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Baroclinic instability of a buoyant coastal current

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Classic models of baroclinic instability, notably the Eady model, depend on the Rossby (or Richardson) number as the sole non-dimensional parameter. Inclusion of a sloping bottom requires an additional parameter, the slope Burger number, $Bu = \alpha N f^{-1}$, where α is the bottom slope. Numerical simulations of the evolution of instabilities along the edge of a coastally trapped buoyant flow suggest that the slope may help to stabilize the flow when the deformation radius is similar to or larger than the with of the buoyant flow, that is, the flow is stable when the slope Burger number is larger than about 0.3. In unstable cases, $Bu < 0.3$, baroclinic instabilities in the flow cause the isopycnals to relax, thereby increasing the local Burger number until the critical condition, $Bu \simeq 0.3$, is met. At this point the instabilities no longer grow in time, preventing further offshore buoyancy flux by the eddies. This final state corresponds approximately to the case where the slope of the ground is similar to the slope of the mean isopycnal surfaces. The nonlinear, three-dimensional numerical simulations are in basic agreement with one-dimensional linear stability analysis, with a few key exceptions. Notably, numerical simulations suggest that cross-shelf buoyancy fluxes are strongest in within the bottom boundary layer, showing a similar pattern to continental shelf waves in the vertical structure of current and tracer variability. Idealized simulations show a marked similarity to instabilities along the Mississippi/Atchafalaya plume front, as seen in observations and realistic regional models. These eddies have been shown to be important in Lagrangian transport of surface particles, notably oil spill trajectory prediction, and create patchiness in bottom dissolved oxygen distributions during periods of summertime seasonal hypoxia.