Spruce and

- **eatland**
- Responses
 - **Under**
- Climatic and

Environmental Change

An experiment to assess the response of northern peatland ecosystems to increases in temperature and exposures to elevated atmospheric CO₂ concentrations

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ORNL Climate Change Response Science Focus Area

- Goal -- Execute targeted experiments to predict vulnerability of important terrestrial ecological systems and their function to projected changes in climate and atmospheric composition
- We are developing an experimental platform for testing mechanisms controlling vulnerability of organisms, ecosystems and ecosystem functions to a range of temperature and CO₂ treatments within an important high-carbon ecosystem
- Experimental Treatments
 - A range of elevated temperature treatments to as much as +8 or +9°C for both above- and belowground environments
 - Elevated atmospheric [CO₂] of 800 to 900 ppm to reflect current expectations for levels that may be associated with end-ofcentury temperatures



The Picea – Sphagnum Ecosystem



A Critical Ecosystem

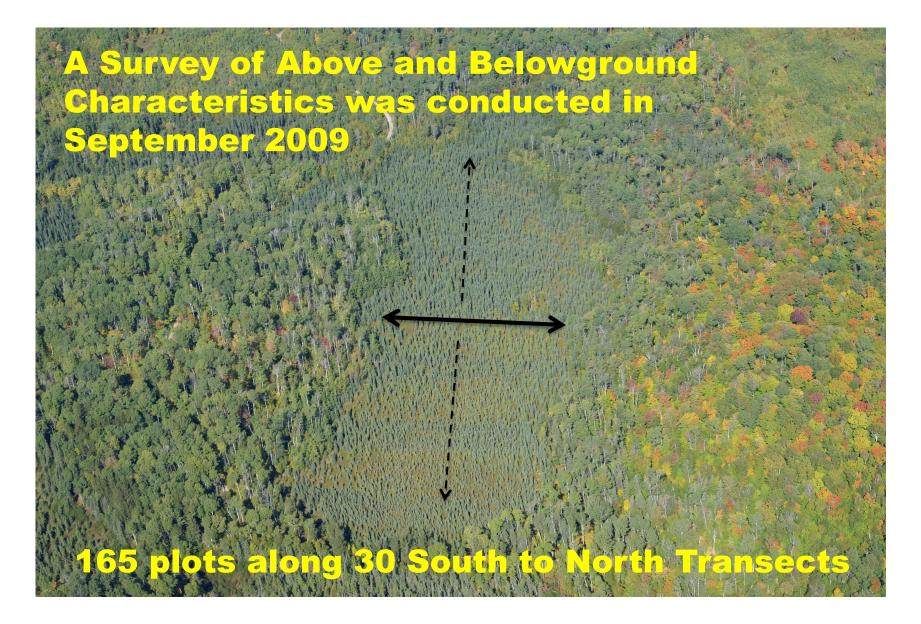
-The experiment will be conducted in a *Picea mariana* [black spruce] - *Sphagnum spp.* forest in northern Minnesota.

-This ecosystem located at the southern extent of the spatially expansive boreal peatland forests is considered vulnerable to climate change and is expected to generate important greenhouse gas feedbacks to the atmosphere under changing future climates.

