—研究ノート—
Scientific note

JARE-43 *Tangaroa* marine science cruise report (Physical oceanography)

Shigeru Aoki[1] and Toshihiko Sato[2]

第43次南極地域観測隊「タンガロア」海洋観測報告（海洋物理）

青木　茂[1]・佐藤壽彦[2]

(Received June 18, 2004; Accepted July 27, 2004)

要旨：南大洋季節海氷域における生物・化学物質循環過程の解明を中心課題として，第43次日本南極地域観測隊「専用観測船」観測が，2002年2月に観測船「タンガロア」号によって実施された．本報告では海洋物理観測の実施状況および測器の運用結果について報告する．CTD電気伝導度に対する航海前後でのキャリブレーションはドリフトの小さいことを示し，塩分換算での差も平均で0.0014に収まった．XCTDの精度を検証する試みも2キャスト実施され，XCTDとCTDとの比較結果についても議論する．本航海では，概ね，良好な精度の物理観測が実施されたものと結論される．

Abstract: To understand the seasonal variation of biological and biogeochemical cycles in the seasonal ice zone in the Southern Ocean, the cruise of JARE-STAGE (Japanese Antarctic Research Expedition-Studies on Antarctic Ocean and Global Environment) was conducted in February 2002 with R/V *Tangaroa*. Physical oceanography implementations of the cruise are described. The results of the manufacturers' CTD conductivity calibrations were consistent between before and after the cruise, and the difference in salinity estimate was expected to be within 0.0014. Two casts were made to validate the XCTD accuracy and comparisons with the CTD are discussed. Generally, it is concluded that reasonably accurate observations were completed in this cruise.

1. Introduction

The Southern Ocean is the key region in the global carbon cycle and biological production. These processes are largely controlled by environmental variations such as solar radiation, surface mixing and advection. However, these processes and their relationship with biochemical cycles in the seasonal ice zone are not yet well known.

To understand the seasonal variation of biological and biogeochemical cycles in the Southern Ocean and their roles in the global environment, the cruise of the JARE-

[1] 北海道大学低温科学研究所．Institute of Low Temperature Science, Hokkaido University, Kita-19, Nishi-8, Kita-ku, Sapporo 060–0819. (e-mail: shigeru@lowtem.hokudai.ac.jp)
[2] 筑波大学下田臨海実験センター．Shimoda Marine Research Center, University of Tsukuba, 625–8 Ogamo, Shimoda, Shizuoka 415–0038.

南極資料，Vol. 48, No. 3, 204–218, 2004
Nankyoku Shiryô (Antarctic Record), Vol. 48, No. 3, 204–218, 2004

STAGE project was conducted in 2001/02 season with R/V *Tangaroa* of the National Institute of Water and Atmospheric Research (NIWA), New Zealand (Odate *et al*., 2001; Fukuchi *et al*., 2002). Physical oceanographic observations were conducted to describe the basic flow field and water mass distribution in this region. Observations were also intended to focus on some physical aspects of deep/bottom water formation, mass transport and their temporal variability.

Physical oceanography aspects of the cruise, especially concerning data quality issues, are given in this report. Background information such as underway weather condition at the observation site is presented. Equipment, instrumentation and other problems that we encountered are described. Results of the manufacturer's Conductivity-Temperature-Depth profiler (CTD) calibrations are briefly compared with bottle sampled salinity and dissolved oxygen. Results of expendable Conductivity-Temperature-Depth profiler (XCTD) validations with simultaneous CTD are also presented to estimate their capability and limitation.

2. Stations

Observations of R/V Tangaroa were conducted along 140°E (Fig. 1), which was the same as the R/V *Hakuho-maru* cruise track in January 2002 and reasonably close to the WOCE/CLIVAR SR3 line in November/December 2001. CTD observations with a Rosette sampler were conducted at observation stations. XCTD, expendable Bathy-Thermograph (XBT), and Shipboard-Acoustic Doppler Current Profiler (S-ADCP) observations were carried out underway. Automatic weather station and intake thermo-salinograph observations were also conducted underway.

2.1. Observational conditions

R/V *Tangaroa* departed Hobart on February 6, 2002. The meridional positions of the cruise track are shown in time sequence in Fig. 2. While conducting underway observations, we entered the intensive observation area south of 61°S on February 11. The southernmost station (66.4°S) was occupied on February 13. Observations were completed at 64°S on February 15. On the way south to the station at 65.75°S on February 18, a few stations were occupied and then *Tangaroa* steamed northward to the station at 60°S on February 27. *Tangaroa* headed northward from 60°S on February 27 and arrived at Hobart on March 4.

Generally, weather was not calm. 50 hours of the planned observation time were abandoned due to bad weather, including passage of a heavy low pressure system on February 16. Air temperature, wind speed, and surface pressure are also shown for the entire cruise period (Fig. 2).

2.2. CTD and hydrography measurements

CTD observations with a Rosette sampler system were conducted at 16 points (Fig. 1). The basic station interval was about 0.75 degree in latitude. In addition, finely spaced observations were carried out on the continental slope. 54 casts were conducted in total; two routine (shallow and deep) casts and iron sampling were conducted at most of the stations, and additional water sampling casts for organic materials were taken at

