Abstract View

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Vorticity Control

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ABSTRACT

A nonlinear one-layer model is considered in order to describe the way that water with a relative vorticity intrudes into an otherwise stagnant channel. The channel has a uniform depth (*D*) and width (*L*) and the fluid is taken to be inviscid. The intruding fluid is separated from the (initially stagnant) water in the channel by a free dividing streamline that corresponds to a "vorticity front." This front intersects the channel wall (at the head of the intrusion) and extends backwards upstream. As the fluid with relative vorticity is intruding into the channel, the fluid with no relative vorticity (i.e., the fluid present in the channel prior to the intrusion) escapes in the opposite direction. This flow compensates for the fluid displaced by the advancing intrusion. Solutions for steadily propagation intrusions are obtained analytically by equating the flow-force ahead of and behind the for steadily propagating intrusions are obtained analytically by equating the flow-force ahead of and behind the intrusion. Namely, steady state solutions correspond to a balance between the forward momentum flux and the form drag exerted on the intrusion by the escaping fluid. The nature of the intersection of the front with the wall is analyzed by methods similar to those employed by Stokes for analyzing the maximum steepness of surface gravity waves.

It is found that the vorticity in the intruding fluid "controls" the amount of fluid that flows through the channel. When the vorticity (ζ) of the intruding fluid is uniform, the width of the intrusion is always 2/3 of the channel width and the net volume flux of the intruding fluid is $(2/27)\zeta DL^2$. In the presence of weak dissipation, the channel can can transfer an amount less than $(2/27)\zeta DL^2$, but, under no circumstances can the channel the so-called hydraulic control $\{\sim O[(gD)^{1/2}DL]\}$, which corresponds to the flux of an intrusion without any relative vorticity. When $\zeta \sim O(f)$, the ratio between the maximum flux allowed by the vorticity control to the flux allowed by the hydraulic control is equivalent to about 1/10 of the ratio between the channel width and the barotropic deformation radius. Hence, for midlatitude channels, the vorticity control may limit the flux *to a few percent* of that associated with the hydraulic control.

Possible application of this theory to various oceanic situations is mentioned.

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