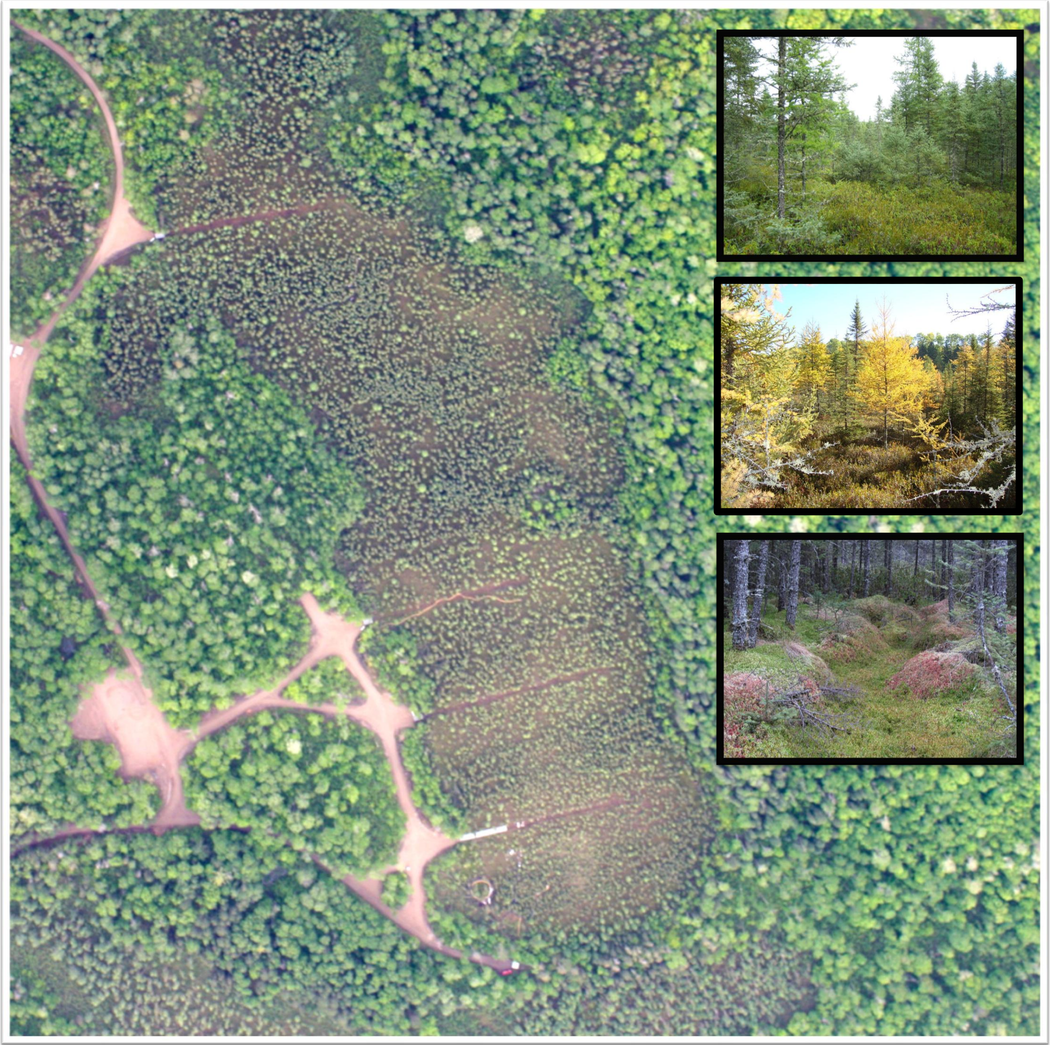
Spruce - Peatland Responses Under Climatic and Environmental change: An *in situ* warming by CO_2 manipulation of a peatland ecosystem

CM Iversen[1,2], PJ Hanson[1], J Childs[1], RJ Norby[1], RK Kolka[3], C Barbier[1], G Bisht[1], NA Griffiths[1], LA Hook[1], B Palik[3], CW Schadt[1], SD Sebestyen[3], JM Steinweg[1], WK Thomas[1], PE Thornton[1], JM Warren[1], DJ Weston[1], SD Wullschleger[1]

