155:00.15E	12.4	4580	1745	49:15.66S	155:00.43E	4550
28	2035	12-APR-93	49:45.33S	155:00.24E	4420	4517	2227	49:45.70S	155:00.58E	12.1	4450	0021	49:45.78S	155:00.97E	4300
29	1354	13-APR-93	50:14.27S	154:59.80E	4540	4690	1553	50:13.39S	155:00.52E	15.2	4500	1803	50:13.12S	155:01.48E	4550
30	2104	13-APR-93	50:44.92S	154:59.88E	4470	4557	2257	50:44.54S	154:59.47E	10.8	4470	0052	50:44.32S	154:59.35E	-
31	0421	14-APR-93	51:15.39S	155:00.61E	4230	4302	0612	51:15.31S	155:00.80E	11.0	4230	0802	51:15.35S	155:01.45E	4220
32	1733	15-APR-93	51:44.91S	154:59.96E	4520	4593	1946	51:44.15S	155:01.85E	9.2	-	2200	51:43.50S	155:03.36E	4500

Table 2: (continued)

stn	P11		start			max P	P11	bottom				P11	end		
no.	time	date	latitude	longitude	d (m)	(dbar)	time	latitude	longitude	alt (m)	d (m)	time	latitude	longitude	d (m)
33	0202	16-APR-93	52:14.38S	154:58.45E	4260	4253	0351	52:13.16S	154:58.68E	15.8	4230	0544	52:11.99S	154:58.87E	4165
34	1011	16-APR-93	52:44.91S	155:00.22E	4230	4278	1153	52:43.86S	155:01.53E	13.8	4230	1343	52:42.64S	155:02.77E	-
35	0311	18-APR-93	53:15.90S	154:59.72E	4075	4115	0517	53:15.82S	155:01.33E	11.6	-	0719	53:15.51S	155:02.67E	4075
36	1209	18-APR-93	53:44.37S	154:59.64E	4200	4243	1404	53:44.12S	154:58.74E	9.2	-	1546	53:43.81S	154:57.42E	4200
37	2108	18-APR-93	54:15.07S	155:00.21E	4015	4089	2300	54:15.71S	155:02.26E	10.8	-	0050	54:16.02S	155:03.77E	4000
38	0445	19-APR-93	54:45.19S	155:00.33E	4290	4280	0610	54:46.07S	155:02.04E	15.2	4260	0758	54:46.95S	155:04.15E	4260
39	1312	19-APR-93	55:14.95S	154:58.13E	4050	116	1318	55:14.91S	154:57.94E	-	-	1323	55:14.85S	154:57.72E	-
40	0325	21-APR-93	55:15.15S	154:59.12E	4040	4083	0509	55:15.49S	154:55.93E	16.4	4020	0649	55:15.60S	154:53.26E	3950
41	1312	21-APR-93	55:44.89S	155:01.48E	4200	4257	1458	55:44.48S	155:02.62E	8.1	4175	1643	55:43.89S	155:03.32E	4170
42	2121	21-APR-93	56:25.15S	155:00.44E	3830	3776	2257	56:25.44S	155:02.64E	10.1	-	0045	56:25.82S	155:04.19E	3850
43	0357	22-APR-93	57:00.09S	155:00.25E	3710	3744	0529	57:00.72S	155:00.69E	14.2	3710	0659	57:00.97S	155:01.12E	-
44	1006	22-APR-93	57:35.04S	155:00.02E	3645	3670	1134	57:35.13S	154:59.76E	10.9	3645	1317	57:35.08S	154:58.87E	-
45	1749	22-APR-93	58:14.78S	155:00.63E	3430	3482	1919	58:14.22S	155:02.58E	10.3	3470	2052	58:13.75S	155:04.16E	3470
46	0100	23-APR-93	58:52.11S	154:28.09E	3225	3222	0227	58:52.08S	154:28.68E	11.8	3250	0356	58:51.79S	154:29.04E	-
47	0809	23-APR-93	59:29.11S	153:56.19E	3175	3184	0935	59:29.46S	153:56.05E	11.2	3182	1117	59:29.75S	153:56.17E	3165
48	1624	23-APR-93	60:04.85S	153:26.35E	2850	2966	1753	60:04.84S	153:27.04E	21.5	2900	1918	60:04.81S	153:27.86E	2750
49	0047	24-APR-93	60:43.21S	152:56.86E	2650	2671	0212	60:43.28S	152:57.15E	11.9	2550	0337	60:43.50S	152:57.31E	2480
50	1303	24-APR-93	61:36.56S	152:10.68E	2825	2771	1420	61:36.07S	152:10.40E	13.0	2710	1559	61:36.31S	152:09.49E	-
51	2056	24-APR-93	62:12.91S	151:41.27E	3880	3910	2237	62:12.33S	151:42.64E	3.5	-	0025	62:12.12S	151:43.45E	-
52	0429	25-APR-93	62:52.02S	151:09.10E	3775	3794	0609	62:52.07S	151:09.47E	8.6	3780	0745	62:52.24S	151:09.87E	-
53	2016	25-APR-93	63:26.01S	150:38.99E	3750	3772	2211	63:25.64S	150:39.30E	14.1	3760	0006	63:25.60S	150:39.55E	3760
54	0433	26-APR-93	64:03.24S	150:05.93E	3645	3650	0607	64:03.42S	150:05.51E	9.3	3645	0738	64:03.46S	150:04.91E	3645
55	1522	26-APR-93	64:34.16S	149:37.81E	3480	3506	1707	64:32.98S	149:38.22E	6.5	-	1849	64:32.16S	149:37.89E	3500
56	0127	27-APR-93	64:58.90S	149:14.74E	3320	3294	0258	64:59.55S	149:16.48E	9.5	3295	0435	64:59.86S	149:17.95E	3275
57	0832	27-APR-93	65:25.60S	149:04.32E	2900	739	0910	65:25.47S	149:03.93E	-	-	0933	65:25.51S	149:03.33E	2875
58	1707	27-APR-93	65:34.65S	148:40.57E	2730	241	1717	65:34.70S	148:40.43E	-	-	1729	65:34.82S	148:40.21E	-
59	2145	27-APR-93	65:38.07S	147:48.38E	2920	393	2202	65:38.05S	147:48.63E	-	-	2221	65:38.00S	147:48.81E	2880
60	2153	28-APR-93	65:47.69S	146:30.58E	2020	2009	2239	65:47.70S	146:30.90E	11.1	2020	2349	65:47.45S	146:31.62E	-
61	0933	29-APR-93	65:45.94S	146:28.60E	2360	2300	1034	65:46.29S	146:29.30E	9.6	2293	1152	65:46.54S	146:30.44E	2270
62	1940	29-APR-93	65:46.35S	146:28.38E	2260	2278	2040	65:46.41S	146:27.04E	11.1	2260	2145	65:46.36S	146:26.26E	2275
63	0628	30-APR-93	65:53.49S	146:28.75E	680	667	0657	65:53.38S	146:28.00E	8.4	690	0734	65:53.27S	146:27.37E	710
64	2303	2-MAY-93	65:26.74S	143:56.78E	2600	303	2319	65:26.85S	143:56.88E	-	2600	2350	65:26.78S	143:57.31E	2630

<u>Table 3:</u> Summary of samples drawn from Niskin bottles at each station, including salinity (sal.), dissolved oxygen (d.o.), nutrients (nuts), dissolved inorganic carbon (d.i.c.), carbon isotopes (C'topes), barium, primary productivity (prim prod), "Seacat" casts, and the following biological samples: pigments (pig), cyanobacteria counts (cyan), lugols iodine fixed algal counts (lugs), and osmium/gluteraldehyde fixed protist identifications (os/gl). Note that 1=sample taken, 0=no sample taken.

station		sal.	d.o.	nuts	d.i.c.	C'topes	barium	prim prod	seacat	pig	cyan	lugs	os/gl
1	TEST	1	1	1	0	0	0	0	0	0	0	0	0
2	SR3	1	1	1	1	0	1	1	1	1	1	1	1
3	SR3	1	1	1	0	0	0	0	0	1	0	0	0
4	SR3	1	1	1	1	0	0	0	0	1	0	0	0
5	SR3	1	1	1	0	0	1	0	0	1	0	0	0
6	SR3	1	1	1	1	0	0	1	1	1	1	1	1
7	SR3	1	1	1	0	0	0	1	1	1	1	1	1
8	SR3	1	1	1	1	0	0	0	0	1	0	0	0
9	SR3	1	1	1	0	0	1	0	0	1	0	0	0
10	SR3	1	1	1	1	0	0	1	1	1	1	1	1
11	SR3	1	1	1	0	0	1	1	1	1	1	1	1
12	SR3	1	1	1	1	0	0	0	0	1	0	0	0
13	SR3	1	1	1	0	0	1	0	0	1	0	0	0
14	SR3	1	1	1	1	0	0	1	1	1	1	1	1
15	SR3	1	1	1	0	0	1	1	1	1	1	1	1
16	SR3	1	1	1	1	0	0	0	0	1	0	0	0
17	SR3	1	1	1	0	0	0	0	0	1	1	1	0
18	SR3	1	1	1	1	0	0	1	0	1	1	1	1
19	SR3	1	1	1	0	0	1	0	0	1	0	0	0
20	SR3	1	1	1	1	0	0	1	1	1	1	1	1
21	SR3	1	1	1	0	0	1	1	1	1	1	1	0
22	SR3	1	1	1	1	0	0	0	0	1	0	0	0
23	SR3	1	1	1	0	0	0	0	0	1	0	0	0
24	SR3	1	1	1	1	0	0	0	0	1	0	0	0
25	SR3	1	1	1	0	0	0	1	1	1	1	1	1
26	SR3	1	1	1	1	0	0	1	1	1	1	1	0
27	SR3	1	1	1	0	0	1	0	0	1	0	0	0
28	SR3	1	1	1	1	0	0	0	0	1	0	0	0
29	SR3	1	1	1	0	0	0	0	0	1	1	1	0
30	SR3	1	1	1	0	0	0	1	1	1	1	1	1
31	SR3	1	1	1	0	0	1	0	0	1	0	0	0
32	SR3	1	1	1	1	0	0	0	0	1	0	0	0
33	SR3	1	1	1	0	0	1	1	1	1	1	1	1
34	SR3	1	1	1	1	0	0	0	0	1	1	1	0
35	SR3	0	0	0	0	0	0	0	0	0	0	0	0
36	SR3	1	1	1	0	0	0	1	1	1	1	1	1
37	SR3	0	0	0	0	0	0	0	1	0	0	0	0
38	SR3	1	1	1	0	0	0	0	1	0	0	0	0
39	TEST	1	0	0	0	0	0	0	0	0	0	0	0
40	SR3	1	1	1	0	0	0	0	0	0	0	0	0
41	SR3	1	1	1	1	0	0	0	0	1	0	0	0
42	SR3	1	1	1	0	0	1	0	1	0	0	0	0
43	SR3	1	1	1	0	0	1	1	1	1	1	1	1
44	SR3	1	1	1	0	0	0	0	1	0	0	0	0
45	SR3	1	1	1	0	0	0	1	1	1	1	1	1
46	SR3	1	1	1	0	0	1	0	0	0	0	0	0
47	SR3	1	1	1	0	0	1	0	0	1	0	0	0
48	SR3	1	1	1	1	0	0	0	0	0	0	0	0
49	SR3	1	1	1	0	0	0	0	0	1	0	0	0

Table 3: (continued)

station	sal.	d.o.	nuts	d.i.c.	C'topes	barium	prim prod	seacat	pig	cyan	lugs	os/gl
50 SR3	1	1	1	0	0	1	0	1	0	0	0	0
52 SR3	1	1	1	1	0	0	0	1	0	0	0	0
51 SR3	1	1	1	0	0	1	1	1	1	1	1	1
53 SR3	1	1	1	0	0	0	1	1	1	0	0	0
54 SR3	1	1	1	1	0	1	0	0	0	0	0	0
55 SR3	1	1	1	0	0	1	0	0	1	0	0	0
56 SR3	1	1	1	1	0	0	0	1	0	0	0	0
57 SR3	1	1	1	0	0	0	1	1	1	1	1	1
58 SR3	1	1	1	0	0	1	1	1	1	0	0	0
59 SR3	1	1	1	0	0	1	0	1	0	0	0	0
60 SR3	1	1	1	1	0	0	0	0	0	0	0	0
61 SR3	1	1	1	0	0	0	0	0	1	0	0	0
62 SR3	1	1	1	0	0	1	0	1	0	0	0	0
63 SR3	1	1	1	0	0	1	1	1	1	1	1	1
64 SR3	0	0	0	0	0	0	0	0	0	0	0	0
1 P11	1	1	1	1	0	0	0	0	1	0	0	0
2 P11	1	1	1	0	0	0	0	0	1	0	0	0
3 P11	1	1	1	1	0	0	0	0	1	0	0	0
4 P11	1	1	1	0	0	0	0	0	0	0	0	0
5 P11	1	1	1	1	0	0	0	0	1	1	1	1
6 P11	1	1	1	0	0	0	1	1	1	1	1	0
7 P11	1	1	1	1	0	0	0	0	1	0	0	0
8 P11	0	0	0	0	0	0	0	0	0	0	0	0
9 P11	1	1	1	1	0	0	0	0	1	1	1	0
10 P11	1	1	1	0	0	0	1	1	1	1	1	1
11 P11	1	1	1	1	0	0	0	0	1	0	0	0
12 P11	1	1	1	0	0	0	1	1	1	1	1	1
13 P11	1	1	1	1	0	0	1	1	1	1	1	0
14 P11	1	1	1	0	0	0	0	0	1	0	0	0
15 P11	1	1	1	1	1	0	1	1	1	0	0	0
16 P11	1	1	1	0	0	0	0	0	1	0	0	0
17 P11	1	1	1	1	0	0	1	0	1	1	1	1
18 P11	1	1	1	0	0	0	1	0	1	1	0	0
19 P11	1	1	1	1	0	0	0	0	1	0	0	0
20 P11	1	1	1	0	0	0	0	0	1	0	0	0
21 P11	1	1	1	0	0	0	1	0	1	1	0	0
22 P11	1	1	1	1	1	0	0	0	1	0	0	0
23 P11	1	1	1	0	0	0	0	0	1	0	0	0
24 P11	1	1	1	1	1	0	1	0	1	1	1	1
25 P11	1	1	1	0	0	0	1	0	1	1	1	0
26 P11	1	1	1	1	1	0	0	0	1	0	0	0
27 P11	1	1	1	0	0	0	0	0	0	0	0	0
28 P11	1	1	1	1	1	0	1	0	1	1	1	0
29 P11	1	1	1	0	0	0	0	0	1	0	0	0
30 P11	1	1	1	1	0	0	1	1	1	1	1	1
31 P11	1	1	1	0	0	0	1	0	1	1	1	0
32 P11	1	1	1	1	1	0	1	1	1	1	1	0
33 P11	1	1	1	0	0	0	1	1	1	1	1	1
34 P11	1	1	1	1	0	0	0	0	0	0	0	0
35 P11	1	1	1	0	0	0	1	0	1	1	1	1
36 P11	1	1	1	1	1	0	0	0	1	0	0	0
37 P11	1	1	1	0	0	0	1	0	1	1	1	1
38 P11	1	1	1	1	1	0	1	0	1	1	0	0

Table 3: **(continued)**

station	sal.	d.o.	nuts	d.i.c.	C'topes	barium	prim prod	seacat	pig	cyan	lugs	os/gl
39 P11	0	0	0	0	0	0	0	0	0	0	0	0
40 P11	1	1	1	1	1	0	1	0	1	1	0	0
41 P11	1	1	1	1	0	0	0	0	1	0	0	0
42 P11	1	1	1	0	0	0	1	0	1	1	1	1
43 P11	1	1	1	1	1	0	1	0	1	1	0	0
44 P11	1	1	1	0	0	0	0	0	1	0	0	0
45 P11	1	1	1	1	1	0	1	0	1	1	0	0
46 P11	1	1	1	0	0	0	1	0	1	1	0	0
47 P11	1	1	1	1	1	0	0	0	1	0	0	0
48 P11	1	1	1	0	0	0	0	0	0	0	0	0
49 P11	1	1	1	1	1	0	1	0	1	1	1	0
50 P11	1	1	1	1	0	0	0	0	1	0	0	0
51 P11	1	1	1	0	0	0	1	0	1	1	0	1
52 P11	1	1	1	1	1	0	0	0	1	0	0	0
53 P11	1	1	1	1	0	0	1	0	1	1	1	1
54 P11	1	1	1	0	0	0	0	0	1	0	0	0
55 P11	1	1	1	1	1	0	0	0	1	0	0	0
56 P11	1	1	1	1	0	0	1	0	1	1	1	0
57 P11	1	1	1	1	0	0	0	0	1	0	1	0
58 P11	1	1	1	0	0	0	0	0	1	0	0	0
59 ICE STN	1	1	1	1	0	0	0	0	1	0	0	0
60 ICE STN	1	1	1	1	0	0	0	0	1	0	0	0
61 ICE STN	1	1	1	0	0	0	0	0	0	0	0	0
62 ICE STN	1	1	1	0	0	0	0	0	1	1	0	1
63 ICE STN	1	1	1	1	0	0	0	0	1	0	0	0
64 ICE STN	1	1	0	0	0	0	0	0	1	0	0	1

3.5 Principal investigators

The principal investigators for the CTD and water sample measurements are listed in Table 6a. Cruise participants are listed in Table 6b.

Table 4: Current meter moorings deployed/recovered along SR3 transect.

site name	deployment time (UTC)	bottom depth (m)	latitude	longitude	current meter depths (m)	nearest CTD station no.
moorings deployed						
SO2	23:46, 15/03/93	3770	50° 33.19'S	142° 42.49'E	300 600 1000 2000 3200	17 SR3
SO3	22:58, 16/03/93	3800	51° 01.54'S	143° 14.35'E	300 600 1000 2000 3200	18 SR3
SO4	02:55, 17/03/93	3580	50° 42.73'S	143° 24.15'E	300 600 1000 2000 3200	17 SR3
SO5	06:24, 17/03/93	3500	50° 24.95'S	143° 31.97'E	1000 2000 3200	16 SR3
moorings recovered						
SO1	13/03/93 (deployed 12/10/91)	3570	50° 42.90'S	143° 22.90'E	570 820 1070 2070 3270	17 SR3

Table 5: ALACE float deployments.

deployment number	serial number	deployment time (UTC)	latitude	longitude	nearest CTD station no.
1	228	09:55, 14/03/93	48° 19.38'S	144° 34.78'E	12 SR3
2	242	08:05, 17/03/93	50° 42.98'S	143° 25.10'E	17 SR3
3	243	06:32, 19/03/93	54° 30.86'S	141° 20.22'E	26 SR3
4	244	20:46, 04/04/93	43° 13.79'S	148° 32.92'E	5 P11
5	233	17:52, 12/04/93	49° 15.68'S	155° 00.56'E	27 P11
6	232	16:55, 21/04/93	55° 43.78'S	155° 03.30'E	41 P11

<u>Table 6a:</u> Principal investigators (*=cruise participant) for water sampling programmes.

measurement	name	affiliation
CTD, salinity, O_2, nutrients	*Steve Rintoul	CSIRO
D.I.C., carbon isotopes	*Bronte Tilbrook	CSIRO
primary productivity	John Parslow	CSIRO
biological sampling	Harvey Marchant	Antarctic Division
barium	Frank deHairs	Vrije Universiteit, Brussels

<u>Table 6b:</u> Scientific personnel (cruise participants).

name	measurement	affiliation
Nathan Bindoff	CTD	Antarctic CRC
Fred Boland	CTD, moorings	CSIRO
Giorgio Budillon	CTD	Instituto Universitario Navale
Phil Morgan	CTD	CSIRO
Steve Rintoul	CTD	CSIRO
Mark Rosenberg	CTD	Antarctic CRC
Bernadette Sloyan	CTD	Antarctic CRC
Giancarlo Spezie	CTD	Instituto Universitario Navale
Ruth Eriksen	salinity, oxygen, nutrients	Antarctic CRC
Val Latham	salinity, oxygen, nutrients	CSIRO
Mark Pretty	D.I.C., carbon isotopes	CSIRO
Bronte Tilbrook	D.I.C., carbon isotopes	CSIRO
Pru Bonham	primary productivity	CSIRO
Liza Fallon	biological sampling, krill biology	Antarctic Division
Alison Turnbull	biological sampling	Antarctic Division
Tonia Cochran	biological sampling, krill biology	Antarctic division
Vicky Lytle	sea ice	Antarctic CRC
Ian Knott	sea ice, electronics	Antarctic CRC
Rob Massom	sea ice	Antarctic CRC
Kelvin Michael	sea ice	Antarctic CRC
Paul Scott	sea ice	Antarctic CRC
Graeme Snow	sea ice	Antarctic Division
Tony Worby	sea ice, CTD	Antarctic Division
David Eades	ornithology	Royal Australasian Ornithologists Union
Paul Scofield	ornithology	Royal Australasian Ornithologists Union
Terry Dennis	seal biology	National Parks and Wildlife
Peter Shaughnessy	seal biology	CSIRO
Mark Conde	computing	Antarctic Division
Peter Gormly	doctor, seal biology	Antarctic Division
Steve Kuncio	computing	Antarctic Division
Steve Nicol	krill biology, voyage leader	Antarctic Division
Andrew McEldowney	deputy voyage leader	Antarctic Division
Jon Reeve	electronics	Antarctic Division
Tim Ryan	underway measurements	Antarctic Division
Andrew Tabor	gear officer	Antarctic Division
Ashley Lewis	helicopters	Helicopter Resources
Tony McNabb	helicopters	Helicopter Resources
Dave Pullinger	helicopters	Helicopter Resources

4 FIELD DATA COLLECTION METHODS

4.1 CTD and hydrology measurements

In this section, CTD and hydrology data collection methods are discussed. CTD data processing techniques are described in detail in Appendix 2, while hydrology laboratory analysis methods are described in Appendix 3. Results of the CTD data calibration, along with data quality information, are presented in Section 6.

4.1.1 CTD Instrumentation

E.G.&G. manufactured Neil Brown Mark IIIB CTD units, together with a model 1401 deck unit, were used for CTD measurements (Table 7). The raw data stream was logged by two separate IBM compatible PC's, using the E.G.&G. data aquisition software CTDACQ, version 3.0. The duplication of the data logging PC's allowed data to be viewed simultaneously (in real time) as column formatted numbers on one screen, and in graphical format on the other; the second PC also provided a backup log of the data.

Table 7: CTD manufacturer specifications.

parameter	sensor	accuracy	resolution
Pressure	Standard Controls Model 211-35-440 strain gauge bridge, stainless steel tube type	±6.5 dbar	0.1 dbar
Temperature	Rosemount Model 171 platinum thermometer	±0.005 °C	0.0005°C
Conductivity	Neil Brown Instruments 4 electrode cell (0.4cm x 0.4cm x 3.0 cm long)	±0.005 mS/cm	0.001 mS/cm
Oxygen	Beckman polarographic oxygen sensor	-	-
Altimeter	Benthos Model 2110	±5%	0.1 m

Two different CTD units were used during the cruise (Table 2). The electronic and data stream configuration of both instruments was identical (Table 8). Note that the fast response thermistor was disconnected from both units.

Rosette configurations of both 24 and 12 bottles were used over the course of the cruise. In both cases, General Oceanics rosette pylons were installed, together with 10 and 5 litre General Oceanics Niskin bottles. The 12-bottle configuration was used on stations 36 to 64 of the SR3 section, while on all other casts, the 24-bottle system was used.

Deep sea reversing thermometers (Gohla-Precision and Yoshino Keiki) were used to keep track of CTD temperature sensor performance. In general, two protected thermometers were mounted on the shallowest Niskin bottle, while three thermometers (two protected and one unprotected) were mounted on the second deepest bottle. The manufacturer specified accuracy of the protected thermometers is to within ±0.01°C for the main thermometer, and ±0.1°C for the auxiliary. Readings can be resolved to the third decimal place for the main on the protected thermometers, and to the second decimal place for auxiliary and unprotected readings.

Table 8: CTD electronic and data stream configuration, and data processing parameters. Note that the scan byte layout applies to both CTD units, and that all parameters (except oxygen temperature) are assigned 2 bytes in the raw data stream. The AD parameters are the additional digitiser channels (unused for this cruise). For the CTD upcast burst data, the first nstart and the last nend data scans are ignored for calculation of burst statistics (Appendix 2); the first jfilt data scans are ignored each time the data lagging recursive filter is restarted (Appendix 2). τ_T is the time constant of the temperature sensor (Appendix 2). jmin is the minimum number of values required in a 2 dbar pressure bin (Appendix 2).

CTD unit number	serial number	scanning frequency (Hz)	bytes per record	bytes per scan	nstart	nend	jfilt	τ_T (s)	jmin
1	1073	15.63	129	28	5	3	8	0.175	9
4	1197	15.63	129	28	5	3	8	0.175	9

Scan byte layout: synch. byte, pressure, temperature, conductivity, utility byte, oxygen current, oxygen temperature, altimeter, AD1, AD2, AD3, AD4, AD5, AD6, end bytes

4.1.2 CTD instrument calibrations

Complete calibration information for the CTD pressure and temperature sensors are presented in Appendix 1. Formulae used for parameter calculations are presented in Appendix 2. Pressure sensors were calibrated prior to the cruise, using a Budenberg Deadweight Tester (accurate to ±0.05% of the pressure being measured) over the range 0 to 5515 dbar. Calibrations were performed for the two cases of increasing and decreasing pressure (due to hysteresis of the pressure sensor response), with a fifth order polynomial fitted in each case (Figure A1.1).

CTD temperature sensors were calibrated at the CSIRO Division of Oceanography Calibration Facility (accredited by Australia's national standards body). Two point calibrations were performed, near the triple point of water (0.010^{o}C) and the triple point of phenoxybenzene (26.863^{o}C), using platinum resistance thermometers as transfer standards. The temperature sensor was calibrated prior to the cruise for CTD unit 4, and following the cruise for CTD unit 1.

CTD conductivity measurements were calibrated from the in situ salinity samples collected at each station (Appendix 2). As a rule, this enables CTD salinity values to be calculated to a much higher accuracy than by the bulk application of a single set of laboratory determined calibration coefficients. Thus there are no laboratory calibrations for the conductivity sensors. Checks were made prior to the cruise to ensure the conductivity sensors were functioning correctly. Similarly, CTD dissolved oxygen measurements were calibrated from the in situ dissolved oxygen samples (Appendix 2). The complete conductivity and oxygen in situ calibrations are presented in a later section.

4.1.3 CTD and hydrology data collection techniques

When on deck, the rosette package was housed in a closed laboratory space. Thus all samples were drawn "indoors". An outward opening hatch, which doubles as a gantry, allowed deployment of the instrument. The package was lowered/raised at the following speeds:

0 to 500 m depth - 20 m/min

500 to 1000 m depth - 40 m/min

below 1000 m depth - 60 m/min

Winch speeds were maintained by constantly adjusting the winch wire tension, and thus are approximate average values only. The altimeter output was used to guide the instrument to within (in most cases) 15 m of the bed (Table 2). Towards the southern end of both sections, the instrument was lowered to within 10 m of the bed for most stations.

CTD data was logged continuously for the entire down and upcast, while Niskin bottles were fired on the upcast only. At each station, the firing depths for the Niskin bottles were decided on using the graphical output of the CTD downcast data. Typically, the deepest bottle was fired at the bottom of the cast, however when vertical motion of the ship increased during rough weather, the CTD was raised approximately 10 m from the bottom of the cast before firing the first bottle. The rosette package was stopped at each level prior to firing a bottle; bottles with reversing thermometers were allowed to equilibrate for 5 min before firing.

A fixed sequence was followed for the drawing of water samples on deck, as follows:

first sample:	dissolved oxygen
	dissolved inorganic carbon
	carbon isotopes
	productivity
	salinity
	nutrients
	barium
last sample:	biology

(see Table 3 for a summary of which samples were drawn at each station). Reversing thermometers were read after the sampling was complete (or nearing completion), typically within one hour of the raising of the rosette package onto the deck. In between stations, the Niskin bottles were only emptied when resetting the bottles for the next station. This helped prevent the crystallization of salt in o-ring seats and spiggots.

4.1.4 Water sampling methods

The methods used for drawing the various water samples from the Niskin bottles are described here. Laboratory analysis techniques are described in later sections.

Dissolved oxygen: sample bottle volume = 300 ml

Bottles are washed and dried before use. As dissolved oxygen samples are drawn first, the Niskin is first tested for obvious leakage by opening the spiggot before opening the air valve. Tight fitting silicon tubing is attached to the Niskin spiggot for sample drawing. Pickling reagent 1 is 1.83 M $MnSO_4$ (0.5 ml used); reagent 2 is 9 M NaOH with 1.8 M KI (1.0 ml used); reagent 3 is concentrated H_2SO_4 (2.0 ml used).

* start water flow through tube for several seconds, making sure no bubbles remain in tube
* pinch off flow in tube, and insert into bottom of sample bottle
* let flow commence slowly into bottle, gradually increasing, at all times ensuring no bubbles enter the flow
* fill bottle, overflow by at least one full volume
* pinch off tube and slowly remove so that bottle remains full to the brim, then rinse glass stopper
* immediately pickle with reagents 1 then 2, inserting reagent dispenser 1 cm below water surface
* insert glass stopper, ensuring no bubbles are trapped in sample
* thoroughly shake sample (at least 30 vigorous inversions)
* store samples in the dark until analysis
* acidify samples with reagent 3 immediately prior to analysis

Dissolved inorganic carbon: sample bottle volume = 250 ml

Tight fitting silicon tubing is attached to the Niskin spiggot for sample drawing. Samples are poisoned with 100 μl of a saturated solution of $HgCl_2$.

* drain remaining old sample from the bottle
* start water flow through tube for several seconds, making sure no bubbles remain in tube

* insert tube into bottom of inverted sample bottle, allowing water to flush out bottle for several seconds
* pinch off flow in tube, and invert sample bottle to upright position, keeping tube in bottom of bottle
* let flow commence slowly into bottle, gradually increasing, at all times ensuring no bubbles enter the flow
* fill bottle, overflow by one full volume, and rinse cap
* shake a small amount of water from top, so that water level is between threads and bottle shoulder
* insert tip of poison dispenser just into sample, and poison
* screw on cap, and invert bottle several times to allow poison to disperse through sample

Salinity: sample bottle volume = 300 ml
* drain remaining old sample from the bottle (bottles are always stored approximately 1/3 full with water between stations)
* rinse bottle and cap 3 times with 100 ml of sample (shaking thoroughly each time); on each rinse, contents of sample bottle are poured over the Niskin bottle spiggot
* fill bottle with sample, to bottle shoulder, and screw cap on firmly
At all filling stages, care is taken not to let the Niskin bottle spiggot touch the sample bottle.

Nutrients: sample tube volume = 12 ml
Two nutrient sample tubes are filled simultaneously at each Niskin bottle.
* rinse tubes and caps 3 times
* fill tubes
* shake out water from tubes so that water level is at or below marking line 2 cm below top of tubes (10 ml mark), and screw on caps firmly
After sampling, the set of nutrient tubes are placed in a freezer until thawing for analysis.

Carbon Isotopes: These are sampled and poisoned in the same fashion as dissolved inorganic carbon, except that 500 ml glass stoppered vacuum flasks are used, and vacuum grease is placed around the stopper before inserting.

Barium samples were acidified with HCl. Biological water sampling methods are not reported here.

4.2 Underway measurements

Throughout the cruise, the ship's data logging system continuously recorded bottom depth, ship's position and motion, surface water properties and meteorological information. All measurements were quality controlled during the cruise, to remove bad data (Ryan, 1993).

After quality controlling of the automatically logged GPS data set, gaps (due to missing data and data flagged as bad) are automatically filled by dead-reckoned positions (using the ship's speed and heading). Positions used for CTD stations are derived from this final GPS data set. Bottom depth is measured by a Simrad EA200 12 kHz echo sounder. A sound speed of 1498 ms^{-1} is used for all depth calculations, and the ship's draught of 7.3 m has been accounted for in final depth values (i.e. depths are values from the surface).

Seawater is pumped on board via an inlet at 7 m below the surface. A portion of this water is diverted to the thermosalinograph (Aplied Microsystems Ltd, model STD-12), and to the fluorometer (Turner Design, peak sensitivity for chlorophyll-a). Sea surface temperatures are measured by a sensor next to the seawater inlet at 7 m depth.

The underway measurements for the cruise are contained in column formatted ascii files (Appendix 4). The two file types are as follows (see Appendix 4 for a complete description):

(i) 10 second digitised underway measurement data, including time, latitude, longitude, depth and sea surface temperature;

(ii) 15 minute averaged data, including time, latitude and longitude, air pressure, wind speed and direction, air temperature, humidity, quantum radiation, ship speed and heading, roll and pitch, sea surface salinity and temperature, average fluorescence, and seawater flow.

5 MAJOR PROBLEMS ENCOUNTERED

The most significant disruption to the measurement program was the loss of the rosette package at station 35 on the SR3 transect, due to a failure of the cable termination just above the rosette frame. As no spare 24 bottle system was available, the rest of the SR3 transect (stations 36 to 64) was completed using a 12 bottle system, double dipping at each station, as follows: a shallow and a deep dip were taken at each station, the shallow dip down to 1000 dbar and the deep dip to the bottom. For the deep dip, the 12 depths sampled were all below 1000 dbar. Note that in most cases, the deep dip was taken first. The unscheduled return to Hobart on completion of the SR3 transect allowed a spare 24 bottle system to be picked up - this system was then used for the P11 transect.

The last good quality dissolved oxygen sensor was lost with the CTD at station 35 on the SR3 transect. Furthermore, no spare sensors were available on the return to Hobart. Thus good quality CTD dissolved oxygen data was only obtained for stations 1 to 35 of the SR3 section. For all remaining stations, dissolved oxygen values are available from the hydrology data only. A lower grade CTD oxygen data calibration was performed for stations 36 to 64 of SR3, and stations 1 to 29 of P11, but these lower grade CTD oxygen data are not included in the cruise data set. CTD oxygen data from stations 30 to 64 of P11 were unusable.

Following the loss of the rosette package, the next few stations were conducted using a different winch system. As a result of the shorter wire on this winch, the next three deep casts (stations 38, 40 and 42 of the SR3 transect) did not reach the bottom (Table 2). Following station 42, measurements were resumed using the original winch system, allowing full depth casts.

A further problem, resulting from the rosette package loss, was the replacement Niskin bottles used. For the remainder of the SR3 transect where a 12 bottle rosette system was used (stations 36 to 64), a full complement of 10 l Niskin bottles was available. However for the P11 transect, conducted using the replacement 24 bottle system, seven 5 l Niskin bottles were employed to make up the full complement of 24 bottles. These 5 l bottles leaked on many occasions, and a high proportion of the samples were rejected in the data processing stage.

