Mem. Fac. Fish. Kagoshima Univ.,
Vol. 37, pp. 97~109 (1988)

Oceanic Conditions in the Western Tropical Pacific in the Summer of 1988

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Keywords : Oceanic condition, Western Tropical Pacific, Equatorial Current

Abstract

Oceanographic observations using a CTD system were made in the Western Tropical Pacific in the summer of 1988.

The first oceanographic section was made along 133°E from 20°N to 10°N from June 13-18th, and the second one from 09°N, 138°E to 00°, 149°E from June 25-28th. The warm surface water having a value of above 29℃ was presented over the whole sea surface. The thermocline with the maximum vertical gradient having a value of 0.17℃/m was the shallowest near 09°N. The low salinity lower than 34.50‰ was presented in the surface mixed layer between 16°N and 02°N.

The conspicuous transitions were formed on each side of the north and south of the low salinity water.

The North Equatorial Current was recognized on the north side of 08°N ; the South Equatorial Current near the Equator ; and the North Equatorial Countercurrent in the region between 08°N and 01°N. Several step-like features and inversion layers were presented in the thermocline at the Equator. The lateral advection of water masses in the surface layer was well developed near the Equator.

Introduction

It is well known that the regions of the North Equatorial Current(NEC) and the North Equatorial Countercurrent(NECC) in the Western Pacific Ocean are abundant in fishes such as tuna, especially yellowfin and bigeye tunas.

The oceanic environment of tuna and skipjack fishing grounds have been studied by many oceanographers ; Nakamura et al. (1959)[1], Kamimura et al. (1963)[2], Yamanaka et al. (1965)[3], Suda(1969)[4] and Hanamoto(1974)[5].

Besides the fishing grounds, these workers had a great interest in the earth's climate, particularly associated with the El Niño Southern Oscillation (ENSO) events. In recent years, the necessity arose to accumulate oceanographic data for monitoring of the oceanic conditions in the Western Tropical Pacific, as described by Delcroix et al. (1987).

In relation to the two subjects mentioned above, the oceanographic observations were

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carried out by the Keiten Maru in June, 1988.

This work describes the analysis of temperature, salinity, dynamic height and the water masses in the Western Tropical Pacific.

Oceanographic Observations

The Keiten Maru (860 tons), fishery training and research ship of the Kagoshima University, carried out the cruise for cadets training between Kagoshima, Japan and Honiara, the Solomoms via Yap, the West Caroline Islands, the Federated States of Micronesia from 10 June to 18 July, 1988.

As shown in Fig. 1 on her cruise from Kagoshima to Yap, the first oceanographic section was made along 133°E, starting with Stn. 1 at 20°N on 13th June and ending with Stn. 8 at 10°N on 18th June(Section A) ; after leaving Yap, the second one was made from Stn. 9 at 9°N, 138°E on 25th June to Stn. 18 at the 00°, 149°E on 28th June(Section B). The distance between adjacent stations was about 90 miles. The data of oceanographic observations were obtained by a CTD(Conductivity, Temperature and Depth Meters) system(Neil Brown Model 1150) and recorded on magnetic tape, and printed on recording paper. The sensor of CTD was cast down from the surface to 1,200 db with a lowering speed of ca. 60 m/min.

Results and Discussion

Temperature Section

Distributions of water temperature in Sections A and B are shown in Fig. 2(a) and (b).

In Fig. 2(a), the warm surface water having a value of above 29℃ was presented over the whole sea surface in the surface mixed layer ; the highest temperature was 29.68℃ at Stn. 3. The isotherm of 29℃ descended from the north to the south, the depths of which were ca. 20m at Stn. 2 and ca. 60m at Stn. 7.

In the subsurface layer, the isotherms from 27 to 12℃, which corresponded to the thermocline, descended towards the north and a sharp slope was presented in the region between Stns. 6 and 7. The depth of thermocline was the shallowest near Stn. 7(12°N) at the depth between 100-200m, and the vertical gradient of temperature in the thermocline was ca. 0.10℃/m.

The isotherms in the thermocline were spreading from Stn. 7 to the north.
The downward slopes of the thermocline from Stn. 7 to the north and to the south were associated with the NEC and the NECC.

At the time of this cruise, the boundary between the NEC and the NECC was recognized to be located near 12°N of the northern region of Yap Islands.

Below the depth of 800m, the isotherms of 5 and 4℃ descended from the north to the south, which was the opposite condition to the thermocline distribution with latitude. In Fig. 2(b), the warm surface water having a value of above 29℃ was presented over the whole sea surface in the surface mixed layer and the value of highest temperature was 30.28℃ at Stn. 12(6°N). The isotherm of 29℃ showed a smoothly concave pattern, and the

