Lateral Oscillations of the Pacific Equatorial Countercurrent[1]

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7 November 1977 and 25 January 1978

ABSTRACT

Long equatorial waves recently discovered in the Pacific Ocean on satellite photographs are being linked to oscillations in sea level at Fanning Island and to the oscillatory trajectory of a drifting buoy. The drift pattern of the buoy suggests that lateral oscillations of the Equatorial Countercurrent with a period of about 34 days are responsible for the observed variations of sea level.

Long waves propagating west along a surface temperature front in the eastern equatorial Pacific have been reported by Legeckis (1977) based on the analysis of infrared satellite images. They had wavelengths between 800 and 1200 km and propagated west with a speed of about 40 km day^{-1}, from which periods between 20 and 30 days are inferred. They were observed between 110 and 130°W and between 1 and 3°N in October and November 1975.

Sea level oscillations of similar periods were observed at Fanning Island (4°N, 159°W), some 3000 km farther west between July 1975 and February 1976 (Fig. 1). This indicates that the long equatorial waves at the boundary between the westward flowing South Equatorial Current and the eastward flowing Countercurrent extend west at least to the Line Islands, where the surface temperature front is much weaker than near 120°W, and that they have signatures in sea level, too. Between August 1975 and February 1976 a total of six peaks and six troughs appear in the sea level record, and clearly define five oscillations with a mean period of 34 days. This period is longer than that estimated by Legeckis (1977) from wavelength and speed between 110 and 130°W. The amplitude of the sea level oscillations is about 7 cm. Legeckis reports that the waves could first be detected in May 1975, while they do not appear in the sea level record of Fanning Island until the end of July. This lends support to the idea that the waves were formed in the eastern Pacific and propagated west. At a speed of propagation of 40 km day^{-1} they would need 75 days to cover a distance of 3000 km which is approximately the time elapsed between their first observation and their appearance at Fanning Island.

[1] Hawaii Institute of Geophysics Contribution No. 874.

0022-3670/78/0530-0532$05.00

On 29 and 30 November 1975 four drifting buoys were launched east of the Line Islands in the North Equatorial Countercurrent (Harris, 1976), a fact which was only briefly mentioned by Legeckis (1977). Two of these drifters were launched at 9°N, 151°W near the northern boundary of the Countercurrent. The northern pair did not drift very far, one buoy transmitting for only one week, the other for 120 days, but it drifted only 500 km to the west, all in the last 25 days. The southern pair was launched at 6°N, 154°W near the center of the Countercurrent on 30 November 1975. The two buoys drifted with excellent correlation for about one month, when one stopped transmitting. The other buoy operated for more than 120 days and followed a very striking pattern of meridional oscillations (Fig. 2). The buoy moved east with the Countercurrent at an average speed of about 27 km day^{-1} (31 cm s^{-1}) covering a distance of more than 2500 km and reaching 130°W in mid March of 1976. Starting at 6°N the buoy is at first nearly stationary for a few days, then it moves south to 4°N and oscillates over 3° of latitude reaching 8°N in January 1976. Thereafter the oscillations appear to be dampened and the buoy drifts east between 7 and 8°N. The northward portion of each oscillation appears to be steeper and swifter, and the buoy reached an average northward speed of 40 km day^{-1} between 19 and 23 December. During December and January the apparent periods of the Lagrangian drifter are 29, 24, 25 and 27 days, when measured between extreme north and south positions. During the same time the periods of the sea level oscillations are 36, 37 and 32 days, which is longer.

The difference in period between the sea level oscillations and the Lagrangian drifter might be interpreted as a Doppler shift, governed by the relation

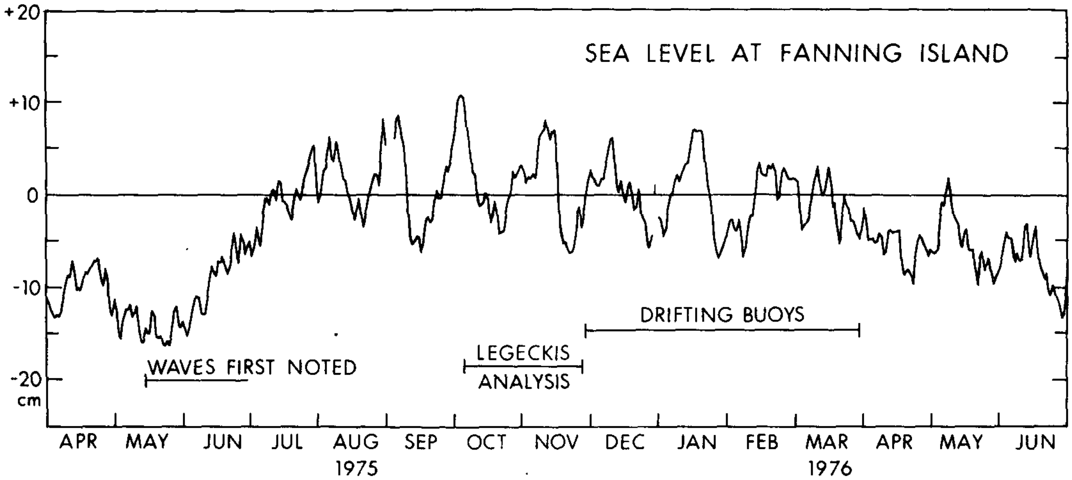

FIG. 1. Average daily sea level at Fanning Island (4°N, 159°W) from April 1975 to June 1976.

