Evaluating High-Carbon Peatland Responses to Environmental Change: A Report on Pre-treatment C Stocks and Fluxes For a Characteristic Ombrotrophic Bog

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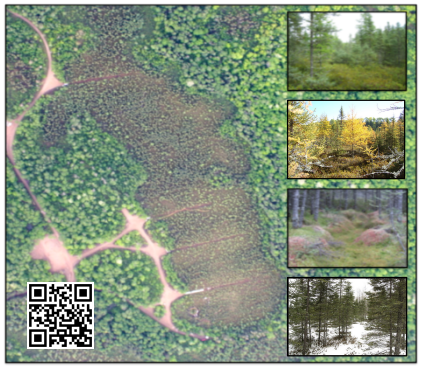
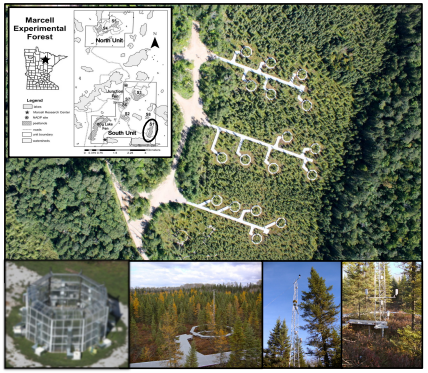


Overview

- 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 emissions of important greenhouse gasses (CO_2 and CH_4).
- We are initiating a field experiment in a high-carbon forested bog in northern Minnesota, USA. The location of the bog, at the southern end of the range of boreal peatlands, suggests its vulnerability 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 concentration.
- Over a period of 10 years, our goal is to identify critical response functions for organisms, communities, and ecosystems to changing climate conditions 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.

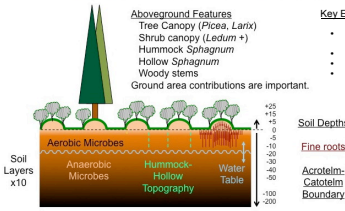


Whole-Ecosystem Warming Experiment

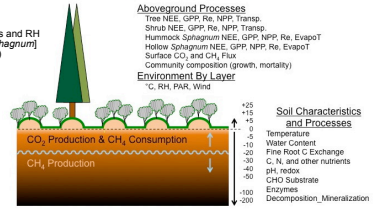
- The SPRUCE experiment is being conducted in an ombrotrophic *Picea mariana* (black spruce) bog located within the Marcell Experimental Forest (N 47° 30.171', W 93° 28.970') in Minnesota.
- SPRUCE will employ a combination of large (12-m diameter) open-top aboveground enclosures and a new method (Hanson *et al*., 2011, *Global Change Biology* 17: 1083) for warming deep soils at a depth of -2 to -3 meters.
- Forced-air heating will be used to warm the aboveground enclosure as much as +9°C above ambient. CO_2 will be added (+500 ppm) to half of the plots during daytime hours of the active growing season by injection into the heated air streams.
- Belowground warming (up to +9 °C) will be accomplished using circumferential rows of vertical heaters which avoid active heating of surface soils.
- 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.

Characterization of Carbon Cycle Stocks and Fluxes

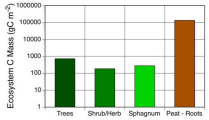
Picea-Sphagnum Ecosystem Requisite 1-D Model Components



Picea-Sphagnum Ecosystem 1-D Model Processes

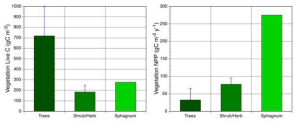


Measured Ecosystem Carbon Stocks



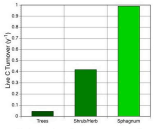
- Mass of C respectively 0.72, 0.18, 0.28 and 132.5 kg C m-2.
- New Peat C estimates from August 2012 sampling are pending.

Live Vegetation Carbon Stocks and NPP



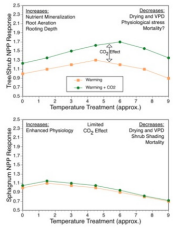
- Root NPP measurements from minirhizotron observations are pending and are not yet included in these values.

Live Carbon Turnover



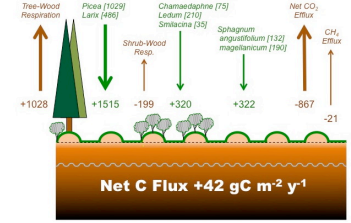
- The turnover time of live biomass is very rapid for *Sphagnum*.

Hypotheses for Species Response

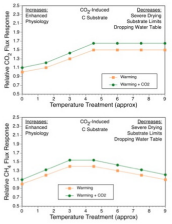


C-Cycle Interpolations for the S1 Bog

(C Flux in gC m^{-2} y^{-1})



Hypotheses for C Flux



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?

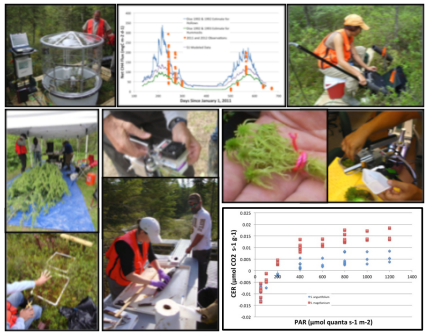
SPRUCE will evaluate peatland ecosystem responses across multiple temporal and spatial scales:

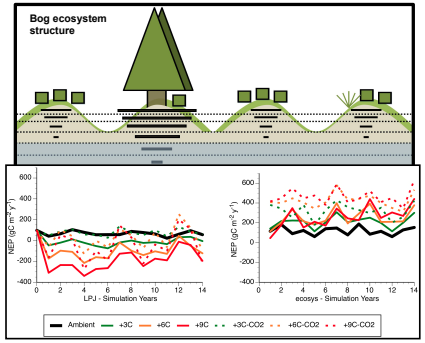
- Plant physiology, growth, composition, phenology
- Peat microbial community composition and activity
- Peat microtopography and biogeochemical cycling

Opportunities for collaboration

- Several groups have been funded to conduct collaborative research on or adjacent to SPRUCE.
- Visit https:// mnspruce.ornl.gov and contact Paul Hanson (hansonpj@ornl.gov) for additional information.

Measurements and Example Data



Links to Prognostic 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. 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.