Inferring C and N dynamics from Foliar Isotopes

Using radiocarbon and stable isotopes to infer vegetation responses to experimental warming and elevated CO_2 at a southern boreal peatland

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Observations & Hypotheses

- Because of added fossil fuel-derived C, chamber atmosphere CO_2 differs greatly in $\delta^{13}C$ and $\Delta^{14}C$ between ambient & elevated CO_2 treatments.
- Peat-respired C should have similar $\delta^{13}C$, $\Delta^{14}C$ in ambient & elevated CO_2 treatments.
- In numerous studies, *Sphagnum* incorporated some peat-respired CO_2.
- Other ground vegetation (here, *Maianthemum*) should also incorporate peat-respired CO_2.
- In open-top chambers, peat C incorporation may increase: ground veg > shrubs > trees.
- Warming increases peat C turnover at SPRUCE (CO_2 release).
- Warming should therefore increase peat C incorporation by vegetation.
- Increased peat C turnover with warming should also increase N release/availability.
- Mobilized deep peat N is high in $\delta^{15}N$, shallow peat N is not.
- *Maianthemum* is suspected to have aerenchyma and has deeper roots than other taxa.
- Taxa accessing deep N should increase more than other taxa in $\delta^{15}N$.

- 5 temperature treatments duplicated at elevated CO_2 concentrations
- Ten 12-m diameter enclosures, aboveground and **belowground** warming
- Continuous full year experimental operation for 10 years
- Added CO_2 differs in $\Delta^{14}C$ and $\delta^{13}C$ from atmospheric and soil-respired CO_2
- Foliage sampled every year for $\Delta^{14}C$, $\delta^{13}C$, %N, and $\delta^{15}N$

Figure 1. Aerial view of chambers with treatments.

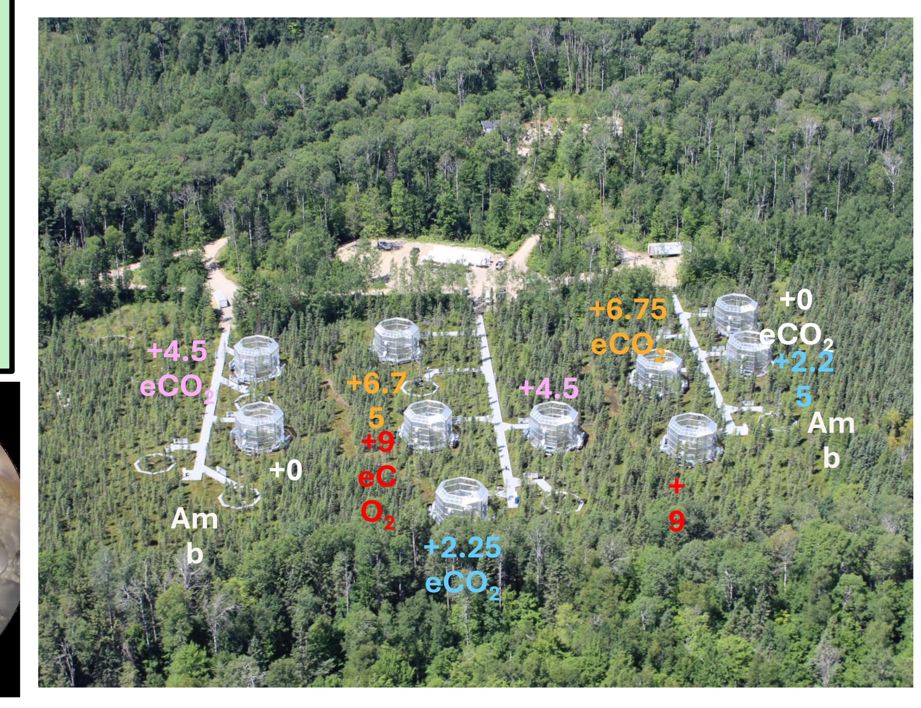


Figure 2. *Maianthemum* has aerenchyma. *Maianthemum trifolium* root cross-section A. at 10x, B. 200x magnification. Arrow points to the same cavity in each panel to orient the reader. Photos by Soren Weber.

