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MERCURY PROCESSES UNDER ELEVATED CARBON DIOXIDE AND SOIL WARMING IN A PEATLAND: HYPOTHESES FOR THE SPRUCE EXPERIMENT

Spruce and **P**eatland **R**esponses **U**nder **C**limatic and **E**nvironmental change

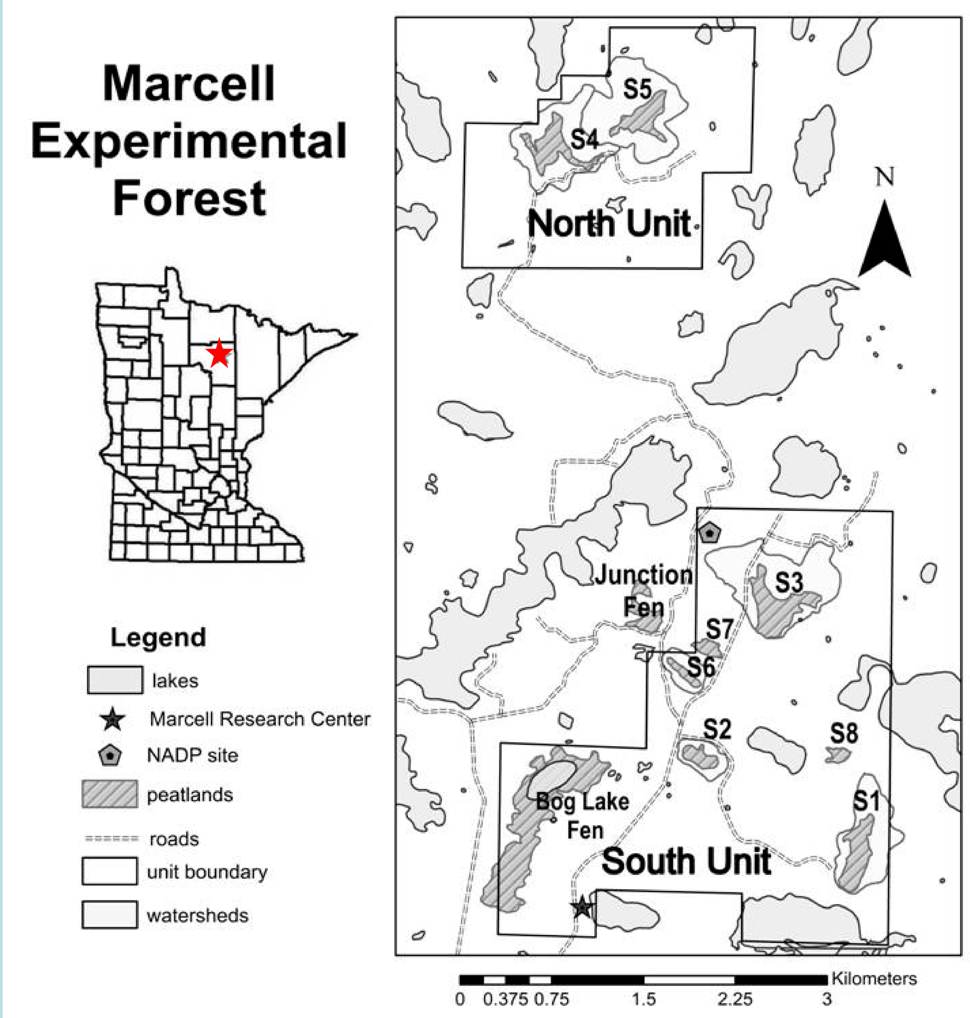
INTRODUCTION

Scientists at the Oak Ridge National Laboratory and the USFS Northern Research Station are developing a large-scale ecosystem study in which temperature and CO_2 will be experimentally increased to quantify effects of climate on a northern peatland – an ecosystem that is considered to be especially vulnerable to climate change and to have important feedbacks to the atmosphere.

Design and prototyping is now occurring with full operation planned for 10 years starting in 2013. We plan to quantify thresholds for organism decline and regeneration, changing greenhouse gas emissions, and responses of biogeochemical and hydrological processes, **including total (THg) and methyl (MeHg) mercury**.