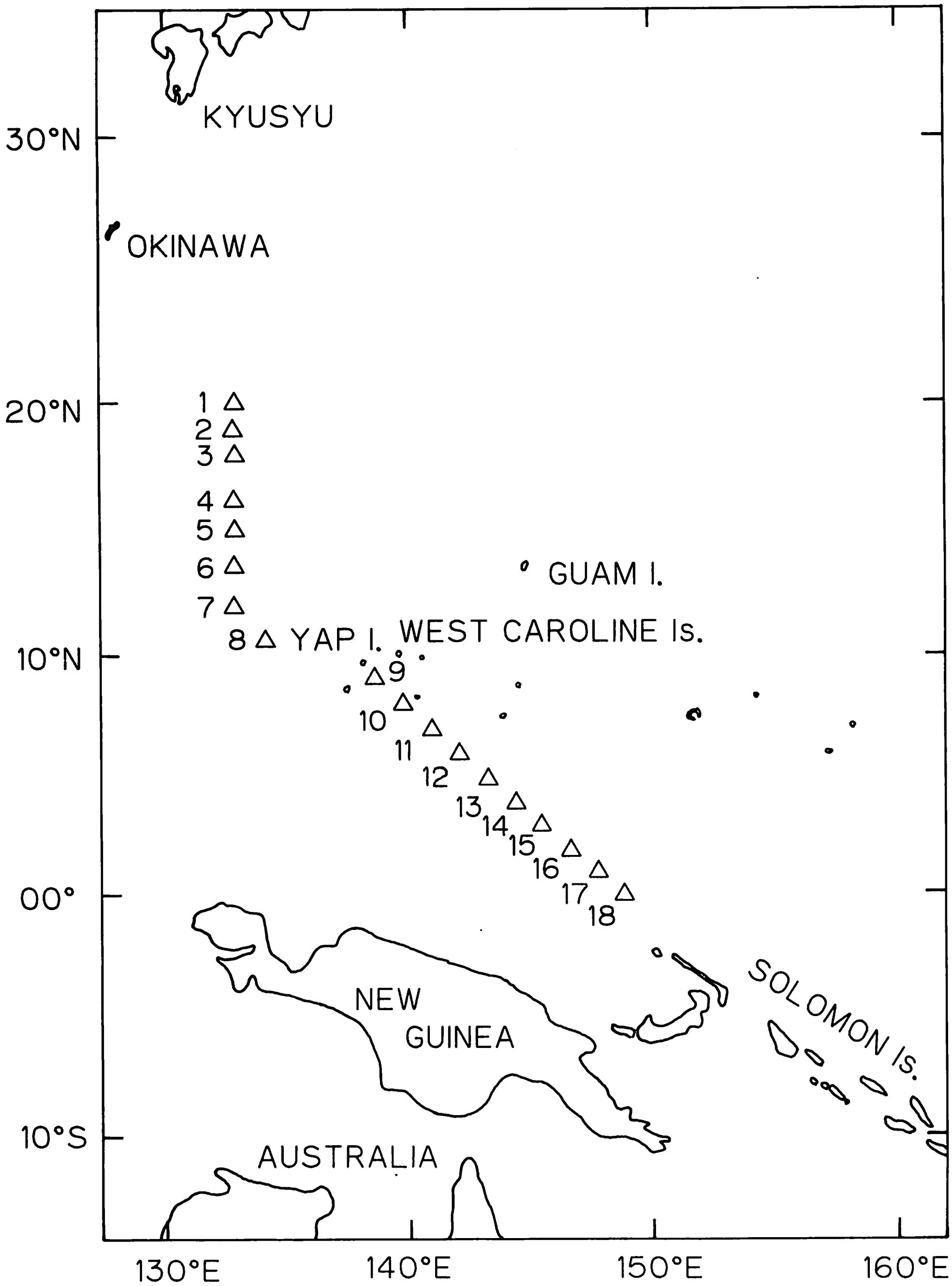

Fig. 1. Map showing the locations of CTD observations carried out along 133°E from 20°N to 10°N (Secion A), and the region between 09°N, 138°E and 00°, 149°E(Section B).

