

A Long Oceanographic Section from Kyushu, Japan to the Equator, 145°E in November 1989

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Salinity section

Abstract

Oceanographic observations using XBT and CTD system were carried out in the Western Tropical Pacific Ocean in November of 1989.

A sharp thermocline whose core temperature of 20°C was found at depths between 100 and 300m in the region from the equator to lat. 15°-00'N. From the region at lat. 15°-00'N toward the north, the thermocline divided into an upper and a lower thermoclines. The Subtropical Mode Water was found at depths between 200 and 400m between these thermoclines. The subsurface saline water with salinity more than 34.70‰, the North Pacific Tropical Water, exists in the thermocline depth and it extended as far south as about lat. 06°-30'N near the southern limit of the North Equatorial Current. The salinity minimum water with salinity lower than 34.40‰, the North Pacific Intermediate Water, extended from the north to south at depths between 500 and 800m. The transition zone between the Western North Pacific Central Water and the Pacific Equatorial Water becomes shallower toward the equator from high latitude and decreased in thickness.

A new interdisciplinary study entitled "Man and the Environment in Papua New Guinea", by Kagoshima University Research Center for the South Pacific was started in 1989.

The Keiten Maru (860 tons), a training and research ship of the Faculty of Fisheries, Kagoshima University served as the research ship in the project. The Keiten Maru with the scientific party departed Kagoshima, Japan on the 10th of November, 1989 and headed southeast to the equator, occupying an oceanographic section along the way to Papua New Guinea.

After the oceanographic observations, the Keiten Maru called on Lae and Port Moresby, Papua New Guinea, and returned to Kagoshima on the 20th of December, 1989.

The objective of the oceanographic observation was to observe the hydrographic conditions through the Kuroshio, the Subtropical Countercurrent (SCC), the North Equatorial Current (NEC), and the North Equatorial Countercurrent (NECC) in November of 1989. The western subtropical and tropical Pacific Ocean is the important region for global climatological and oceanographical conditions, such as the *El Nino* event, and for skipjack fishing in fishery aspects.

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Oceanographic Observation

We occupied a section from 30°N, 130°–50'E to the equator, 145°E, from 10th to 18th November, as shown in Fig. 1.

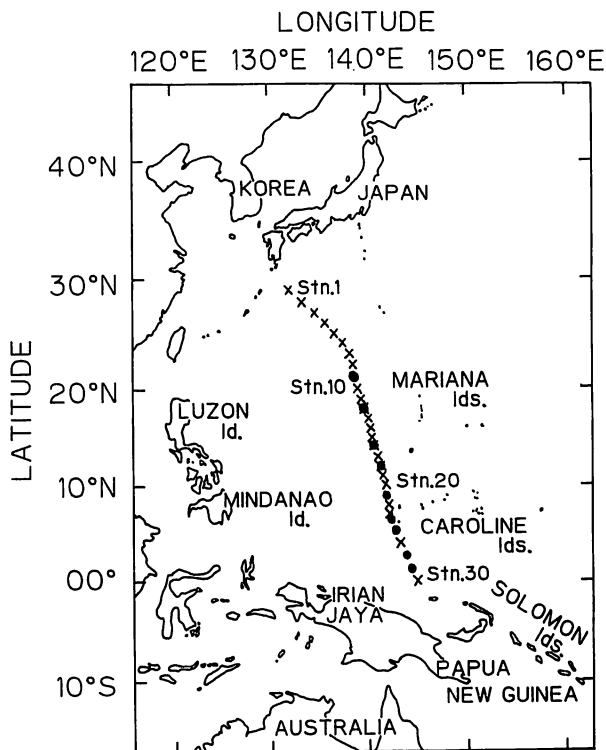


Fig. 1. Map showing observing stations. Symbol: dots, CTD observation. crosses, XBT observation.

The oceanographic data were obtained by Expendable Bathythermographs (XBT) and the Conductivity, Temperature, and Depth Recorder system (CTD, Neil Brown Instrument Model 1150). The XBTs were launched from the surface to 900m in depth for every one degree of latitude and the sensor of CTD was lowered from the surface to 1,000m in depth with a lowering speed about 60m/min. at 9 stations along the section.

Results and Discussion

Temperature section

The vertical section of water temperature using XBT and CTD data is shown in Fig. 2.

The warm surface water with temperature values of 25°C to 29°C is presented in the surface mixed layer. The surface mixed layer occupies about 75m thick over the whole section.

