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Turbulence modification by stable stratification in channel flow

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— We study the modification of the turbulent structure of plane channel flow under stable stratification through direct numerical simulations. The simulations are performed at moderate Reynolds numbers (up to Retau=550), in very large computational boxes (up to Lx = 60 h, Lz = 25 h where h is the channel half height) and considering a wide range of stratification levels (up to Ritau=1920). For weak stratification or high Reynolds number, the turbulence is affected by buoyancy in the core of the channel but the near-wall region differs little from the neutral case. With increasing stratification, the near-wall streaks remain essentially unmodified while large-scale super-streaks are damped. In the central region internal gravity waves are dominant. In addition, there is an intermediate outer layer where the dynamics of the turbulent structures is governed by local fluxes. In this region energy spectra collapse when using local Obukhov scaling. With strong stratification, large laminar patches appear in the near wall region, and turbulent momentum and buoyancy fluxes vanish in the core of the channel. Linear transient-growth analysis of the mean velocity and density profiles reproduces the damping of the super-streaks in stratified channels, and predicts maximum energy amplification for infinitely-wide perturbations that are consistent with the internal waves observed in the simulations.

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