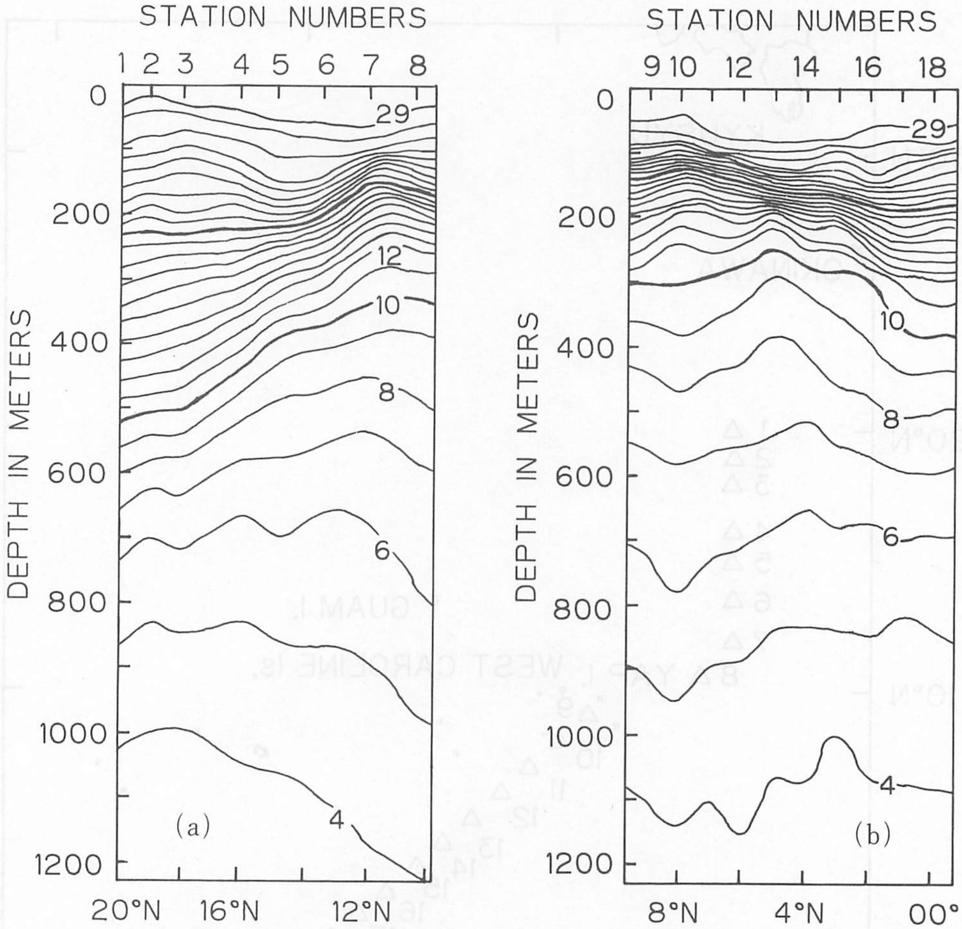

Fig. 2 Distributions of water temperature (℃) on the Sections A(a) and B(b).

maximum depth was ca. 75m in the region between Stns. 11 and 15. The upwelling was not found at the Equator.

In the subsurface layer, the thermocline descended slightly from 8°N to the Equator. The vertical gradient of temperature in the thermocline was ca. 0.17℃/m at Stn. 13, showing the largest value in the whole region. The thermocline spreading at the Equator was apparently existent, indicating that the Equatorial Undercurrent(EUC) did exist. The thermocline descended from the north to the south, in association with the NECC. The Equatorial Countercurrent ridge of the thermocline was located in the boundary(8°N) between the NEC and the NECC. The ridge in this section was located ca. 240 miles on the south side of that in Fig. 2(a), and seemed to exist in the meandering situation of the current boundary.

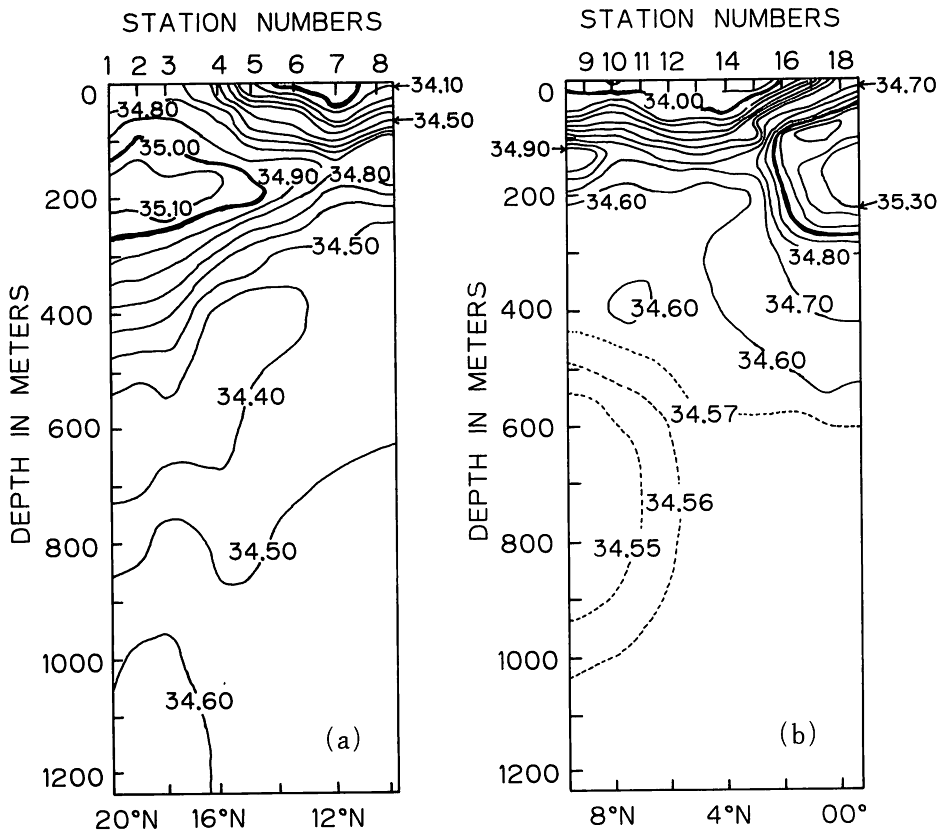

Fig. 3 Vertical distributions of salinity (‰) on Sections A(a) and B(b).

