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Numerical study of buoyancy reversal in stably stratified flows

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Recent work suggests that shallow cumulus convection is the major point of departure among climate-model representations of climate sensitivity. A characteristic feature of the stratocumulus-topped boundary layer (STBL) is the contact discontinuity, and accompanying sharp temperature inversion, that separates the top of the cloud from the overlying quasi-laminar, free troposphere. This temperature inversion resists the tendency of the underlying turbulent layer to grow through entrainment into the free-troposphere, which allows the lower layer to moisten and clouds to develop therein. This sharp transition and the importance of the mixing between the two layers, greatly frustrates attempts to represent the STBL numerically, e.g. via large eddy simulation (LES), due to insufficient resolution.

The subtile small scale interaction of molecular effects and turbulence might only be accessed using direct numerical simulation (DNS) and stochastic turbulence models where the latter keep full resolution of physical processes at least in one dimension.

First we will present results of a stochastic one-dimensional mixing model used to explore laboratory analogs to the cloud top mixing problem. Here radiatively induced buoyancy reversal is investigated. Further we explore the buoyancy reversal problem using 2D and 3D DNS. The basic configuration now is a two-layer system, stably stratified because of the temperature difference between the two layers but undergoing evaporative cooling in the mixing regions, which may lead to buoyancy reversal.