Reports

Ocean Eddies Generated by Seamounts in the North Pacific

Abstract. *Small-scale (diameters of about 37 kilometers) fluctuations in dynamic topography north of Hawaii along 158°W are well correlated with upstream seamounts. The fluctuations are subsurface but are manifested as baroclinic eddies at the sea surface. These eddies are confirmed by direct observations and supported by theoretical considerations. The eddies cause small-scale variability in the currents and hydrographic structures in this area, and they should be considered in any sampling programs of the region.*

Eddies with diameters of approximately 37 km have been observed in closely spaced hydrographic data north of Hawaii. These features are present in at least the upper 1000 m of the water column. It is probable that they are the result of the interaction between the North Pacific Current and nearby upstream seamounts. The existence of these eddies is confirmed by the Lagrangian drifter study of Kirwan *et al.* (*1*). These eddies can have a significant effect on direct current measurements or small-scale hydrographic surveys in the region. The eddies provide a mechanism by which the mean flow of the North Pacific Current is converted into vortices and subsequently dissipated into still smaller scale turbulence.

Closely spaced (37 km) conductivity-temperature-depth profiles were acquired along 158°W from 56°N to 22°N in a 2-week period beginning on 22 October 1976. This opportunity arose because during that time the R.V. *Moana Wave* was in transit from Alaska to Hawaii. I selected this particular longitude because intercomparison with U.S. Coast Guard hydrographic data along this line is possible and also because the transect bisects the region that is being sampled in the Anomaly Dynamics Study (ADS); ADS is a part of the North Pacific Experiment (NORPAX), a program of the International Decade for Ocean Exploration (IDOE).

The large-scale hydrographic features of the region have been described in some detail (*2, 3*). The dominant features in the dynamic topography (Fig. 1) are the Alaska Stream, shown as a negative southward gradient from 55.5°N to 54°N, and the broad eastward-flowing North Pacific Current south of 54°N, as shown by the positive gradient in dynamic topography. The different dynamic topographies (0/100, 100/500, 500/1000, and 1000/1500 dbar) represent the dynamic height of the first pressure surface relative to the second. The differences in the slopes of the curves give a measure of the vertical baroclinic velocity shears. The 1000/1500-dbar dynamic topography indicates eastward baroclinic flow from 55°N to 33°N where the sampling deeper than 1000 m was curtailed. Sampling to depths greater than 1000 m was done at 111-km intervals. The sign change in the 500/1000-dbar topography gradient at about 35°N suggests a westward baroclinic flow at latitudes south of 35°N.

Superimposed on these large-scale features are some mesoscale (400 to 600 km) gradients between 35°N and 22°N. They are most clearly seen in the 0/1000-dbar and 100/500-dbar topographies. These mesoscale eddies have been discussed by Bernstein (*4*). They are barely discernible in the 0/100-dbar topography, and they are not locally generated. Possible generating mechanisms for these eddies have been suggested by Roden (*3*).

Embedded on the 0/1000-dbar and 100/500-dbar topographies are small-scale features with scale lengths of approximately 75 km. These features are predominantly in the 500/1000-dbar topography, which suggests that their generating mechanisms are subsurface. If an accuracy in the dynamic height determination of ± 1 dynamic centimeter is assumed, four sections of the dynamic topography can be identified as containing these small-scale fluctuations. These sections are labeled A, B, C, and D in Fig. 1. Each of these sections is downstream from a seamount or seamounts. Specifically, section A is to the east of Pritchett Seamount (3370 m), section B is to the east of several unnamed seamounts at depths between 3900 and 4590 m, section C is to the east of an unnamed seamount at a depth of 3380 m, and section D is in the Mendocino Fracture Zone where there are numerous seamounts. These features rise above a bottom at approximately 5500 m. All of the seamounts are to the west of 158°W. South of 33°N, seamounts to the east of 158°W can influence the dynamic topography since the subsurface current is westward there. The fluctuations are well correlated with seamounts but not vice versa. The good correlation between fluctuations in dynamic topography and nearby upstream seamounts suggests that the small-scale fluctuations are caused by eddies created through flow around and over seamounts. The lack of correlation between seamounts and fluctuations is due to the fact that the transect does not intersect all eddies generated by the seamounts.

These observations are supported by a theoretical study of the interactions between seamounts and fluctuating currents, which indicates that a seamount of height 800 m in 4000 m of water can cause the formation of warm and cold eddies in the water column (*5*). Such eddies are generated beneath the main thermocline, and they can be trapped by the feature or move downstream. The data presented here suggest the occurrence of this phenomenon north of Hawaii. Similarly, in the North Atlantic, Atlantis II Seamount has been shown to influence the hydrographic properties of downstream water in the Gulf Stream (*6*).

