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Transition to turbulence in stratified Ekman flow

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The Ekman boundary layer is an idealization of the atmospheric boundary layer (ABL), where most of the exchanges between the surface and the free atmosphere take place by turbulent processes. The transition to turbulence in the non-stratified Ekman layer has been well studied and proved useful to understand the generation of turbulence and coherent structures in the neutral ABL. Here we focus on the less-studied transition to turbulence in the stably stratified Ekman layer with the expectation that insights on turbulence generation in the stable ABL can be gained.

Transition to turbulence in the stratified Ekman layer is controlled by the Reynolds number, the bulk Richardson number and the Prandtl number. The stratified Ekman flow is subject to an inflection-point instability for sufficiently high Reynolds number and sufficiently low Richardson number. We investigate the non-linear saturation of the instability into Kelvin-Helmholtz like roll vortices. We find that, depending on the Prandtl number, finite-amplitude vortices can exist at the Richardson numbers equal to or larger than the critical Richardson number for primary instability. By means of direct numerical simulations of the nonlinear and linearized Boussinesq equations we investigate the secondary instability of the Kelvin-Helmholtz vortices and its evolution into turbulence.