Improved Climate Prediction through Process-Rich Understanding of Arctic Terrestrial Ecosystems

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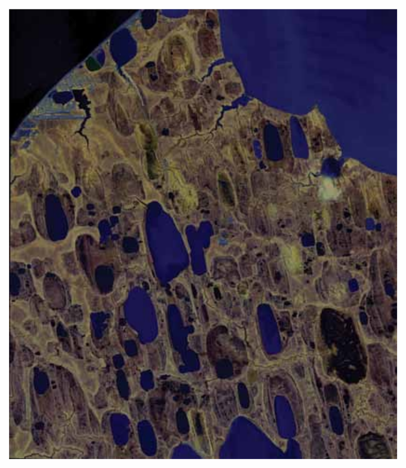
Introduction

Characterized by vast amounts of carbon stored in permafrost and a rapidly evolving landscape, the Arctic has emerged as an important focal point for the study of climate change. These are sensitive systems, yet the mechanisms responsible for those sensitivities are not well understood and many remain uncertain in terms of their representation in Earth System Models. Increasing our confidence in climate projections for high-latitude regions of the world will require a coordinated set of investigations that target improved process understanding and model representation of important ecosystem-climate feedbacks.

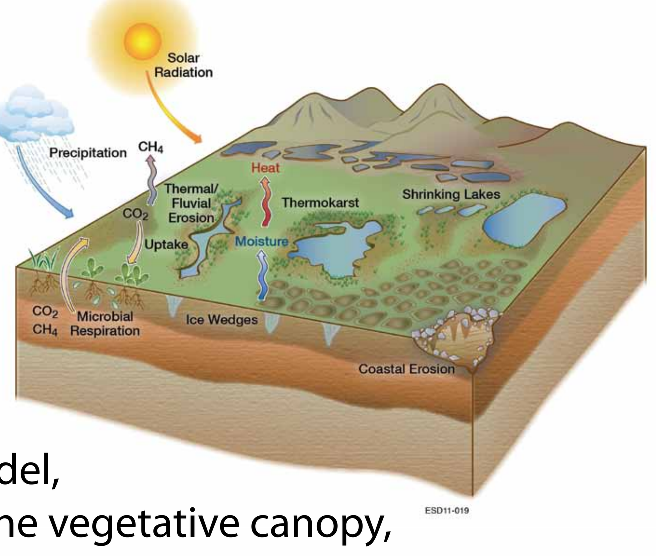
Scientific Challenge

The Next-Generation Ecosystem Experiments (NGEE Arctic) seeks to address this challenge by quantifying the physical, chemical, and biological behavior of terrestrial ecosystems in Alaska. Initial research will focus on the highly dynamic landscapes of the North Slope where thaw lakes, drained thaw lake basins, and ice-rich polygonal ground offer distinct land units for investigation and modeling. The project will focus on interactions that drive critical climate feedbacks within these environments through greenhouse gas fluxes and changes in surface energy balance associated with permafrost degradation, and the many processes that arise as a result of these landscape dynamics.



Satellite images (Terra/MODIS) of the coastal plains on the North Slope of Alaska. Distinct land units are evident and in the vicinity of Barrow can be categorized as thaw lakes, drained thaw lake basins, and interstitial polygonal ground.

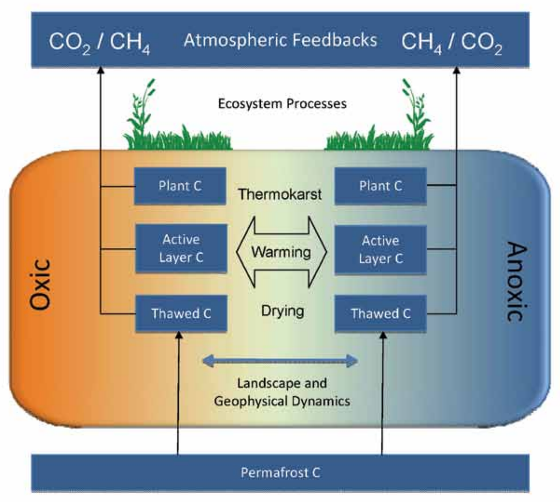
Vision of Integrated Experiment-Model Activities



The overarching goal of the NGEE Arctic project is to reduce uncertainty in climate prediction through improved representation of Arctic tundra processes. A focus on scaling based on process understanding and 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).

Executing This Vision Will Require

Mechanistic studies in the field and in the laboratory that target critical and interrelated water, nitrogen, carbon, and energy dynamics, and characterization of important interactions from molecular to landscape scales that drive feedbacks to the climate system.



Adapted from Schuur et al. 2008

Hydrology and Geomorphology

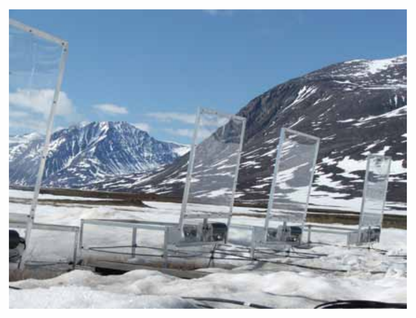
Permafrost thaw and degradation will lead to thermal erosion and thermokarst formation, with cascading effects on drainage networks, biogeochemistry, carbon fluxes, and vegetation.

Capabilities to measure and model consequences of permafrost degradation, landscape dynamics, and evolution of Arctic landscapes are needed for projections of future climate.

Representation of heterogeneity in Earth System Models will be advanced through new process algorithms that couple physical, chemical, and biological processes at local to regional scales.

