Field Performance of the SPRUCE Whole-Ecosystem Warming Facility for Tall-Stature Peatland Vegetation

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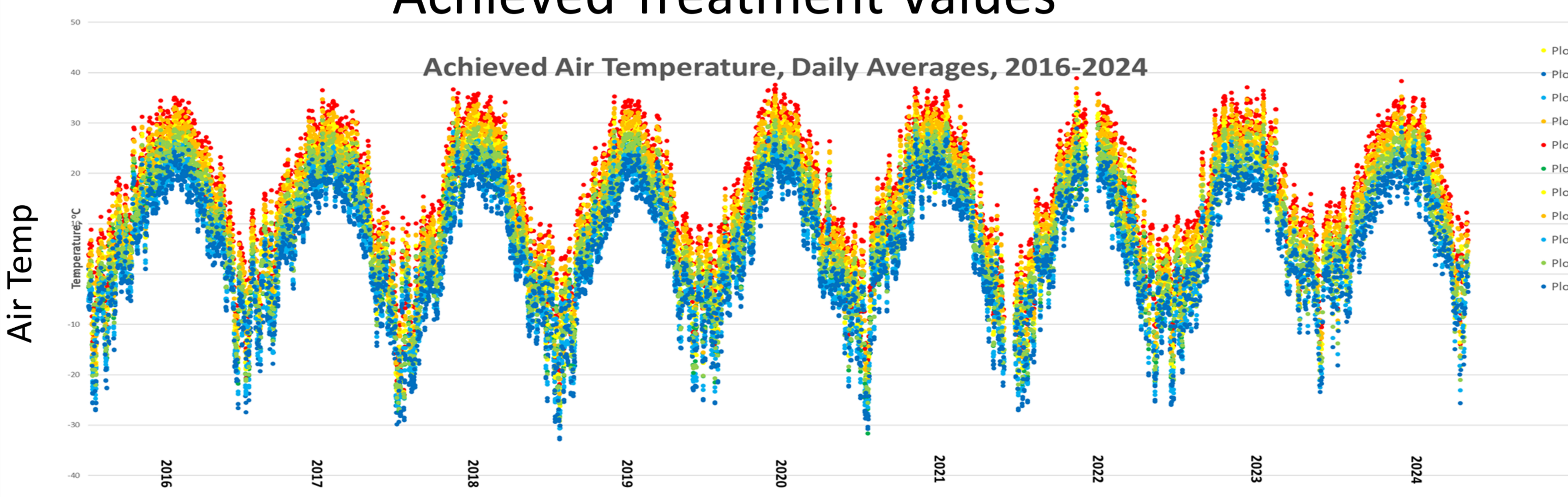
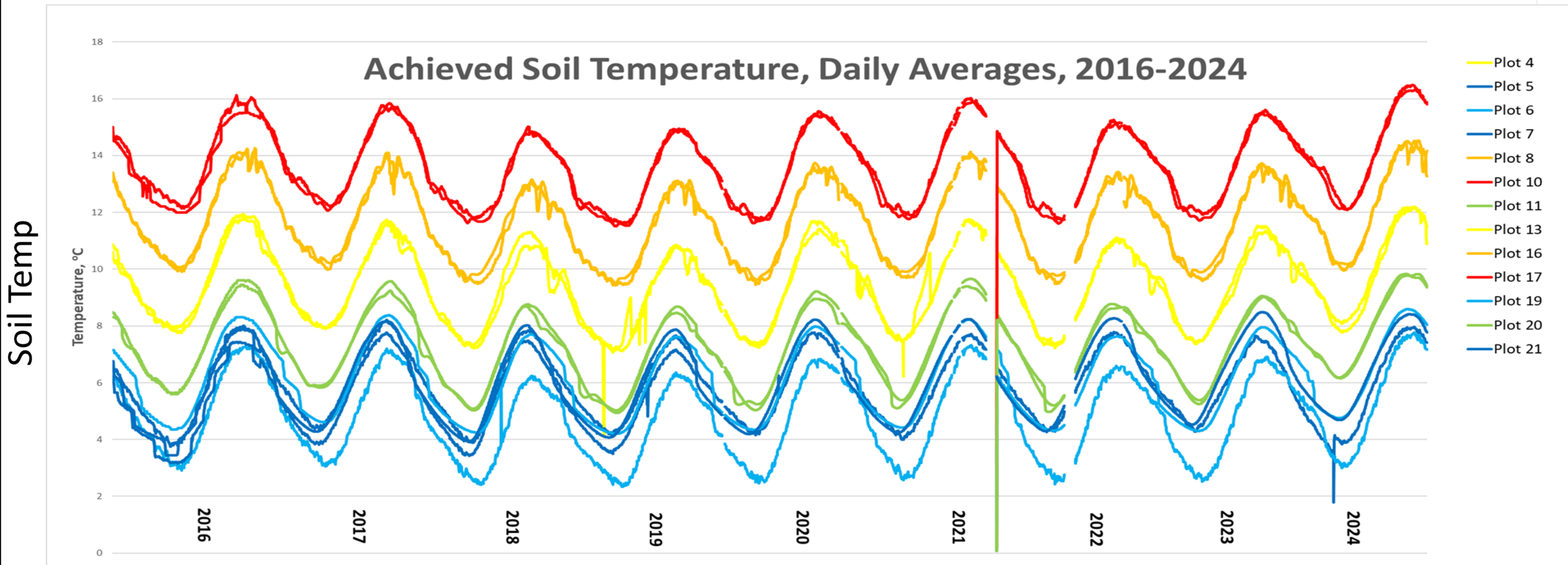
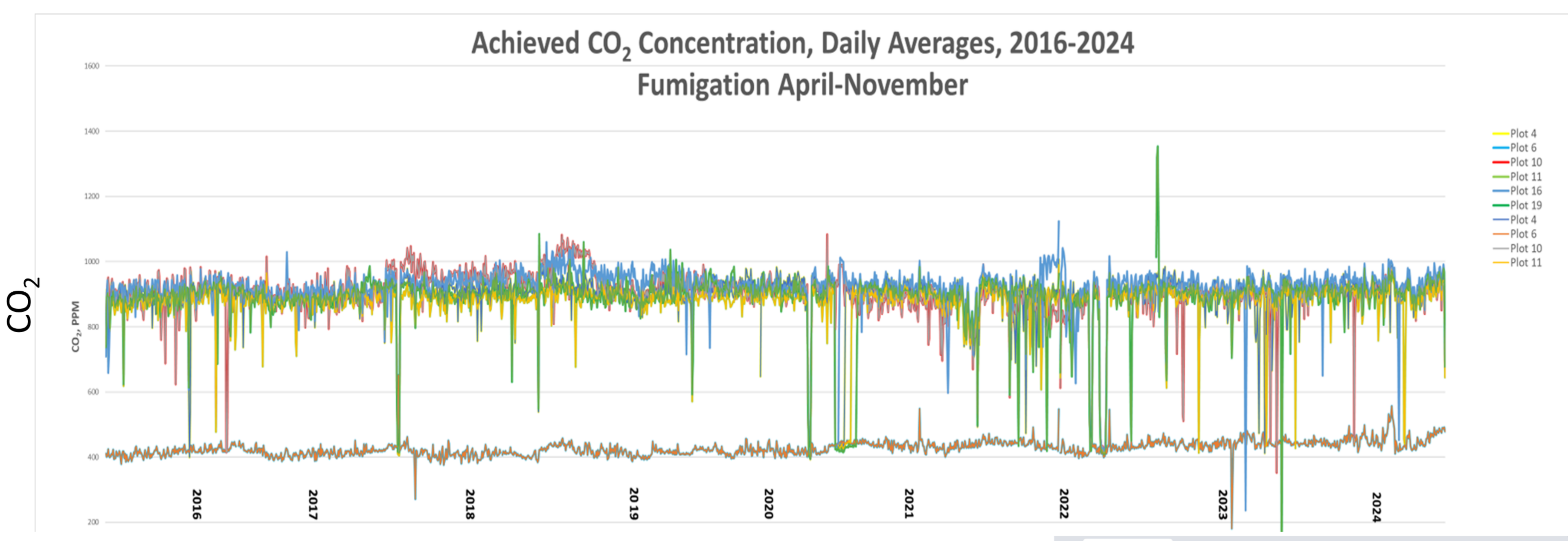
Treatment Reliability