$$\frac{L}{T_{\mathrm{Eul}}} = \frac{L}{T_{\mathrm{Lag}}} - U,$$

where L is the wavelength, U the speed of the flow in which the Lagrangian drifter is embedded, T_{Lag} the period observed by the Lagrangian drifter and T_{Eul} the period of the wave observed at a fixed spot. Observed values are $T_{\mathrm{Eul}} = 34$ days, $T_{\mathrm{Lag}} = 26$ days, $L = 1100$ km, which results in $U = 10$ km day^{-1}. The observed speed of the drifter was 27 km day^{-1}. In comparing these two values one should realize that the different parameters were neither observed at the same time nor at the same location. Sea level was measured at 157°W, the buoy drifted between 154 and 130°W, and the satellite photos identified the wave between 130 and 110°W at a different time. Moreover, these equatorial waves seem to be highly nonlinear, and the speed of the drifter near the center of the Countercurrent may be larger than the speed near the temperature front and the latter may be responsible for the difference in the Eulerian and Lagrangian periods.

In order to explain the observed sea level oscillations of about 15 cm at Fanning Island, one needs to consider the topography of the sea surface associated with the equatorial current system. The

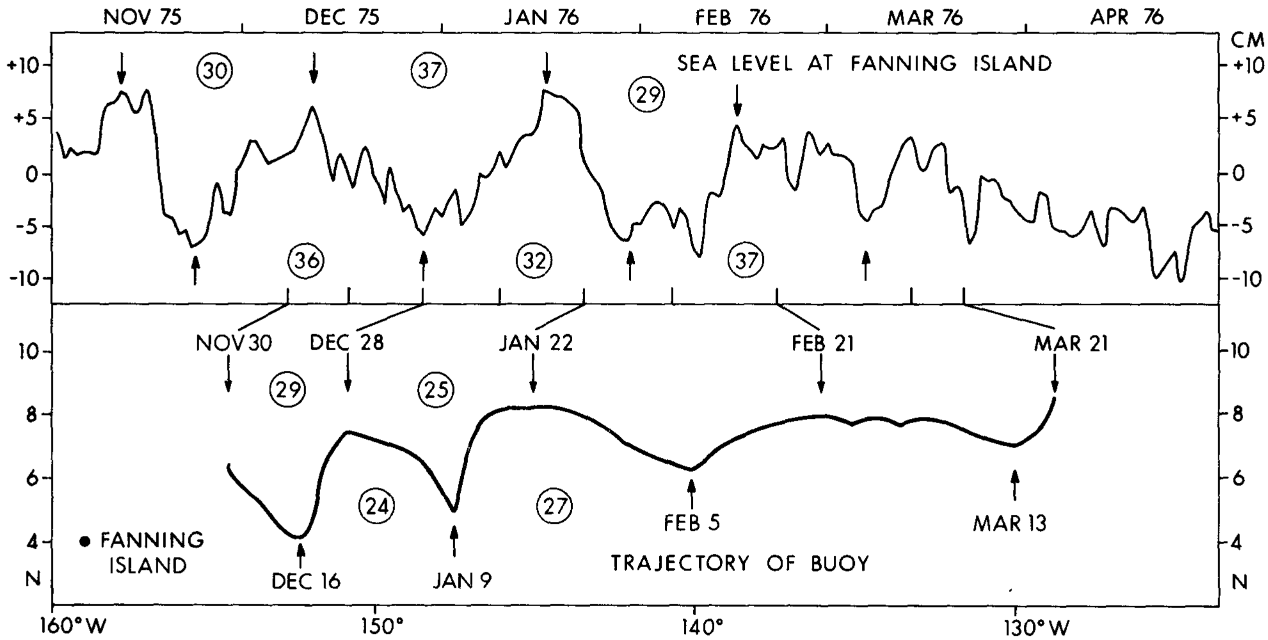

FIG. 2. Average daily sea level at Fanning Island (top) and trajectory of a drifting buoy in the Equatorial Countercurrent (bottom). Numbers in circles represent the apparent periods between maxima or minima of the two records.

Countercurrent flows east between a ridge in the sea surface topography near 4°N and a trough near 10°N. The mean difference between ridge and trough relative to 1000 db is about 35 cm in the vicinity of the Line Islands (Wyrtki, 1975). The decrease of sea level to the south is much less steep. Since Fanning Island is located at 4°N near the ridge a southward shift of the Countercurrent and of the ridge implies a drop of sea level at Fanning. From the drift pattern of the buoy and from the oscillations of sea level at Fanning one is led to the conclusion that the waves observed by Legeckis (1977) constitute large lateral oscillations of the Countercurrent. From the total drop of sea level at Fanning during each oscillation (10–15 cm) one must conclude that a substantial portion of the Countercurrent moves to the south of Fanning during the passage of each wave.

A search of the sea level record at Fanning from December 1972 to the present reveals that similar waves have been recorded in September–October 1973 having a period of about 27 days and in October–November 1974 with a period of about 30 days. The amplitudes were similar to those observed in 1975, but the duration was much shorter, involving only two full oscillations in each year. The waves appear to occur at Fanning in the fall, coinciding with the strongest flow in the Countercurrent, and following the annual peak of the southeast trade winds between July and September. Although the surface temperature front is much weaker near Fanning Island than in the eastern Pacific Ocean, corresponding temperature fluctuations were observed at Fanning from August to December 1975 (Vitousek, personal communication). The magnitude of these fluctuations is only about 1°C, barely detectable by the satellite.

Acknowledgments. This research was supported by the National Science Foundation as part of the North Pacific Experiment of the International Decade of Ocean Exploration. This support is gratefully acknowledged.

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