Hydrographical Researches in the Western Equatorial Pacific

by

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Abstract

Several hydrographical researches in the western Equatorial Pacific were made by Kagoshima-maru and Keiten-maru in 1952 and 1954–1956. A preliminary sammary of the results is presented, showing the existence and some characters of the contra solem vortex, which may be considered as the western boundary vortex between the North Equatorial Current and the Equatorial Counter Current, and some other features found from these researches.

1. Introduction

Several hydrographical researches in the western Equatorial Pacific were made by Kagoshima-maru and Keiten-maru in 1952 and 1954-1956 in connection with tuna-fishing experiments. The first research, July-August 1952, was made by the former in areas from east-northeast off the Philippines to Sawu Sea via Molucca Passage; the second one, January 1954, by also the former in Macassar Strait and Molucca Sea; the third, November 1954 to January 1955, by the latter in areas from east-northeast off the Philippines to east off Australia, crossing the equatorial currents obliquely; the fourth, June-July 1955, by the former in some scattered areas from northwest off New Guinea to Celebes Sea. The fifth research, July-August 1956, was made by the former along the meridian of 130° E from 20° N to the Equator and by the latter along 135° E

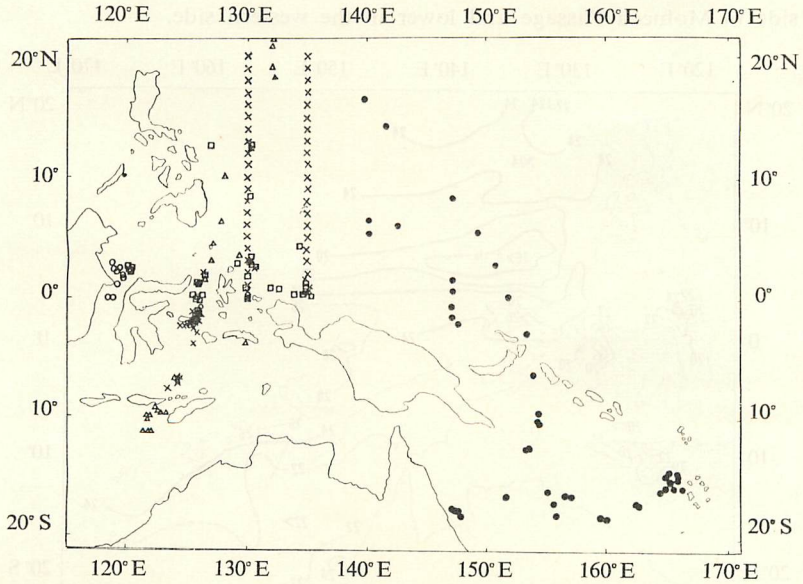

Fig. 1. Map showing observing stations. Symbols: triangles, July–August 1952; circles, January 1954; dots, November 1954-January 1955; squares, June–July 1955; crosses, July–August 1956.

within the same range of latitude, which represented the participation of Kagoshima University in EQUAPAC Program[1], and in some scattered areas in the inland seas by the two. The observing points are shown in Fig. 1. A preliminary sammary of the results obtained from these researches is presented, showing the general features of the hydrographical conditions in the region.

2. Temperature

The horizontal distribution of water temperature on the 150 m level is given in Fig. 2, disregarding possible variations with time. A cold region of distorted elliptic form is found in a area surrounding 7° N and 135° E, east off Mindanao Island, elongating to the roughly longitudinal direction. The same feature is also found on the levels up to 75 m and down to 500 m depth though somewhat less marked. This is a notable fact which has never got any special notice, though it was suggested by K. Koenuma[2] in somewhat different situation on the base of few materials. The absolute values of the water temperature about the center of this area are ca. 24, 20, 15, 10, and 7 °C at 75, 100, 150, 200, and 500 m depths respectively and the horizontal temperature gradient is very weak within the area, which is surrounded with a zone of strong horizontal temperature gradient. Outerward of this zone the horizontal temperature gradient is comparatively weak again.

Northeast off Australia, to the south of the Equator, the horizontal temperature gradient almost vanish at the depth of 150 m within this area (Fig. 2), though the lower temperature is found at the higher latitude in the layer above the depth. It must be added that a zone of higher temperature than 10° C appears around 15° S at the 500 m depth (Fig. 3).

