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Surface heterogeneity and atmospheric stability effects on land-atmosphere interactions from large-eddy simulations with dynamic subgrid models

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The parameterization of regional-scale turbulent fluxes over heterogeneous terrain relies on our understanding of the complex coupling between land surface characteristics and atmospheric boundary layer (ABL) dynamics. Atmospheric stability and its interaction with surface heterogeneity add a level of complexity that is not captured by current turbulent flux parameterizations. Improving our understanding of the combined effects of surface heterogeneity and atmospheric stability requires detailed and accurate knowledge of the spatial and temporal distribution of the turbulent velocity and temperature fields. To obtain this information, we use large-eddy simulations (LESs) with state-of-the-art scale-dependent dynamic Lagrangian subgrid-scale (SGS) models for both the SGS stress and the SGS flux. These models require no tuning since the model coefficients are computed dynamically based on the dynamics of the resolved scales. The simulations are run with different synthetic surface roughness patterns under weak and moderately stable atmospheric stability. Results from the simulations are used to study the effect of stability on the local flow characteristics, and the ability of the dynamic SGS models to adjust in a consistent manner. The simulations are also used to assess the applicability of Nieuwstadt's local scaling hypothesis to heterogeneous stable ABLs. These results are expected to add further understanding of the limitations of current stability parameterizations used in large-scale weather and climate models.