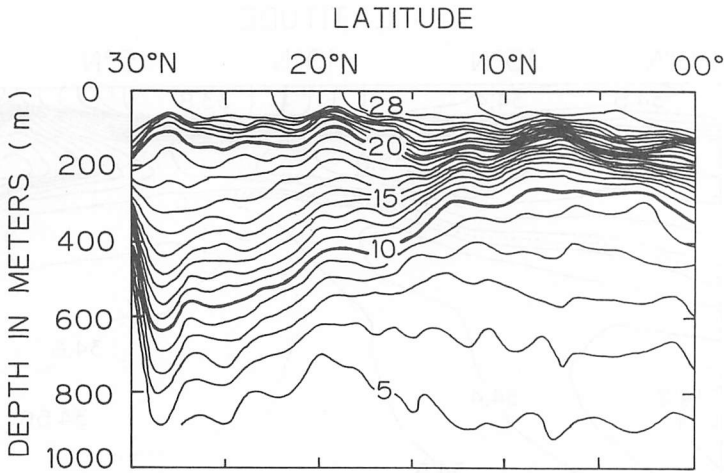


Fig. 2. The vertical distribution of water temperature (°C) between 30° N and the equator.

Weak surface thermal front is found in about lat. 12°N, 18°N, 22°N, and 28°N, respectively. A sharp thermocline with a core temperature of 20°C is found from the equator to lat. 15°–00°N at depths between 100 and 300m.

The thermocline slopes up from the equator to 07°–30°N, and it slopes down from lat. 07°–30°N to 15°–00°N. The ridge of the thermocline at about lat. 07°–30°N (so called the countercurrent ridge), which indicates the boundary between the NEC and the NECC. The 20°C isotherm depth at the countercurrent ridge is about 110m, though it was about 120m in June, 1988 (Yuwaki *et al.*, 1988).¹⁾ The 20°C isotherm depth at the countercurrent ridge is a good indicator of the warm water in the western tropical Pacific Ocean, which relate to the *El Nino* event (Wyrki, 1985)²⁾.

At about lat. 15°–00°N, the thermocline divide into an upper and a lower thermoclines. The upper thermocline forms the subsurface thermal front at about lat. 19°–00°N and the lower one forms the main thermocline with temperatures of 10°C to 12°C in the subtropical region. Between these thermoclines, a nearly isothermal water is found at depths between 100 and 400m, which is the Subtropical Mode Water reported by Masuzawa (1967)³⁾ or the 18°C Water in the North Atlantic Ocean pointed out by Worthington (1959)⁴⁾. The largest slope of the main thermocline in lat. 30°–00°N is thought to correspond to the Kuroshio.

Salinity section

The vertical section of salinity using CTD data is shown in Fig. 3. The conditions of the characteristic water mass defined by salinity are as follows:

The low salinity surface water of less than 34.50‰ occupies 50m thick over the whole section. The surface salinity minimum water less than 34.00‰ found the region of the NECC occupies in the region between 09°N and 04°N.

The subsurface saline water of more than 34.70‰, which called the North Pacific Trop-