Salinity Section

Vertical distributions of salinity in Sections A and B are shown in Fig. 3(a) and (b).

In Fig. 3(a), the surface salinity water lower than 34.00‰ was presented in the surface mixed layer near Stn. 7(12°N), in association with the boundary between the NEC and the NECC. The isohaline of 34.50‰ was seen in the center between the low salinity surface water and the subsurface saline water extending from the north, and reached to the sea surface at Stn. 4.

In the subsurface layer, the saline water higher than 34.90‰ extended from the north to the south at a depth between ca. 150-300 m. The depth of the highest salinity water higher than 34.90‰ nearly coincided with that of isotherm of 22℃. Below the subsurface layer, the Intermediate Water lower than ca. 34.40‰ ascended towards the south and its core was presented at a depth between ca. 550 and 700m at Stn. 1, and ca. 400m at Stn. 6.

In Fig. 3(b), the surface water lower than 34.00‰ was presented in the surface mixed layer, the depths of which were ca. 25m near Stn. 10 and ca. 60m at Stn. 14. The isohaline of 34.00‰ reached to the sea surface near Stn. 16. The minimum value of the salinity was 33.70‰ at the sea surface at Stn. 15. The conspicuous transition zone (the Equatorial salinity front) was presented between the low salinity surface water and the high salinity tongue of water originating in the center of the South Pacific Subtropical Gyre as seen in the sea surface between Stns. 16(2°N) and 18(Equator). The edge of the high salinity tongue of the North Pacific was presented at a depth of ca. 150 m at Stn. 9. The relatively low salinity region between the high salinity tongues extending from the north and the south was associated with the NECC.

Below the subsurface layer, the salinity amounted to 34.50-34.60‰ in the whole water column to 1,200m. The low salinity tongue of the North Pacific Intermediate Water was not clearly found, but the edge of its salinity tongue reached the depth of ca. 200 m at 03°-30′N.

Dynamic Height Section

Dynamic height section referred to 1,000 db in Sections A and B are shown in Fig. 4(a) and (b), in order to understand the zonal current.

In Fig. 4(a), the equi-geopotential surface mostly declined from the north to Stn. 7(12°N), which is associated with the NEC. Between Stns. 7 and 8, the eastward current was the NECC.

In Fig. 4(b), the relatively complicated zonal current structure can be seen. The larger part of the eastward current was associated with the NECC. At the Equator, a very weak

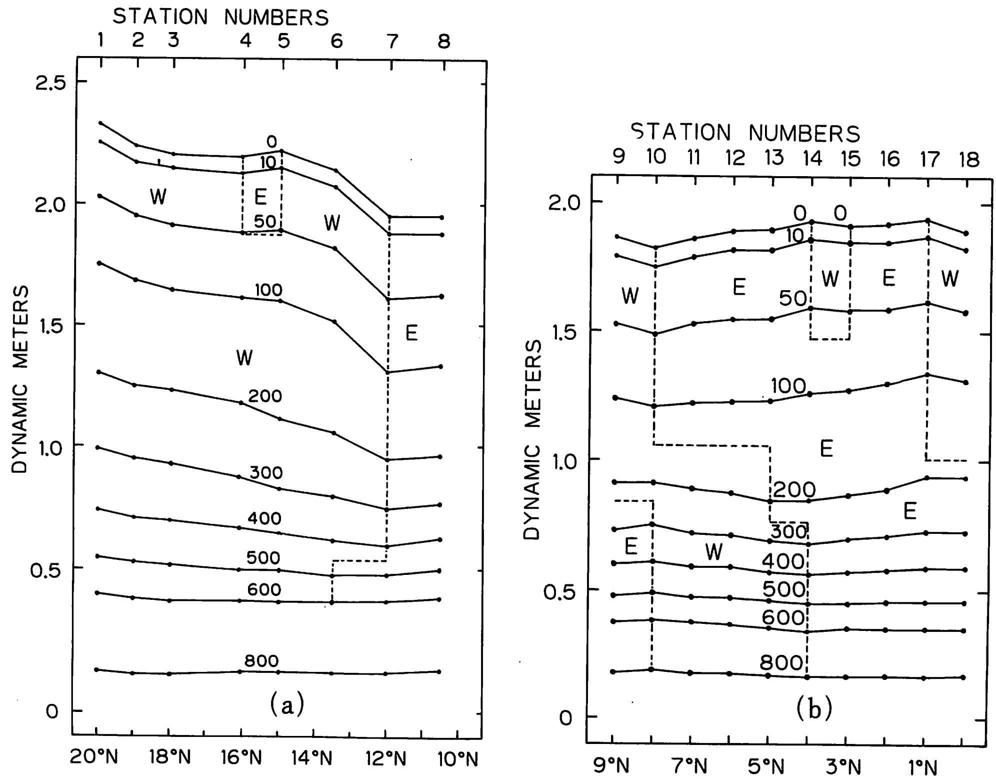

Fig. 4 Dynamic topography(dynamic meters) referred to 1,000 db on the Sections A(a) and B(b).

eastward current was recognized below the surface westward current. If the eastward current at the Equator was the Equatorial Undercurrent(EUC), the NECC might be connected to the EUC by continuous eastward current.