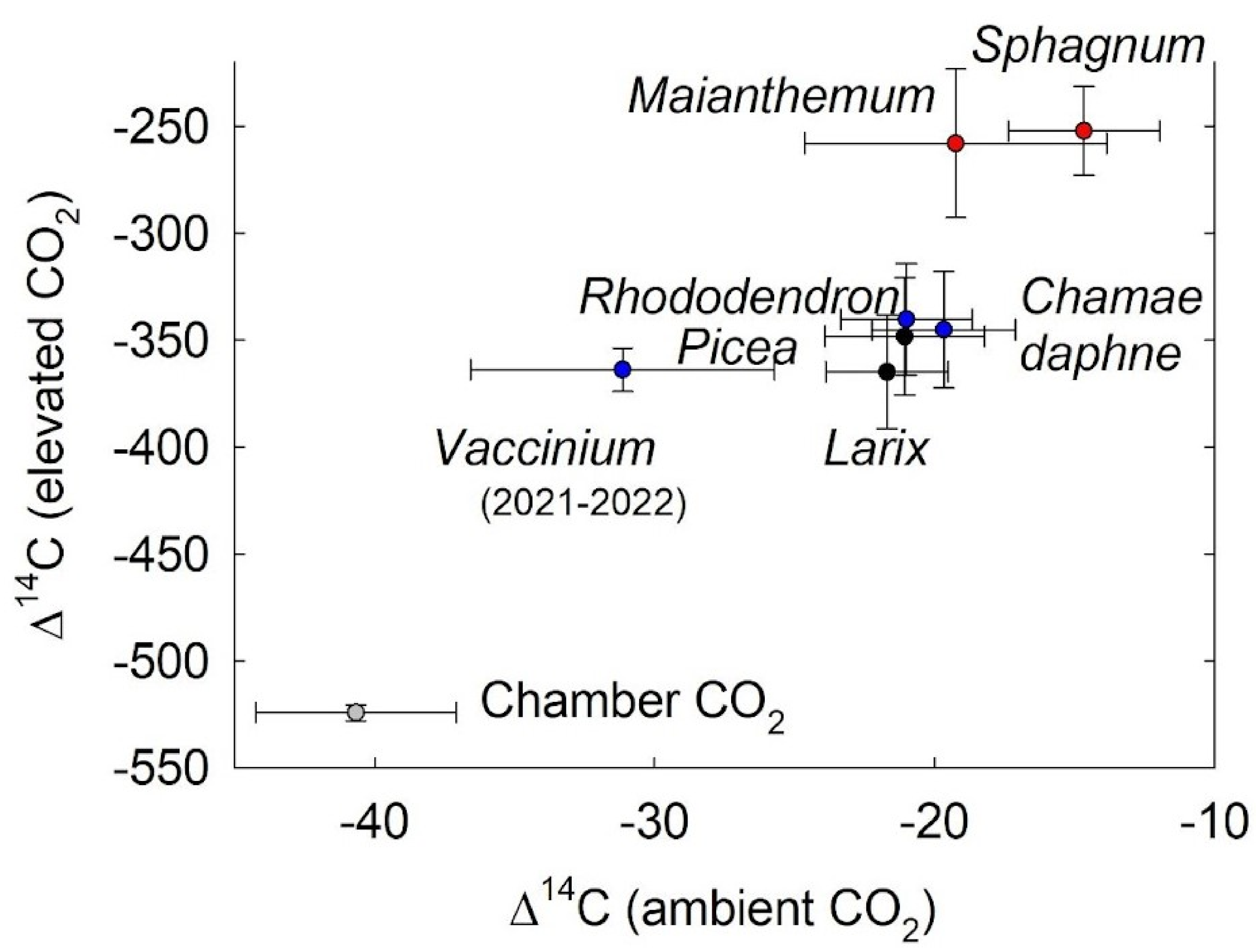


Figure 3. The $\Delta^{14}C$ of foliage of seven taxa under ambient and elevated CO_2, averaged across all years and temperature treatments, ± se. Values in ‰. Higher values indicate an increasing contribution of CO_2 sources other than the chamber atmosphere. Shrubs, blue; trees, black; ground vegetation, red.

