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DRIFTING BUOY TRAJECTORIES IN THE ATLANTIC NORTH EQUATORIAL COUNTERCURRENT DURING 1983

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Abstract. During 1983, 21 freely drifting buoys measured trajectories in the vicinity of the Atlantic North Equatorial Countercurrent. These provide a visualization of the flow field and the first direct measure of the seasonal variation of the velocity during a single year. From February to May the buoys moved gradually westward. From June to December the buoys moved swiftly eastward with maximum speeds of 90 cm sec^{-1} located in the western Atlantic. The seasonal variation in current was similar to that measured by historical ship drifts except that the onset of the Countercurrent in 1983 was about a month earlier than usual. Of the buoys that drifted eastward in the Countercurrent, three went into the North Equatorial Current, two into the South Equatorial Current and seven into the Guinea Current.

Introduction

Historical ship drifts and subsurface temperatures show that the Atlantic North Equatorial Countercurrent undergoes an enormous seasonal change [Schumacher, 1940; Richardson and McKee, 1984; Garzoli and Katz, 1983]. In summer and fall the Countercurrent flows swiftly eastward across the Atlantic (between 5-10N approximately) and into the Guinea Current. In winter and spring the Countercurrent disappears west of 20W and the velocity becomes westward. Aside from ship drifts, the only direct current measurements in the Countercurrent are some short time current meter series during GATE [Bubnov and Egorikhin, 1979; Halpern, 1980] and a few drifting buoys [Cochrane, personal communication; Molinari, 1983]. No direct measurements exist that give current variations over a single year.

The purpose of the present experiment is to directly measure the seasonal variation in the Countercurrent and to relate this to the variation of wind forcing. During 1983 drifters were launched at several sites and times and current meters were moored in the Countercurrent. The preliminary drifter trajectories described here give a visualization of the velocity field during 1983 and its seasonal variation.

Measurements

Twenty-one satellite tracked freely drifting buoys were deployed -- seven in February and early March, two in April, three in July and nine in September. The buoys were made by Polar Research Laboratory, had partially floating tethers, window shade drogues at 20 m, and sea surface thermometers; thirteen had anemometers. Approximately five positions per day per buoy are being obtained. Weekly positions are used here in order to present recent results concerning the large scale and long time character of the currents.

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Results

Trajectories are displayed three different ways. Figure 1 shows clusters of trajectories of buoys launched together with a few additional ones that passed near the launch locations and times. Figure 2 shows monthly summaries of all trajectories. Figure 3 shows time-longitude trajectories of buoys located in the Countercurrent region 4-9N.