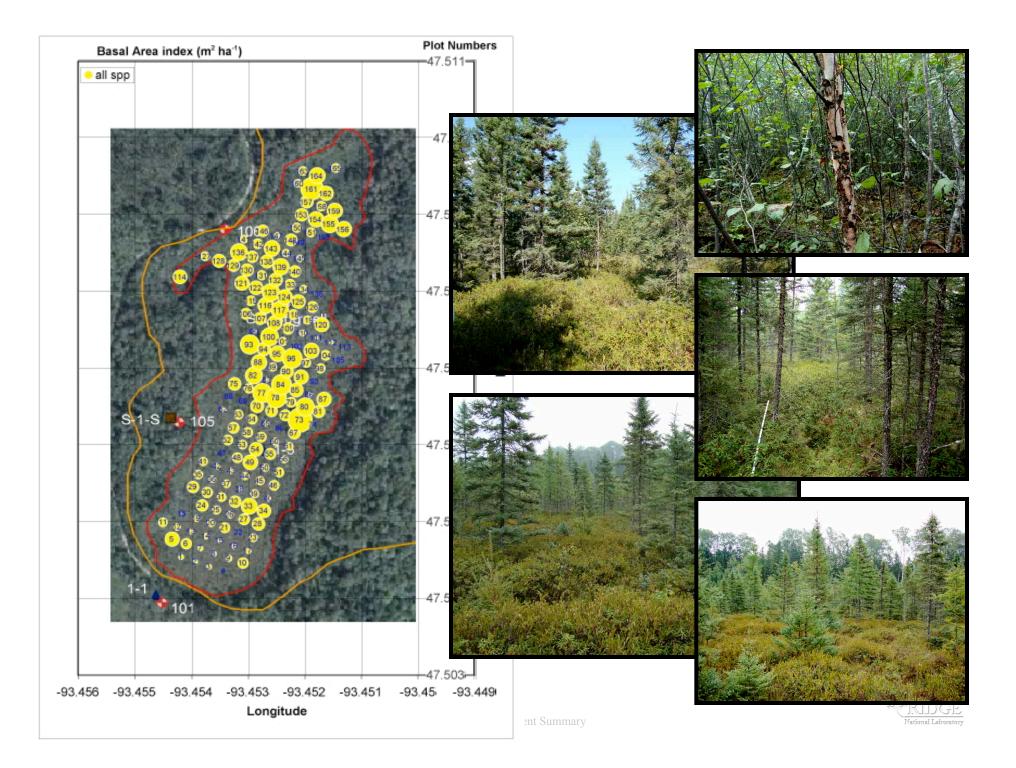
SPRUCE Science Questions

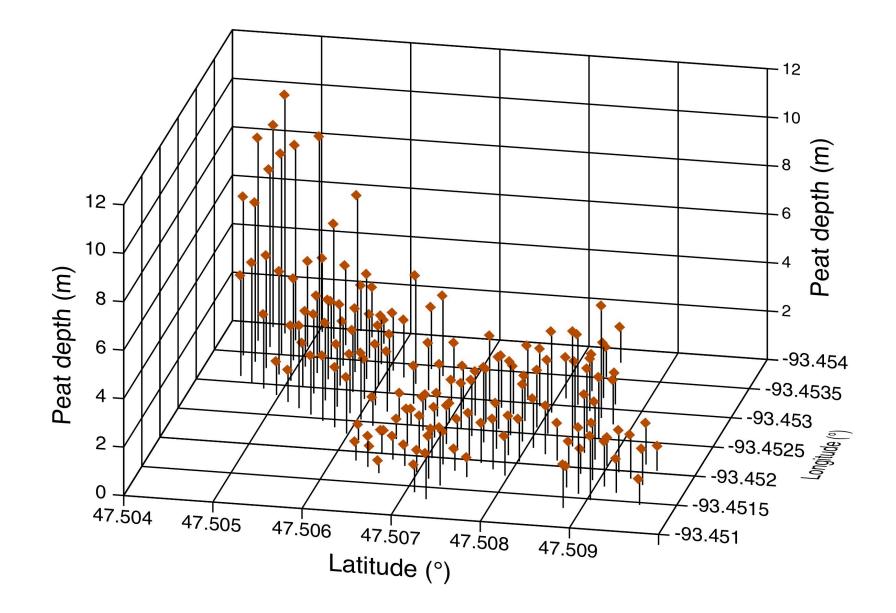
- How <u>vulnerable</u> are terrestrial ecosystems and their component organisms to atmospheric and climatic change?
- Will <u>novel species assemblages or loss of species</u> that result from speciesspecific responses to climatic and atmospheric change have unanticipated impacts on ecosystem processes?
- What are the <u>critical air and soil temperature response functions</u> for ecosystem processes and their constituent organisms? Do those response functions for ecosystem processes depend on shifts in species interactions and composition?
- Will full belowground warming result in <u>unexpected levels of CO₂ and CH₄</u> <u>emissions</u> from high-C-content northern forests.
- To what degree will changes in plant physiology under elevated CO₂ (eCO₂) impact a species' sensitivity to climate or competitive capacity within the community?
- Will ecosystem services (e.g., biogeochemical, hydrological or societal) be compromised or enhanced by atmospheric and climatic change?