In Banda Sea and its adjacent areas more or less irregular temperature distribution is found, which may be partly attributed to the lack of simultaneousness of observations. At the 500 m depth, however, it is seen in Fig. 3 that the temperature is higher in the eastern side in Molucca Passage and lower in the western side.

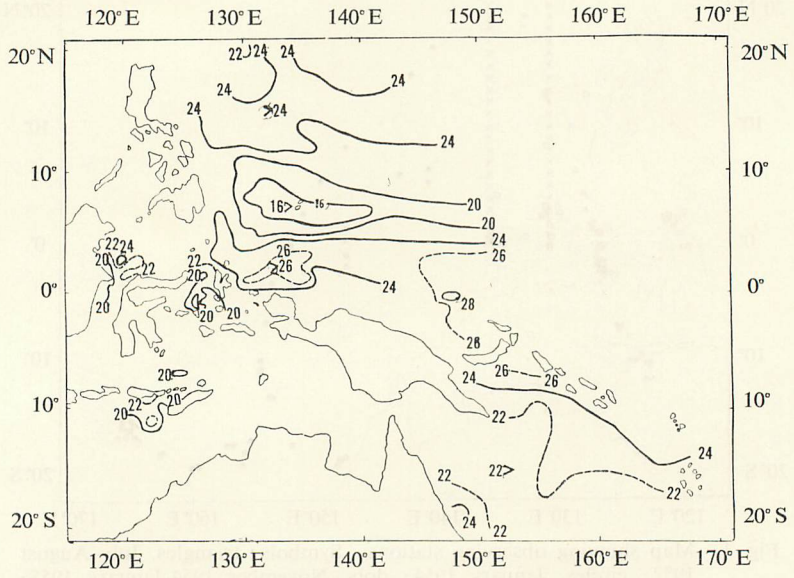

Fig. 2. Horizontal distribution of temperature on 150 m level.

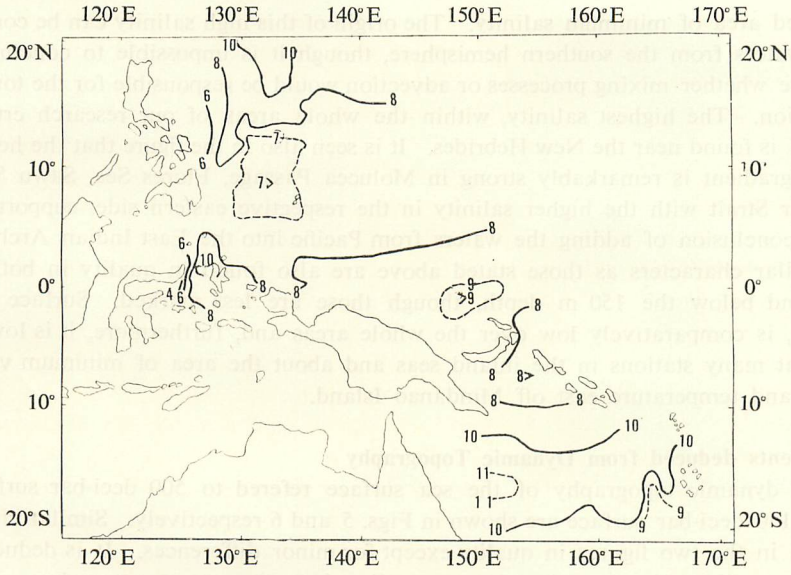

Fig. 3. Horizontal distribution of temperature on 500 m level.

3. Salinity

It is noticed in Fig. 4 presenting the horizontal distribution, disregarding possible variations with time, of salinity on the 150 m level that the region of minimum value of temperature east off Mindanao Island, stated in the previous section, is also the region of minimum value of salinity less than 34.8 ‰, suggesting the upwelling of the intermediate water. A tongue of higher salinity than 35.4 ‰ is found in areas from north off New Guinea towards Mindanao Island, to the southwestern side of the above-

