Fine-scale modeling of permafrost using the Advanced Terrestrial Simulator

Data collected by the NGEE Artic team at the Barrow Environmental Observatory (BEO) is refining the Advanced Terrestrial Simulator (ATS) and, conversely, ATS is informing field studies. Through this ModEx strategy, the fine scale modeling team and collaborators in NGEE Arctic are gaining understanding of permafrost change in a changing climate. The ATS is a hydrothermal model built using a modern modular computational framework to address complex multi-physics problems, which includes a snow surface energy balance, coupled with a variably saturated subsurface thermal hydrology model.

Our modeling has improved our understanding of fine-scale processes in the Arctic permafrost and identified fine-scale phenomena that have large-scale implications. Multipoint calibration identified model structural adequacy and led to refinements in ATS including a more observation-consistent subsurface model and improved snow representation. Projections of permafrost thaw through the end of this century subjected to calibration-constrained soil property uncertainty indicated a factor of 3 increase in active layer thickness (maximum annual thaw depth). Comparisons of the effect of soil property uncertainty to climate model selection uncertainty indicated that while soil properties are a significant contributor to permafrost thaw projection uncertainty, climate model selection uncertainty is larger. We quantified the relative affect of three dominant environmental conditions, organic layer thickness, snowdepth, and amount of water on the landscape. Furthermore, sensitivity analysis using ATS identified the canceling effects of interaction between increased latent heat demand and thermal conductivity due to variable saturation.

Given these advances in NGEE Arctic Phase 1, we look forward to coming work in Phase 2, especially continuing efforts to incorporate NGEE field data into fine-scale models. We will describe the integration of geophysical forward modeling into ATS, focused on the integration of electrical resistivity tomography (ERT) surveys with ATS hydrothermal simulations. The results of this work will be a joint inversion framework for coupling ERT surveys and ATS simulations. Similarly, models are being evaluated using the Barrow tracer experiment to gain understanding of the role of lateral flow within a polygon. And finally, we will discuss plans for Seward Peninsula models as NGEE Arctic moves to this new field site.