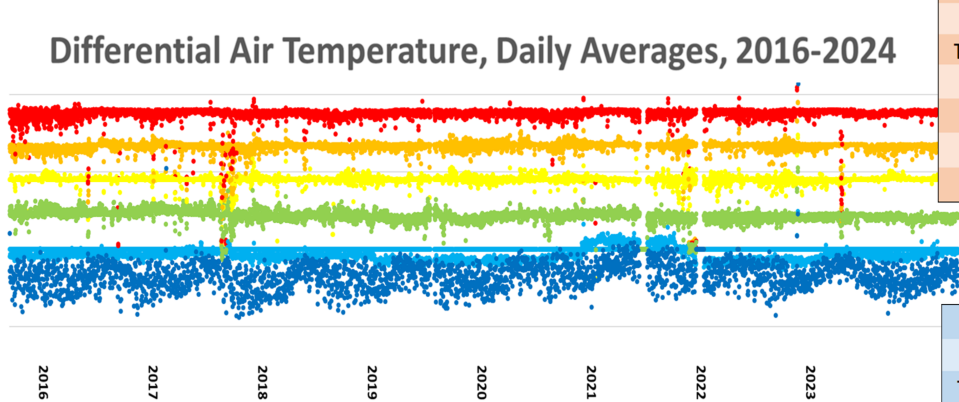
Achieved Treatment Values

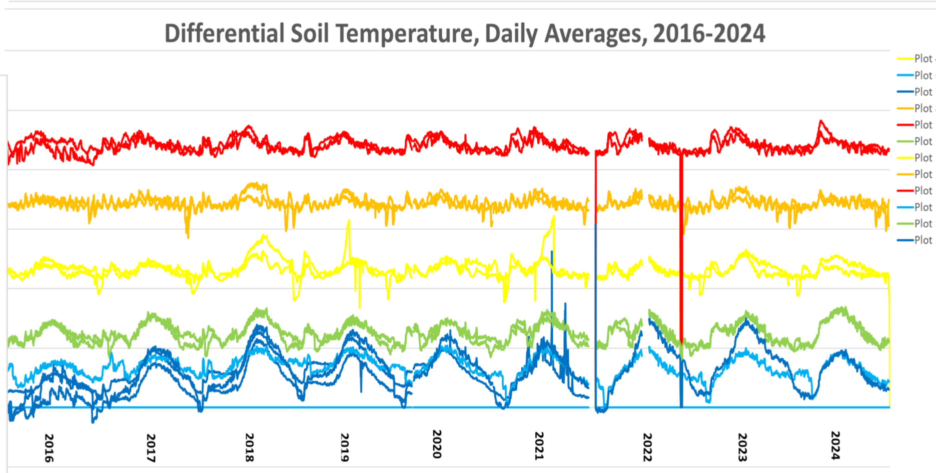






Differential Treatment Values





Treatment Performance

Air Temp % Time Within 1°C of Target, Yearly Average

Treatment	2016	2017	2018	2019	2020	2021	2022	2023	2024
2.25 °C	93%	90%	94%	93%	92%	98%	83%	99%	100%
4.5°C	98%	98%	98%	98%	98%	94%	97%	98%	99%
6.75°C	91%	95%	94%	96%	94%	100%	89%	97%	100%
9°C	86%	94%	93%	93%	94%	99%	91%	97%	100%