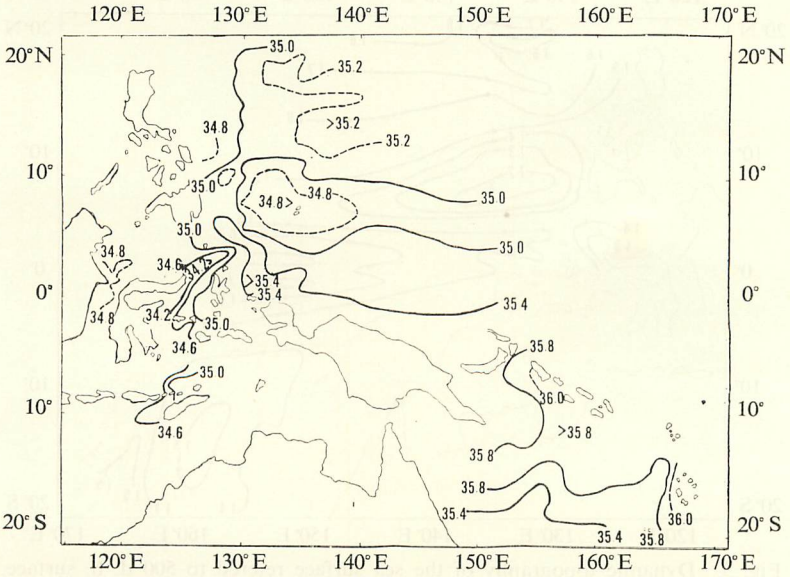

Fig. 4. Horizontal distribution of salinity on 150 m level.

mentioned area of minimum salinity. The origin of this high salinity can be considered as the waters from the southern hemisphere, though it is impossible to conclude from the figure whether mixing processes or advection would be responsible for the tonguelike distribution. The highest salinity, within the whole areas of our research cruises, of ca. 36 ‰ is found near the New Hebrides. It is seen also in the figure that the horizontal salinity gradient is remarkably strong in Molucca Passage, Flores Sea, Sawu Sea, and Macassar Strait with the higher salinity in the respective eastern side, supporting van Riel's[3] conclusion of adding the waters from Pacific into the East Indian Archipelago.

Similar characters as those stated above are also found in quality in both layers above and below the 150 m depth, though those are less marked. Surface salinity, however, is comparatively low over the whole areas and, furthermore, it is lower than 34.0 ‰ at many stations in the inland seas and about the area of minimum values of salinity and temperature east off Mindanao Island.

4. Currents deduced from Dynamic Topography

The dynamic topography of the sea surface refered to 500 deci-bar surface and that of 150 deci-bar surface are shown in Figs. 5 and 6 respectively. Similar characters are seen in the two figures in quality except for minor differences. It is deduced from these figures that the approximate current directions at any corresponding points on these two surfaces are similar in general, in spite of the existence of the thermocline between them. It is difficult from these figures to detect the Undercurrent which was found by T. Cromwell and others[4] in the central Equatorial Pacific.

The most notable feature in the figures is the existence of a contra solem vortex, east off Mindanao Island, between the North Equatorial Current and the Equatorial Counter Current, extending over a area of ca. 400 and ca. 1000 miles in meridional and longitudinal directions respectively. It may be considered as the western boundary vortex between them. Comparing these figures with Figs. 2 and 4, it is noticed that

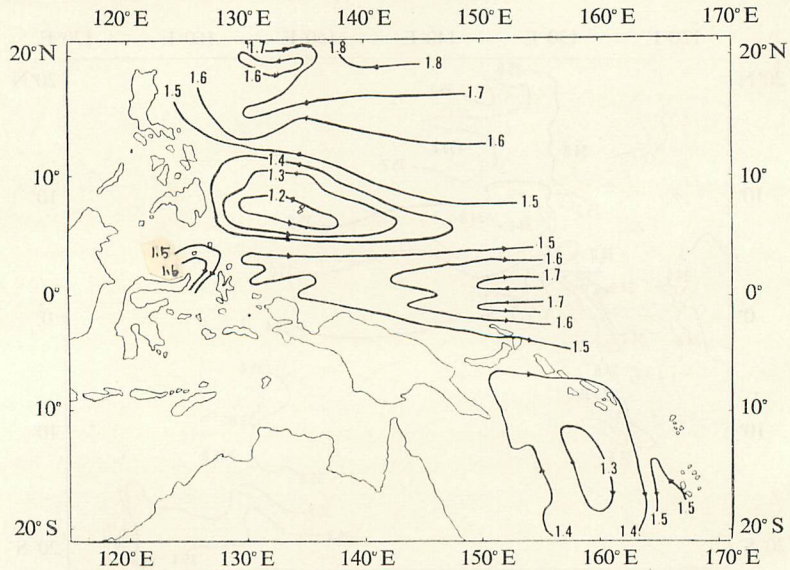

Fig. 5. Dynamic topography of the sea surface refered to 500 d. b. surface. Approximate current directions indicated by arrows.