Seven buoys were launched in February and

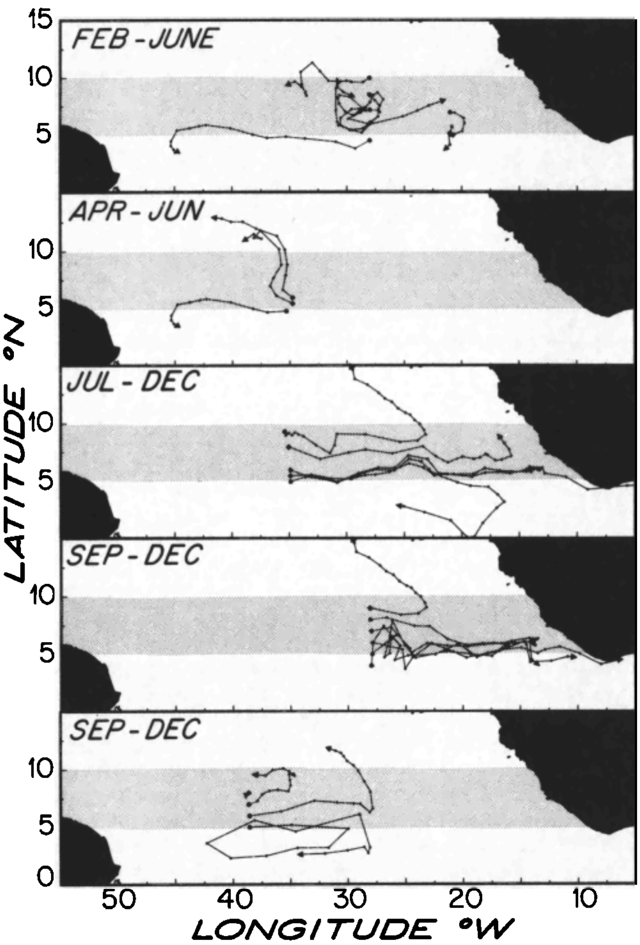

Fig. 1. Trajectories of 21 freely drifting satellite-tracked buoys launched in the vicinity of the North Equatorial Countercurrent during February, April, July and September 1983. Dots are spaced at approximately weekly intervals. Shading indicates the general location of the Countercurrent during summer and fall.