Soil Temp % Time Within 1°C of Target, Yearly Average

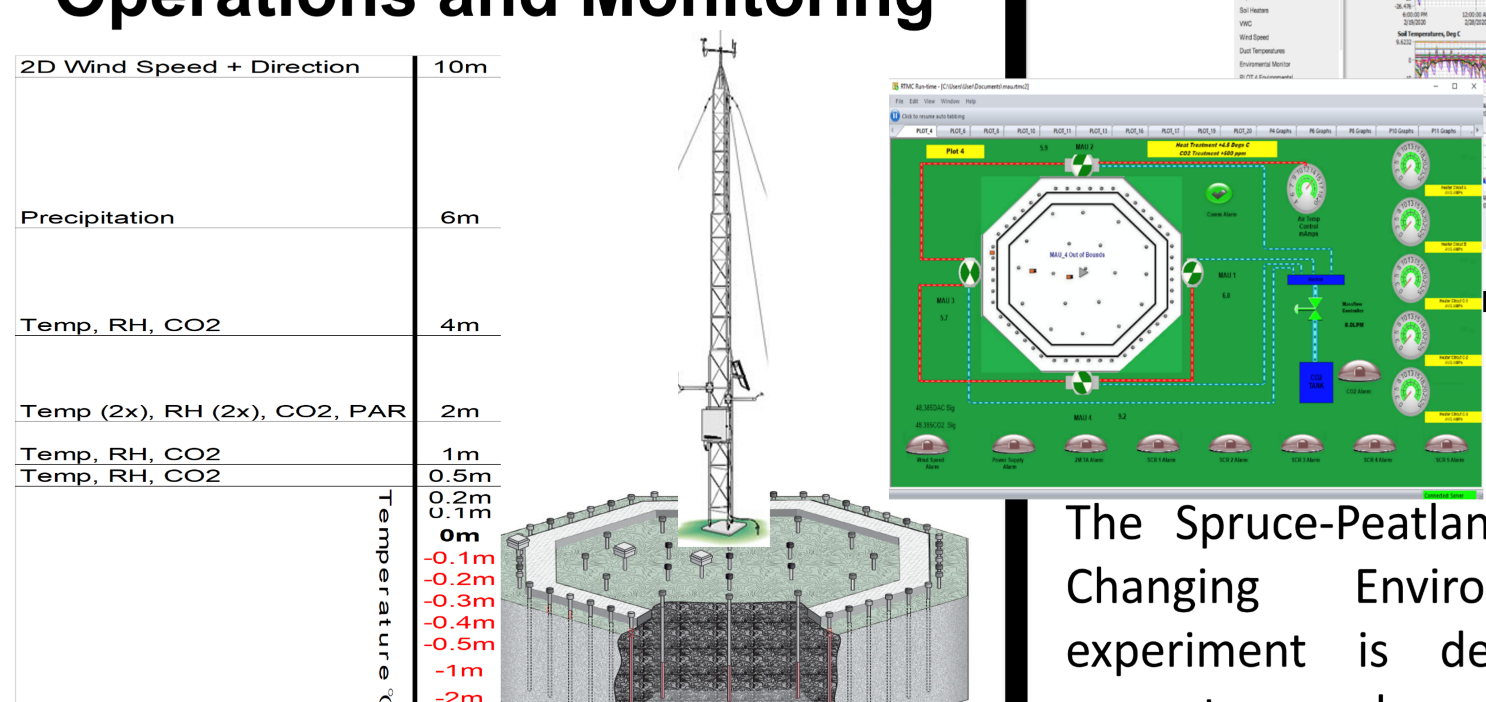
Treatment	2016	2017	2018	2019	2020	2021	2022	2023	2024
2.25 °C	100%	99%	96%	100%	100%	99%	99%	99%	93%
4.5°C	100%	100%	94%	98%	100%	94%	100%	100%	100%
6.75°C	100%	100%	100%	100%	100%	100%	100%	100%	100%
9°C	100%	100%	100%	100%	100%	100%	100%	100%	100%

CO2 % Time Within 20% of Target, Yearly Average

Plot #	2016	2017	2018	2019	2020	2021	2022	2023	2024
4	88.8%	92.1%	85.1%	78.4%	92.9%	87.5%	85.0%	74.6%	93.0%
10	82.0%	83.9%	63.6%	64.5%	92.3%	81.6%	75.0%	78.4%	91.4%
11	91.3%	90.9%	87.8%	87.9%	93.3%	82.6%	85.0%	78.2%	90.9%
16	92.1%	91.3%	75.9%	72.8%	93.9%	89.4%	82.0%	78.2%	95.2%
19	92.7%	94.3%	88.8%	78.2%	90.5%	81.9%	81.0%	79.7%	82.6%

CO_2 Fumigation is active April through November during daylight hours. Fumigation is suspended during periods of 5 m/s sustained winds, scheduled preventative maintenance and routine system safety checks.