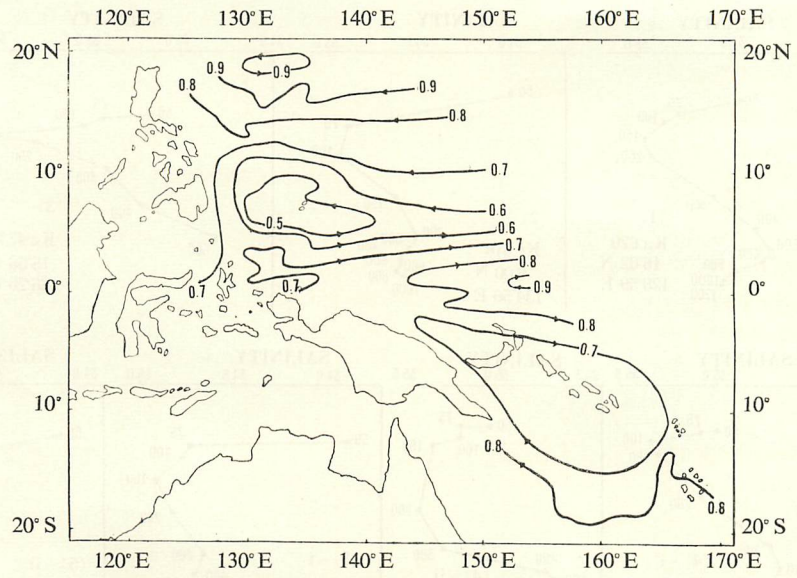

Fig. 6. Dynamic topography of 150 d. b. surface refered to 500 d. b. surface. Approximate current directions indicated by arrows.

this vortex covers the area of minimum values of temperature and salinity stated in the preceding section. The highest speed in the vortex is ca. 3 knots and is found at about 5° N in eastward flow. To the south of the vortex, the South Equatorial Current seems to hardly arrive at areas north off the western New Guinea, though high salinity of southern origin is found there, as stated in the previous section.

Another small contra solem vortex seems to exist around 19° N within the North Equatorial Current spreading over broad areas. No area can be found where the speed of the North Equatorial Current exceeds 1 knot, except for some small areas around the vortex. Another contra solem vortex with a tilting vertical axis appears northeast off Australia. The center of this vortex lies in Coral Sea on the sea surface, and around the Solomon Islands on 150 m level.

5. Temperature-Salinity Relations

Drawing and inspecting the temperature-salinity curves from the observed data of all the observational stations, these can be classified into the following five groups according to geographical areas. Examples belonging to each group are shown in Fig. 7.

(1) In the area of the North Equatorial Current, the temperature-salinity curves have a similar character to each other. Two kinds of water are clearly found between the surface water affected by the weather conditions and the deep water. The one, the upper water, is characterized by a salinity maximum at a depth about 150 m depth; and the other, the intermediate water, a salinity minimum about 500 m depth.

(2) In the contra solem vortex characterized by the horizontal minimum values of temperature and salinity east off Mindanao Island, the two kinds of water stated above are not so conspicuous as before, especially the latter almost vanishes, showing the latter's upwelling and the development of mixing processes within this area. The salinity varies slightly with depth except for the layer above 100 m depth. The deep water is similar as before.