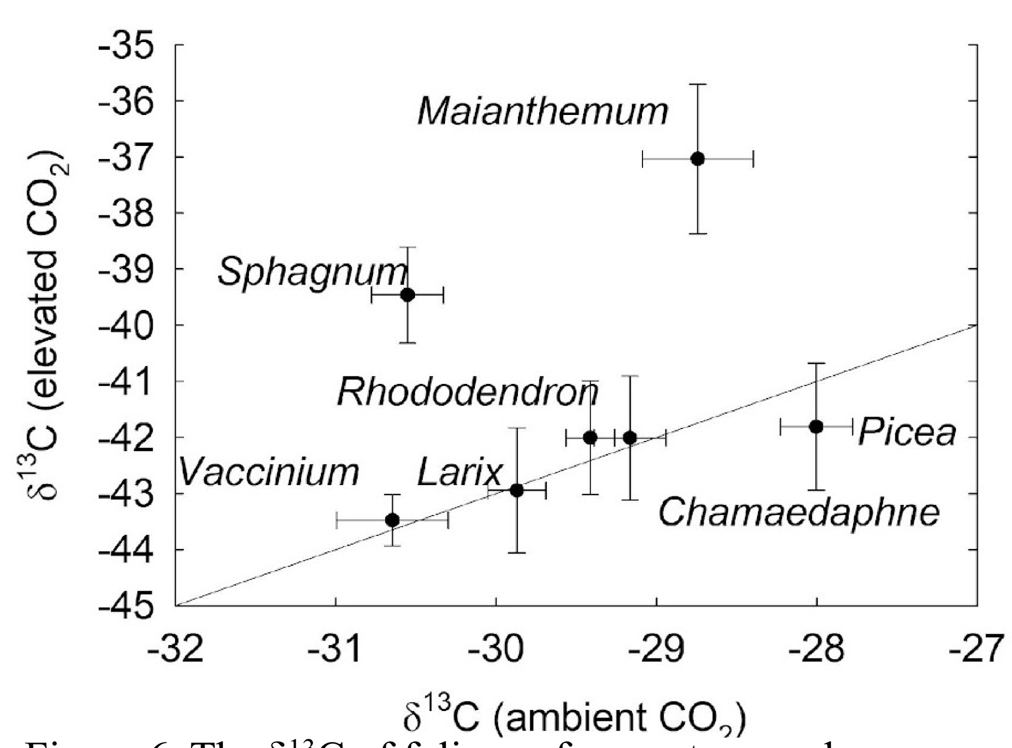


Figure 6. The $\delta^{13}C$ of foliage of seven taxa under ambient and elevated CO_2, averaged across all years and temperature treatments, ± se. Values in ‰. The five woody taxa fall on the line corresponding to $\delta^{13}C_{elevated} = \delta^{13}C_{ambient} - 13‰$. The $\delta^{13}C$ of ambient CO_2 is -9.4 ± 0.1‰ and of elevated CO_2 is -27.4 ± 0.2‰