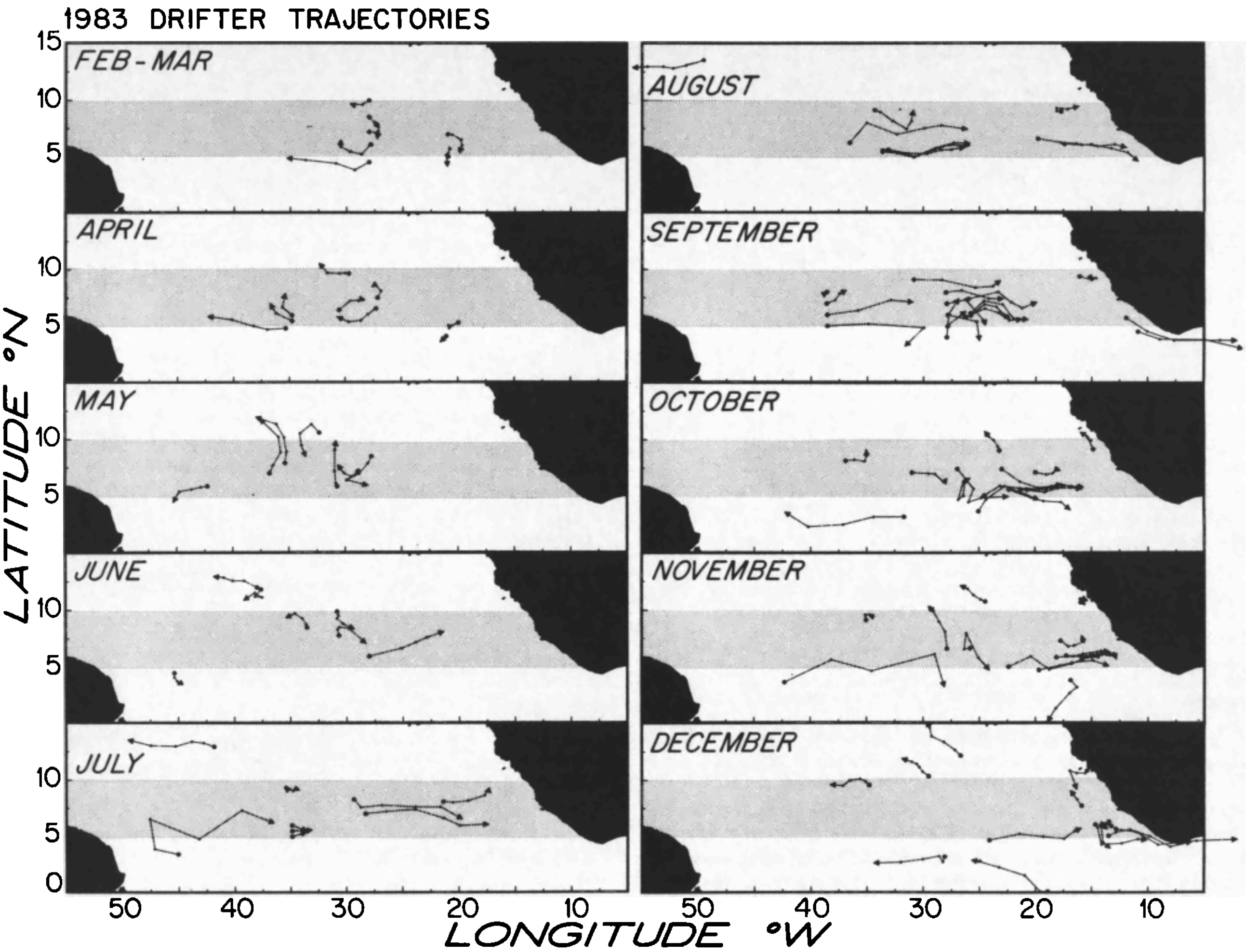

Fig. 2. Monthly trajectories during 1983 of 21 drifting buoys. In May and June buoys began to move eastward in the Countercurrent. Some buoys continued eastward through December.

March (Figure 1, panel 1). The northern buoy drifted westward at 10 cm sec^{-1} in the North Equatorial Current (NEC), and the southern buoy drifted westward at 30 cm sec^{-1} in the South Equatorial Current (SEC). Both buoys subsequently entered the Countercurrent in July. Two buoys near 20W went southward toward the SEC but both died prematurely. From February to May the three middle buoys launched in the vicinity of the Countercurrent at 28W drifted gradually westward at 1-3 cm sec^{-1}, more slowly than the buoys in the NEC and SEC. The three trajectories are dominated by mesoscale eddy motions. An inspection of trajectories (and velocities) shows fluctuations that have a characteristic speed of 10-20 cm sec^{-1}, diameter of a few hundred km, and period of a few months. In May and June these three buoys began to drift eastward as the Countercurrent accelerated. All three continued into the Gulf of Guinea, two in September, and one in 1984.

In April two buoys were launched along 35W (Figure 1, panel 2); they drifted northward through the Countercurrent region and turned westward in the NEC north of 10N. One drifted westward and went aground on Martinique in September; the other died prematurely. The southern buoy (Figure 1, panel 2) entered the Countercurrent in July and reappears as the second to northernmost buoy in Figure 1, panel 3.

In May the trajectories in the vicinity of the Countercurrent had a strong meridional component -- southward at 28W, northward at 31W, southward at 34W, northward at 36W. This suggests spatially periodic motion with a wavelength of about six degrees of longitude (Figure 2, panel 3).

In July eight buoys drifted eastward in the Countercurrent. The western one was fastest and meandered eastward with a speed up to 90 cm sec^{-1} and wavelength of about 6-7 degrees of longitude. This meandering may be caused by an instability associated with the strong shear between the Countercurrent and SEC. Three buoys were launched in July along 35W at 5.0N, 5.5N, and 6.0N. These three drifted eastward together at 30 cm sec^{-1} for two months without diverging from each other. One peeled off southward in October and entered the SEC; the other two continued eastward together into December. Of the five that drifted eastward across 35W in July (Figure 1, panel 3), two went into the NEC, one went into the Guinea Current, one went into the SEC, and one slowed near the Coast of Africa.

In September five buoys were launched along 28W and a sixth, the northern one in Figure 1, panel 4, was there by chance. All six moved