Biogeochemistry

Greenhouse gas fluxes from degrading permafrost will depend on complex interactions at the soil column to landscape scales between hydrology, soil physical properties, and ecosystem dynamics.



Subsurface microbial, geochemical, and hydrologic processes that determine the fate of organic carbon will need to be characterized to better predict CO_2 and CH_4 fluxes from Arctic landscapes.

An improved understanding of organic matter vulnerability in thawing permafrost will greatly advance modeling of greenhouse gas flux from subsurface environments and the atmosphere.

Vegetation Dynamics

A shift in the distribution of plant communities will drive important interactions between ecosystems, carbon cycle processes, and local to regional energy balance.

Improved understanding of resource availability, particularly nitrogen and water, is needed to predict changes in plant community composition and expected feedbacks to atmospheric and climatic systems.

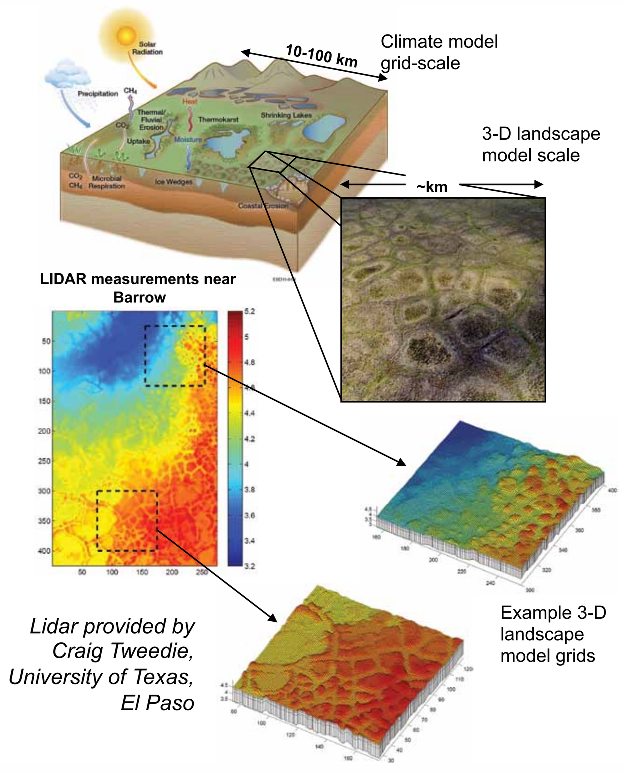
Quantifying processes that underlie vegetation dynamics will help refine models of Arctic ecosystems by linking biogeochemistry to land-climate models at regional to global scales.

Delivering on Expectations Will Also Require

A suite of climate-, intermediate- and fine-scale models to guide observations and interpret data, while process studies will serve to initialize state variables in models, provide new algorithms and process parameterizations, and evaluate model performance.

Process-rich land surface model

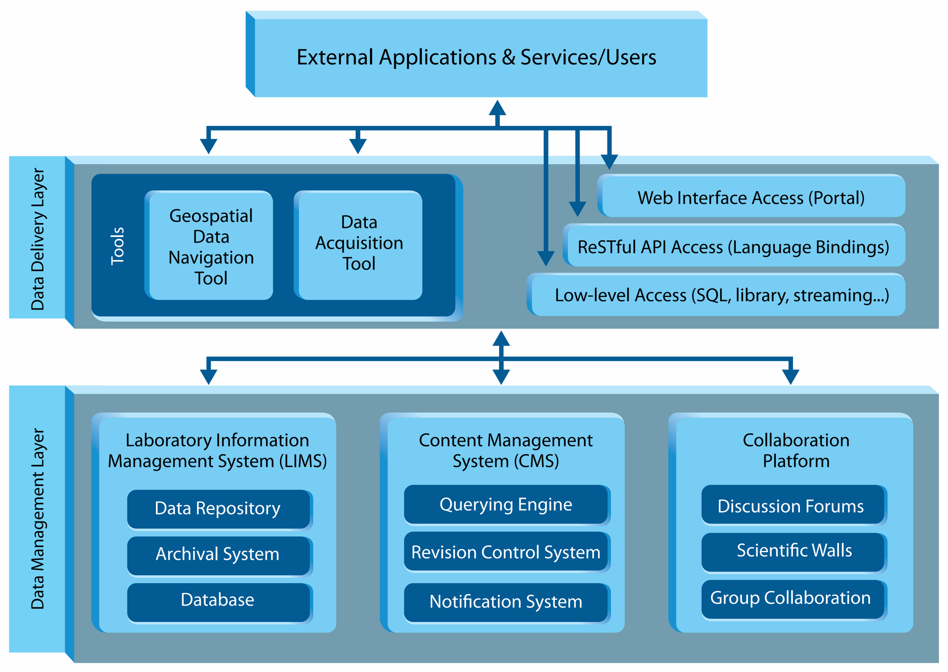
- New parameters and algorithms
  - Plant functional types
  - Nitrogen-driven photosynthesis
  - Rooting in the active layer
  - Biogeochemistry
  - Hydrology
- Initialization
  - Topography
  - Geophysical surveys
  - Plant distribution
  - Soil carbon stocks
- Evaluation
  - Eddy covariance
  - Water outflow
  - Albedo
- Discovery science



Lidar provided by Craig Tweedie, University of Texas, El Paso

Innovation in Communication and Data Management

The NGEE Arctic project will develop 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.



Next-Generation Ecosystem Experiments (NGEE Arctic)

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