Prior to the last station on SR3 (station 64), the water in the CTD sensor covers froze. On deployment of the instrument at this station, the sensors froze again as the package was about to enter the water. Subsequent conductivity measurements on the P11 transect revealed that the CTD conductivity cell had been altered by the freezing - the response of the conductivity cell was significantly changed.

Freezing of instrumentation resulted in data loss in the southern part of both transects. For SR3 station 64, no useful CTD data was obtained due to the ice on the sensors, while no Niskin bottles were successfully fired owing to the frozen rosette pylon. For P11 stations 55 to 64, CTD downcast data could not be used due to ice on the sensors: upcast data was used instead, as discussed in a later section. In general, a logistical problem exists with deployment of the instrumentation in very cold conditions. When deployment of the package commences at each station, the instruments are exposed to the air for a short time before entering the water. Under extreme conditions of cold (Table 9), any moisture on the CTD sensors will freeze as the sensors are exposed to the air, rendering the CTD data unusable as long as ice remains on the sensors. Normally, the CTD sensors are kept in fresh water between stations, however storage in a hypersaline solution may help prevent the freezing of any moisture on the sensors. This method will be trialed on future cruises.

The hydrology laboratory lacked temperature control, affecting the quality of hydrology analyses: over the entire cruise, lab temperatures over the range 8 to 30^{o}C were noted. Temperature fluctuations in the laboratory meant that analyses at times had to be abandoned and resumed at a later time: for silicates in particular, repeat analysis runs were often needed. Laboratory temperatures are shown for the times of dissolved oxygen analyses (Figure 2).

Table 9: Air temperature and wind speed for stations where CTD sensors froze. Note that the CTD is deployed from the port side of the ship, thus the port side air temperature is shown. Also note that wind chill factor has not been included.

transect	station number	port air temperature (deg. C)	wind speed (knots)
SR3	64	-13.6	35.4
P11	55	-10.4	6.1
P11	56	-6.4	21.6
P11	57	-14.0	16.5
P11	58	-6.7	14.4
P11	59	-1.6	7.6
P11	60	-11.3	8.6
P11	61	-13.4	12.6
P11	62	-12.6	14.7
P11	63	-17.1	13.2
P11	64	-15.1	19.4

At station 21 on the P11 transect, several samples were lost due to repeated misfiring of the rosette pylon. The misfiring was thought to have been caused by fouling of the mechanical parts, and/or contamination of the mineral oil in the pylon. Following servicing of the pylon, alignment of the pylon stepping motor proved difficult, and several attempts at realignment were made for the rest of the P11 transect. As a result of the alignment problem, double firing of the rosette occurred during many of the remaining casts. In most cases, bottle firing sequence could be deduced by comparison of the hydrology samples with the uncalibrated CTD data. Note however that this task became increasingly difficult further south in the P11 transect where there are very weak vertical gradients in the measured parameters.

6 RESULTS

This section details information relevant to the creation and the quality of the final CTD and hydrology data set. For actual use of the data, the following is important:

CTD data - Tables 16, 17 and 18, and section 6.1.2;

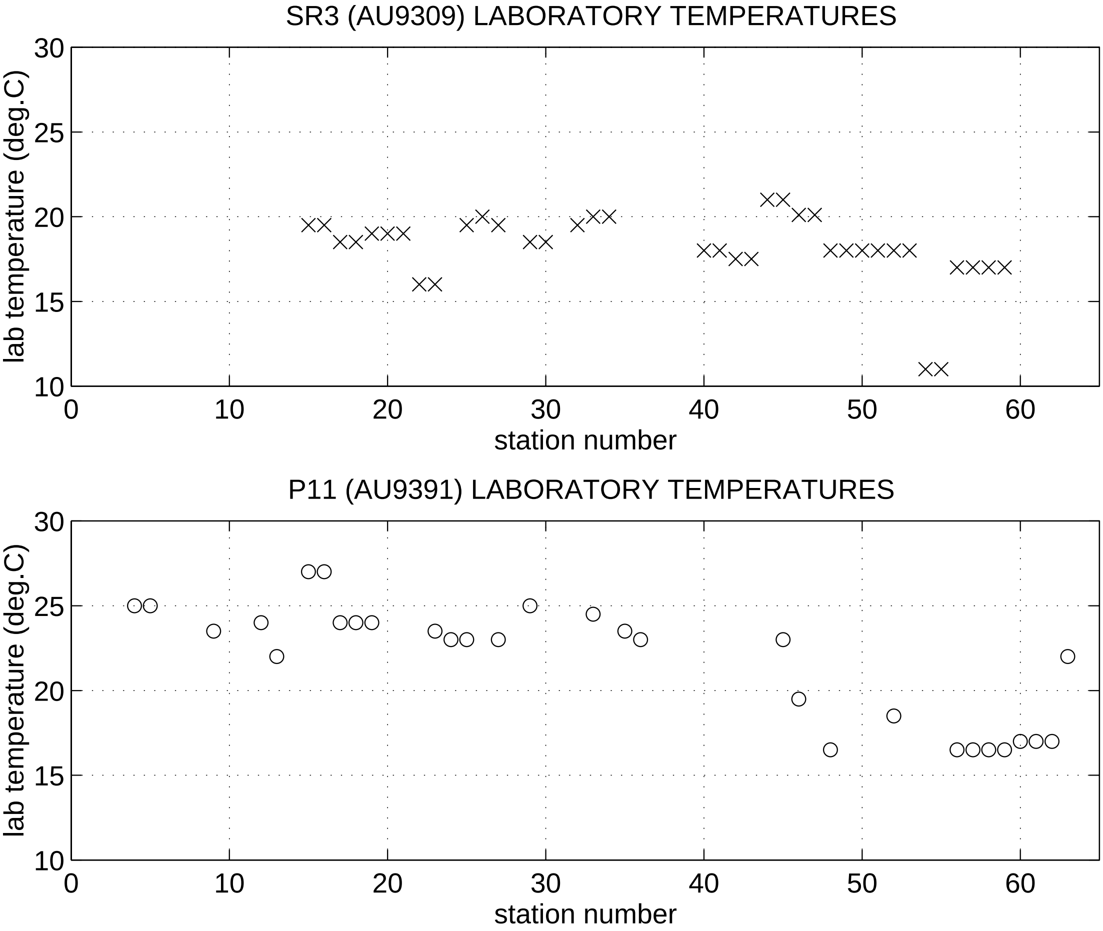
hydrology data - Tables 22 and 23.

Historical data comparisons are made in Appendix 6.

6.1 CTD measurements

6.1.1 Creation of CTD 2 dbar-averaged and upcast burst data

Information relevant to the creation of the calibrated CTD 2 dbar-averaged and upcast burst data is tabulated, as follows:



<u>Figure 2:</u> **Hydrology laboratory temperatures at the times of dissolved oxygen analyses.**

* Table 10 lists the bad raw data scans, with more than 8 missing bytes, identified during the conversion of the raw binary CTD data to Unix unformatted files (Appendix 2, section A2.4).

* Surface pressure offsets calculated for each station (Appendix 2, section A2.6.1) are listed in Table 11. Note that for 4 of the stations, the value is estimated from the surrounding stations (data logging did not commence until after the CTD was in the water).

* Missing 2 dbar data averages (Appendix 2, section A2.8) are listed in Table 12. For stations which include CTD dissolved oxygen data, there may be additional 2 dbar averages where the oxygen data only is missing - these data are referred to in Table 19.

* CTD conductivity calibration coefficients (Appendix 2, section A2.10), including the station groupings used for the conductivity calibration, are listed in Tables 13 and 14.

* CTD raw data scans flagged for special treatment (Appendix 2, section A2.11.1) are listed in Table 15.

* Suspect 2 dbar averages are listed in Tables 16 and 17 (for more details, see Appendix 2, section A2.11.2). Note that Table 16 refers to CTD salinity data only. Table 18 lists 2 dbar averages which are linear interpolations of the surrounding 2 dbar averages.

* Table 19 lists the 2 dbar data for which there is no dissolved oxygen data.

* CTD dissolved oxygen calibration coefficients (Appendix 2, section A2.12) are listed in Table 20. The starting values used for the coefficients prior to iteration, and the coefficients varied during the iteration, are listed in Table 21.

* Upcast CTD burst data automatically flagged with the code -1 (rejected for conductivity calibration) or 0 (questionable value, but still used for conductivity calibration) (Appendix 2, section A2.7.4) are listed in Appendix 5, Table A5.1.

* The different protected thermometers used for the stations are listed in Appendix 5, Table A5.4.

6.1.2 CTD data quality

The CTD data was processed in four separate groups, as follows:

* SR3 stations 1 to 35 : CTD unit 4
* SR3 stations 36 to 63 : CTD unit 1, shallow/deep cast pairs at each location
* P11 stations 1 to 54 : CTD unit 1
* P11 (and sea ice) stations 55 to 64 : CTD unit 1, upcast data used for 2 dbar-averaging

SR3 stations

The CTD dissolved oxygen sensor degraded progressively over stations 10 to 13 of the SR3 transect. The accuracy of CTD dissolved oxygen data for stations 11, 12 and 13 is diminished (particularly for stations 12 and 13), as can be seen from the higher dox values in Table 20. The sensor was changed following station 13. Note also that for SR3 station 13, a negative value for the dissolved oxygen calibration coefficient K_6 (Table 20) was required to obtain a reasonable fit (positive values are normally expected). In addition, for SR3 stations 3, 11, 12, 19 and 24, the coefficient K_5 is greater than 1, while for SR3 station 4, $K_5<0$ (Table 20). Strictly speaking, we should have $0\leq K_5\leq 1$ (Millard and Yang, 1993).

For SR3 station 22, the salinity residual is high for the entire station (Figure 5a). Salinity samples from rosette positions 3 to 7 may have been drawn out of sequence. For samples above this, inspection of the raw upcast CTD data did not reveal any obvious fouling. This indicates that the

Niskin bottle salinity values for this station are suspect. All bottles were rejected for the conductivity calibration, and the station was grouped with the calibrations applied to SR3 stations 18 to 21 (Table 13).

No bottle samples were obtained for SR3 station 35, due to loss of the rosette package. For the conductivity calibration, the station was grouped with the calibrations applied to SR3 stations 32 to 34 (Table 13); for the dissolved oxygen calibration, station 35 was grouped with the calibrations for SR3 stations 33 and 34 (Table 20).

For SR3 station 36, only 6 salinity samples were taken over the 1000 m cast. These samples were all rejected for the conductivity calibration. For SR3 station 37, no bottle samples were taken. Stations 36 and 37 were both grouped with the calibrations applied to SR3 stations 38, 39 and 40 (Table 13).

SR3 stations 1 and 39 were both test casts, with all bottles fired at a single depth. Conductivity calibrations for these two stations therefore rely heavily on the station groupings in which they fall (Table 13).

As noted in Table 11, the surface pressure offset value for station 51 of the SR3 transect was estimated from the surrounding stations. Any resulting additional error in the CTD pressure data is judged to be small (no more than 0.2 dbar).

For SR3 station 55, the conductivity sensor was fouled ~150 dbar from the bottom of the downcast, and remained fouled for the entire upcast. The upcast data was therefore unusable, and all the upcast bursts were rejected for the conductivity calibration. The station was grouped with the calibrations applied to SR3 stations 53, 54 and 56 (Table 13).

P11 and sea ice stations

For the P11 data, the response of the CTD conductivity cell was altered by the freezing of the sensors at SR3 station 64 (section 5). The conductivity calibration routine adequately dealt with the new cell response (Figure 4c).

For P11 stations 8 and 39, the cast was abandoned in both cases before the bottom was reached, due to unfavourable weather conditions. No Niskin bottle samples were obtained, however casts at both locations were repeated with, respectively, stations 9 and 40. For stations 8 and 39, CTD conductivity was calibrated in the station groupings listed in Table 13.

The surface pressure offset values for P11 stations 9, 20 and 24 (similarly to station 51 of the SR3 transect) were estimated from the surrounding stations. Any resulting additional error in the CTD pressure data is judged to be small (no more than 0.2 dbar).

Double firing of the rosette pylon occurred during many of the casts following P11 station 21 (section 5). For vertical positions where the accidental double firings occurred, the first sample of the pair was rejected for the conductivity calibration (Appendix 5, Table A5.3). This, together with the large number of rejections due to the leaking 5 l Niskin bottles (section 5), resulted in a significantly higher sample rejection rate for the P11 transect than for the SR3 data set (see Figure 4). Note however that the double firings provided a useful data set for dissolved oxygen and nutrient sample analysis replication (section 6.2.2).

For P11 station 38, the conductivity sensor was fouled for the entire upcast above 400 dbar. The upcast data above 400 dbar was therefore unusable, and the upcast bursts for rosette positions 19 to 24 were rejected for the conductivity calibration.

Similarly for P11 station 43, the conductivity sensor was fouled for the entire upcast above 700 dbar - the upcast bursts for rosette positions 16 to 24 were rejected for the conductivity calibration.

For P11 station 47, the conductivity sensor was fouled near the bottom of the downcast, and remained fouled for the entire upcast. The upcast data was therefore unusable, and all the upcast bursts were rejected for the conductivity calibration. The station was grouped with the calibrations applied to P11 stations 44 to 46 (Table 13). The relatively large salinity residual scatter of 0.0029 psu for this group (Table 13, and Figure 5c) may also be due to fouling for all these stations. Indeed the near surface CTD 2 dbar values for these stations are noted as suspect in Table 17.

For P11 (and sea ice) stations 55 to 64, ice on the CTD sensors (see section 5) rendered the downcast data unusable. Upcast data was used to form the 2 dbar-averaged data for these stations. The accuracy of the CTD salinity data for this group of stations, as revealed by the CTD conductivity calibration, is diminished (see σ values in Table 13, and Figure 5d: in the figure, the scatter is greatest for stations 56 and 60). For some of these stations, ice may have remained on the sensors during the upcast. Indeed the maximum water temperature for these stations, always less than 2 degrees C, may not have been sufficient to remove all the ice from the sensors. Bubbles may also have become trapped in the conductivity sensor during freezing. CTD salinity accuracy of the order 0.01 psu should be assumed for this group of stations.

For P11 (and sea ice) stations 57, 58, 59 and 64, shallow casts only were taken (Table 2), due to unfavourable weather and sea ice conditions.

The bottom position for P11 station 63 (Table 2) was interpolated from the start and end positions for the station, as no value was available from the underway measurements.

Summary

The following is a summary of the data quality cautions discussed above:

station no.	CTD parameter	caution
1 SR3	salinity	test cast - all bottles fired at same depth
11 SR3	dissolved oxygen	diminished CTD dissolved oxygen accuracy due to degrading sensor
12 SR3	dissolved oxygen	diminished CTD dissolved oxygen accuracy due to degrading sensor
13 SR3	dissolved oxygen	diminished CTD dissolved oxygen accuracy due to degrading sensor
22 SR3	salinity	CTD conductivity calibrated with bottles from stations 18, 19, 20, 21
35 SR3	salinity	CTD conductivity calibrated with bottles from stations 32, 33, 34
35 SR3	dissolved oxygen	CTD dissolved oxygen calibrated with bottles from stations 33, 34
36 SR3	salinity	CTD conductivity calibrated with bottles from stations 38, 39, 40
37 SR3	salinity	CTD conductivity calibrated with bottles from stations 38, 39, 40
38 SR3	all parameters	CTD cast not all the way to the bottom
39 SR3	salinity	test cast - all bottles fired at same depth
40 SR3	all parameters	CTD cast not all the way to the bottom
42 SR3	all parameters	CTD cast not all the way to the bottom
51 SR3	pressure	surface pressure offset estimated from surrounding stations
55 SR3	salinity	CTD conductivity calibrated with bottles from stations 53, 54, 56
8 P11	salinity	CTD cast not all the way to the bottom; CTD conductivity calibrated with bottles from stations 4, 5, 6, 7, 9
9 P11	pressure	surface pressure offset estimated from surrounding stations
20 P11	pressure	surface pressure offset estimated from surrounding stations
24 P11	pressure	surface pressure offset estimated from surrounding stations
38 P11	salinity	top 6 samples not used in conductivity calibration
39 P11	salinity	shallow cast; CTD conductivity calibrated with stations 40, 41 bottles
43 P11	salinity	top 9 samples not used in conductivity calibration
47 P11	salinity	CTD conductivity calibrated with bottles from stations 44, 45, 46
55 to 64 P11	all parameters	files contain upcast data; salinity accuracy reduced
57 to 59 P11	all parameters	shallow cast only
63 P11	bottom position	lat/long. when CTD at bottom interpolated from start and end lat/long.
64 P11	all parameters	shallow cast only

The final calibration results for conductivity/salinity and dissolved oxygen, along with the performance check for temperature, are plotted in Figures 3 to 6. Four plots are included for each parameter, corresponding to the four groups in which the data were processed. For temperature, salinity and dissolved oxygen, the respective residuals (T_{therm} - T_{cal}), (s_{btl} - s_{cal}) and (o_{btl} - o_{cal}) are plotted. For conductivity, the ratio c_{btl}/c_{cal} is plotted. T_{therm} and T_{cal} are respectively the protected thermometer and calibrated upcast CTD burst temperature values; s_{btl}, s_{cal}, o_{btl}, o_{cal}, c_{btl} and c_{cal} are as defined in Appendix 2, sections A2.10.1, A2.10.3 and A2.12.1. The plots include mean and standard deviation values, as described in Appendix 2, section A2.14.

The temperature residuals are shown in Figures 3a to d, along with the mean offset and standard deviation of the residuals. The thermometer value used in each case is the mean of the two protected thermometer readings (protected thermometers used are listed in Appendix 5, Table A5.4). Note that in the figures, the “dubious” and “rejected” categories refer to corresponding bottle samples and upcast CTD bursts in the conductivity calibration. Within the accuracy of the reversing thermometers (section 4.1.1), the checks demonstrate stable performance of the CTD temperature sensors for the two CTD units.

The conductivity ratios for all bottle samples are plotted in Figures 4a to d, while the salinity residuals are plotted in Figures 5a to d. The final standard deviation values for the salinity residuals (Figure 5) indicate the accuracy of the CTD salinity data as ±0.002 psu, except for P11/sea ice stations 55 to 64 (as discussed above).

The dissolved oxygen residuals are plotted in Figure 6. The final standard deviation values are within 1% of full scale values (where full scale is approximately equal to 250 μmol/l for pressure > 750 dbar, and 350 μmol/l for pressure < 750 dbar). Note that the final standard deviation values would be reduced by excluding stations 11, 12 and 13 from the estimation.

6.2 Hydrology data

Hydrology analytical methods are detailed in Appendix 3.

6.2.1 Hydrology data quality

Quality control information relevant to the hydrology data is tabulated, as follows:

* Questionable dissolved oxygen and nutrient Niskin bottle sample values are listed in Tables 22 and 23 respectively. Questionable values are included in the hydrology data file, whereas bad values have been removed.

* Laboratory temperatures at the times of dissolved oxygen and nutrient analyses are listed in Tables 24 and 25 respectively. As laboratory temperature was not recorded for nutrient analyses, the values in Table 25 are estimated by interpolating between the values from Table 24 at the times of nutrient analysis runs.

* Dissolved oxygen Niskin bottle samples flagged with the code -9 (rejected for CTD dissolved oxygen calibration) (Appendix 2, section A2.12.3) are listed in Appendix 5, Table A5.2.

* P11 bottles rejected due to double firing of the rosette pylon (section 5) are listed in Appendix 5, Table A5.3.

Nutrients

For the phosphate analyses, it was found that the Autoanalyser peak height of a sample which was run immediately after a series of carrier solution vials (low nutrient sea water) was suppressed by, on average, 2%. It is suspected that this was due to the phosphomolybdate complex sorbing onto the walls of the instrument tubing after being cleaned by the carrier solution. Later tests proved that frequent flushing with sodium hydroxide reduced the severity of the effect, but did not eliminate it. For later cruises, the manifold and chemistry of the Autoanalyser phosphate channel will be modified in an attempt to minimise the effect. Phosphate samples thus effected (in most cases from rosette positions 12 and 24) are deleted from the hydrology data set.

For several stations, the entire set of values for one of the nutrient analyses was suspect, and therefore deleted from the hydrology data, as follows:

* P11 station 10, nitrate+nitrite : poor calibration for Autoanalyser nitrate channel;
* P11 station 33, silicate : sensitivity decreased by fluctuating lab. temperature; very large gain adjustment had to be applied;
* P11 station 35, nitrate+nitrite : poor calibration for Autoanalyser nitrate channel;
* P11 station 44, silicate : very large gain adjustment had to be applied;
* P11 station 46, silicate : sensitivity decreased by fluctuating lab. temperature (3 repeats tried with no success);
* P11 station 56, phosphate : values too high - no explanation;
* P11 station 62, nitrate+nitrite : values too low - no explanation.

The following notes also apply to the nutrient data:

* For SR3 stations 1 and 39 (test casts), no nutrient samples were collected.
* For SR3 stations 48, 49, 50 and 51, phosphate concentrations were derived from manual integrations of autoanalyser peak heights.
* For P11 station 51, data for all the nutrients were lost during a computer failure.
* For P11 station 64, no nutrient samples were collected.

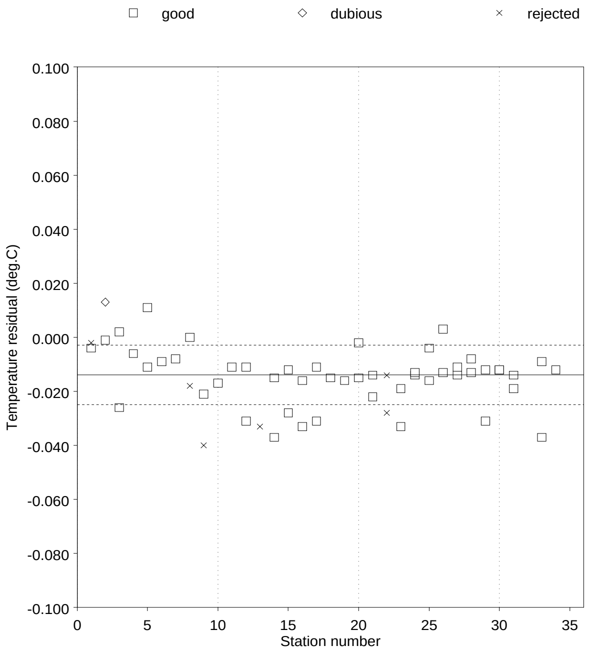
6.2.2 Hydrology sample replicates

Although no organised sample replication was carried out, a series of replicates were obtained through the unintentional double firing of Niskin bottles during the P11 transect (section 5). For each pair of Niskin bottles tripped simultaneously at the same depth, samples were drawn and analysed from each bottle, and the difference between the sample pairs calculated for each measured parameter (Figure 7). A quality control element was introduced by rejecting pairs for which the difference of upcast CTD burst temperatures was ≥0.01°C; two additional bottles were also rejected from the analysis, due to questionable salinity and/or dissolved oxygen values. The results are summarised as follows (note that the standard deviations are calculated for the absolute value of the differences):

parameter	standard deviation of differences	number of samples	full scale deflection
salinity	0.0008 psu	60	-
dissolved oxygen	1.3420 μmol/l	57	~350 μmol/l for p< 750dbar ~250 μmol/l for p>750 dbar
phosphate	0.0101 μmol/l	49	3.0 μmol/l
nitrate+nitrite	0.2635 μmol/l	55	35.0 μmol/l
silicate	1.5407 μmol/l	53	140 μmol/l

It is assumed that these precision values would be significantly reduced if the sample pairs were drawn from the same Niskin bottle. Also note that outliers have not been removed - for instance, by removing the single outliers for the case of dissolved oxygen and silicate (Figure 7), the standard deviations are greatly reduced, to the respective values 0.6851 and 0.4511 μmol/l.

(a)



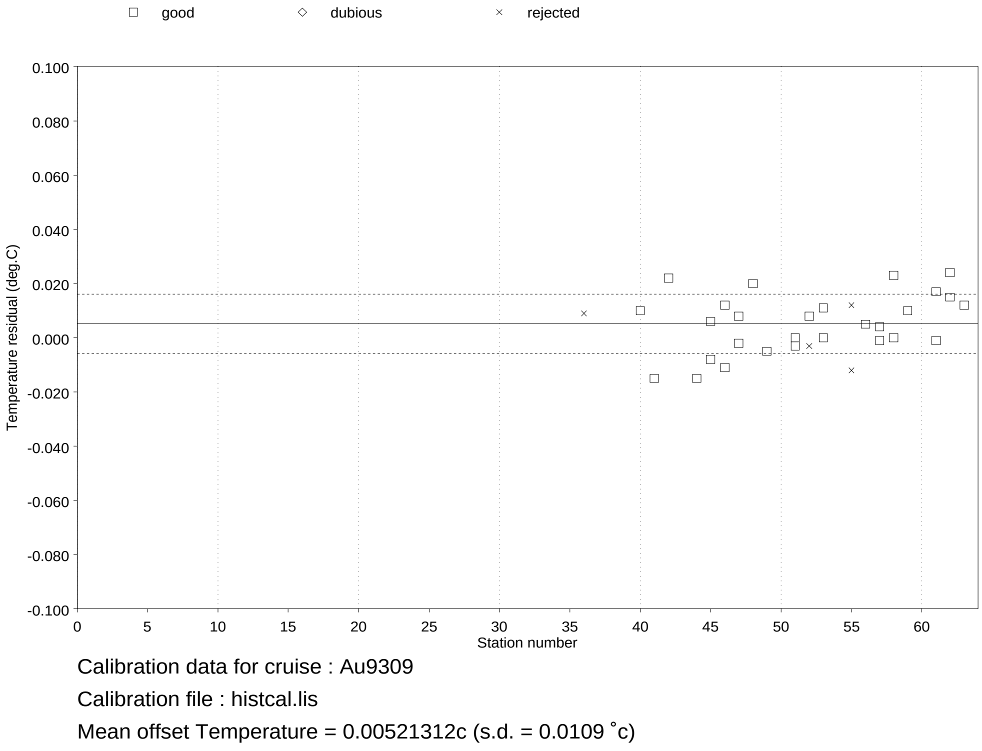
Calibration data for cruise : Au9309

Calibration file : histcal.lis

Mean offset Temperature = -.01392312c (s.d. = 0.0110 ˚c)

Number of samples used = 51 out of 57

(b)



Calibration data for cruise : Au9309

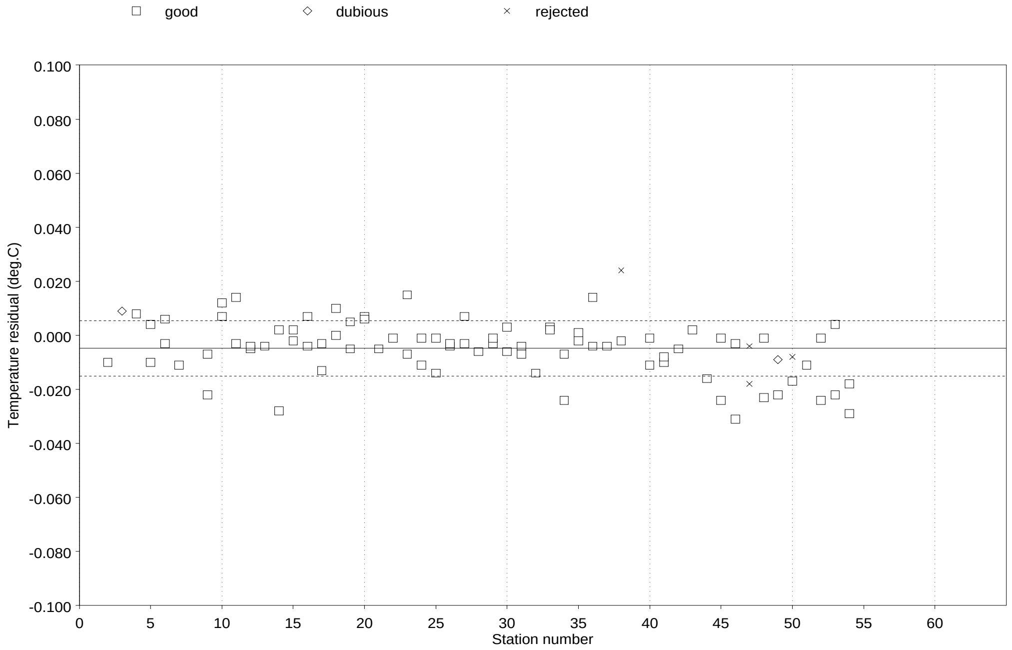
Calibration file : histcal.lis

Mean offset Temperature = 0.00521312c (s.d. = 0.0109 ˚c)

Number of samples used = 28 out of 32

Figure 3a and b: **Temperature residual (T_{therm} - T_{cal}) versus station number for SR3. The solid line is the mean of all the residuals; the broken lines are ± the standard deviation of all the residuals (as defined in section A2.14, Appendix 2). Note that the "dubious" and "rejected" categories refer to the conductivity calibration.**

(c)



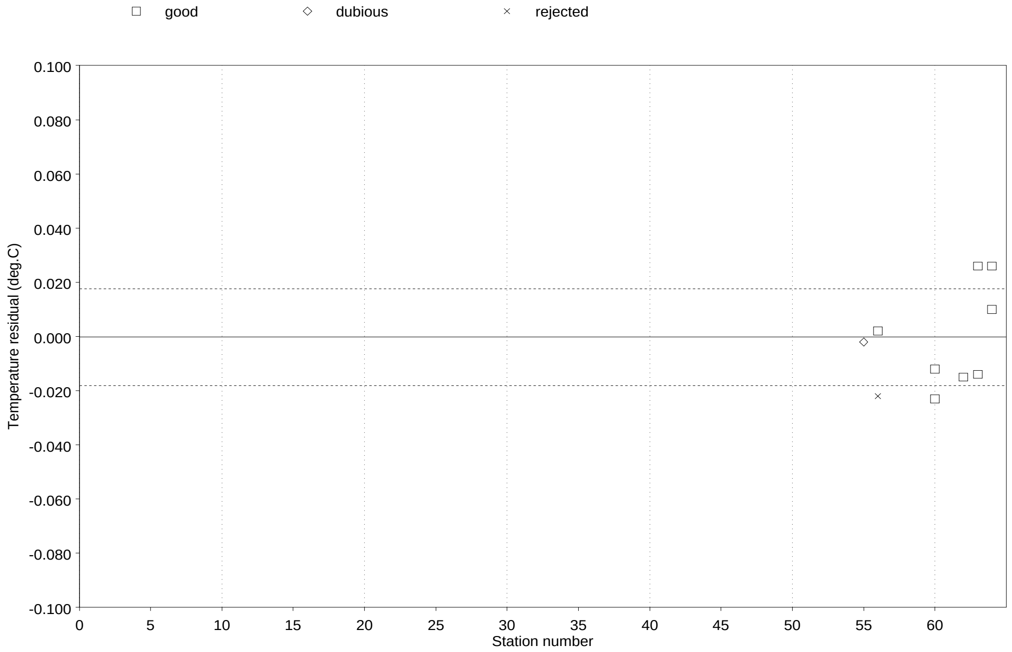
Calibration data for cruise : Au9391

Calibration file : histcal.lis

Mean offset Temperature = -.00482312c (s.d. = 0.0102 ˚c)

Number of samples used = 84 out of 88

(d)



Calibration data for cruise : Au9391

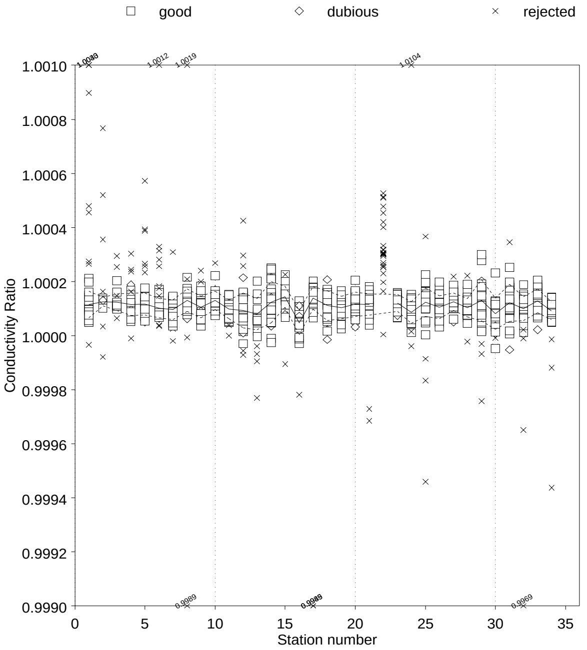
Calibration file : histcal.lis

Mean offset Temperature = -.00022312c (s.d. = 0.0179 ˚c)

Number of samples used = 9 out of 10

<u>Figure 3c and d:</u> Temperature residual (T_{therm} - T_{cal}) versus station number for P11 and sea ice stations. The solid line is the mean of all the residuals; the broken lines are ± the standard deviation of all the residuals (as defined in section A2.14, Appendix 2). Note that the "dubious" and "rejected" categories refer to the conductivity calibration.