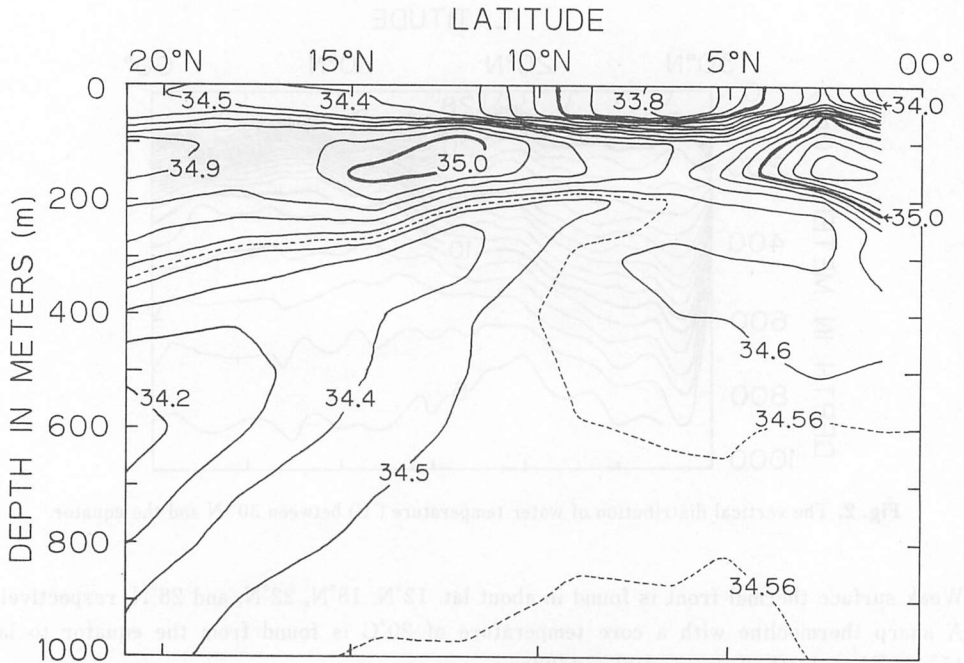


Fig. 3. The vertical distribution of salinity (‰) between 20°N and the equator.

ical Water (Cannon, 1966)⁵⁾, is found in the thermocline layer at depths between 75 and 200m and extends as far south as about lat. 06°–30°N near the southern limit of the NEC. The other subsurface saline water of more than 35.00‰ originating in the South Pacific extends as far north as about 06°N at depths between 50 and 200m near the northern limit of the NECC.

The salinity minimum water of less than 34.50‰, the North Pacific Intermediate Water (N P In W), extends as far south as 09°N at depths between 200 and 800m.

The other salinity minimum water of less than 34.60‰ extends as far north as about 12°–00°N at depths between 500 and 800m, and may originate in the South Pacific Intermediate Water (Reid, 1965).⁶⁾

Transition zone between the Western North Pacific Central Water and the Pacific Equatorial Water

In order to examine the transition zone between the Western North Pacific Central Water (WNPC) and the Pacific Equatorial Water (PE) as defined by Sverdrup *et al.* (1942),⁷⁾ the observed temperature–salinity relations between the two water masses are entered in Fig. 4, as already shown by Barnes *et al.* (1948).⁸⁾

As seen in Fig. 4, the temperature–salinity relations with latitudes show transition stage from the deeper PE to the shallower WNPC. At 01°N the water below 400m is all PE, and the water above 250m is in the transition zone. At 12°N the transition zone commences at

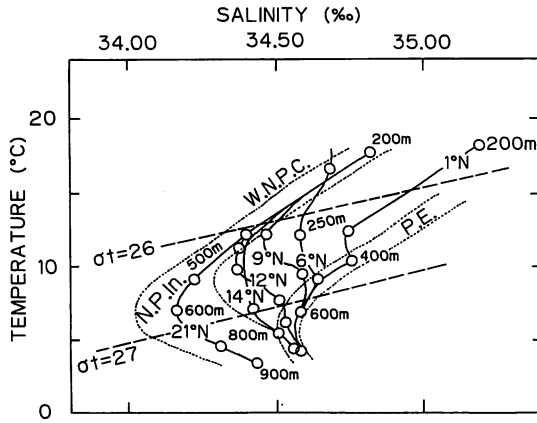


Fig. 4. T-S curves with latitudes along the section between 21°N and 01°N
 W N P C: the western North Pacific Central Water,
 P E: Pacific Equatorial Water
 N P In: North Pacific Intermediate Water

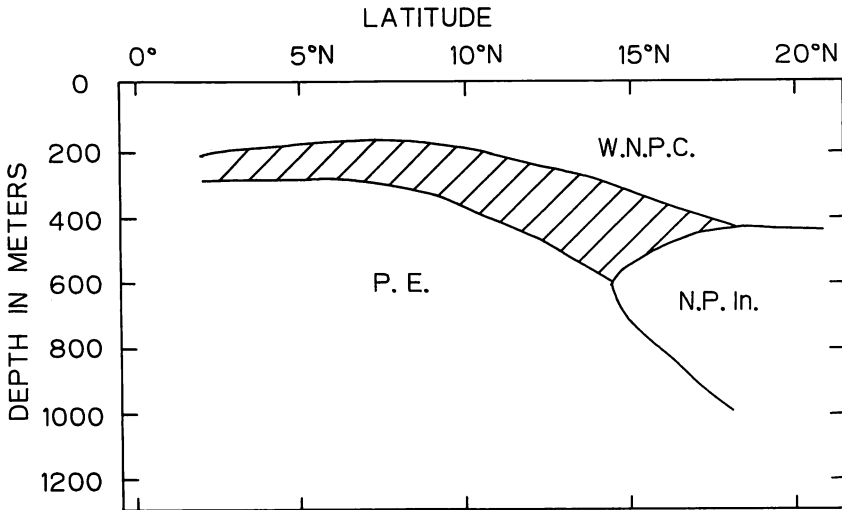


Fig. 5. The transition zone with latitude is indicated by shaded portion.