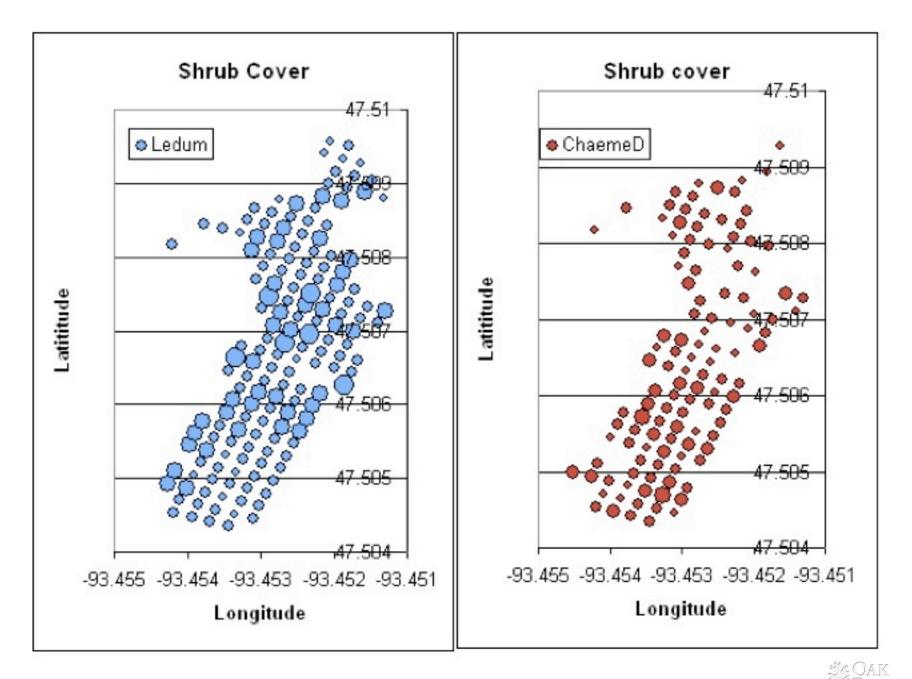






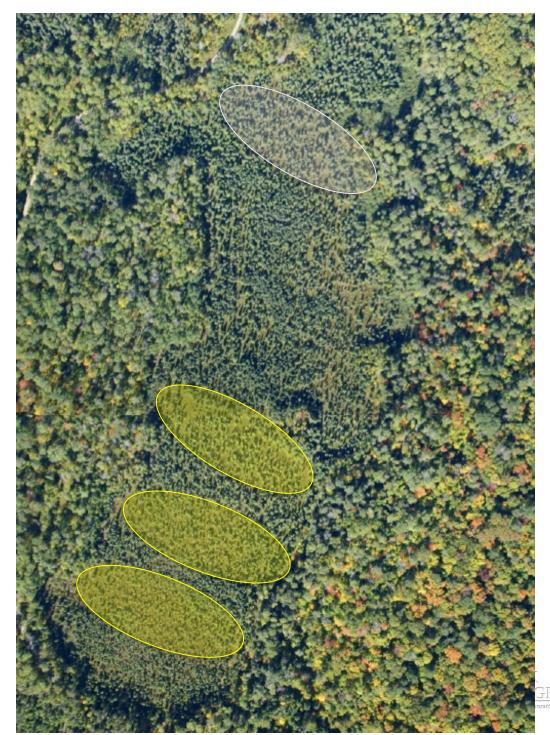


National Laboratory



Proposed Experimental blocks within the S-1 bog

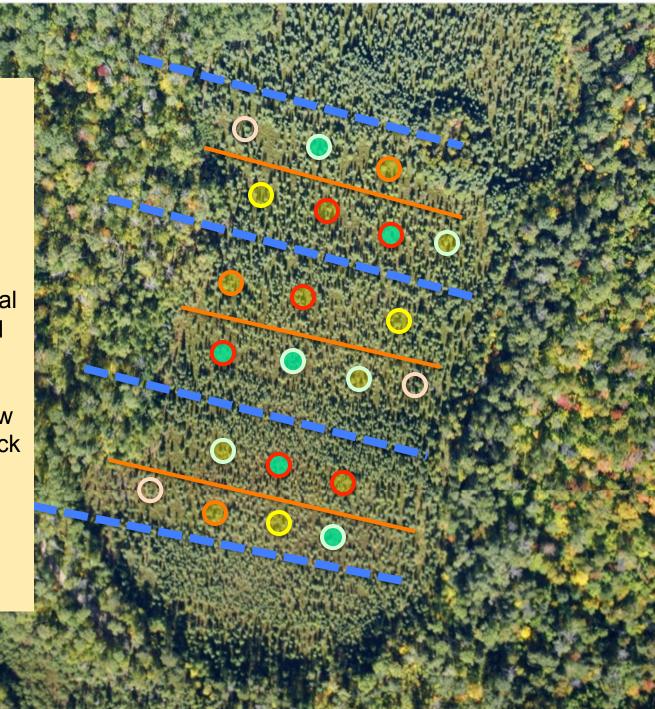
Chosen to avoid: •areas with taller trees •the extreme southern area of really deep peat • a central zone of the bog with shallow peat.



