Seasonal variation of the alongshore velocity field over the continental shelf off Oregon[1]

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Abstract

The seasonal variation in the alongshore velocity field is inferred from direct current observations made over the Oregon continental shelf at various locations and irregular intervals since 1965. Monthly mean currents are computed and compared with earlier studies to give a description of the seasonal variation in the alongshore currents. In winter, the alongshore flow is generally northward and independent of depth. In spring, flow is southward at all depths but stronger near the surface. In summer, surface flow is southward and deep flow is northward; the southward surface flow forms a coastal jet and the deep northward velocity increases with distance offshore.

Direct current measurements from moored arrays have been made off Oregon at various intervals since 1965. Although most observations were made during the upwelling season, particularly in July and August, some are also available from other times of the year. Our purpose here is to describe the seasonal variation observed in the alongshore velocity field.

The currents over the continental shelf off Oregon are highly variable. Since the kinetic energy spectra frequently show peaks at periods of several days (Cutchin and Smith 1973; Smith 1974) as well as at tidal and inertial periods, current records of several years duration are necessary to determine the annual cycle with a high degree of confidence. In practice, long current records are difficult to obtain, and it is useful to infer as much as possible from existing observations.

The data used have been published in a series of data reports (Oregon State Univ., School of Oceanogr. Data Rep. 23, 30, 40, 43, 46, 57, and 58) and various aspects of the observations have been discussed in some detail (e.g. Collins et al. 1968; Huyer and Pattullo 1972). Synthesis of these results and further study of some aspects of the data result in a qualitative understanding of the seasonal variation of the alongshore field.

The observations were made possible by a series of grants from the Office of Naval Research, the National Science Foundation, and the Office for the International Decade of Ocean Exploration. C. A. Collins and C. N. K. Mooers contributed greatly to the early current observations off Oregon.

Observations

Most of the early observations were made along a line extending seaward from Depoe Bay, Oregon (44°50′N). During the 1972 Coastal Upwelling Experiment (CUE-I) observations were made along a line extending westward from Newport, Oregon (44°40′N), as well as along the Depoe Bay line and during CUE-II (1973) observations were made along the "K" line (at about 45°16′N). A single array of current meters (Poinsettia) has been continuously maintained in 100 m of water 44°45′N since December 1972. Figure 1 shows the locations of these arrays.

Until CUE-I in 1972, the observations were made with Braincon current meters; since then Aanderaa current meters have been used. Both types have Savonius rotors

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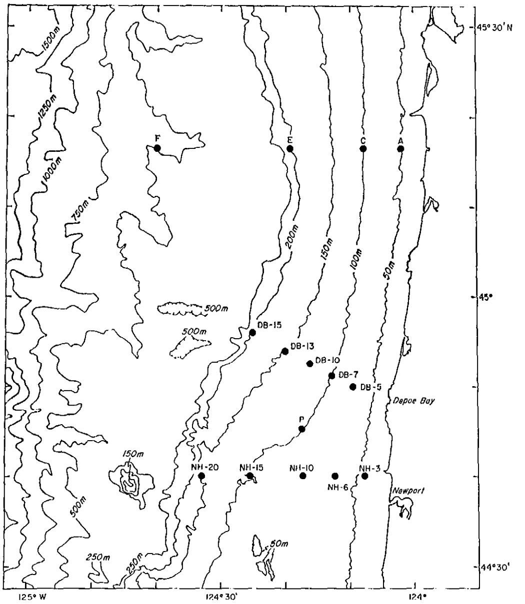

Fig. 1. Locations of current meter arrays moored along the Newport line (NH-3 to NH-20), Depoe Bay line (DB-5 to DB-15), the "K" line (F,E,C,A,), and at Poinsettia (P).

and were moored in arrays with subsurface flotation (Pillsbury et al. 1969) to reduce mooring motion and with the shallowest current meter usually 20 or 25 m below the surface.