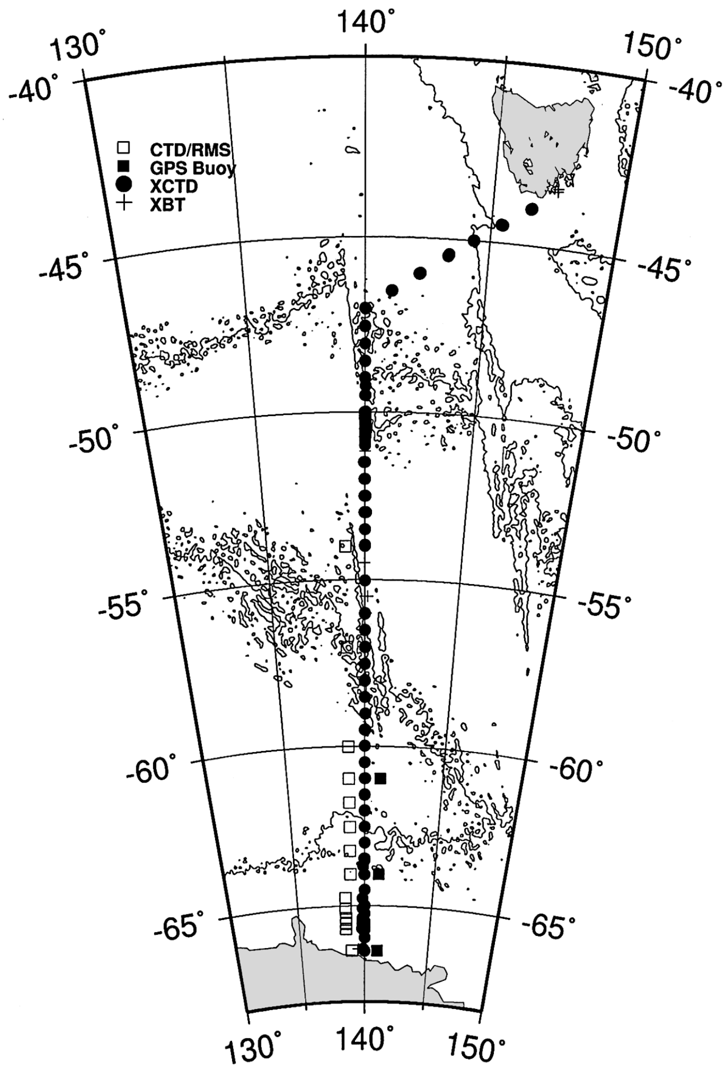

Fig. 1. Observation station positions of R/V Tangaroa. *Open squares denote CTD/RMS observations, filled squares GPS buoy deployment, dots XCTD, and crosses XBT, respectively. The line denotes the 3000 m isobath.*

some intensive study stations. Positions and depths of the casts are given in Table 1.

2.3. XCTD/XBT measurements

XCTDs were conducted as routine observations with the interval of 0.5 degree in latitude, while XBTs were deployed for observations of the high-resolution structure of the Sub-Antarctic Front and for the XBT/XCTD observational system check (Fig. 1). 101 XCTDs and 131 XBTs were taken. Positions and depths of the casts are given in Table 2.

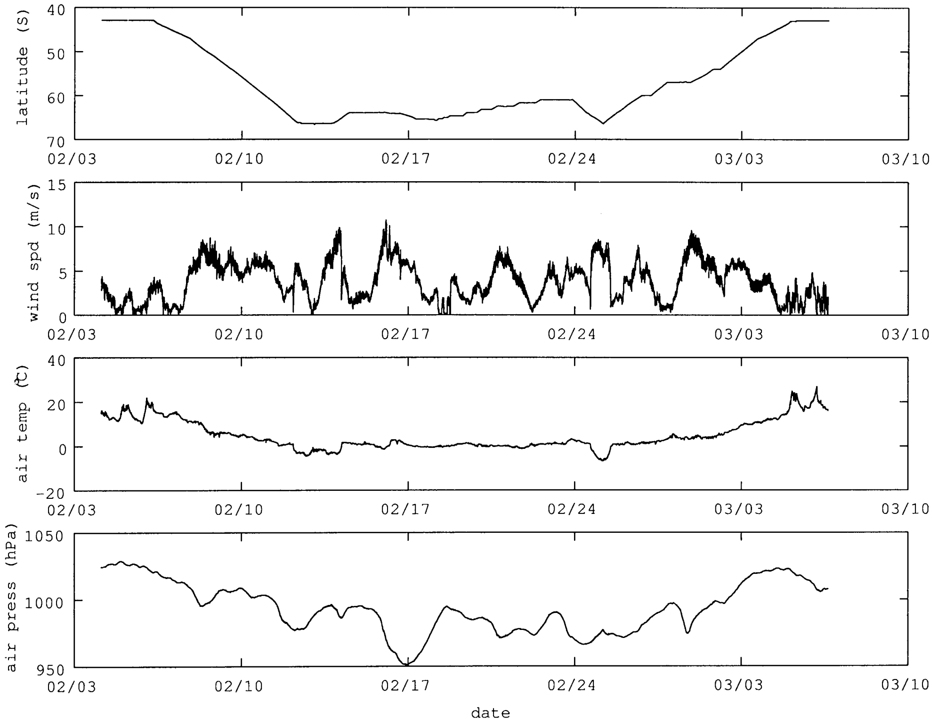

Fig. 2. Weather condition and meridional position during the cruise. a) latitude, b) wind speed (m/s), c) air temperature (℃), and d) air pressure (hPa).

3. Data collection methods

In this section, CTD, XCTD/XBT, and S-ADCP data collection and processing methods are described.

3.1. CTD instrumentation

Seabird 911 CTD units were used, with 10 litre Ocean Test Equipment Niskin bottles (non-coated) and 12 litre General Oceanics X-Niskin bottles (teflon coated). A 24 position Rosette package was deployed for all stations.

The CTD unit had two sensors for temperature, conductivity, and dissolved oxygen (DO), and one sensor for pressure, fluorometer and the photosynthetically active radiation unit (PAR: only for casts shallower than 1000 m).

Generally, the primary and secondary sensors worked very well except for a few initial casts (see Walkington, 2002). For the primary temperature, conductivity, and pressure sensors, calibrations were conducted at Seabird Inc. before and after the cruise.

The CTD/Rosette system was put into water directly to about 20 m depth. After the cell pump turned on, it was brought up to just below the surface, held there for a while, and then lowered.