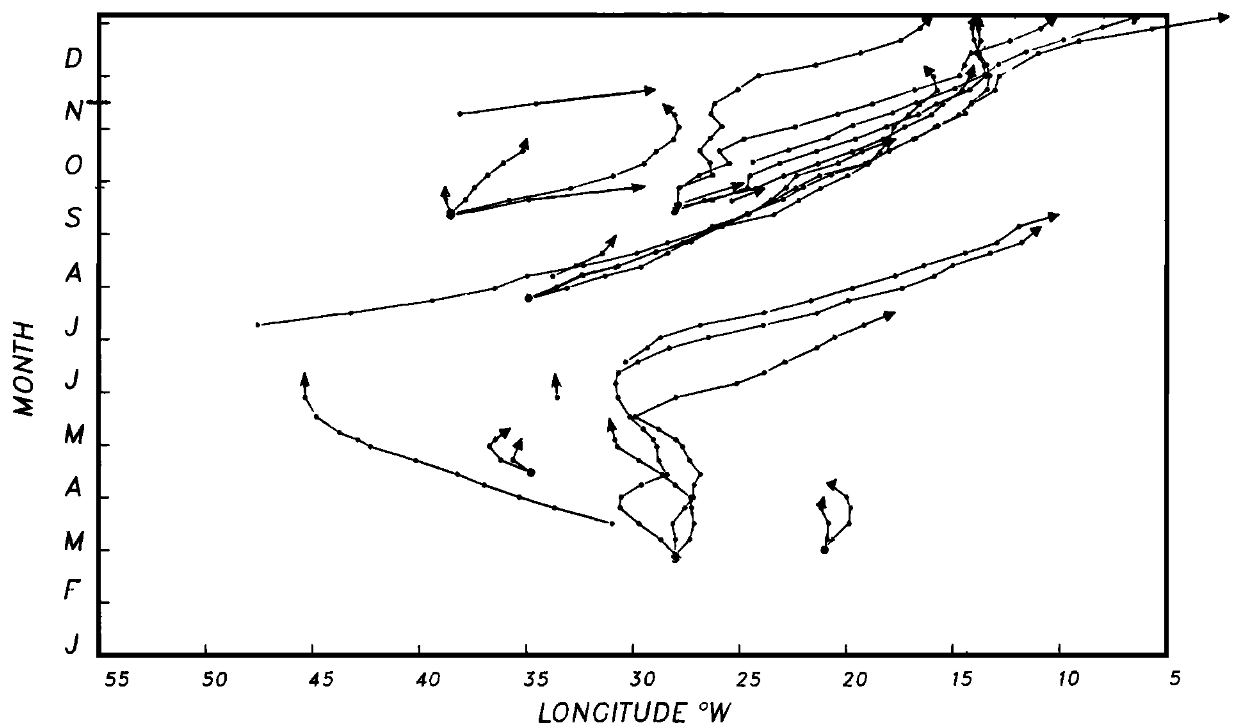

Fig. 3. Time-longitude plot of buoys in the latitude band of the Countercurrent, 4-9N. The zonal velocity is indicated by the direction and slope of the trajectories. The trajectories most nearly horizontal are the swiftest ones.

eastward in the Countercurrent. One entered the NEC, one died, one stalled near the coast and the other three entered the Guinea Current (two of them in 1984). During September and October one buoy was trapped for two months in an anti-cyclonic eddy centered near 6N, 27W. Three other buoys were deflected around it. The buoy in the eddy looped with a swirl of speed of 20 cm sec^{-1}, period of a month and diameter of 150 km.

Four buoys were launched in September along 38W (Figure 1, panel 5). The northern one was very slow and died prematurely. The next one south drifted slowly northeastward and entered the NEC. The two southern buoys drifted rapidly eastward with (weekly) average speeds up to 90 cm sec^{-1}. These two buoys left the Countercurrent near 25-30W. The northern one entered the NEC, and the southern one entered the SEC, drifted westward, entered the Countercurrent and repeated its earlier trajectory. The circulation time for the Countercurrent-SEC loops was about two months.

My interpretation of these trajectories and Figure 3 is that from September to November the eastward flow in the Countercurrent slowed or was blocked near 25-30W and that the Countercurrent was divided into a western and eastern region. The eastern Countercurrent continued to flow eastward at least through December, and the western Countercurrent continued at least through November, the last months that buoys were in the vicinity of the Countercurrent. Historical ship drifts agree with this result in that they show that the average monthly eastward velocity in the Countercurrent decreases to zero first near 25-30W (in December). The eastern Countercurrent (east of 20W) continues throughout the year, but the western Countercurrent has eastward flow only from July to January [Richardson and McKee, 1984].