Temperatures: +0, 3, 6, and 9°C Elevated CO₂: at +0 and +9°C One ambient plot

These treatment combinations yield 7 total chambers per block and provide ample space between treatment chambers and may allow us to afford a full 4th block within the experimental design.

The 4th block is not shown.

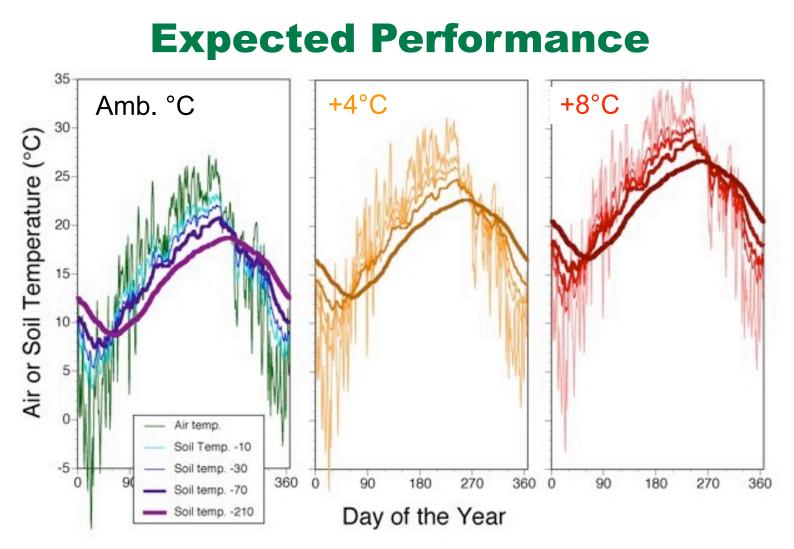


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Our Approach to Warming

- By 2100 future terrestrial environments may be 4 to 8°C warmer than today (Solomon et al. 2007) depending on the location.
- An overlooked reality is that mean deep (>1m) soil temperatures will also rise with climate warming (Huang 2006).
- Experimental systems must be improved to provide the best atmospheric and soil conditions appropriate for characterizing terrestrial ecosystem responses to year 2100 scenarios -- air and soil warming by as much as 8 to 10 °C.

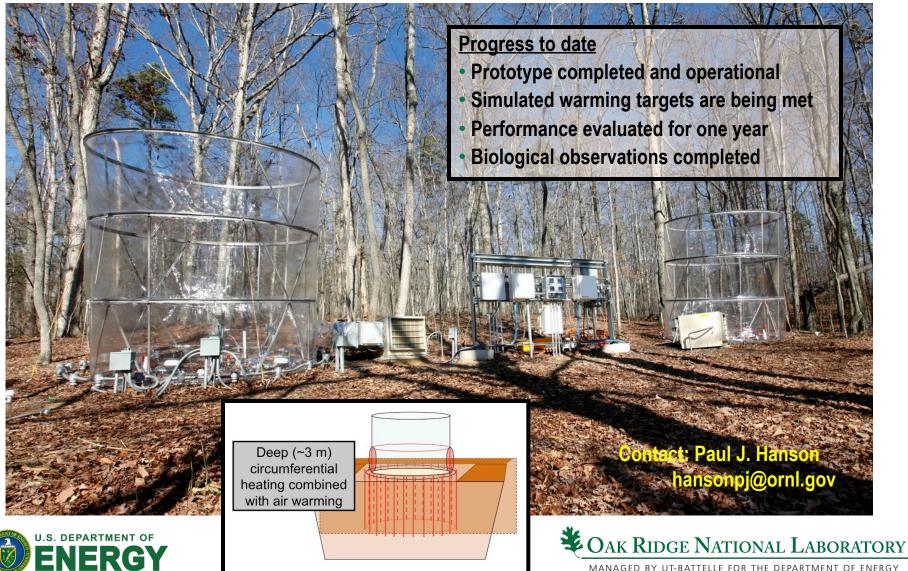




• By controlling only air and a single deep soil target temperature we will elevate ecosystem temperatures, but retain diurnal and seasonal patterns inherent to the ecosystem.