ENVIRONMENTAL SETTING

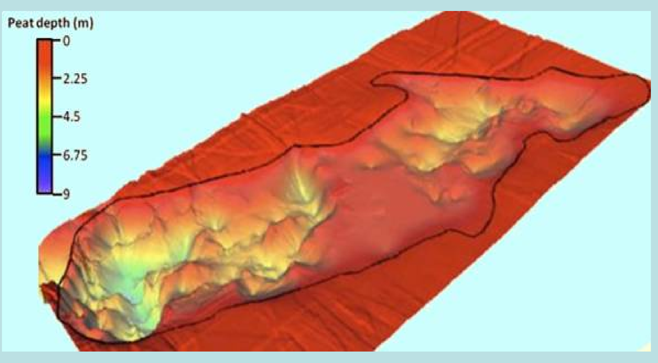
SPRUCE will occur on the 8.1 ha peatland in the S1 catchment on the Marcell Experimental Forest (MEF). The MEF is a research site of the Northern Research Station, USDA Forest Service. Long-term monitoring began in 1961 with forest management experiments starting in 1969. The landscape includes uplands, bogs, fens, lakes, and streams within the Marcell hills moraine complex that drains to both the Mississippi River and Hudson Bay.

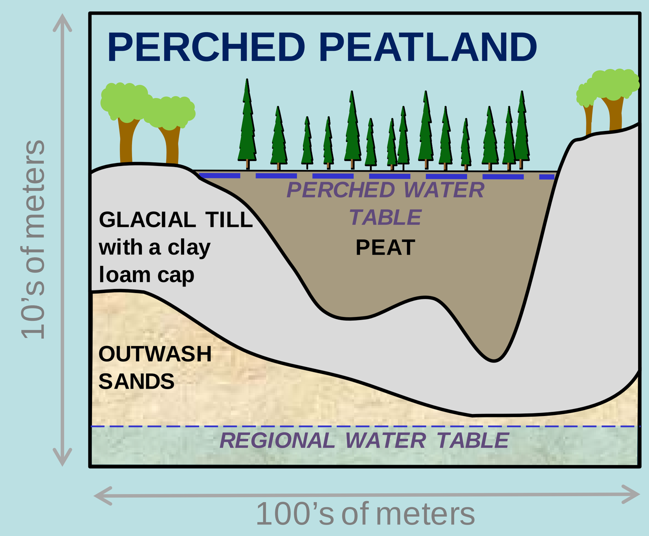


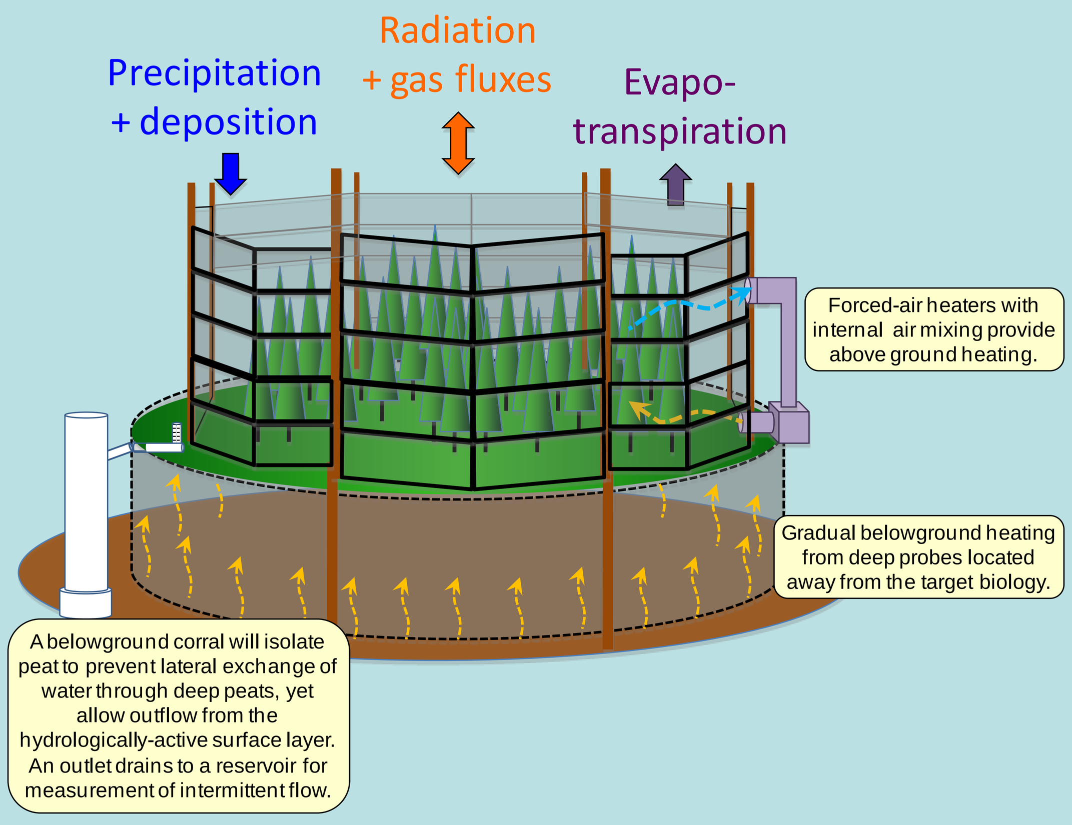
EXPERIMENTAL DESIGN

The final design (with 28 potential experimental units within a blocked design) will balance statistical demands and operating costs. We are considering a blocked ANOVA design with replication or the application of a regression continuum of temperature treatments to be duplicated at elevated CO_2.

