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19. Supported by ONR grant N 00014-66-C0036. We are deeply indebted to L. J. Battan and R. R. Braham for their comments, frequently critical, which led to changes in the original draft of the paper. However, all the responsibility for the paper is ours.

24 January 1969

Surfacing of Pacific Equatorial Undercurrent: Direct Observation

Abstract. *Measurements of current speed and direction from the sea surface to below 400 meters made on the equator in the eastern Pacific in April 1968 indicate that the Equatorial Undercurrent extends from 300 meters to the sea surface. These measurements, when compared with previous observations, indicate that eastward motion at the surface is a result of surfacing of the undercurrent caused by a release of the surface wind stress.*

During Eastropac (Eastern Tropical Pacific) Expedition 75 (R.V. *Thomas Washington,* 15 February through 15 April 1968), 5 days were spent on the equator about 400 miles west of the Galapagos Islands (0°07′S,97°40′W). On two of these days detailed measurements of current speed and direction were made from the sea surface to below 400 m. The measurements made on 1 April are here described (*1*).

Current measurements were made with two Richardson current meters (Geodyne Corporation) spaced 10 m apart on the lowering wire, capable of transmitting information through the supporting cable to analog and digital recorders on deck. Measurements were made at 10-m intervals from the sea surface down to 440 m. A measurement at each depth usually lasted about 4 minutes and consisted of about 70 samples of speed and direction from each current meter.

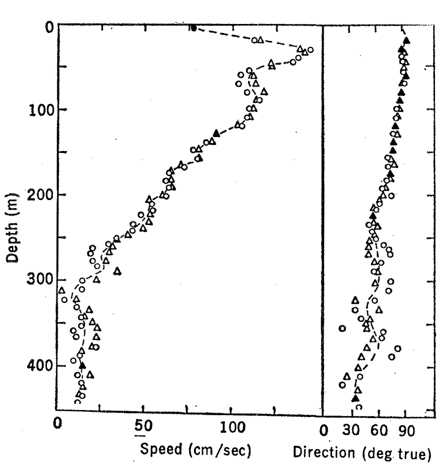

Fig. 1. Current speed and direction profiles taken on 1 April 1968 at 0°07′S,97°40′W. The ordinate in this figure represents the depth as interpreted from records of the pressure sensor. Open circles represent values from the lower current meter; open triangles represent values from the current meter 10 m above; closed triangles represent values from both current meters.

During the measurements, the position of the ship relative to a reference buoy was determined every 10 minutes. An estimate of current speed and direction was obtained from the analog traces by determining the average relative velocity at 10-m intervals and adding these values to the ship's velocity relative to the reference mooring. Figure 1 shows an averaged profile of the speed and direction between the sea surface and 440 m. The horizontal distance between the two adjacent symbols identifying the two different current meters in the figure represents the combined effects of time variation in the current velocity and inaccuracies in the determination of the absolute velocities. The greatest difference in speed between two successive measurements at the same depth is 12 cm/sec; this value will be taken as a measure of the maximum error in the observations.

Between the surface and 200 m, the eastward component of the velocity is at least 94 percent of the value shown in Fig. 1, since the direction is within 20° of due east. The speed profile shows a maximum of 143 cm/sec between 30 and 35 m with a slight secondary maximum of 113 cm/sec at 90 m. Below the secondary maximum, the current speed gradually decreases in a nearly stepwise manner to a minimum of 13 cm/sec at 315 m.

The current direction from the surface to 100 m is within 5° of due east. Below this depth the direction tends toward the north, reaching a relative minimum of 55° true north at 240 m. At greater depths, observations of current direction are somewhat erratic because of the lower absolute speeds, but flow is generally toward the northeast. Because near-surface estimates of current direction with this type of current meter are affected by the magnetic field of the ship, the values given at the surface (Fig. 1) are averages of four successive observations of the ship's velocity relative to the reference buoy taken while the ship was drifting just before the current measurements were made.

The speed profile can be compared with profiles of temperature and salinity measured with an *in situ* profiling device (Bissett-Berman salinity-temperature-depth system) immediately after completion of the current measurements (Fig. 2). The upper speed maximum is in the thermocline (16° to 18°C) and coincides with a layer of increased salinity (35.05 to 35.10 parts per thousand). Salinity inversions in this layer are probably the result of dynamic mixing between less saline surface water and the water of high salinity associated with the core of the undercurrent. The secondary speed maximum is also associated with a slight increase in salinity (35.01 to 35.05 parts per thousand) and with nearly isothermal water.

Below 20 m the profile of east-west velocity resembles observations of the Equatorial Undercurrent made in 1958 and 1961 by Knauss (*2, 3*). Table 1 summarizes the pertinent features of the two sets of observations near 97°W with the zonal component of the observations described here. The depths

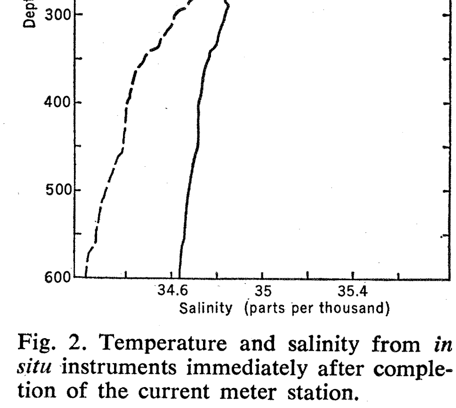

Fig. 2. Temperature and salinity from *in situ* instruments immediately after completion of the current meter station.