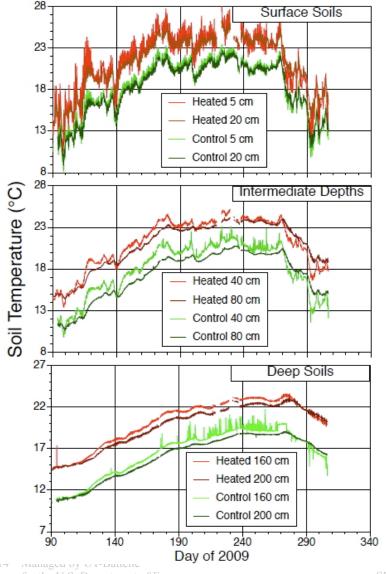
Project to Achieve Belowground Warming (LDRD – 05169)

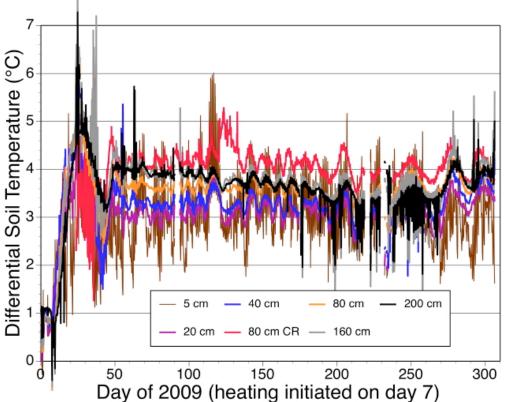
"Design, simulate and prototype facilities for macro-scale experiments of ecosystem response to climate change warming scenarios"



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Performance of The Warming Concept in a 3-m Prototype



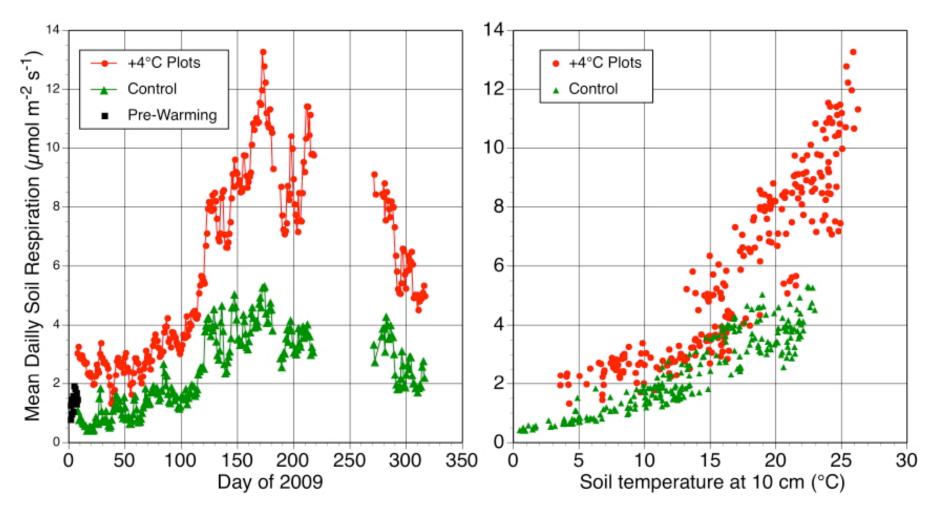


- Temperatures close to the +4°C target are achieved at all levels
- Diurnal and seasonal patterns are retained