Table 1. CTD cast information

ST	CN	MN	DG	HM	LAT	MN	LON	MN	DEP	MAXD
8	1	2	12	1309	66	26.081	140	00.038	1035	202
8	2	2	12	1640	66	26.054	139	59.958	1030	306
8	3	2	13	0258	66	25.991	140	00.027	1025	330
8	4	2	13	0847	66	25.306	139	59.700	982	954
8	5	2	13	1222	66	26.059	140	00.865	1059	989
8	6	2	13	1705	66	25.860	140	00.580	1031	201
5	1	2	14	1311	64	00.056	140	00.040	-	202
5	2	2	14	1630	64	00.055	139	59.953	-	303
5	3	2	15	0200	64	00.049	140	00.715	-	201
5	4	2	15	0500	64	00.040	140	00.104	-	201
5	5	2	15	0824	64	00.147	140	00.298	-	753
5	6	2	15	1243	63	59.589	140	02.130	-	250
5	7	2	15	1450	63	59.994	139	59.955	-	301
5	8	2	15	2031	64	00.556	140	01.765	3702	3512
7	1	2	17	0831	65	25.389	139	51.414	1871	301
7	2	2	17	1104	65	25.917	139	50.901	2015	300
7	2b	2	17	1128	65	25.975	139	50.909	2020	303
7	3	2	17	1310	65	26.075	139	50.860	2019	606
7	4	2	17	1530	65	26.085	139	50.880	1870	1851
7.1	1	2	17	2105	65	31.430	139	50.608	1344	1343
7.2	1	2	17	2345	65	33.930	139	50.372	906	903
7.3	1	2	18	0300	65	44.472	139	49.442	301	293
6.2	1	2	18	0705	65	23.015	139	51.963	2491	2428
6.1	1	2	18	1210	65	06.906	139	50.590	2814	2812
6	1	2	18	1845	64	44.574	139	50.413	2814	302
6	2	2	18	2200	64	44.951	139	52.664	2777	42
6	3	2	19	0153	64	44.882	139	50.490	2811	2804
6	4	2	19	0533	64	45.198	139	50.742	2791	205
5	1	2	19	1304	64	00.020	140	00.003	3696	3644
4	1	2	20	0212	63	14.965	139	59.693	-	299
4	2	2	20	0705	63	14.979	140	00.790	3818	3765
4	3	2	20	1110	63	13.891	140	00.327	3818	299
3	1	2	20	1940	62	28.232	140	03.640	3757	298
3	2	2	21	0415	62	30.002	140	00.177	3942	3882
3	3	2	21	0840	62	32.569	140	02.289	-	299
2	1	2	21	1855	61	43.385	140	01.056	4308	300
2	2	2	22	0135	61	45.028	140	00.075	4306	3948
2	3	2	22	0730	61	45.292	140	00.075	-	301
1	1	2	22	1332	60	59.905	140	00.145	4386	208
1	2	2	22	1650	61	00.134	140	00.330	4386	302
1	3	2	22	1850	61	01.125	140	00.356	4385	748
1	4	2	23	0300	60	59.895	139	59.200	4386	203
1	5	2	23	0755	61	01.719	139	57.014	4384	207
1	6	2	23	1130	60	59.969	139	59.932	-	204
1	7	2	23	1400	61	00.116	139	59.938	-	3932
9	1	2	26	2050	59	59.543	140	00.711	4473	305
9	2	2	26	2030	60	00.116	139	59.812	-	3920
9	3	2	27	0410	60	00.355	140	00.180	-	301
10	1	2	27	2128	57	01.329	140	00.652	4156	303
10	2	2	28	0242	56	59.815	140	00.518	4060	3951
10	3	2	28	0730	57	00.222	139	59.464	4070	300
11	1	3	01	1920	54	00.257	139	59.338	3318	300
11	2	3	01	2107	54	00.369	139	59.949	3349	3265
11	3	3	02	0138	54	00.015	140	00.048	3271	304

ST denotes station number, and CN cast number. MN/DG/HM denote day and hour, minutes in GMT, LAT/MN latitude and minutes, LON/MN latitude and minutes, DEP bottom depth (m). MAXD was the deepest level of the CTD cast (dbar).

Table 2. XCTD and XBT information

Type	CN	MN	DG	HM	LAT	MN	LON	MN	DP
T-6	1	2	6	2030	43	21.304	147	27.211	
T-6	2	2	6	2052	43	25.765	147	26.448	
XCTD	1	2	7	0135	43	59.976	146	30.273	
XCTD	2	2	7	0630	44	30.034	145	24.025	
XCTD	3	2	7	1111	45	00.177	144	21.337	
XCTD	4	2	7	1535	45	28.966	144	22.301	850
XCTD	5	2	7	2052	46	00.026	142	13.100	970
XCTD	6	2	8	0140	46	30.130	141	06.324	
XCTD	7	2	8	0631	46	59.910	140	00.054	
XCTD	8	2	8	0916	47	30.617	140	00.400	
XCTD	9	2	8	1149	48	00.180	139	59.940	
XCTD	10	2	8	1435	48	30.220	139	59.950	350
XCTD	11	2	8	1442	48	30.840	139	59.951	200
XCTD	12	2	8	1445	48	31.243	139	59.944	236
XCTD	13	2	8	1728	48	59.000	140	00.507	120
XCTD	14	2	8	1733	49	01.027	140	00.616	89
T-6	3	2	8	1741	49	02.407	140	00.718	210
T-6	4	2	8	1833	49	11.296	140	01.515	
XCTD	15	2	8	1855	49	14.000	140	01.860	
XCTD	16	2	8	2026	49	30.200	140	02.110	
XCTD	17	2	8	2334	49	59.710	140	02.000	
T-6	5	2	9	0003	50	03.947	140	02.095	
T-6	6	2	9	0008	50	04.900	140	02.110	
T-6	7	2	9	0015	50	06.000	140	02.176	
T-6	8	2	9	0021	50	07.000	140	02.211	
T-6	9	2	9	0028	50	08.000	140	02.263	
T-6	10	2	9	0034	50	09.000	140	02.317	
T-6	11	2	9	0040	50	10.000	140	02.344	
T-6	12	2	9	0053	50	12.060	140	02.418	
T-6	13	2	9	0100	50	13.000	140	02.470	
T-6	14	2	9	0113	50	15.080	140	02.526	
T-6	15	2	9	0119	50	16.000	140	02.551	
T-6	16	2	9	0126	50	16.997	140	02.553	
T-6	17	2	9	0133	50	17.997	140	02.572	
T-6	18	2	9	0140	50	19.000	140	02.610	
T-6	19	2	9	0147	50	20.020	140	02.662	
T-6	20	2	9	0155	50	21.040	140	02.763	
T-6	21	2	9	0202	50	22.030	140	02.859	
T-6	22	2	9	0209	50	23.020	140	02.930	
T-6	23	2	9	0217	50	24.040	140	03.000	
T-6	24	2	9	0209	50	25.080	140	03.040	
T-6	25	2	9	0231	50	25.990	140	03.090	
T-6	26	2	9	0238	50	27.000	140	03.143	
T-6	27	2	9	0246	50	28.000	140	03.193	
T-6	28	2	9	0253	50	29.017	140	03.221	
XCTD	18	2	9	0300	50	30.030	140	03.271	
T-6	29	2	9	0309	50	31.260	140	03.290	300
T-6	30	2	9	0315	50	32.050	140	03.280	
T-6	31	2	9	0322	50	33.018	140	03.253	
T-6	32	2	9	0329	50	34.030	140	03.209	
T-6	33	2	9	0336	50	35.041	140	03.163	
T-6	34	2	9	0342	50	35.978	140	03.070	
T-6	35	2	9	0349	50	36.868	140	02.953	
T-6	36	2	9	0356	50	38.000	140	02.700	
T-6	37	2	9	0403	50	38.974	140	02.700	
T-6	38	2	9	0410	50	39.969	140	02.540	
T-6	39	2	9	0417	50	41.010	140	02.402	
T-6	40	2	9	0424	50	42.006	140	02.256	
T-6	41	2	9	0431	50	43.014	140	02.100	
T-6	42	2	9	0438	50	44.015	140	01.937	
T-6	43	2	9	0445	50	45.017	140	01.750	
T-6	44	2	9	0452	50	46.000	140	01.520	
T-6	45	2	9	0459	50	46.973	140	01.351	300

