Title: Topographic controls on scaling of hydrologic and thermal processes in polygonal ground features of an Arctic ecosystem

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Abstract

Arctic and sub-Arctic soils currently contain approximately 1700 billion metric tones of frozen organic carbon, approximately 200 times current annual anthropogenic emissions. This carbon is vulnerable to release to the atmosphere as CO_2 and CH_4 as high-latitude temperatures increase due to climate change. Microtopographic features, such as polygonal ground, are characteristic sources of landscape heterogeneity in the Alaskan Arctic costal plain. Polygonal ground structures, with high or low centers, influence the distribution of snow depth, thereby impacting the energy balance, biogeochemical dynamics, vegetation communities, and carbon releases from the subsurface. In spite of the importance of heterogeneous snowpack on local hydrologic and thermal processes, they are not explicitly accounted for in land surface models.

In this study, we develop a snow redistribution algorithm, which accounts for microtopography, in the Community Land Model (CLM4.5). We perform simulations for four sites in Barrow, AK at multiple horizontal resolutions across several years with imposed soil heterogeneity. Results indicate that heterogeneous distribution of snow, accumulated during winter months, has a strong influence on spatial distribution of active layer depth and surface energy fluxes during the summer season. In winter, soil temperature variance (σ_T^2) exhibits a non-linear relationship with spatial scale. Coarse resolution simulations under predict σ_T^2 when compared to the spatial average of the fine resolution simulations. Lastly, we investigate the role of 3D versus 1D subsurface thermal processes by including lateral subsurface thermal transport in CLM4.5. The 3D process representation leads to lower winter soil temperature variability when compared to 1D simulations.