SPRUCE Experiment Summary

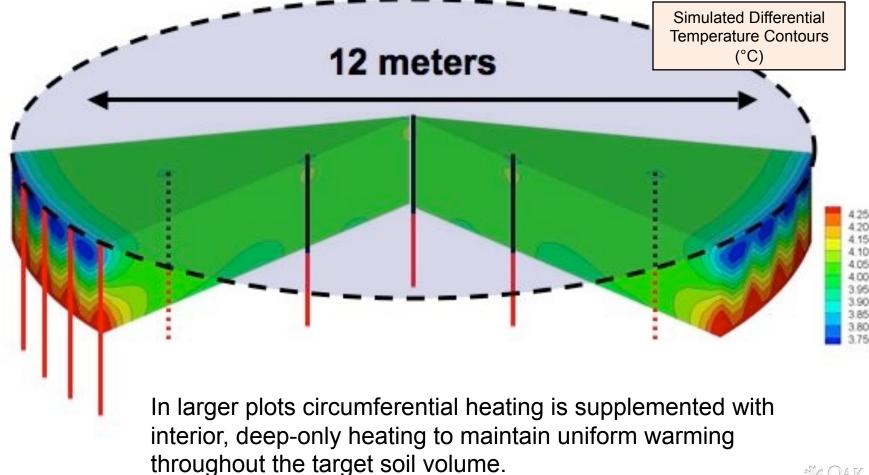
Is Deep Warming Worth the Extra Effort?



 Deep, full-profile warming enhanced soil respiration to a greater degree than expected.

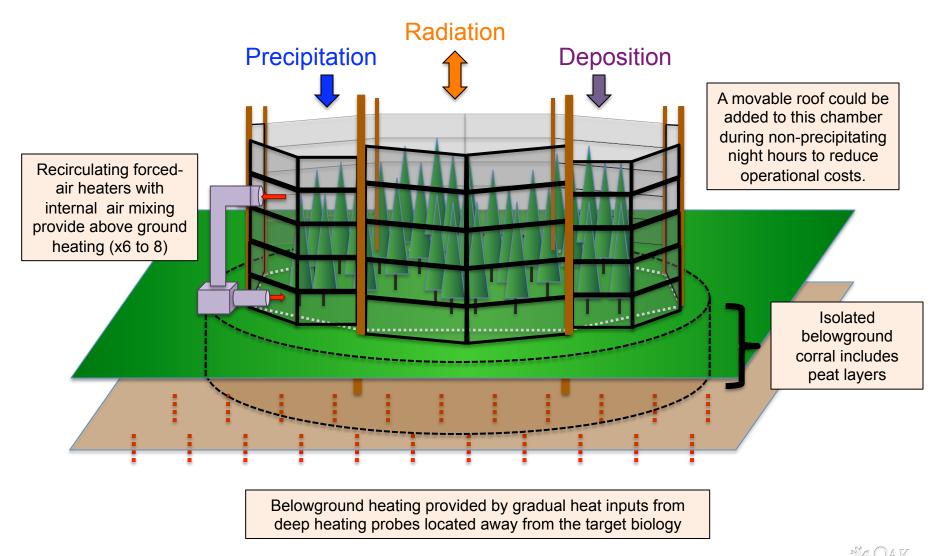


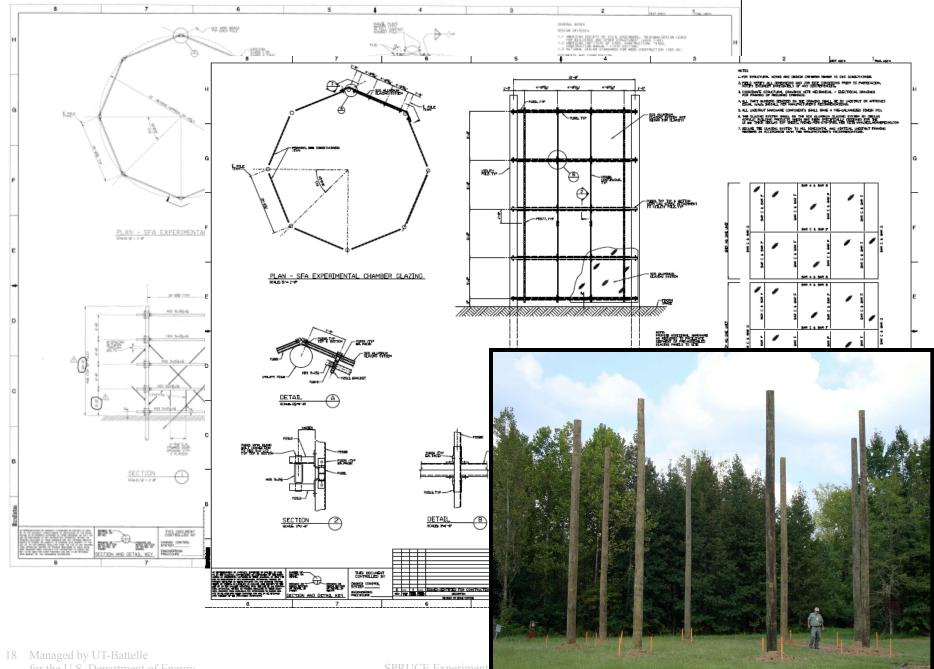
- Larger designs to accommodate full ecological diversity have been simulated and are being constructed for testing for application to the wholeecosystem manipulations in the replicated study in the S-1 bog.
- The design and simulation of improved aboveground warming technologies to match these belowground improvements is and important challenge in progress.