(a)



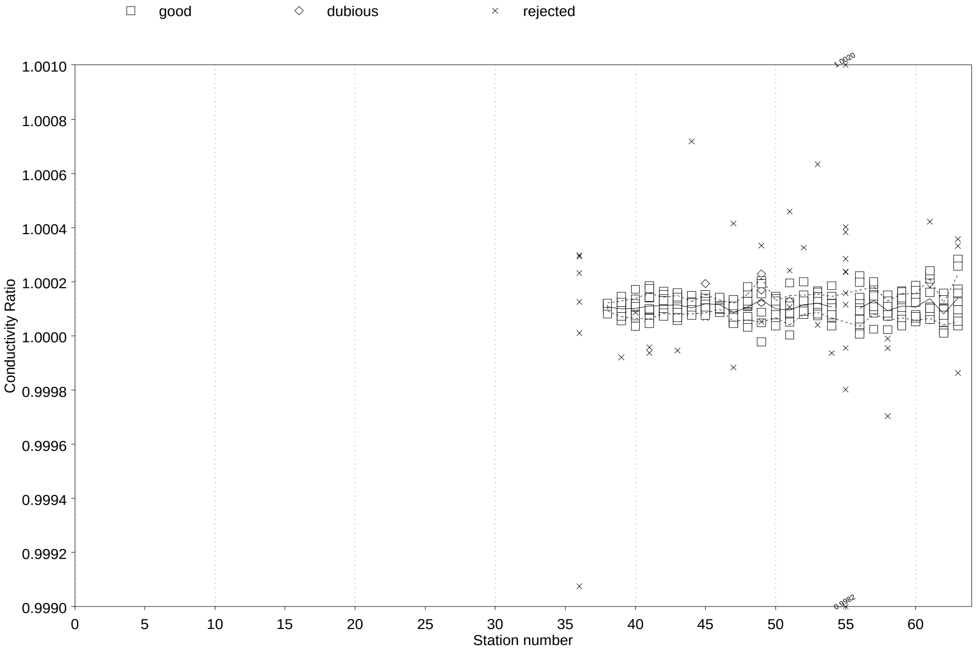
Calibration data for cruise : Au9309

Calibration file : histcal.lis

Conductivity s.d. = 0.00005

Number of bottles used = 630 out of 777 Mean ratio for all bottles = 1.00000

(b)



Calibration data for cruise : Au9309

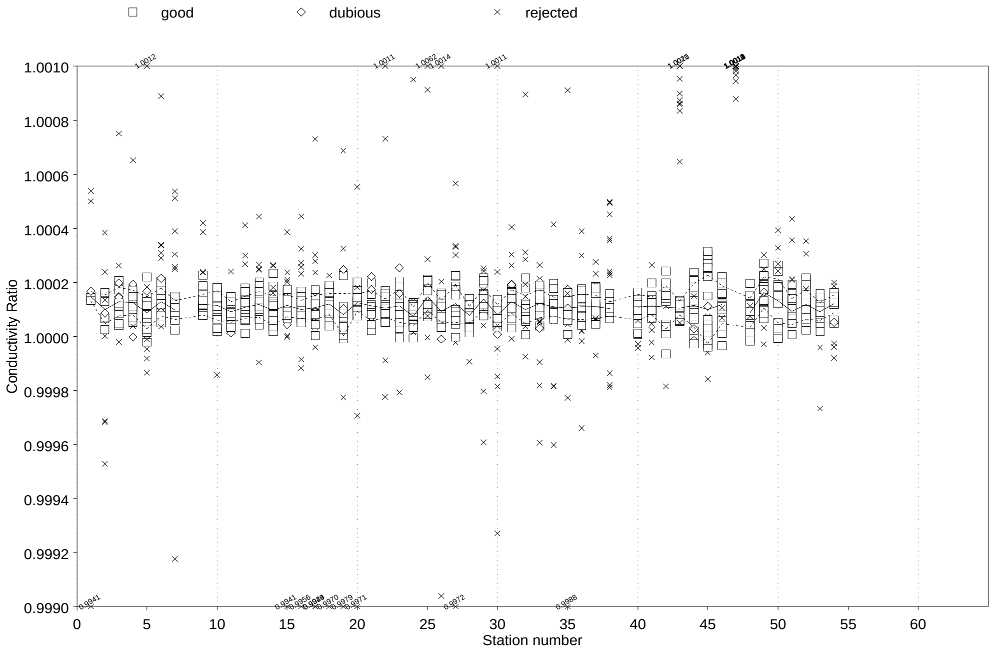
Calibration file : histcal.lis

Conductivity s.d. = 0.00004

Number of bottles used = 264 out of 309 Mean ratio for all bottles = 1.00000

<u>Figure 4a and b:</u> Conductivity ratio c_{btl}/c_{cal} versus station number for SR3. The solid line follows the mean of the residuals for each station; the broken lines are ± the standard deviation of the residuals for each station (as defined in section A2.14, Appendix 2).

(c)



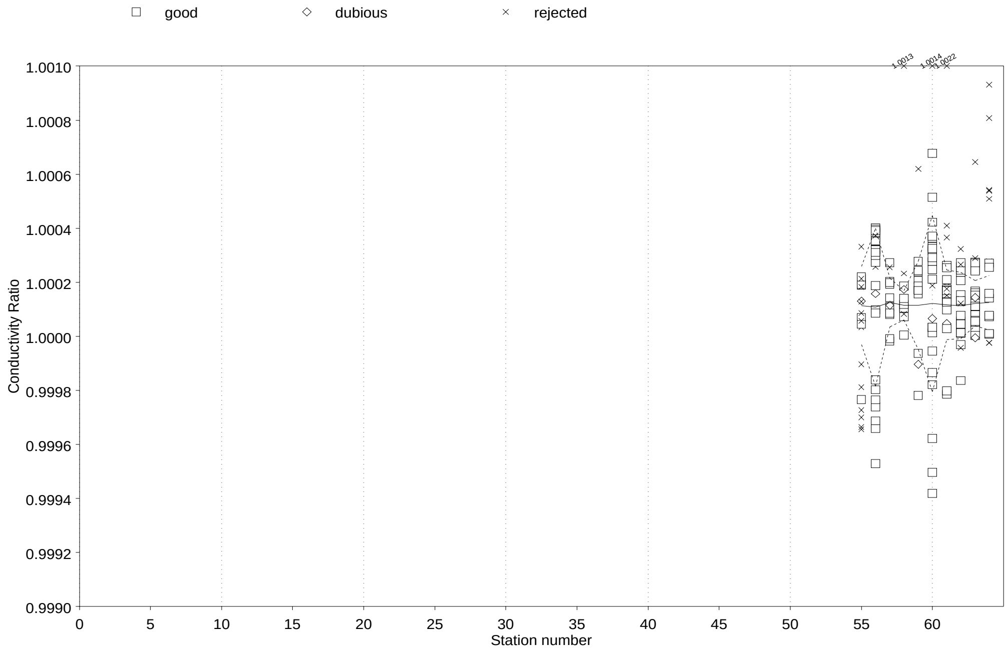
Calibration data for cruise : Au9391

Calibration file : histcal.lis

Conductivity s.d. = 0.00005

Number of bottles used = 856 out of 1188 Mean ratio for all bottles = 1.00000

(d)



Calibration data for cruise : Au9391

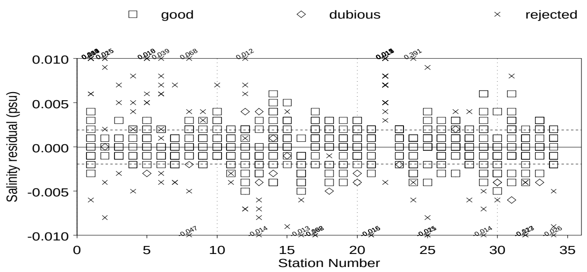
Calibration file : histcal.lis

Conductivity s.d. = 0.00018

Number of bottles used = 149 out of 195 Mean ratio for all bottles = 1.00000

<u>Figure 4c and d:</u> Conductivity ratio c_{btl}/c_{cal} versus station number for P11 and sea ice stations. The solid line follows the mean of the residuals for each station; the broken lines are ± the standard deviation of the residuals for each station (as defined in section A2.14, Appendix 2).

(a)



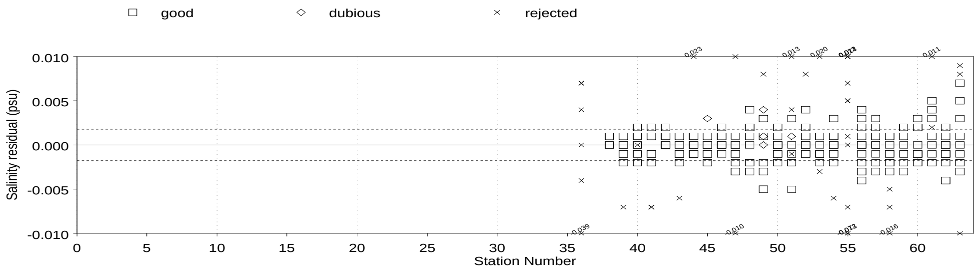
Calibration data for cruise : Au9309

Calibration file : histcal.lis

Mean offset salinity = 0.0000psu (s.d. = 0.0019 psu)

Number of bottles used = 630 out of 777

(b)



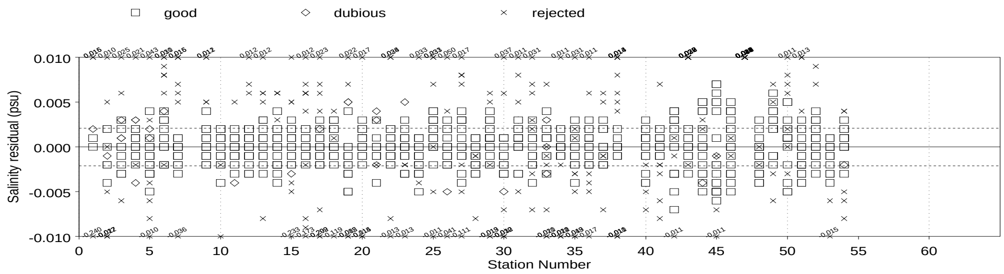
Calibration data for cruise : Au9309

Calibration file : histcal.lis

Mean offset salinity = 0.0000psu (s.d. = 0.0018 psu)

Number of bottles used = 264 out of 309

(c)



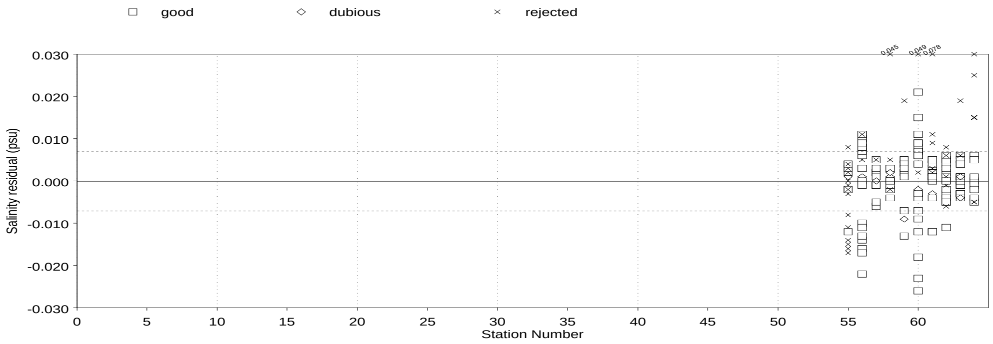
Calibration data for cruise : Au9391

Calibration file : histcal.lis

Mean offset salinity = 0.0000psu (s.d. = 0.0021 psu)

Number of bottles used = 856 out of 1188

(d)



Calibration data for cruise : Au9391

Calibration file : histcal.lis

Mean offset salinity = -0.0001psu (s.d. = 0.0071 psu)

Number of bottles used = 149 out of 195

<u>Figure 5a to d:</u> Salinity residual (s_{btl} - s_{cal}) versus station number for SR3, P11 and sea ice stations. The solid line is the mean of all the residuals; the broken lines are ± the standard deviation of all the residuals (as defined in section A2.14, Appendix 2).

Mean of Residual = -0.048umol/dm**3

S.D. of residual = 2.574umol/dm**3 (Equiv to 0.058ml/l)

Used 627 bottles out of total 723

S.D. deep (>750m) 2.284umol/dm**3 (equiv to 0.051ml/l)

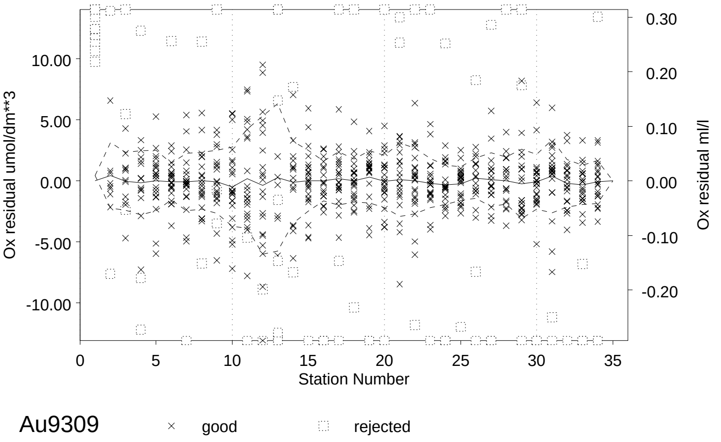


Figure 6: **Dissolved oxygen residual (o_{btl} - o_{cal}) versus station number for SR3 stations 1 to 35. The solid line follows the mean residual for each station; the broken lines are ± the standard deviation of the residuals for each station (as defined in section A2.14, Appendix 2).**

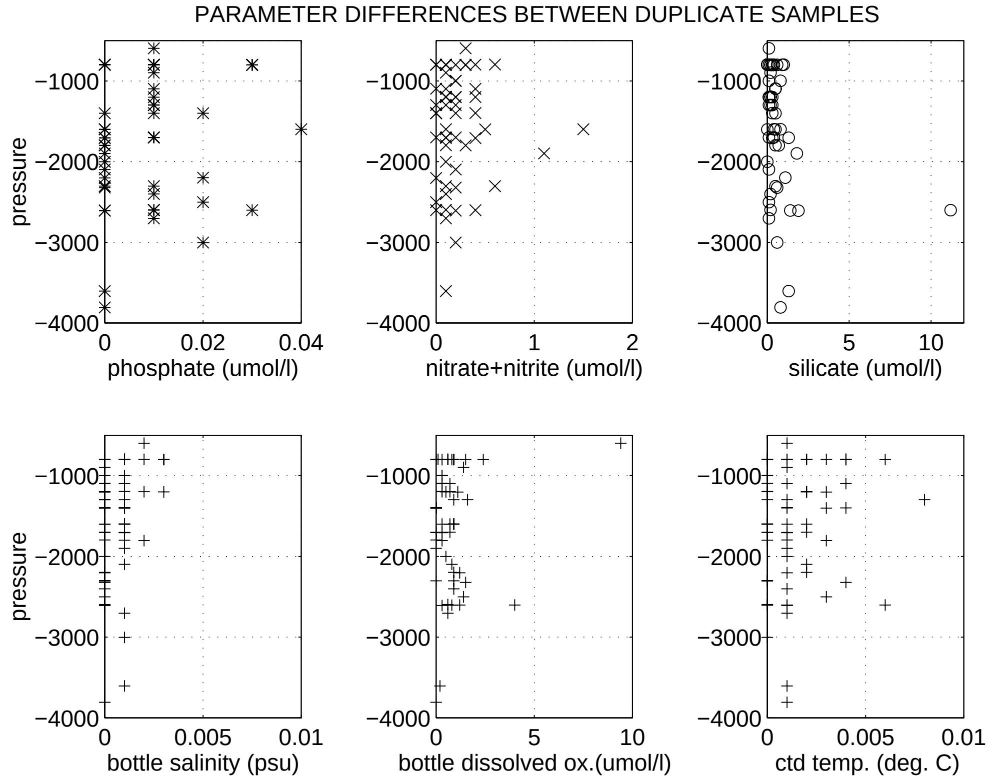


Figure 7: **Absolute value of parameter differences between sample pairs derived from Niskin bottle pairs tripped at the same depth. Note that no pressure dependent trend is evident.**

Table 10: **Bad record log for ship-logged CTD raw binary data files.**

station	no. of bad records	scan nos for the bad records	station	no. of bad records	scan nos for the bad records
34 SR3	1	28692	20 P11	2	14232,14239
43 SR3	2	1899,1906	32 P11	1	20264
44 SR3	4	8987,8994,24349,24439	37 P11	1	16722
51 SR3	2	9377,9390	56 P11	1	37532
			57 P11	3	9890,9981,10001

Table 11: **Surface pressure offsets. ** indicates that value is estimated from surrounding stations (as data logging commenced after CTD was in the water).**

station number	surface p offset (dbar)	station number	surface p offset (dbar)	station number	surface p offset (dbar)	station number	surface p offset (dbar)
1 SR3	-0.10	17 SR3	-0.50	33 SR3	0.00	49 SR3	1.40
2 SR3	-0.50	18 SR3	-0.60	34 SR3	0.00	50 SR3	1.10
3 SR3	-0.30	19 SR3	-0.50	35 SR3	-0.10	51 SR3	1.10**
4 SR3	-0.30	20 SR3	-0.30	36 SR3	0.90	52 SR3	1.20
5 SR3	-0.70	21 SR3	-0.80	37 SR3	1.40	53 SR3	1.40
6 SR3	-0.60	22 SR3	-0.70	38 SR3	1.80	54 SR3	0.80
7 SR3	-0.60	23 SR3	-0.40	39 SR3	1.20	55 SR3	1.40
8 SR3	-0.60	24 SR3	-0.30	40 SR3	1.60	56 SR3	1.10
9 SR3	-0.60	25 SR3	-0.50	41 SR3	1.50	57 SR3	1.70
10 SR3	-0.30	26 SR3	-0.40	42 SR3	1.20	58 SR3	1.40
11 SR3	-1.20	27 SR3	-0.10	43 SR3	1.60	59 SR3	1.60
12 SR3	-0.40	28 SR3	-0.30	44 SR3	1.00	60 SR3	1.20
13 SR3	-0.50	29 SR3	1.30	45 SR3	1.20	61 SR3	1.70
14 SR3	1.10	30 SR3	-0.40	46 SR3	1.10	62 SR3	1.50
15 SR3	-0.30	31 SR3	-0.20	47 SR3	1.50	63 SR3	1.70
16 SR3	-0.50	32 SR3	-0.10	48 SR3	1.20		
1 P11	-1.50	17 P11	-1.60	33 P11	0.00	49 P11	-0.30
2 P11	-1.20	18 P11	-1.30	34 P11	-1.00	50 P11	-1.00
3 P11	-1.10	19 P11	-1.20	35 P11	-1.20	51 P11	0.50
4 P11	-1.10	20 P11	-1.20**	36 P11	-1.00	52 P11	0.10
5 P11	-1.10	21 P11	-1.10	37 P11	-0.70	53 P11	-0.60
6 P11	-1.10	22 P11	-1.10	38 P11	-0.30	54 P11	0.70
7 P11	-1.90	23 P11	-1.30	39 P11	-0.10	55 P11	0.60
8 P11	-1.80	24 P11	-1.00**	40 P11	-1.10	56 P11	0.60
9 P11	-1.30**	25 P11	-0.80	41 P11	-1.00	57 P11	0.30
10 P11	-1.30	26 P11	-0.90	42 P11	-0.30	58 P11	-0.10
11 P11	-1.10	27 P11	-1.30	43 P11	-0.30	59 P11	0.40
12 P11	-1.90	28 P11	-0.50	44 P11	-0.30	60 P11	1.00
13 P11	-1.50	29 P11	-1.50	45 P11	-0.50	61 P11	1.10
14 P11	-1.40	30 P11	-0.60	46 P11	0.00	62 P11	-0.60
15 P11	-2.50	31 P11	-0.60	47 P11	-0.20	63 P11	1.20
16 P11	-2.10	32 P11	-1.90	48 P11	-0.50	64 P11	-0.60

<u>Table 12:</u> Missing data points in 2 dbar-averaged files; jmin is the minimum number of data points required in a 2 dbar bin to form the 2 dbar average (Table 8).

station number		pressures (dbar) where data missing	reason
22	SR3	2422	no. of data pts in 2 dbar bin < jmin
31	SR3	86, 2200	no. of data pts in 2 dbar bin < jmin
35	SR3	2128	no. of data pts in 2 dbar bin < jmin
38	SR3	1862	no. of data pts in 2 dbar bin < jmin
43	SR3	308, 310	no. of data pts in 2 dbar bin < jmin
51	SR3	2 to 38	logging of CTD data started at 39 dbar
7	P11	2846, 2854, 2856	no. of data pts in 2 dbar bin < jmin
9	P11	2904 to 2910	no. of data pts in 2 dbar bin < jmin
15	P11	2858 to 2862	no. of data pts in 2 dbar bin < jmin
19	P11	2916, 2920 to 2924	no. of data pts in 2 dbar bin < jmin
20	P11	2892, 2894	no. of data pts in 2 dbar bin < jmin
21	P11	2898 to 2902	no. of data pts in 2 dbar bin < jmin
24	P11	2, 4	logging of CTD data started at 5 dbar
25	P11	2704	no. of data pts in 2 dbar bin < jmin
36	P11	2240	no. of data pts in 2 dbar bin < jmin
37	P11	2668 to 2674	no. of data pts in 2 dbar bin < jmin
38	P11	144, 150	no. of data pts in 2 dbar bin < jmin
40	P11	2064 to 2068	no. of data pts in 2 dbar bin < jmin
43	P11	1800	no. of data pts in 2 dbar bin < jmin
46	P11	492, 494, 498	no. of data pts in 2 dbar bin < jmin
48	P11	1072	no. of data pts in 2 dbar bin < jmin
50	P11	382	no. of data pts in 2 dbar bin < jmin
52	P11	1358	no. of data pts in 2 dbar bin < jmin
55	P11	730, 890, 900, 910, 912, 920, 922, 962, 970, 972	no. of data pts in 2 dbar bin < jmin
57	P11	138, 370, 394	no. of data pts in 2 dbar bin < jmin
63	P11	658 to 662	no. of data pts in 2 dbar bin < jmin

Table 13: **CTD conductivity calibration coefficients F_1 , F_2 and F_3 are respectively conductivity bias, slope and station-dependent correction calibration terms. n is the number of samples retained for calibration in each station grouping; σ is the standard deviation of the conductivity residual for the n samples in the station grouping (eqn A2.22).**

station grouping	F_1	F_2	F_3	n	σ
01 to 03 SR3	-0.87027432E-01	0.10017877E-02	0.10859350E-07	31	0.001300
04 to 09 SR3	-0.83701358E-01	0.10016142E-02	0.55501037E-09	94	0.001243
10 to 14 SR3	-0.78860776E-01	0.10014170E-02	0.25279478E-07	102	0.001956
15 to 17 SR3	-0.85449315E-01	0.10004824E-02	0.88519662E-07	63	0.001908
18 to 22 SR3	-0.77938486E-01	0.10015112E-02	0.43526756E-08	84	0.001515
23 to 25 SR3	-0.78034870E-01	0.10009759E-02	0.23816527E-07	61	0.001446
26 to 28 SR3	-0.11344760	0.10017975E-02	0.35008045E-07	69	0.001160
29 to 31 SR3	-0.12312104	0.10044041E-02	-0.39590036E-07	65	0.002103
32 to 35 SR3	-0.45634971E-01	0.10001842E-02	0.91926248E-08	61	0.001375
36 to 40 SR3	0.21777478E-01	0.98457210E-03	-0.13856960E-07	27	0.000837
41 to 44 SR3	-0.30707095E-01	0.98499649E-03	0.15361759E-07	44	0.000889
45 to 48 SR3	-0.42736690E-01	0.98605541E-03	-0.66427282E-09	45	0.001273
49 to 52 SR3	-0.65699587E-01	0.98930618E-03	-0.47225885E-07	41	0.001601
53 to 56 SR3	-0.11637961E-02	0.98666472E-03	-0.36153105E-07	33	0.001344
57 to 59 SR3	-0.52398276E-01	0.98827823E-03	-0.32865597E-07	33	0.001361
60 to 63 SR3	0.16151333E-01	0.98275386E-03	0.19604304E-07	41	0.001887
01 to 03 P11	-0.31795846E-01	0.98572167E-03	0.13552725E-07	22	0.002011
04 to 09 P11	-0.46275229E-01	0.98612725E-03	-0.74828649E-09	88	0.001611
10 to 13 P11	-0.47789830E-01	0.98627146E-03	-0.16757783E-07	80	0.001457
14 to 15 P11	-0.48213369E-01	0.98631891E-03	-0.73256222E-08	35	0.001642
16 to 17 P11	-0.60969827E-01	0.98546887E-03	0.63554902E-07	30	0.001115
18 to 20 P11	-0.43918874E-01	0.98611745E-03	-0.26277663E-08	56	0.002054
21 to 22 P11	-0.40540240E-01	0.99177983E-03	-0.27246037E-06	32	0.001370
23 to 26 P11	-0.43497114E-01	0.98601958E-03	-0.66065918E-08	74	0.001879
27 to 31 P11	-0.46853495E-01	0.98585209E-03	0.67960792E-08	82	0.001754
32 to 35 P11	-0.29913756E-01	0.98647257E-03	-0.29720600E-07	60	0.001447
36 to 38 P11	-0.12768778E-01	0.98389993E-03	0.31673400E-07	42	0.001282
39 to 41 P11	-0.36303034E-01	0.98454817E-03	0.30142259E-07	33	0.001357
42 to 43 P11	-0.75863129E-01	0.98361994E-03	0.77030262E-07	30	0.002289
44 to 47 P11	-0.81708355E-01	0.99161204E-03	-0.87058417E-07	61	0.002925
48 to 51 P11	-0.66000414E-01	0.98524873E-03	0.26616089E-07	75	0.001989
52 to 54 P11	-0.27064281E-01	0.98750556E-03	-0.43742540E-07	56	0.001276
55 to 56 P11	-0.11739958E-01	0.99332894E-03	-0.17130823E-06	31	0.007388
57 to 58 P11	-0.31888641E-01	0.98091544E-03	0.63203397E-07	20	0.002033
59 to 60 P11	0.12828883	0.99354871E-03	-0.25069381E-06	33	0.007798
61 to 62 P11	0.56253874E-01	0.96530435E-03	0.20215141E-06	36	0.003554
63 to 64 P11	-0.30621303	0.95767099E-03	0.51973919E-06	29	0.002307

Table 14: Station-dependent-corrected conductivity slope term ($F_2 + F_3 . N$), for station number N, and F_2 and F_3 the conductivity slope and station-dependent correction calibration terms respectively.

station number	($F_2 + F_3 . N$)	station number	($F_2 + F_3 . N$)	station number	($F_2 + F_3 . N$)
1 SR3	0.10017986E-02	22 SR3	0.10016070E-02	43 SR3	0.98565704E-03
2 SR3	0.10018094E-02	23 SR3	0.10015236E-02	44 SR3	0.98567241E-03
3 SR3	0.10018203E-02	24 SR3	0.10015475E-02	45 SR3	0.98602552E-03
4 SR3	0.10016164E-02	25 SR3	0.10015713E-02	46 SR3	0.98602485E-03
5 SR3	0.10016170E-02	26 SR3	0.10027077E-02	47 SR3	0.98602419E-03
6 SR3	0.10016175E-02	27 SR3	0.10027427E-02	48 SR3	0.98602352E-03
7 SR3	0.10016181E-02	28 SR3	0.10027777E-02	49 SR3	0.98699211E-03
8 SR3	0.10016187E-02	29 SR3	0.10032560E-02	50 SR3	0.98694488E-03
9 SR3	0.10016192E-02	30 SR3	0.10032164E-02	51 SR3	0.98689766E-03
10 SR3	0.10016698E-02	31 SR3	0.10031768E-02	52 SR3	0.98685043E-03
11 SR3	0.10016951E-02	32 SR3	0.10004783E-02	53 SR3	0.98474860E-03
12 SR3	0.10017204E-02	33 SR3	0.10004875E-02	54 SR3	0.98471245E-03
13 SR3	0.10017457E-02	34 SR3	0.10004967E-02	55 SR3	0.98467630E-03
14 SR3	0.10017710E-02	35 SR3	0.10005059E-02	56 SR3	0.98464014E-03
15 SR3	0.10018102E-02	36 SR3	0.98407325E-03	57 SR3	0.98640489E-03
16 SR3	0.10018987E-02	37 SR3	0.98405939E-03	58 SR3	0.98637203E-03
17 SR3	0.10019873E-02	38 SR3	0.98404554E-03	59 SR3	0.98633916E-03
18 SR3	0.10015896E-02	39 SR3	0.98403168E-03	60 SR3	0.98393012E-03
19 SR3	0.10015939E-02	40 SR3	0.98401782E-03	61 SR3	0.98394972E-03
20 SR3	0.10015983E-02	41 SR3	0.98562632E-03	62 SR3	0.98396933E-03
21 SR3	0.10016026E-02	42 SR3	0.98564168E-03	63 SR3	0.98398893E-03
1 P11	0.98573522E-03	23 P11	0.98586762E-03	44 P11	0.98778147E-03
2 P11	0.98574878E-03	24 P11	0.98586102E-03	45 P11	0.98769441E-03
3 P11	0.98576233E-03	25 P11	0.98585441E-03	46 P11	0.98760735E-03
4 P11	0.98612425E-03	26 P11	0.98584781E-03	47 P11	0.98752030E-03
5 P11	0.98612350E-03	27 P11	0.98603559E-03	48 P11	0.98652630E-03
6 P11	0.98612276E-03	28 P11	0.98604238E-03	49 P11	0.98655292E-03
7 P11	0.98612201E-03	29 P11	0.98604918E-03	50 P11	0.98657953E-03
8 P11	0.98612126E-03	30 P11	0.98605598E-03	51 P11	0.98660615E-03
9 P11	0.98612051E-03	31 P11	0.98606277E-03	52 P11	0.98523095E-03
10 P11	0.98610388E-03	32 P11	0.98552151E-03	53 P11	0.98518721E-03
11 P11	0.98608712E-03	33 P11	0.98549179E-03	54 P11	0.98514346E-03
12 P11	0.98607036E-03	34 P11	0.98546207E-03	55 P11	0.98390698E-03
13 P11	0.98605361E-03	35 P11	0.98543235E-03	56 P11	0.98373567E-03
14 P11	0.98621635E-03	36 P11	0.98504017E-03	57 P11	0.98451804E-03
15 P11	0.98620902E-03	37 P11	0.98507184E-03	58 P11	0.98458124E-03
16 P11	0.98648575E-03	38 P11	0.98510352E-03	59 P11	0.97875777E-03
17 P11	0.98654931E-03	39 P11	0.98572372E-03	60 P11	0.97850708E-03
18 P11	0.98607015E-03	40 P11	0.98575386E-03	61 P11	0.97763559E-03
19 P11	0.98606752E-03	41 P11	0.98578401E-03	62 P11	0.97783774E-03
20 P11	0.98606489E-03	42 P11	0.98685521E-03	63 P11	0.99041455E-03
21 P11	0.98605816E-03	43 P11	0.98693224E-03	64 P11	0.99093429E-03
22 P11	0.98578570E-03				

Table 15: CTD raw data scans, in the vicinity of artificial density inversions, flagged for special treatment. Note that the pressure listed is approximate only; the action taken is either to ignore the raw data scans for all further calculations, or to apply a linear interpolation over the region of the bad data scans. Causes of bad data, listed in the last column, are detailed in Appendix 2 (section A2.11.1); note that for P11, after station 54, preliminary dips were conducted to remove ice from the sensors. For the raw scan number ranges, the lowest and highest scans numbers are not included in the interpolate or ignore actions.

station number	approximate pressure (dbar)	raw scan numbers	action taken	reason
1 SR3	80; 842	3349-455; 30588-681	interpolate	wake effect
2 SR3	102; 120	8630-942; 9265-444	“	“ “
2 SR3	148	10133-43	interpolate	sal. spike in steep grad.
2 SR3	192	11304-14	ignore	“ “ “ “ “
3 SR3	158; 166;	8113-213; 8298-421;	interpolate	wake effect
3 SR3	222	10474-633 & 10647-785	“	“ “
3 SR3	872	26389-484	“	“ “
4 SR3	110; 150; 884	8148-228; 8985-9094; 22195-281	“	“ “
4 SR3	895	22364-431	ignore	“ “
5 SR3	952-962	23510-613 & 23681-832 & 23861-24012	interpolate	“ “
5 SR3	1438	34451-511	“	“ “
6 SR3	74	3396-504	ignore	“ “
6 SR3	78; 82	3598-715; 3744-842	interpolate	“ “
10 SR3	298	10797-801	ignore	sal. spike in steep grad.
12 SR3	120	7590-669	“	wake effect
14 SR3	986	22851-944	interpolate	“ “
16 SR3	158	5976-9	ignore	sal. spike in steep grad.
17 SR3	118	16181-297	“	wake effect
17 SR3	324	21501-59	interpolate	“ “
17 SR3	596	28138-43	ignore	fouling of cond. cell
18 SR3	742	16877-913	“	wake effect
20 SR3	74	4465-538	ignore	“ “
20 SR3	94; 108; 168	4872-913; 5134-99; 6288-377	interpolate	“ “
20 SR3	180	6554-71	“	sal. spike in steep grad.
20 SR3	224; 256; 280	7485-98; 8159-70; 8621-34	ignore	“ “ “ “ “
24 SR3	75	6527-94	“	wake effect
25 SR3	190; 203	9459-543; 9931-10052	“	“ “
25 SR3	198	9754-861	interpolate	“ “
27 SR3	90	5095-188	“	“ “
28 SR3	166	12240-345	ignore	“ “
28 SR3	172; 175	12418-543; 12562-655	interpolate	“ “
29 SR3	83; 94	9423-91; 9589-674	“	“ “
31 SR3	82; 84	5326-98; 5421-532	ignore	“ “
31 SR3	90; 131	5564-646; 6456-549	interpolate	“ “
32 SR3	372	11300-79	“	possible fouling
33 SR3	96	5512-45	ignore	wake effect
34 SR3	254	7224-90	“	“ “
37 SR3	84; 88	2658-775	“	“ “
39 SR3	84; 90	4598-635; 4725-71	“	“ “
43 SR3	84	4124-36	“	“ “
44 SR3	1686	41078-85	interpolate	bad data
47 SR3	2	1453-1667	ignore	bad data near surface
49 SR3	48	1668-2241	“	fouling of cond. cell
54 SR3	0	278-312	“	CTD out of water
55 SR3	859-bottom	17031 to bottom of downcast	“	fouling of cond. cell

<u>Table 15:</u> (continued)

station number	approximate pressure (dbar)	raw scan numbers	action taken	reason
9 P11	780	29906-54	ignore	fouling of cond. cell
11 P11	686	26295-403	interpolate	fouling of cond. cell
14 P11	70; 86	5514-86; 6087-178	ignore	wake effect
14 P11	74; 79; 83	5664-756; 5792-920; 5946-6049	interpolate	“ “
21 P11	1203	36619-50	ignore	fouling of cond. cell
22 P11	2	1013-15	“	bad data near surface
22 P11	69; 75	3541-605; 3664-745	“	wake effect
27 P11	126; 144	4572-615; 4920-75	“	“ “
33 P11	2	1595-9	“	bad data near surface
33 P11	86	4908-75	interpolate	wake effect
33 P11	97; 104	5321-413; 5530-607	ignore	“ “
35 P11	110	8136-293	“	fouling of cond. cell
36 P11	2	161-3	“	bad data near surface
36 P11	244	8200-351	interpolate	wake effect
38 P11	142; 148	6807-906; 6961-7056	ignore	“ “
40 P11	127; 134; 142	4210-62; 4324-466; 4515-648	“	“ “
40 P11	437	14845-915	“	“ “
42 P11	183	7189-293	“	“ “
44 P11	2	155-7	“	bad data near surface
44 P11	114	3694-764	“	wake effect
47 P11	84	4560-675	interpolate	“ “
47 P11	87; 93	4709-911; 5101-202	ignore	“ “
47 P11	2746-bottom	71144 to bottom of downcast	“	fouling of cond. cell
49 P11	2	1004-6	“	bad data near surface
50 P11	2	410-13	“	“ “ “
52 P11	2	1084-6	“	“ “ “
53 P11	2	61-3	“	“ “ “
54 P11	2	62-248	“	“ “ “
55 P11	0-100	1-18178	ignore	preliminary dip to 100 dbar
56 P11	0-100	1-9844	“	“ “ “
57 P11	0-100	1-13716	“	“ “ “
63 P11	0-100	1-5911	“	preliminary dip to 50 dbar
63 P11	664-659	26769-828	“	fouling on upcast

