STOCHASTIC PARAMETERIZATION OF TURBULENCE: WHY AND HOW?

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Numerous studies have shown that the nocturnal or stable boundary layer (SBL) tends to manifest itself in distinct regimes, namely a weakly stable and a strongly stable regime. Sudden transitions between fully turbulent states and quiescent, quasi laminar states have been highlighted by observational and modelling studies. Such rapid transitions have important consequences on the level of mixing with the higher levels of the atmosphere. Numerical weather prediction and climate models encounter challenges in accurately representing the distinct flow regimes and transitions between them, leading to an inadequate depiction of regime occupation statistics. To improve theoretical understanding, we use stochastic conceptual models as a tool to systematically investigate what types of unsteady flow features may trigger abrupt transitions in the mean boundary layer state. The findings show that simulating intermittent turbulent mixing may be key in some cases, where transitions in the mean state follow from initial transient bursts of mixing.

Turbulent mixing is a parameterized process in atmospheric models, and the theory underpinning the parameterization schemes (Monin Obukhov Similarity Theory, MOST) was developed for homogeneous and flat terrain, with stationary conditions. The parameterized turbulent mixing lacks key spatio-temporal variability that induces transient perturbations of the mean dynamics. This variability could be effectively included via stochastic parameterization schemes, provided one knows how to define the strength or memory characteristics of random perturbations. Towards that goal, we use a systematic data-driven approach to quantify the uncertainty of parameterisations and inform us on how and when to incorporate uncertainty using stochastic models. Applying this approach on field measurements results in a stochastic generalization of Monin Obukhov Similarity Theory that alters the turbulent momentum diffusion and accounts for sporadic events of possibly unknown origin that cause unsteady mixing. The stochastic formulation accommodates both the short-term intermittent behavior and the long-term averages. It could thus present a way forward for dealing with the complexities of unsteady flows in numerical weather prediction or climate models.