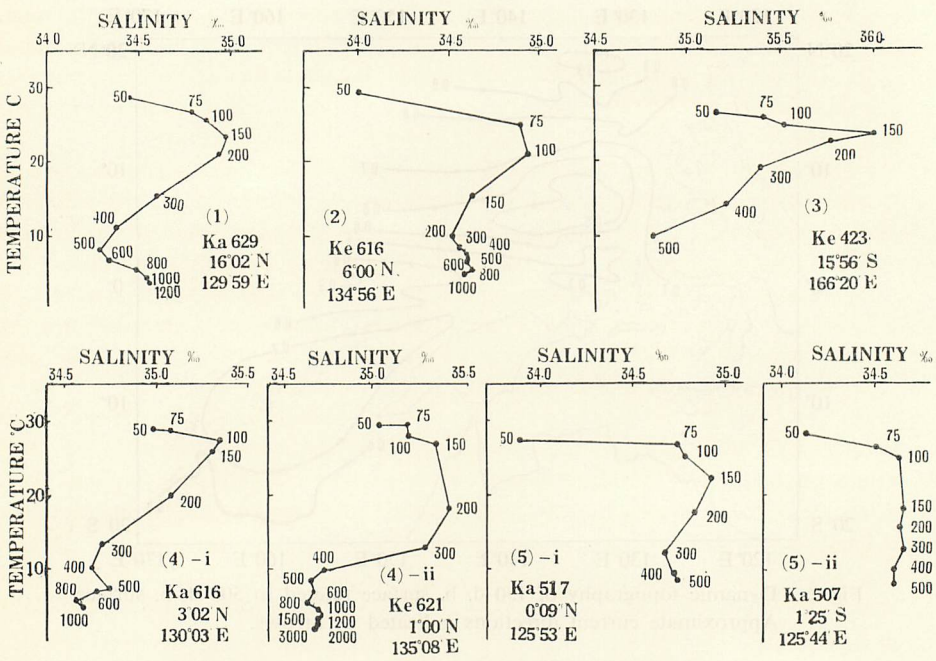

Fig. 7. Examples of temperature-salinity curves in (1) the North Equatorial Current, (2) the western boundary vortex between the North Equatorial Current and the Equatorial Counter Current, (3) Coral Sea, (4) areas north off the western New Guinea (i the western portion, ii the eastern portion), (5) Molucca Passage. Observing depths are entered.

(3) In Coral Sea and its adjacent areas, they are characterized by the quite conspicuous salinity maximum amounting to almost 36 ‰ at ca. 150 m depth. Unfortunately, the observed data in the areas are available only above the 500 m depth.

(4) North off the western New Guinea, to the south of the contra solem vortex located east off Mindanao Island, the temperature-salinity relations are somewhat different according to locality, showing transitional stages. In the western portion of the areas under consideration, they are similar considerably as those of type (2) except that the absolute values of the maximum salinity in the temperature-salinity curves of the former are much higher than the latter. In the eastern portion, the protuberance of the maximum salinity in them is more or less flatted, spreading over broad range of temperature, though the absolute values of the maximum salinity approach to those of type (3).

(5) In Molucca Passage, confused changes covering broad ranges of temperature and salinity are found in the temperature-salinity relations according to time and locality, showing the irregular situations of mixing processes in this area. They are obliged to be out of discussion in other portions of the inland seas, i. e. Macassar Strait, Flores Sea and its adjacent areas, where the observed data only above 200 m depth, unfortunately, are available except for a few scattered stations.

6. Conclusion

The following facts are found from the studies stated above:

(1) East off Mindanao Island, between the North Equatorial Current and the Equatorial Counter Current, there is a contra solem vortex, which may be considered as the

western boundary vortex between them. It is characterized by the horizontal minimum values of temperature and salinity with the vanishing intermediate salinity minimum, showing the upwelling of the intermediate water and the development of mixing processes. The maximum current velocity of ca. 3 knots is found in the eastward flow on its southern side.

(2) North off the western New Guinea, to the south of the contra solem vortex stated above, there is a protuberance of high salinity towards Mindanao Island originated from the southern hemisphere. The South Equatorial Current, however, seems to hardly arrive at the areas under consideration on the base of the dynamic topography and the temperature-salinity relations varies according to locality, showing transitional stages.

(3) Northeast off Australia, another contra solem vortex with a tilting vertical axis is found. The latitudinal change of temperature seems to vanish almost at the 150 m level, where the maximum salinity approaching to 36‰ prevails.

(4) In the North Equatorial Current, there is no area where the current speed exceeds 1 knot except for the areas around a small contra solem vortex located at ca 19° N. The two kinds of water, the upper water characterized by a salinity maximum at ca. 150 m depth and the intermediate water a salinity minimum at ca. 500 m depth, are found clearly.

(5) In Molucca Passage, Flores Sea, Sawu Sea, and Macassar Strait, the higher salinity is found in the respective eastern side and in Molucca Passage the higher temperature at 500 m depth is also found in the eastern side, though the temperature and the salinity varies rather irregularly in broad ranges according to time and locality in general, showing different situations of mixing processes of the Pacific waters into the adjacent waters.

References

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(3) van Riel, P. M., 1932: The Snellius Expedition, Conseil Perm. Int. p. l'Explor. d. la Mer, Jour. du Conseil, 7, 212.

(4) Cromwell, T., R. B. Montgomery, and E. D. Stroup, 1954: Equatorial undercurrent in Pacific Ocean revealed by new method, Science 119, 648.