[1]Oak Ridge National Laboratory; [2]iversencm@ornl.gov; [3]USDA Forest Service, Northern Research Station



Overview

- Climate-induced changes in the carbon balance of peatland ecosystems, which currently store a large amount of carbon in deep peat deposits, are expected to have important feedbacks on the atmosphere and climate through net emissions of important greenhouse gasses (CO_2 and CH_4).
- We are constructing an experiment in a forested bog ecosystem in northern Minnesota, USA. The location of the bog, at the southern end of the range of boreal peatlands, makes it highly vulnerable to climate change.
- We have developed new methods for whole-ecosystem warming at plot scales of 12-m diameter. We will test ecosystem responses to multiple levels of warming combined with elevated [CO_2].
- Over a period of 10 years, our goal is to identify critical response functions for organisms, communities, and ecosystems to rapidly changing climate conditions in order to refine models needed for full Earth-system analyses.
- This projected is funded by the U.S. Department of Energy, Office of Science, Biological and Environmental Research.

Science questions

How vulnerable are peatland structure and function to a range of projected atmospheric and climatic change?

What are the air and soil temperature response functions for organisms and ecosystem processes, and how are these functions altered by elevated [CO_2]?

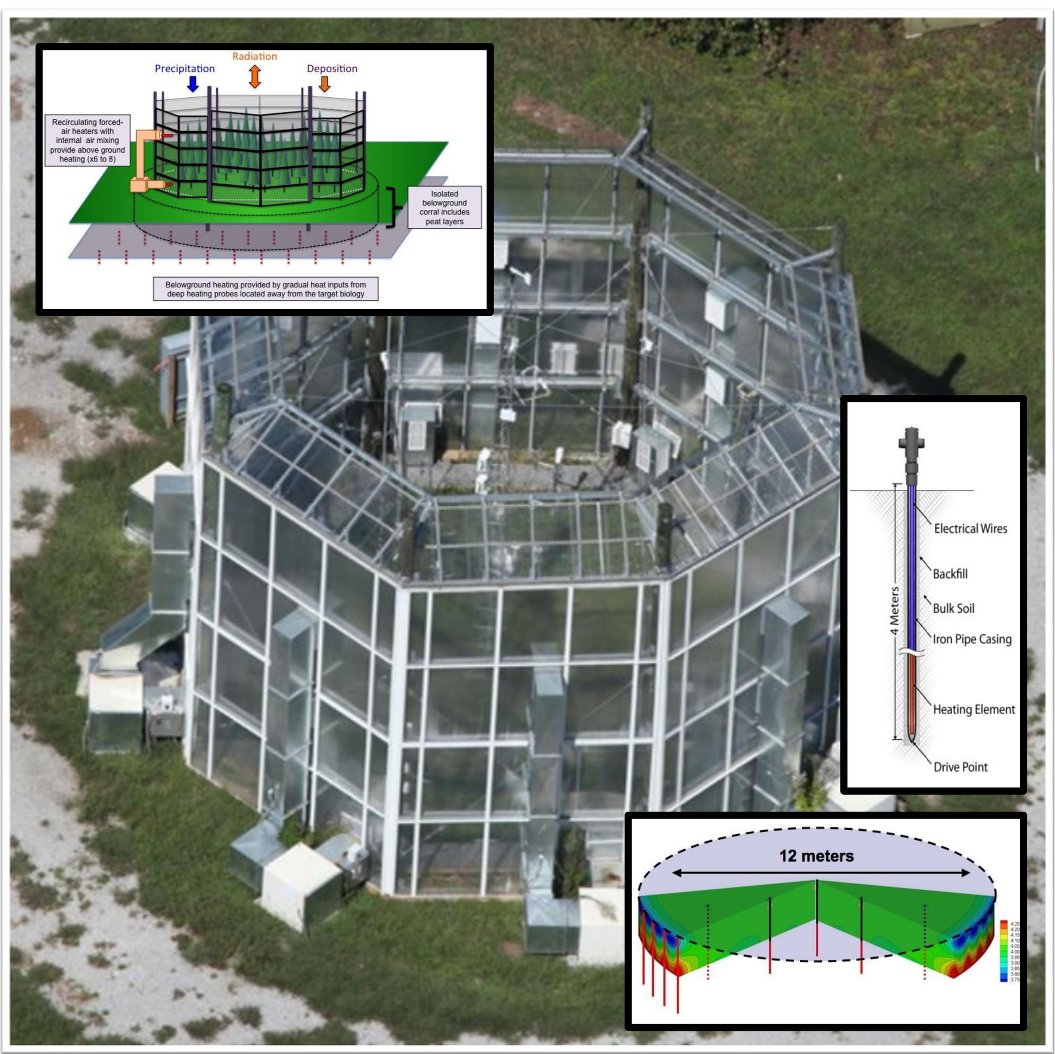
Will combined above- and belowground warming result in greater releases of greenhouse gases to the atmosphere than those predicted from aboveground warming alone?