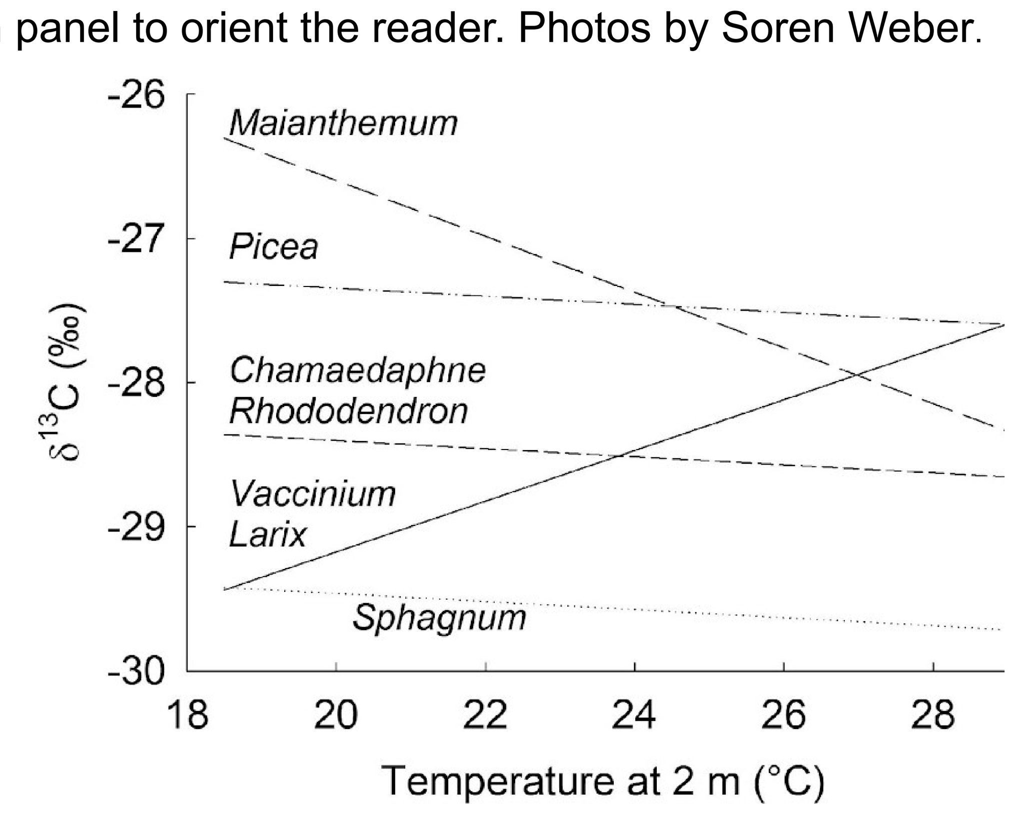
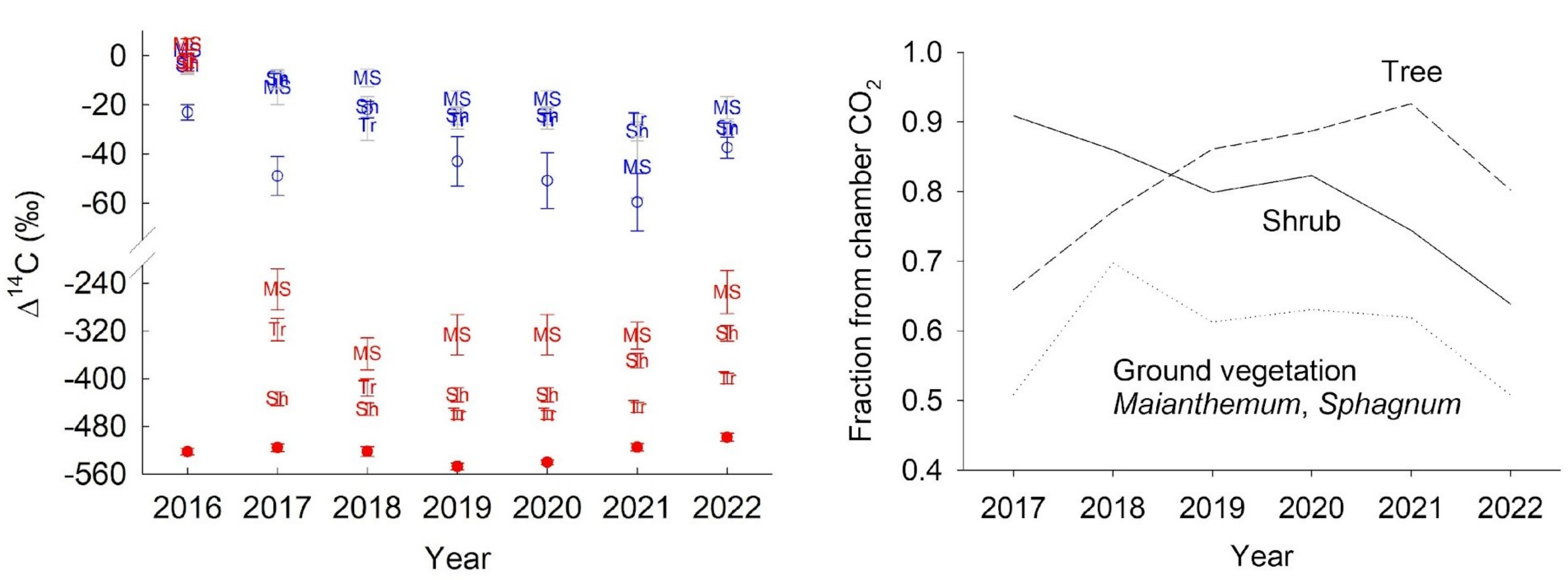