This zonal current structure had often been observed in the Western Tropical Pacific (Delcroix et al., 1987)[6].

The westward current near the Equator in the surface layer was recognized as the South Equatorial Current(SEC).

Upper Water Oceanic Structure

Upper water oceanic structure seemed to be related to the tuna fishing ground and the air-sea boundary process.

For this purpose, the profiles of temperature, salinity and dissolved oxygen above 600 m were examined.

In Fig. 5(a), (b) and (c), the profiles of temperature, salinity and dissolved oxygen are shown as records obtained by a CTD at Stns. 3(18°N), 12(6°N)and 18(Equator), respectively.

The profiles at Stn. 3 (Fig. 5, a) in the NEC showed that the thin mixed surface layer and the relatively thin subsurface salinity maximum with small spike-like features above ca. 200m, and the subsurface oxygen minimum exists at the salinity maximum. The profiles at Stn. 12 (Fig. 5, b) in the NECC showed that the mixed surface layer was well developed, and then the approximately two layer ocean exists (Wyrtki et al., 1967)[7] in the subsurface salinity maximum in the center of the thermocline, and the subsurface oxygen minimum exists at a depth of ca. 200m below the salinity maximum water. The profiles at Stn. 18 (Fig. 5, c) at the Equator showed that several step-like features and inversion layers exist in the thermocline and the thick salinity maximum with several large inversion layers indicates active mixing near the Equator and lateral advection with salinity transport from the South Pacific. These conspicuous salinity inversions were found at 3°N, and the subsurface oxygen minimum at the layer of the salinity maximum.

Temperature-Salinity(T-S) diagrams at the same stations as referred to in Fig. 5 are shown in Fig. 6(a), (b) and (c), respectively. The T-S diagrams at Stns. 3 (Fig. 6, a) and 12(Fig. 6, b) showed numerous small step-like and inversion features above 15℃. On the other hand, the T-S diagram at the Equator(Fig. 6, c) also showed several large step-like and inversion features above 15℃. McPhaden(1985) indicated using about 40 θ (potential temperature)-S diagrams at 00°, 150°W that lateral advection of different water masses in the thermocline and air-sea bouyancy fluxes at the surface existed at the Equator.

The upper water oceanic structure will be discussed in detail in another paper.

Summary

Based on the CTD data obtained by the Keiten Maru in the summer of 1988, the oceanographic conditions in the Western Tropical Pacific were summarized as follows :

1) The warm surface water having a value of above 29℃ was presented in the surface mixed layer. The depth of the surface mixed layer in Section A was smaller than that in