250m and ends at 500m. At 21°N the water is all WNPC.

From Fig. 4, the thickness of the transition zone with latitude is read in Fig. 5.

The transition zone become shallower and thinner toward the equator from the high latitude at depths between 600 and 200m.

Summary

Based on the data obtained by XBT and CTD observations in November of 1989, the oceanographic conditions along the section from Kyushu, Japan to the equator are summarized as follows :

- (1) The warm surface water of 25°C to 29°C is presented over the whole section at a depth of 75m. The weak surface thermal fronts are found in about lat. 12°N, 18°N, 22°N, and 28°N.
- (2) A sharp thermocline centered around 20°C is found in the region from the equator to lat. 15°-00'N at depths between 100 and 300m. The vertical gradient of temperature in the thermocline was largest with a value of 0.13°C/m in about lat. 07°-30'N over the whole section.
- (3) At about lat. 15°-00'N, the thermocline divides into an upper and lower thermoclines. Between these thermoclines, the Subtropical Mode Water is found at depths between 200 and 400m.
- (4) The subsurface saline water of more than 35.00‰, the Pacific Tropical Water, extends from the north and the south at depths between about 50 and 200m. The salinity minimum water with salinity less than 34.55‰, the Pacific Intermediate Water, extends the north and the south at depth between from about 500 and 800m.
- (5) The transition zone between the WNPC and PE becomes shallower toward the equator from the high latitude.

Acknowledgement

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References

- 1) Yuwaki Y. *et al.* (1988) : Oceanic Conditions in the Western Tropical Pacific in the Summer of 1988. *Mem. Fac. Fish., Kagoshima Univ.*, **37**, 97-109.
- 2) Wyrtki, K. (1985) : Water displacements in the Pacific and the genesis of *El Nino* cycles. *J. Geophys. Res.*, **90**, C4 7129-7132.
- 3) Masuzawa Jotaro (1967) : An oceanographic section from Japan to New Guinea at 137°E in January 1967. *Oceanogr. Mag.* **19**, 95-118.
- 4) Worthington, L. V. (1959) : The 18°C water in the Sargasso Sea. *Deep-Sea Res.*, **5**, 297-307.
- 5) Cannon, G. A. (1966) : Tropical waters in the western Pacific Ocean, August-September 1957. *Deep-Sea Res.*, **13**, 1139-1148.
- 6) Reid J. L., Jr. (1965) : Intermediate Water of the Pacific Ocean. *Johns Hopkins Oceanogr. Stud.*, (2), 85 pp.
- 7) Sverdrup, H. U., Johnson, M. W. and Fleming, R. H. (1942) : *The oceans: their physics, chemistry and general biology*. Prentice-Hall, New York. 605-761.

- 8) Barnes, C. A., D. F. Bumpus and J. Lyman (1948) : Ocean circulation in Marshall Islands area. *Trans. Amer. Geophys. Union*, **29**, 871–876.

Appendix

Date	1989. 11. 10	1989. 11. 11	1989. 11. 11	1989. 11. 11	1989. 11. 12
Time	23 : 52	07 : 42	14 : 58	22 : 43	07 : 45
Stn.	1 (XBT)	2 (XBT)	3 (XBT)	4 (XBT)	5 (XBT)
Lat.	30°-01.'5N	28°-56.'5N	28°-00.'0N	27°-00.'1N	26°-00.'1N
Long.	130°-49.'9E	132°-08.'5E	133°-21.'5E	134°-36.'5E	135°-49.'4E
m	Temp. (°C)	Temp. (°C)	Temp. (°C)	Temp. (°C)	Temp. (°C)
0	25.32	24.46	24.62	24.95	25.99
10	25.40	24.53	24.67	24.97	26.04
20	25.45	24.62	24.72	25.03	26.21
30	25.56	24.62	24.68	24.98	26.25
50	25.51	24.67	24.53	24.92	26.33
75	25.20	24.42	21.60	24.58	25.23
100	24.84	21.59	20.26	21.76	22.24
150	22.62	19.39	18.96	19.66	20.20
200	19.33	18.69	18.50	18.77	18.72
250	17.14	18.08	17.90	18.08	17.56
300	13.93	17.28	17.51	17.38	16.70
400	9.81	15.24	15.67	14.81	14.13
500	6.16	13.20	13.57	11.74	12.07
600		10.46	10.79	8.95	9.34
700		7.89	8.80	6.85	7.16
800		6.53	6.60	5.49	5.49
900		894 m 5.43	894 m 5.53	894 m 4.83	894 m 4.57

