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Lateral Momentum Flux in Boundary Currents

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ABSTRACT

Some simple momentum advection effects are considered in a current aligned with the y axis on which there is superimposed a "cross" flow in the x-z plane. The cross flow coupled with horizontal shear in the current tends to generate differences along the vertical in the longshore velocity, while vertical mixing tends to even out such differences. As in the scalar diffusion problem considered by Taylor, a balance is possible between the two tendencies. The equilibrium velocity distribution may support considerable lateral momentum flux, which, in the case of zero rotation, is directed down the velocity gradient, allowing the definition of an effective horizontal viscosity. When rotational effects are significant, both the sense and the magnitude of the momentum flux come to depend in a complex way on the total vorticity f + S, where f is Coriolis parameter and S the current shear.

Some illustrative examples are calculated for cross flow produced by frictional effects in a boundary current. These show that horizontal momentum flux by this type of cross flow can be significant in shallow water under some circumstances. A consideration of observational evidence from the Great Lakes leads to the conclusion that this mechanism of momentum transfer may well be responsible for the observed asymmetry of wind-generated coastal jets, i.e., the strengthening of the "right-hand" jet (looking along the wind) at the expense of the left-hand jet.

A crude estimate of horizontal momentum transport by cross flow due to the 18 water formation mechanism of Worthington in the North Atlantic shows this to be as high as implied by viscous theories of ocean circulation and to be able to generate the positive vorticity necessary for the boundary current to penetrate regions with increasing planetary vorticity. The cross flow type of momentum flux, however, differs from the viscous fluid type in several respects, i.e., in that it is consistent with a zero momentum flux condition at the boundary, and that, in a rotating fluid, it may well be directed counter to the momentum gradient.

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