Mean monthly currents

For each data record with at least 5 days duration in any 1 month, we computed the vector mean horizontal current from hourly data. Usually the mean was computed from data of less than a month's duration; we made no adjustment for the timing of the observations within each month. Values from different years were not combined and the monthly means from different years are shown independently in our figures. We considered three depth classes: shallow, intermediate, and deep, corresponding to the upper, middle, and bottom thirds of the water column.

The alongshore flow has been represented in terms of the north–south component rather than a component parallel to the local isobath. This simplified the analysis without altering the qualitative results in any way. For example, the results of Fig. 2 are not altered by using the parallel-to-isobath rather than the northward component, even where the isobath angle is greatest (at NH-15, 28 km from shore): mean along-isobath components during August 1972 are –8.8, –3.6, 1.6, and 3.6 cm sec^{-1} compared with –5.6, –3.2, 1.6, and 3.9 cm sec^{-1} for the northward components at 20, 40, 60, and 80 m. The onshore–offshore flow at the instrument depths is both considerably smaller and more complex, and we have not been able to make a comparable analysis meaningful for the onshore–offshore flow regime; we therefore restrict our discussion to the alongshore flow.

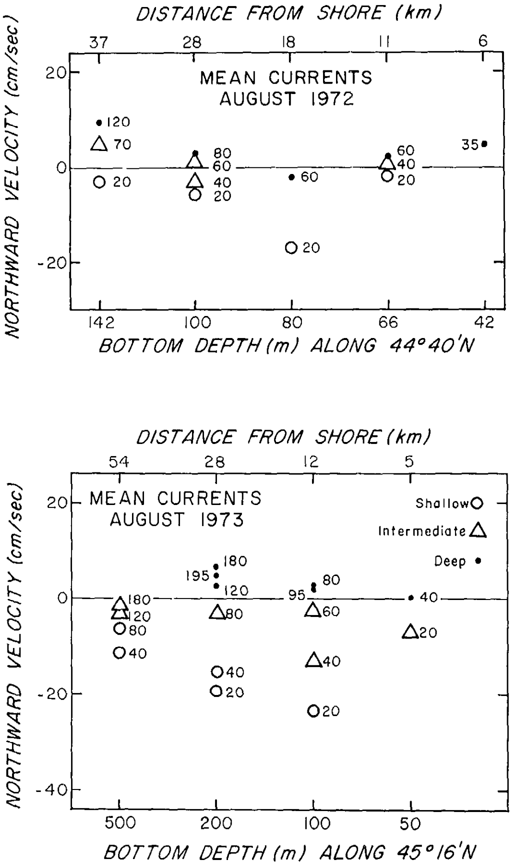

Fig. 2. Northward component of the mean current in August 1972 and 1973 as function of depth and distance offshore.

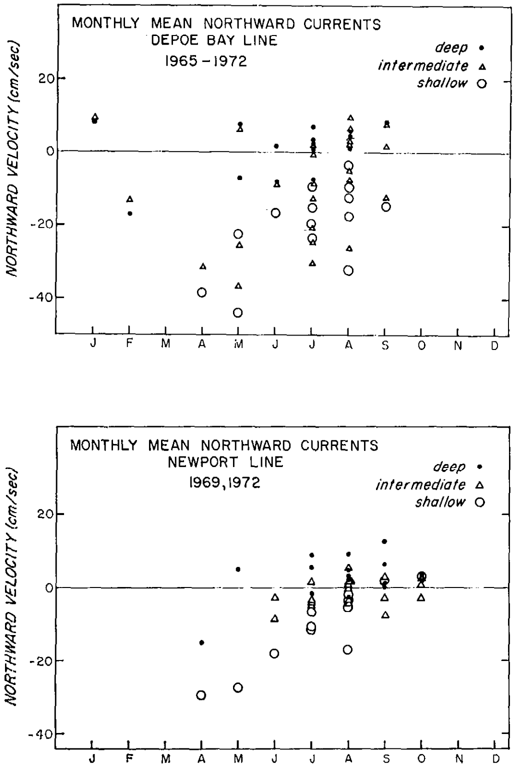

Fig. 3. Northward component of the monthly mean current at locations along the Depoe Bay line and along the Newport line.