Date	1989. 11. 12	1989. 11. 12	1989. 11. 13	1989. 11. 13
Time	14 : 35	21 : 09	06 : 06	11 : 30
Stn.	6 (XBT)	7 (XBT)	8 (XBT)	9 (XBT)
Lat.	25°-00.'0N	24°-00.'6N	23°-00.'5N	22°-00.'0N
Long.	136°-43.'5E	137°-29.'5E	138°-15.'1E	138°-33.'0E
m	Temp. (°C)	Temp. (°C)	Temp. (°C)	Temp. (°C)
0	27.26	26.99	25.71	26.46
10	25.57	25.29	25.75	26.45
20	25.64	25.48	25.85	26.57
30	25.58	25.44	25.90	26.53
50	25.50	25.38	25.77	26.60
75	24.61	24.92	24.55	25.29
100	23.03	23.57	21.74	22.63
150	20.19	19.48	19.59	19.69
200	18.59	18.58	18.47	17.99
250	17.65	17.59	17.56	16.67
300	16.73	16.85	16.64	15.80
400	14.19	14.63	13.98	13.21
500	11.54	11.55	10.67	10.22
600	9.27	8.95	7.97	7.57
700	7.37	6.56	6.14	5.93
800	5.79	5.09	4.99	5.14
900	850 m 5.34	850 m 4.66	894 m 4.40	894 m 4.27

Date	1989. 11. 13		1989. 11. 13		1989. 11. 13	
Time	16 : 55		17 : 02		23 : 20	
Stn.	10 (CTD)		10 (XBT)		11 (XBT)	
Lat.	21°-00.'2N		21°-00.'2N		20°-00.'0N	
Long.	138°-47.'4E		138°-37.'3E		139°-05.'4E	
m	Temp. (°C)	Sal. (‰)	Temp. (°C)		Temp. (°C)	
0	26.72	34.564	27.26		26.09	
10	26.75	34.531	26.91		26.11	
20	26.60	34.557	26.97		26.30	
30	26.58	34.554	26.94		26.27	
50	26.55	34.560	26.94		26.07	
75	25.59	34.718	26.14		21.66	
100	22.90	34.986	23.40		20.46	
150	19.40	34.930	19.78		18.20	
200	17.48	34.823	17.84		16.90	
250	16.11	34.729	16.42		15.83	
300	15.17	34.653	15.48		14.09	
400	11.97	34.392	12.12		10.69	
500	8.90	34.214	9.20		8.08	
600	6.80	34.153	7.06		6.19	
700	5.18	34.210	5.47		4.97	
800	4.41	34.303	4.72		4.25	
900	3.79	34.391	894 m 4.16		894 m 3.96	
1000	995 m 3.22	34.429				

Date	1989. 11. 14		1989. 11. 14		1989. 11. 14	
Time	06 : 28		11 : 42		11 : 32	
Stn.	12 (XBT)		13 (XBT)		13 (CTD)	
Lat.	19°-00.'0N		18°-00.'2N		18°-00.'2N	
Long.	139°-22.'4E		139°-41.'5E		139°-41.'4E	
m	Temp. (°C)		Temp. (°C)		Temp. (°C)	Sal. (‰)
0	26.88		27.37		27.26	34.445
10	26.93		27.39		27.23	34.444
20	26.79		27.45		27.18	34.449
30	26.55		27.43		27.16	34.455
50	24.92		27.14		26.18	34.654
75	21.81		25.25		23.51	34.820
100	19.82		21.49		20.58	34.859
150	17.99		18.96		18.46	34.852
200	16.42		17.11		16.71	34.770
250	15.42		15.60		15.28	34.655
300	13.95		13.58		13.33	34.487
400	10.66		10.66		10.44	34.311
500	7.71		8.00		7.74	34.255
600	5.82		6.12		5.98	34.278
700	4.95		5.23		4.97	34.387
800	4.58		4.57		4.32	34.454
900	894 m 4.35		894 m 4.14		3.78	34.503
1000					995 m 3.33	34.541

