Simulating the Impact of Regional Subsidence and Polygonal Ground Degradation on Arctic Permafrost Hydrology

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Many permafrost-affected regions in the Arctic manifest a polygonal-patterned ground, which is characterized by large carbon stores and vulnerability to climate change. In these areas, warming temperatures drive melting of ice wedges and distributed bulk ice, resulting in systematic polygon degradation and subsidence, and thawing of the underlying carbon-rich soils, resulting in increased decomposition rates. Predicting the fate of this carbon is difficult. The system is controlled by complex, nonlinear physics coupling biogeochemistry, thermal-hydrology, and geomorphology, and there is a strong spatial scale separation between microtopography (at the scale of an individual polygon) and the scale of landscape change (at the scale of thousands of polygons). The Next Generation Ecosystem Experiment – Arctic has developed a multi-scale, process-rich modeling strategy for understanding how geomorphology and thermal-hydrology combine to determine the hydrologic environment as these soils thaw. Over the life of the project, physics-based models were developed, and scaling strategies to move from fine-scale, mechanistic models of individual polygons to intermediate-scale models over many polygons have been developed. Here we demonstrate how the resulting multi-scale strategy can be used to study the interplay between thermal-hydrology and geomorphology. It has long been hypothesized that regional subsidence, caused by melting of distributed bulk ice, can decrease porosity, resulting in apparently wetter soil. Polygon degradation has been shown to increase the connectivity of flow pathways, resulting in better drainage and apparently drier soil. We demonstrate that our model can represent those effects individually, and begin to address how the competing effects collectively determine the evolution of polygonal tundra hydrology in a warming climate.