<u>Table 16:</u> Suspect *salinity* 2 dbar averages.

station number		suspect 2 dbar values (dbar) bad	questionable	reason
3	SR3	68	-	salinity spike in thermocline
5	SR3	80	-	" "
5	SR3	1442	-	salinity spike in steep local gradient
9	SR3	1024	-	" " "
11	SR3	-	78-82	salinity spike in thermocline
21	SR3	-	74-78	" "
23	SR3	-	70-78	" "
24	SR3	-	72-76	" "
25	SR3	72-74	70	" "
26	SR3	76-80,88-90	-	" "
27	SR3	86-88	82-84	" "
28	SR3	80-82	84	" "
29	SR3	80-86,94	-	" "
30	SR3	76-78	80	" "
31	SR3	80-84	78,92	" "
32	SR3	92-96	98	" "
33	SR3	94-96	90-92	" "
34	SR3	96-98	92-94	" "
35	SR3	86-88	-	" "
37	SR3	82	-	" "
39	SR3	88	-	" "
40	SR3	84	-	" "
42	SR3	86-88	-	" "
43	SR3	86	-	" "
45	SR3	-	82	" "
22	P11	72	-	salinity spike in thermocline
36	P11	112	-	" "
40	P11	434	-	salinity spike in steep local gradient
44	P11	-	114	salinity spike in thermocline
54	P11	78-82	84	wake effect in thermocline
64	P11	-	44-88	possible fouling

Table 17a: Suspect 2 dbar-averaged data from near the surface (applies to all parameters, except where noted).

station number	suspect 2 dbar values (dbar) bad	questionable	comment
1-2 SR3	-	2	
4 SR3	-	2	
13 SR3	-	2	
16 SR3	-	2	
19 SR3	-	2-8	temperature ok
20-21 SR3	-	2	
24 SR3	-	2	
26 SR3	-	2	
28-31 SR3	-	2	
33 SR3	-	2	
36-38 SR3	-	2-4	
39-43 SR3	-	2	
44 SR3	-	2-4	
45 SR3	-	2	
46 SR3	-	2-4	
47 SR3	-	2	
48 SR3	-	2-4	
49 SR3	-	2-6	
50 SR3	-	2-22	possible fouling
52-53 SR3	-	2	
55 SR3	-	2	
59 SR3	-	2	
60 SR3	-	2-4	
61-62 SR3	-	2	
12 P11	2	-	
13 P11	-	2	
15 P11	-	2-6	temperature ok
21-23 P11	-	2	
29 P11	-	2	
30 P11	-	2-10	temperature ok
31-32 P11	-	2-8	
33 P11	-	2	
34-35 P11	-	2-4	
36-38 P11	-	2	
39 P11	-	2-4	
42 P11	-	2	
43 P11	-	2-6	
44 P11	2-32	-	fouling
45 P11	2-14	-	fouling
46 P11	2-10	-	fouling
47 P11	2-6	-	fouling
48 P11	2	4-6	
49 P11	-	2	
50 P11	2-14	-	
51 P11	-	2-4	
52-54 P11	-	2-6	

Table 17b: Suspect 2 dbar-averaged dissolved oxygen data from near the surface.

station number	suspect dissolved oxygen 2 dbar values (dbar) bad	questionable
4 SR3	-	2-40
7 SR3	-	2-18
15 SR3	-	2-24
16 SR3	2-62	-
19 SR3	-	2-46
20 SR3	2-24	-
26 SR3	-	2-44
27 SR3	-	2-14
28 SR3	2-20	-
29 SR3	-	2-48
30 SR3	-	2-46
31 SR3	-	2-46
32 SR3	2-12	14-18
33 SR3	2-12	14-48
34 SR3	2-10	12-48
35 SR3	-	2-12

Table 18: **2 dbar averages interpolated from surrounding 2 dbar values (applies to all parameters).**

station number	interpolated 2 dbar values (dbar)	station number	interpolated 2 dbar values (dbar)
1 SR3	80,846	11 P11	686,688
2 SR3	104,120,122,148	14 P11	76,80,84
3 SR3	158,166,222,224,226,876	33 P11	88
4 SR3	110,150,886	36 P11	244,246
5 SR3	952,954,960,964,1438	40 P11	130,136,144,440
6 SR3	80,84	47 P11	86
14 SR3	986,988		
17 SR3	326		
20 SR3	96,110,172,182		
25 SR3	200		
27 SR3	92		
28 SR3	174,178		
29 SR3	84,94		
31 SR3	90,134		
32 SR3	374,376,378		
44 SR3	1686		

Table 19: **2 dbar-averaged data for which there is no dissolved oxygen data.**

station number	pressures (dbar) where dissolved oxygen data is missing
1 SR3	no dissolved oxygen data for entire station
9 SR3	346 to 360 (bad data, removed from 2 dbar file)
13 SR3	822 to 4166 (bad data, removed from 2 dbar file)
28 SR3	104
36 to 63 SR3	no disssolved oxygen data for entire station
1 to 64 P11	no dissolved oxygen data for entire station

Table 20: **CTD dissolved oxygen calibration coefficients. K_1, K_2, K_3, K_4, K_5 and K_6 are respectively oxygen current slope, oxygen sensor time constant, oxygen current bias, temperature correction term, weighting factor, and pressure correction term. dox is equal to 2.8σ (for σ defined as in eqn A2.27); n is the number of samples retained for calibration in each station or station grouping.**

station number (SR3)	K_1	K_2	K_3	K_4	K_5	K_6	dox	n
2	2.0274	8.0000	0.010	-0.17132E-01	0.75000	0.15000E-03	0.15755	8
3	2.0110	8.0000	0.009	-0.13799E-01	1.88960	0.24338E-03	0.14222	11
4	2.7177	8.0000	-0.103	-0.42809E-01	-0.23938	0.20380E-03	0.15926	14
5	2.1200	8.0000	0.022	-0.24495E-01	0.76225	0.14176E-03	0.15091	21
6	2.2364	8.0000	0.001	-0.29764E-01	0.72814	0.14337E-03	0.09138	21
7	2.1626	8.0000	-0.006	-0.29297E-01	0.32787	0.14602E-03	0.14403	21
8	2.3164	8.0000	-0.064	-0.40570E-01	0.73754	0.14970E-03	0.14250	20
9	1.6075	8.0000	-0.042	-0.26481E-01	0.19379	0.12127E-03	0.15818	20
10	1.3971	8.0000	-0.036	-0.16300E-01	0.90868	0.13229E-03	0.19734	24
11	1.3144	8.0000	-0.105	-0.18048E-01	1.16040	0.11158E-03	0.24851	21
12	1.3226	8.0000	-0.064	-0.17154E-01	1.22800	0.75203E-04	0.34541	21
13	1.7061	8.0000	-0.077	-0.40801E-01	0.92952	-0.69989E-04	0.35414	8
14	1.9428	8.0000	0.042	-0.25338E-01	0.85151	0.14716E-03	0.20176	15
15	2.4379	8.0000	-0.028	-0.36510E-01	0.58714	0.15051E-03	0.15346	23
16	2.4229	8.0000	-0.017	-0.35613E-01	0.71932	0.14756E-03	0.09936	17
17	2.1960	8.0000	0.012	-0.24537E-01	0.63182	0.14800E-03	0.13343	21
18	2.4823	8.0000	-0.033	-0.39815E-01	0.45117	0.15443E-03	0.10719	21
19	1.9844	8.0000	0.049	-0.12796E-01	1.00540	0.14438E-03	0.13158	20
20	2.4533	8.0000	-0.014	-0.41319E-01	0.49795	0.14375E-03	0.13144	22
21	2.1079	8.0000	0.040	-0.35278E-01	0.01040	0.14420E-03	0.18382	21
22	2.2612	8.0000	0.006	-0.32143E-01	0.44994	0.15311E-03	0.16557	22
23	2.3880	8.0000	-0.013	-0.38390E-01	0.23562	0.14765E-03	0.12333	20
24	2.5164	8.0000	-0.050	-0.34064E-01	1.29880	0.16609E-03	0.10001	19
25	2.4740	8.0000	-0.027	-0.40397E-01	0.62429	0.14327E-03	0.08337	22
26	2.1406	8.0000	0.008	-0.14545E-01	0.73058	0.16129E-03	0.10123	16
27	2.3617	8.0000	-0.009	-0.36968E-01	0.49548	0.14765E-03	0.13378	17
28	2.4899	8.0000	-0.032	-0.39682E-01	0.57692	0.15114E-03	0.11739	18
29	2.3508	8.0000	-0.024	-0.22407E-01	0.88302	0.15834E-03	0.17424	20
30	2.4132	8.0000	-0.007	-0.39170E-01	0.28909	0.14126E-03	0.13782	22
31	2.1545	8.0000	0.040	-0.30173E-01	0.24521	0.13766E-03	0.18215	21
32	2.4132	8.0000	-0.014	-0.36240E-01	0.78105	0.15136E-03	0.11923	20
33-35	2.2272	8.0000	0.012	-0.21553E-01	0.56467	0.15220E-03	0.10213	40

Table 21: **Starting values for CTD dissolved oxygen calibration coefficients prior to iteration, and coefficients varied during iteration (sections A2.12.1 and A2.12.3). Note that coefficients not varied during iteration are held constant at the starting value.**

station number (SR3)	K_1	K_2	K_3	K_4	K_5	K_6	coefficients varied
2	2.3000	8.0000	0.010	-0.200E-01	0.750	0.15000E-03	K_1 K_4
3	2.4000	8.0000	0.010	-0.200E-01	0.750	0.15000E-03	K_1 K_3 K_4 K_5 K_6
4	2.6000	8.0000	-0.050	-0.500E-01	0.100	0.15000E-03	K_1 K_3 K_4 K_5 K_6
5	2.3000	8.0000	0.000	-0.360E-01	0.750	0.15000E-03	K_1 K_3 K_4 K_5 K_6
6	2.3000	8.0000	0.000	-0.360E-01	0.750	0.15000E-03	K_1 K_3 K_4 K_5 K_6
7	2.1000	8.0000	0.000	-0.300E-01	0.750	0.15000E-03	K_1 K_3 K_4 K_5 K_6
8	2.2000	8.0000	-0.020	-0.360E-01	0.750	0.15000E-03	K_1 K_3 K_4 K_5 K_6
9	1.5000	8.0000	-0.020	-0.300E-01	0.750	0.15000E-03	K_1 K_3 K_4 K_5 K_6
10	1.5000	8.0000	0.010	-0.360E-01	0.750	0.15000E-03	K_1 K_3 K_4 K_5 K_6
11	1.3300	8.0000	-0.020	-0.300E-01	1.000	0.00000	K_1 K_3 K_4 K_5 K_6
12	1.3400	8.0000	-0.020	-0.200E-01	0.750	0.00000	K_1 K_3 K_4 K_5 K_6
13	1.5000	8.0000	0.030	-0.300E-01	0.750	0.00000	K_1 K_3 K_4 K_5 K_6
14	2.0000	8.0000	0.100	-0.300E-01	0.750	0.15000E-03	K_1 K_3 K_4 K_5 K_6
15	2.4500	8.0000	0.000	-0.360E-01	0.750	0.15000E-03	K_1 K_3 K_4 K_5 K_6
16	2.4000	8.0000	0.000	-0.360E-01	0.750	0.15000E-03	K_1 K_3 K_4 K_5 K_6
17	2.3000	8.0000	0.000	-0.360E-01	0.750	0.15000E-03	K_1 K_3 K_4 K_5 K_6
18	2.4000	8.0000	0.000	-0.360E-01	0.750	0.15000E-03	K_1 K_3 K_4 K_5 K_6
19	2.3000	8.0000	0.160	-0.300E-01	0.750	0.15000E-03	K_1 K_3 K_4 K_5 K_6
20	2.4000	8.0000	0.000	-0.400E-01	0.750	0.15000E-03	K_1 K_3 K_4 K_5 K_6
21	2.5000	8.0000	-0.010	-0.360E-01	0.750	0.15000E-03	K_1 K_3 K_4 K_5 K_6
22	2.2000	8.0000	0.000	-0.360E-01	0.750	0.15000E-03	K_1 K_3 K_4 K_5 K_6
23	2.3500	8.0000	0.000	-0.360E-01	0.750	0.15000E-03	K_1 K_3 K_4 K_5 K_6
24	2.5000	8.0000	-0.080	-0.360E-01	0.750	0.15000E-03	K_1 K_3 K_4 K_5 K_6
25	2.4500	8.0000	-0.020	-0.360E-01	0.750	0.15000E-03	K_1 K_3 K_4 K_5 K_6
26	2.3000	8.0000	0.010	-0.300E-01	0.750	0.15000E-03	K_1 K_3 K_4 K_5 K_6
27	2.3500	8.0000	0.000	-0.360E-01	0.750	0.15000E-03	K_1 K_3 K_4 K_5 K_6
28	2.4000	8.0000	-0.030	-0.360E-01	0.750	0.15000E-03	K_1 K_3 K_4 K_5 K_6
29	2.3000	8.0000	0.000	-0.360E-01	0.750	0.15000E-03	K_1 K_3 K_4 K_5 K_6
30	2.3000	8.0000	0.000	-0.400E-01	0.750	0.15000E-03	K_1 K_3 K_4 K_5 K_6
31	2.1000	8.0000	0.000	-0.360E-01	0.750	0.15000E-03	K_1 K_3 K_4 K_5 K_6
32	2.5000	8.0000	0.000	-0.360E-01	0.750	0.15000E-03	K_1 K_3 K_4 K_5 K_6
33-35	2.2000	8.0000	0.000	-0.360E-01	0.750	0.15000E-03	K_1 K_3 K_4 K_5 K_6

Table 22: **Questionable dissolved oxygen Niskin bottle sample values (not deleted from hydrology data file).**

station number	rosette position	station number	rosette position
		5 P11	17
1 SR3	1,16,20,23	7 P11	14
3 SR3	1	16 P11	4
8 SR3	4	25 P11	5
9 SR3	14,21	30 P11	11
22 SR3	24	51 P11	8,13
24 SR3	19	52 P11	7
41 SR3	9	53 P11	13,23,24
58 SR3	1	58 P11	10

Table 23: **Questionable nutrient sample values (not deleted from hydrology data file).**

PHOSPHATE		NITRATE		SILICATE	
station number	rosette position	station number	rosette position	station number	rosette position
		4 SR3	20		
5 SR3	7			5 SR3	24
				12 SR3	21,22,23,24
16 SR3	whole station				
17 SR3	whole station				
20 SR3	3	20 SR3	3	20 SR3	3
29 SR3	20				
42 SR3	1				
		54 SR3	whole station		
				58 SR3	3
				60 SR3	3
				4 P11	8
				7 P11	6,7,8
				10 P11	9
13 P11	4	13 P11	4	13 P11	4,7
		24 P11	1		
26 P11	4	26 P11	4		
30 P11	11	30 P11	11	30 P11	11
				36 P11	22,24
45 P11	5	45 P11	5	45 P11	5
47 P11	2	47 P11	2	47 P11	2
48 P11	14	48 P11	10,14	48 P11	10
		49 P11	10		
53 P11	13,19	53 P11	1,13,19	53 P11	13
54 P11	3	54 P11	3		
		55 P11	17		
60 P11	16,17	60 P11	10,13		

Table 24: Laboratory temperatures T_l at the times of dissolved oxygen analyses. Values marked ** are values estimated from temperatures for surrounding stations.

stn no.	T_l (^{o}C)	stn no.	T_l (^{o}C)	stn no.	T_l (^{o}C)	stn no.	T_l (^{o}C)	stn no.	T_l (^{o}C)	stn no.	T_l (^{o}C)
1 SR3	20**	12 SR3	20**	23 SR3	16	34 SR3	20	45 SR3	21	56 SR3	17
2 SR3	20**	13 SR3	20**	24 SR3	16**	35 SR3	-	46 SR3	20.1	57 SR3	17
3 SR3	20**	14 SR3	19.5**	25 SR3	19.5	36 SR3	19**	47 SR3	20.1	58 SR3	17
4 SR3	20**	15 SR3	19.5	26 SR3	20	37 SR3	-	48 SR3	18	59 SR3	17
5 SR3	20**	16 SR3	19.5	27 SR3	19.5	38 SR3	19**	49 SR3	18	60 SR3	17**
6 SR3	20**	17 SR3	18.5	28 SR3	18.5**	39 SR3	-	50 SR3	18	61 SR3	17**
7 SR3	20**	18 SR3	18.5	29 SR3	18.5	40 SR3	18	51 SR3	18	62 SR3	17**
8 SR3	20**	19 SR3	19	30 SR3	18.5	41 SR3	18	52 SR3	18	63 SR3	17**
9 SR3	20**	20 SR3	19	31 SR3	19**	42 SR3	17.5	53 SR3	18		
10 SR3	20**	21 SR3	19	32 SR3	19.5	43 SR3	17.5	54 SR3	11		
11 SR3	20**	22 SR3	16	33 SR3	20	44 SR3	21	55 SR3	11		
1 P11	25**	12 P11	24	23 P11	23.5	34 P11	24**	45 P11	23	56 P11	16.5
2 P11	25**	13 P11	22	24 P11	23	35 P11	23.5	46 P11	19.5	57 P11	16.5
3 P11	25**	14 P11	22**	25 P11	23	36 P11	23	47 P11	19.5**	58 P11	16.5
4 P11	25	15 P11	27	26 P11	23**	37 P11	23**	48 P11	16.5	59 P11	16.5
5 P11	25	16 P11	27	27 P11	23	38 P11	23**	49 P11	16.5**	60 P11	17
6 P11	25**	17 P11	24	28 P11	23**	39 P11	-	50 P11	18.5**	61 P11	17
7 P11	25**	18 P11	24	29 P11	25	40 P11	23**	51 P11	18.5**	62 P11	17
8 P11	-	19 P11	24	30 P11	25**	41 P11	23**	52 P11	18.5	63 P11	22
9 P11	23.5	20 P11	24**	31 P11	25**	42 P11	23**	53 P11	17.5**	64 P11	22**
10 P11	24**	21 P11	23.5**	32 P11	25**	43 P11	23**	54 P11	16.5**		
11 P11	24**	22 P11	23.5**	33 P11	24.5	44 P11	23**	55 P11	16.5**		

Table 25: **Laboratory temperatures T_l at the times of nutrient analyses, used for conversion to gravimetric units for WOCE format data (Appendix 7). Note that all these values are estimated by interpolation between the Table 24 values at the times of nutrient analyses.**

stn no.	T_l (^{o}C)	stn no.	T_l (^{o}C)	stn no.	T_l (^{o}C)	stn no.	T_l (^{o}C)	stn no.	T_l (^{o}C)	stn no.	T_l (^{o}C)
1 SR3	19.5	12 SR3	16n,p	21 SR3	19.5	32 SR3	20	43 SR3	21	56 SR3	24
2 SR3	18.5n,p	12 SR3	24s	22 SR3	18.5	33 SR3	20p,s	44 SR3	21	57 SR3	24
2 SR3	22s	13 SR3	16	23 SR3	18.5	33 SR3	22n	45 SR3	21	58 SR3	24
3 SR3	18.5n,p	14 SR3	16	24 SR3	19	34 SR3	19	46 SR3	21	59 SR3	24
3 SR3	22s	15 SR3	16	25 SR3	19	35 SR3	-	47 SR3	21	60 SR3	24
4 SR3	18.5	16 SR3	16n,s	26 SR3	19	36 SR3	19	48 SR3	18	61 SR3	24
5 SR3	18.5	16 SR3	27p	27 SR3	19	37 SR3	-	49 SR3	18	62 SR3	24
6 SR3	19	17 SR3	16n,s	28 SR3	27	38 SR3	19p,s	50 SR3	18	63 SR3	24
7 SR3	19	17 SR3	27p	29 SR3	27n,p	38 SR3	22n	51 SR3	18		
8 SR3	19	18 SR3	16	29 SR3	24s	39 SR3	-	52 SR3	18		
9 SR3	19	19 SR3	19.5n,s	30 SR3	20n,p	40 SR3	21	53 SR3	18		
10 SR3	19	19 SR3	24p	30 SR3	22s	41 SR3	21	54 SR3	18		
11 SR3	19	20 SR3	19.5	31 SR3	20	42 SR3	21	55 SR3	18		
1 P11	24	12 P11	25	23 P11	23	34 P11	19.5	45 P11	16.5	56 P11	22
2 P11	24	13 P11	24.5	24 P11	23	35 P11	16.5	46 P11	17	57 P11	22
3 P11	24	14 P11	24.5	25 P11	23	36 P11	17.5	47 P11	17	58 P11	22
4 P11	24	15 P11	24	26 P11	23	37 P11	16.5	48 P11	17	59 P11	22
5 P11	23.5	16 P11	24	27 P11	23	38 P11	16.5	49 P11	22	60 P11	22
6 P11	23.5	17 P11	24	28 P11	23	39 P11	-	50 P11	22	61 P11	22
7 P11	24	18 P11	24	29 P11	23	40 P11	16.5	51 P11	22	62 P11	22
8 P11	-	19 P11	23.5	30 P11	18.5	41 P11	16.5	52 P11	22	63 P11	22
9 P11	24	20 P11	23.5	31 P11	18.5	42 P11	16.5	53 P11	22	64 P11	-
10 P11	24	21 P11	23.5	32 P11	18.5	43 P11	16.5	54 P11	22		
11 P11	24	22 P11	23	33 P11	16.5	44 P11	16.5	55 P11	22		

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APPENDIX 1 CTD Instrument Calibrations

Table A1.1: **Calibration coefficients from pressure and platinum temperature sensor calibrations for the 2 CTD units used during RSV Aurora Australis cruise AU9309/AU9391. Note that for each station, the pressure calibration offset coefficients (i.e. pdcal1 and pucal1) are reset according to the surface pressure offset (see section A2.6.2, Appendix 2). Also note that temperature calibrations are for the ITS-90 scale.**

coefficient	CTD unit 1 (serial 1073)	CTD unit 4 (serial 1197)
pressure calibration coefficients (after terminology of eqns A2.1 to A2.5, Appendix 2)		
pdcal1	-9.9636e-02	-8.3917
pdcal2	8.6203e-03	8.4561e-03
pdcal3	-1.3318e-05	-1.3702e-05
pdcal4	7.4695e-09	6.7540e-09
pdcal5	-1.6429e-12	-1.3336e-12
pdcal6	1.2231e-16	9.2391e-17
pucal1	-0.6203	-8.4082
pucal2	-2.6182e-03	-5.3668e-03
pucal3	-1.6092e-06	-3.1088e-06
pucal4	2.7248e-09	3.7279e-09
pucal5	-7.8409e-13	-9.6233e-13
pucal6	6.5036e-17	7.6358e-17
platinum temperature calibration coefficients (after terminology of eqn A2.6, Appendix 2)		
Tcal1	8.0015e-03	3.3504e-06
Tcal2	9.9952e-01	9.9966e-01

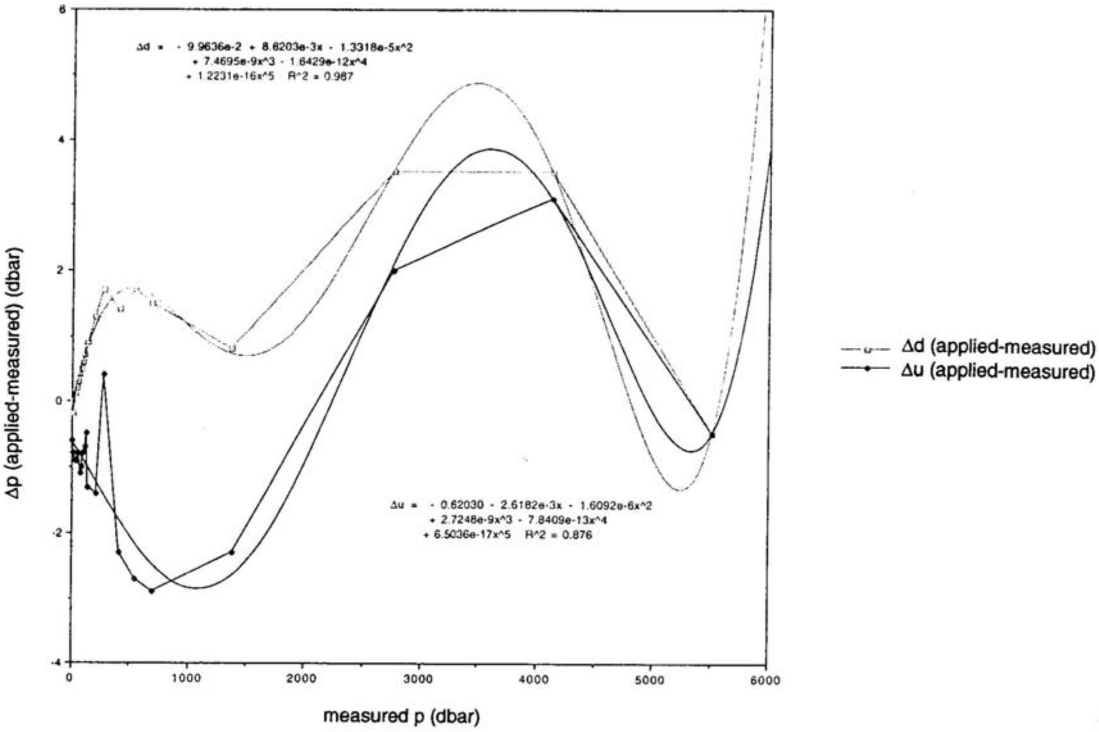
Table A1.2: **Platinum temperature calibration data. All temperatures and corrections are determined in terms of the ITS-90 scale. The amount shown as the correction is the amount to be added to the CTD reading at that temperature.**

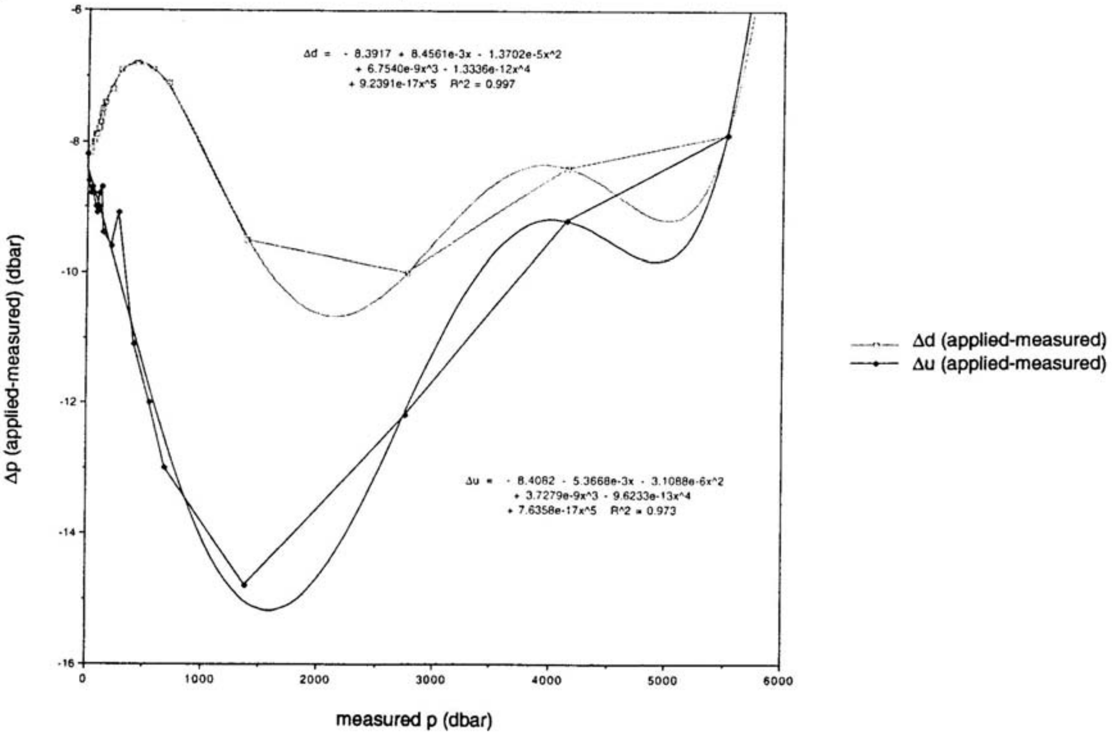
CTD unit 1 (serial 1073)

date	correction	temperature	99% confidence interval
18/5/93	0.008°C	0.011°C	0.003°C
18/5/93	0.008°C	0.011°C	0.003°C
19/5/93	-0.005°C	26.862°C	0.005°C
19/5/93	-0.005°C	26.862°C	0.005°C

CTD unit 4 (serial 1197)

date	correction	temperature	99% confidence interval
11/92	0.000°C	0.010°C	0.003°C
11/92	-0.009°C	26.860°C	0.005°C


(a) **CTD unit 1 (serial no. 1073)**


(b) **CTD unit 4 (serial no. 1197)**

<u>Figure A1.1a and b:</u> Pressure sensor calibration data, for down and upcast calibrations. In the figures, Δd is for downcast data, and Δu is for upcast data (calibrated August 1991).

APPENDIX 2 CTD and Hydrology Data Processing and Calibration Techniques

ABSTRACT

Complete details are presented of the calibration and data processing techniques used to generate calibrated and quality controlled CTD 2 dbar-averaged data, and hydrology data. Attention is given to the order in which the various calculations and corrections are applied, as any variation will affect the final data values produced.

A2.1 INTRODUCTION

This Appendix details the data processing and calibration techniques employed in the production of the final CTD data set on shore. Logging of the data at sea is discussed in the main text. The different sections in this Appendix, and the description within each section, are ordered to match the steps in the data processing flow. Most of the data processing software is written in FORTRAN.

Data sets for different cruises may vary in the specifications of the CTD (Tables 7 and 8 in the main text), and in the parameters generated. The generality of this description is retained so that it will be applicable to future data sets. Thus, the processing of a CTD raw data stream which includes pressure, temperature, conductivity, oxygen current, oxygen temperature, and additional digitiser channels (e.g. fluorescence, photosynthetically active radiation, etc.) (Table 8) is detailed here. For the cruise described in this report (AU9309/AU9391), no additional digitiser channels were active. For future cruise data sets, any variation in the processing and calibration techniques described here will be detailed in the data report attached to the data set.

A2.2 DATA FILE TYPES

The various data files used throughout the data calibration procedure on shore (and produced by it) are outlined below. A complete description of final calibrated data files is given in Appendix 4.

A2.2.1 CTD data files

Throughout this report, three types of CTD file are referred to:

(i) raw CTD files, which contain the complete CTD data prior to removal of pressure reversals, and prior to averaging; note that a data scan refers to one complete data line containing all the logged parameters - thus the raw data is logged at N data scans per second, where N is the scanning frequency (Table 8);

(ii) intermediate CTD files prior to 2 dbar averaging, despiked and with sensor lags applied, and with pressure reversals removed for downcast data;

(iii) 2 dbar-averaged CTD files, which contain the CTD data averaged over 2 dbar bins.

The CTD filenames are of the form vyyccusss.xxx:n (e.g. a93094046.raw:1) where

v = vessel (e.g. "a" for Aurora Australis)
yy = year (e.g. 93)
cc = cruise number (e.g. 09)
u = CTD unit number (i.e. instrument number) (e.g. 4)

sss = station number (e.g. 046)
xxx = file type (e.g. "raw" for raw data file)
n = dip number (i.e. 1 for downcast data, 2 for upcast burst data) (does not apply to 2 dbar-averaged files)

The various file suffixes (xxx in the above naming convention) are

raw = raw data file
cda = intermediate data file, which is the raw data file despiked and with pressure reversal removed, and with appropriate data lagging applied between parameters
unc = uncalibrated 2 dbar-averaged file
ave = calibrated (except for dissolved oxygen) 2 dbar-averaged file
oxy = same as ave, but including the oxygen current derivative with respect to time (for the calibration of dissolved oxygen)
all = final calibrated 2 dbar-averaged file (with or without dissolved oxygens)

A2.2.2 Hydrology data files

The final hydrology data file produced on shore contains the Niskin bottle data, output from the hydrology data processing program “HYDRO” (Appendix 3), merged with averages calculated from upcast CTD burst data. The file is named vyycc.bot (e.g. a9309.bot), where v, yy and cc are as above in the CTD file naming convention. During the CTD calibration procedure, intermediate hydrology data files are produced, named calib.dat:nn (e.g. 01), where "nn" is the version number. In general, the later version numbers are for more advanced stages in the quality control of Niskin bottle data.

A2.2.3 Station information file

This file contains station information, including position, time, depth etc. The file is named vyycc.sta (e.g. a9309.sta), where v, yy and cc are as above.

A2.3 STATION HEADER INFORMATION

Position: All station position information is derived from the quality controlled GPS underway measurement data set (Section 4.2, and Appendix 4).

Bottom depth: On the Aurora Australis, bow thrusters are used to maintain station. Unfortunately, the turbulence caused by the thrusters interferes with the echo sounder readings, so that the digital output from the sounder is unusable while thrusters are engaged on station. Depths while on station (Table 2) are obtained by reading the echo sounder printout, and are entered manually to the CTD data logging PC at sea. The automatically logged underway depth measurements immediately before and after station (i.e. when the bow thrusters are not in operation) are later used to check the plausibility of the manually entered values.

Times: All start and end times recorded in the header information are stamped automatically by the CTD data acquisition program at the start and end of CTD data logging. Times are derived from the internal clock on the logging PC; this clock is independent of the ship’s main time log, but is checked prior to each station. Bottom times (i.e. time at the bottom of the CTD cast) are as recorded manually at the bottom of each cast during data logging.

A2.4 CONVERTING SHIP-LOGGED RAW DATA FILES FOR SHORE-DATA PROCESSING

For the CTD instruments used on the Aurora Australis, the raw binary data files (as logged by the PC system on board the ship) are fixed record length binary files consisting of data scans, length n bytes, arranged in records with a length of 129 bytes. The value of n is fixed for each CTD instrument (Table 8). The last byte of each 129 byte record is a record end byte. All further CTD data processing on shore is carried out on a Unix system. After transferring the files to the Unix system, the raw binary files are reformatted to generate Unix format unformatted files. During this conversion, the record length is checked by confirming the placement of the record end byte every 129 bytes. Occasionally a record is found with less than 129 bytes, due to missing bytes in the original data logging. For these cases, the records are padded out to 129 bytes using null bytes at the end of the record (prior to the record end byte). Up to 8 missing bytes in a record are allowed at this stage; if more bytes are missing from the record, the entire record is skipped and the bad record is noted (Table 10).

