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Semigeostrophic Wind-Driven Thermocline Upwelling at a Coastal Boundary

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ABSTRACT

We formulate analytically and solve numerically a semigeostrophic model for wind-driven thermocline upwelling at a coastal boundary. The model has a variable-density entraining mixed layer and two homogeneous interior layers. All variables are uniform alongshore. The wind stress and surface heating are constant. The system is started from rest, with constant layer depths and mixed layer density. A modified Ekman balance is prescribed far offshore, and the normal-to-shore velocity field responds on the scales of the effective local internal deformation radii, which themselves adjust in response to changes in layer depths, interior geostrophic vorticity, and mixed layer density. Sustained upwelling results in a steplike horizontal profile of mixed layer density, as the layer interfaces "surface" and are advected offshore. The upwelled fronts have width $O(u_*/f)$, as in the two-layer model of de Szoeke and Richman (1984). For fixed initial layer depths, the interior response and the horizontal separation of the upwelled fronts scale with the initial internal deformation radii. Around the fronts, surface layer divergence occurs that is equal in magnitude to the divergence in the upwelling zone adjacent to the coast, but its depth penetration is inhibited by the stratification.

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