- The *Picea mariana* (black spruce) – *Sphagnum spp*. bog is ombrotrophic and located at the southern margin of the boreal zone.
- Peatlands at the MEF like S1 contain deep peat deposits that are perched several meters above the regional groundwater table.
- Responses of vegetation, large carbon pools in peat, and the water cycle are expected to have important feedbacks on the atmosphere and climate through changes in net emissions of CO_2 and CH_4

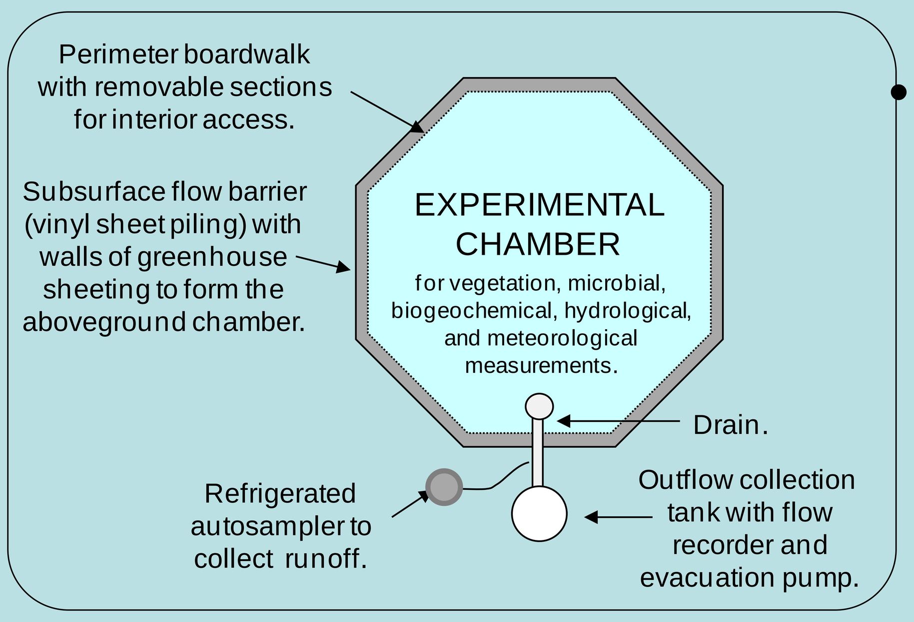






Chambers will:

- Be open topped with 12-m diameter internal study areas, 8-m tall sidewalls, and peat that is 2 to 4-m deep.
- Be warmed at levels from ambient to +9°C (above and below ground).
- Have elevated CO_2 in the range of 800 to 900 ppm.