Operations and Monitoring



- Operational control is maintained through real-time monitoring. Central tower arrays in each plot collect relevant environmental data to establish treatment control signals. Control and environmental data may be viewed remotely to evaluate treatment performance and determine operational objectives.

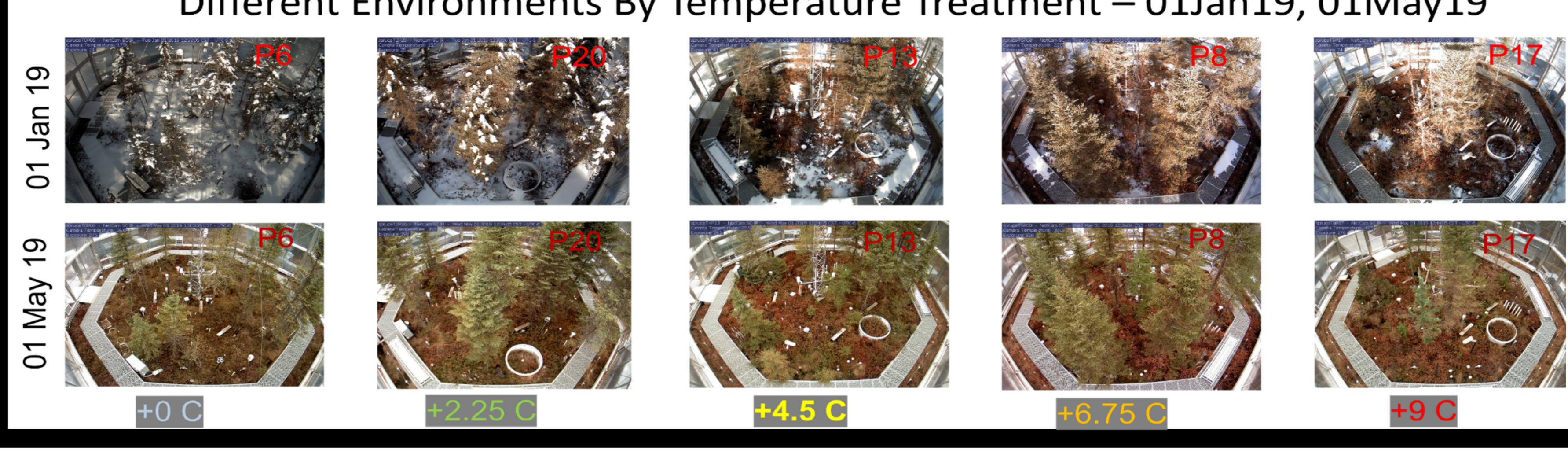
Environmental Separation

Recorded DOY for *Larix laricina* Leaf-Out (2016-2018) and Bud Break (2019-2021)

Temp. Elevation	Plot	2016	2017	2018	2019	2020	2021
9°C	17	99	103	115	88	86	82
	10	99	103	120	88	86	89
6.75°C	16	99	103	120	100	98	89
	8	99	103	120	93	98	89
4.5°C	13	111	103	120	100	98	96
	4	106	103	123	114	105	96
2.25°C	20	117	109	130	114	111	96
	11	111	109	127	114	107	96
0°C	19	111	117	130	114	119	110
	6	117	109	127	114	119	103
Ambient	21	125	131	141	114	119	118
	7	125	131	141	120	119	110

