Using fine-scale models to inform next-generation Earth system models

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Understanding and predicting the impacts of and feedbacks on climate in the terrestrial Arctic is made difficult by two major issues – the extreme complexity of the coupled thermal-hydrological-mechanical-biogeochemical system, and the differences in scale between the coarse scale at which Earth system models run and the fine scale at which physical process descriptions and many field measurements are appropriate. In NGEE Arctic, we have made extensive use of fine-scale models as an integration tool, interpreting existing and new observations at a scale relevant to that observation. In turn, the fine-scale model is used to inform decisions on how to appropriately represent processes in Earth system models.

Here we discuss one of NGEE Arctic's fine-scale simulation capabilities -- the Arctic Terrestrial Simulator (ATS), describing how it can be used as this integration tool and demonstrating ongoing work in fine-scale modeling. We demonstrate how ATS builds on Arcos, a strategy for managing complexity and enabling experimentation with process representation. Arcos enables process-rich modeling capabilities by allowing complexity to be extended incrementally, with testing, validation, and ModEx-driven calibration at each step to build trust in the model. We show a workflow in which remote sensing and field observations are used to develop meshes, inform spatially distributed parameters, and provide input data for simulations. And finally, we show ATS's value as a model experimentation and predictive tool, enabling flexibly configured, process-rich simulations of ecosystems in a variety of dimensions, at a variety of spatial and temporal resolutions, and with a variety of process complexities. As a key component in NGEE Arctic's strategy, we show how application of ATS and fine-scale models to 2 and 3D domains is being used to understand the interplay between micro-topography in ice-wedge polygon landscapes and thermal hydrologic response and its evolution with a warming climate.