SPRUCE will evaluate peatland ecosystem responses across multiple temporal and spatial scales:

- Plant physiology, growth, composition, phenology
- Peat microbial community composition and activity
- Peat microtopography and biogeochemical cycling

Opportunities for collaboration

Several groups have been funded to conduct collaborative research on or adjacent to SPRUCE. We encourage the participation of additional groups that have expertise beyond that of already funded collaborations and the core activities of ORNL and the USDA Forest Service. Please visit https:// mnspruce.ornl.gov, or contact Paul Hanson (hansonpj@ornl.gov) for additional information.

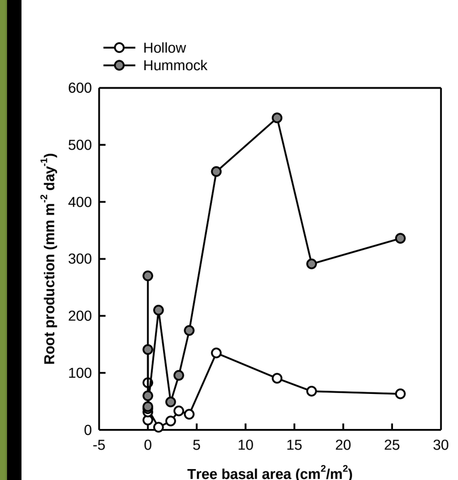


Methodology development

- SPRUCE will employ a combination of large (12-m diameter) open-top aboveground enclosures and a new method (Hanson *et al*., 2011, *Global Change Biology* 17: 1083) for warming soils from the peat surface down to approximately 2 to 3 meters depth.
- Forced-air heating will be used to warm the aboveground enclosure. CO_2 will be added to half of the plots during daytime hours of the active growing season by injection into the heated air streams.
- Belowground warming will be accomplished using circumferential rows of vertical heaters.
- A full prototype was built at ORNL, and complex fluid dynamics modeling was used to design and evaluate performance and energy use of the warming technology.
- We are also testing a subsurface flow barrier that could be installed to a depth of 2 to 3 m beneath each enclosure to isolate the hydrologic footprint of each plot.

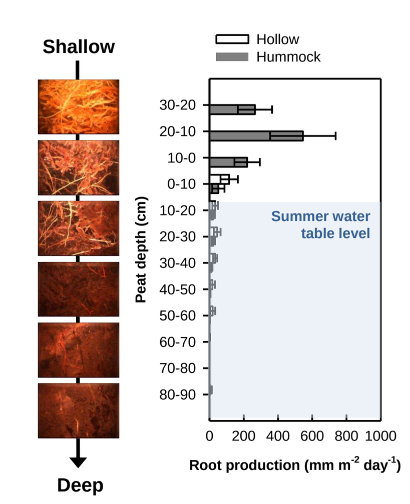
Preliminary data: Fine roots

Fine-root dynamics throughout the 2011 growing season were determined from 24 minirhizotrons installed in paired hummock/hollow topography across gradients of tree density in the south and north ends of the bog in summer, 2010.