Table 2. Continued.

XCTD	19	2	9	0628	51	00.060	140	00.414	
XCTD	20	2	9	0928	51	29.991	139	56.387	
XCTD	21	2	9	1223	51	59.795	139	58.882	
XCTD	22	2	9	1526	52	29.999	140	01.634	
XCTD	23	2	9	1822	53	00.300	140	02.400	
XCTD	24	2	9	2111	53	30.299	139	59.183	
XCTD	25	2	10	0000	53	58.311	140	00.474	
T-7	46	2	10	0333	54	29.565	139	58.611	
XCTD	26	2	10	0630	55	01.260	140	00.170	
T-7	47	2	10	0909	55	30.006	140	01.243	
XCTD	27	2	10	1158	56	00.000	140	00.000	30
XCTD	28	2	10	1201	56	00.468	139	59.900	
T-7	48	2	10	1446	56	30.151	140	00.395	
XCTD	29	2	10	1726	57	00.160	140	02.090	
T-7	49	2	10	2013	57	30.000	139	59.960	
XCTD	30	2	10	2253	57	59.855	139	59.860	
T-7	50	2	11	0141	58	30.011	139	59.485	
XCTD	31	2	11	0427	59	00.023	140	01.204	
XCTD	32	2	11	0714	59	30.023	140	00.624	
XCTD	33	2	11	0958	59	59.556	139	59.800	
XCTD	34	2	11	1250	60	30.080	140	00.040	
XCTD	35	2	11	1529	60	59.227	140	00.190	
XCTD	36	2	11	1827	61	30.009	139	59.782	
XCTD	37	2	11	2108	62	00.126	139	59.105	
XCTD	38	2	11	2343	62	30.001	140	00.116	
XCTD	39	2	12	0214	62	59.961	140	00.652	
XCTD	40	2	12	0449	63	29.936	140	00.576	
XCTD	41	2	12	0720	63	59.930	139	58.650	
XCTD	42	2	12	0950	64	29.936	140	00.615	
XCTD	43	2	12	1221	65	00.020	139	59.410	
XCTD	44	2	12	1336	65	15.113	139	59.842	
XCTD	45	2	12	1448	65	29.722	139	59.917	(170)
XCTD	46	2	12	1458	65	31.990	140	00.330	
XCTD	47	2	12	1516	65	35.005	140	00.440	
XCTD	48	2	12	1525	65	36.690	140	00.320	
XCTD	49	2	12	1543	65	39.968	139	59.312	
XCTD	50	2	12	1610	65	45.048	139	58.848	
XCTD	51	2	12	1728	66	00.050	139	59.199	80
XCTD	52	2	12	1732	66	00.790	139	59.199	
T-7	51	2	14	0728	66	22.020	139	31.270	
T-7	52	2	20	0841	63	49.506	139	53.559	
XCTD	53	2	20	0920	63	43.890	139	53.982	
XCTD	54	2	20	1052	63	29.990	139	56.983	
XCTD	55	2	24	1101	61	30.056	140	00.466	1043
XCTD	56	2	24	1322	61	59.841	140	00.163	1095
XCTD	57	2	24	1543	62	30.089	140	00.723	890
XCTD	58	2	24	1803	63	00.007	139	58.971	900
XCTD	59	2	24	2041	63	33.055	140	00.106	890
XCTD	60	2	24	2254	63	59.981	139	59.960	
XCTD	61	2	25	0359	64	45.374	139	50.906	(300)
XCTD	62	2	25	0640	65	04.852	139	49.565	
XCTD	63	2	25	0847	65	22.650	139	50.188	
XCTD	64	2	25	0910	65	25.928	139	50.462	
XCTD	65	2	25	0952	65	31.831	139	51.243	
XCTD	66	2	25	1005	65	33.886	139	51.409	
XCTD	67	2	25	1017	65	35.569	139	51.208	
XCTD	68	2	25	1104	65	42.776	139	47.641	
XCTD	69	2	25	1457	66	21.164	139	53.008	
XCTD	70	2	25	1523	66	25.662	139	58.987	
T-7	53	2	26	1147	63	00.039	140	00.211	
XCTD	71	2	26	2348	61	00.009	140	01.648	100
T-7	54	2	26	2352	61	00.100	140	01.600	240
XCTD	72	2	27	1826	59	29.941	140	02.571	
XCTD	73	2	27	2103	59	00.047	140	01.221	

Table 2. Continued.