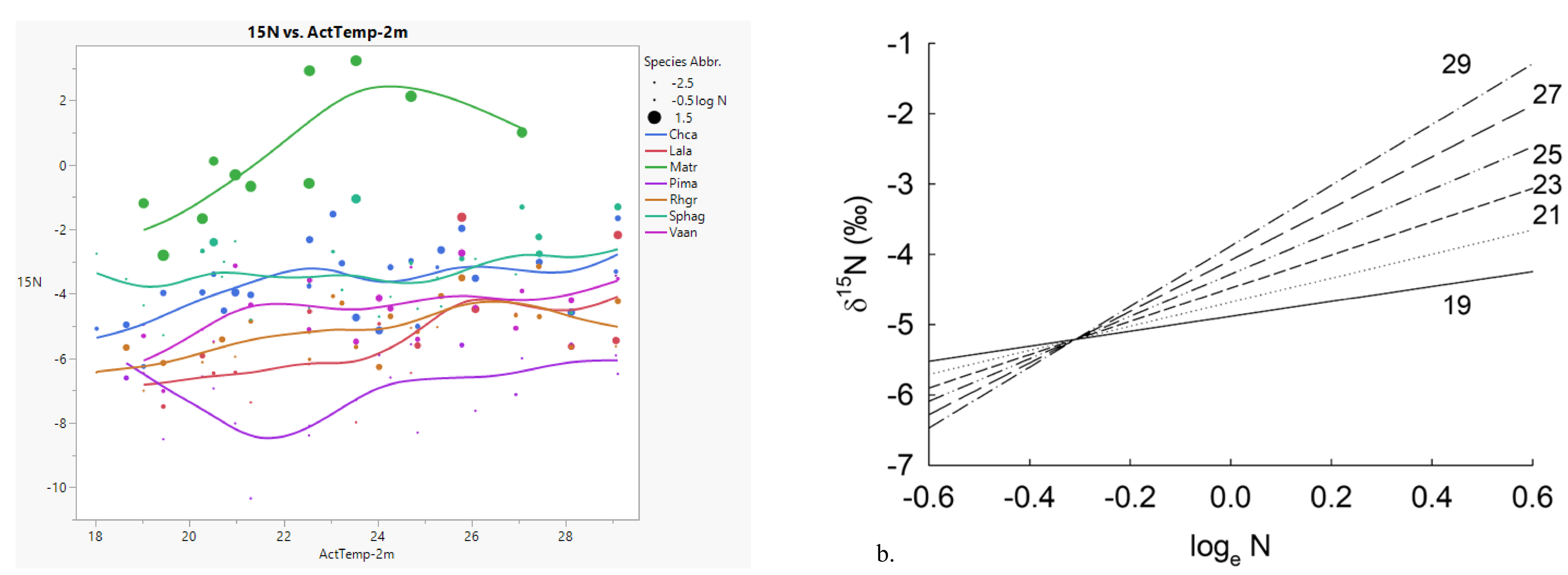