The observations from the Depoe Bay line form the most complete subset: observations are available for eight different months spread over the years 1965–1969 and 1972 and for five different locations at 9, 13, 18, 24, and 28 km from the coast. Figure 3 shows the northward component of all monthly means from the Depoe Bay line. In spring and summer (April through August) there is considerable difference, or shear, between the deep and shallow observations; the shallow currents are always more southward. In winter (January and February) there is almost no difference at the deep and intermediate current meters; although speed data were not available at the shallow current meter, the direction data show that reversals in the sign of the current occurred at the same time at all depths, and therefore that there was no mean shear (Collins and Pattullo 1970).

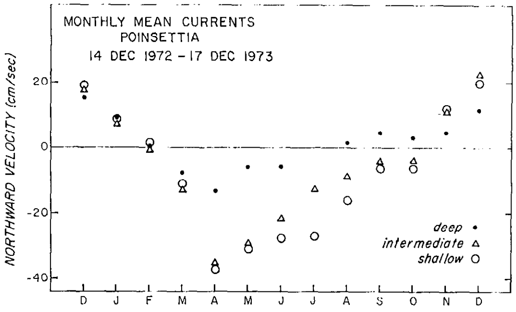

Fig. 4. Northward component of the monthly mean current at Poinsettia.

The difference between the shallow and deep currents seems to be greatest in spring and smallest in winter. Data from the Newport line are available only from April to October (Fig. 3). A similar shear between shallow and deep is observed during spring and summer with no shear in October.

A single array (Poinsettia) was moored at 44°45′N, 124°18′W in December 1972 and has been replaced at intervals of a few months in an attempt to get a nearly continuous long data record. By December 1973 year-long current records were available at depths of about 25 and 40 m with only a week-long gap; the 80-m record was interrupted by one 2-week gap at the end of March and one 5-week gap in late June and July. The monthly means for this array (Fig. 4) show a similar trend to that of the data from the Depoe Bay and Newport lines. No vertical shear occurs from December 1972 to March 1973, but in November and December 1973 surface currents are more strongly northward than the deeper currents. A mean vertical shear with surface flow more southward than the deep currents is established in about a month in spring and decays more slowly during late summer and fall.

We analyzed the data further to determine whether the alongshore current also varied with distance offshore. Although the Depoe Bay data are inadequate for this, observations from CUE-I and CUE-II show some systematic variation in the mean current with water depth (or distance off-

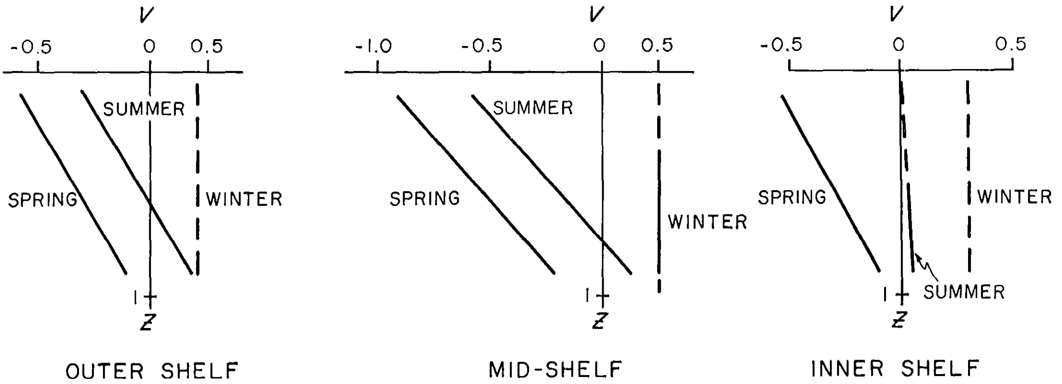

Fig. 5. The variation of the alongshore current (v—fraction of maximum speed) with depth (z—fraction of water depth).

shore) during summer (Fig. 2) and a nearshore maximum in the surface southward flow (coastal jet) about 18 km offshore at 44°40′N in 1972 and about 12 km offshore at 45°16′N in 1973. The deep northward flow appeared to increase with distance offshore except nearshore (in water less than 80 m deep) along 44°40′N in 1972.