XCTD	74	2	27	2345	58	29.891	139	59.503	
XCTD	75	2	28	0227	57	59.959	140	00.151	
XCTD	76	2	28	0507	57	29.930	140	00.247	
XCTD	77	2	28	1351	56	59.869	140	00.445	
XCTD	78	3	1	1132	56	29.727	139	59.690	160
T-7	56	3	1	1140	56	28.000	140	00.000	130
T-7	58	3	1	1603	56	00.000	140	05.000	230
T-7	60	3	1	2014	55	30.000	140	09.000	250
XCTD	79	3	2	0815	54	00.409	139	59.952	
XCTD	80	3	2	1654	53	30.254	139	59.947	
XCTD	81	3	2	1833	52	59.970	139	58.974	
XCTD	82	3	2	2104	52	30.054	139	58.526	
XCTD	83	3	2	2340	51	59.748	139	59.599	
XCTD	84	3	3	0219	51	29.744	139	59.760	
T-7	61	3	3	0407	51	10.128	140	00.148	
T-7	62	3	3	0447	51	02.854	140	00.090	
T-7	63	3	3	0452	51	01.957	140	00.088	
T-7	64	3	3	0457	51	00.920	140	00.088	
XCTD	85	3	3	0503	50	59.877	140	00.109	
T-7	65	3	3	0510	50	58.603	140	00.141	
T-7	66	3	3	0514	50	57.949	140	00.172	
T-7	67	3	3	0519	50	56.985	140	00.205	
T-7	68	3	3	0525	50	55.993	140	00.260	
T-7	69	3	3	0530	50	55.032	140	00.325	
T-7	70	3	3	0535	50	54.037	140	00.370	
T-7	71	3	3	0541	50	53.020	140	00.368	
T-7	74	3	3	0548	50	51.730	140	00.382	
T-7	75	3	3	0552	50	50.986	140	00.371	
T-7	76	3	3	0558	50	50.034	140	00.370	
T-7	77	3	3	0603	50	49.021	140	00.304	
T-7	78	3	3	0609	50	48.036	140	00.263	
T-7	79	3	3	0615	50	47.044	140	00.239	
T-7	80	3	3	0620	50	46.004	140	00.213	
XCTD	86	3	3	0626	50	44.932	140	00.206	
T-7	81	3	3	0633	50	43.754	140	00.170	
T-7	82	3	3	0637	50	43.038	140	00.141	
T-7	83	3	3	0643	50	42.027	140	00.115	
T-7	84	3	3	0648	50	41.028	140	00.097	
T-7	85	3	3	0654	50	40.030	140	00.096	
T-7	88	3	3	0701	50	38.682	140	00.103	
T-7	89	3	3	0705	50	37.988	140	00.114	
T-7	90	3	3	0710	50	37.038	140	00.132	
T-7	91	3	3	0716	50	36.030	140	00.155	
T-7	92	3	3	0721	50	35.042	140	00.166	400
T-7	94	3	3	0723	50	34.621	140	00.172	
T-7	95	3	3	0727	50	33.977	140	00.172	
T-7	96	3	3	0733	50	33.006	140	00.183	
T-7	97	3	3	0738	50	32.008	140	00.188	
T-7	98	3	3	0744	50	31.008	140	00.210	
XCTD	87	3	3	0749	50	30.054	140	00.216	
T-7	99	3	3	0756	50	28.846	140	00.199	
T-7	100	3	3	0801	50	28.000	140	00.190	
T-7	101	3	3	0806	50	27.028	140	00.190	
T-7	102	3	3	0812	50	26.004	140	00.197	
T-7	103	3	3	0818	50	25.043	140	00.200	
T-7	104	3	3	0823	50	24.011	140	00.188	
T-7	105	3	3	0830	50	22.990	140	00.203	
T-7	106	3	3	0835	50	22.002	140	0.2030	
T-7	108	3	3	0838	50	21.618	140	00.180	
T-7	109	3	3	0843	50	20.745	140	00.174	
T-7	110	3	3	0847	50	19.998	140	00.160	
T-7	111	3	3	0853	50	18.952	140	00.135	
T-7	112	3	3	0900	50	17.772	140	00.094	
T-7	113	3	3	0904	50	16.959	140	00.069	

Table 2. Continued.

T-7	114	3	3	0910	50	16.002	140	00.032	
XCTD	88	3	3	0916	50	14.954	140	00.002	
T-7	115	3	3	0923	50	13.775	139	59.991	
T-7	116	3	3	0927	50	13.036	139	59.866	460
T-7	118	3	3	0929	50	12.688	139	59.856	
T-7	119	3	3	0933	50	12.010	139	59.812	
T-7	120	3	3	0939	50	11.058	139	59.748	
T-7	121	3	3	0946	50	09.850	139	59.668	
T-7	122	3	3	0950	50	09.017	139	59.604	
T-7	123	3	3	0956	50	07.999	139	59.527	
T-7	124	3	3	1002	50	06.971	139	59.478	
T-7	125	3	3	1008	50	06.038	139	59.455	
T-7	126	3	3	1014	50	04.996	139	59.410	
T-7	127	3	3	1019	50	04.004	139	59.368	
T-7	128	3	3	1025	50	03.019	139	59.326	
T-7	129	3	3	1031	50	02.057	139	59.264	570
T-7	131	3	3	1036	50	01.024	139	59.195	
XCTD	89	3	3	1042	49	59.956	139	59.142	
XCTD	90	3	3	1326	49	30.035	139	59.514	978
XCTD	91	3	3	1612	48	59.784	140	00.396	
XCTD	92	3	3	1853	48	29.850	139	59.693	973
XCTD	93	3	3	2135	48	00.018	139	59.579	
XCTD	94	3	4	0021	47	29.704	140	00.615	930
XCTD	95	3	4	0305	47	00.114	140	01.284	
XCTD	96	3	4	0814	46	29.885	141	07.242	
XCTD	97	3	4	1259	46	00.000	142	15.000	(50)
XCTD	98	3	4	1305	45	59.123	142	15.646	
XCTD	99	3	4	1733	45	25.531	143	24.014	
XCTD	100	3	4	2115	44	59.805	144	21.398	850
XCTD	101	3	5	0137	44	30.385	145	27.213	
XCTD	102	3	5	0550	44	00.020	146	29.833	
XCTD	103	3	5	0558	43	59.016	146	31.911	

Type denotes the probe types (T-7 and T-6 are of XBT), and CN cast number in XCTD and XBT. MN/DG/HM denote month, day and hour/minutes in GMT, LAT/MN latitude and minutes, LON/MN latitude and minutes. Numbers in the DP column indicate the aborted depths (m) before normal completion. The numbers in the parentheses are the aborted depths, indicating that the depths were unreliable due to the mal-functioning of the depth calculation.

