Evaluating Spruce-Peatland Responses Under Climatic and Environmental Change Using An *In Situ* Field Manipulation

Paul J. Hanson[1], Randall K. Kolka[2], Richard J. Norby[1], Brian Palik[2], Stan D. Wullschleger[1], Charles T. Garten Jr. [1], Stephen D. Sebestyen[2], Peter E. Thornton[1], John Bradford[2], Patrick J. Mulholland[1], Donald E. Todd[1], Colleen Iversen[1] and Jeffrey Warren[1]

[1]Environmental Sciences Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee
[2]USDA Forest Service, Marcell Experimental Forest, Grand Rapids, Minnesota

Summary

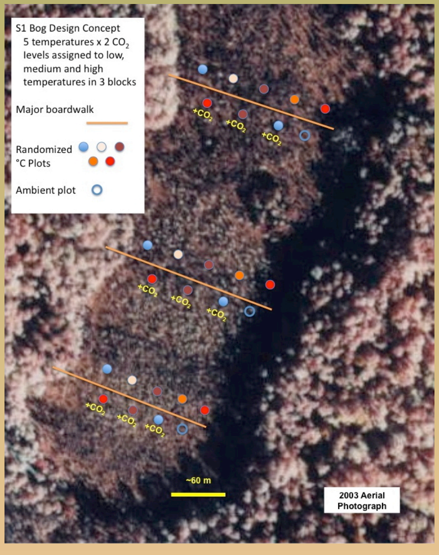
Identification of critical environmental response functions for terrestrial organisms, communities, and ecosystems to rapidly changing climate conditions are needed to evaluate ecological consequences and feedbacks. Such research has the most real-world relevance when conclusions are drawn from controlled manipulations operating in natural field settings. When fully constructed and instrumented, the experiment will provide a platform for testing mechanisms controlling vulnerability of organisms and ecosystems to important climate change variables (e.g., thresholds for organism decline or mortality, limitations to regeneration, biogeochemical limitations to productivity). The experiment will also allow for the evaluation of responses across multiple spatial scales including: microbial communities, bryophyte populations, various higher plant types, and some faunal groups. Direct and indirect effects of these experimental perturbations will be analyzed for the development and refinement of models needed for full Earth system analyses.

Science Questions

1.How vulnerable are terrestrial ecosystems and their component organisms to atmospheric and climatic change? Can we quantify the potential for shifts in local species dominance and regeneration success to assist projections of future biome changes over decades to centuries?
2.Will novel species assemblages or loss of species that result from species-specific responses to climatic and atmospheric change have unanticipated impacts on ecosystem processes? Do changes in ecosystem services precipitate a change in state (e.g., loss of a dominant plant functional type)?
3.What are the critical air and soil temperature response functions for ecosystem processes and their constituent organisms? Do those response functions for ecosystem processes depend on shifts in species interactions and composition?
4.Will full belowground warming release unexpected amounts of CO_2 and CH_4 from high-C-content northern forests.
5.To what degree will changes in plant physiology under elevated CO_2 (eCO_2) impact a species' sensitivity to climate or competitive capacity within the community?
6.Will ecosystem services (e.g., biogeochemical, hydrological or societal) be compromised or enhanced by atmospheric and climatic change?

Experimental Design

We are planning a large-scale, climate change manipulation focusing on the combined response of multiple levels of warming and elevated CO_2 exposures. Five warming levels from ambient to +8°C will be combined with additional elevated CO_2 exposures (800 to 900 ppm) for the ambient, +4°C and +8°C warming treatments. The experiment will be replicated in three blocks. Such an experiment will evaluate the response of existing biological communities to a range of warming levels from ambient to +8°C. The ambient, +4°C and +8°C warming treatments will also be conducted at eCO_2 (in the range of 800 to 900 ppm).



Target Ecosystem

The experiment will be conducted in a *Picea mariana* [black spruce] – *Sphagnum* spp. forest in northern Minnesota. This forest type is located at the southern extent of the spatially expansive boreal peatland forests is considered to be especially vulnerable to climate change and to have important feedbacks on the atmosphere and climate through changes in net emissions of CO_2 and CH_4.

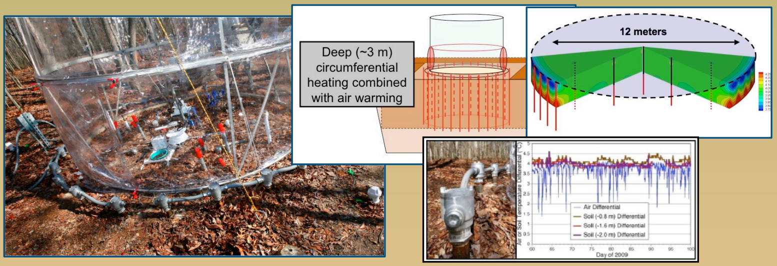
The planned experimental site is an ombrotrophic bog within the Marcell Experimental Forest (MEF; N 47° 30.171', W 93° 28.970'). The MEF is within the Laurentian Mixed Forest Province, which is a transitional zone between boreal and broadleaf deciduous forests.

Warming Technology

The experiment will employ a combination of large (12-m diameter) open-top aboveground enclosures and a new method for warming soils from the surface down to approximately 2 to 3 meters using circumferential vertical heaters to achieve the target levels of ecosystem warming. Forced–air heating will be used to warm an aboveground encircled treatment space. The final design will represent a compromise between a totally open system (too costly) and a constrained space that still allows substantial exposure of the treatment area to natural radiation, precipitation, and atmospheric deposition. Elevated CO_2 will be added during daytime hours of the active growing season (May through September) by injection into the heated air streams. Because the warming treatment will reduce the relative humidity of the air entering the open-top chambers, we will outfit all warmed plots with steam-generated humidity control systems under feedback control. Water vapor will be added in the inlet plenum during non-freezing conditions to maintain relative humidity (measured at 2 m above the ground) equal to that in the control chamber.

Because of the routinely high water tables in the *Picea-Sphagnum* bog under the current climate, we are contemplating a subsurface flow barrier approximately 2 to 3 m depth outside of the enclosures. We will design subsurface lateral water flow barriers to 1) maintain hydrological losses via evapotranspiration under extreme warming and to slow vertical flow through the underlying clay aquitard, and 2) prevent the lateral inflow of water into the treated areas.

Prototype-Scale Warming System



Planned Measurements

1.Plant Growth Responses
   Vascular plant production, Bryophyte production, leaf and litter production, belowground production
2.Plant Community Composition
   Tree demography, Understory communities (ericaceous shrubs, tree seedlings, forbs, *Sphagnum* spp.
3.Soil Microbial Community Composition
4.Phenology
5.Microtopography
6.Plant Physiological Responses
   Photosynthesis and respiration, water relations
7.Biogeochemical Cycling Responses
   Hydrologic cycle, Element cycles, Carbon stocks
8.Environmental monitoring
9.Mechanistic Modeling

Opportunities for Collaboration

1.Canopy albedo changes
2.Remote sensing of canopy function (NDVI, etc.)
3.Microscale LiDAR
4.Whole-chamber flux of CO_2 and water
5.Bole respiration
6.Biogeochemical cycling of trace elements (e.g., Hg)
7.Other trace gas emissions
8.Mycorrhizal studies
9.N fixation
10. Herbivory
11. Insect populations
12. Amphibian and reptile populations
13. Food web linkages
14. Lichen productivity and decomposition
15. Pest and pathogen interactions (host defenses vs. pathogen virulence

Sponsor: Office of Science, U.S. Department of Energy