Seasonal variation

Combining the results of the previous section with earlier studies of different subsets of the data, we obtain a tentative description of the seasonal variation of the alongshore flow as a function of depth and distance offshore, summarized in a series of schematic diagrams (Figs. 5, 6, and 7) in which the lines indicate qualitative features of the flow regime. None of the curves were calculated, and dashed lines indicate considerable uncertainty. Axes are dimensionless, with z being a fraction of the total water depth, L being a fraction of the width of the continental shelf, and v being the fraction of the maximum speed.

Vertical shear (Fig. 5) is absent in winter but present in summer, with surface flow more southward than deep flow and greatest shear at about the middle of the shelf. The deep flow is southward in spring and northward in summer. Variation of flow with distance offshore (Fig. 6) shows a southward coastal jet at the surface in both spring and summer. In summer, the deep northward flow is strongest at the outer edge of the shelf. The variation of the alongshore flow with time (Fig. 7) indicates greatest vertical shear in summer over the midshelf area, presumably because

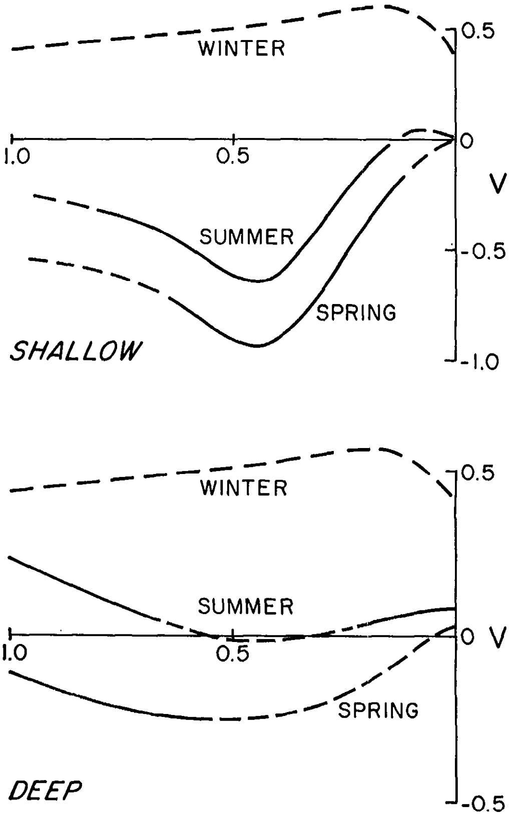

Fig. 6. The variation of the alongshore current (v—fraction of maximum speed) with distance offshore (horizontal axis is fraction of shelf width).

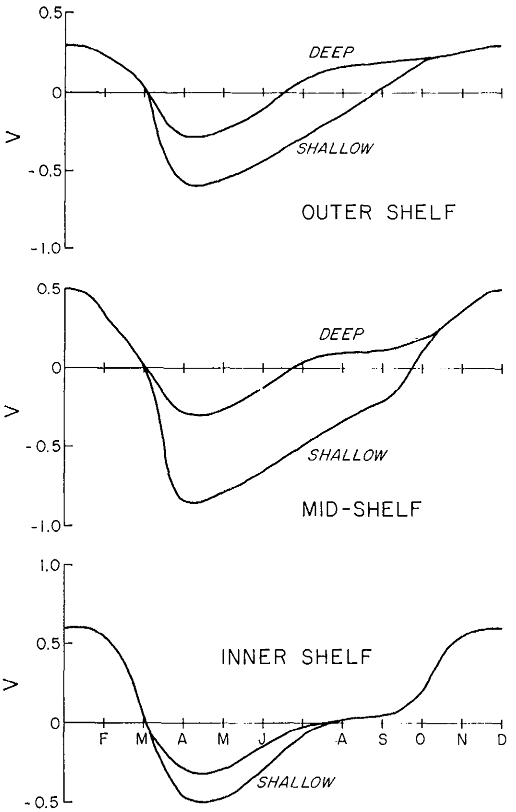

Fig. 7. The seasonal variation of the alongshore current (v—fraction of maximum speed) field.

maximum horizontal density gradients occur in this region (Huyer 1973).