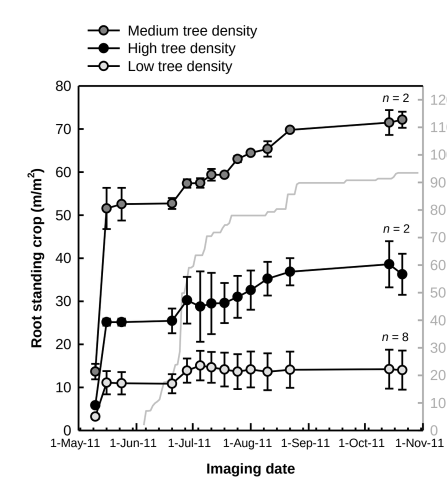
Root production peaked at intermediate levels of tree density (calculated from the basal area of trees within 1.5 m of each pair of minirhizotron tubes).

Most root production occurred in raised hummock topography.



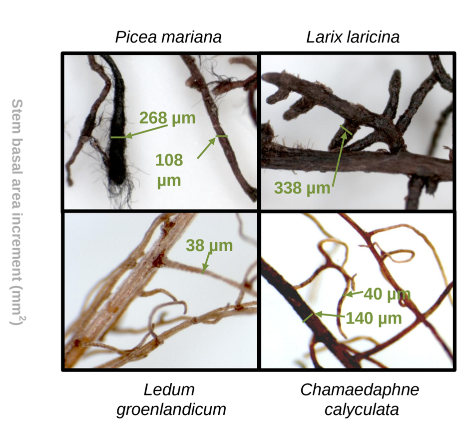
Little root production was observed below 10 cm (the average summer water-table depth in 2011).

Data shown are from areas of 'low' tree density (< 5 cm²/m²); hummocks are plotted as 0 to +30 cm.



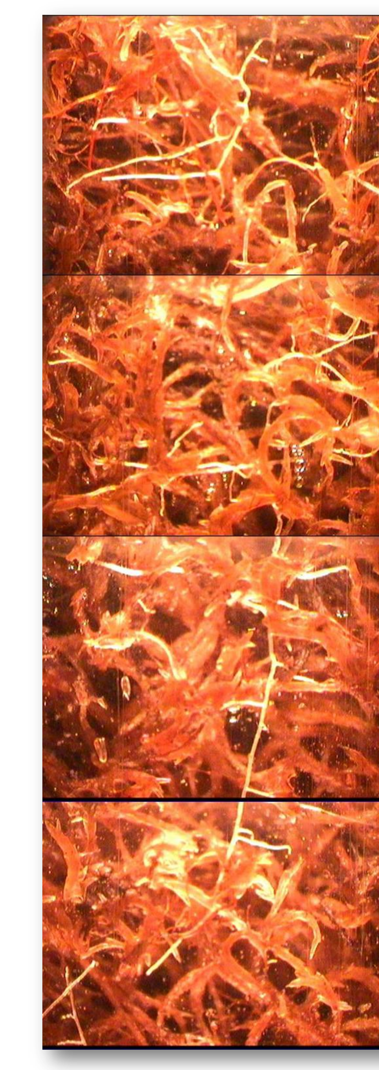
Root standing crop (data shown from hummocks only) increased quickly in the spring, well before wood growth was initiated.

