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Interaction of an upwelling front with external vortices: impact on cross-shore particle exchange. (English) Zbl 07441646

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Summary: Coastal upwellings, due to offshore Ekman transport, are more energetic at the western boundaries of the oceans, where they are intensified by incoming Rossby waves, than at the eastern boundaries. Western boundary upwellings are often accompanied by a local vortex field. The instability of a developed upwelling front and its interaction with an external vortex field is studied here with a three-dimensional numerical model of the hydrostatic rotating Navier-Stokes equations (the primitive equations). The baroclinic instability of the front leads to the growth of meanders with 100–200 km wavelength, in the absence of external vortex. On the f-plane, these waves can break into a row of vortices when the instability is intense. The β-effect is stabilizing and strongly decreases the amplitude of meanders. Simulations are then performed with a front initially accompanied by one or several external vortices. The evolutions in this case are compared with those of the unstable jet alone. On the f-plane, when an external vortex is close to the front, this latter sheds a long filament which wraps up around the vortex. This occurs over a period similar to that of the instability of the isolated front. Cyclones are more efficient in tearing such filaments offshore than anticyclones. On the β-plane, the filaments are short and turbulence is confined to the vicinity of the front. At long times, waves propagate along the front, thus extending turbulence alongshore. The initial presence of a vortex alley leads to a stronger destabilization of the front and to a larger cross-shore flux than for a single vortex, with many filaments and small vortices pushed far offshore. In the ocean, this cross-shore exchange has important consequences on the local biological activity.

MSC:

76E05 Parallel shear flows in hydrodynamic stability
76E20 Stability and instability of geophysical and astrophysical flows
76U05 General theory of rotating fluids
76B47 Vortex flows for incompressible inviscid fluids

Keywords:

coastal upwelling front; vortices; filaments; baroclinic instability; frontal waves; particle motion and tracking

Software:

ROMS; Gibbs Seawater; GSW

Full Text: DOI

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