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Direct numerical simulations of miscible, small Atwood number Rayleigh-Taylor instability-induced mixing

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Experimental and numerical investigations have been conducted to investigate the effects of initial conditions on the evolution of the large- and small-scale dynamics of an incompressible, miscible, statistically-stationary, small Atwood number Rayleigh-Taylor mixing layer. Experiments were performed at Texas A&M University on an existing water channel facility (Snider & Andrews 1994; Wilson & Andrews 2001; Ramaprabhu & Andrews 2004). Density and velocity fluctuations were measured using a high-resolution thermocouple system and particle image velocimetry (PIV). Quantities in both the streamwise and spanwise directions were measured to determine the initial conditions of the mixing layer in two-dimensional space. The temporal evolutions of various velocity and density statistics were also recorded for comparison with simulation results.

High-resolution two- and three-dimensional direct numerical simulations (DNS) of the experiment were performed using the MIRANDA spectral/compact difference code (Cook & Dimotakis 2001) at Lawrence Livermore National Laboratory. The simulation parameters were chosen to match as closely as possible the experimental values of the densities, viscosities, diffusivities, physical dimensions, and gravitational acceleration. The experimentally measured initial density and velocity fluctuations were used to provide the initial perturbations for the DNS. Comparisons of statistical turbulent and mixing quantities inferred from the experimental measurements and from the DNS are presented. Differences in the evolution of statistics and spectra between the two- and three-dimensional DNS are discussed, including the dependence upon initial conditions of the late-time transition to an $\alpha A g t^2$ mixing layer width. It is shown that DNS using experimentally determined initial velocity *and* density perturbations yields spectra and statistics in very good agreement with the corresponding quantities obtained from the experimental data.

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