Two files are generated during the conversion of the raw data files to Unix unformatted files:

vyyccusss.raw:1 (also known as the "dip 1" file) e.g. a93091046.raw:1
vyyccusss.raw:2 (also known as the "dip 2" file) e.g. a93091046.raw:2

The dip 1 file contains the CTD data (uncalibrated), where only the downcast data has been preserved (down to the maximum pressure value recorded by the pressure sensor prior to the first Niskin bottle firing.) The dip 2 file contains CTD data bursts extracted from the upcast portion of the data at times corresponding to Niskin bottle firings. At each bottle firing, the 5 seconds of CTD data previous to the firing is stored in the dip 2 file.

A2.5 PRODUCING THE DATA PROCESSING MASTER FILE

A master file named "ctdmaster.sho" is created as a template from CTD header information. This file stores all data processing and calibration information, including station header details (e.g. positions, times, maximum pressure etc.), calibration coefficients, calibration status, and digitiser channel information. The master file is automatically updated by the data processing and calibration programs at all stages of the calibration procedure.

A2.6 CALCULATION OF PARAMETERS

The CTD pressure and temperature sensor calibration coefficients (Appendix 1) are written to the master file. The conductivity and dissolved oxygen sensors are calibrated entirely from cruise Niskin bottle data, thus final conductivity and dissolved oxygen calibration coefficients are not included till a later stage in the processing. Note that for pressure, temperature, conductivity, salinity and parameters for additional digitiser channels, all calculations (including application of calibration coefficients) are performed on the complete raw data prior to averaging into 2 dbar intervals. The calibration of dissolved oxygen data is performed on the 2 dbar averaged data only.

A2.6.1 Surface pressure offset

The point at which the CTD enters the water is found by identifying the first conductivity value greater than 10 mS/cm. The second data scan after this is then nominated as the first "in water" value. The value of the pressure for this scan is usually slightly greater than or less than zero, due both to atmospheric pressure variation, and to small calibration drift in the pressure sensor. The surface pressure offset value, equal to -1 times the pressure reading when the CTD enters the water, is retained for each station (Table 11), and each offset is added to all pressure values for the station.

A2.6.2 Pressure calculation

A fifth order polynomial fit is used for calibration of pressure data. Due to hysteresis in the pressure sensor response, a different polynomial is required for each of the two cases of pressure increasing and pressure decreasing (Appendix 1). Thus there are six pressure calibration coefficients for downcast data, and another six for upcast data. For downcast data, calibrated pressure p is given by

$$p = p_{ctd} + pdcal1 + pdcal2.p_{ctd} + pdcal3.p_{ctd}^2 + pdcal4.p_{ctd}^3 + pdcal5.p_{ctd}^4 + pdcal6.p_{ctd}^5 \quad \text{(eqn A2.1)}$$

where pdcal1 to pdcal6 are the downcast pressure calibration coefficients, and p_{ctd} is the raw pressure p_{raw} output by the CTD and converted to approximate engineering units by

$$p_{ctd} = p_{raw} / 10 \quad \text{(eqn A2.2)}$$

The CTD pressure is calibrated over the range 0 to 5515 dbar. No greater pressures were reached during the cruise. For casts that do not reach the maximum pressure of the calibration (i.e. 5515 dbar), a transition is required between the down and upcast pressure calibrations when calculating pressures from upcast data. This is achieved by applying an exponential decay "feathering" between the downcast and upcast calibration polynomials over the first 300 dbar of the upcast. Thus the upcast pressure data are calibrated as follows:

$$p = p_{ctd} + p_2 + (p_1 - p_2) \,.\, \exp[- (p_{max} - p_{ctd}) / 300] \quad \text{(eqn A2.3)}$$

where p_{max} is the maximum pressure in the cast, and where

$$p_1 = pdcal1 + pdcal2.p_{ctd} + pdcal3.p_{ctd}^2 + pdcal4.p_{ctd}^3 + pdcal5.p_{ctd}^4 + pdcal6.p_{ctd}^5 \quad \text{(eqn A2.4)}$$

and

$$p_2 = pucal1 + pucal2.p_{ctd} + pucal3.p_{ctd}^2 + pucal4.p_{ctd}^3 + pucal5.p_{ctd}^4 + pucal6.p_{ctd}^5 \quad \text{(eqn A2.5)}$$

for upcast pressure calibration coefficients pucal1 to pucal6. Note that

pucal1 = pdcal1 = surface pressure offset.

A2.6.3 Temperature calculation

CTD temperature values are in terms of the International Temperature Scale of 1990 (ITS-90). A linear fit is used for calibration of the temperature data, as follows:

$$T = Tcal1 + Tcal2 \,.\, T_{ctd} \quad \text{(eqn A2.6)}$$

where T is the calibrated temperature, Tcal1 and Tcal2 are temperature calibration coefficients (Appendix 1), and T_{ctd} is the raw temperature T_{raw} output by the CTD and converted to approximate engineering units by

$$T_{ctd} = T_{raw} / 2000 \quad \text{(eqn A2.7)}$$

When conversion of temperature as ITS-90 to temperature expressed on the International Practical Temperature Scale of 1968 (IPTS-68) is required (e.g. for salinity PSS-78 calculation), the following conversion factors are used (Saunders, 1990):

$$T_{68} = 1.00024\, T_{90} \quad \text{(eqn A2.8)}$$
$$T_{90} = 0.99976\, T_{68} \quad \text{(eqn A2.9)}$$

A2.6.4 Conductivity cell deformation correction

Conductivity cell geometry is effected by temperature and pressure. The correction applied for this cell deformation is

$$c = g_{ctd} \, . \, [1 - 6.5e^{-6} (T - 15) + 1.5e^{-8} (p / 3)] \qquad \text{(eqn A2.10)}$$

for conductivity c, calibrated temperature and pressure T and p respectively, and where g_{ctd} is the raw conductance g_{raw} as measured by the CTD and converted to approximate engineering units by

$$g_{ctd} = g_{raw} / 1000 \qquad \text{(eqn A2.11)}$$

A2.6.5 Salinity calculation

Salinity is calculated from the conductivity, temperature and pressure using the practical salinity scale of 1978 (PSS-78), via the algorithm SAL78 (Fofonoff and Millard, 1983). Note that temperatures expressed on the ITS-90 scale must first be converted to IPTS-68 temperatures (eqn A2.8) for input into the salinity PSS-78 routine.

A2.6.6 Oxygen current and oxygen temperature conversion

The raw oxygen current and oxygen temperature, o_{craw} and o_{traw} respectively as measured by the CTD, are converted to o_{cctd} and o_{tctd} in approximate engineering units by

$$o_{cctd} = o_{craw} / 2000 \qquad \text{(eqn A2.12)}$$
$$o_{tctd} = o_{traw} / 2000 \qquad \text{(eqn A2.13)}$$

Calibration of the dissolved oxygen using these parameters is performed on 2 dbar averages only.

A2.6.7 Additional digitiser channel parameters

Manufacturer supplied polynomial fit coefficients are applied to digitiser channel parameters. No further calibration is applied to these values.

A2.7 CREATION OF INTERMEDIATE CTD FILES, AND AUTOMATIC QUALITY FLAGGING OF CTD BURST DATA

Several processing steps take place when the intermediate CTD files are produced (section A2.7.5). Briefly, the parameters are despiked, sensor lagging corrections are applied, and pressure reversals are removed. For the upcast CTD burst data, individual bursts are automatically assigned a quality code.

A2.7.1 Despiking

Spurious data points are replaced by the previous data point. This preserves the equal time spacing between data points, required for the sensor lagging corrections discussed below. The criteria used to reject data values are shown in Table A2.1. Note that these criteria are unchanged over the entire water column.

For pressure, temperature, conductivity and salinity, if any one of these parameters falls outside the criteria for acceptable data (Table A2.1), then the entire data scan is replaced by the previous data scan (i.e. all parameters are replaced by the previous value), and the scan replacement counter nrep is incremented by 1. If more than 3 consecutive data scans require replacement by the previous scan (i.e. nrep > 3), then all parameters are reset to their current value (i.e. the scan is not replaced by the previous scan) and nrep is reset to 0.

For oxygen current o_c and oxygen temperature o_t, if either of these parameters falls outside the criteria in Table A2.1, then the current o_c and o_t values are replaced by null data points; the other parameters are unaffected, and nrep is not incremented. Note that when o_c and o_t are replaced by null values, then the maximum allowable step criterion (Table A2.1) is not applied to the next o_c and o_t values; however the low and high limit tests (Table A2.1) are still applied.

For any parameters from the additional digitiser channels, no automatic check is made for spurious data values.

Table A2.1: **Criteria used to determine spurious data values. The low and high limits are respectively the minimum and maximum allowable values for the parameter. The maximum allowable step is the maximum difference permitted between consecutive values.**

parameter	units	low limit	high limit	maximum allowable step
pressure	dbar	0	5515	5.0 for downcast data 1.0 for upcast data
temperature	^oC	-5	32	1.0
conductivity	$mS.cm^{-1}$	5	80	1.0
salinity	psu	10	50	0.25
oxygen current	μA	0	2	0.25
oxygen temperature	^oC	-5	32	1.0

A2.7.2 Sensor lagging corrections

Lag corrections are required to compensate for the different response times of the sensors. Data from the faster sensors (pressure and conductivity) are slowed down to match the slowest sensor (temperature). A recursive filter (Millard, 1982) is used to lag the pressure and conductivity data, of the form

$$y(t) = y(t - dt) \,.\, W_0 + x(t) \,.\, W_1 \qquad \text{(eqn A2.14)}$$

where

$y(t)$ = output lagged conductivity or pressure at time t
dt = recording interval of the instrument
$x(t)$ = input conductivity or pressure prior to lagging
$W_0 = \exp(-dt / \tau)$
$W_1 = 1 - W_0$

The time constant τ is obtained as follows. The response of the pressure sensor is assumed to be instantaneous; the response time of the conductivity cell is taken as 0.03 seconds, which is equal to the flushing time of the 3 cm conductivity cell at a lowering rate of 1 $m.s^{-1}$. Thus for τ_T equal to the response time of the temperature sensor, we have

$\tau = \tau_T$ when pressure is being lagged, and

$\tau = \tau_T - 0.03$ when conductivity is being lagged.

τ_T is obtained by performing a cross-correlation between the temperature and conductivity data to determine the response difference between the two sensors. Typically, a value of 0.175 s is used for τ_T (Table 8).

The same recursive filter (eqn A2.14) is applied to the oxygen current and oxygen temperature, as well as to data in the additional digitiser channels. For all these parameters, the value $\tau = \tau_T$ is used for the time constant.

A2.7.3 Pressure reversals

After despiking and application of the lagging correction, for downcast data all pressure reversals are removed. Stepping through the data scans, the maximum pressure value is updated each time the pressure increases, and the scan is written to the intermediate CTD file (including the case where pressure does not change); data scans with a pressure value less than the current maximum pressure value are not written to the intermediate file. Thus for downcast data, the intermediate CTD file contains data for non-decreasing pressure. For upcast burst data, pressure reversals are not removed.

A2.7.4 Upcast CTD burst data

A burst of CTD data is associated with each firing of a Niskin bottle, each burst consisting of the 5 seconds of CTD data prior to the bottle firing. For each burst, the mean and standard deviation of the parameters are calculated: for these calculations, the first nstart and last nend data scans (Table 8) in each burst are ignored. The range of the parameters in each burst is also found (equal to the difference of the maximum and minimum values). The mean values from the burst data are used for comparison with the salinity and dissolved oxygen bottle samples, for the subsequent calibration of the conductivity and dissolved oxygen sensors.

<u>Table A2.2:</u> Criteria for automatic flagging of upcast CTD burst data. The subscripts std and range refer respectively to the standard deviation and range of the parameter over the data burst. The data quality code iqual has the following values:

iqual=1 acceptable value, used for conductivity calibration
iqual=0 questionable value, but still used for conductivity calibration
iqual=-1 bad value, not used for conductivity calibration

Note that setting iqual to -1 takes precedence over setting iqual=0, which in turn takes precedence over setting iqual=1.

STANDARD DEVIATION CRITERIA		RANGE CRITERIA	
set iqual = -1 for following cases	set iqual = 0 for following cases	set iqual = -1 for following cases	set iqual = 0 for following cases
$4.00 < p_{std}$	$2.00 < p_{std} \leq 4.00$		$(T_{range})/(c_{range}) < 0.5$
$0.04 < T_{std}$	$0.02 < T_{std} \leq 0.04$		$(T_{range})/(c_{range}) > 2.0$
$0.04 < c_{std}$	$0.02 < c_{std} \leq 0.04$		$c_{range} = 0$
$0.01 < s_{std}$	$0.005 < s_{std} \leq 0.01$	$0.02 < s_{range}$	$0.01 < s_{range} \leq 0.02$
$0.40 < o_{cstd}$	$0.20 < o_{cstd} \leq 0.40$		
$0.40 < o_{tstd}$	$0.20 < o_{tstd} \leq 0.40$		
$1998 < ad_{std}$	$999 < ad_{std} \leq 1998$		

The standard deviations and ranges of the burst data are used to assign a quality code to each burst (Table A2.2). Note that there is only one quality code assigned to each data burst and associated Niskin bottle sample in the hydrology data file: this code refers to values used in the calibration of the CTD conductivity. For the criteria in Table A2.2, setting of the quality code to -1 takes precedence over setting to 0. If none of the criteria are met, the quality code is set to 1 i.e. value accepted for calibration of the conductivity.

The standard deviation x_{std} of parameters x in each data burst is calculated from

$$x_{std} = \left\{ \left[\sum_{i=nstart}^{n-nend} (x_i - \bar{x})^2 \right] / [n - (nstart+nend+1)] \right\}^{1/2} \qquad \text{(eqn A2.15)}$$

where n is the total number of data points x_i in the burst, and the mean value $\bar{x}$ for each burst is given by

$$\bar{x} = \left(\sum_{i=nstart}^{n-nend} x_i \right) / (n-nstart-nend) \qquad \text{(eqn A2.16)}$$

A2.7.5 Processing flow

Stepping through the raw data scans one scan at a time, the parameters in the scan first have the calculations and corrections applied, as described in section A2.6. The data is then despiked (section A2.7.1); spurious values are replaced by the previous data scan, up to a maximum of 3 consecutive scans, after which time the scan is reset to the current value. The sensor lagging correction is then applied via the recursive filter (section A2.7.2). When the filter is started, the first jfilt scans (Table 8) are ignored. Note that whenever nrep > 3 (section A2.7.1), the filter is restarted, and the first jfilt scans are again ignored. Salinity is recalculated for each data scan, after all lagging corrections have been applied. Data is then written to the intermediate CTD file, removing pressure reversals for the case of downcast data (section A2.7.3). For upcast burst data, statistical calculations are performed and a quality code assigned for each burst (section A2.7.4). The mean values and quality codes for the bursts are written to a template intermediate hydrology data file.

A2.8 CREATION OF 2 DBAR-AVERAGED FILES

Data scans from the intermediate CTD files are sorted into 2 dbar pressure bins, with each bin centered on the even integral pressure value, starting at 2 dbar, as follows. A data scan is placed into the ith 2 dbar pressure bin if

$$pmid_i - 1 < p \leq pmid_i + 1 \qquad \text{(eqn A2.17)}$$

where $pmid_i$ is the ith 2 dbar pressure bin centre, and p is the pressure value for the data scan.

After sorting, the temperature, conductivity, oxygen current, oxygen temperature and additional digitiser channel values in each 2 dbar bin are averaged and written to the 2 dbar-averaged file. There is no pressure centering of these parameters i.e. for the ith 2 dbar pressure bin, the parameters are assigned to the even integral pressure value at the centre of the bin. Note that if the number of points in a bin is less than jmin (Table 8), no averages are calculated for that bin (Table 12).

The salinity s_{av} for each 2 dbar bin is calculated from T_{av}, c_{av} and pmid, where T_{av} and c_{av} are respectively the temperature and conductivity averages for the bin. Note that T_{av} is first converted from the ITS-90 scale to the IPTS-68 scale using eqn A2.8 (this also applies to the calculations below for σ_T, δ and $\Delta\Phi$).

The following quantities are also calculated for each 2 dbar bin, and are written to the 2 dbar-averaged file:

σ_T : sigma-T is equal to (ρ - 1000), where the density ρ is calculated at the surface, and at the in situ temperature and salinity T_{av} and s_{av} respectively, using the 1980 equation of state for seawater (Millero et al., 1980; Millero and Poisson, 1981).

δ : specific volume anomaly (units x10^8 $m^3.kg^{-1}$), calculated with T_{av}, s_{av} and pmid, using the 1980 equation of state for seawater (Millero et al., 1980; Millero and Poisson, 1981).

$\Delta\Phi$: geopotential anomaly (units $J.kg^{-1}$), calculated relative to the sea surface (p=0), from

$$\Delta\Phi = \int_{p=0}^{p=pmid} \delta \, . \, dp \qquad \text{(eqn A2.18)}$$

nbin : number of points in the 2 dbar bin

$Tbin_{std}$: standard deviation of all temperature values in the bin

$cbin_{std}$: standard deviation of all conductivity values in the bin

When 2 dbar averages are calculated for oxygen current and oxygen temperature, an additional test is made to exclude suspect oxygen data, as follows. For a 2 dbar bin, if we have either

standard deviation of binned $o_c > 0.1$

or

standard deviation of binned $o_t > 0.5$

then the following 2 conditions must be met for a scan to be included in the averaging of o_c and o_t for the bin:

$$0 < o_c \leq 2.047 \qquad \text{(eqn A2.19)}$$

$$| o_t - T | \leq 5 \qquad \text{(eqn A2.20)}$$

After this test has been made, if the number of scans in the bin has been reduced by more than half, then no o_c or o_t data is included for the bin.

A2.9 HYDROLOGY DATA FILE PROCESSING

An intermediate hydrology data file is formed by merging the results from the salinity, dissolved oxygen and nutrient laboratory analyses with the averages calculated from the upcast CTD burst data (section A2.7.4). Prior to calibration of the CTD conductivity and dissolved oxygen data, the Niskin bottle data undergo preliminary quality control. Salinity bottle data which are obviously bad are given the quality code -1 (i.e. bottle not used for calibration of CTD conductivity) in the intermediate hydrology data file. Reasons for rejecting salinity bottle data at this stage include bad samples due to leaking or incorrectly tripped Niskin bottles, mixed up samples due to misfiring rosette pylon, samples drawn out of sequence from Niskin bottles, etc.

Dissolved oxygen bottle data pass through an initial quality control similar to salinity bottle data, except that bad dissolved oxygen bottle values are deleted from the hydrology data file. Questionable dissolved oxygen bottle values (not deleted) are noted (Table 22). Suspect reversing thermometer readings are also deleted at this stage. Nutrient data are quality controlled at a later stage, following calibration of all the CTD data.

A2.10 CALIBRATION OF CTD CONDUCTIVITY

For the CTD conductivity data, calibrations are carried out by comparing the upcast CTD burst data with the hydrology data, then applying the resulting calibrations to the downcast CTD data. The conductivity calibration follows the method of Millard and Yang (1993). For groups of consecutive stations, a conductivity slope and bias term are found to fit the CTD conductivity from the upcast burst data to the hydrology data; a linear station-dependent slope correction (Millard and Yang, 1993) is applied to account for calibration drift of the CTD conductivity cell. Note that data from the entire water column are used in the conductivity calibration. Also note that no correction is made for the vertical separation of the Niskin bottles and the CTD sensors (of the order 1 m).

A2.10.1 Determination of CTD conductivity calibration coefficients

The following definitions apply for the conductivity calibration:

c_{ctd} = uncalibrated CTD conductivity from the upcast burst data
c_{cal} = calibrated CTD conductivity from the upcast burst data
c_{btl} = 'in situ' Niskin bottle conductivity, found by using CTD pressure and temperature from the burst data in the conversion of Niskin bottle salinity to conductivity
F_1 = conductivity bias term
F_2 = conductivity slope term
F_3 = station-dependent conductivity slope correction
N = station number

CTD conductivities are calibrated by the equation

$$c_{cal} = (1000\ c_{ctd}) . (F_2 + F_3 . N) + F_1 \qquad \text{(eqn A2.21)}$$

Niskin bottle salinity data are first converted to 'in situ' conductivities c_{btl}. The ratio c_{btl}/c_{cal} for all bottle samples is then plotted against station number, along with the mean and standard deviation of the ratio for each station (Figure 4 is the version of this plot for the final calibrated data). Groups of consecutive stations are selected to follow approximately linear trends in the drift of the station-mean c_{btl}/c_{cal} (Table 13). For each of these groups, the three calibration coefficients F_1, F_2 and F_3 are found by a least squares fit: F_1, F_2 and F_3 in eqn A2.21 are all varied to minimize the variance σ^2 of the conductivity residual (c_{btl}-c_{cal}), where σ^2 is defined by

$$\sigma^2 = \sum (c_{btl} - c_{cal})^2 / (n - 1) \qquad \text{(eqn A2.22)}$$

for n equal to the total number of bottle samples in the station grouping.

Note that samples with a previously assigned quality code of -1 (sections A2.7.4. and A2.9) are excluded from the above calculations. In addition, samples for which

$$| (c_{btl} - c_{cal}) | > 2.8\ \sigma \qquad \text{(eqn A2.23)}$$

are also flagged with the quality code -1, and excluded from the final calculation of the conductivity calibration coefficients F_1, F_2 and F_3. Samples rejected at this stage often include those collected in steep vertical temperature and salinity gradients, and not already rejected.

A2.10.2 Application of CTD conductivity calibration coefficients

The set of coefficients F_1, F_2 and F_3 found for each station (Table 13) are first used to calibrate the upcast CTD conductivity burst data in the hydrology data file. The conductivity calibration is applied to the mean value for each burst only (as opposed to each raw data scan in the burst). Similarly, upcast CTD salinity burst values are recalculated from the calibrated CTD burst mean values of conductivity, temperature and pressure.

Next, the intermediate CTD files are reproduced (as per section A2.7) for the downcast data only. Note that on this occasion, following application of the conductivity cell deformation correction (eqn A2.10), the coefficients F_1, F_2 and F_3 are used to calibrate the raw conductivity data scans. The 2 dbar-averaged CTD downcast data are then recalculated, as in section A2.8.

A2.10.3 Processing flow

The intermediate hydrology file data, containing upcast CTD burst data means and Niskin bottle data, are used to determine the conductivity calibration coefficients F_1, F_2 and F_3. Station groupings are determined from the bias drift of the conductivity cell with time (section A2.10.1). For each station group, the following occurs:

1. 3 iterations are made of the least squares fitting procedure (section A2.10.1) to calculate F_1, F_2 and F_3, each iteration beginning with the latest value for the coefficients;

2. bottles are rejected according to the criterion of eqn A2.23;

3. steps 1 and 2 are repeated until no further bottle rejection occurs.

For each station group, there is a single value for each of the 3 coefficients F_1, F_2 and F_3 (Table 13); following the station-dependent correction, an individual corrected slope term ($F_2 + F_3.N$) (as in eqn A2.21) applies to each station (Table 14). When final values of the coefficients have been obtained, the conductivity calibration is applied to both the upcast CTD burst data and the downcast CTD data (section A2.10.2). Finally, plots are made of both the ratio c_{btl}/c_{cal} and the residual ($s_{btl} - s_{cal}$) versus station number (Figures 4 and 5), where s_{btl} is the Niskin bottle salinity and s_{cal} is the calibrated CTD salinity from the upcast burst data (section A2.10.2).

Following calibration of the CTD conductivity, the mean of the salinity residuals ($s_{btl} - s_{cal}$) for the entire data set is equal to 0. The standard deviation about 0 of the salinity residual (section A2.14) provides an indicator for the quality of the data set. To meet WOCE specifications, this standard deviation should be less than or equal to 0.002 psu (Joyce et al., 1991).

A2.11 QUALITY CONTROL OF 2 DBAR-AVERAGED DATA

Two levels of quality control are undertaken for the 2 dbar-averaged data. Suspicious raw data scans, indicated by suspicious 2 dbar averages, are flagged for later action (Table 15); and remaining suspect 2 dbar averages are noted (Tables 16 and 17) (suspect 2 dbar averages are never directly removed, except for dissolved oxygen data).

A2.11.1 Investigation of density inversions

The calibrated 2 dbar-averaged data are searched automatically for density inversions i.e. for instances where the in situ density (calculated from in situ pressure, temperature and salinity) decreases with depth. Raw CTD data in the vicinity of the density inversions are then examined for anything which might artificially cause the inversions. The most commonly encountered problems are

(a) water from the wake of the moving instrument package catching up to the CTD sensors during rolls induced by surface waves;
(b) fouling of the CTD sensors;
(c) salinity spikes caused by mismatching of the temperature and conductivity data in very steep vertical gradients, where the sensor lagging corrections (section A2.7.2) are not adequate.

If these or any other problems are identified in the raw CTD data, one of two possible actions follow:

(i) the relevant data scans are ignored for all further calculations - a counter preserves the constant scanning frequency required for application of the sensor lagging corrections; note that for cases where the ignoring of raw data scans results in missing 2 dbar averages, a linear interpolation is applied between surrounding 2 dbar averages to fill any data gaps (Table 18);

(ii) a linear interpolation is applied over the region of bad data, in which case the interpolation is applied to the raw CTD data scans prior to any calibration calculations.

The status of data scans flagged for special treatment (Table 15) is updated in the data processing master file (section A2.5).

A2.11.2 Manual inspection of data

Data plots of the 2 dbar-averaged data are inspected to identify any additional suspicious data. Suspect values remaining are most commonly due to the following:

(a) large salinity spikes (as in section A2.11.1) in very steep gradients in the thermocline - for these large salinity spikes, 2 dbar averages are flagged instead of raw data scans (Table 16);

(b) suspect data near the surface due to transient effects of the sensors entering the water (e.g. bubbles trapped on sensors, or fouling) (Table 17).

2 dbar-averaged data regarded as suspicious for these or any other reasons are flagged accordingly.

A2.12 CALIBRATION OF CTD DISSOLVED OXYGEN

For the CTD dissolved oxygen data, the calibration procedure is carried out using the downcast uncalibrated CTD data. Downcast CTD data is matched with the Niskin bottle dissolved oxygen samples on equivalent pressures. The calibration is based on the method of Owens and Millard (1985).

A2.12.1 Determination of CTD dissolved oxygen calibration coefficients

The following definitions apply for the dissolved oxygen calibration:

o_{cal} = calibrated CTD dissolved oxygen
o_c = CTD oxygen current
o_t = CTD oxygen temperature
T = CTD temperature
s = CTD salinity
p = CTD pressure
$\partial o_c/\partial t$ = oxygen current derivative with respect to time
K_1 = oxygen current slope
K_2 = oxygen sensor time constant
K_3 = oxygen current bias
K_4 = temperature correction term

K_5 = weighting factor of o_t relative to T
K_6 = pressure correction term
o_{btl} = Niskin bottle dissolved oxygen value

All the above CTD parameters are 2 dbar-averaged data. CTD dissolved oxygen is calibrated using the sensor model of Owens and Millard (1985), as follows:

$$o_{cal} = [K_1 . (o_c + K_2 . \partial o_c/\partial t + K_3)] . \mathrm{oxsat}(T,s) . \exp\{ K_4 . [T + K_5 . (o_t - T)] + K_6 . p \} \qquad \text{(eqn A2.24)}$$

where the oxygen saturation value oxsat is calculated at T and s using the formula of Weiss (1970):

$$\mathrm{oxsat}(T,s) = \exp\{ A_1 + A_2.(100/T_K) + A_3.\ln(T_K/100) + A_4.(T_K/100) + s.[B_1 + B_2.(T_K/100) + B_3.(T_K/100)^2] \}$$

(eqn A2.25)

for T_K equal to the CTD temperature in degrees Kelvin (=T+273.16), and the additional coefficients having the values (Weiss, 1970):

$A_1 = -173.4292$ $B_1 = -0.033096$
$A_2 = 249.6339$ $B_2 = 0.014259$
$A_3 = 143.3483$ $B_3 = -0.0017$
$A_4 = -21.8492$

Note that the CTD temperature T in equations A2.24 and A2.25 is first converted from the ITS-90 scale to the IPTS-68 scale using eqn A2.8.

$\partial o_c/\partial t$ in eqn A2.24 is calculated as follows. A time base is first estimated from the 2 dbar averaged data by assigning the time t_k in seconds at the kth 2dbar value equal to

$$t_k = [\sum_{i=1}^{k-1} nbin_j / 30] + (nbin_k / 60) \qquad \text{(eqn A2.26)}$$

where $nbin_k$ is the number of data scans in the kth 2 dbar bin (for bins with no data points, nbin is set to 30). Note that this time base is an approximation only, as nbin does not include data scans in pressure reversals (sections A2.7.3 and A2.8), and in addition, a constant lowering rate of the instrument package is being assumed. $\partial o_c/\partial t$ is then calculated at the kth 2 dbar value by applying a linear regression over a 16 dbar interval centered on the kth 2dbar value: $\partial o_c/\partial t$ is the slope of the linear best fit line of the oxygen currents

$$(o_{ck-4}, o_{ck-3}, o_{ck-2}, o_{ck-1}, o_{ck}, o_{ck+1}, o_{ck+2}, o_{ck+3}, o_{ck+4})$$

to the times

$$(t_{k-4}, t_{k-3}, t_{k-2}, t_{k-1}, t_k, t_{k+1}, t_{k+2}, t_{k+3}, t_{k+4}).$$

If there is no data for either of o_{ck} or o_{tk} (section A2.8), a null value is assigned to $(\partial o_c/\partial t)_k$.

In most cases, CTD dissolved oxygen is calibrated for individual stations; station groupings (as in the CTD conductivity calibration) may be formed to cover casts with few Niskin samples, or else for deep/shallow cast pairs at a single location. For each individual station, or each station grouping, the calibration coefficients K_1 to K_6 in eqn A2.24 are found by varying some or all of the 6 coefficients in order to minimize the variance σ^2 of the dissolved oxygen residual $o_{btl} - o_{cal}$, where σ^2 is defined by

$$\sigma^2 = \sum (o_{btl} - o_{cal})^2 / n \qquad \text{(eqn A2.27)}$$

for n equal to the total number of bottle samples at the station (or in the station grouping). A non-linear least squares fitting routine, utilising the subroutines MRQMIN, MRQCOF, COVSRT and GAUSSJ in Press et al. (1986), is applied to find K_1 to K_6. In application of the routine, convergence is judged to have occurred when

$$\sum (o_{btl} - o_{cal})^2 / (0.6)^2 \ < \ 0.96\ n \qquad \text{(eqn A2.28)}$$

or else after a maximum of 5 iterations. Note that when calculating σ^2 for each Niskin bottle sample, the pressure from the upcast CTD burst data (i.e. the pressure assigned to the bottle sample) is used in eqn A2.24, while all other parameters are from the downcast data (at the nearest equivalent 2 dbar pressure value). Downcast CTD pressure is used in eqn A2.24 when the resulting calibration is being applied to finalise the entire 2 dbar dissolved oxygen data. Also note that there is no automatic rejection of dissolved oxygen bottle data analogous to eqn A2.23 in the conductivity calibration.

A2.12.2 Application of CTD dissolved oxygen calibration coefficients

The set of coefficients K_1 to K_6 found for each station or station grouping (Table 20) are used in eqn A2.24 to calculate CTD dissolved oxygen 2 dbar data from the existing 2 dbar pressure, temperature, salinity, oxygen current and oxygen temperature data.

A2.12.3 Processing flow

* The *.oxy* files (section A2.2.1), which include values of $\partial o_c/\partial t$ (calculated as in section A2.12.1) as well as all the other downcast 2 dbar data, are first created from the existing calibrated 2 dbar-averaged files.

* For each station, the upcast CTD burst pressure values from the hydrology data file (sections A2.7.4 and A2.7.5) are matched to the closest 2 dbar pressure values in the *.oxy* file; then for each Niskin bottle sample, the following data are written to the file *oxydwn.dat*:

p (upcast CTD burst value)
T, s, o_c, o_t, $\partial o_c/\partial t$ (all 2 dbar downcast values)
o_{btl}
o_{btl} quality code

The -1 bottle quality code (sections A2.7.4 and A2.9) is not relevant to the dissolved oxygen calibration. Instead, a code of -9 in the *oxydwn.dat* file indicates that the bottle is not used for the dissolved oxygen calibration calculations.

* All calibration calculations are performed on dissolved oxygen (i.e. Niskin bottle and CTD dissolved oxygen values, and oxygen saturation values) in units of ml/l; all values are reported in units of μmol/l. The conversion factor used is

$$(\ \mu\text{mol/l}\ ) \ = \ 44.6596\ .\ (\ \text{ml/l}\ ) \qquad \text{(eqn A2.29)}$$

* The fitting routine is applied to find values of the coefficients K_1 to K_6 (section A2.12.1), using the data in the *oxydwn.dat* file. The number of coefficients varied may be chosen, as well as the starting values for the coefficients prior to iteration (Table 21). Starting values are typically close to the following:

$K_1 = 2.50$ $K_4 = -0.036$
$K_2 = 8.0$ $K_5 = 0.75$
$K_3 = 0.0$ $K_6 = 0.00015$

With successive attempts at fitting the CTD data to the Niskin bottle data, bottles which are suspect are flagged manually with the quality code -9 in *oxydwn.dat*, and are rejected for further calibration attempts. The number of coefficients chosen to vary, and the coefficient starting values, are varied to achieve the best fit of the CTD to the bottle data. In general, the fit for a station (or group of stations) is not considered satisfactory until $2.8\sigma < 0.3$ (for σ defined as in eqn A2.27) (Table 20).

* Following calibration of the CTD dissolved oxygen, the residuals ($o_{btl} - o_{cal}$) are plotted against station number (Figure 6). The mean of the residuals for the entire data set is very close to 0. The standard deviation about the mean of the residuals (section A2.14) provides an indicator for the quality of the data set. To meet WOCE specifications, this standard deviation should be less than 1% of full scale (Joyce et al., 1991) i.e. approximately < 2.5 μmol/l below 750 dbar, and approximately < 3.5 μmol/l above 750 dbar, for the data set presented in this report (see section 6.2.2 in the main text for full scale values).

A2.13 QUALITY CONTROL OF NUTRIENT DATA

Nutrient data which are obviously bad are removed from the hydrology data file. Causes of bad samples include leaking or incorrectly tripped Niskin bottles, and errors occurring during analysis. On occasion, autoanalyser sampling errors may necessitate the flagging of an entire station as suspect. The data are checked by overlaying vertical profiles of groups of consecutive stations, looking at bulk plots (e.g. nitrate versus phosphate) of large numbers of stations, and by comparing values to any available historical data. Questionable nutrient data (not obviously bad, and therefore not deleted from the hydrology data file) are noted (Table 23).