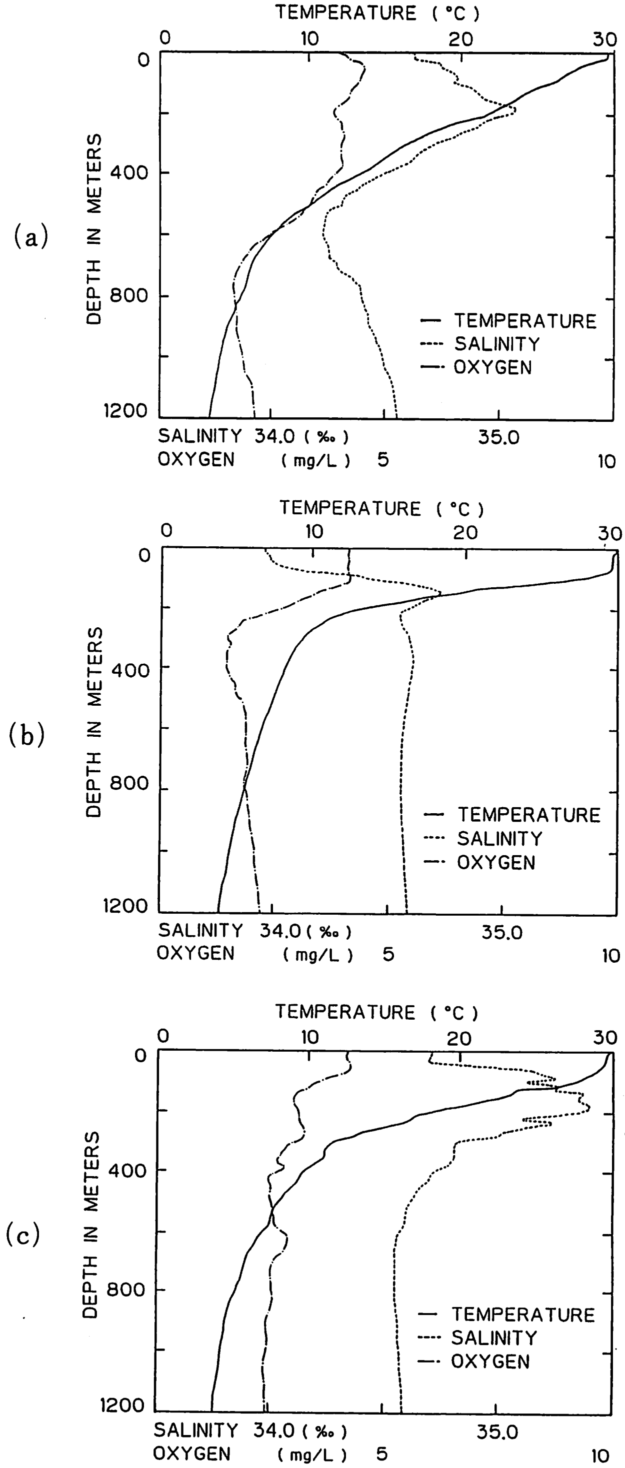

Fig. 5 CTD profiles at stations 3(18°N)(a), 12(6°N)(b) and 18(Equator)(c).

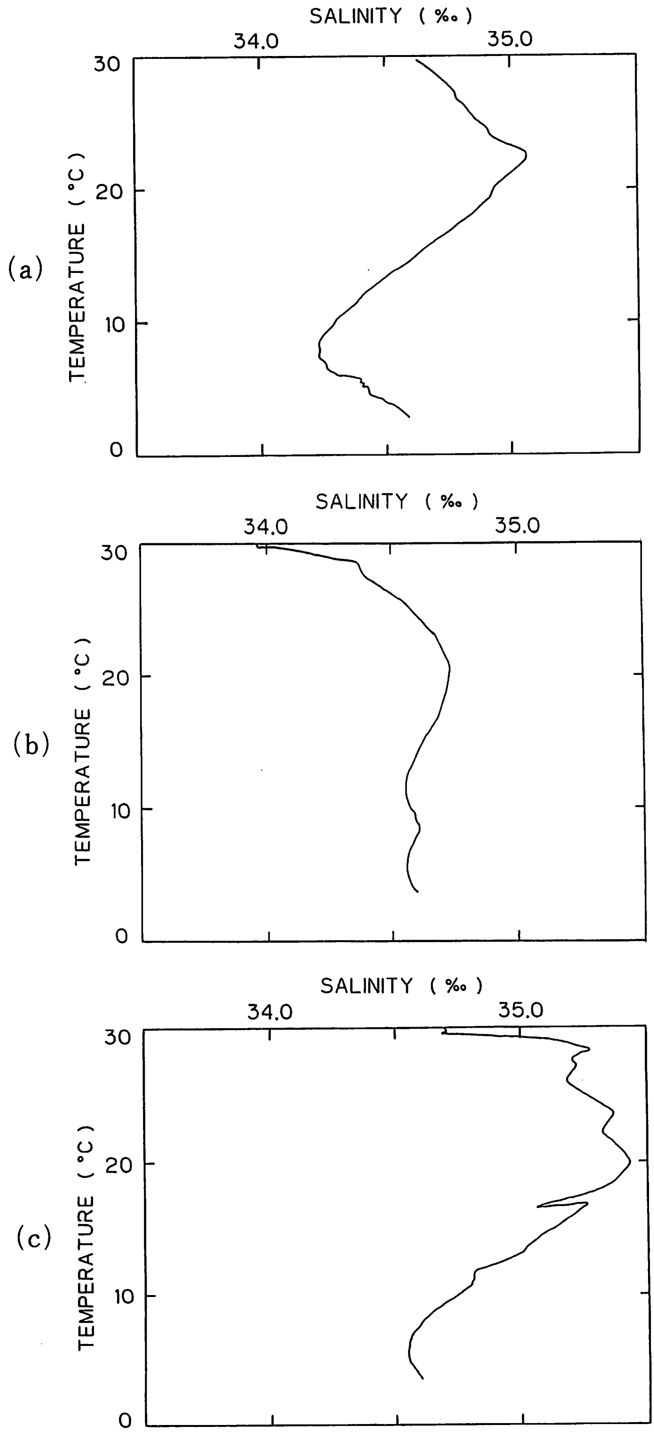

Fig. 6 Temperature-Salinity(T-S) diagrams at stations 3(18°N)(a), 12(6°N)(b) and 18(Equator)(c).

Section B.

2) The thermocline ascended from the north to the south, which was the shallowest near 09°N at a depth between ca. 100-200m, and descended gradually towards the Equator. The largest vertical gradient of temperature in the thermocline was presented near 07°N having a value of 0.17℃/m.

3) The low salinity water lower than 34.50‰ was presented between 16°N and 02°N in the surface mixed layer. The conspicuous transition zones were formed between the low salinity surface water and the higher salinity waters extending from the north and the south. The edge of the high salinity tongue of the North Pacific was found at the depth of ca. 150m at 09°N and that of South Pacific at 03°N. The Intermediate Water lower than 34.340‰ ascended towards the south, the protrusion of which reached to 13°N at the depth of ca. 400 m.

4) The North Equatorial Current was recognized in the surface layer at the north side of 08°N, the South Equatorial Current near the Equator and the North Equatorial Countercurrent between 08°N and 01°N.

5) Several large step-like features and inversion layers existed in the thermocline at the Equator. The mixing process and the lateral advection in the surface layer were well developed near the Equator. The oxygen minimum was found at the layer of the salinity maximum.