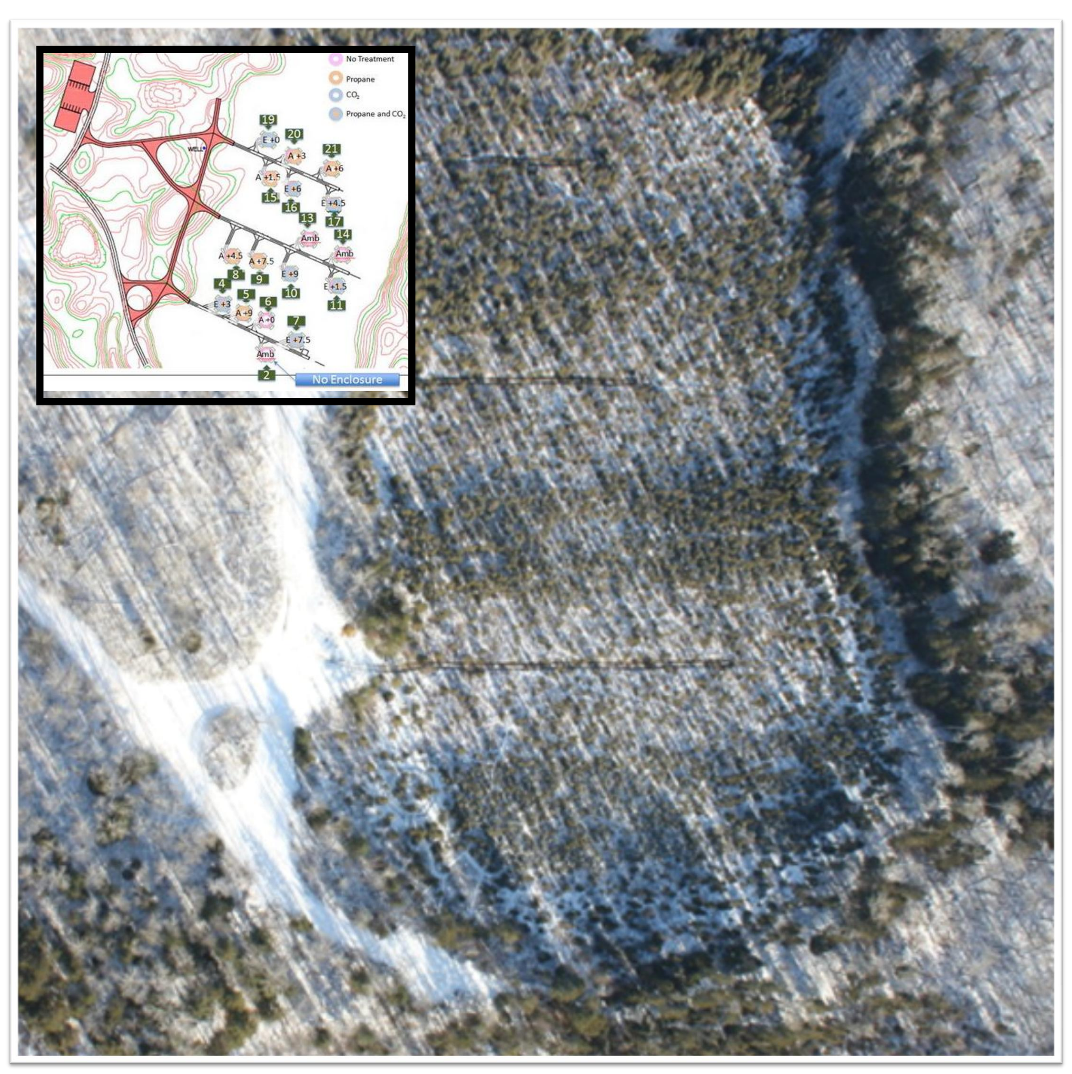
Root standing crop was lowest in areas of 'low' tree density, a characteristic of many SPRUCE experimental plots.



The lowest (most distal) root orders of dominant plant species encompass a range of root morphology and diameter distributions, as well as mycorrhizal colonization.

Note that the ericaceous shrubs have an extremely small root diameter.



