Poster #216

Intermediate-scale Simulations of Thermal Hydrology of Polygonal Tundra

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Current environmental system simulation software tools often lack the flexibility to efficiently implement the thoughtful approximations that are critical to effective simulations of environmental systems. The Interoperable Design of Extreme-scale Application Software (IDEAS) project is addressing this barrier to productivity using integrated surface/subsurface thermal hydrology of thawing polygonal tundra as a use case. Simulating the soil thermal hydrology system in degrading permafrost regions is challenging because of strong coupling among thermal and hydrologic processes, the important role of organized microtopography in controlling water flows, strong coupling between the surface and subsurface, and the potential for topographic changes as ground ice melts. To address those challenges, we have implemented an intermediate-scale model using the ATS software (Painter et al. 2016). The computational strategy uses individual ice-wedge polygons as the horizontal discretization of the landscape. Associated with each ice-wedge polygon is a one-dimensional column comprising subsurface, a surface water reservoir, snow pack, and a surface energy balance. Those columns are simulated independently, then coupled indirectly through an overland flow system. Effects of neglected microtopography are included through subgrid parameterizations informed by fine-scale simulations. Results using this mixed-dimensional model structure compare well with fully three-dimensional simulations, but with significantly smaller computational burden. Projections of a 468-polygon region of the Barrow Environmental Observatory to year 2100 combine fine- and intermediate-scale simulations, and thus demonstrate part of the Next Generation Ecosystem Experiments-Arctic (NGEE-Arctic) scaling strategy. Inundation fractions extracted from those intermediate-scale simulations provide the additional link to climate-scale simulations. Simulations that include thaw-induced subsidence become tractable in our intermediate-scale model because the subsurface thermal hydrology and deformation processes are represented on independent one-dimensional columns. In addition, the mixed-dimensional spatial structure has broader applicability in watershed modeling. Managing the multiple meshes and multiple process representations in these intuitively appealing mixed-dimensional simulations is a significant software challenge. As part of the IDEAS project's broader goal of enabling a "virtual ecosystem" of composable software components, this Use Case demonstrates how a configurable model coupling system (Coon et al. 2016) can enable this class of multiscale, multiphysics models.