Annual Variation of Thermocline Topography in the Western Tropical Pacific

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Abstract

The annual variation of the north equatorial trough near 15°N and the north equatorial countercurrent ridge near 7.5°N in the thermocline topography was investigated by making the 20°C isotherm depth topography in time and space over a six years period. The annual variation in the latitudinal position of the north equatorial trough has an annual cycle, being in the north from November to April and in the south from May to October. The countercurrent ridge has a semiannual cycle, with the northward shifts from March to April and October to November, and the southward shifts from July to September and December to January, respectively. The annual variation in the depth of both the north equatorial trough and the countercurrent ridge tends to have an annual cycle, which is deeper from spring to early summer, and shallower from fall to winter. The annual variation in dynamic heights and sea levels near 7.5°N in the western tropical Pacific depends partly on the northward and southward shift of the countercurrent ridge in thermocline depths.

Introduction

For the monitoring of geostrophic flow of the equatorial current system, the thermocline depth is a useful indicator in the same manner as dynamic heights and sea levels in oceanic islands (Wyrtki, 1979; Chaen and Wyrtki, 1981). The principal troughs and ridges on the thermocline topography are especially valuable for this purpose. North of the equator, we have the north equatorial trough (a ridge in dynamic topography) near 15°N, the north equatorial countercurrent ridge (hereafter referred to as the countercurrent ridge) near 7.5°N, the equatorial trough near 3°N, and the equatorial ridge at the equator. The north equatorial trough and the countercurrent ridge indicate the northern boundary of the southern band of the north equatorial current (White and Hasunuma, 1981) and the boundary between the north equatorial current and the north equatorial countercurrent, respectively.

Recently, White and Hasunuma (1980), Meyers, White and Hasunuma (1982) have studied the interannual, annual, and semiannual variation of the baroclinic gyre structure of the western north Pacific, by means of statistics and harmonic analysis making use of much data. They pointed out that the semiannual amplitude in the dynamic height

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variability exceeds the residual and is larger than the annual amplitude between the equator and 10°N. Meyers (1982) discussed the relationship between typical seasonal and interannual variations in sea level at Truk Island at 7.5°N (see Fig. 1), and pointed out that typical seasonal cycle obtained averaging non-El Niño years is dominated by the semiannual cycle.

The purpose of this study is to examine the annual variation in the north equatorial trough and the countercurrent ridge of the thermocline topography in the western tropical Pacific, by making the 20°C isotherm depth topography.

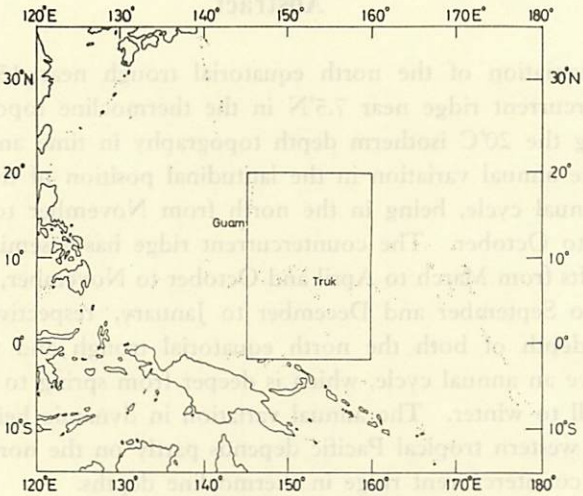

Fig. 1. The area of the study is shown inside the rectangle.

20°C Isotherm Depth Topography in Time and Space

The area between 20°N and 2°S, and 145°E and 160°E was investigated (Fig. 1) because of the relatively large number of meridional mechanical bathythermograph (MBT) sections occupied by Japanese fishing training vessels, and the east-west gradient of the thermocline depth is small as can be inferred from the temperature atlas by Robinson (1976). A total of 152 meridional sections consisting of 2,020 points observed from April of 1965 to November of 1970 have been used in this study (Fisheries Agency of Japan, 1968-1973). Data from 1971 to the present cannot be adapted for this purpose because the obsevations were not made throughout the year.