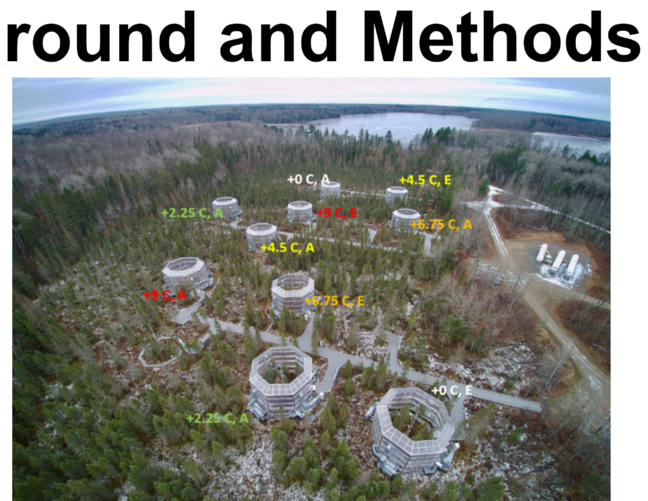
- WEW-induced environmental conditions produce differing phenological progression. Ground-level observations are taken on a weekly basis during the growing season. Plot-level and shrub-level cameras capture images year-round.

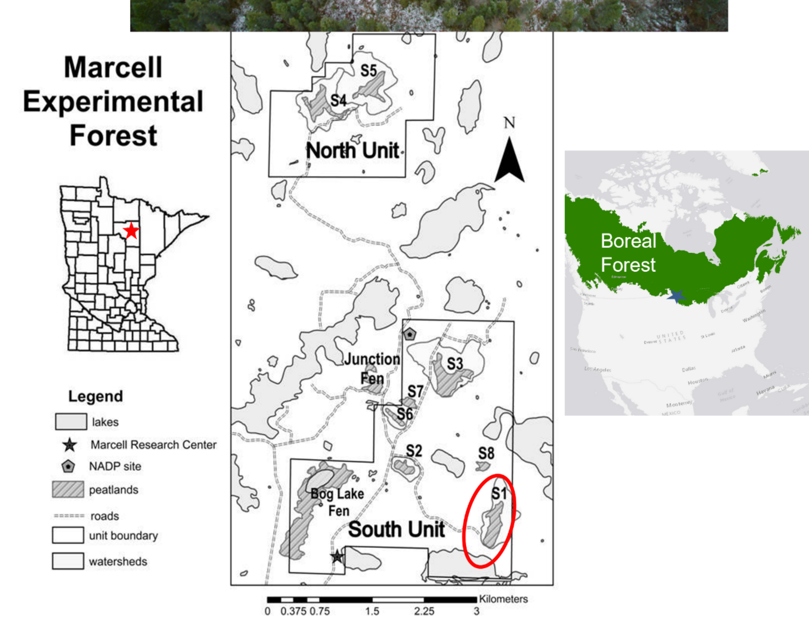
Different Environments By Temperature Treatment – 01Jan19, 01May19



Background and Methods

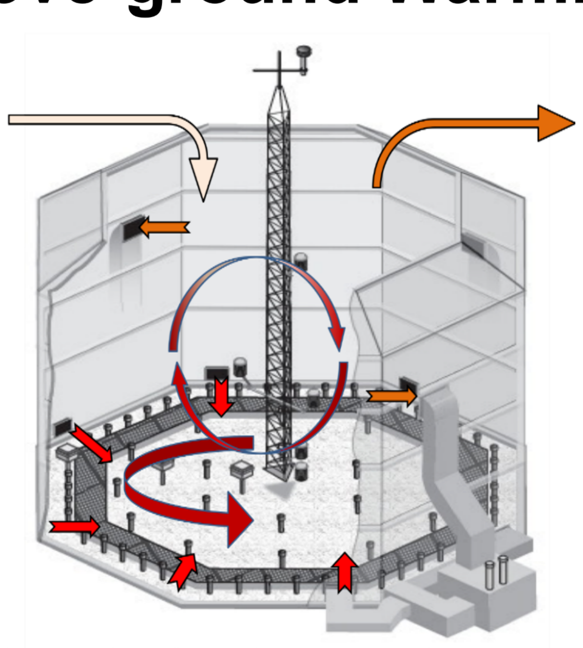
The Spruce-Peatland Responses Under Changing Environments (SPRUCE) experiment is designed to identify ecosystem and organism level response functions of Boreal peatlands to rapidly changing environmental conditions. An industrial scale environmental manipulation facility completed in August 2015 subjects multiple naturally occurring plots of tall statured peatland vegetation (Picea-Larix trees) to a range of above and belowground warming treatments and elevated levels of atmospheric Carbon Dioxide.