The seasonal variation of zonal velocity in the Countercurrent centered near 6N, 28W measured with drifters is similar to that measured with a current meter at 20 m during 1983 and to that calculated from historical ship drifts (Figure 4). All three data sets show westward velocity during spring and eastward velocity during summer and fall. In comparison to the historical ship drifts, both drifters and the current meter have slower westward velocity in spring, faster velocity in summer, and an earlier onset of the Countercurrent (by about a month). The early onset of the Countercurrent is in accord with the onset of the winds near the equator and upwelling in the Gulf of Guinea both of which were 1-2 months earlier than usual in 1983 [Garzoli and Katz, 1984; Houghton, 1984]. The differences in velocity between drifters and current meter are mainly due to differences of the space-time averages of drifters in a 3 by 10 degree box versus the time average of current meter values at a point. When a drifter passes close to the current meter their velocities agree closely.

Summary and Conclusions

The trajectories show that the Countercurrent had disappeared from February to May and that generally westward velocity occurred. At this time the central region of the Countercurrent had a slower westward velocity than the nearby NEC and SEC. In May and June the buoys drifted eastward as the Countercurrent accelerated. From September to at least November the eastward drift of buoys in the Countercurrent was disrupted near

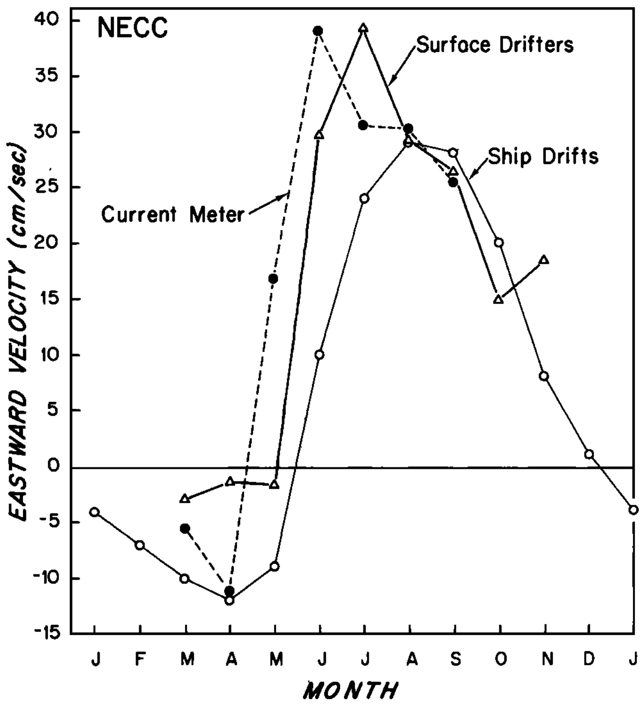

Fig. 4. Seasonal variation of near-surface zonal velocity in the Countercurrent during 1983. Monthly averages are from a current meter at 20 m near 6N, 28W, drifting buoys located in a box whose limits are 5-8N, 23-33W. Also shown is the long-term average zonal velocity from historical ship drifts in a box bounded by 5-8N, 25-30W.

25-30W. Both east and west of this location the Countercurrent continued to flow eastward. The western Countercurrent was fastest with drift velocities up to 90 cm sec^{-1}.

During the period February-May when the Countercurrent had disappeared and the mean zonal velocity was weak, the trajectories were dominated by mesoscale eddy motion. Eddy motion was also observed near 25-30W as the Countercurrent decayed during the fall (September-November). During the period June-August the mean eastward velocity in the Countercurrent was 30-40 cm sec^{-1}, larger than the mesoscale velocity, and trajectories were more nearly linear.

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