Table 1. Comparison of pertinent features of this set of observations with previous observations at 97°W. The surface velocity, maximum eastward velocity, and depth of the core vary according to the speed of the average surface winds. The velocity is positive eastward.

Date of measurement	Surface velocity (cm/sec)	Maximum eastward velocity (cm/sec)	Depth of core (m)	Maximum shear from core to surface $\times 10^{-2}$ (sec^{-1})	Transport per unit cross section $\times 10^{5}$ (cm^2/sec)	Average surface winds (m/sec)
May 1958	~0	130	40	3.25	7.3	0.3–3.3
October 1961	−68	87	65	2.40	7.7	3.4–7.9
April 1968	+78	143	30	2.27	22.8	0–1.5

and maximum velocities of the core are similar in the 1958 and 1968 profiles; on the 1961 profile the maximum speed is about 30 percent less and is located about 25 to 30 m deeper. The speed at the surface in the 1958 observations is not given, but, since no mention is made (*2*) of any eastward surface component, it must be assumed that it was either slightly westward or negligible [Fig. 6 (*2*) is unclear on this point]. In 1961 a westward surface current extended down to 30 m with a maximum westward component of 68 cm/sec at the surface. In contrast to this, the 1968 profile shows a strong eastward surface component of 75 cm/sec. Furthermore, in 1961 significant eastward flow extended only to 200 m, whereas in 1968 such flow reached 315 m.

The maximum shear calculated from the surface to the velocity core is surprisingly similar for all three profiles, averaging about 2.8×10^{-2} sec $^{-1}$. The transport per unit cross section at this location is about the same for the 1958 and 1961 observations; in 1968 it is more than three times those values. A comparison with calculations at more westerly locations on the equator (*3*) shows that the transport per unit cross section at 97°40′W in 1968 was greater than any previously measured, indicating significant variations in the strength of the current.

Cromwell *et al.* (*4*) first suggested that observations of eastward surface currents at the equator resulted from a subsurface eastward current (the Equatorial Undercurrent) reaching to the surface. They suggested that eastward ship drift close to the equator in the eastern Pacific and Atlantic, which was noted by Puls (*5*), might be caused by surfacing of the undercurrent that occurs when the wind stress is small.

Montgomery (*6*) summarized the observations of equatorial ship drift of Schott (*7*) in the Pacific and Krummel (*8*) in the Atlantic and concluded that those occurrences of eastward motion represent a surfacing of the Equatorial Undercurrent when the local trade wind fails. A direct observation of surfacing in the Atlantic was reported by Voigt (*9*) from current-meter measurements made on 21 and 22 May 1959 at 0°09′N,30°W. In his summary of observations of ship drift in the eastern tropical Pacific, Wyrtki (*10*) indicated eastward components between 110° and 98°W near the equator during the months of March and April. In the text accompanying the charts he stated that this eastward flow is probably a surfacing of the Equatorial Undercurrent in the absence of easterly winds.

The winds in the eastern equatorial Pacific vary seasonally, with maximum trade winds experienced in the late southern winter around August and a minimum in March (*11*). The three sets of observations discussed here reflect this pattern. Reported wind speeds during the 4 days spent between 106°57.5′ and 97°56′W in late May 1958 on the Dolphin Expedition (*12*) varied between Beaufort 1 and 2 (0.3 to 3.3 m/sec). On Expedition Swansong in October 1961, the winds were near a maximum for this area, varying between Beaufort 3 and 4 (3.4 to 7.0 m/sec) (*13*), whereas the recorded winds during the 5 days spent at the equator during the Eastropac Expedition were a minimum, varying between Beaufort 0 and 1 (0 to 1.5 m/sec).

It seems likely that the structure of the Equatorial Undercurrent in the eastern Pacific depends on the surface winds. The tendency of an easterly component of the wind to set up a shallow westward surface current appears to affect strongly the depth of the high velocity core of the undercurrent as well as the maximum eastward velocity and the transport per unit cross section. In extreme conditions when winds are slight, the westward surface current disappears and the Equatorial Undercurrent surfaces as observed in April 1968.

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1. The second set of measurements made on 2 April 1968 was similar to those described here, but the calculation of absolute velocities is somewhat in doubt because of constantly varying wire angles (between 0° and 22°) throughout the cast.
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25-Hydroxycholecalciferol: Stimulation of Bone Resorption in Tissue Culture

Abstract. *25-Hydroxycholecalciferol stimulates release of previously incorporated calcium-45 from fetal rat bones in doses of 0.9 to 27 units per milliliter. This effect cannot be produced by much larger doses of vitamin D_3. Comparison of stimulation of bone resorption by 25-hydroxycholecalciferol and parathyroid hormone reveals similarities with respect to time course, dose-response slope, and inhibition by calcitonin.*

Although there is substantial evidence that vitamin D stimulates bone resorption in vivo (*1*), attempts to demonstrate an effect in tissue culture have required large doses and have given inconsistent results (*2, 3*). To