Recent Observations of a Large Eddy in the Gulf of Alaska

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ABSTRACT—Data in September 1978 revealed an intense clockwise eddy in the Gulf of Alaska which appeared to form as a result of vorticity conservation in the flow near Pratt Seamount. The existence of many large seamounts in this region suggests that well-developed eddies may be common. These circulation features are important to resource assessment because the movement of food organisms may be modified.

Introduction

On 26 June 1978 the Seasat-A satellite was launched to evaluate and demonstrate the potential of its sensors to provide assessments of ocean waves, winds, temperature, and currents. The availability of this information in real time could establish a new era in providing services of value to fisheries, shipping, weather forecasting, and other activities. As part of efforts to obtain ''ground truth'' for Seasat-A, a suite of measurements was carried out by the NOAA ship *Oceanographer* in the Gulf of Alaska and seaward of Vancouver Island in September 1978, which fortuitously occurred before the satellite system's demise from a power failure in October 1978. The *Oceanographer* obtained only limited information on circulation in the region, but the data did reveal a well-developed eddy in the flow, which appeared to be induced by bottom topography. These observations and their implications are the subject of this article.

Distributions and Circulation

The long CTD (conductivity/temperature/depth) section (stations 19-34) shown in Figure 1 was taken to assess the northward flow into the Gulf of Alaska. While examining the data aboard ship, a strong reversal in the density slopes near Pratt Seamount was noted, and a short section (stations 36-41) was added in an effort to define the limits of this feature.

Figure 2 presents vertical sections of sigma-t (density minus one times 10^3) for both of the CTD sections occupied in early September. The northernmost section (Fig. 2a, stations 19-34) reveals a departure from the general downward slope of isolines; at station 24, just north of Pratt Seamount, the isolines reach their greatest depth and then slope upward and flatten out. On the basis of only this information one would suspect that a clockwise eddy was present in the general northward flow. The feature is well developed from 100 to over 1,000 m, but the signature disappears near the surface. (It should be noted, however, that Surveyor Seamount, between stations 21 and 22, does not seem to affect the density field, probably because its steepest part is downstream of this section.) The second CTD section (Fig. 2b, stations 36-41) indicates a general northward flow with only a slight reversal in slope at mid-depths. Thus the large density perturbation appears to have formed between the two CTD profiles.

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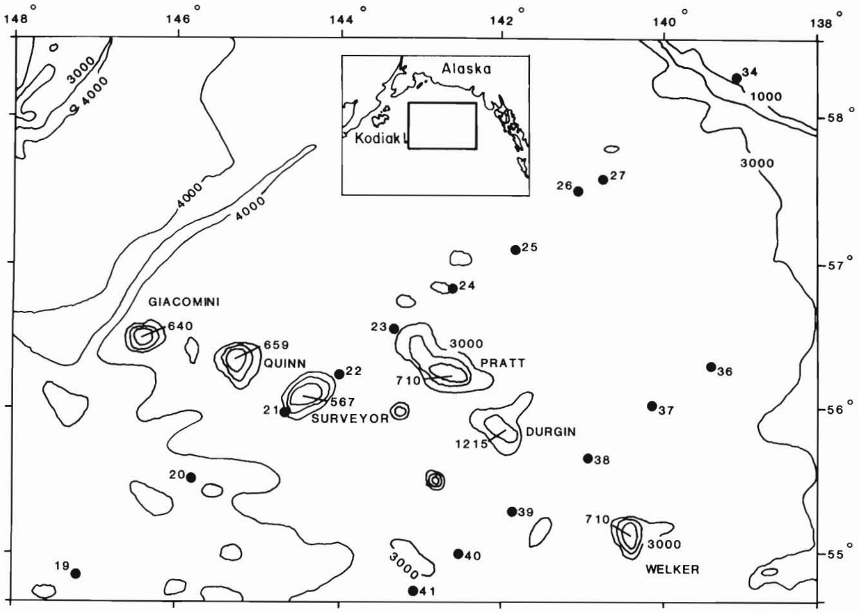

Figure 1.—Location of CTD stations taken by the NOAA ship *Oceanographer,* 4-7 September 1978. The bathymetry is in meters from National Ocean Survey Chart 500, dated November 1976. The insert shows the location of this area in the Gulf of Alaska.