Date	1989. 11. 14		1989. 11. 14		1989. 11. 15	
Time	18 : 11		23 : 09		04 : 17	
Stn.	14 (XBT)		15 (XBT)		16 (XBT)	
Lat.	17°-00.'0N		16°-00.'0N		14°-59.'4N	
Long.	140°-07.'3E		140°-20.'2E		140°-34.'2E	
m	Temp. (°C)		Temp. (°C)		Temp. (°C)	
0	27.39		28.19		28.70	
10	27.38		28.15		28.78	
20	27.52		28.13		28.78	
30	27.43		28.24		28.93	
50	27.25		23.23		28.97	
75	26.44		26.13		27.11	
100	23.53		23.50		25.63	
150	19.65		19.54		21.93	
200	17.71		18.05		18.10	
250	16.18		16.25		15.50	
300	13.79		14.24		12.96	
400	10.70		10.18		9.43	
500	7.81		7.86		7.13	
600	6.52		6.20		6.24	
700	5.64		5.48		5.82	
800	4.99		4.97		5.16	
900	894 m 4.53		894 m 4.57		894 m 4.57	
1000						

Date	1989. 11. 15		1989. 11. 15		1989. 11. 15	
Time	08 : 04		08 : 07		16 : 49	
Stn.	17 (CTD)		17 (XBT)		18 (XBT)	
Lat.	14°-18.'3N		14°-18.'1N		13°-00.'0N	
Long.	140°-43.'9E		140°-44.'0E		141°-07.'8E	
m	Temp. (°C)	Sal. (‰)	Temp. (°C)		Temp. (°C)	
0	28.69	34.279	28.66		28.76	
10	28.54	34.388	28.68		28.56	
20	28.53	34.398	28.74		28.72	
30	28.53	34.400	28.86		28.74	
50	28.53	34.402	28.90		28.77	
75	27.58	34.776	28.18		27.77	
100	26.01	34.925	26.45		25.94	
150	22.25	35.043	22.95		21.24	
200	18.58	34.902	18.90		16.19	
250	14.83	34.609	14.95		12.08	
300	11.54	34.390	11.72		9.81	
400	8.76	34.395	8.96		8.43	
500	6.94	34.410	7.17		7.02	
600	5.99	34.454	6.22		6.27	
700	5.23	34.495	5.52		5.73	
800	4.70	34.521	4.98		5.48	
900	4.22	34.546	894 m 4.54		894 m 4.99	
1000	994 m 3.82	34.567				

Date	1989. 11. 15		1989. 11. 15		1989. 11. 16	
Time	22 : 08		22 : 49		06 : 59	
Stn.	19 (XBT)		19 (CTD)		20 (XBT)	
Lat.	12°-06.'3N		12°-06.'2N		11°-00.'0N	
Long.	141°-24.'5E		141°-24.'2E		141°-38.'3E	
m	Temp. (°C)		Temp. (°C)	Sal. (‰)	Temp. (°C)	
0	28.82		28.70	34.371	29.37	
10	28.86		28.71	34.370	29.21	
20	28.96		28.71	34.370	29.29	
30	29.01		28.71	34.371	29.39	
50	29.03		28.70	34.392	29.25	
75	27.38		25.95	34.963	28.13	
100	25.37		23.98	35.064	26.46	
150	19.84		19.55	34.983	20.86	
200	15.08		14.69	34.584	16.82	
250	11.78		11.43	34.367	12.36	
300	10.04		9.80	34.358	10.14	
400	8.06		7.83	34.489	8.08	
500	7.09		6.77	34.495	6.97	
600	6.53		6.19	34.512	6.18	
700	5.83		5.52	34.527	5.72	
800	5.33		5.04	34.539	5.28	
900	894 m 5.02		4.68	34.549	894 m 4.97	
1000			995 m 4.14	34.564		