Response SFA Experimental Plot "A Full-Size Prototype Is Under Construction"





SPRUCE Experiment

SPRUCE Experiment Schedule

FY2010

- Institutional approvals (i.e., MOU, NEPA)
- Biological Survey Campaigns and Methods Testing
- A priori modeling of expected responses
- Complete construction plans

FY2011 and FY201

- Construction (a winter focus to avoid damage)
- Pre-treatment biological observations
- Environmental observations

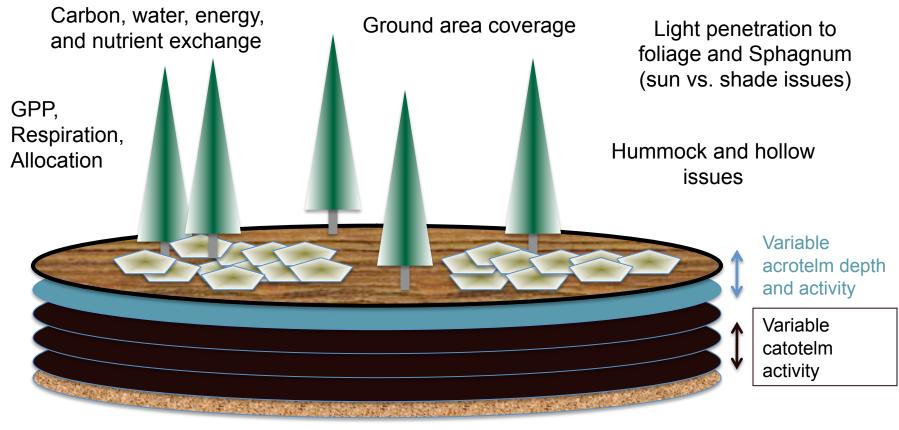
FY2013

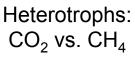
• Full operation



A priori Modeling

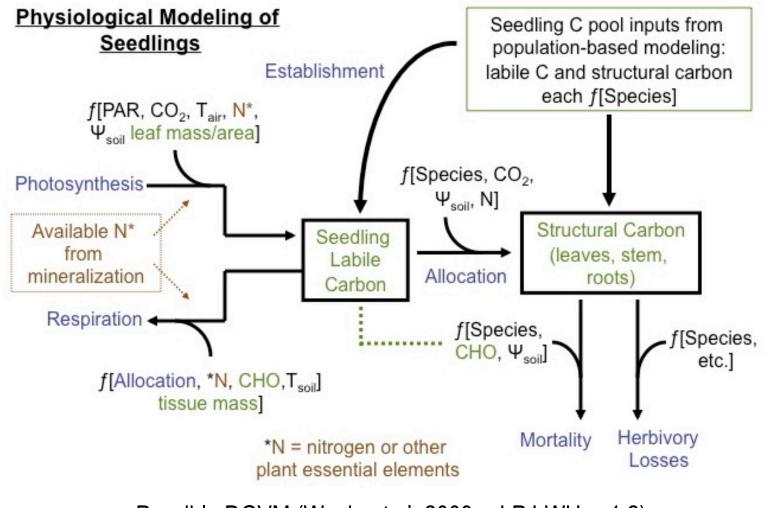
Biogeochemistry models of temperature, CO₂, and hydrologic responses Coded CLM-CN based for application and extrapolation Stella-based for conceptualization





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A priori Modeling – Vegetation Response



Possible DGVM (Wania et al. 2009 -- LPJ-WHy v1.2)



