Geophysical Research Abstracts, Vol. 7, 04820, 2005
SRef-ID: 1607-7962/gra/EGU05-A-04820

Mixing and Entrainment in hydraulically driven stratified Sill Flows

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The investigation involves the hydraulic behaviour of a dense layer of fluid flowing over an obstacle and subject to entrainment of mass and momentum from a dynamically inactive (but possibly moving) overlying fluid. An approach based on the use of reduced gravity, shallow-water theory with a cross-interface entrainment velocity is compared with numerical simulations based on a model with continuously varying stratification and velocity. The locations of critical flow (hydraulic control) in the continuous model are estimated by observing the direction of propagation of small-amplitude long-wave disturbances introduced into the flow field. Although some of the trends predicted by the shallow-water model are observed in the continuous model, the agreement between the interface profiles and the position of critical flow is quantitatively poor. A reformulation of the equations governing the continuous flow suggests that the reduced gravity model systematically underestimates inertia and overestimates buoyancy. These differences are quantified by shape coefficients that measure the vertical non-uniformities of the density and horizontal velocity that arise, in part, by incomplete mixing of entrained mass and momentum over the lower-layer depth. Under conditions of self-similarity (as in Wood's similarity solution) the shape coefficients are constant and the formulation determines a new criterion for and location of critical flow. This location generally lies upstream of the critical section predicted by the reduced-gravity model. Self-similarity is not observed in the numerically generated flow, but the observed critical section continues to lie upstream of the location predicted by the reduced gravity model. The factors influencing this result are explored.