Date	1989. 11. 16		1989. 11. 16		1989. 11. 17	
Time	12 : 19		18 : 07		00 : 14	
Stn.	21 (XBT)		22 (CTD)		23 (XBT)	
Lat.	10°-00.'0N		09°-00.'2N		08°-00.'0N	
Long.	141°-47.'1E		141°-56.'7E		142°-10.'0E	
m	Temp. (°C)		Temp. (°C)	Sal. (‰)	Temp. (°C)	
0	29.37		29.20	33.926	29.19	
10	29.39		29.25	33.925	29.21	
20	29.45		29.25	33.924	29.29	
30	29.54		29.25	33.932	29.41	
50	29.63		29.24	33.933	29.41	
75	29.07		28.23	34.475	26.79	
100	27.30		25.27	34.779	23.35	
150	21.42		17.77	34.811	17.17	
200	14.53		12.11	34.464	12.35	
250	11.17		10.20	34.531	10.54	
300	9.96		9.29	34.579	9.48	
400	8.39		8.20	34.597	8.42	
500	7.07		7.33	34.571	7.43	
600	6.41		6.53	34.557	6.35	
700	5.94		5.86	34.548	5.84	
800	5.46		5.27	34.554	5.24	
900	894 m 5.07		4.72	34.565	894 m 4.84	
1000			995 m 4.26	34.574		

Date	1989. 11. 17		1989. 11. 17		1989. 11. 17	
Time	05 : 08		07 : 58		15 : 02	
Stn.	24 (XBT)		25 (CTD)		26 (CTD)	
Lat.	06°-59.'3N		06°-25.'6N		05°-07.'7N	
Long.	142°-22.'0E		142°-28.'5E		142°-53.'8E	
m	Temp. (°C)		Temp. (°C)	Sal. (‰)	Temp. (°C)	Sal. (‰)
0	29.35		29.44	33.735	29.83	33.817
10	29.41		29.43	33.734	29.56	33.806
20	29.47		29.42	33.736	29.52	33.806
30	29.56		29.42	33.737	29.51	33.807
50	29.61		29.44	33.770	29.58	33.999
75	27.69		28.49	34.331	28.22	34.391
100	21.98		25.18	34.696	26.31	34.672
150	16.26		16.58	34.676	21.47	34.829
200	12.71		12.69	34.569	14.00	34.603
250	10.40		10.44	34.581	10.78	34.566
300	9.49		9.07	34.627	9.28	34.601
400	8.42		8.04	34.599	8.17	34.601
500	7.63		7.28	34.582	7.41	34.583
600	6.77		6.68	34.565	6.65	34.564
700	6.11		5.92	34.552	6.02	34.556
800	5.60		5.47	34.552	5.33	34.559
900	894 m 5.18		4.84	34.563	4.81	34.564
1000			994 m 4.45	34.567	995 m 4.28	34.573

Date	1989. 11. 17		1989. 11. 18		1989. 11. 18	
Time	22 : 01		05 : 04		13 : 34	
Stn.	27 (XBT)		28 (CTD)		29 (CTD)	
Lat.	04°-00.'0N		02°-35.'9N		01°-07.'9N	
Long.	143°-22.'2E		143°-53.'2E		144°-31.'4E	
m	Temp. (°C)		Temp. (°C)	Sal. (‰)	Temp. (°C)	Sal. (‰)
0	29.85		29.37	34.315	29.15	33.875
10	29.68		29.37	34.315	29.14	33.876
20	29.85		29.37	34.320	29.17	33.898
30	29.70		29.45	34.430	29.23	34.005
50	29.06		29.46	35.005	29.34	34.303
75	28.71		29.34	35.089	29.61	34.934
100	28.18		28.35	35.277	29.00	35.081
150	22.96		23.75	35.374	21.57	35.296
200	15.76		16.06	34.644	18.23	35.193
250	11.01		10.74	34.540	12.38	34.741
300	9.40		8.85	34.596	10.53	34.753
400	8.20		8.14	34.618	8.89	34.644
500	7.37		7.83	34.605	7.58	34.589
600	6.63		6.55	34.552	6.62	34.560
700	5.99		5.92	34.553	5.87	34.548
800	5.47		5.50	34.555	5.46	34.553
900	894 m 5.06		5.23	34.557	5.08	34.553
1000			994 m 5.01	34.558	995 m 4.79	34.563

Date	1989. 11. 17	
Time	20 : 28	
Stn.	30 (XBT)	
Lat.	00°-00.'0N	
Long.	145°-00.'0E	
m	Temp. (°C)	
0	29.21	
10	29.40	
20	29.64	
30	29.63	
50	29.95	
75	30.00	
100	29.67	
150	23.08	
200	18.23	
250	14.43	
300	11.64	
400	9.31	
500	7.49	
600	7.00	
700	6.27	
800	5.71	
900	864 m 5.53	
1000		