Figure 7. Regression model predictions of the effect of taxon and temperature on $\delta^{13}C$. The figure combines the intercept (Term 0), taxon (Terms 2, 3), and the interactions of temperature and taxon (Terms 9, 10).



a. b.

Figure 4. a. ^{14}C signatures (± se) of trees (Tr), shrubs (Sh), and ground vegetation (MS), and atmospheric CO_2 (circles) by year under elevated and ambient CO_2. Ambient, blue symbols; elevated, red symbols. b. Estimated yearly fraction of plant C for three functional groups derived from Equation (1) and the yearly $\Delta^{14}C$ of chamber CO_2, trees, shrubs, and ground vegetation.



b.

Figure 8. a. Foliar $\delta^{15}N$ increases with rising temperatures. Symbol and line colors correspond to taxa, with *Chamaedaphne* blue, *Larix* red, *Maianthemum* green, *Picea* purple, *Rhododendron* orange, *Sphagnum* blue-green, and *Vaccinium* purple-red. Symbol size corresponds to $\log_e N$.

(will change figure) b. Modeled effect of foliar $\log_e$ on foliar $\delta^{15}N$ becomes increasingly positive as mean active season temperature increases (in Celsius, on figure).

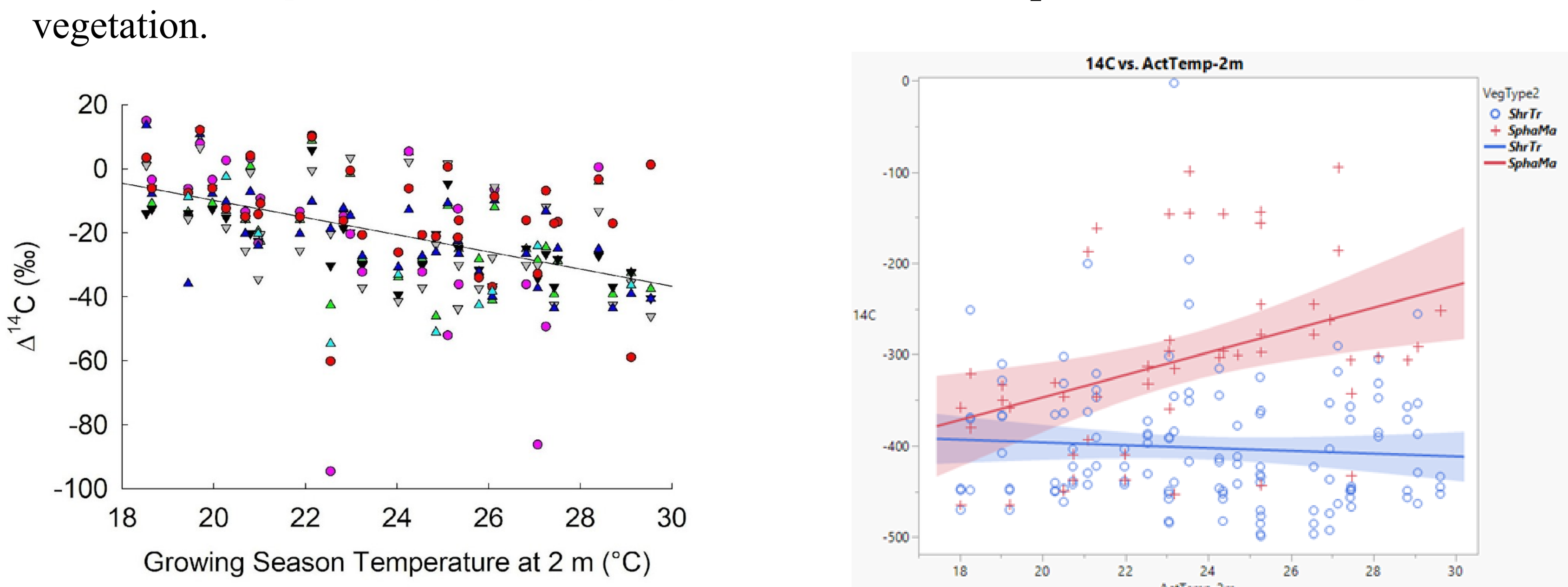


Figure 5. Foliar $\Delta^{14}C$ in ambient or elevated CO_2 plots correlated with temperature. a. Ambient: Colors indicate taxa. *Chamaedaphne*, green; *Larix*, black; *Maianthemum*, magenta; *Picea*, grey; *Rhododendron*, blue; *Sphagnum*, red; *Vaccinium*, light blue. b. Elevated, 2017-2022: Shrubs and trees indicated by blue circles, *Sphagnum* and *Maianthemum* indicated by red crosses.

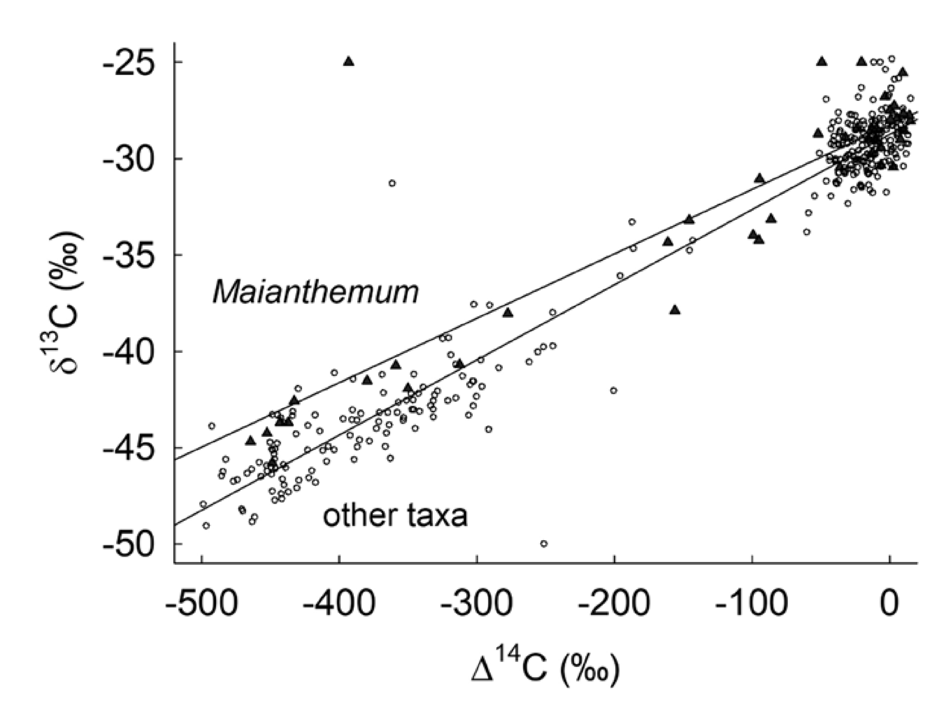


Figure 9. Foliar $\Delta^{14}C$ and $\delta^{13}C$ are strongly correlated across elevated and ambient CO_2 chambers. Slope differs between *Maianthemum* and other taxa. Symbols: *Maianthemum*, black triangles; other taxa, clear circles.