The depth (in meters) of the 20°C isotherm, which represents the thermocline depth in the area is interpolated from temperature values listed for depths of 0, 10, 20, 30, 50, 75, 100, 150, 200, and 250 m. The depth of the 20°C isotherm has been plotted in time and space, to allow drawing of the isopleths of the 20°C isotherm depth topography (Fig. 2). This topography demonstrates the behavior to the troughs and ridges in time. It can be seen in this topography that the existence of the north equatorial trough and the countercurrent ridge, marked by the chain of crosses. The countercurrent ridge is more conspicuous than the north equatorial trough. Both the equatorial trough near 3°N and the equatorial ridge at the equator cannot be recognized in this topography owing to the small amount of data and the small Coriolis parameter

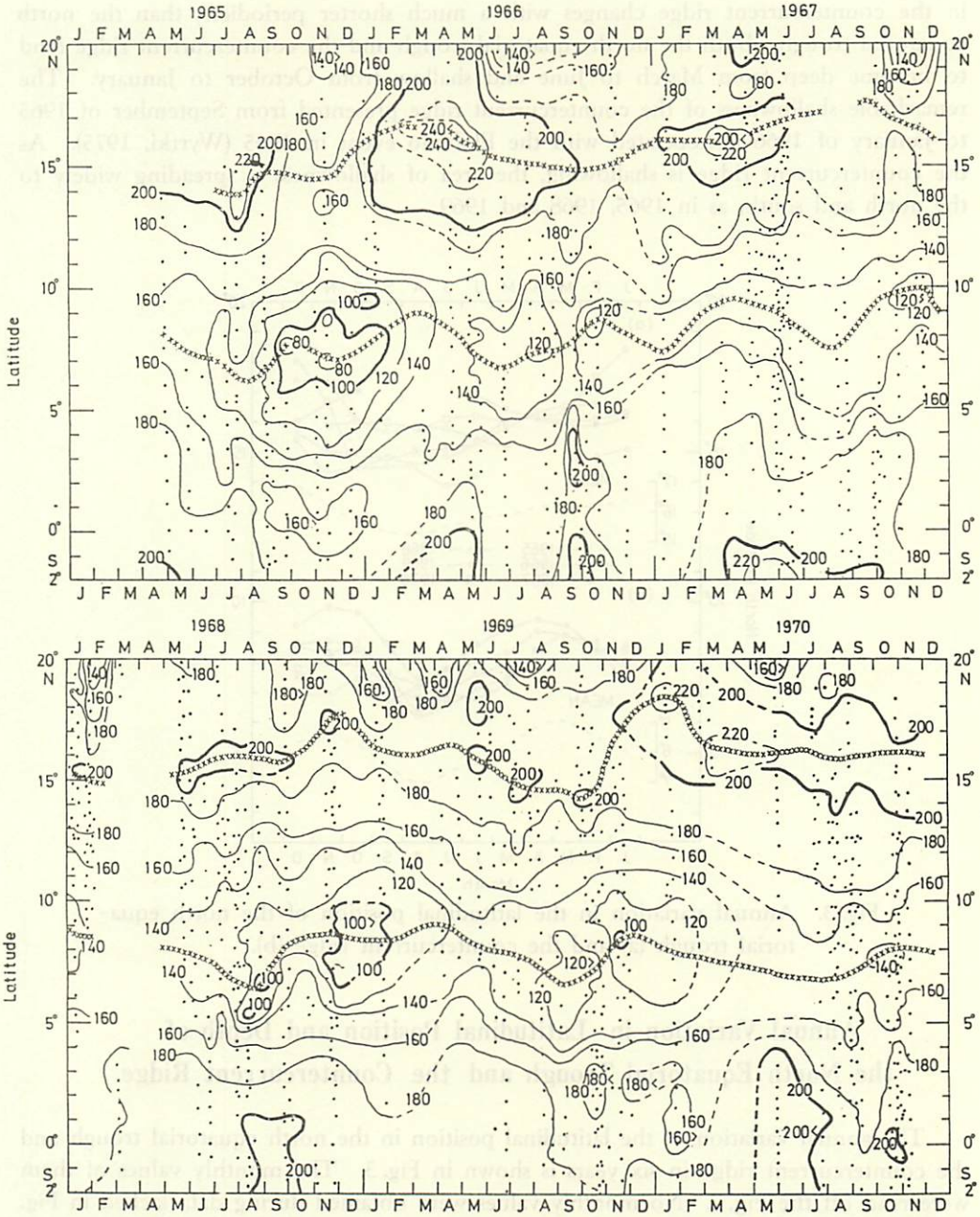

Fig. 2. Isopleths of the 20°C isotherm depth topography (in meters) from 1965 to 1970. Dots indicate data available. The chain of crosses indicates the north equatorial trough (upper) and the countercurrent ridge (lower), respectively.

near the equator.

The latitudinal position of the north equatorial trough and the countercurrent ridge is found between 14°N and 19°N, and 6°N and 10°N, respectively. Their northward and southward shifts are generally synchronized, although the latitudinal position

in the countercurrent ridge changes with a much shorter periodicity than the north equatorial trough. Both the north equatorial trough and the countercurrent ridge tend to become deep from March to June and shallow from October to January. The remarkable shallowness of the countercurrent ridge presented from September of 1965 to January of 1966 is associated with the El Niño event in 1965 (Wyrtki, 1975). As the countercurrent ridge is shallowing, the area of shallowness is spreading widely to the north and south, as in 1965, 1968 and 1969.

