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Mixing in stratified turbulence

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Quantifying diapycnal mixing in stably stratified turbulence is fundamental to the understanding and modeling of geophysical flows. In this study, we use direct numerical simulations (DNS) to study mixing and dispersion in decaying stably stratified turbulence from a Lagrangian perspective. The change in density of fluid particles owing to small-scale mixing is extracted from the simulations to provide insight into the mixing process. These changes are driven by temporally and spatially intermittent events that are strongly suppressed as the stratification increases and overturning motions disappear. The relationship between the diapycnal diffusivity and vertical dispersion coefficients is found to be strongly dependent on stratification. Models for the mixing following fluid particles are investigated. The time scale for the density changes due to small-scale mixing is shown to be approximately independent of N and instead remains linked to the energy decay time scale which is relatively insensitive to stratification. Data of diapycnal mixing from a number of different DNS studies of homogeneous stratified turbulence and from grid turbulence experiments are analyzed to investigate the scaling of the diapycnal diffusivity. In these homogeneous flows the instantaneous diapycnal diffusivity is given exactly by $K_d = \varepsilon_\rho (d\rho/dz)^2$ where ε_ρ is the dissipation rate of density fluctuations, and $d\rho/dz)^2$ is the mean density gradient. The diffusivity K_d may be expressed in terms of the large scale properties of the turbulence as $K_d = \gamma L_E^2/T_L$, where L_E is the Ellison overturning length-scale, T_L is the turbulence decay timescale, and γ is half the mechanical to scalar time-scale ratio. Our results show that L_E and T_L can explain most of the variations in K_d over a wide range of shear and stratification strengths while γ remains approximately constant.

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