Implementation and Evaluation of 3D radiative transfer parameterizations to represent topographic effects in the E3SM land model

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Effects of mountain, vegetation structure and snow impurities on the surface radiation budget have been investigated and evaluated in stand-alone land, regional, and global atmospheric models. However, no complete and inherently consistent land surface radiation transfer treatment (e.g. mountains, multi-layer canopy, and snow) has been implemented in any CMIP6-class Earth System models (ESMs). At the first stage, we mainly focus on the radiation flux parameterization accounting for the effects of mountain shading and multiple reflections between mountains and snow in the Energy Exascale Earth System Model (E3SM). Currently, most ESMs adopt a plane-parallel (PP) radiative transfer schemes which assume the terrain is flat and simply neglect the topographic effects. In this study, we first incorporated a well-validated radiation transfer parameterization to quantify the effects of three-dimensional (3-D) topography on surface radiation flux, including the shadows and multiple reflections between surfaces, in the E3SM land model. We further used the improved E3SM land model to evaluate the topographic effects on surface energy balance at different spatio-temporal scales. We also used the Moderate Resolution Imaging Spectroradiometer (MODIS) data to evaluate the performance of the E3SM land model with and without topographic parameterization. The results show that topography has non-negligible effects on surface energy budget and snow cover. Incorporating the topographic effects reduces the biases of E3SM's simulated land surface albedo with MODIS data over mountainous areas. Such improvements will contribute to advancing our understanding of role of the surface topography in the Earth's land-atmosphere interactions.