Next-Generation Ecosystem Experiments-Arctic (NGEE)

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PROJECT WEBSITE: http://ngee.ornl.gov

Arctic tundra site on the Barrow Environmental Observatory, Barrow, Alaska

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PROJECT DESCRIPTION

The Arctic has emerged as an important focal point for the study of climate change. Characterized by its heterogeneous landscape and vast amounts of carbon stored in permafrost, this region is already experiencing rapid changes in climate, particularly temperature. It is a fragile landscape and highly sensitive to future environmental change. It is also a region that is critical to understanding how complex systems will respond to a changing climate *and* how processes underlying those changes can be represented in climate models. Improving climate prediction in high-latitude ecosystems will require understanding permafrost and snow dynamics and the many cascading impacts of a changing geophysical system on vegetation, subsurface processes, land-atmospheric interactions, and landscape processes.

In addressing this challenge, the Next-Generation Ecosystem Experiments (NGEE) project will address how experiments, observations, and process models can quantify the response of physical, ecological, and biogeochemical processes to atmospheric and climatic change across molecular to landscape scales. Our focus is on interactions that drive ecosystem-climate feedbacks through greenhouse gas fluxes and changes in surface energy balance. Fundamental knowledge will reduce uncertainty and improve representation of processes in Earth System Models. Specific goals are to:

- Understand and quantify the response and sensitivity of physical, ecological, and biogeochemical processes to atmospheric and climatic change across molecular to landscape scales, focusing on important interactions that drive regional and global climate feedbacks through greenhouse gas fluxes and changes in albedo.
- Use fundamental knowledge to improve representation of ecosystem dynamics, subsurface biogeochemistry, and land-atmosphere processes in regional and global models to reduce uncertainty and improve prediction of climate change in high-latitude ecosystems.

Our research approach is to conduct field and lab experiments and observations that together will advance our understanding of system-level behavior. Across these studies we will implement advanced monitoring approaches to quantify how continuous and threshold-dominated permafrost dynamics vary as a function of physical heterogeneity and temperature, and how these dynamics impact resource availability and microclimate that are important to the structure and function of tundra plant and microbial communities. Changes in vegetation dominance between shrubs, grasses, and forbs will create substantial ecosystem-climate feedbacks through changes in albedo, energy exchange, snow depth, timing and extent of permafrost thaw, microbial activity, and

CO_2 and CH_4 uptake and release. The timing, rate, amount, and spatial distribution of greenhouse gas emissions from degrading permafrost will depend on complex interactions at the soil column to landscape scales between hydrology, soil physical and mechanical properties, above- and below-ground ecosystem processes, and soil carbon content and characteristics. It will be especially important that we identify key plant and microbial community interactions with the use of genomic, metabolomic and proteomic tools and measure CO_2 and CH_4 production in the field as well as in highly-instrumented microcosm and mesocosm studies.

US Army Corps of Engineers (USACE) Permafrost Tunnel Research Facility Fairbanks, Alaska

SIGNIFICANCE

Prediction of global climate change at decadal to century time scales requires Earth system models that couple physical, biological, and ecological processes, capturing the most significant climate change drivers and representing critical feedback mechanisms. Unfortunately, while current models represent many of the processes that govern important land-atmosphere interactions, there is a continuing need for data to represent new processes in models, constrain model predictions, and test models against experimentally-derive datasets. Scientific investigation of the response of Arctic ecosystems to climate is critical to our overall understanding of the impacts of global environmental change. This is because this region is currently experiencing rapid changes in the climate system, the biophysical system of the Arctic is particularly vulnerable to these changes, and there is currently large uncertainty in the net effect of these biophysical changes and their feedbacks to climate. Current changes observed in the Arctic system may be a harbinger of near-future changes and their regional to global impacts at other latitudes.

Scientists observing Permafrost tunnel at USACE Permafrost Tunnel Research

INTERESTING FINDINGS

Understanding the vulnerability of Arctic ecosystems to climate change and their potential feedbacks at regional to global scales will require that we quantify mechanisms of response through process-level studies tied directly to GCM-scale process representations, and that we characterize spatial variation in mechanisms through observations. Such an effort will require that we use that fundamental knowledge to improve representation of ecosystem dynamics, biogeochemistry, hydrology, and land-atmosphere feedbacks in regional and global models to reduce uncertainty and improve prediction of climate and climate change in high latitude ecosystems. The NGEE project will describe how experiments, observations, and process models can address the sensitivity and vulnerability of Arctic ecosystems to atmospheric and climatic change. Field and laboratory studies will span genomics to geophysics, and will benefit from a bottom-up and top-down approach to understanding system complexity. This approach paces a priority on our ability to design experiments and observations that together aim to understand the interactions and feedbacks that occur between biological, geochemical, and landscape processes in the Arctic. Such an approach must consider how different components of complex systems are linked, and the interplay in space and time that determines system behavior.