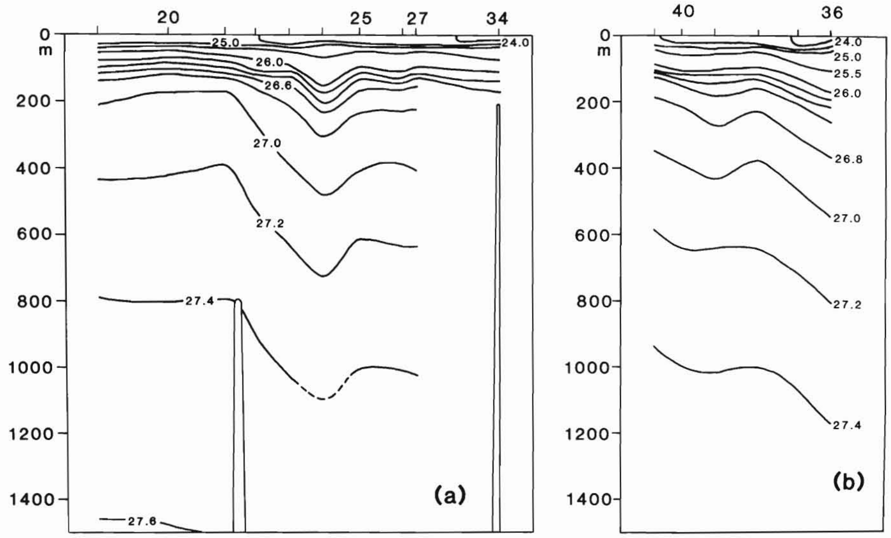

Figure 2. — Vertical sections of sigma-t density ($\mu g/cm^3$): (a) stations 19-34, 4-6 September 1978; and (b) stations 36-41, 6-7 September 1978.

In the absence of direct current measurements, circulation is usually inferred from the geopotential topography; the topography of the sea surface and 500 m, referred to 1,500 m, is shown in Figure 3. (The surface topography was extended inshore to station 34 by consideration of the isopycnal slopes at the deepest common level between stations 27 and 34.) Although the data are rather sparse for an adequate resolution of the flow, two unambiguous features do emerge. First, there is a broad northward flow across the region with maximum surface speeds of about 20 cm/sec. Second, there is a well developed eddy-like feature near Pratt Seamount, which appears to bifurcate the northward flow. The relief across the eddy-like feature at 500 m is less than half that at the sea surface. The features evident in Figure 3 extend appreciably deeper than 500 m, however; the 1,000/1,500-m topography (not shown) indicates weak patterns throughout the area which are similar to those at levels above.

Formation of the Eddy

The clockwise, rotary feature near Pratt Seamount (hereafter referred to as the "eddy" even though the data are insufficient to determine precisely its shape or if streamlines are closed) appears to be generated downstream of CTD stations 36-41. This evidence would certainly suggest that the eddy may form through interaction of the flow with Pratt, and perhaps Durgin, Seamount. Pratt Seamount is a massive feature which could be expected to influence the flow through vorticity constraints, although other aspects of topographic influence on dynamics may be important (Huppert and Bryan, 1976). If vorticity is approximately conserved, clockwise curvature may increase when a northward flow crosses a region of decreasing depth. Thus the existence of the eddy near Pratt Seamount is in keeping with these simple concepts.

Surface Features

It was noted earlier that the density distribution near the surface was not indicative of the marked relief that was present at mid-depths; obviously though the eddy is a major feature in the surface current field (Fig. 3). Near-surface density slopes are frequently not the same as those below, but this only slightly alters the flow because it reflects the integrated slopes above the reference level. The fact that there appears to be some decay in eddy energy near the surface is in agreement with theory on the vertical scale of obstacle-induced flow (Huppert and Bryan, 1976), however.

Sea surface temperature is the most easily sensed parameter (through ship reports or satellite observations) of potential value to users, and a number of such products are issued on a regular basis (the biweekly temperature maps produced by the National Marine Fisheries Service, Southwest Fisheries Center, La Jolla, Calif., for example). In this instance, however, sea surface temperature (Fig. 4) was not of value as an index of the general surface flow or the eddy; the temperature range across the northernmost CTD section is only 1°C (hardly detectable by satellite radiometers), and the temperature slope between stations 24 and 25 is in the opposite sense to what would be expected for a clockwise eddy. Although satellite imagery does suggest the existence of eddies in the Gulf of Alaska (G. Hufford, National Environmental Satellite Service, Anchorage, Alaska), the energetic eddy described here would not have been detected by these surface measurements.

Implications

From even a cursory examination of a nautical chart or bathymetric map, it is apparent that the eastern Gulf of Alaska has many large seamounts with minimum depths less than 1,000 m. Several of them are shown in Figure 1, but there is another chain of seamounts southeast of Welker Seamount, bounded by Bowie Seamount on the south and