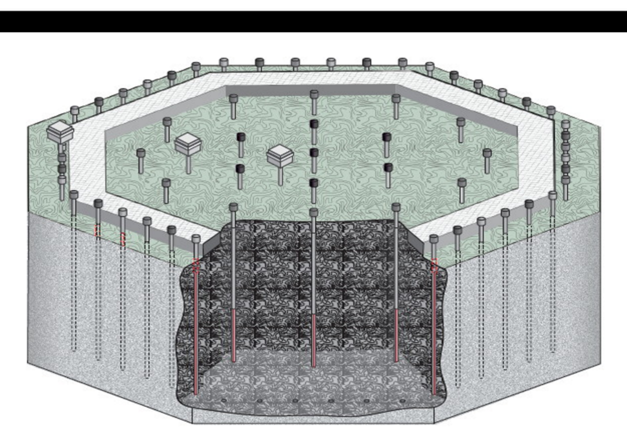
Open top greenhouse style enclosures facilitate below and above-ground ecosystem warming and CO_2 enrichment in the Boreal environment. Each enclosure is 12m in diameter and encompasses an above ground volume of 911 m³. The facility is designed to support a decade of continuous operation with minimal interruption. All treatments preserve natural seasonal and diurnal patterns by applying a differential manipulation to ambient conditions. Temperature differentials range from 0°C to 9°C above ambient conditions while CO_2 additions follow a protocol of ambient +500 ppm.

Above-ground Warming



- Four indirectly fired LP Make-Up Air Units (MAU) administer warmed air to the plot 1m above the bog surface.
- Air flow patterns created through interaction of natural wind and forced turbulence can be seen at left.
- PID control based on 2m air temp measurements drives warmed air additions.

Below-ground Warming



- Three independently controlled, concentric zones of electric resistance heaters warm the peat column.
- Zone A and B heaters warm the plot interior and heat from -2m to -3m depth.
- Zone C heaters surround the plot perimeter and heat from the surface to a depth of 3m.

CO_2 Enrichment

- Pure CO_2 of known isotopic signature (fossil source) is metered and injected into MAU ductwork to encourage uniform mixing with ambient air within the enclosure.
- Pure CO_2 additions are driven by PID control based on wind speed and CO_2 concentrations at 2m to achieve a differential of +500 ppm over ambient conditions. CO_2 concentration is continuously monitored on the central tower at 4m, 2m, 1m and 0.5m heights.

Citations

- Barbier C, Hanson PJ, Todd DE Jr, Belcher D, Jekabson EW, Thomas WK, Riggs JS (2012) Air Flow and Heat Transfer in a Temperature Controlled Open Top Enclosure, ASME International Mechanical Engineering Congress and Exposition, 2012, Houston, TX, Paper #IMECE2012-86352.
- Krassovski MB, Riggs JS, Hook LA, Nettles WR, Boden TA, Hanson PJ (2015) A comprehensive data acquisition and management system for an ecosystem-scale peatland warming and elevated CO_2 experiment. *Geoscientific Instrumentation Methods and Data Systems* 4:203–213, doi:10.5194/gi-4-203-2015
- Hanson PJ, Riggs JS, Nettles WR, Phillips JR, Krassovski MB, Hook LA, Richardson AD, Aubrecht DM, Ricciuto DM, Warren JM, Barbier C (2017) Attaining whole-ecosystem warming using air and deep soil heating methods with an elevated CO2 atmosphere. *Biogeosciences* 14: 861–883, doi: 10.5194/bg-14-861-2017
- Data DOI: http://dx.doi.org/10.3334/CDIAC/spruce.032