3.2. XCTD/XBT instrumentation

Tsurumi Seiki XCTD and XBT systems were used. The MK-130 digital converter was used to retrieve data, with a launcher equipped with specially manufactured 50 m cable. The deck unit was placed in the entrance of the CTD operation room and a launcher cable length of 50 m was needed to reach her afterpart. Background level was taken at the metal beard portion of the portside window. XCTD, T-6 and T-7 XBT probes were used.

3.3. S-ADCP instrumentation

S-ADCP of RDI 150 kHz was operated underway. Position data were fed from the differential GPS POS/MV system.

4. Major problems encountered

Major problems we had in the observations are described in this section.

4.1. *Logistics*

At the initial planning stage, a CTD winch cable of at least 5000 m length was required, but the CTD winch length used was limited to about 4000 m. Thus, the CTD/Rosette did not reach near the bottom at St. 2, 1, 9, 10, and 11.

For the two casts at St. 3, the sea state was so rough that the Rosette sampler could not be brought up after a short stay at 20–30 m depth. Thus reliable values near the surface, especially for conductivity and dissolved oxygen, were lost for these particular casts.

4.2. *CTD sensors and relevant equipment*

The main conductivity sensor initially went bogus at St. 8, probably due to the cold atmospheric temperature. It returned to normal after its deployment under water. The depth sensor did not work at St. 8 and the Rosette sampler hit the bottom twice. However, it worked perfectly afterward.

The processing computer froze in the middle of the retrieval operation in the deep cast at St. 7. It worked again after replacement of the hard disk drive and reinstallation of the software and operating system.

More details are reported by Walkington (2002).

4.3. *XCTD/XBT*

Signal cutoff at shallow depths occurred for both XCTDs and XBTs south of 48°S. This latitude coincides with that of deployment of the Continuous Plankton Recorder (CPR), deployed with the rear winch, and it was suspected that the probes' signal wires were cut by the CPR's lateral motion. This trouble was mostly avoided by launching probes from the other side (port side) of the hull on the way the south. On the way the north, however, the error rates increased regardless of which side was chosen. This error occurred independently of wind direction. About 16% of the probes did not work properly.

4.4. *S-ADCP*

The new GPS gyro system went down soon after departure (A. Falconer, personal communication). Thus reliable information on ship's precise attitude, which is essential to oceanic current estimation, especially in a rough sea, was not collected at all.

Sudden failure of the power supply occurred after 60°S on the way south from February 11. Thus, data acquisition after that was intermittent, and totally stopped after St. 5 on the way north. We contacted personnel of NIWA at that time, but the trouble could not be overcome during the cruise. The fault was caused by the malfunction of an internal cooling fan, effectively causing the deck unit to overheat (A. Falconer, personal communication).

Moreover, the data acquisition system was totally re-installed after the cruise, and the replacement made it difficult to convert the old binary ADCP data to readable format.

Because of these difficulties, we abandoned the data retrieval and further processing.

The ADCP also affected the 120 kHz output of the SIMRAD EK500, which was used for the zooplankton survey. Vertical "dips" due to the S-ADCP triggers were clearly visible on the echo sounder output.

5. Data manipulation

The processing of the retrieved data is described below.

5.1. CTD data processing

The CTD data were recorded with the SBE Seasave-Win32 Ver. 5.25 on Windows 98.

The data were preliminary processed with the SBE Data processing-Win32 Ver. 5.25 on Windows 98, Me and XP. The programs ⟨Data Conversion⟩ and ⟨Bin Average⟩ for 1 db were used for preliminary processing of the downcast data.

The ⟨Bin Average⟩ routine simply averages all available data, and did not exclude the initial unstable values at deployments. These initial data should be excluded in subsequent data processing.

5.2. XCTD/XBT data processing

The TS-MK-130 software version 1.00 was operated on Windows 98 on an IBM Thinkpad. Depth average for 1 m was applied.

6. Results

Results of the CTD data calibration, along with data quality information, are presented. XCTD validation, with the simultaneous CTD measurements, is also described.

6.1. Salinity

A Guildline 'Autosal' salinometer was used for the salinity calibration. However, the salinometer calibration suffered from a significant discontinuity. Fig. 3 shows the difference between bottle and CTD salinity. The difference was relatively stable for the former half of the cruise, but we experienced a "jump" in the middle and it went much unstable after that. From initial 212 samples (from cast numbers 1 to 15 in Fig. 3), offset of 0.0044 compared to CTD post calibration was obtained on average. From the subsequent 129 bottles (from cast numbers 16 to 25), offset of −0.0086 compared to CTD post calibration was obtained on average.

The stability obtained by comparing with the pre- and post-cruise calibration of salinity suggests that continuous randomness of the salinometer. Generally, temperature control in the calibration room was not adequate. However, the reason for the "jump" was not clear. Therefore special attention is required to utilize the bottle sampled salinity.

Results of the pre- and post-cruise calibrations were generally good. A salinity difference of 0.0014 on average was obtained. This is much smaller than the uncertainty of the bottle salinity. Thus it is recommended to use CTD salinity data NOT calibrated with onboard bottle samples.