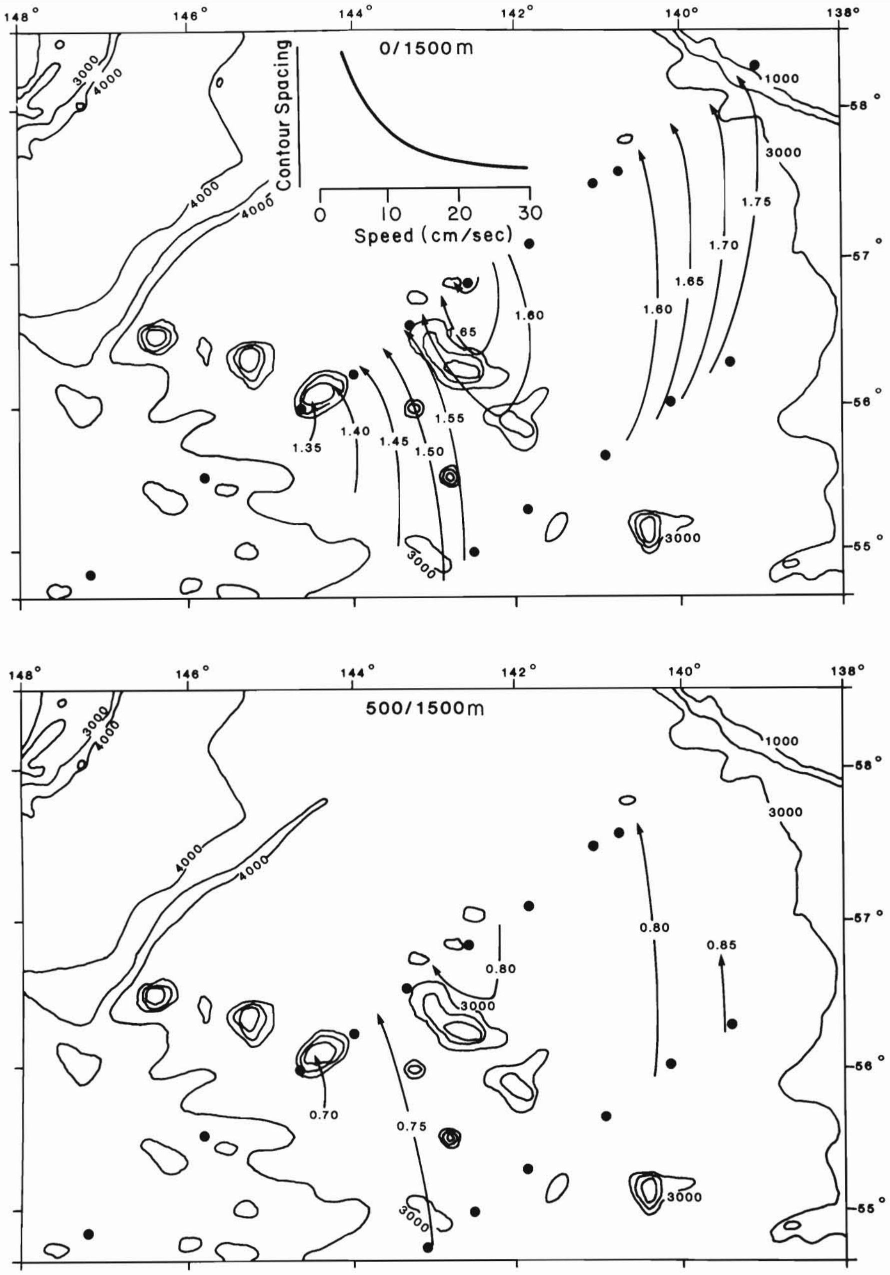

Figure 3.—Geopotential topography (in dyn m) at the sea surface and 500 m, both referred to 1,500 m, 4-7 September 1978.

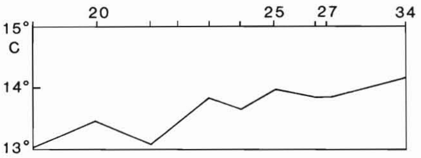

Figure 4.—Sea surface temperature (°C) at stations 19-34, 4-6 September 1978.

Brown Seamount on the north. Many of these features could be expected to affect the northward flow significantly. If vorticity constraints play the dominant role in the topographic interactions with the flow as suggested by the data here, one might expect the generation of numerous clockwise eddies. These features are not readily apparent in most historical data, but the widely spaced observations available do suggest numerous perturbations in the northward flow (Dodimead et al., 1963; Favorite et al., 1976).

Traditionally, fisheries scientists have been especially concerned about the effects of counterclockwise eddies or upwelling zones on the ecosystem because the rising waters may replenish nutrients from below and enhance primary productivity of the upper water. Clockwise eddies should have the opposite effect, but this does not mean that these features should be ignored. These rotary systems are dynamically important, and it is certainly conceivable that they tend to trap food organisms or in other ways interfere with the drift of zooplankton and larvae. Thus the location of clockwise eddies in the Gulf of Alaska should be quite relevant to fisheries assessments. The data presented here, however, suggest that these features can only be reliably defined by subsurface measurements. Rapid XBT surveys and the use of satellite-tracked drifting buoys could perhaps provide useful information at reasonable cost.

Literature Cited

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