Mixing in a gravity current: a Prandtl mixing length model

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Mixing in stratified shear flows is an important process in many geophysical situations. Of particular current interest is the mixing and entrainment of oceanic overflows that contributes to the transport of heat and salinity in the global ocean via the thermohaline "conveyor belt" [1]. Such circulations are thought to play an essential role in possible decadal climate change.

In regions like the Denmark Strait, the denser water originating in the colder and saltier Arctic Sees flows over a sill towards the bottom of the Atlantic Ocean. At large enough Richardson number, the resulting shear overcomes the stabilizing effect of the density stratification to produce Kelvin-Helmholtz instability, resulting in a mixing between the current and the ambient waters. Due to limited spatial resolution in global climate prediction simulations, the small-scale dynamics of oceanic mixing must be properly modeled. Understanding the physics of these processes and providing a simple description for the development of coarse-grain models of this mixing is an important step in improving predictions of global climate change [2].

We built a laboratory Oceanic Overflow Facility, to investigate the fine structure of the entrainment and mixing [3]. Inside a water tank, lighter, turbulent fluid with Taylor Reynolds number $R_\lambda \approx 100$ is introduced along an inclined plate into a denser environment. Simultaneous high-resolution PIV (velocity field) and PLIF (density field) measurements are conducted to visualize and quantify the flow structure. The data are used to characterize the turbulent mixing.

Our main result is that the turbulent transport of momentum and buoyancy are described in a very direct and compact form by a Prandtl mixing length model [4]: the turbulent vertical fluxes of momentum and buoyancy are found to scale with the vertical mean gradients of velocity $\partial_z \overline{u}$ and density $\partial_z \overline{\rho}$ as an eddy viscosity $\nu_T = L_m^2 \partial_z \overline{u}$ and an eddy diffusivity $\xi_T = L_\rho^2 \partial_z \overline{u}$ where L_m and L_ρ are approximately constant over the mixing zone of the stratified shear layer. A similar description does not work well when the flow is unstratified, suggesting that stratification plays an essential role in the Prandtl mixing length model.

[1] M. Winton, R. Hallberg, and A. Gnanadesikan. Simulation of density-driven frictional downslope flow in z-coordinate ocean models. *J. Phys. Ocean.*, 28:2163–2174, 1998.

[2] J. Willebrand, B. Barnier, et al. Circulation characteristics in three eddy-permitting models of the North Atlantic. *Prog. Oceanogr.*, 48:123–161, 2001.

[3] J. Chen, P. Odier, M.K. Rivera, and R.E. Ecke. Laboratory measurement of entrainment and mixing in oceanic overflows. *Proceedings of 2007 Joint ASME/JSME Fluids Engineering Summer Conference, San Diego, CA, USA*, 2007.

[4] P. Odier, J. Chen, M. K. Rivera, and R. E. Ecke. Fluid mixing in stratified gravity currents: The prandtl mixing length. *Physical Review Letters*, 102(13):134504, 2009.