A2.14 FINAL CTD DATA RESIDUALS/RATIOS

The final residuals ($T_{therm} - T_{cal}$), ($s_{btl} - s_{cal}$) and ($o_{btl} - o_{cal}$) are plotted (Figures 3 to 6) for temperature, salinity and dissolved oxygen (T_{therm} and T_{cal} are respectively the protected thermometer and calibrated upcast CTD burst temperature values); for conductivity, the ratio c_{btl}/c_{cal} is plotted. The plots include mean and standard deviation values, as follows:

temperature, salinity and dissolved oxygen: The standard deviations of the residuals for temperature, salinity and dissolved oxygen are calculated from

$$x_{std} = \left\{ \left[\sum_{i=1}^{n} (x_i - x_{mean})^2 \right] / (n-1) \right\}^{1/2} \qquad \text{(eqn A2.30)}$$

where x_{std} is the standard deviation of x (for x equal to the temperature, salinity or dissolved oxygen residual). For both temperature and salinity, the summation in eqn A2.30 does not include points rejected for the CTD conductivity calibration. Similarly for dissolved oxygen, the summation does not include points rejected for the CTD dissolved oxygen calibration. Thus n is equal to the total number of data points x_i not rejected for the relevant calibration, with mean value x_{mean} of the x_i values (x_{mean} is the mean for all the stations in the plot).

conductivity: The standard deviation of the conductivity ratio is calculated as in eqn A2.30, except that in the summation, for each point x_i the value x_{mean} is the mean for the particular station to which x_i belongs. x in eqn A2.30 is equal to the conductivity ratio. The summation in eqn A2.30 does not include points rejected for the CTD conductivity calibration.

A2.15 CONCLUSIONS

A complete description is presented of the CTD data calibration methods. Sufficient details are supplied to minimize the need for cross-referencing, and to provide a useful reference for comparison with the calibration methods used by other institutions. Any variation in the techniques employed at each stage of the processing, and the order in which the various techniques are applied, ultimately affect the final data values produced. As such, all CTD data sets need to be considered in conjunction with the calibration details.

ACKNOWLEDGEMENTS

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APPENDIX 3 Hydrology Analytical Methods

This Appendix covers the analytical techniques and data processing routines employed in the Hydrographic Laboratory onboard the RSV Aurora Australis for cruise AU9309/AU9391, March 11 to May 9, 1993. All analysis results are merged with station details in the program “HYDRO” (CSIRO Division of Oceanography). Output from HYDRO is ultimately used for merging with CTD data.

A series of replicate samples drawn from Niskin bottles fired at the same depth was obtained from one of the cruise transects. Estimates of nutrient, dissolved oxygen and salinity precision derived from these data are discussed in section 6.2.2 of the main text.

A3.1 NUTRIENT ANALYSES

A3.1.1 Equipment and technique

Nutrient analyses were performed by two analysts from the Antarctic CRC (University of Tasmania) and CSIRO Division of Oceanography, Hobart. A new Alpkem "Flow Solution" Autoanalyser was used for the simultaneous analysis of reactive silicate, nitrate plus nitrite, and orthophosphate in seawater. All analyses were carried out in the Segmented Flow Analysis (SFA) mode, although the instrument can be configured for Flow Injection Analysis. This was the Alpkem's "maiden voyage" at sea, replacing the Technicon AAII which had been used previously. Data output from the Autoanalyser was processed by the commercial software package “DAPA” (DAPA Scientific Version 1.43, Curtin University, Box 58 Kalamunda Western Australia 6070).

The Alpkem instrumentation, particularly the 510 Monochromator Detectors, was found to be very susceptible to vibration, causing problems with the maintenance of regular gas segmentation in the analytical manifold. Bubble break-up was a major problem, causing the debubbler units to be overwhelmed, and the detection cells to fill with fine bubbles. Insulating the detectors with foam pads, and increasing the back pressure on the flowcell by lengthening the waste line from the detector improved the situation. The orientation of the detectors was altered so that tubing lengths between the analytical cartridge and the flow cell was minimised. The wide bore "low refractive index" flowcells were found to more suitable for shipboard work than the narrow bore flowcells supplied with the detectors, as they were less susceptible to "bubble trouble".

A3.1.1.1 Silicate

Reactive silicate was analysed in accordance with the method provided for seawater analysis in the Alpkem Manual (Alpkem Corp, 1992). The silica in solution as silicic acid or silicate reacts with a molybdate reagent in acid media to form β-molybdo silicic acid. The complex is then reduced to a highly coloured molybdenum blue following mixing with ascorbic acid. Interference from phosphate is suppressed by the addition of oxalic acid. Absorbance is measured at 660 nm.

A3.1.1.2 Nitrate plus nitrite

Nitrate plus nitrite was analysed using an Imidazole buffer chemistry in place of the Alpkem methodology. A 12" Open Tubular Cadmium Reductor (OTCR) supplied by Alpkem is used for quantitative reduction of nitrate to nitrite. The nitrite due to nitrate, plus the nitrite originally present in the sample, then undergoes diazotization with sulphanilamide and subsequent coupling with N-1-napthylethylene-diamine dihydrochloride. The azo dye is detected at 540 nm. A standard nitrite solution is used frequently to check the reduction efficiency of the column. Efficiencies over 95% are commonly achieved. The columns are re-activated with a 2% copper sulphate solution after every second station. Details of the chemistry and procedures for nitrate plus nitrite analysis follow.

Methodology for nitrate plus nitrite analysis in seawater

All reagents are analytical grade (AR), unless otherwise specified. All volumetric glassware for reagent preparation is A grade dedicated glassware, and acid cleaned prior to each voyage. Glassware is stored full of deionised water when not in use.

Reagent chemistry

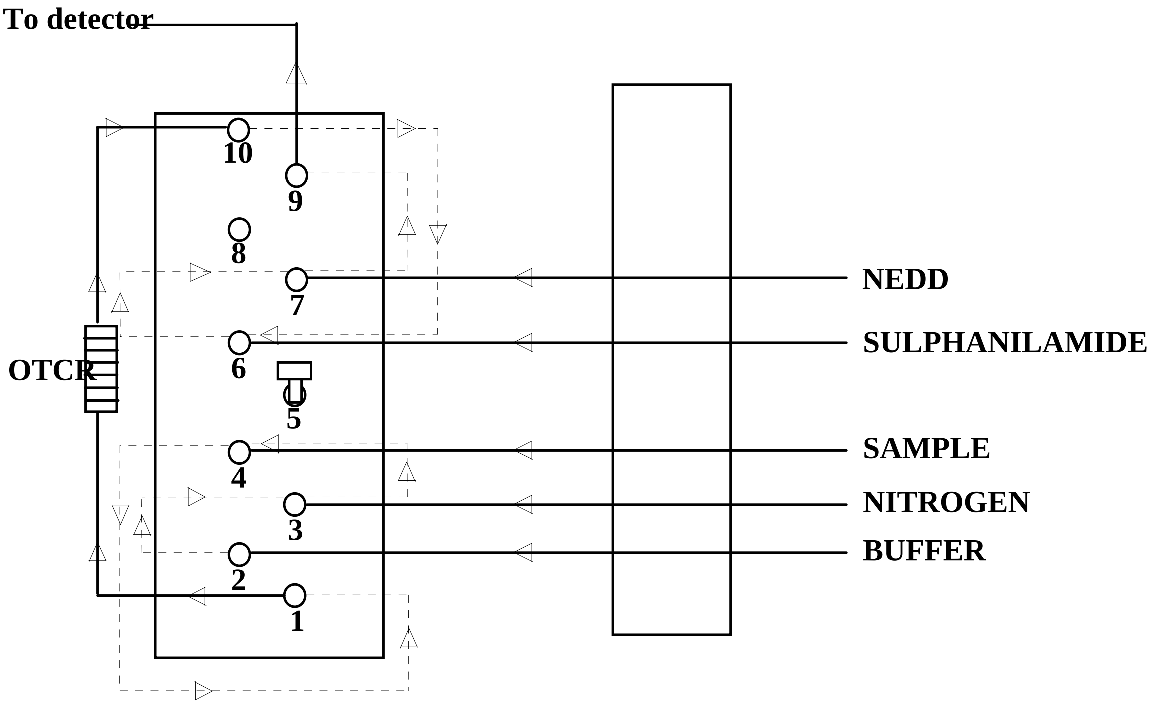
Start-up solution: Add 0.5 ml of 30% w/v Brij-35 to 200 ml of deionised water. Mix thoroughly. This reagent is refreshed daily.

Imidazole buffer pH 7.8: Dissolve 4.25 g of Imidazole buffer in 800 ml of deionised water. Add 11.25 ml of 10% HCl to adjust the final pH to 7.8. Make up to a litre and mix well. Add 1 ml of 30% w/v Brij-35 after decanting liquid to reagent container. Store at 4^{o}C when not in use. Replenish every 2 to 3 days.

N-1 napthylethylene-diamine dihydrochloric acid (NEDD): Dissolve 0.31 g of NEDD in 1 l of deionised water. Add 1 ml of 30% w/v Brij-35 after decanting to reagent container. Store at 4^{o}C when not in use.

Sulphanilamide: Dissolve 3.12 g of sulphanilamide in 800 ml of deionised water in a 1 l volumetric flask. Add 31 ml of concentrated HCl carefully, and make up to the mark.

Figure A3.1: **Cartridge configuration for nitrate + nitrite analysis.**



Pump configuration

Reagent	Pump tube	Flow rate at 50% pump speed
NEDD	Orange/yellow	0.18 ml/ min
Sulphanilamide	Orange/yellow	0.18 ml/min
Imidazole Buffer	Black/black	0.32 ml/min
Nitrogen	Orange/white	0.25 ml/min
Sample	Black/black	0.32 ml/min

Activation of the OTCR

The activation and installation of the OTCR is performed in accordance with the method in the Alpkem Manual (Alpkem Corp, 1992). A separate batch of Imidazole buffer, that does not contain Brij-35, is used for the activation and storage of the OTCR.

A3.1.1.3 Phosphate

Phosphate analysis was carried out using the methodology supplied by Alpkem (Alpkem Corp, 1992). The chemistry involves reaction with an acidified molybdate reagent and potassium antimonyl tatrate. The compound produced is then reduced by ascorbic acid to a highly coloured molybdenum blue complex. The monochromator detector was modified to increase the upper wavelength selection limit from 800 to 900 nm. It was found that using 880 nm as the detection wavelength, instead of 660 nm as recommended by Alpkem, increased the sensitivity of the method by 30%.

A3.1.2 Sampling procedure

Nutrients were sampled after dissolved gases and salinity samples had been drawn. Typically, 30 to 45 minutes lapsed between the arrival of the CTD on deck and sampling for nutrients. Duplicate samples were collected in 12 ml polypropylene screw cap tubes with a 10 ml mark to prevent overfilling. Tubes and caps were rinsed three times with approximately half the volume of the tube before drawing the final sample (see section 4.1.4 in the main text).

For both transects, pairs of tubes were placed into polystyrene trays, and snap frozen without any chemical preservation. When required, samples were thawed, mixed thoroughly and placed directly into the autosampler, so that no sample transfers were necessary. The racks of the autosampler had been specially modified by Alpkem to take the 12 ml sample tubes. Experiments conducted at CSIRO Division of Oceanography (R. Plaschke, unpublished notes) have shown that with careful thawing procedures, silicate samples processed within one week of freezing undergo no significant loss of silicate by polymerisation.

All frozen duplicate samples were returned to Hobart and retained until data processing was completed.

A3.1.3 Calibration and standards

Standard ranges used for nutrient analyses are shown in Table A3.1. Combined standards are prepared using an Eppendorf Multipette and dedicated A grade volumetric glassware, using artificial seawater made from high purity reagents as a diluent. The calibration standards are run prior to analysing each station, in order to check the linearity of detector response, and to calculate the calibration factor required to convert peak height of an unknown sample to a concentration in μmol/l.

Stock standards were prepared from analytical grade reagents one month prior to departure on the voyage. The new batch of stock standard nutrient solutions were compared to the previous batch of stock standards as a QC check.

Table A3.1: Range of calibration standards and concentration of QC standards used for analysis of nutrients on SR-3 and P11 transects.

Nutrient	Range of standards used (μmol/l)	QC standard (μmol/l)
Reactive silicate (high range) as Na_2SiF_6	0, 28, 56, 84, 112, 140	140
Orthophosphate as KH_2PO_4	0, 0.6, 1.2, 1.8, 2.4, 3.0	3
Nitrate plus nitrite as KNO_3	0, 7, 14, 21, 28, 35	35

A3.1.4 Low Nutrient Sea Water (LNSW)

LNSW is prepared from high purity NaCl, and used as a diluent for standard solutions and as the carrier solution in the analytical manifold. If pure water were used as a carrier/wash solution, each peak on the phosphate and nitrate channels would be accompanied by a significant spike as the interface between pure water and seawater alternately refracts and focuses light on the photodiode. The data processing software DAPA cannot be programmed to ignore the refractive index spike, and so erroneous concentrations would be reported. By using artificial seawater, of similar salinity to the samples, the refractive index disturbance that occurs when a pure water baseline is used is eliminated. Even the highest purity NaCl, however, can be significantly contaminated with respect to phosphate. A background colour reagent is used to correct for traces of phosphate present in the wash solution and also in the analytical reagents.

A3.1.5 Temperature effects and corrections

During the cruise, there was no temperature regulation in the hydrographic laboratory, resulting in fluctuations in sensitivity of the silicate channel of up to 20% in one day. It was not possible to maintain a stable environment, so the worst analysis runs were rejected and repeated. Those stations still showing a drift in silicate sensitivity were corrected for drift by applying a linear gain adjustment (Table A3.2) available in the data processing software DAPA. During the course of an analytical run, quality control standards are interspersed at regular intervals. These QC standards are equivalent in concentration to the top standard for each nutrient, and are used to check for drift, carryover etc. Adjacent pairs of QC standards were measured and compared; if adjacent standard peaks varied by more than 3% of the top standard (where top standard=140 μmol/l for silicate), the heights of sample peaks that fell between them were corrected by linear interpolation. Note that this gain adjustment was also required for SR3 stations 33 and 38 nitrate plus nitrite values. The concentration of calibration and QC standards are shown in Table A3.1.

Table A3.2: Stations where a linear gain adjustment has been made to silicate analysis peak heights, to compensate for QC standard drift. Note that a similar adjustment was also made for nitrate plus nitrite values for SR3 stations 33 and 38.

SR3 stations:	2, 4, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 20, 21, 22, 23, 24, 25, 26, 27, 32, 33, 34, 36, 38, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51
P11 and sea ice stations:	4, 5, 7, 11, 12, 13, 16, 24, 33, 35, 36, 37, 40, 42, 43, 44, 45, 46, 47, 48, 49, 53, 57, 58, 59, 60, 61, 63

When data processing in DAPA is completed, the data is imported into the program HYDRO where it is merged with the relevant cruise and station data.

A3.2 DISSOLVED OXYGEN ANALYSIS

A3.2.1 Equipment and technique

Dissolved oxygen analysis was conducted using the manual Winkler titration method described in Major et al. (1972). The method differs significantly from the Chesapeake Bay Institute technique for Winkler dissolved oxygen method recommended by WOCE (Culberson, in WHP Office Report WHPO 91-1). The manual method used on this voyage has since been replaced by an automated dissolved oxygen system, based on that developed by Knapp et al. (1990) at the Woods Hole Oceanographic Institution (WHOI). Table A3.3 summarises the details of the manual and automated dissolved oxygen methods. The equations used for the calculation of dissolved oxygen concentration are detailed in Eriksen and Terhell (in prep.).

Sodium thiosulphate is standardised using 0.1N KIO_3, prepared by oven drying the salt at 100^oC for 2 hours. Blanks are determined to check for the presence of oxidising species in the reagents, but the value is not used in the equations for calculating the concentration of dissolved oxygen present in a sample. Manganese sulphate is omitted from the standard solution, despite being present in both blank and sample solutions. Standardisations were performed at each analytical session.

Dissolved oxygen samples were the first samples to be drawn once the rosette package had been secured to the deck. Samples were collected in 300 ml Wheaton BOD bottles, pickled with the reagents and volumes specified in Table A3.3, and analysed within 4 to 36 hours of collection. Samples were acidified prior to analysis, and an aliquot of the sample was collected by pouring the sample into a 100 ml dispenser with an overflow arm connected to a vacuum. Samples were titrated until colourless using a Metrohm 10 ml burette, with "Vitex" indicator solution used to enhance endpoint detection. Duplicate titrations were performed every 10 samples as a check on the reproducibility of titrations. The precision of replicate titrations (determined as the standard deviation of 84 titration pair differences) was 0.4 μmol/l.

The reagent chemistry is based on the method of Jacobsen et al. (1950), but has undergone several modifications, documented in Major et al. (1972). The method has been in use by CSIRO Division of Oceanography since at least 1960 (G.Dal Pont, pers. comm.), but, at the time of writing, is being phased out on all ships and in all laboratories.

The major inadequacies in the manual method are that :

* The reagent chemistry differs significantly from the Carpenter (1965) modifications to the Winkler method, causing unwanted side reactions to be favoured.
* The absolute amount of oxygen added with reagents is unknown.
* The blank procedure is unsuitable.
* The accuracy of the method is 1-2%.
* The precision of the method is greater than 0.1%.

Table A3.3: Summary of details of CSIRO manual oxygen method (used for oxygen analyses in the cruise described here) and WHOI automated oxygen method (Knapp et al., 1990). Modifications to the WHOI automated method (used for cruises after this report) include:
(a) 300 ml sample bottles are used rather than 150 ml (*note a* in the table), and subsequently
(b) 2 ml of reagents are added to the sample bottle rather than 1 ml (*note b* in the table).

	CSIRO Manual method	Automated method
Endpoint:	Visual starch (Vitex)	Amperometric
Bottle volume:	300 ml	300 ml *(note a)*
Aliquot volumes:	100 ml	50 ml
Size of burette:	10 ml	10 ml
Smallest measurable volume increment (μl):	20	1
Standard solution:	0.1 N KIO_3	0.01N $KH(IO_3)_2$
Standard preparation:	Oven dried, 100-110°C	Vacuum dried
Standard volume:	1 ml	15 ml
Blank determined:	Yes	Yes
Blank tests for:	Oxidising species	Redox species in reagents plus bias in measured endpoint.
Blank result used in calculations:	No	Yes
Scope for negative blank:	No	Yes
Mn reagent in standards:	No	Yes
Standardise daily:	Yes	No
Thiosulphate normality:	0.01 N	0.01 N
Reagent chemistry:	40% (1.83 M) $MnSO_4$ (0.5 ml) 9 M NaOH/1.8 M KI (1.0 ml) 18 M H_2SO_4 (2.0 ml)	3 M $MnCl_2$ (2 ml) *(note b)* 8 N NaOH/4 M NaI (2 ml) *(note b)* 10 N H_2SO_4 (2 ml) *(note b)*
Reagents filtered:	No	All double filtered
Final sample pH:	< 1	2
Specified reaction time:	None	2-4 hours
Correction for DO in reagents:	No	Yes
Standard and sample handling procedures the same:	No	Yes
Average sample processing time:	1.5-2 minutes	1.5-2 minutes

A3.2.2 Sampling procedure

Samples were drawn in accordance with the protocols documented in section 4.1.4 of the main text. Occasional problems were encountered with insufficient mixing of samples at the pickling stage, causing incomplete formation of the $MnO(OH)_2$ complex.

A3.3 SALINITY ANALYSIS

A3.3.1 Equipment and technique

Salinity analysis was conducted using a YeoKal Mark 4 Inductively Coupled Salinometer (Yeokal Electronics, Sydney Australia). The manufacturer claims that with sufficient care, and in a constant temperature environment, an experienced operator should be able to attain an accuracy of ±0.003 psu.

The salinometer was standardised daily using IAPSO P-series salinity standards, in accordance with WOCE guidelines. Immediately after the standardisation procedure was completed, the conductivity ratio of a bulk seawater "substandard" was measured. The substandard was then measured in triplicate every 10 samples, to monitor the electronic drift of the instrument. If the drift exceeded 0.00005 conductivity units, then another vial of IAPSO International seawater was used to check the calibration of the instrument. Samples were left for 12 to 24 hours to equilibrate to room temperature before analysing. The station to be analysed next was always positioned beside the substandard and international standard, to ensure that all three fell within the same temperature compensation bandwidth. The YeoKal salinometers do not have a thermostated bath around the conductivity cell, thus the temperature at which conductivity ratios are determined is also measured, and must be confined to a narrow range. Fluctuations in laboratory temperature often made this extremely difficult, and the instrument had to be frequently rechecked with IAPSO standard seawater.

A3.3.2 Sampling procedure

Samples were collected in accordance with the protocol detailed in section 4.1.4 of the main text.

A3.3.3 Data processing

Conductivity ratios were entered manually into the HYDRO program, which calculates salinity (PSS-78) from the conductivity and calibration data acquired on the salinometer. The program also calculates and corrects for any instrument drift by linear interpolation between pairs of substandard observations.

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APPENDIX 4 Data File Types

A4.1 UNDERWAY MEASUREMENTS

The underway measurements for the cruise, as logged automatically by the ship's data logging system, and quality controlled by human operator (Ryan, 1993), are contained in column formatted ascii files. The two file types contain 10 sec digitised data, and 15 min averaged data. In both cases, missing data or data flagged as bad are replaced by the null value -999. The files are padded out to commence on the first digitising interval of the first day in the file, and ending at the last digitising interval on the last day in the file.

A4.1.1 10 second digitised underway measurement data

Data at the minimum digitised interval of 10 sec. are contained in files named *.alf (Table A4.1), where the data filename prefix corresponds to the cruise acronym ("woes" or "worse"). A two line header is followed by the data as follows:

column	parameter
1	decimal time (0.0=midnight on December 31st, therefore, for example, 1.5=midday on January 2nd)
2	day
3	month
4	year
5	hour
6	minute
7	second
8	latitude (decimal degrees, +ve=north, -ve=south)
9	longitude (decimal degrees, +ve=east, -ve=west)
10	depth (m)
11	sea surface temperature (^{o}C) (measured at the seawater inlet at 7 m depth)

Note that all times are UTC.

<u>Table A4.1:</u> Example 10 sec digitised underway measurement file (*.alf file).

```
Aurora Australis data - GPS pos. (deg), depth (m), sea surface temp (deg C)
 decimaltime  day mn  yr   hr m  s         lat        lon         depth   SST
  70.00000004  12  3 1993   0  0  0      -999.0000 -999.0000     -999.0 -999.0
  70.00011578  12  3 1993   0  0 10      -999.0000 -999.0000     -999.0 -999.0
  70.00023148  12  3 1993   0  0 20       -44.0044  146.3534      284.6   15.2
  70.00034722  12  3 1993   0  0 30       -44.0044  146.3529     -999.0   15.2
  70.00046296  12  3 1993   0  0 40       -44.0044  146.3530      283.5   15.2
  70.00057870  12  3 1993   0  0 50       -44.0044  146.3523      287.4   15.2
  70.00069444  12  3 1993   0  1  0       -44.0043  146.3519      282.2   15.2
  70.00081019  12  3 1993   0  1 10       -44.0044  146.3515      282.4   15.2
  70.00092593  12  3 1993   0  1 20       -44.0044  146.3511      283.3   15.2
  70.00104167  12  3 1993   0  1 30       -44.0044  146.3507      286.0   15.2
  70.00115741  12  3 1993   0  1 40       -44.0044  146.3507      286.3   15.2
  70.00127315  12  3 1993   0  1 50       -44.0044  146.3502      286.8   15.2
  70.00138889  12  3 1993   0  2  0       -44.0043  146.3498      287.4   15.2
  70.00150463  12  3 1993   0  2 10       -44.0043  146.3493      291.0   15.2
```

A4.1.2 15 minute averaged underway measurement data

15 minute averaged data are contained in files named *.exp (Table A4.2), where the data filename prefix corresponds to the cruise acronym ("woes" or "worse"). Note that wind direction and ship's heading are instantaneous values. All times represent the *centre* of the averaging interval. A two line header is followed by the data as follows:

column	parameter
1	decimal time (as for 10 sec digitised files)
2	latitude (as for 10 sec digitised files)
3	longitude (as for 10 sec digitised files)
4	air pressure (hecto Pascals)
5	wind speed (knots)
6	wind direction (deg. true)
7	port air temperature (^{o}C)
8	starboard air temperature (^{o}C)
9	port relative humidity (%)
10	starboard relative humidity (%)
11	quantum radiation (μmol/s/m^{2})
12	ship speed (knots) (speed through the water)
13	ship heading (deg. true)
14	ship roll (deg.)
15	ship pitch (deg.)
16	sea surface salinity (parts per thousand) (from seawater inlet at 7 m depth)
17	sea surface temperature (^{o}C) (at seawater inlet, 7 m depth)
18	average fluorescence (arbitrary units) (from seawater inlet at 7 m depth)
19	seawater flow (l/min) (flow rate at seawater inlet)

Note that all times are UTC.

Table A4.2: Example 15 min averaged underway measurement file (*.exp file).

```
Aurora Australis  DLS data: dumped by EXPORT. Column units: days,deg,deg,hPa,knots,degTrue,degC,degC,%,%,umol/s/m2,knots,degTrue,deg,deg,ppt,degC, - ,l/min
 decimaltime       lat         long       airP windsp windd poairT stairT pohum sthum qrad shipspd shiphdg  roll    pitch     ssSAL     ssT     avfluo  seaflow
70.00520833  -44.00310  146.33583   1022.2  19.6  293  14.2  14.2  93  88   -999  6.56  235.5   1.185341  0.486591  35.175   15.20  -999.000   9.95
70.01562500  -44.00076  146.31305   1022.3  22.1  290  14.2  14.3  92  87   -999  1.15  235.5   1.295333 0.346111  35.165   15.10  -999.000   9.97
70.02604167  -44.00056  146.31239   1022.3  20.6  305   14.0  14.0  94  89   -999  0.00  235.5   2.568000 0.287667  35.159   15.10  -999.000   9.98
70.03645833  -44.00036  146.31232   1022.2  20.6  298   14.1  14.0  94  89   -999  0.00  235.5  1.303000 0.274444  35.165   15.10  -999.000   9.99
70.04687500  -44.00000  146.31136   1022.2  20.1  298  14.0  14.0  95  90   -999  0.00  234.5  1.380111  0.433667  35.166   15.10  -999.000   9.99
70.05729167  -43.99958  146.31143   1022.2  20.7  288  14.1  14.1  94  89    222   0.00  234.5  1.801667  0.464667  35.165   15.10  -999.000   9.97
70.06770833  -43.99918  146.31229   1022.3  18.5  295  13.8  14.1  96  90    170   0.00  234.5  1.619333  0.398334  35.164   15.20  -999.000   9.99
```

A4.2 2 DBAR AVERAGED CTD DATA FILES

The final format in which CTD data is distributed is as 2 dbar averaged data, contained in column formatted ascii files, named *.all (Table A4.3) (the filename prefix is discussed in Appendix 2). Averaging bins are centered on even pressure values, starting at 2 dbar. A 15 line header is followed by the data, as follows:

column	parameter
1	pressure (dbar)
2	temperature (^{o}C) (ITS-90)
3	salinity (psu)
4	σ_T = density-1000 (kg.m^{-3})
5	specific volume anomaly x 10^{8} (m^{3}.kg^{-1})

6	geopotential anomaly (J.kg^{-1})
7	dissolved oxygen (μmol.l^{-1})
8	number of data points used in the 2 dbar averaging bin
9	standard deviation of temperature values in the 2 dbar bin
10	standard deviation of conductivity values in the 2 dbar bin

All files start at the 2 dbar pressure level, incrementing by 2 dbar for each new data line. Missing data are filled by blank characters (this most often applies to dissolved oxygen data).

Table A4.3: **Example 2 dbar averaged CTD data file (*.all file).**

```
SHIP                 : R.V. Aurora Australis
STATION NUMBER       :   30
DATE                 : 20-MAR-1993  (DAY NUMBER  79)
START TIME           : 2343 UTC = Z
BOTTOM TIME          : 0104 UTC = Z
FINISH TIME          : 0219 UTC = Z
CRUISE               : Au93/09
START POSITION       : 56:26.22S 140:06.15E
BOTTOM POSITION      : 56:26.07S 140:06.15E
FINISH POSITION      : 56:26.10S 140:05.84E
MAXIMUM PRESSURE: 4014 DECIBARS
BOTTOM DEPTH         :   3940    METRES

PRESS TEMP   SAL SIGMA-T  S.V.A.  G.A.    D.O.
     (T-90)
  2.0  4.363  33.822  26.812  122.67  0.025  353.0      25  0.007  0.002
  4.0  4.356  33.827  26.816  122.26  0.049  370.7      26  0.003  0.003
  6.0  4.353  33.828  26.817  122.15  0.073  368.8      42  0.001  0.002
  8.0  4.354  33.827  26.817  122.24  0.098  366.7      36  0.002  0.001
 10.0  4.352  33.828  26.817  122.23  0.122  358.5      20  0.001  0.001
 12.0  4.351  33.828  26.817  122.21  0.147  338.4      20  0.000  0.000
 14.0  4.351  33.828  26.818  122.21  0.171  335.8      27  0.000  0.000
 16.0  4.351  33.828  26.818  122.22  0.196  332.8      27  0.000  0.001
 18.0  4.352  33.828  26.817  122.26  0.220  332.8      28  0.000  0.000
 20.0  4.351  33.828  26.817  122.29  0.245  333.4      34  0.001  0.000
 22.0  4.351  33.828  26.818  122.27  0.269  331.6      27  0.001  0.001
 24.0  4.354  33.828  26.817  122.33  0.293  330.9      21  0.001  0.001
 26.0  4.357  33.828  26.817  122.36  0.318  330.3      21  0.001  0.001
 28.0  4.359  33.828  26.817  122.43  0.342  328.4      26  0.000  0.000
```

A4.3 HYDROLOGY DATA FILES

Files named *.bot (where the filename prefix is the the cruise code e.g. a9309) are column formatted ascii files containing the hydrology data, together with CTD upcast burst data (Table A4.4). The columns contain the following values:

column	parameter
1	station number
2	CTD pressure (dbar)
3	CTD temperature (^{o}C)
4	reversing thermometer temperature (^{o}C)
5	CTD conductivity (mS.cm^{-1})

6 CTD salinity (psu)
7 bottle salinity (psu)
8 ortho phosphate concentration (μmol.l^{-1})
9 nitrate + nitrite concentration (μmol.l^{-1})
10 reactive silicate concentration (μmol.l^{-1})
11 bottle dissolved oxygen concentration (μmol.l^{-1})
12 bottle quality flag (-1=rejected, 0=suspect, 1=good)
13 niskin bottle number

Missing data values are filled by a decimal point (surrounded by blank characters). Parameters 2,3,5 and 6 are mean values from the upcast CTD burst data at the time of bottle firing, where each burst contains the data 5 sec previous to the time of bottle firing. Parameters 7 to 11 are laboratory values for the hydrology analyses. Parameter 12, the bottle quality flag, is relevant to the calibration of CTD salinities - bottles flagged 1 and 0 are used for calibration, while those flagged -1 are rejected. Criteria for flagging of the bottle data are discussed elsewhere (Appendix 2). Parameter 13, the niskin bottle number, is a unique identifier for each bottle. Note that the bottle number does not always correspond with rosette position.

<u>Table A4.4:</u> Example hydrology data file (*.bot file).

2	8.556	15.155	15.154	43.109	35.032	35.031	0.29	8.80	7.7	247.10	1	11
2	25.593	15.111	.	43.076	35.034	35.035	0.28	0.20	3.7	248.50	1	9
2	50.992	15.105	.	43.085	35.038	35.038	0.27	0.30	2.2	249.10	1	8
2	73.718	14.188	.	42.227	35.068	35.077	0.48	4.40	2.8	228.70	-1	7
2	98.376	12.840	.	40.910	35.055	35.051	0.66	7.70	2.5	227.60	-1	6
2	123.524	12.490	.	40.618	35.089	35.081	0.76	9.60	3.0	223.10	-1	5
2	148.516	11.904	.	40.025	35.052	35.067	0.85	11.10	3.4	223.30	-1	4
2	200.278	11.085	.	39.174	34.963	34.965	0.90	13.30	4.0	226.40	-1	3
2	247.807	10.678	10.691	38.758	34.914	34.914	1.02	13.90	4.1	230.40	0	2
2	289.188	9.625	.	37.640	34.769	34.794	1.13	15.80	4.8	232.40	-1	1
3	8.609	15.984	15.958	44.199	35.274	35.275	.	0.20	1.6	270.80	1	16
3	21.504	15.975	.	44.198	35.276	35.275	0.25	0.20	1.5	266.60	1	15
3	48.210	15.935	.	44.171	35.277	35.276	0.25	0.40	0.7	264.60	1	14
3	73.795	15.897	.	44.140	35.273	35.270	0.27	0.80	1.6	238.30	-1	13
3	98.905	14.011	.	42.238	35.229	35.236	0.63	7.50	2.3	.	-1	12
3	148.674	12.557	.	40.763	35.155	35.155	0.81	10.90	4.1	216.00	0	11
3	197.813	11.432	.	39.575	35.033	35.033	0.92	12.80	3.9	227.30	1	10
3	298.658	10.110	.	38.158	34.828	34.831	1.10	15.40	4.6	230.70	1	9
3	396.295	9.214	.	37.238	34.702	34.703	1.28	18.70	6.0	226.20	-1	8
3	496.675	8.371	.	36.405	34.604	34.603	1.52	22.50	9.3	210.60	1	7
3	597.207	7.385	.	35.469	34.524	34.524	1.71	25.90	14.6	199.30	1	6
3	697.115	6.587	.	34.751	34.487	34.486	1.90	28.30	20.6	195.30	1	5
3	778.707	5.739	.	33.995	34.458	34.458	2.05	30.50	27.8	.	1	4
3	900.509	4.315	.	32.710	34.381	34.382	2.20	32.70	33.6	198.50	1	3
3	1000.091	4.027	4.029	32.574	34.471	34.471	2.34	34.30	49.6	171.00	1	2
3	1113.395	3.403	.	32.110	34.517	34.522	2.42	35.40	61.3	169.90	-1	1
4	23.926	15.341	.	43.397	35.121	35.120	0.26	0.10	0.6	230.60	1	23
4	49.736	15.198	.	43.231	35.088	35.087	0.26	0.30	0.6	229.10	1	22
4	99.651	13.388	.	41.599	35.202	35.200	0.77	9.00	2.6	200.60	1	21
4	148.952	12.164	.	40.341	35.114	35.122	0.86	12.90	3.8	221.80	-1	20
4	196.847	11.114	.	39.222	34.985	34.980	0.95	11.40	3.6	233.30	-1	19
4	298.033	9.997	.	38.028	34.804	34.803	1.02	13.80	.	254.10	-1	18
4	384.198	9.235	.	37.228	34.676	34.677	.	.	.	256.20	-1	17
4	495.853	8.452	.	36.455	34.578	34.577	1.43	20.70	8.1	232.70	-1	16

A4.4 STATION INFORMATION FILES

Station information files, named *.sta (Table A4.5) (where the filename prefix is the cruise code), contain position, time, bottom depth and maximum pressure of cast for CTD stations. The CTD instrument number is specified in the file header. Position and time (UTC) are specified at the start, bottom and end of the cast, while the bottom depth is for the start of the cast. Note that small inconsistencies may exist between bottom depth and maximum pressure, due to drift of the vessel between the start and bottom of the cast. In addition, a single value is assumed for the sound velocity in seawater for echo sounder calculations (1498 m.s^{-1}), which may cause small errors in water depth values.

