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Mixed frictional-Kelvin–Helmholtz destabilization of source-driven abyssal overflows in the ocean

Source-driven ocean currents that flow over topographic sills are important initiation sites for the abyssal component of the thermohaline circulation. These overflows exhibit vigorous space and time variability over many scales as they progress from a predominately gravity-driven down slope flow to a geostrophic along slope current. Observations show that in the immediate vicinity of a sill, grounded abyssal ocean overflows can possess current speeds greater than the local long internal gravity wave speed with bottom friction and down slope gravitational acceleration dominating the flow evolution. It is shown that these dynamics lead to the mixed frictionally-induced and Kelvin–Helmholtz instability of grounded abyssal overflows. Within the overflow, the linearized instabilities correspond to bottom-intensified baroclinic roll waves and in the overlying water column amplifying internal gravity waves are generated. The stability characteristics are described as a function of the bottom drag coefficient and slope, Froude, bulk Richardson and Reynolds numbers associated with the overflow and the fractional thickness of the abyssal current compared to the mean depth of the overlying water column. The marginal stability boundary and the boundary separating the parameter regimes where the most unstable mode has a finite or infinite wavenumber are determined. When it exists, the high wavenumber cut-off is obtained. Conditions for the possible development of an ultra-violet catastrophe are determined. In the infinite Reynolds number limit, an exact solution is obtained which fully includes the effects of mean depth variations in the overlying water column associated with a sloping bottom. For parameter values characteristic of the Denmark Strait overflow, the most unstable mode has wavelength of about 19 km, a geostationary period of about 14 hours, an e-folding amplification time of about 2 hours and a down slope phase speed of about 74 cm/s.