Acknowledgment

The authors wish to express their hearty thanks to Dr. M. Chaen, the Faculty of Fisheries of Kagoshima University, for his kind guidance and encouragement.

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Appendix

Date	13 June 1988		14 June 1988		15 June 1988	
Stn.	1		2		3	
Lat.	20°−00′.0 N		19°−06′.1 N		18°−02′.0 N	
Long.	133°−00′.0 E		132°−59′.0 E		133°−00′.4 E	
	Temp. (℃)	Sali. (‰)	Temp. (℃)	Sali. (‰)	Temp. (℃)	Sali. (‰)
0	29.55	34.580	29.44	34.841	29.68	34.767
10	29.56	34.703	29.44	34.842	29.67	34.768
20	29.52	34.712	29.33	34.824	29.60	34.766
30	29.14	34.772	28.48	34.786	28.86	34.827
50	28.00	34.794	27.52	34.859	27.52	34.883
75	27.57	34.882	27.16	34.967	26.94	34.930
100	26.83	34.903	26.48	35.011	25.88	34.939
150	24.56	35.036	24.13	35.166	23.74	35.072
200	22.40	35.167	21.28	35.148	22.00	35.197
250	19.08	35.038	18.84	35.028	18.71	35.021
300	17.56	34.948	16.84	34.892	16.42	34.855
400	13.90	34.677	13.72	34.668	13.29	34.621
500	10.55	34.436	10.26	34.422	10.11	34.439
600	8.01	34.335	7.35	34.309	7.45	34.353
700	6.34	34.380	6.01	34.383	6.14	34.426
800	5.49	34.474	5.18	34.469	5.43	34.545
900	4.70	34.529	4.53	34.547	4.53	34.569
1000	4.14	34.588	3.99	34.617	3.97	34.622
1200	3.39	34.619	3.14	34.680	3.27	34.689

Date	16 June 1988		17 June 1988		17 June 1988	
Stn.	4		5		6	
Lat.	16°−10′.5 N		14°−59′.9 N		13°−30′.1 N	
Long.	132°−59′.9 E		132°−59′.8 E		133°−00′.0 E	
	Temp. (℃)	Sali. (‰)	Temp. (℃)	Sali. (‰)	Temp. (℃)	Sali. (‰)
0	29.43	34.586	29.62	34.063	29.54	33.940
10	29.23	34.572	29.48	34.070	29.41	33.937
20	29.23	34.604	29.47	34.084	29.29	33.957
30	29.24	34.623	29.26	34.371	29.39	34.413
50	28.68	34.774	29.15	34.504	29.22	34.477
75	27.36	34.835	27.83	34.563	28.26	34.491
100	26.59	34.896	27.13	34.732	27.41	34.664
150	24.17	35.104	25.97	34.952	25.79	35.022
200	21.19	35.077	22.38	35.078	20.19	34.822
250	18.50	34.894	17.11	34.726	15.78	34.650
300	15.60	34.668	13.80	34.513	12.59	34.435
400	11.43	34.359	9.54	34.316	9.15	34.345
500	8.35	34.312	7.79	34.394	7.68	34.437
600	6.62	34.352	6.74	34.437	6.48	34.461
700	5.67	34.429	6.01	34.459	5.73	34.492
800	5.14	34.483	5.44	34.493	5.22	34.522
900	4.65	34.514	4.68	34.514	4.88	34.537
1000	4.18	34.543	4.23	34.541	4.40	34.551
1200	3.49	34.576	3.51	34.571	3.68	34.579

Date	18 June 1988		18 June 1988		25 June 1988	
Stn.	7		8		9	
Lat.	11°−59.′9 N		10°−34.′2 N		08°−59.′8 N	
Long.	133°−00.′0 E		134°−17.′7 E		138°−44.′0 E	
	Temp. (℃)	Sali. (‰)	Temp. (℃)	Sali. (‰)	Temp. (℃)	Sali. (‰)
0	29.45	33.885	29.39	34.097	29.13	33.969
10	29.39	33.893	29.37	34.105	29.14	33.980
20	29.40	33.897	29.34	34.099	29.14	33.993
30	29.41	33.915	29.25	34.160	29.14	34.000
50	29.46	34.029	28.47	34.375	29.05	34.079
75	28.61	34.338	27.72	34.444	27.63	34.357
100	27.05	34.461	26.31	34.808	26.36	34.619
150	19.73	34.843	21.92	34.937	19.29	34.932
200	15.39	34.631	15.74	34.638	14.15	34.609
250	12.26	34.526	12.23	34.489	11.87	34.568
300	10.79	34.488	10.55	34.523	10.08	34.565
400	8.75	34.563	8.75	34.549	8.39	34.584
500	7.33	34.474	7.97	34.571	7.45	34.557
600	6.42	34.469	6.77	34.468	6.69	34.536
700	5.90	34.505	6.41	34.536	6.15	34.536
800	5.37	34.531	5.83	34.541	5.51	34.541
900	4.98	34.540	5.34	34.536	5.04	34.552
1000	4.61	34.555	4.87	34.540	4.51	34.564
1200	3.93	34.576	4.05	34.572	3.74	34.588