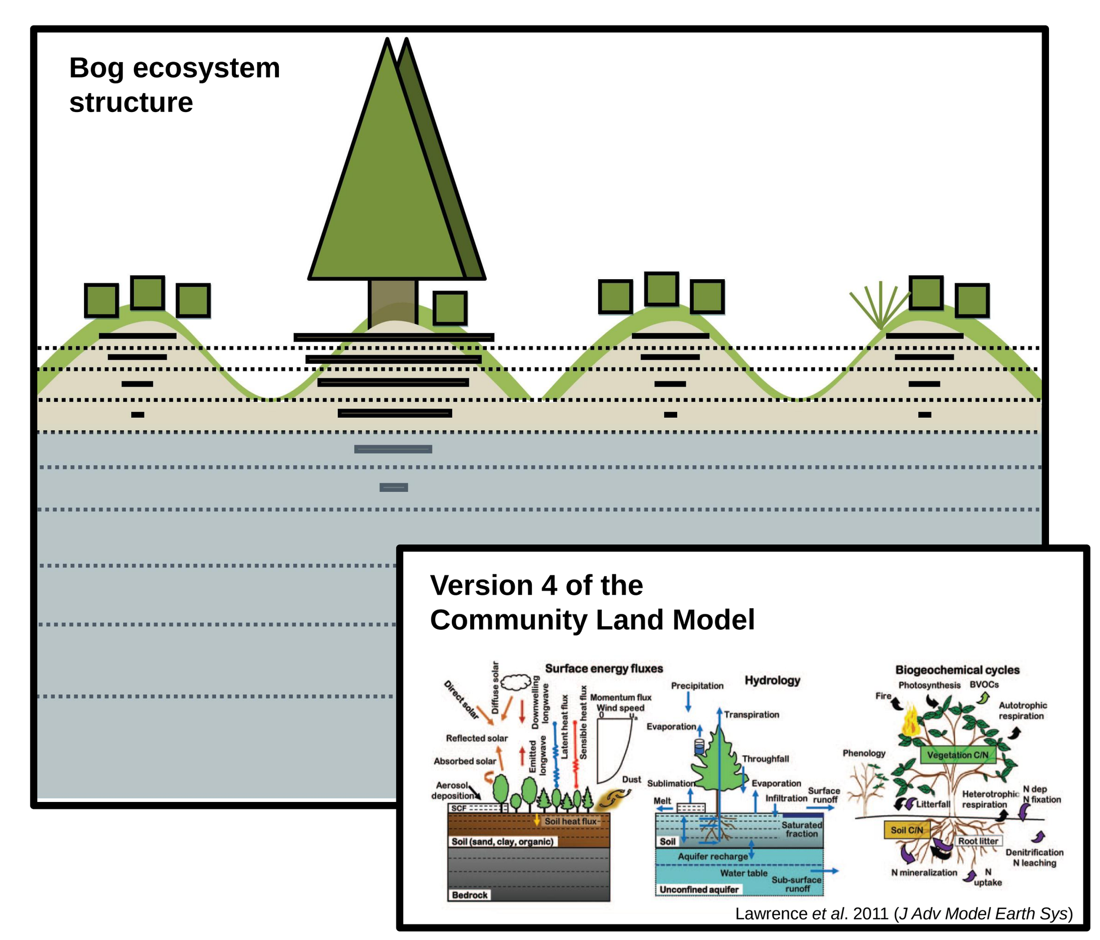


Experimental design

- The SPRUCE experiment will be conducted in an ombrotrophic *Picea mariana* (black spruce) bog located within the Marcell Experimental Forest (N 47° 30.171', W 93° 28.970') in northern Minnesota, USA.
- SPRUCE is a large-scale climate change manipulation focused primarily on warming, with elevated CO_2 acting as an important interacting factor that may mediate changes in peat decomposition (CO_2 or CH_4 release).
- Experimental temperature treatments will be applied using a regression approach. Treatments have been assigned to plots along three boardwalks in a randomized design, and infrastructure additions are underway.
- For both air and deep soil, temperature will range from ambient to a +9°C differential from ambient. Temperature treatments will be repeated in combination with ambient or elevated CO_2 (atmospheres approaching 900 ppm).
- Automated monitoring of environmental variables of interest will occur in each enclosure. Preliminary data collection outside of treatment plots began in 2010.

Links to models

- The SPRUCE experiment will inform and test the Community Land Model (CLM) component of the Community Earth System Model (CESM). CLM4 does not currently include wetland plant functional types, and a point version of CLM4 that includes wetland hydrology, micro-topography, and plants is being developed.
- Collaborators have conducted *a priori* model runs with ecosystem-scale models successfully used in wetlands, including LPJ-WHyMe (P. Miller, Lund University) and *ecosys* (R. Grant, University of Alberta). The models produced divergent expectations for the sensitivity of net ecosystem productivity to warming and elevated [CO_2], likely due to the presence/absence of nutrient feedbacks, and underscore the need for experimental manipulation.
- Other *a priori* model runs using the plant-scale model LaRS (J. Amthor, University of Sydney) indicated that acclimation of plant respiration and photosynthesis to warming and elevated [CO_2] may have important implications for net primary production in the SPRUCE manipulation.



Climate Change Science Institute
Oak Ridge National Laboratory
Northern Research Station