This description of the alongshore flow regime is supported by earlier studies. Drift bottles indicate that the northward flow (the Davidson Current) is more than 150 km wide, considerably wider than the continental shelf (Burt and Wyatt 1964; Wyatt et al. 1972; Lung 1973). This was also shown by direct current observations over the continental slope during fall 1969 (Sakou and Neshyba 1972). Collins and Pattullo (1970) found that the winter northward flow was independent of depth. Mooers et al. (unpublished) showed evidence for the vertical shear in summer, which has been supported by the studies of Cutchin (1972), Pillsbury (1972), Huyer (1974) and Smith (1974). Mooers et al. (unpublished) presented evidence for the southward surface coastal jet which was confirmed by Huyer et al. (1974) and Huyer (1974). Cutchin (1972) and Huyer (1974) showed that while the deep flow was poleward in late summer, it was southward in the spring.

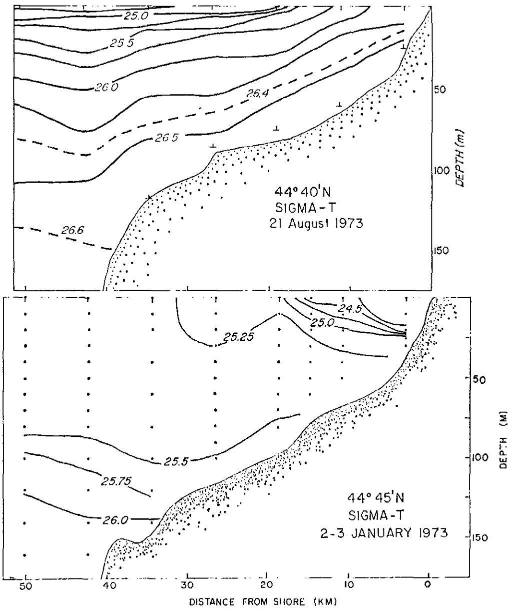

Fig. 8. Density sections over the continental shelf observed in January and August 1973. Dots indicate discrete bottle samples; ⊥—deepest observation with conductivity-temperature-depth probes.

Discussion

The seasonal variation in the currents over the continental shelf is undoubtedly related to seasonal variations in the wind, sea level, and hydrographic regime. The predominant winds are northeastward from late fall to early spring, becoming southward from late spring to summer. Bakun (1973) has shown that the winds become favorable for upwelling in April, the month in which the observed alongshore velocity shear develops. Associated with this is a change in the hydrographic regime, as indicated by typical winter and summer density sections across the continental shelf (Fig. 8). A horizontal gradient of density results from the isopycnals sloping upward toward the coast during upwelling. Under the geostrophic assumption (thermal wind relation), this is consistent with the vertical shear observed in spring and summer. Mean sea level also varies with season, being highest in December and January and lowest in May through July (Brunson and Elliott 1974). These months of highest and lowest mean sea level at the coast correspond to the periods of strongest northward flow and, approximately, strongest southward flow respectively; this is again consistent with the geostrophic assumption. A more detailed or sophisticated comparison of these variables is meaningful for specific time periods using actual observations (e.g. Smith 1974) but probably not for the simple monthly means computed from rather scarce or sporadic observations.

The schematic diagrams (Figs. 5, 6, and 7) of the alongshore flow we have presented are inferred from observations scattered in different months, depths, and locations. Results are therefore rather speculative and their value may properly be questioned, but the conclusions we have drawn are internally consistent and agree with earlier studies. Since the results are qualitative, they should not be used to infer details of the flow regime, e.g. the depth at which the alongshore flow changes from southward to northward. The value of the results lies not in the prediction of these details, but in that they are a coherent synthesis of the current measurements made to date off the Oregon coast. The results provide a framework for future observations and represent hypotheses that can be tested.

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