The horizontal scale lengths associated with these eddies in the North Pacific are of the order of the Rossby half wavelength. For a current of 2.5 cm/sec, the Rossby half wavelength is 35 km. The vertical scale length is of the order of fL/N, where f is the Coriolis frequency, N is the Brunt-Väisälä frequency, and L is the horizontal scale length of the seamount (*6*). In this case L = 35 km, f = 0.84×10^{-4} per second, and N = 1.05×10^{-3} per second which gives a vertical scale length of 2800 m. Both of these scale lengths support the possibility that eddies due to seamounts with diameters of about 35 km are found in the upper 1000 m. This likelihood is consistent with the observations.

Details of the surface (relative to 1000 dbar) baroclinic currents between 34°N and 41°N along 158°W (Fig. 2) give evidence of several current reversals (westward). These reversals begin in the region downstream from the seamount at 3493 m and are no longer present south of the seamount at 2096 m. Since the scale length of these reversals is identical with the station spacing, a smaller sampling grid is necessary for a more precise estimate of the eddy dimensions. A mean rotation speed of 7 to 10 cm/sec gives a revolution period of 17.6 to 12.3 days. Lagrangian drifter measurements carried out in the area by Kirwan *et al.* (*1*) followed circular trajectories with radii of 25 to 50 km and a period of 21 days. These data give mean rotational speeds of 8.7 to 17.3 cm/sec, which are similar to the speeds of 7 to 10 cm/sec shown in Fig. 2.

Although the seamounts do not significantly alter the large-scale circulation of the North Pacific, the evidence presented here suggests that they provide a mechanism for the creation of eddies which may dissipate the energy of the North Pacific Current into smaller scale turbulence. Recognition of these features is essential to the planning of oceanic sampling schemes in this region.

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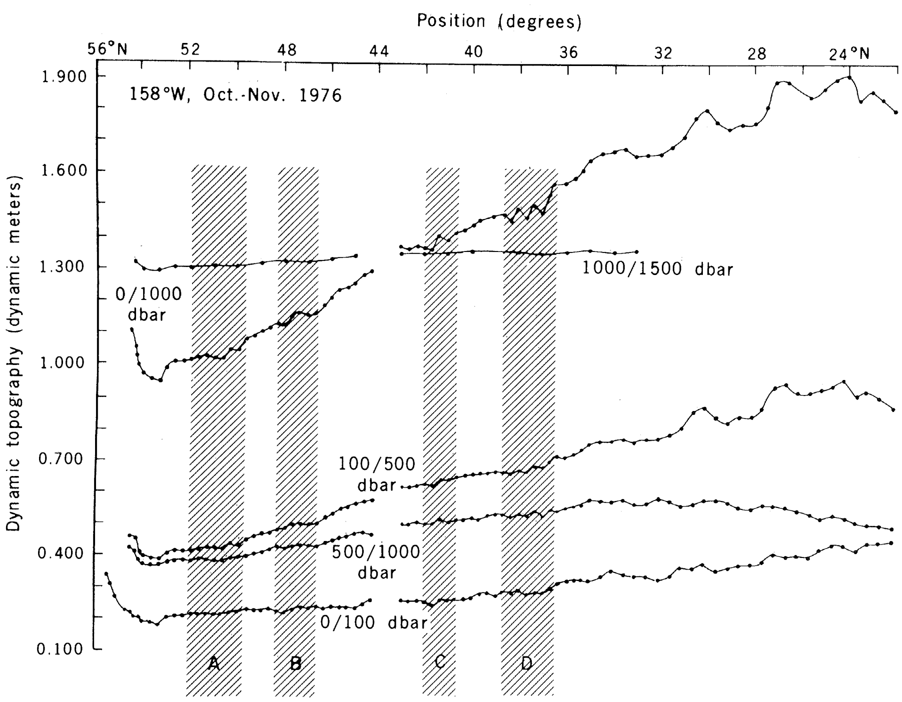

Fig. 1. Dynamic topography from Alaska to Hawaii along 158°W, October to November 1976.

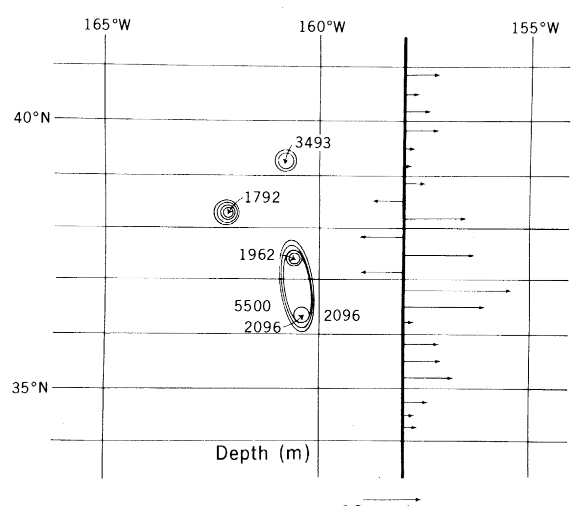

Fig. 2. Baroclinic geostrophic currents relative to 1000 dbar.

References and Notes

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