Geophysical Research Abstracts, Vol. 7, 09617, 2005
SRef-ID: 1607-7962/gra/EGU05-A-09617

Two-dimensional density currents in a confined basin.

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We present new experimental results on the mechanisms through which steady two-dimensional density currents lead to the formation of a stratification in a closed basin. A motivation for this work is to verify underlying assumptions in a diffusive “filling box" model that describes the oceanic thermohaline circulation (Hughes and Griffiths, 2005). They hypothesized that even weakly entraining density currents on a low-angle slope could have an important influence on the background stratification and circulation, due to the integrated effect of the weak along-slope entrainment resulting in a much larger horizontal entrainment ratio of $E_{eq} \sim 0.1$. This entrainment was then predicted to lead a non-uniform upwelling velocity. We experimentally measure the relationship between the along-slope entrainment ratio of a density current E, to the horizontal entrainment ratio, E_{eq}, of an equivalent vertical plume. The along-slope entrainment ratios show the same quantitative decrease with slope as observed by Ellison and Turner (1959), whereas the horizontal entrainment ratio E_{eq} appears to asymptote to a value of $E_{eq} = 0.08$ at low slopes. Using the measured values of E_{eq} we show that two dimensional density currents drive circulations that are in good agreement with the two dimensional filling box model of Baines and Turner (1969). We find that the vertical velocities of density fronts collapse onto their theoretical prediction that $U = -2^{-2/3}B^{1/3}E_{eq}^{2/3}(H/R)\zeta$, where U is the velocity, H the depth, B the buoyancy flux, R the basin width, E_{eq} the entrainment ratio and $\zeta = z/H$ the dimensionless depth. The density profiles are well fitted with $\Delta = 2^{-1/3}B^{2/3}E_{eq}^{-2/3}H^{-1}[ln(\zeta) + \tau)]$ where τ is the dimensionless time.

The oceanographic applications of these results are discussed, and as a simple example of a diffusive filling box model we show how the density stratification of the deep Caribbean waters (below 1850 m depth) can be described by a balance between a steady 2D entraining density current and vertical diffusion in a triangular basin.