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Capturing the Variability of the Nocturnal Boundary Layer through Localized Perturbation Modeling

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Numerical weather prediction and climate models encounter challenges in accurately representing flow regimes in the stably stratified atmospheric boundary layer and the transitions between them. This leads to an inadequate depiction of regime occupation statistics and, therefore, to biases in forecasts of near-surface temperature. To explore inherent uncertainties in modeling regime transitions, the response of the near-surface temperature inversion to transient small-scale phenomena is analyzed based on a stochastic modeling approach. A sensitivity analysis is conducted by augmenting a single-column model for the atmospheric boundary layer with deterministic perturbations accounting for small-scale fluctuations in the wind and temperature dynamics and with a stochastic stability function to account for turbulent bursts. The model is a tool to systematically investigate what types of unsteady flow features may trigger abrupt transitions in the mean boundary layer state. Previous research showed that incorporating enhanced mixing, a common practice in numerical weather prediction models, blurs the two regime characteristics of the stably stratified atmospheric boundary layer. Simulating intermittent turbulence through a stochastic stability function is shown to provide a potential workaround for this issue. Including key uncertainty in models could lead to a better statistical representation of the regimes in long-term climate simulation.