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Long-term ecophysiological signals from isotopomers: Principles and applications.

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Understanding plant responses to increasing CO_2 is essential for predictions of plant productivity and of future climate (Walker et al. 2020). Isotope ratios ($^{13}C/^{12}C$ and $^2H/^1H$) have long been used in plant ecophysiology and for reconstruction of environmental variables. But it has also been known since decades that heavy isotopes are distributed unevenly WITHIN biological metabolites, i.e. that the abundances of ^2H and ^{13}C isotopomers vary. Because isotopomer variation is caused by enzyme isotope fractionation, it carries signals on the regulation of biochemical pathways. If such signals can be recovered from archives of plant material, they can report on plant-climate interactions on time scales from decades to millennia.

We use NMR (nuclear magnetic resonance) to analyze isotopomers of the glucose units of plant archives, and I will describe the principles and practicalities of isotopomer measurements. First, in manipulation experiments we calibrate isotopomer responses to environmental drivers, in particular CO_2 and T. Second, we analyse isotopomers in plant archives such as tree-ring series over previous decades of rising CO_2, and use the calibrations from the manipulation experiments to deduce shifts in photosynthetic metabolism over decades. We will present results on ^2H and ^{13}C isotopomer variation and associated ecophysiological signals.

We present data on ^{13}C isotopomers in tree-ring cellulose and annual plants (Wieloch et al 2018). The results have implications for interpretation of the d^{13}C of respired CO_2. Furthermore, we show how ^{13}C isotopomers give new insight into the pathways of C metabolism (Wieloch et al 2023).

Photorespiration is a side reaction of photosynthesis that reduces C assimilation in most vegetation. Photorespiration is reduced by increasing CO_2 yet exacerbated by rising T, so its evolution under climate change and implications for global C fluxes are highly uncertain. We present data showing how ^2H isotopomers can be used to track photorespiration in

response to CO_2 and T. The opposing effects of CO_2 and T on photorespiration will determine if forests will in the future be a sink or source of CO_2 (Van der Sleen et al. 2015; Sperry et al. 2019). For select tree species, we compare results from FACE experiments and from decades-long tree ring series, to detect possible acclimation of gas exchange of broad-leaved trees over

In summary, the presentation will describe how isotopomers can improve mechanistic understanding of plant function on long time scales, to be incorporated into Dynamic global vegetation models to improve predictions of C fluxes under climate change scenarios.

References

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