Date	25 June 1988		26 June 1988		26 June 1988	
Stn.	10		11		12	
Lat.	08°−00.′1 N		07°−00.′3 N		06°−00.′0 N	
Long.	139°−52.′5 E		141°−02.′1 E		142°−10.′8 E	
	Temp. (℃)	Sali. (‰)	Temp. (℃)	Sali. (‰)	Temp. (℃)	Sali. (‰)
0	29.09	33.872	29.48	33.862	30.28	33.978
10	29.02	33.852	29.50	33.883	30.02	33.970
20	29.07	33.979	29.49	33.995	29.71	33.964
30	29.05	34.000	29.50	34.021	29.70	33.981
50	28.77	34.267	29.52	34.079	29.66	33.985
75	27.93	34.375	28.90	34.301	29.54	34.096
100	24.78	34.650	27.25	34.474	27.86	34.380
150	16.78	34.677	17.63	34.686	19.45	34.721
200	12.52	34.565	12.91	34.567	13.83	34.592
250	10.76	34.557	11.06	34.555	10.70	34.557
300	10.09	34.580	9.85	34.588	9.42	34.592
400	8.78	34.606	8.43	34.597	8.21	34.605
500	7.67	34.568	7.41	34.562	7.41	34.582
600	6.89	34.547	6.79	34.557	6.66	34.563
700	6.38	34.549	6.23	34.549	6.08	34.555
800	5.92	34.549	5.49	34.547	5.48	34.555
900	5.29	34.551	4.97	34.556	4.94	34.560
1000	4.77	34.561	4.42	34.570	4.52	34.568
1200	3.82	34.588	3.59	34.595	3.88	34.586

Date	26 June 1988		27 June 1988		27 June 1988	
Stn.	13		14		15	
Lat.	04°−59.′9 N		04°−00.′1 N		02°−59.′9 N	
Long.	143°−13.′9 E		144°−24.′1 E		145°−30.′0 E	
	Temp. (℃)	Sali. (‰)	Temp. (℃)	Sali. (‰)	Temp. (℃)	Sali. (‰)
0	29.84	33.840	29.67	33.809	30.08	33.697
10	29.63	33.829	29.78	33.922	29.79	33.937
20	29.53	33.817	29.73	33.921	29.74	33.934
30	29.59	33.879	29.74	33.933	29.71	33.931
50	29.65	33.970	29.72	33.935	29.81	34.176
75	29.38	34.172	29.68	34.114	29.70	34.587
100	27.87	34.347	27.81	34.419	26.59	34.408
150	21.62	34.708	22.63	34.740	23.27	34.763
200	12.25	34.540	14.15	34.571	14.68	34.609
250	9.77	34.558	10.98	34.603	11.08	34.608
300	8.80	34.600	9.18	34.575	9.39	34.578
400	7.84	34.597	8.07	34.601	8.61	34.634
500	7.23	34.578	7.08	34.565	7.50	34.577
600	6.60	34.563	6.31	34.556	6.56	34.558
700	5.87	34.556	5.72	34.554	5.84	34.550
800	5.19	34.558	5.18	34.559	5.26	34.555
900	4.72	34.566	4.66	34.568	4.49	34.569
1000	4.33	34.576	4.29	34.578	3.98	34.583
1200	3.71	34.592	3.54	34.599	3.41	34.602

Date	27 June 1988		28 June 1988		28 June 1988	
Stn.	16		17		18	
Lat.	01°−59.′8 N		00°−59.′9 N		00°−00.′1 N	
Long.	146°−39.′1 E		147°−44.′8 E		148°−52.′1 E	
	Temp. (℃)	Sali. (‰)	Temp. (℃)	Sali. (‰)	Temp. (℃)	Sali. (‰)
0	29.86	33.955	29.97	34.086	29.79	34.707
10	29.83	33.973	29.82	34.091	29.63	34.706
20	29.76	34.084	29.70	34.525	29.61	34.704
30	29.50	34.255	29.62	34.556	29.56	34.693
50	29.15	34.589	29.55	34.695	29.29	34.947
75	28.67	34.816	28.20	34.965	28.52	35.203
100	27.43	35.161	27.11	35.275	27.12	35.136
150	24.69	35.104	24.15	35.293	23.08	35.323
200	17.72	35.011	19.04	35.251	18.03	35.337
250	12.84	34.920	15.47	35.154	15.19	35.140
300	9.97	34.726	11.06	34.738	11.70	34.810
400	8.88	34.660	9.62	34.709	9.62	34.716
500	7.70	34.598	8.17	34.622	8.00	34.609
600	6.64	34.561	6.90	34.572	6.90	34.565
700	5.78	34.551	5.99	34.557	5.90	34.551
800	5.22	34.552	5.05	34.558	5.26	34.550
900	4.76	34.558	4.69	34.564	4.53	34.563
1000	4.43	34.570	4.30	34.576	4.24	34.571
1200	3.48	34.598	3.58	34.597	3.70	34.590