Table A4.5: Example CTD station information file (*.sta file).

```
________________________________________________________________________________________________________________
|                                                                                                              |
|  RSV Aurora Australis     Cruise : Au93/09            CTD station list          (CTD unit 4)                 |
|                                                                                                              |
________________________________________________________________________________________________________________
| stat |                       start                bottom   | max P |          bottom           |        end                 |
| no.  | time    date       latitude   longitude   depth(m) |(dbar) | time  latitude  longitude  | time  latitude  longitude  |
________________________________________________________________________________________________________________
|      |                                                     |       |                            |                            |
|  1   | 2032  11-MAR-93  44:06.73S  146:14.35E    1000      |  956  | 2118  44:06.37S  146:14.35E | 2154  44:06.19S  146:14.60E |
|      |                                                     |       |                            |                            |
|  2   | 0027  12-MAR-93  44:00.06S  146:18.61E     300      |  289  | 0042  44:00.03S  146:18.77E | 0115  43:59.97S  146:18.64E |
|      |                                                     |       |                            |                            |
|  3   | 0513  12-MAR-93  44:07.51S  146:14.89E    1100      | 1115  | 0549  44:07.48S  146:15.06E | 0632  44:07.39S  146:15.23E |
|      |                                                     |       |                            |                            |
|  4   | 0854  12-MAR-93  44:27.89S  146:07.94E    2340      | 2335  | 0938  44:27.52S  146:07.30E | 1028  44:27.32S  146:07.51E |
|      |                                                     |       |                            |                            |
|  5   | 1437  12-MAR-93  44:56.71S  145:56.67E    3380      | 3465  | 1606  44:56.10S  145:56.52E | 1727  44:55.56S  145:56.36E |
|      |                                                     |       |                            |                            |
________________________________________________________________________________________________________________
```

REFERENCES

Ryan, T., 1993. *Data Quality Manual for the data logged instrumentation aboard the RSV Aurora Australis.* Australian Antarctic Division, unpublished manuscript.

APPENDIX 5 Data Processing Information

Table A5.1a: Upcast CTD bursts automatically flagged during creation of intermediate CTD files (Appendix 2) - SR3 data.

station	rosette position	
number	flag=-1	flag=0
1 SR3	16	22,23
2 SR3	1,3,4,6,7	2,5
3 SR3	1,8,12,13	11
4 SR3	9,14,15,16,17,18	10,13,19
5 SR3	16,20,21,22	13,14,15,17,18
6 SR3	9,11,13,14,20,21,22	5,8,10,12,16,18
7 SR3	19,21	
8 SR3	15,16,18	12,13,17,23
9 SR3	14,21,23	9,10,11,13,15
10 SR3	21	11,12,13,14,20,23
11 SR3	15,17,21	14,16
12 SR3	12,15,20,21,23	14,16,17,18,22
13 SR3	15,21	14,18,19
14 SR3	21	11,14
15 SR3	13,16,20	11,14,21
16 SR3	16,21	12,13,14,15,17,18
17 SR3	21	17
18 SR3	19,20	15,16,17,18,21
19 SR3	16,19,21	15,18
20 SR3	17,21	19,20
21 SR3	15,18,20,21	
22 SR3	19	
23 SR3	21	15,17
24 SR3	18,19,21	
25 SR3	18,19,21	20
26 SR3		17,21,22
27 SR3	21	5,19
28 SR3	21	19
29 SR3	18	20,21
30 SR3	19,20,21	11,17,18
31 SR3	20	19,21
32 SR3	17,18,20,21	19
33 SR3	21	19,20
34 SR3	19,20,21	17
35 SR3	19,20	
36 SR3		10
41 SR3		7,8,9
43 SR3		7
45 SR3	10	8
49 SR3	7,8	4,6,9
51 SR3	9	8,10
53 SR3	9	
55 SR3	7,8,10	9
58 SR3	10	8
61 SR3	7,9,10	8
63 SR3	6,8	

Table A5.1b: **Upcast CTD bursts automatically flagged during creation of intermediate CTD files (Appendix 2) - P11 and sea ice stations.**

station number	rosette position	
	flag=-1	flag=0
1 P11	1,2,3,5	4
2 P11	11,12	4,10
3 P11	15	2,3,6,9,13,16
4 P11		6,12,15,18,19,20,22
5 P11	17,21	13,16,18,19,20
6 P11	5,17,19,21	10,11,13,16,18,20
7 P11	9,12,13,19,21	17
9 P11	13,18,21	15,20
10 P11	22	19,20,21
11 P11	20,21	14
12 P11	21	19
13 P11	19,21	17,18,23
14 P11	21	19,20
15 P11	18,20	19
16 P11	19,20,21,22	12,13,15
17 P11	19	12,13,20
18 P11	16	19,20,21
19 P11	21	12,14,18,20
20 P11	21	22
21 P11	13,18 to 24	8,11,14,15
22 P11	21	16
23 P11	21	15,20
24 P11		21
25 P11	21	16
26 P11	14,21	13,22
27 P11	21	15,19,20
28 P11	21	13,16
29 P11	13,21	
30 P11	16,21,22	13,18,23
31 P11	13,16,21	19,20
32 P11	12,16,21	11,14

station number	rosette position	
	flag=-1	flag=0
33 P11	17,18,19,21	12,14,15,20
34 P11	18,20,21	12,13
35 P11	15,20,21	16,18,19
36 P11	20,21	18
37 P11	15,17	20
38 P11	19	20
40 P11	19	
41 P11	21	14,19
42 P11	20,22	
43 P11	16,19	17,18
44 P11	21	18,20
45 P11	20	15,22
46 P11		20
47 P11	21	12,18,22
49 P11	21	2
50 P11		21
52 P11	21	
53 P11	22	
54 P11	21,22	19
55 P11	1,2,3,5,6,7,10,12,13,15,17,19,22	21,24
56 P11	24	11
57 P11	12,13	
58 P11	2,4,10	9
59 P11	12	11,13
60 P11		19
61 P11		18,19
62 P11	6,7,8,9,11,18	
63 P11		1,3
64 P11	4,9,10,11,14,20	5,17,18

Table A5.2: **Dissolved oxygen Niskin bottle samples flagged as -9 for dissolved oxygen calibration. Note that this does not necessarily indicate a bad bottle sample - in many cases, flagging is due to bad CTD dissolved oxygen data.**

station number	rosette position	station number	rosette position
2	3,11	20	23,24
3	1,11,13	21	19,22
4	12,17,23	22	19,24
6	23	23	20,21
7	22	24	18,19,21
8	4,21	25	24
9	14,18,21	26	17,21,24
11	9,10	27	20,21,24
12	9,23	28	21
13	1 to 14	29	18,19,23
14	13,21	30	23,24
15	24	31	23,24
16	22,23,24	32	24
17	21,22,24	33	20,23,24
18	20,22	34	21,23,24
19	23,24		

Table A5.3: **Duplicate samples from P11 transect, due to accidental double firing of rosette pylon. Note that all samples listed here are the first sample of the pair (i.e. at the lower rosette position number). Also note that the samples listed here are flagged with the quality code -1 (Appendix 2), if not already flagged thus i.e. rejected for the CTD conductivity calibration.**

P11 (and sea ice) station number	rosette position	P11 (and sea ice) station number	rosette position	P11 (and sea ice) station number	rosette position
22	9,11	33	5,9,11,13	45	8,10,13
23	8,11	34	5,11,13	46	5,9
24	6,13	35	1,5,13	47	5,8
25	3,5,13	36	11,13	48	5,8
26	13	37	5,8,11,13	49	8
27	5,13	38	11,13	50	9
28	5,14	40	5,11,13,15	52	8,13
29	11,13	41	5,8,11,13	53	8,11
30	11	42	5,8,11,13	54	8,10
31	13	43	5,11,13	55	8,11
32	14	44	5,8	61	5,6

Table A5.4: **Protected reversing thermometers used (serial numbers are listed).**

station numbers	shallow position thermometers	deep position thermometers
SR3 1 to 2	13323,13343	13135, 13133
SR3 3 to 8	13323,13343	9418,13133
SR3 9 to 35	13323,13343	9418,9960
SR3 36 to 63	7761,7762	13133,13135
P11 1 to 3	7761,7762	13133,13135
P11 4 to 8	7564,9494	13133,13135
P11 9 to 64	7564,9494	13133,9965

APPENDIX 6 Historical Data Comparisons

A6.1 INTRODUCTION

In this Appendix, a brief comparison is presented between the au9309/au9391 cruise data and historical data sets. Three sources of historical data exist for the region of the Southern Ocean corresponding to sections SR3 and P11, as follows. Positions for all stations referred to in the figures are listed in Table A6.1.

au9101

Section SR3 was first occupied during cruise au9101 in September to October, 1991, on the RSV Aurora Australis (Rintoul and Bullister, in prep.).

fr8609

Cruise data set fr8609 was collected by the RV Franklin in November 1986, along section P11 (Mackey and Lindstrom, principal investigators, in Sloyan, 1991). Most casts for this cruise were taken to a maximum pressure of only 1500 dbar or less. For comparison with the au9391 (P11) data, CTD temperatures for fr8609 data have been converted from IPTS-68 to ITS-90 using equation A2.9 (Appendix 2).

Eltanin data

Data collected by the Eltanin (Gordon, Molinelli and Baker, 1982) exists in the vicinity of both the SR3 and P11 sections. The data, derived from both CTD and bottle samples, has been interpolated to 44 standard pressures. CTD temperatures have been converted from IPTS-68 to ITS-90 (eqn A2.9, Appendix 2).

Table A6.1: **Positions for all stations referred to in Figures A6.1 to A6.13.**

au9309			au9101			Eltanin			au9391			fr8609		
stn	lat.°S	long.°E	stn	lat.°S	long.°E	stn	lat.°S	long.°E	stn	lat.°S	long.°E	stn	lat.°S	long.°E
13	48.783	144.320	14	48.751	143.917	689	45.198	147.375	19	45.251	155.001	71	45.500	155.000
14	49.270	144.088	15	49.214	143.635	686	48.190	148.219	25	48.248	154.999	61	46.014	154.994
15	49.752	143.869	16	49.748	143.420	678	54.058	151.129	36	53.740	154.994			
25	54.067	141.596	30	54.113	141.665				37	54.251	155.004			
30	56.437	140.103	22	56.462	140.617				21	46.250	155.002	59	46.497	155.012
48	61.846	139.854	25	61.784	138.105				23	47.250	154.995	54	46.966	154.986
5	44.945	145.945				892	44.968	139.925				52	47.485	155.002
16	50.233	143.636				896	50.110	140.117	27	49.253	154.995	47	48.998	155.005
18	51.030	143.235				898	51.001	139.984				46	49.487	154.985
26	54.535	141.320				903	54.548	140.057						

A6.2 RESULTS

A6.2.1 SR3 section

CTD temperature and salinity

TS diagrams for 6 au9309 stations are overlain with the closest corresponding au9101 stations (Figure A6.1). Data above 800 dbar are excluded from the plots, thus removing the most seasonally variable waters. The closest correspondence between the two data sets occurs in the vicinity of the salinity maximum i.e. Lower Circumpolar Deep Water (Gordon, 1967). Note that for the two cruises, the meridional variation of this salinity maximum is in general agreement. Thus the difference in salinity maxima for the au9309 and au9101 data evident in Figures A6.1e and f is isolated, and does not reflect the overall correspondence for other stations.

Similarly for the comparison between au9309 and Eltanin data (Figure A6.2), the closest correspondence is found for the Lower Circumpolar Deep Water. Note however that the spatial separation between stations being compared is greater than for the au9101/au9309 comparison, and the correspondence between TS diagrams is not as close, particularly around the salinity minimum (Figure A6.2a).

Dissolved oxygen

Vertical profiles of dissolved oxygen Niskin bottle data are compared for au9309 and au9101 in Figure A6.3. Reasonable correspondence exists for concentrations at the dissolved oxygen minimum (characterising the Upper Circumpolar Deep Water of Gordon, 1967). Below the minimum, dissolved oxygen concentrations appear to be depressed for the later cruise by an amount of the order 5 μmol/l.

Nutrients

Nutrient data for cruises au9309 and au9101 are compared in Figures A6.4 to A6.6. The nitrate+nitrite versus phosphate ratio for the two cruises does not correspond (Figure A6.4). At the time of writing, comparison with the latest nutrient data from the SR3 transect in January 1994 (unpublished) indicates an error lies in the phosphate data for cruise au9101, with au9101 phosphate concentrations greater by an average of 0.15 μmol/l. The integrity of the au9309 phosphate data was confirmed by comparison with the closest Eltanin data, along longitude 132°E, and also by the consistency found between the au9391 and fr8609 nutrient data (Figure A6.10) (noting that the nitrate+nitrite versus phosphate ratios for au9391 and au9309 are similar). The error in the au9101 phosphate values is most likely due to a combination of

(i) the different analytical instruments used - Alpkem Autoanalyser for au9309/au9391 data, and Technicon AAII for au9101 data;

(ii) the different integration techniques used for the two cruises for measuring the concentration of samples relative to standard solutions.

Note that the analysis instrument and methodology for cruises au9101 and fr8609 are the same, thus the error seems to be specific to au9101 data. Further investigation into the cause of the offset is currently underway.

For the nitrate+nitrite comparison (Figure A6.5), the closest correspondence exists south of the Subantarctic Front (as defined by Gordon et al., 1977) (Figures A6.5d to f) and below the concentration minimum. Reasonable correspondence is found for the silicate data (Figure A6.6), with the exception of the southernmost station (Figure A6.6f). Near surface nutrient concentration differences (Figure A6.5 and A6.6) reflect the different seasons in which the two data sets were collected.

A6.2.2 P11 section

For the data available for comparison with au9391 (P11) data, station positions do not correspond as well with au9391 positions as for the SR3 comparison. The closest corresponding fr8609 stations are typically 15' of latitude north and south of the au9391 stations.

CTD temperature and salinity

As for the SR3 case, the closest correspondence between the au9391 data and the fr8609 (Figure A6.7) and Eltanin (Figure A6.8) data is found in the Lower Circumpolar Deep Water in the vicinity of the salinity maximum (the fr8609 data in most cases does not extend down to the salinity maximum).

Dissolved oxygen

The spatial correspondence of available dissolved oxygen data is limited in this case, restricting station by station comparisons. From the TO diagrams in Figure A6.9, the two data sets appear consistent.

Nutrients

Nutrient data for cruises au9391 and fr8609 are compared in Figures A6.10 to A6.13. The nitrate+nitrite versus phosphate ratio for the two cruises is consistent (Figure A6.10). For all three nutrients, concentration values for the two cruises are fairly consistent for the top part of the water column, with near surface concentration values reflecting seasonal differences between the two data sets (Figures A6.11 to A6.13). Insufficient data is available for fr8609 to compare values below 1500 m. Note that the deep water nutrient concentrations for fr8609 station 61 appear anomalously high, particularly for silicate (Figure A6.13a and b).

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Gordon, A.L. 1967. *Structure of Antarctic waters between 20^{o}W and 170^{o}W.* Antarctic Map Folio Series, Folio 6, Bushnell, V. (ed.). American Geophysical Society, New York.

Gordon, A.L. and Molinelli, E.J. and Baker, T.N., 1982. *Southern Ocean Atlas (1982)*. Columbia University Press, New York. 35 pp + 248 pl.

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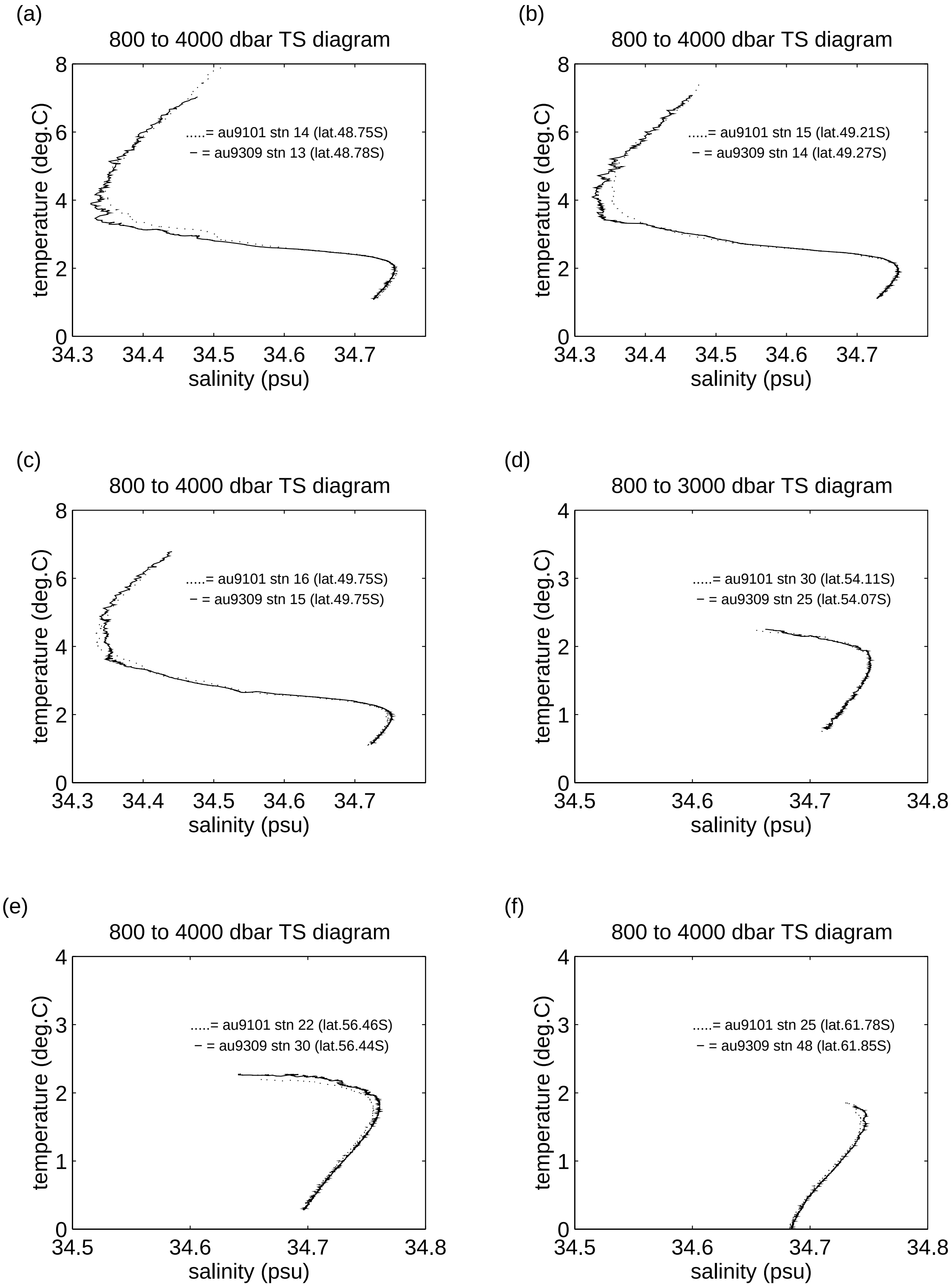
Rintoul, S.R. and Bullister, J.L. (in preparation). A late winter section between Tasmania and Antarctica: Circulation, transport and water mass formation.

Sloyan, B.M., 1991. *A study of Southern Ocean structure along 155^o E between 57^o S and 45^o S.* Honours Thesis, Institute of Antarctic and Southern Ocean Studies, University of Tasmania (unpublished manuscript). 147pp.



<u>Figure A6.1:</u> TS diagrams for comparison of au9309 and au9101 data.

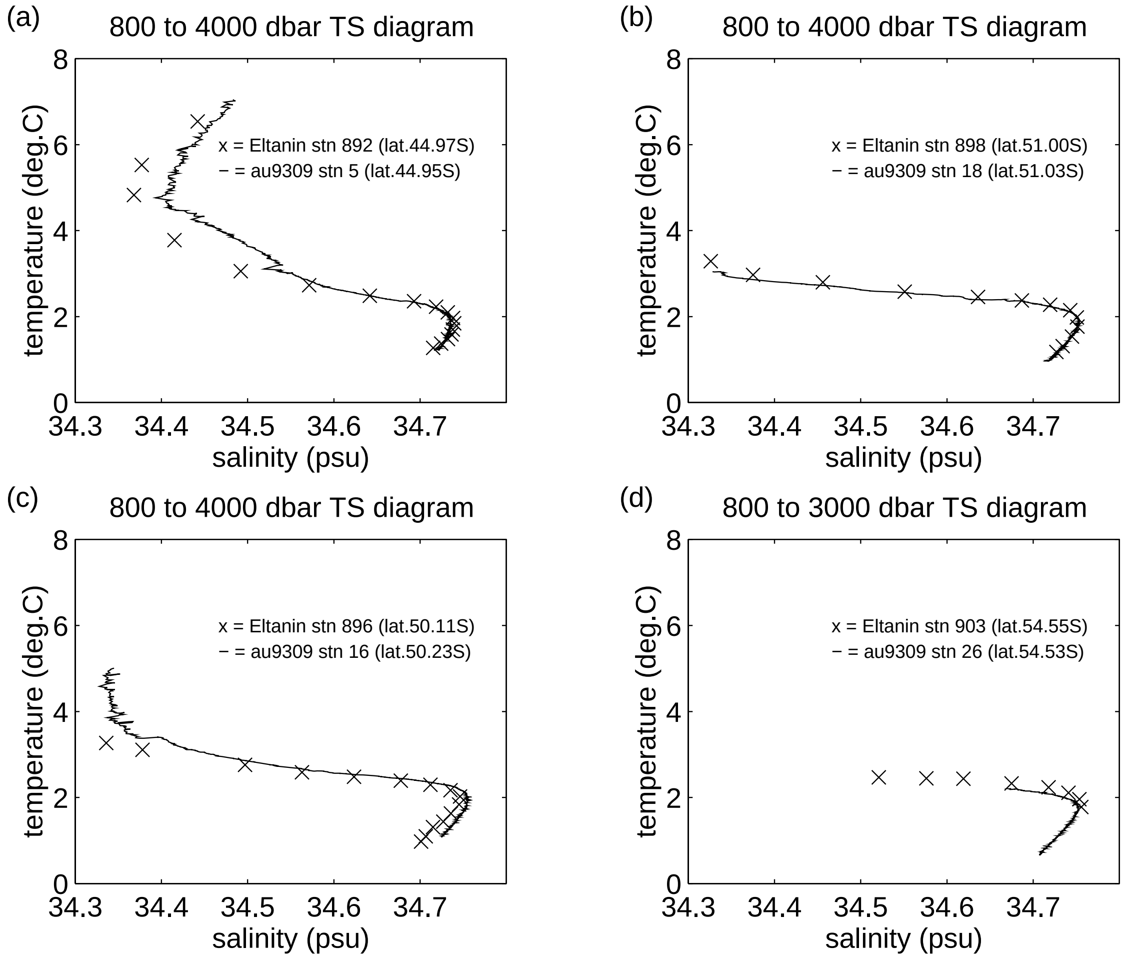
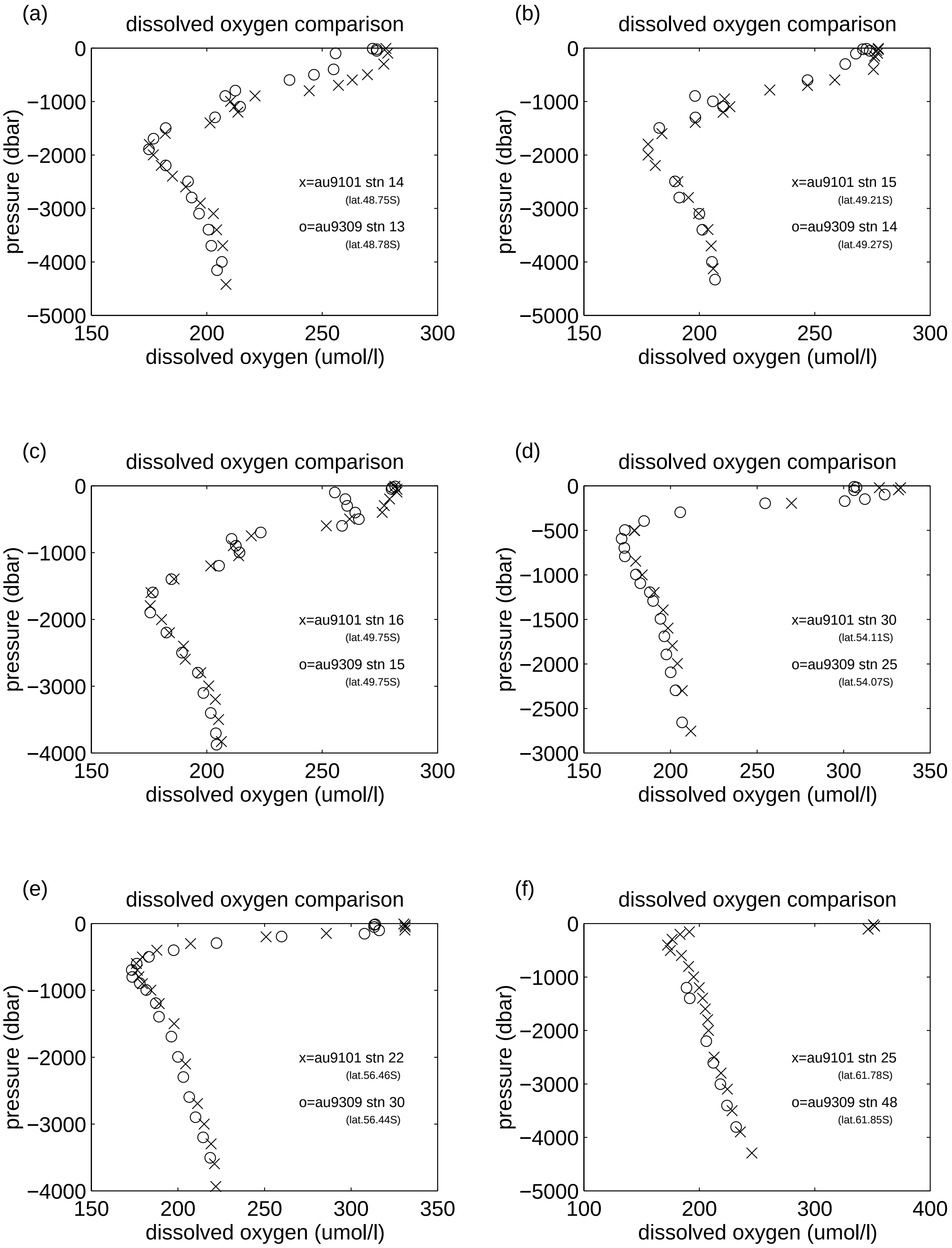
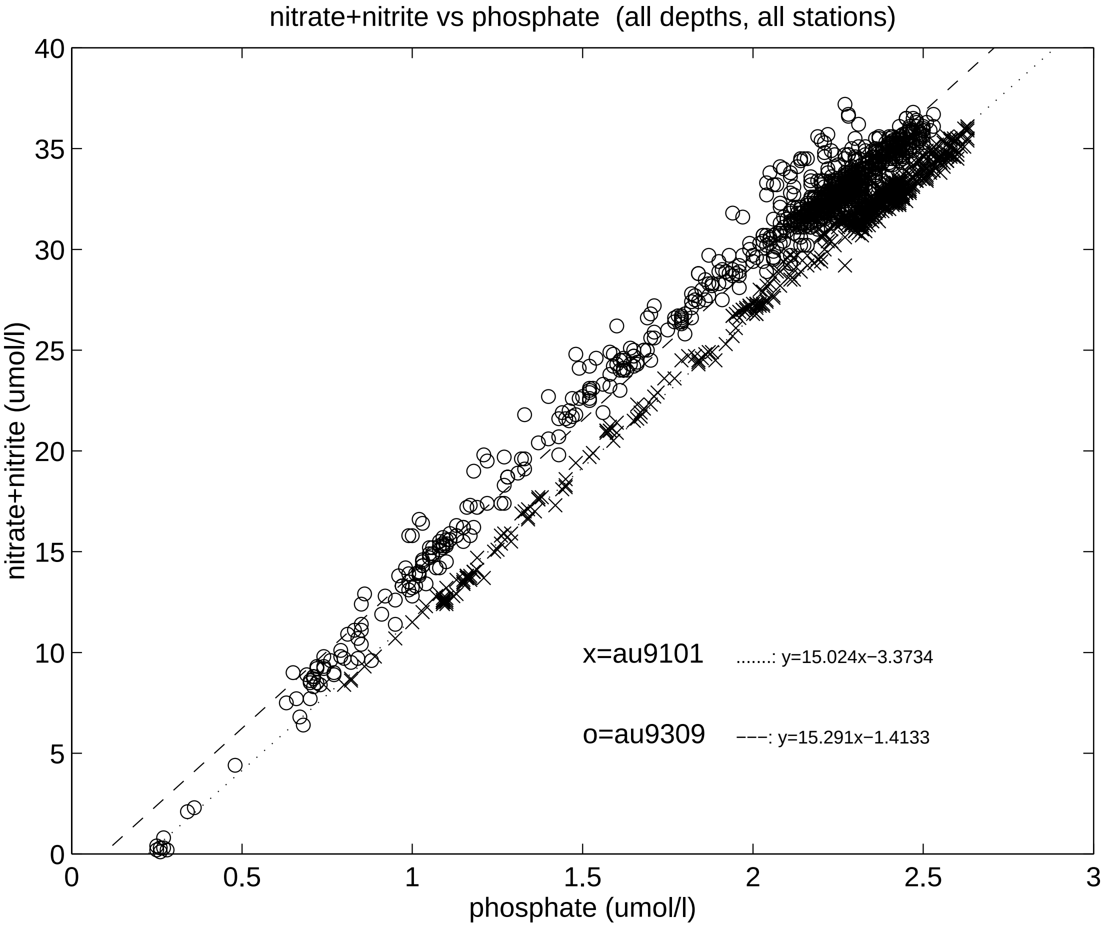


Figure A6.2: **TS diagrams for comparison of au9309 and Eltanin data.**



<u>Figure A6.3:</u> Dissolved oxygen vertical profile comparisons for au9309 and au9101 data.



