Next-Generation Ecosystem Experiments (NGEE Arctic)

Extended Project Abstract

An important challenge for Earth System models is to properly represent the land surface. This can be problematic, yet failure to identify and appropriately account for complexities at the landscape scale can compromise climate predictions. The Next-Generation Ecosystem Experiments (NGEE Arctic) project will address this challenge for sensitive and rapidly changing ecosystems of the Arctic tundra through a combination of field and laboratory studies, observations, and multi-scale model simulation. A focus on model-data integration and scaling based on geomorphological units will allow us to deliver **a process-rich ecosystem model, extending from bedrock to the top of the vegetative canopy, in which the evolution of Arctic ecosystems in a changing climate can be modeled at the scale of a high resolution Earth System Model grid cell (i.e., 30x30 km grid size).**

A distinguishing characteristic of the Arctic tundra, especially the coastal plains of the North Slope is the existence of recognizable and quantifiable landscape units which are repeated over large domains, and which occur at multiple spatial scales. These include active thaw lakes, drained thaw lake basins, and ice-rich polygonal ground that consist of low-, high-, and transitional polygons. Our scaling approach will build on the hypothesis that the transfer of information across spatial scales can be organized around these discrete geomorphological units for which processes are represented explicitly at finer scales, with information passed to coarser scales through sub-grid parameterization of Earth System models. By extending an already well-established framework for fractional sub-grid area representations to allow dynamic sub-grid areas and hydrological and geophysical connections among sub-grid units, we expect to be able to characterize permafrost dynamics and the influence of thermokarst at multiple spatial scales in Arctic tundra landscapes. Our fundamental scaling approach will be to identify processes likely to have the largest influence on climate, based on current knowledge of the Arctic tundra system, and then to define a nested hierarchy of modeling necessary to resolve those processes. This approach allows us to integrate new knowledge into a climate model, while establishing a quantitative framework connecting this scale to more process-rich models implemented at finer spatial resolution and over smaller spatial domains. Process studies and observations of hydrology, geomorphology, biogeochemistry, vegetation patterns, and energy exchange and their couplings will be undertaken to populate the hierarchical modeling framework and to achieve a broader goal of optimally informing process representations in a global-scale model. Field activities to inform model development will be carried out across a gradient of polygonal ground nested within a chronosequence of drained thaw lake basins near Barrow, Alaska. Geophysical characterization of these sites will be essential as we describe critical surface-subsurface variability and interactions, as will assessments of fine-scale topography that controls local hydrology. Process studies and observations that have the greatest potential for reducing prediction uncertainty have been prioritized, including studies focused on improving the mechanistic understanding of permafrost degradation and its influence on water distribution; quantifying mechanisms and rates associated with organic carbon decomposition in Arctic soils; and developing response functions relating plant community composition and phenology to resource gradients created by high-centered and low-centered polygons and other thermokarst features. Insights generated from these studies will provide improved model algorithms and constraints to model algorithm parameterization; model initialization, and evaluation. A metric of effectiveness for our scaling approach will be the degree to which prediction at each successive scale is improved as the result of iterative scaling. The NGEE Arctic project will implement innovative communication and data management strategies as we work both within a multi-disciplinary team environment and with the larger scientific community to chart a course for an improved process-rich, high-resolution Arctic terrestrial simulation capability.

Contact: Stan D. Wullschleger, NGEE Arctic Project Director
Email: wullschlegsd@ornl.gov