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Measurements of the California Countercurrent at a Depth of 250 meters

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ABSTRACT

Measurements of the flow at 250 m below the surface were made with parachute drogues laid out at 5-mile intervals on a line 125 nautical miles in length (true bearing 067°) extending landward from 35°52.0’ N, 124°28.9’ W to the 1000-fathom curve at 36°36’ N off Monterey, California. The drogues were followed for 48 hours. A northward flow, about 40 miles in width, with a maximum flow of 0.44 kt at the center, was seen near the coast. Along the next 60 miles of the drogue line, flow was to the southeast at speeds up to 0.51 kt. In the section farthest offshore, flow was to the northeast and appeared to be turning to the east and southeast at speeds of 0.39-0.49 kt.

Introduction. Several investigators (Sverdrup and Fleming, 1941; Sverdrup, et al., 1942; Reid, et al., 1958) have presented evidence of a countercurrent flowing along the coast beneath the southeastward-flowing California Current. The collective evidence is of two sorts: (1) the warm, highly saline subsurface water of low oxygen content suggest southern origin; and (2) geostrophic flow at the 200-decibar surface, with respect to both the 500- and 1000-decibar surfaces, indicates a northward-flowing current, 30–60 miles in width near the coast north of 30°N and somewhat wider to the south. It seemed useful to augment this evidence with direct measurements.

Methods. Parachute drogues have been used by Volkmann, et al. (1956) and Wooster and Gilmartin (1961) to measure subsurface flow. A similar technique was used in the present study. A parachute 8.5 m in diameter with a 9-kg weight was hung 250 m below a float, using wire 0.22 cm in diameter. The float was an automobile tire inner-tube with a 6-m bamboo pole attached. The pole, which extended about 3 m above the water, had a 9-kg weight at its lower end, and on its upper part a radar-reflector, flag, and number.

Since relatively low speeds were expected, it was necessary to work where
LORAN was available as a navigational aid. An area was chosen between 35° and 38°N, where the position lines of LORAN station 2H2 are nearly perpendicular to the coast.

The Measurements. I. On 24 November 1961, when the vessel reached the working area, the wind was 22–30 knots from the southeast and it was not possible to track more than one drogue at a time. The first 48 hours were spent following three drogues: a 250-m drogue launched at 35°32.9'N, 124°30.0'W (about 130 miles offshore) and two 10-m drogues placed near it successively. The deep drogue moved northward 20 miles at an average speed of 0.42 kt. Each of the 10-m drogues was followed for about eight hours during daylight. The one observed on the 24th moved northward 3.3 miles at 0.39 kt, the one on the 25th, 3.4 miles at 0.48 kt. During the times when they were observed they did not move northward as fast as the deeper drogue, even though the wind was strong and from the southeast.

II. On the morning of 26 November the wind had decreased to about 12 kt, and a line of drogues could be tracked. The drogues were placed at a depth of 250 m at five-mile intervals along a line extending landward 125 nautical miles (067°T) from 35°52.0'N, 124°28.9'W to the 1000-fathom curve (about seven miles from shore). After the 12-hr launching run, the vessel traversed the line out and in twice, determining the longshore positions of the drogues by LORAN and the offshore positions by celestial navigation or by estimated distance run. During the afternoon and evening of 28 November the wind rose to 25 kt from the southeast. By the end of the second traverse, both radar and visual search were ineffective and the last seven inshore drogues were not seen.

A chart of the movement of the various drogues (Fig. 1) shows a northward flow for about 40 miles seaward (including the first seven drogues) from the coastal end of the line; in the center of this flow the speed reached as high as 0.44 kt. Beyond that, the next 12 drogues (covering 60 miles) moved southeastward at speeds up to 0.51 kt. The six drogues at the western end moved northeastward and eastward at speeds of 0.39–0.49 kt, and appeared to be turning to the right, with some crossing the paths of others.

The observed speed of the 10-m drogues relative to the deep drogues, both before and after the line of drogues was launched, was to the south at not more than 0.4 kt. The effect of this amount of shear on the motion of the 250-m drogues would be less than 0.06 kt (Volkmann, et al., 1956); therefore no correction has been applied to the observed trajectories or computed speeds shown in Fig. 1.

III. On 1 December 1961 the wind had dropped to about 20 kt from about 345°T and a search was made for the 26 deep drogues observed previously, but none was found. To check the steadiness of the boundary of the northward flow near shore, another 250-m drogue was launched at 36°35.8 N,
123°01.0 W, which is approximately where the flow changed from a northerly to a southeasterly direction (Fig. 1). After 50 hours the drogue had moved only two miles to the southwest. This is not a significant flow (0.04 kt) in view of the limit of navigational error and the current shear. At that time the drogue was damaged and was replaced by another that moved 3 miles in 30 hours, or 0.1 kt, toward the southeast. This motion also is probably not significant, since 10-m drogues observed concurrently moved to the southeast, about 0.4 kt faster; and the drag of the wire and float may have accounted for half of the deeper movement.

Conclusions. Measurements made at a depth of 250 m below the sea surface showed a northward flow seaward of the 1000-fm contour. This may be called the California Countercurrent. Its width was observed to be 40 miles, with a maximum speed of about 0.44 kt near the center. Further offshore (40–100 miles from the 1000-fm contour) flow was southeastward, and the measurements farthest offshore (100–125 miles) indicated flow toward the northeast, possibly turning toward the southeast. The offshore northeastward flow occurred above 2000 fms of water and cannot be ascribed to any immediate
topographical effect. Since some of the outer drogues crossed each other’s paths, the motion was not steady, and it may represent part of one of the large eddies frequently observed at the surface and at 200 m depth in the geostrophic flow (Reid, et al., 1958).

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REFERENCES

Reid, J. L. Jr., G. I. Roden and J. G. Wyllie

Sverdrup, H. U. and R. H. Fleming

Sverdrup, H. U., M. W. Johnson and R. H. Fleming

Volkmann, G., J. Knauss and A. Vine

Wooster, W. S. and Malvern Gilmartin