Stochastic modeling of transient neutral and stably-stratified Ekman boundary layers

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Turbulence is a transient phenomenon in atmospheric boundary layers. These transients occur often due to surface temperature variations (e.g. due to diurnal forcing) that directly influence the near-surface flow by local stratification effects. Relevant dynamical and transport processes occur on a scale of meters near the surface which is a standing challenge for numerical weather and climate prediction. Here we investigate neutral and stably-stratified Ekman flows as a canonical problem for the night-time atmospheric boundary layer over flat terrain. The set-up used consists of an incompressible fluid over a smooth horizontal no-slip wall in a rotating frame of reference. The bulk flow is in geostrophic balance and acts as momentum source. In the case of stable stratification, temperature is prescribed as sudden cooling on a fully-developed turbulent neutrally-stratified Ekman boundary layer. When the stratification is weak, the temperature behaves like a passive scalar, but when it is strong, turbulence may locally disappear.

Transient simulations across a relevant range of Reynolds and Froude numbers are made feasible by utilizing the stochastic one-dimensional turbulence (ODT) model. ODT aims to resolve vertical (wall-normal) transport processes on all relevant scales for a one-dimensional domain. Deterministic molecular diffusion and Coriolis forces are directly resolved, whereas turbulent advection is modeled by a stochastic process. The model obeys several relevant physical principles as, for example, Richardson's 1/4 law of stratified turbulence. Preliminary results suggest that the stand-alone model generally captures Reynolds (turbulence) and Froude number (stratification) effects when stratification is weak. For low Froude number (strong stratification), these results indicate that the model tends to overestimate turbulence effects near the surface unless stratification becomes so strong that near-surface turbulence is energetically prohibited.

In the talk, we will address the model formulation and its application to Ekman flow. We will show and discuss model results for surface fluxes, boundary-layer profiles, and corresponding fluctuation statistics. In addition, we will discuss stratification effects and comment on their representation in the model.