NOTES AND CORRESPONDENCE

On the Vertical Structure of Velocity in the Eastern Equatorial Pacific[1]

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ABSTRACT

We report observations of the vertical structure of horizontal currents on the equator at 110°W in the eastern Pacific Ocean. Profiles indicate high, vertical-mode, deep currents with zonal velocities of up to 20 cm s^{-1} at a depth of 1500 m. The general similarity between our measurements and those reported in other equatorial regions suggest that such vertical structure is a ubiquitous equatorial phenomenon.

1. Introduction

Recent observations in the Indian and central Pacific Oceans (Luyten and Swallow, 1976; Luyten and Eriksen, personal communication) have shown the existence of deep, persistent, equatorially trapped currents which have small vertical scales. These jetlike structures occur below the classical equatorial undercurrent and extend to at least 2000 m depth. Since both the Indian and central Pacific (179°E) are subjected to monsoonal winds, it has been proposed that the observed high modal structure may be related to this forcing (Wunsch, 1977). On the other hand, such vertical structure may be a general equatorial phenomenon related to the short time scales of geostrophic response in this region (Philander, 1978). Our measurements in the eastern Pacific (110°W) investigate the current structure in a new regime. The forcing associated with the southeast trade winds does not reverse seasonally. In addition, the thermocline (and the equatorial undercurrent) are ~100 m shallower in the eastern Pacific compared to the central Pacific. Our observation of high, vertical-mode, deep currents in this region suggests that these structures are a general feature of equatorial circulation.

2. Observations

The observations reported here were made from the NOAA ship *Oceanographer* on 9–11 July 1979 at 0°2.5′N, 109°58′W as part of the Equatorial Pacific Ocean Climate Study (EPOCS). Measurements of horizontal velocity were made by acoustically tracking a freely falling dropsonde called TOPS. The complete suite of instrumentation on TOPS included a Neil Brown Instrument Systems (NBIS) acoustic velocimeter for shear measurements, an NBIS CTD microprofiler, and accelerometers to monitor package motions. In this report only the acoustically tracked profiles are considered. The technique employed is similar to that used with the White Horse profiler (Luyten and Swallow, 1976). An array of three bottom-moored acoustic transponders was deployed; the relative positions were accurately determined by a shipboard survey. TOPS was then acoustically tracked as it fell (fall rate 30–60 cm s^{-1}) to determine horizontal position at 30 s intervals. Tracked data were recorded onboard ship using an E.G.&G. Sea Link ATNAV II Acoustic Navigation System. This shipboard recording is the principal difference between our measurements and the internally recording White Horse. A greater navigational uncertainty is inherent in our shipboard technique since both ship and profiler position must be determined. However, comparison of up-down profiles showed an rms difference of <2 cm s^{-1} in the smoothed profiles which indicates that the increased uncertainty is not large. Profiles presented here are preliminary results from unedited shipboard measurements. We do not expect that final processing will significantly alter the measured velocity structure.

Fig. 1 shows computed velocity profiles from four drops made over a 27 h period. These drops were to maximum depths of 3300 m (TOPS 9, 14), 1500 m (TOPS 12) and 800 m (TOPS 10). Tracked data for TOPS 14 began at 600 m because ship noise obscured the early part of the drop. Total water depth at this

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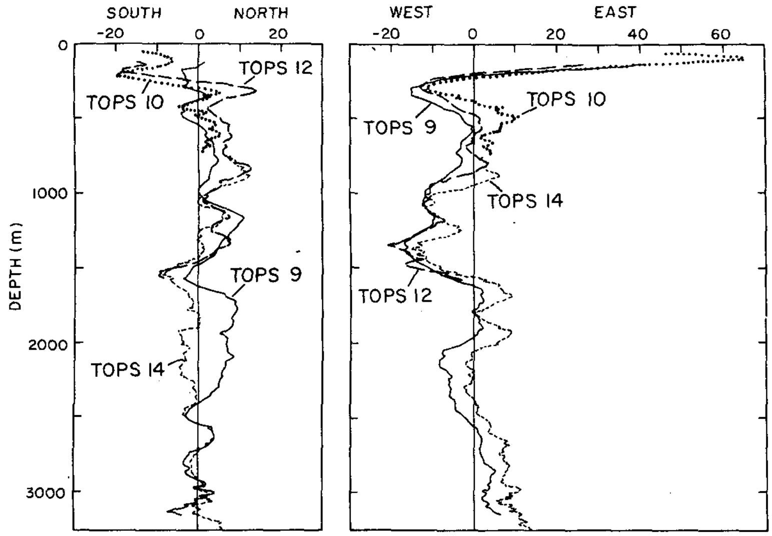

FIG. 1. Four vertical profiles of horizontal velocity at 0°2.5′N, 109°58′W collected over a 27 h period. Total water depth was 3800 m.

location is 3800 m. Times of the three drops relative to TOPS 9 were 17 h 7 min, 24 h and 27 h 13 min for TOPS 10, 12 and 14, respectively. Thus, sampling spanned various phases of the dominant semidiurnal tidal component.

