Process Studies and Observations in the Arctic to Inform a Hierarchical Scaling Framework for Improved Climate Predictability

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Introduction

A fundamental goal of the Next-Generation Ecosystem Experiments (NGEE Arctic) project is to improve climate prediction through process understanding and representation of that knowledge in Earth System models. A comprehensive suite of process studies and observations of hydrology, geomorphology, biogeochemistry, vegetation patterns and energy exchange, and their couplings and dependence on landscape characteristics, will be undertaken. These laboratory, in-situ and remote sensing activities will be strongly linked to model development and application requirements in order to improve process representation, initialize multi-scale model domains, calibrate models and evaluate predictions.

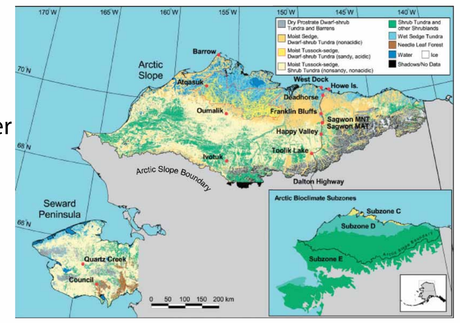
Southern Seward Peninsula

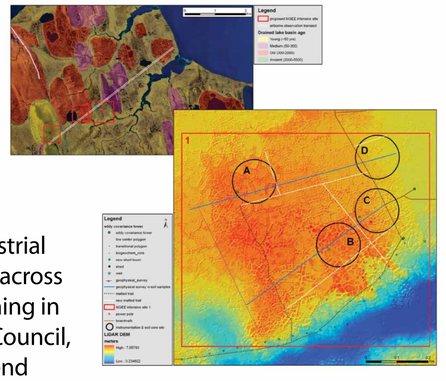
Alaska Coastal Plain

Photos by C. Wilson

Site Selection and Observation Framework

A central focus of the NGEE Arctic project is to advance process understanding and prediction of the hydrologic and thermal responses and feedbacks to climate-driven active layer deepening, ground ice degradation and thermokarst development in ice-rich landscapes and how these changes will control the spatial and temporal availability of water for biogeochemical, ecological, and physical feedbacks to the climate system. How the landscape evolves with climate change will depend on a hierarchy of environmental factors including climate, geology, elevation, geomorphic processes, and hydrology, which together determine soil biogeochemistry and vegetation type.





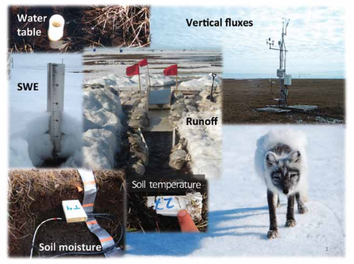
NGEE proposes to undertake terrestrial process research within a transect across a suite of bioclimatic zones beginning in Barrow, Alaska, and extending to Council, Alaska. These two sites represent end members of the bioclimatic transect. Barrow is characterized by flat terrain, deep continuous permafrost, hundreds of shallow thaw lakes, and Drained Thaw Lake Basins (DTLBs), abundant polygonal ground, and wet graminoid and moss tundra vegetation. Council is characterized by hills, shallow discontinuous permafrost, deep dynamic thermokarst ponds, and erect shrub tundra with sparse spruce vegetation. Other locations will be considered.

Process Science

We will focus initial research on the Barrow area, where we will undertake process studies across a gradient of polygonal ground types nested within a DTLB age gradient. The timing of lake drainage determines the development of micro-topography due to the formation of polygonal ground and its evolution through ice wedge development and degradation cycles. Slight changes in elevation (sub-meter to meters) lead to dramatic variation in local hydrologic conditions that favor different plant species and soil biogeochemistry.

Hydrology and Geomorphology

activities aim to advance process understanding and prediction of climate-driven Arctic landscape evolution and its impact on Arctic hydrology. Key process needs include



- Mechanisms and controls relating to permafrost and ground ice stability and frost table dynamics
- Interactions between thermal, hydrologic, and soil mechanical processes
- The spatial and temporal distribution, and lateral and vertical fluxes, of surface and subsurface heat and water

Biogeochemistry

activities will focus on reducing uncertainty in models' greenhouse gas response functions attributable to impacts on C turnover times associated with

- Temperature, moisture and aqueous chemistry (e.g., pH and redox potential)
- Soil organic matter structure and chemistry
- Sorption and physical protection by soil minerals
- Freeze-thaw cycles and microbial adaptation

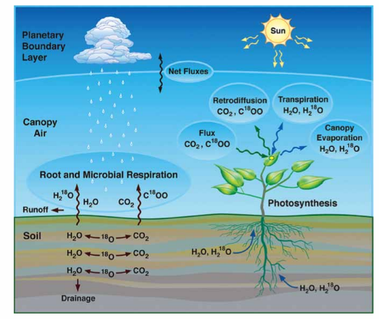
Vegetation Dynamics

tasks aim to describe and quantify the mechanisms that drive structural and functional responses of the tundra plant community to changing resource availability. Our approach will rely on the use of plant functional types (PFTs), which group plant species according to common morphological or physiological traits (e.g., broadleaf woody plants, sedges, mosses, and lichens). We will focus on

- Observations to estimate current PFT distribution across the landscape
- Data to inform functional relationships describing GPP of arctic PFTs
- Process understanding to project how PFT distribution will change with permafrost degradation

Integrated Process Understanding with Isotopes

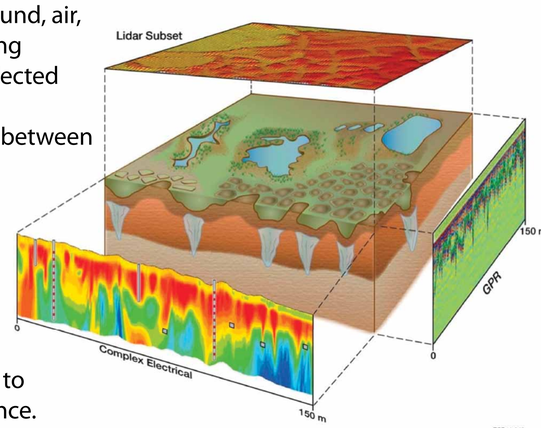
Stable and radiogenic isotope measurements will be made to understand the processes controlling coupled carbon and water cycles. ^{14}C will be used to understand soil organic matter turnover time and the age of carbon respired in CO_2 and CH_4. Stable isotopes will be used to characterize evapo-transpiration for Arctic vegetation, track hydrologic pathways and differentiate plant and microbial respiration.



Riley et al. 2002, 2003

Observations to Initialize and Evaluate Models

Multi-scale in-situ and ground, air, and satellite remote sensing measurements will be collected and analyzed to develop quantitative relationships between readily classified remote sensing features and surface and subsurface properties and process domains. The derived observation products will be used to initialize and calibrate models, and to evaluate model performance.



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Conclusion

Multi-scale process observations from laboratory incubation experiments and vertical soil temperature measurements, to geophysical surveys of active layer depth and satellite surveys of NDVI will be used to improve process representation and initialize and evaluate models within the proposed scaling framework for improved climate prediction.

Next-Generation Ecosystem Experiments (NGEE Arctic)

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