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Viscous generation of potential enstrophy in breaking gravity waves

Ertel's potential vorticity (PV) is an important quantity in the study of stratified flows in environmental and geophysical fluid dynamics. In the absence of viscosity, diffusion, and forcing, PV is materially conserved. In the quasi-geostrophic regime, the entire flow can be found by inverting the PV. But even for unbalanced flows at higher Rossby numbers, PV is useful for identifying vortical motions and distinguishing them from gravity waves. In turbulence, viscous effects are generally dissipative and restricted to small length scales. But because PV is quadratic in the flow variables, viscosity and diffusion can affect it in unexpected ways. Herring, Kerr and Rotunno (1994) showed that viscous and diffusive effects are not necessarily dissipative or restricted to small scales; instead, they can generate large-scale PV. In this work, we revisit this problem in high-resolution direct numerical simulations of stratified turbulence. The initial condition is a standing internal gravity wave, which is a linear solution to the equations of motion that notably has zero PV. However, the wave eventually breaks, generating small-scale stratified turbulence. We explore the growth of potential enstrophy (squared PV) and its dependence on Froude and Reynolds numbers. Results are interpreted using scale analysis and cascade theories for stratified turbulence. Implications for the use of PV to identify vortices in stratified turbulence are discussed.