Zonal velocity profiles in Fig. 1 looked remarkably similar throughout the sample period. These profiles show the classical equatorial undercurrent at a depth of 60 m. Maximum observed velocity was ~75 cm s^{-1}. Near-surface westward flow was apparent in the unsmoothed profiles, but was not resolved in the smoothed data shown in Fig. 1. Below the undercurrent two westward velocity layers (at 275 and 1400 m) had speeds in excess of 15 cm s^{-1}. Structures continued to appear down to the maximum measured depth but the amplitudes were less than 10 cm s^{-1}. Eastward flow beneath the undercurrent was weak except that both profiles showed a relatively large flow at 3300 m. A significant near-bottom eastward transport cannot be ruled out. The two deep casts had a systematic offset below ~1700 m. This velocity difference (~5 cm s^{-1}) which indicates the presence of a low vertical-mode zonal flow could be associated with the semidiurnal tide.

Meridional velocity profiles did not show the energetic near-surface structure seen in the zonal flow. Speeds were less than 20 cm s^{-1}. In the upper water column, these profiles appear less coherent than the east–west velocity profiles. All drops had southward velocity through the undercurrent in contradistinction to the northward flow from hydrographic analysis (Knauss, 1966). Below the undercurrent, all profiles showed a small-scale northward flow at 300 m and a broad northward flow from 500 to 1000 m. The two deep profiles had nearly identical meridional velocity between 2400 and 3000 m.

3. Summary and discussion

We have observed deep currents on the equator at 110°W in the eastern Pacific which are similar in structure to previously reported measurements in the Indian and central Pacific Oceans (Luyten and Eriksen, personal communication). Zonal currents up to 20 cm s^{-1} with vertical wavelengths of a few hundred meters occurred as deep as 1500 m. These structures continued down to the maximum depth measured (3300 m) with only a small reduction in amplitude. The zonal velocity structure was persistent over the one day of measurement, although a low-wavenumber current change with an amplitude of 5 cm s^{-1} occurred in the deep water. Meridional velocity also exhibited high modal structure. However, the temporal variability in the upper water was greater. At the deepest levels the meridional structure was virtually unchanged over 27 h.

The observations reported here can be compared with measurements elsewhere in the Pacific. At 179°W Eriksen (personal communication) observed eastward jets at 150 m (the "equatorial undercurrent") and at 550 m. A secondary eastward flow below the thermocline was also reported by Taft *et al.* (1974) at 150°W and by Taft and Jones (1973) at 115°30′W. This deep undercurrent does not occur in our profiles. It may be an intermittent structure since it was not present in Knauss' (1966) measurements at 118°W. Below the eastward jets Eriksen observed a series of westward current oscillations with a maximum amplitude of 15 to 25 cm s^{-1}. Qualitatively the structure observed at 110°W was similar; however, here the westward component was not as dominant. The deep eastward flow we observe is consistent with the abyssal current direction inferred by Knauss (1962) from an analysis of deep temperature data. At 150°W Taft *et al.* (1974) and at 115°W Taft and Jones (1973) also observed a deep eastward current. Taft and Jones (1973) report a relatively large near-bottom shear (2×10^{-4} s^{-1}) which is similar to the shear observed at 3000 m in our profiles.

The measurements reported here are a preliminary look at the vertical structure of horizontal velocities in the eastern Pacific. We do not know whether the observed structures persist for months as reported for the Indian Ocean (Luyten and Swallow, 1976), have long zonal coherence as seen in the central Pacific (Luyten and Eriksen, personal communication), or are truely equatorially trapped. Subsequent EPOCS experiments will examine these features. In addition, preliminary shipboard analysis of the TOPS velocity shear data indicated that the deep velocity field was rich in finestructure (1–50 m) variability. Thus, the smoothed profiles presented here may represent the long-wavelength portion of a continuous spectrum of equatorially trapped motions.

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