Acknowledgements and Organization

Research sponsored by

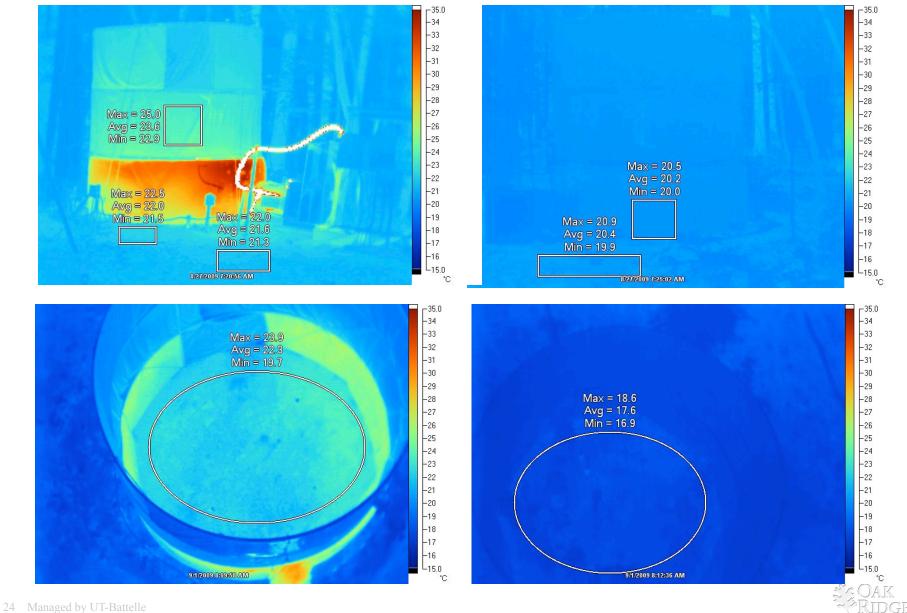
- U. S. Department of Energy, Office of Biological and Environmental Research
- The SPRUCE experiment is a multi-year cooperative interaction among scientists of the
 - Oak Ridge National Laboratory operated by UT-Battelle, LLC,
 - U.S.D.A Forest Service, Northern Research Station, Marcell Experimental Forest in Grand Rapids, Minnesota,
 - An external Advisory Panel in development, and
 - Anticipated discipline-specific cooperators

Project Website

http://mnspruce.ornl.gov

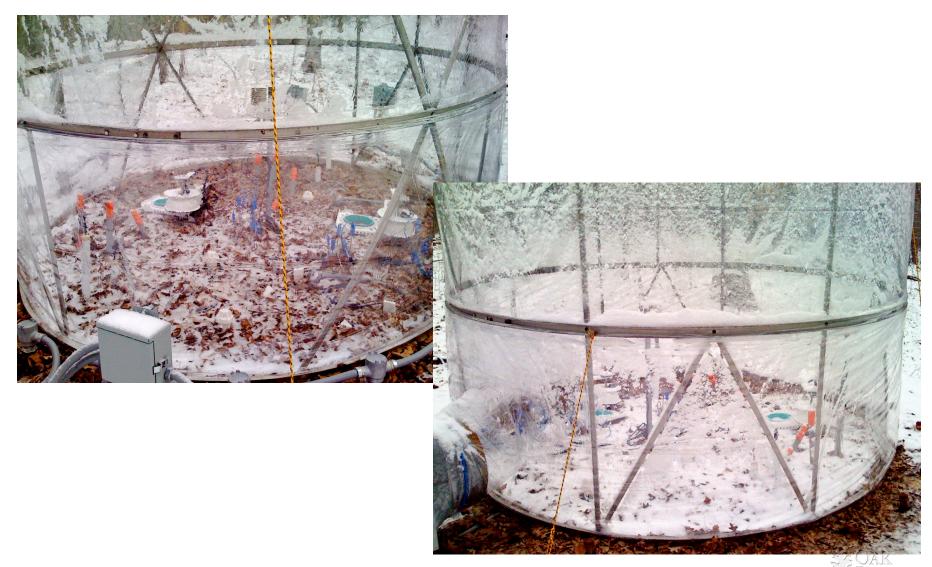


Warming System Thermal Images



for the U.S. Department of Energy

Winter Performance (20 Jan 2009) Heated (left) vs. Ambient (right)



SPRUCE Experiment Summary