OVERALL RESEARCH QUESTIONS

- How vulnerable are peatland ecosystems and their component organisms to atmospheric and climatic change?
- To what degree will changes in plant physiology under elevated CO_2 impact a species' sensitivity to climate or competitive capacity within the community?
- Will full belowground warming release unexpected amounts of greenhouse gases and solutes from high-C-content northern forests?
- What are the critical air and soil temperature response functions for ecosystem processes and their constituent organisms?
- Will ecosystem services (e.g., biogeochemical, hydrological, or societal) be compromised or enhanced by atmospheric and climatic change?

The SPRUCE experiment is being developed to determine ecological responses across a broad range of above- and belowground temperature increases, and how those responses to increased temperature will be altered by elevated atmospheric CO_2 concentration.

PROPOSED MEASUREMENTS AND MODELING

- Plant community composition, growth, physiology, and phenology: tree demography and understory communities; vascular plant, bryophyte, leaf and litter, and belowground production; photosynthesis and respiration; water relations.
- Soil microbial community composition.
- Meteorological and hydrological parameters for water and energy budgets: water table elevations, surface water drainage from chambers, measurement of water vapor fluxes.
- Biogeochemical cycling of nitrogen, carbon, phosphorus, metals (**including Hg**), and dissolved organic matter.
- Water and organic soil chemistry including nutrients, ions, metals (**including Hg**), and organic matter (concentrations and compositional measures).
- Peat physical properties and geophysical imaging of the surface and subsurface environments.
- Mechanistic modeling leading to more comprehensive parameterization of peatland processes in general circulation models such as CLM.
- Water and trace gas fluxes with an emphasis on CO_2 and CH_4.

ADVANCING GLOBAL CHANGE SCIENCE AND ECOSYSTEM RESEARCH

- SPRUCE will provide quantitative evidence of the effects of climatic forcing by temperature and elevated CO_2 on northern peatland ecosystems and the vast C stores that are associated with the hydrology and biogeochemistry of these globally widespread landscape features.
- The data are crucial to predicting feedbacks on global climate as well as ecosystem productivity, water availability, and biogeochemical transformations in these ecosystems.
- The data will also provide valuable insight on climatic factors that affect carbon stocks and solute yields.