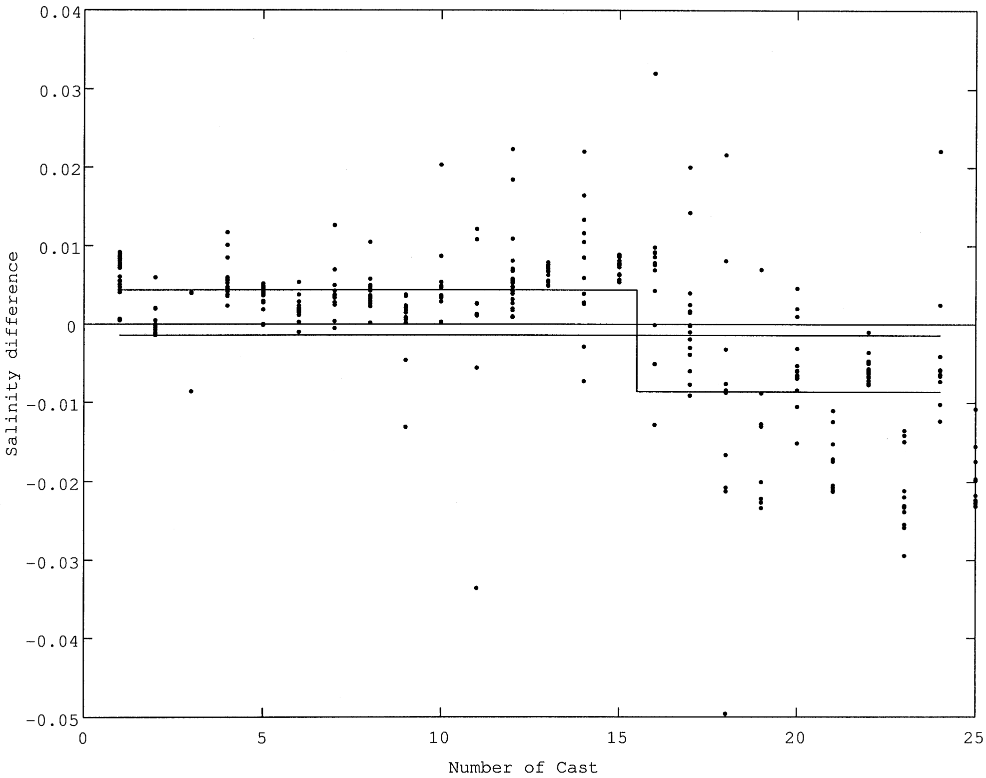

Fig. 3. Salinity residual (salinity (bottle)–salinity (CTD)). The straight solid line denotes the averaged difference for all samples, and the kinked line denotes the averaged level for casts 1 to 15 and for casts 16 to 25.

6.2. *Dissolved oxygen*

Using a NIWA—manufactured instrument based on the design developed by Scripps Institution of Oceanography, DO was measured according to the titration protocol compliant with JGOFS regulation. Bottles were prepared by NIWA. The KIO3—CSK standard was used, and fixing fluids were made by dilution of Kanto Kagaku Co. reagents (see Watanabe and Hamanaka, 2002 for more details). Although there were some indications of systematic differences with the type of bottle used, bottled DO analyses generally went well except for a few samples. Repetitive error was estimated to be 0.056 m*l*/*l* from the ten surface water bottles.

The CTD DO result was tested for the sampled DO (Fig. 4). The difference was significant in shallow depths, while it was more constant in deeper depths. The systematic differences below about 1000 m can be calibrated with a polynomial of relatively low order, but the characteristics of the differences near the surface vary from station to station.

6.3. *XCTD validation*

Two simultaneous tests with the Seabird CTD unit were conducted at 57°S and

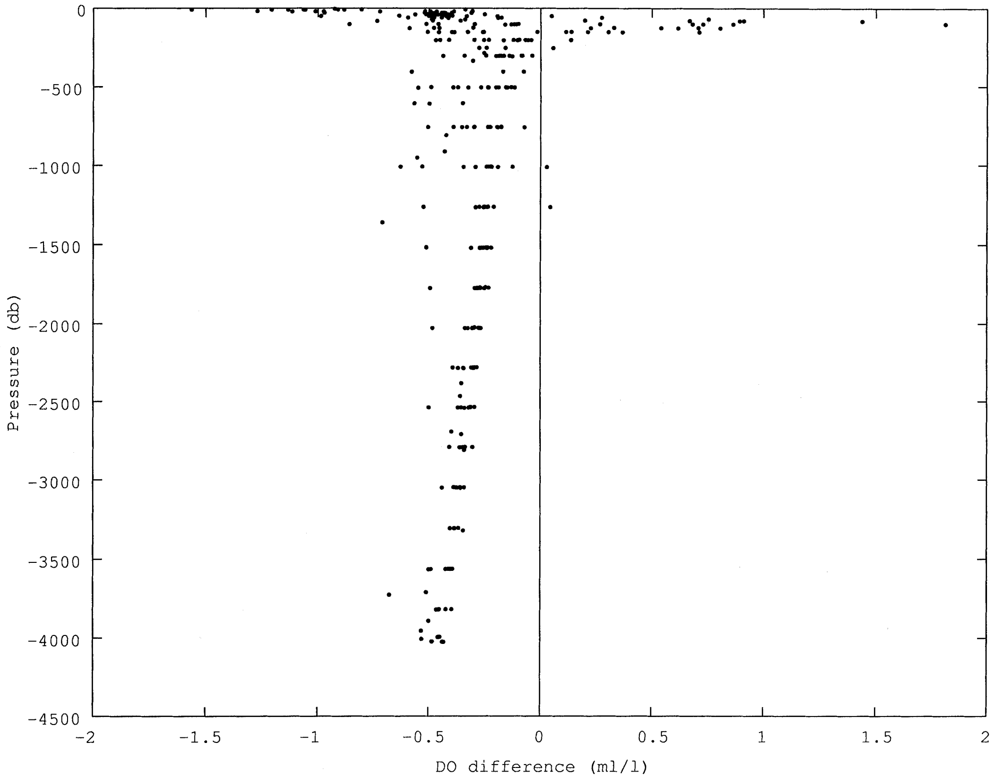

Fig. 4. Dissolved Oxygen residual (DO (bottle)—DO (CTD))

54°S to validate the accuracy of the XCTD (Fig. 5). The original XCTD data were given in meter units, so the depths were converted into pressure units and interpolated from the nearest pressure.

The results were quite different between the two; comparison at 57°S was generally good while that at 54°S was poor. This indicates a high dependence on which probe is used. For temperature, the averaged difference and standard deviation are 0.0015 ± 0.0209°C (0.0024 ± 0.0214°C) for the depth range of 10–1000 db (100–1000 db) at 57°S, while they are -0.0285 ± 0.0470°C (-0.0260 ± 0.0200°C) at 54°S. For salinity, the averaged difference and standard deviation are -0.0083 ± 0.0085 (-0.0077 ± 0.0056) for the depth range of 10–1000 db (100–1000 db) at 57°S, while they are 0.0334 ± 0.0174 (0.0359 ± 0.0105) at 54°S.

Temperature accuracy was generally within 0.05°C. However, shallow temperature was not properly observed (assuming that the Seabird CTD was correct). The error at 54°S showed a significant offset with a weak dependence on depth.

