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Numerical Investigation of Entrainment of Turbulent Dense Currents

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Entrainment in dense overflows has fundamental importance for understanding the transport of densest water in the ocean. Estimation of entrainment is extremely challenging and to-date we do not have a fundamental framework that parameterizes entrainment. A highly accurate direct numerical simulation and large eddy simulation solvers have been developed to simulate dense currents over range of smooth- and rough-surfaces. Simulations have been performed for both lock-exchange currents and constant flux currents. A mathematical framework has been developed to estimate entrainment of 2-D and 3-D dense currents. Entrainment has been calculated from first-principles as the relative change in the volume of the dense current in time with respect to the buoyancy forcing that drives the dense current. A combination of threshold method, wherein the height of current is evaluated as height corresponding to the specified threshold value and sorting method, wherein, the mixed fluid is sorted into bins ranging from dense fluid at the bottom to ambient fluid at the top has been used to evaluate the interface between the dense and ambient fluid. Entrainment is sensitive to the method of evaluation of the interface height. Finally, we obtained the dependency of entrainment parameter on non-dimensional parameters. Analysis has demonstrated lock-exchange currents have less mixing and entrainment for same Reynolds number and Froude's number than constant flux currents. The differences exist due to differences in nature of Kelvin-Helmholtz instabilities and lobe-cleft currents. Rough-bottom surfaces introduces additional dynamics of the dense currents. The spacing between the roughness elements has demonstrated to be important metric in entrainment parameters for lock-exchange currents. Densely spaced (D-type) currents travel slower as roughness causes hindrance on density current propagation due to enhanced drag and produces additional eddies and instabilities compared to sparsely distributed roughness (k-type). The work is of fundamental importance, and has important implications in modeling of ocean circulation and continental overflows