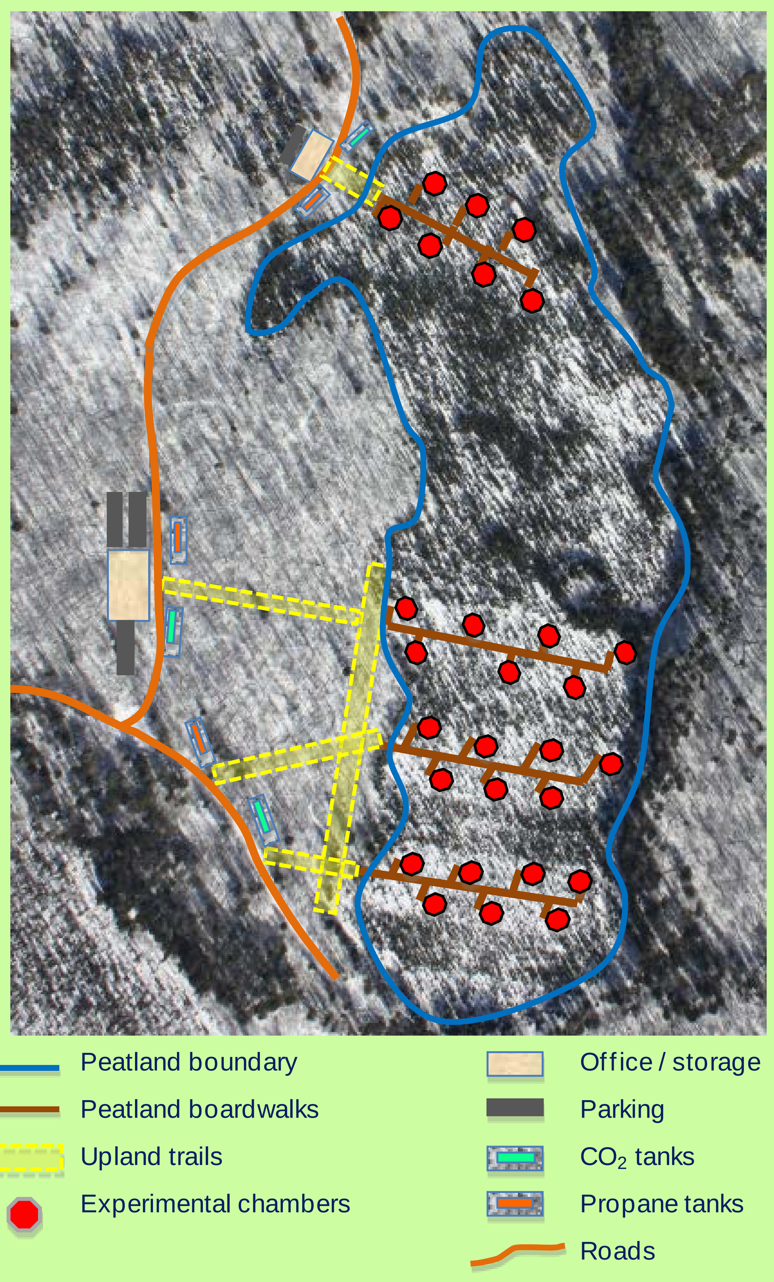
http://mnspruce.ornl.gov
http://nrs.fs.fed.us/ef/marcell

We seek interaction with the mercury community on the design and hypotheses of the SPRUCE experiment.

MERCURY HYPOTHESES

We anticipate that the soil warming treatments alone or in combination with elevated CO_2 will increase productivity and lower water tables as a result of more transpiration and evaporation. As a result, we hypothesize that:

1) THg and MeHg concentrations will decline with lower water tables as deeper organic soils with lower mercury burdens contribute to pore water chemistry.
2) During rainfall and snowmelt runoff, treatments with lower initial water tables will have more Hg available for methylation and thus higher MeHg concentrations, than those with initially higher water tables, especially under heated conditions.
3) Gaseous Elemental Mercury (GEM) fluxes will increase with temperature and lower water tables as microbial communities in newly oxidative peat are able to more efficiently convert soil Hg to GEM.



MERCURY METHODS

We plan to measure THg and MeHg in atmospheric deposition, soils, vegetation shallow and deep pore water, runoff and GEM to calculate the mass balance of Hg.

1) Deposition will be measured at a MDN site located 3 km from S1.
2) Soils will be measured in 5 cm increments to underlying mineral soils. Soil and vegetation will be measured prior to treatment installation and then every 2 years for the duration of the experiment.
3) Each chamber will have a nest of piezometers, runoff collector, and a pair of sippers to measure routine chemistry as well as total Hg (THg) and methyl Hg (MeHg). Piezometer nests will include samples from near the soil surface to near the peat-mineral interface at depth. Sipper samples will be collected at 5 cm increments down to 50 cm. Runoff collectors will capture surface and near surface runoff of acrotelem waters.
4) We will use gradient or eddy covariance techniques on a subset of chambers to measure net gaseous fluxes of GEM.

STUDY INTEGRATION

Associated studies are being developed at the Biotron Facility at the University of Western Ontario (UWO) that will parallel the SPRUCE experiment to explore interactions of temperature, water tables and carbon dioxide enrichment on carbon and trace metal cycling. We will install "live" vegetated soil monoliths in several of the Biomes at UWO and subject them to a range of conditions that are beyond those of the field installation (e.g. overlapping plus different combinations of soil and air temperatures, soil moistures, and carbon dioxide levels). By implementing parallel monitoring at the Biotron, we will gain insight on the full-scale experiment and better define tipping points due to heating and enriched CO_2.