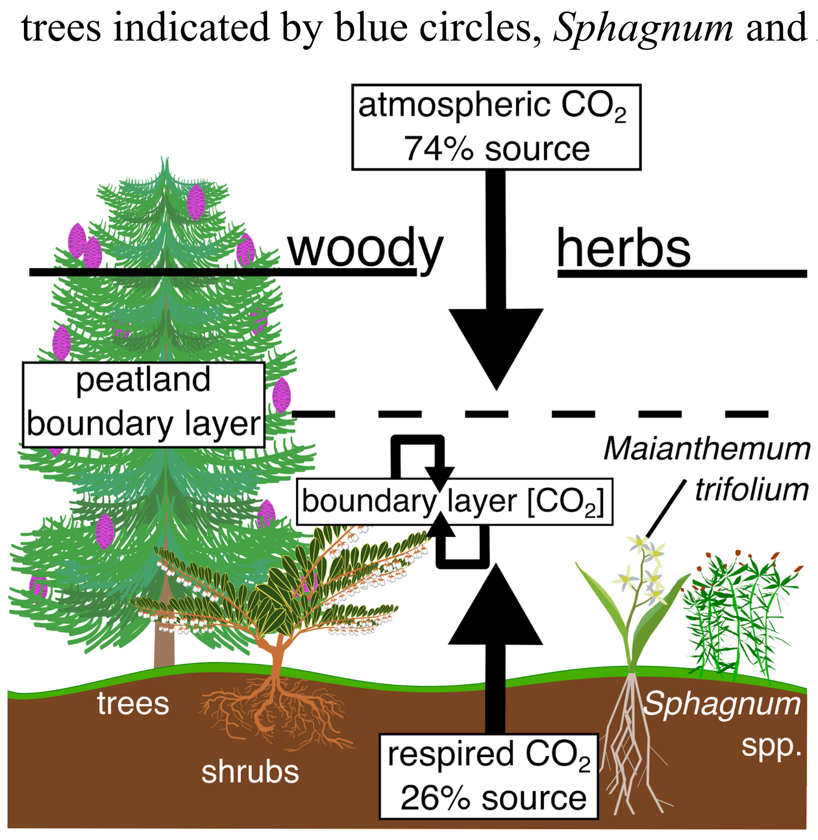


Figure 10. (comments welcome) Key findings from SPRUCE using $\Delta^{14}C$, $\delta^{13}C$, and $\delta^{15}N$ data.

- Overall, 40% of the CO_2-C contributing to new tissue development for both *Maianthemum* and *Sphagnum*, which reside within the peatland boundary layer, is sourced from older and decomposing peat deposits.
- Deep roots and aerenchyma of *Maianthemum* access deeper CO_2 and N than other plants.
- Increased C and N turnover with warming. 2.4% increased C incorporation in plants from peat sources per °C.
- Deep C source $\Delta^{14}C$ ~ -110‰, ~1000 years old.

Summary

- Secondary sources of CO_2 were18-20% (trees, shrubs) & 40% (ground veg) of photosynthesis
- No clear evidence that methanotrophy influenced *Sphagnum*. (*Maianth.* = *Sphag.*)
- Peat C turnover increased with rising temperature.
- *Maianthemum* shown to have aerenchyma.
- *Maianthemum* captured deep N released with peat warming & turnover.
- Age of secondary C source ~1000 years, 30-40 cm deep on average.
- *Maianthemum* or other aerenchymatous plants could be used as sensors of peat turnover
- Future work: Finish nitrogen isotopes (just 3 years now).
- Test natural temperature gradients for shifts in $\delta^{13}C$, $\Delta^{14}C$, and $\delta^{15}N$ of different peatland plants

Acknowledgements

This material is based upon work supported in part by the U.S. Department of Energy, Office of Science, Office of Biological and Environmental Research.

Oak Ridge National Laboratory is managed by UT-Battelle, LLC, for the U.S. Department of Energy under contract DE-AC05-00OR22725.

DOE grant ER65430 to Iowa State University and a PIFI fellowship from the Chinese Academy of Sciences also supported this work.

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