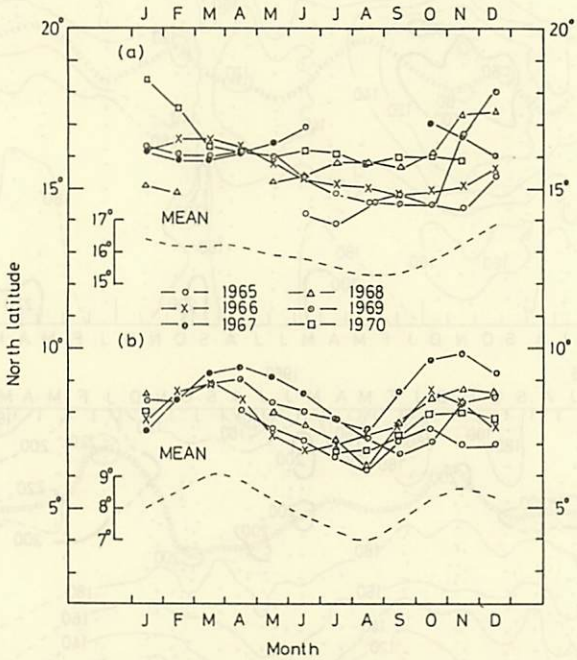

Fig. 3. Annual variation in the latitudinal position of the north equatorial trough (a) and the countercurrent ridge (b).

Annual Variation in Latitudinal Position and Depth of the North Equatorial Trough and the Countercurrent Ridge

The annual variation of the latitudinal position in the north equatorial trough and the countercurrent ridge in six years is shown in Fig. 3. The monthly values of them were read off the Fig. 2. No monthly values were obtained during data lacked in Fig. 2. The monthly mean latitudinal positions were calculated except of values in the 1965 El Niño year, and are also shown in Fig. 3. The annual variation of the latitudinal position in the north equatorial trough tends to have an annual cycle, being in the north from November to April and in the south from May to October. The annual variation of the countercurrent ridge, on the other hand, has a distinct semiannual cycle, with the northward shifts from March to April and October to November, and the southward shifts from July to September and December to January, respectively. This variation in the countercurrent ridge coincides with the semiannual oscillation observed

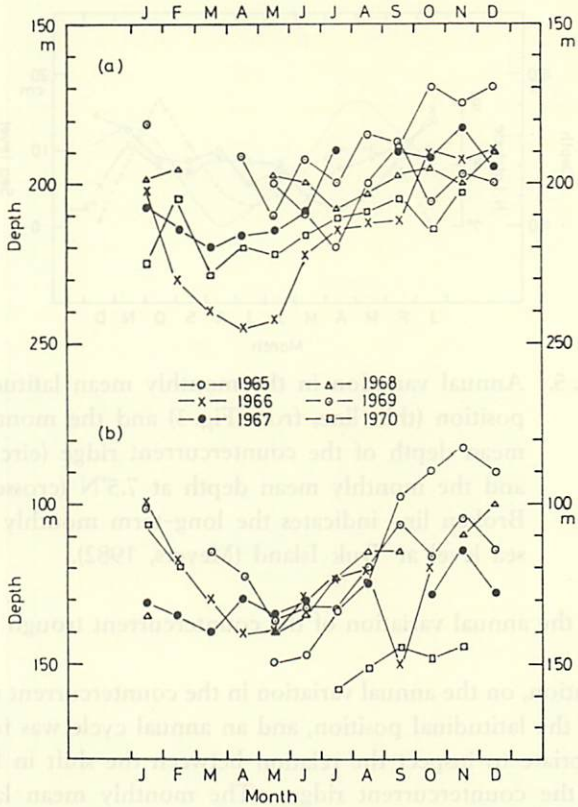

Fig. 4. Annual variation in the depth of the north equatorial trough (a) and the countercurrent ridge (b).

in the thermocline depth between the equator and 10°N, east of 180° (Meyers, White and Hasunuma, 1982), and in the monthly mean sea level at Truk Island (Meyers, 1982). According to Meyers (1979), the oscillation is apparently forced by wind. The strength of the equatorial easterly wind has a semiannual constituent in the central Pacific. The semiannual shift in latitudes of the countercurrent ridge seems to be associated with the semiannual oscillation produced by easterly wind stress. Maximum easterly wind occurs in June and December (Meyers, 1982. Fig. 8), and one or two months later, the countercurrent ridge tends to be in the southernmost position in August and January.

