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A large-eddy simulation study of turbulent flow over multiscale topography

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Most natural landscapes are characterized by multiscale (often multifractal) topography with well-established scale-invariance properties. For example, the spectral density of landscape elevation fields is often found to have a power-law scaling behavior (with a -2 slope in log-log scale) over a wide span of spatial scales, typically ranging from tens of kilometers down to a few meters. Even though the effect of topography on the atmospheric boundary layer (ABL) has been the subject of numerous studies, few of them have focused on multiscale topography. In this study, Large-Eddy Simulation (LES) is used to investigate boundary layer flow over multiscale topography, and guide the development of parameterizations needed to represent the effects of subgrid-scale (SGS) topography in numerical models. Particular emphasis is placed on the formulation of an effective roughness used to account for the increased aerodynamic roughness associated with SGS topography. The LES code uses the scale-dependent Lagrangian dynamic SGS model for the turbulent stresses (Stoll and Porté-Agel, 2006) and a terrain-following coordinate transformation to explicitly resolve the effects of the topography at scales larger than the LES resolution. The terrain used in the simulations is generated using a restricted solid-on-solid (RSOS) landscape evolution model, and it is characterized by a -2 slope of the elevation power spectrum, similar to that of natural landscapes. Results from simulations performed using elevation fields filtered at different spatial resolutions indicate a clear scaling region of the effective roughness with SGS standard deviation of elevation.