<u>Figure A6.4:</u> **Bulk plot of nitrate+nitrite versus phosphate for all au9309 and au9101 data, together with linear best fit lines.**

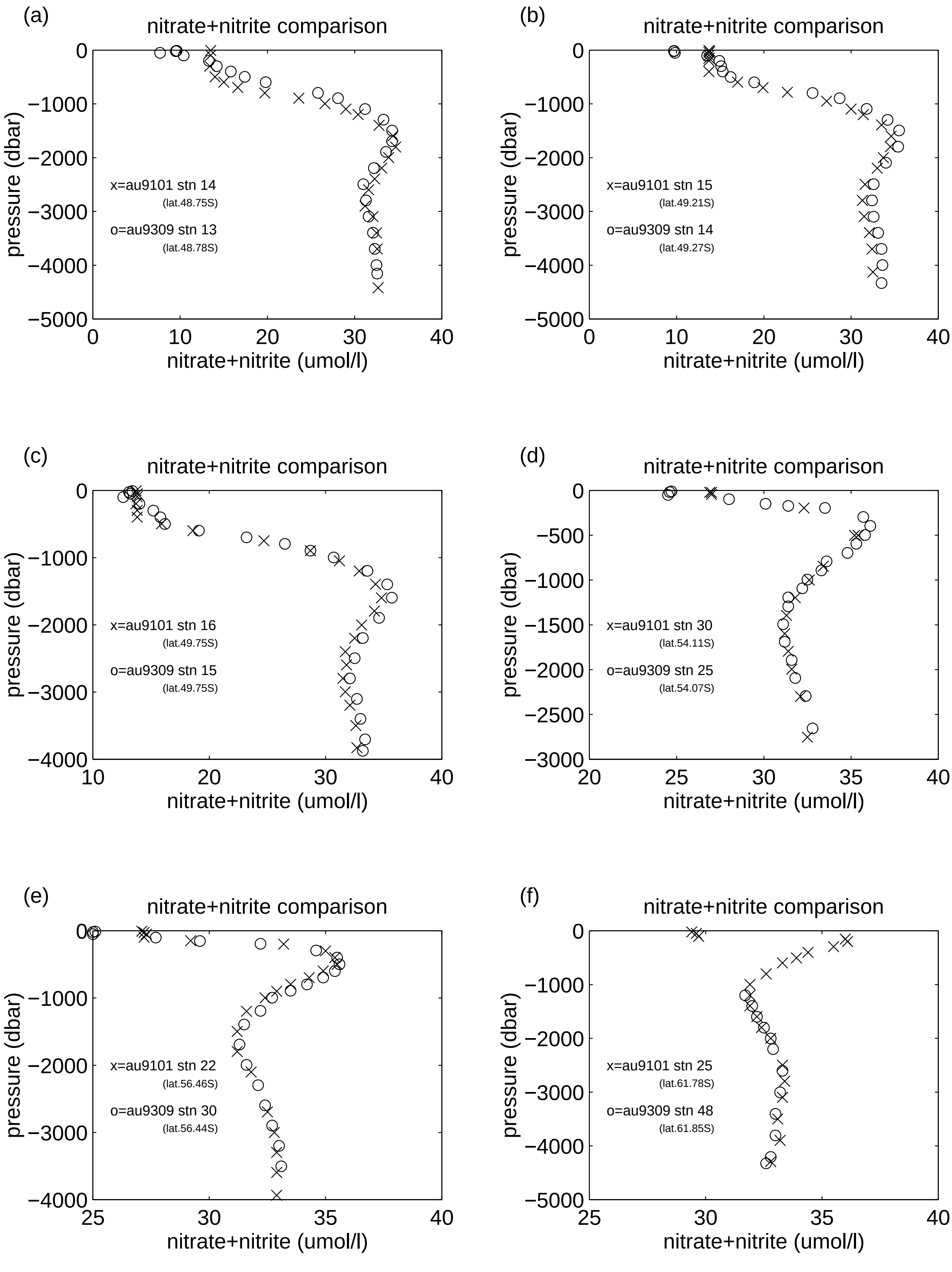


Figure A6.5: **Nitrate+nitrite vertical profile comparisons for au9309 and au9101 data.**

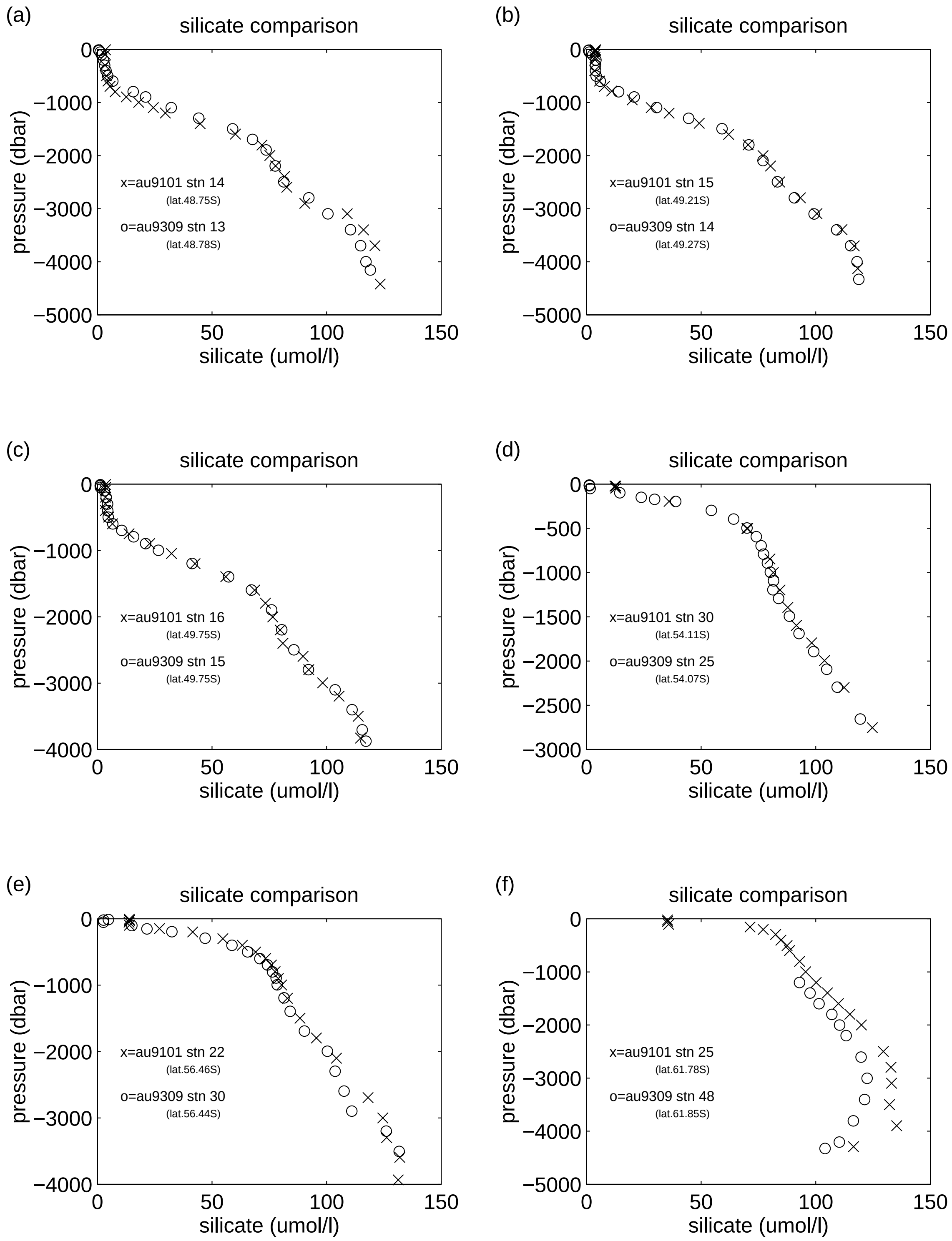


Figure A6.6: **Silicate vertical profile comparisons for au9309 and au9101 data.**

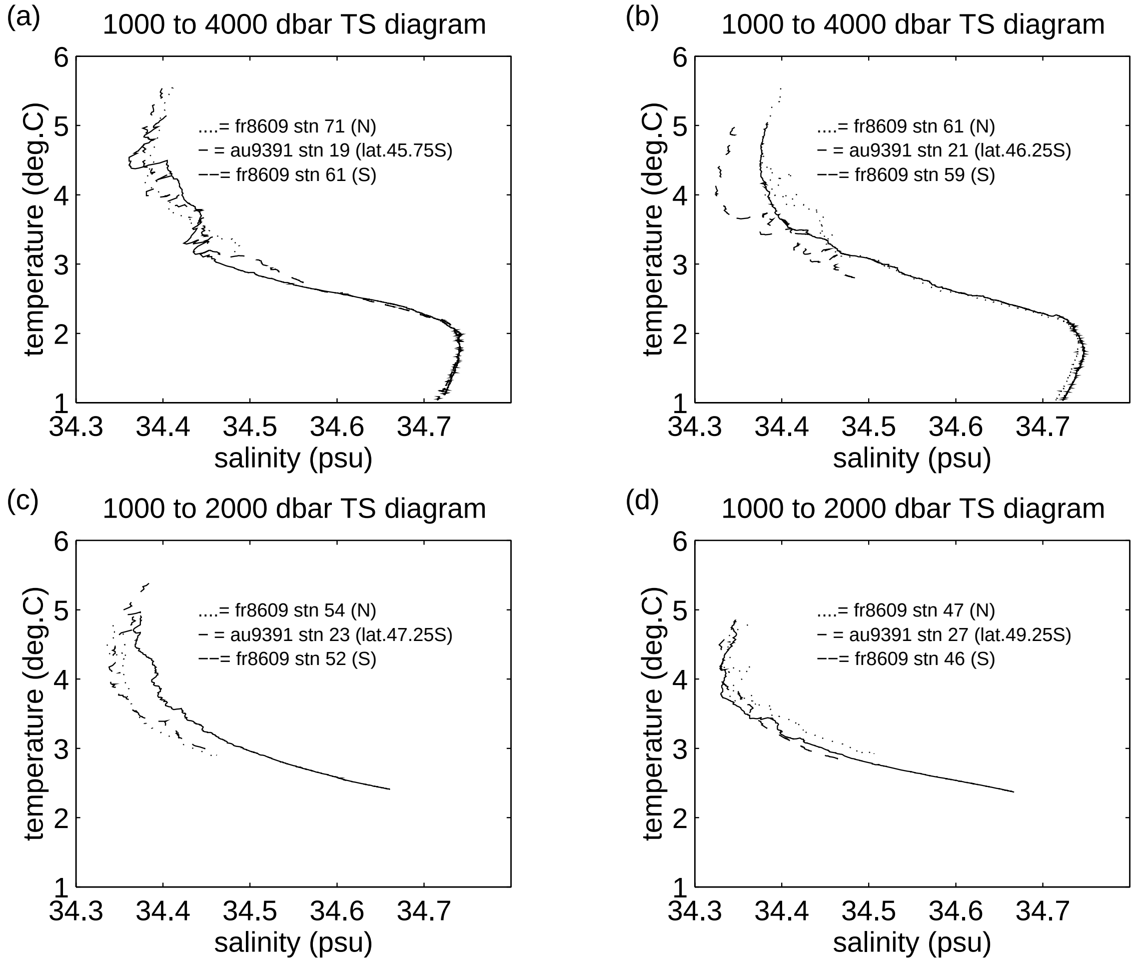


Figure A6.7: **TS diagrams for comparison of au9391 and fr8609 data.**

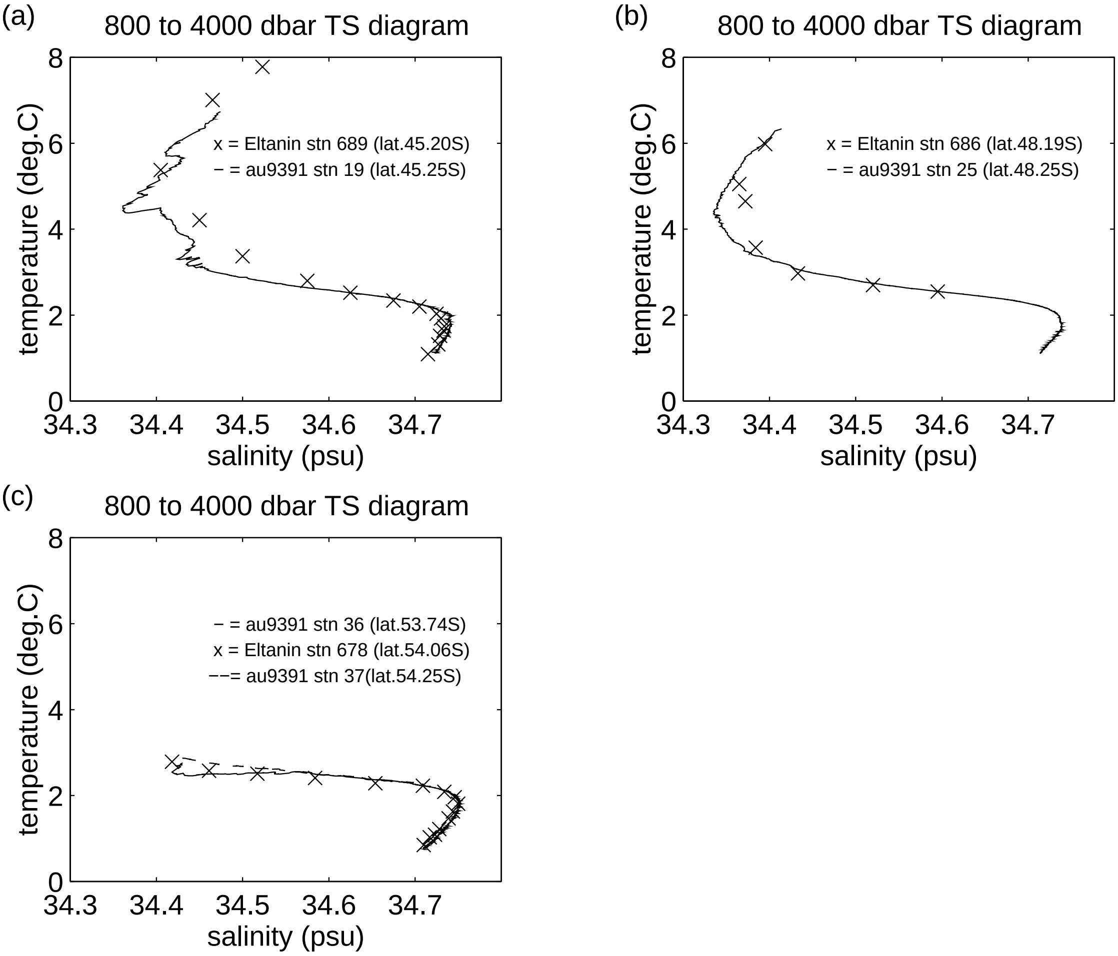
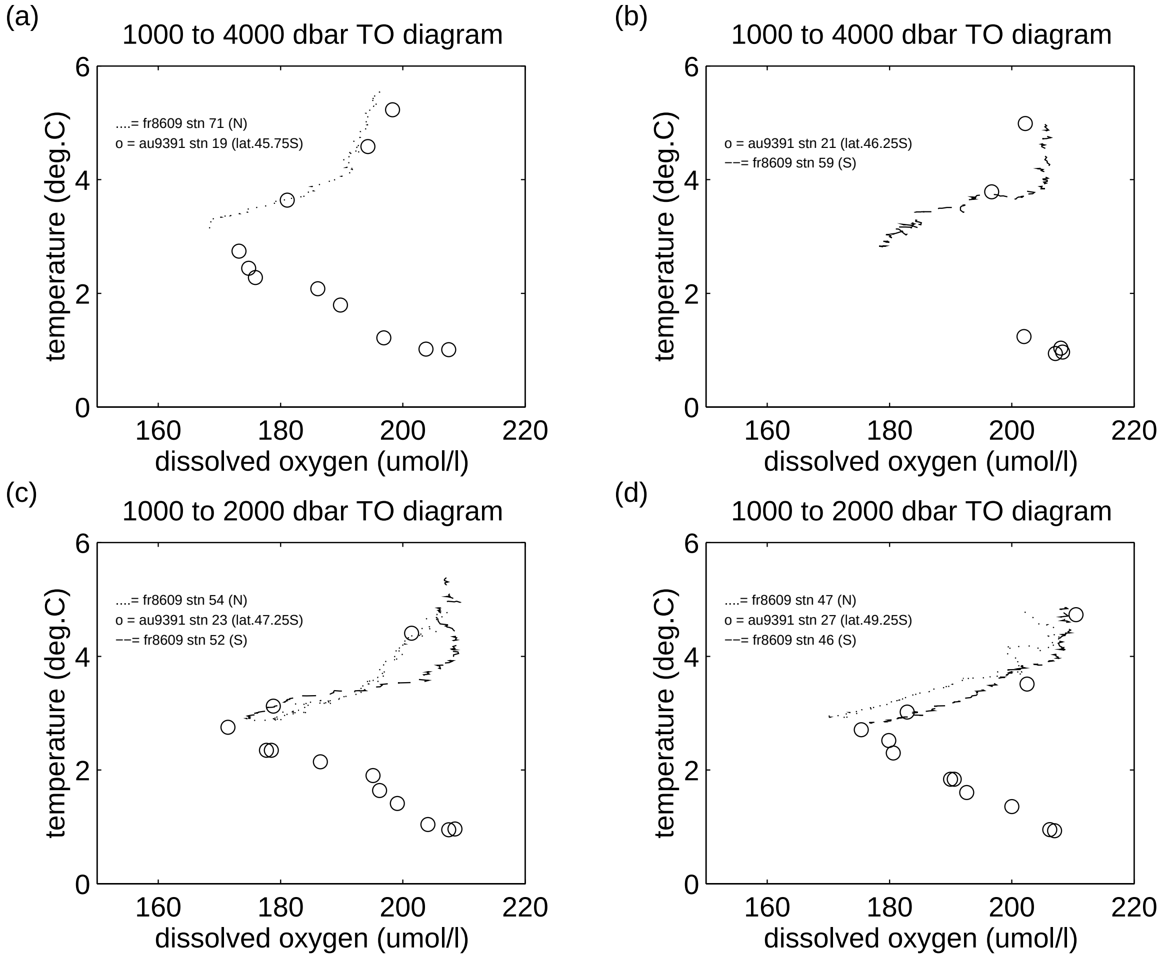


Figure A6.8: **TS diagrams for comparison of au9391 and Eltanin data.**



<u>Figure A6.9:</u> TO diagrams for comparison of au9391 and fr8609 data.

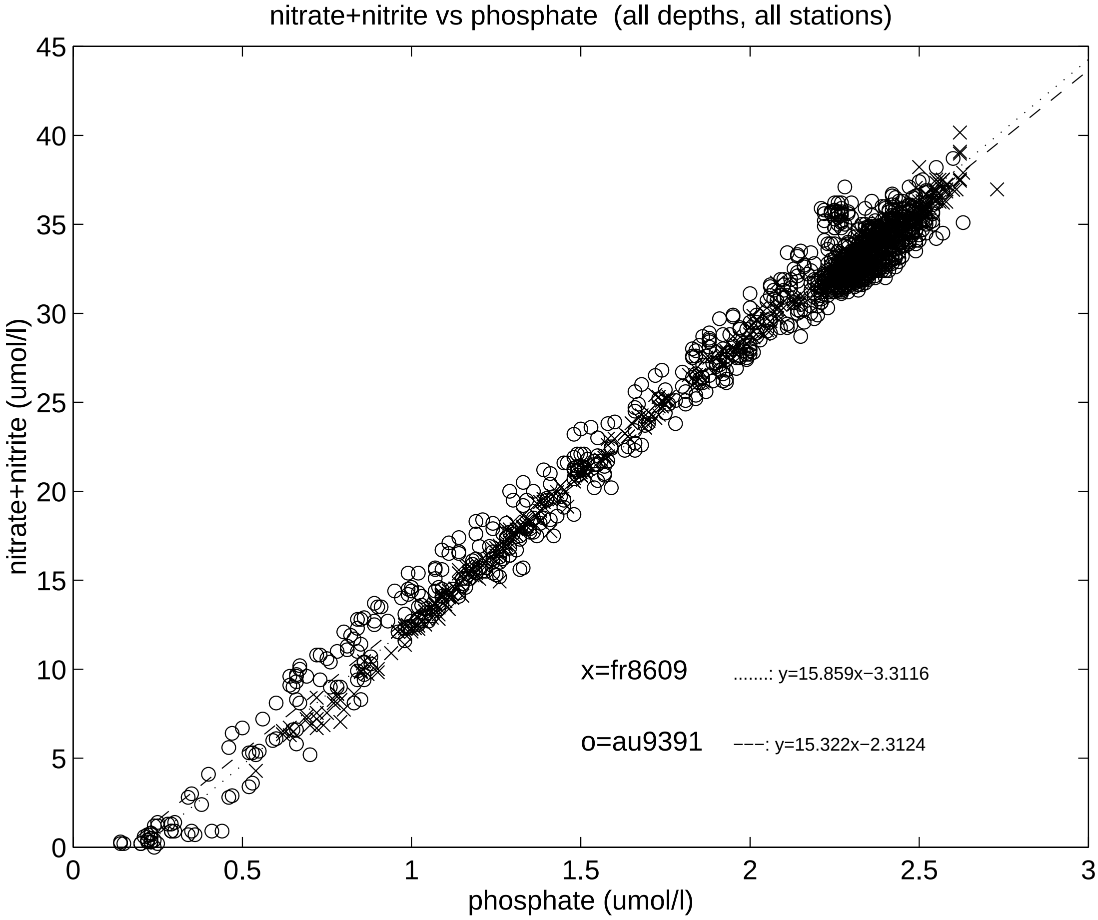


Figure A6.10: **Bulk plot of nitrate+nitrite versus phosphate for all au9391 and fr8609 data, together with linear best fit lines.**

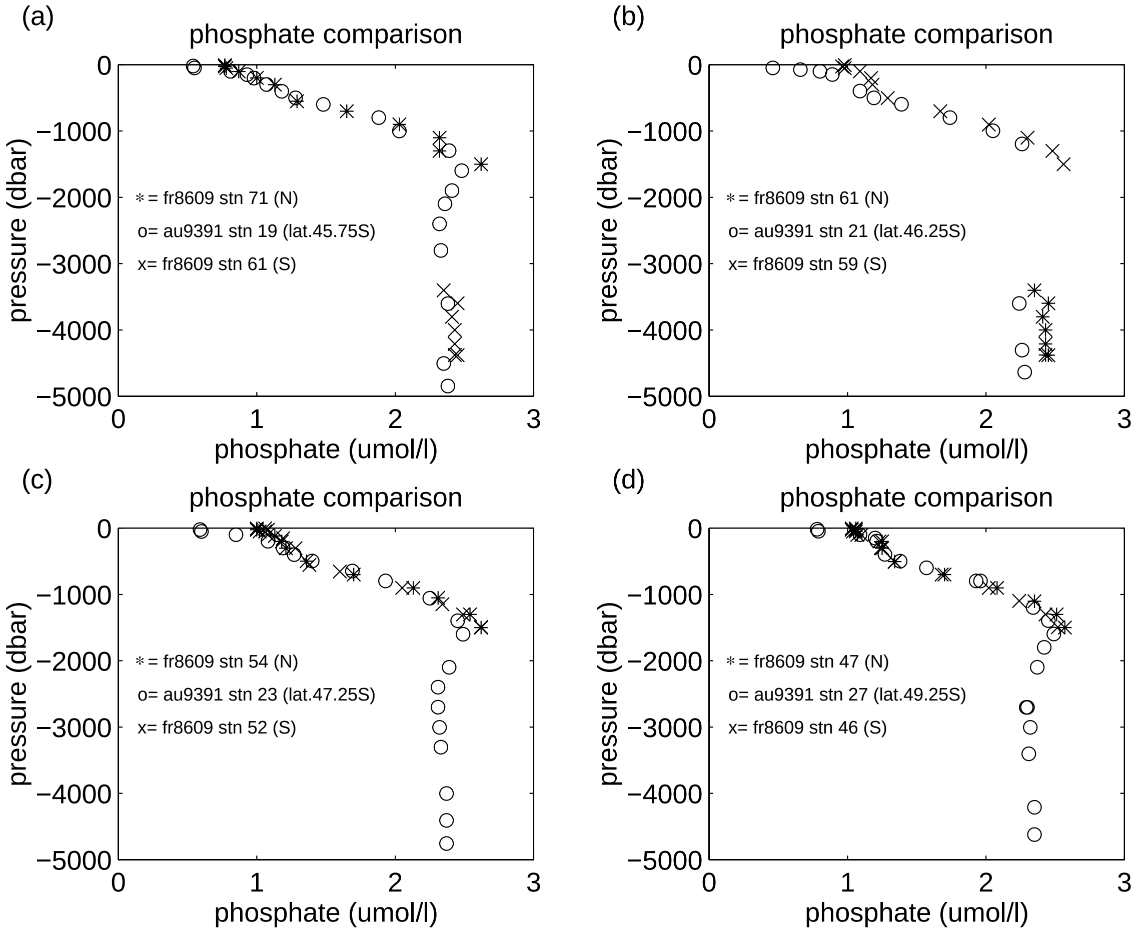


Figure A6.11: **Phosphate vertical profile comparisons for au9391 and fr8609 data.**

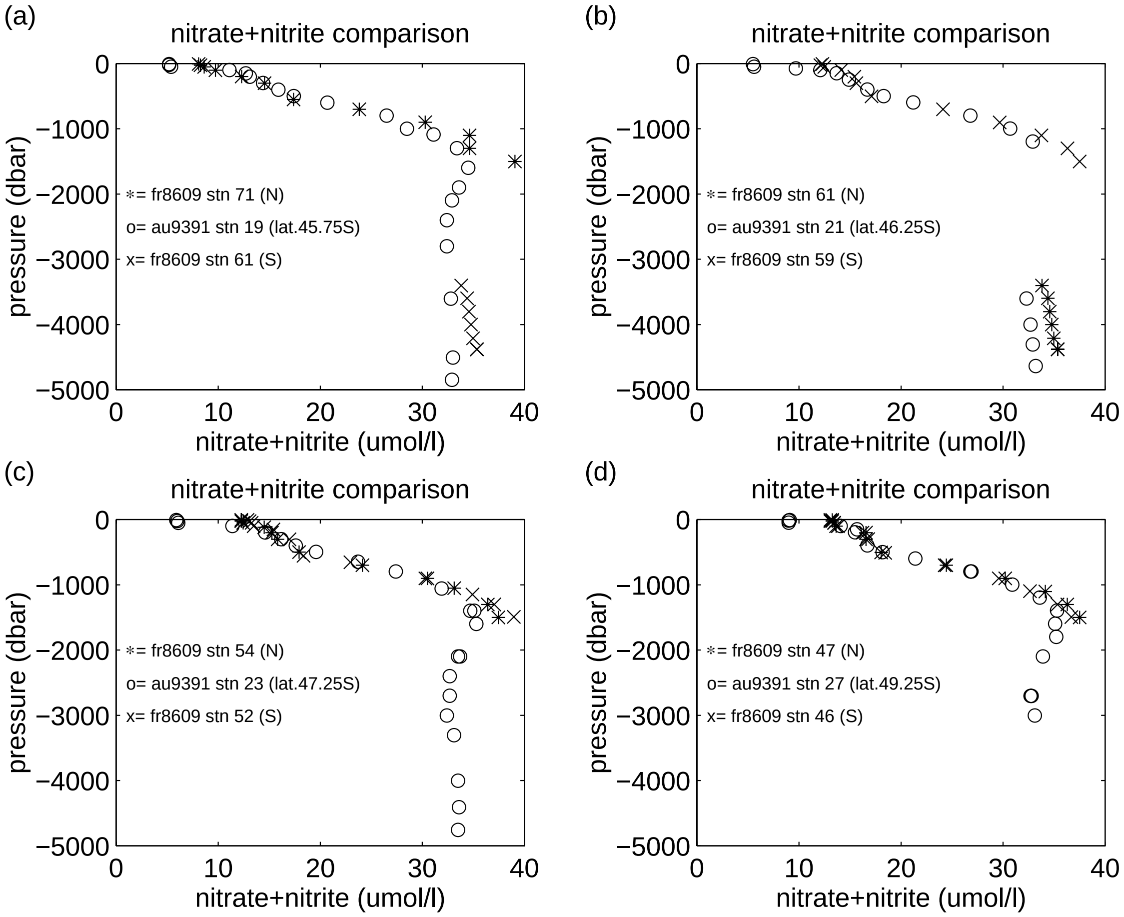
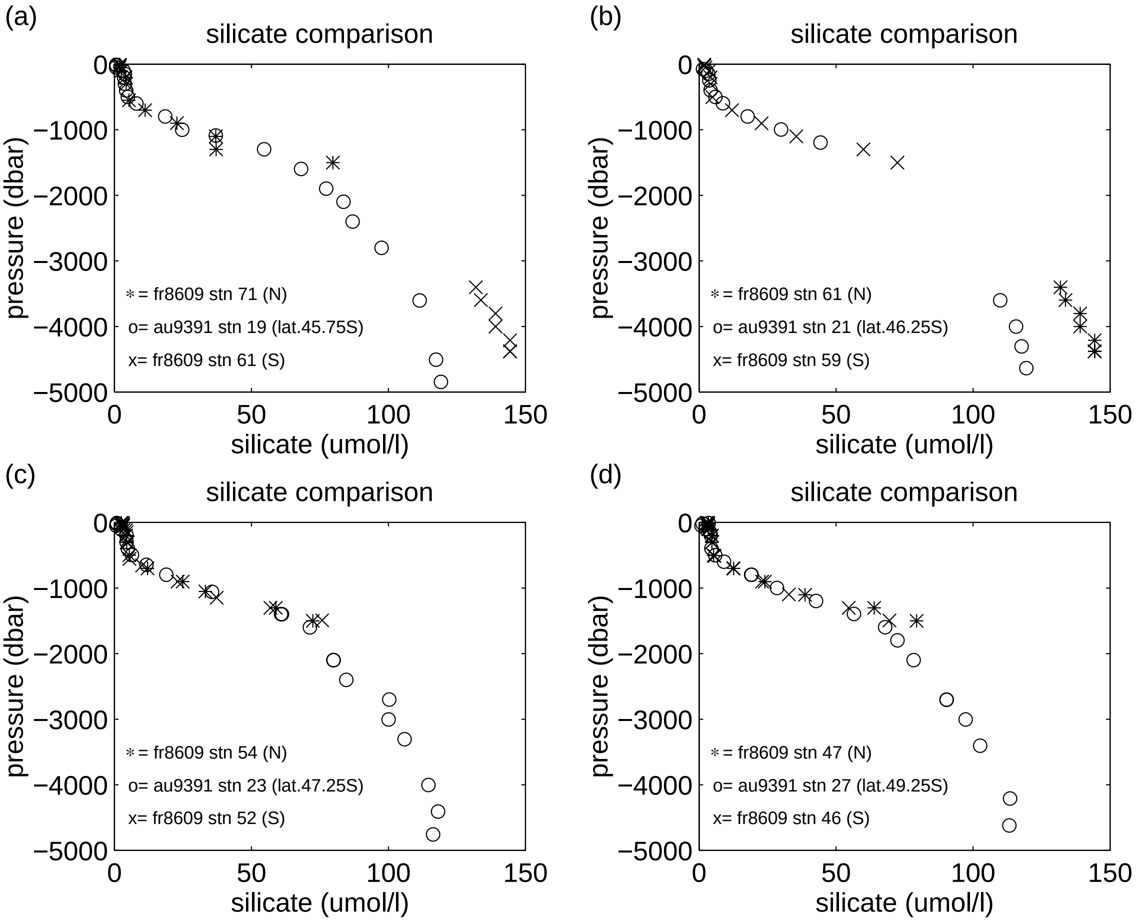


Figure A6.12: **Nitrate+nitrite vertical profile comparisons for au9391 and fr8609 data.**



<u>Figure A6.13:</u> Silicate vertical profile comparisons for au9391 and fr8609 data.

APPENDIX 7: WOCE Data Format Addendum

A7.1 INTRODUCTION

This Appendix is relevant only to data submitted to the WHP Office. For WOCE format data, file format descriptions as detailed earlier in this report should be ignored. Data files submitted to the WHP Office are in the standard WOCE format as specified in Joyce et al. (1991).

A7.2 CTD 2 DBAR-AVERAGED DATA FILES

* CTD 2 dbar-averaged file format is as per Table 3.12 of Joyce et al. (1991), except that measurements are centered on even pressure bins (with first value at 2 dbar).
* CTD temperature and salinity are reported to the third decimal place only.
* Files are named as in Appendix 2, section A2.2.1, except that for WOCE format data the suffix ".all" is replaced with ".ctd".
* The quality flags for CTD data are defined in Table A7.1. Data quality information is detailed in earlier sections of this report.

A7.3 HYDROLOGY DATA FILES

* Hydrology data file format is as per Table 3.7 of Joyce et al. (1991), with quality flags defined in Tables A7.2 and A7.3.
* Files are named as in Appendix 2, section A2.2.2, except that for WOCE format data the suffix ".bot" is replaced by ".sea".
* The total value of nitrate+nitrite only is listed.
* Silicate and nitrate+nitrite are reported to the first decimal place only.
* CTD temperature (including theta), CTD salinity and bottle salinity are all reported to the third decimal place only.
* CTD temperature (including theta), CTD pressure and CTD salinity are all derived from upcast CTD burst data; CTD dissolved oxygen is derived from downcast 2 dbar-averaged data (see Appendix 2).
* Raw CTD pressure values are not reported.
* SAMPNO is equal to the rosette position of the Niskin bottle.

A7.4 CONVERSION OF UNITS FOR DISSOLVED OXYGEN AND NUTRIENTS

A7.4.1 Dissolved oxygen

Niskin bottle data

For the WOCE format files, all Niskin bottle dissolved oxygen concentration values have been converted from volumetric units μmol/l to gravimetric units μmol/kg, as follows. Concentration C_k in μmol/kg is given by

$$C_k = 1000\, C_l / \rho(\theta,s,0) \qquad \text{(eqn A7.1)}$$

where C_l is the concentration in μmol/l, 1000 is a conversion factor, and $\rho(\theta,s,0)$ is the potential density at zero pressure and at the potential temperature θ, where potential temperature is given by

$$\theta = \theta(T,s,p) \qquad \text{(eqn A7.2)}$$

for the *in situ* temperature T, salinity s and pressure p values at which the Niskin bottle was fired. Note that T, s and p are upcast CTD burst data averages (see Appendix 2, section A2.7.4).

CTD data

In the WOCE format files, CTD dissolved oxygen data are converted to μmol/kg by the same method as above, except that T, s and p in eqns A7.1 and A7.2 are CTD 2 dbar-averaged data.

A7.4.2 Nutrients

For the WOCE format files, all Niskin bottle nutrient concentration values have been converted from volumetric units μmol/l to gravimetric units μmol/kg using

$$C_k = 1000\ C_l / \rho(T_l,s,0) \qquad \text{(eqn A7.3)}$$

where 1000 is a conversion factor, and $\rho(T_l,s,0)$ is the water density in the hydrology laboratory at the laboratory temperature T_l and at zero pressure. T_l values used for each station are listed in Table 25 of the main text. Upcast CTD burst data averages are used for s. Note that T_l values for nutrient analyses (Table 25) are estimates made by interpolating between recorded T_l values. Any error in these temperature values is at most $\pm 5^{o}$C. After converting concentrations to μmol/kg, this translates into a concentration error of at most 0.3% of full scale (and usually significantly less).

Table A7.1: Definition of quality flags for CTD data (after Table 3.11 in Joyce et al., 1991). These flags apply both to CTD data in the 2 dbar-averaged *.ctd files, and to upcast CTD burst data in the *.sea files.

flag	definition
1	not calibrated with water samples
2	acceptable measurement
3	questionable measurement
4	bad measurement
5	measurement not reported
6	interpolated value
7,8	these flags are not used
9	parameter not sampled

Table A7.2: Definition of quality flags for Niskin bottles (i.e. parameter BTLNBR in *.sea files) (after Table 3.8 in Joyce et al., 1991).

flag	definition
1	this flag is not used
2	no problems noted
3	bottle leaking, as noted when rosette package returned on deck
4	bottle did not trip correctly
5	bottle leaking, as noted from data analysis
6	bottle not fired at correct depth, due to misfiring of rosette pylon
7,8	these flags are not used
9	samples not drawn from this bottle

<u>Table A7.3:</u> Definition of quality flags for water samples in *.sea files (after Table 3.9 in Joyce et al., 1991).

flag	definition
1	this flag is not used
2	acceptable measurement
3	questionable measurement
4	bad measurement
5	measurement not reported
7	nutrient autoanalyser peak measured manually
6,8	these flags are not used
9	parameter not sampled

A7.5 STATION INFORMATION FILES

* File format is as per section 2.2.2 of Joyce et al. (1991), and files are named as in Appendix 2, section A2.2.3, except that for WOCE format data the suffix ".sta" is replaced by ".sum".

* All depths are calculated using a uniform speed of sound through the water column of 1498 ms^{-1}. Reported depths are as measured from the water surface. Missing depths are due to interference of the ship's bow thrusters with the echo sounder signal, as described in Appendix 2, section A2.3.

* An altimeter attached to the base of the rosette frame (approximately at the same vertical position as the CTD sensors) measures the elevation (or height above the bottom) in metres. The elevation value at each station is recorded manually from the CTD data stream display at the bottom of each CTD downcast. Motion of the ship due to waves can cause an error in these manually recorded values of up to ±3 m.

* Lineout (i.e. meter wheel readings of the CTD winch) were unavailable.

* The bottom latitude/longitude for station 63 in the file a9391.sum is interpolated from the start and end positions.

REFERENCES

Joyce, T., Corry, C. and Stalcup, M., 1991. *Requirements for WOCE Hydrographic Programme Data Reporting.* WHP Office Report WHPO 90-1, Revision 1, WOCE Report No. 67/91, Woods Hole Oceanographic Institution. 71 pp.