The annual variation of the depth in the north equatorial trough and the countercurrent ridge is shown in Fig. 4. The monthly values of them were read off the Fig. 2 and the monthly projected profile of meridional topography of the 20°C isotherm depth (not presented). It can be seen in Fig. 4 that both the north equatorial trough and the countercurrent ridge tend to become deep from March to June and shallow from September to January, although the monthly values are not completed throughout the year. Wyrtki (1974) showed that the annual cycle in dynamic heights of the countercurrent trough near 9°N, 140°E-180°, is highest in spring and lowest in winter. This is consistent with the annual variation in the 20°C isotherm depth of the countercurrent ridge. Mayers, White, and Hasunuma (1982) demonstrated, however, that the semiannual

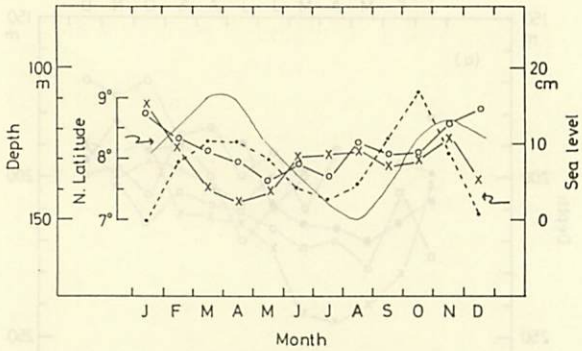

Fig. 5. Annual variation in the monthly mean latitudinal position (thin line, from Fig. 3) and the monthly mean depth of the countercurrent ridge (circles) and the monthly mean depth at 7.5°N (crosses). Broken line indicates the long-term monthly mean sea level at Truk Island (Meyers, 1982).

cycle was found in the annual variation of the countercurrent trough in dynamic height, mentioned before.

In this investigation, on the annual variation in the countercurrent ridge, a semiannual cycle was found in the latitudinal position, and an annual cycle was found in the depth. It might be appropriate to inspect the relation between the shift in latitudinal position and the depth of the countercurrent ridge. The monthly mean latitudinal position, the depth of the countercurrent ridge and the depth at 7.5°N are shown in Fig. 5. Both the monthly mean values of the depth of the countercurrent ridge and at 7.5°N were obtained by averaging values in Fig. 4. It is seen in Fig. 5 that the variation in the countercurrent ridge has an annual cycle a year, while the depth at 7.5°N tends to have a semiannual cycle, excepting the period from October to December. The northward and southward shifts of the countercurrent ridge corresponds with deep and shallow in the depth at 7.5°N, respectively, excepting the period from October to December. This shows that the annual variation of the thermocline depth near the countercurrent ridge depends partly on the semiannual variation in the latitudinal position of the countercurrent ridge.

In Fig. 5 is also shown the long-term monthly mean of sea level (cm) at Truk Island, averaging over non-El Niño years (Meyers, 1982, Fig. 4). This is to examine the relation between the sea level at Truk Island and the northward and southward shifts of the countercurrent ridge. It is recognized that the northward and southward shift of the countercurrent ridge corresponds with high and low in the sea level, respectively. This shows that the high and low in the monthly mean sea level at Truk Island depends partly on the northward and southward shift of the countercurrent ridge. The effect of the shift in the countercurrent ridge to the variation in sea levels at Truk Island seems to be small because the high correlation was existed between the depth in the countercurrent ridge and the monthly mean sea level at Truk Island (Chaen and Wyrtki, 1981).

Summary

The annual variation of the north equatorial trough and the countercurrent ridge on the thermocline topography was investigated by making the 20°C isotherm depth topography for six years, on the basis of MBT data by Fisheries Agency of Japan.

The latitudinal position in the north equatorial trough varies between 14°N and 19°N, while the countercurrent ridge varies between 6°N and 10°N. The annual variation in the monthly mean latitudinal position of the north equatorial trough has an annual cycle, while the countercurrent ridge has a distinct semiannual one (Fig. 2 and 3). The semiannual variation in the northward and southward shift of the countercurrent ridge seems to be associated with the semiannual oscillation produced by easterly wind stress as pointed out by Meyers (1979, 1982). According to Meyers (1982), the maximum easterly wind occurs in June and December. One or two months later of them, the countercurrent ridge attains its southernmost position in August and January.

The annual variation in the depth of the north equatorial trough and the countercurrent ridge tends to have an annual cycle, which is deeper from spring to early summer, and shallower from fall to winter (Fig. 4) as shown by Wyrtki (1974).

The northward and southward shift of the countercurrent ridge corresponds with deep and shallow in the depth at 7.5°N, and high and low in sea level at Truk Island, respectively, excepting the period from October to December. This shows that the annual variation in dynamic heights and sea levels near 7.5°N in the western tropical Pacific depends partly on the northward and southward shift of the countercurrent ridge in thermocline depths.

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