Salinity measurements were generally good at 57°S. At 54°S, however, salinity error increased to 0.05 at 1000 m. This is comparable to the background change between 54°S and 57°S, and therefore this indicates that the deep (deeper than a few hundred meters) salinity structure was significantly contaminated.

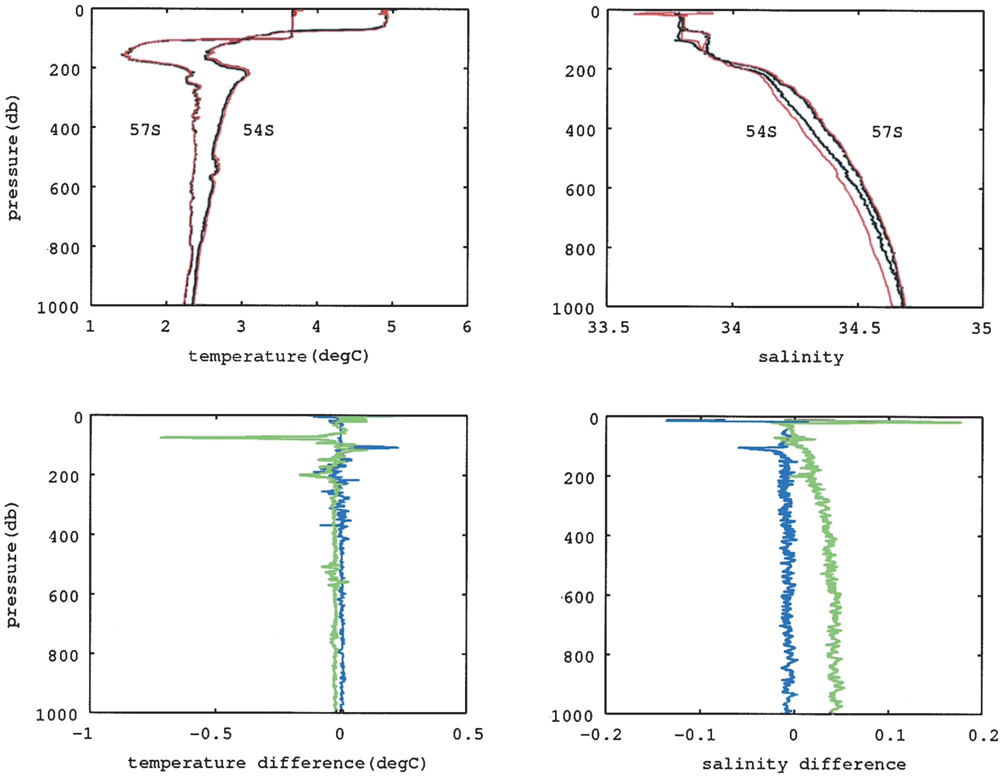

Fig. 5. Comparison between CTD and XCTD at 54 and 57°S. Left panels are for temperature and right for salinity. Red lines in the upper panels are CTD reference values, and black lines denote XCTD measurements. The lines in the lower panels show residuals (blue for 57°S and green for 54°S).

In dynamic height relative to 1000 m, the difference was 0.323 dyn-cm (in 67.4 dyn-cm) at 57°S and 3.115 dyn-cm (in 75.5 dyn-cm) at 54°S.

From the rough validation above, it is suggested, in a very general sense, that the XCTD is and is not available for the following issues in this study area:

Good for:

- locating the main thermocline
- locating the occasional anomalous feature
- temperature
- identification of fronts

Unreliable for:

- shallow temperature and salinity (down to several tens of meters), and thus short-term stratification
- shallow thermocline
- quantitative estimate of anomalous features
- deep salinity

7. Conclusions

The physical observations generally went well, except for the S-ADCP failure. The manufacture's CTD calibrations gave reasonable agreement between pre- and post-cruise estimates. The salinity calibration on-board, on the other hand, has a significant uncertainty from unknown factors. Strict temperature control of the calibration room is required at least.

A rough sketch of the XCTD limitations has been given. Dense spatial coverage is helpful to reduce random errors. However, significant subsurface change in eddy-like features (Hirawake *et al.*, 2003) will limit the error reduction that can be accomplished by simple combination.

It is concluded that this marine science cruise was a successful step forward for oceanography under JARE. The authors hope that this will lead to sustainable Japanese observations of the Southern Ocean in the future.

Acknowledgments

The authors would like to thank Matt Walkington for his general support in physical observations and capability in fixing instrumental troubles. Thanks are extended to Andrew Falconer for his help in assessing the S-ADCP outcome. Intense XBT observations were kindly supported by Gen Hashida, Hidekatsu Suzuki, Shuichi Watanabe, Tamihito Nishida, So Kawaguchi, and Sakae Kudoh, in spite of severe weather conditions. Routine XCTD observations were conducted by all participants. The authors express thanks for help from Tsuneo Odate, the cruise leader, and for support from Andrew Leachman, the captain, and his crew.

References

Fukuchi, M., Odate, T. and Kudoh, S. (2002): Marine biological processes in the Antarctic Ocean: its importance to the global environmental change. The 9th International Symposium on Antarctic Science, Programme and Abstract, 8–10 October 2002, Ansan, KORDI, 25–26.

Hirawake, T., Kudoh, S., Aoki, S. and Rintoul, S.R. (2003): Eddies revealed by SeaWiFS ocean color images in the Antarctic Divergence zone near 140°E. Geophys. Res. Lett., **30**(9), 10.1029/2003GL016996.

Odate, T., Kudoh, S. and Fukuchi, M. (2001): Report on workshop "Planning of future science in the Antarcitc Ocean study with cooperation among study groups". Nankyoku Shiryô (Antarct. Rec.), **45**, 362–370 (in Japanese with English abstract).

Walkington, M. (2002): Personal voyage report. Preliminary Report on the 43rd Japanese Antarctic Research Expedition Marine Science Cruise by Research Vessel *Tangaroa*, ed. by T. Odate. Tokyo, Natl. Inst. Polar Res. (CD-ROM).

Watanabe, S. and Hamanaka, J. (2002): Chemical oceanography report (in Japanese). Preliminary Report on the 43rd Japanese Antarctic Research Expedition Marine Science Cruise by Research Vessel *Tangaroa*, ed. by T. Odate. Tokyo, Natl. Inst. Polar Res. (CD-ROM).