Field measurements of photosynthetic 13C discrimination of Fagus Sylvatica branches using laser spectrometry

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Isotopic discrimination against $^{13}CO_2$ during photosynthesis ($^{13}\Delta$) causes the overall ^{13}C depletion of the terrestrial biosphere compared to the atmosphere. $^{13}\Delta$ varies in response to environmental variables that influence photosynthetic gas exchange. For C_3 plants, $^{13}\Delta$ mainly reflects the balance between the CO_2 supply to and the CO_2 demand by the carboxylation sites, but it is, to a smaller extent, also influenced by carbon isotope fractionations occurring during mitochondrial and photo-respiration. Understanding and predicting $^{13}\Delta$ variability has gained relevance for CO_2 flux partitioning on the global and the ecosystem scale, for tree ring analysis or for insights into plant/soil dynamics. Estimates of $^{13}\Delta$ are commonly obtained by combining carbon isotope measurements of plant-derived organic matter or air profiles with $^{13}\Delta$-models. In contrast, direct, gas exchange-based measurements of $^{13}\Delta$ under field conditions are sparse, due to the technical deployment involved. Hence, we have little experimental verification of diurnal and seasonal variabilities of $^{13}\Delta$ and their relation to environmental drivers. We further lack a thorough field-based evaluation of the Farquhar et al. (1982) $^{13}\Delta$-model.
Here, we present continuous, hourly field measurements of $^{13}\Delta$ of Fagus sylvatica L.branches, conducted with three custom-made open branch bags and a laser spectrometer for CO_2 isotopologue measurements (QCLAS-ISO, Aerodyne Research Inc.). Data from two field campaigns (in total 38 and 60 days) in a mature, temperate mixed-deciduous forest in Switzerland during August / September 2009 and 2010 are shown. We observed a high diurnal variability of $^{13}\Delta$, with average diurnal amplitudes of ≈ 10‰ and maximum diurnal amplitudes of ≈ 20‰. Highest $^{13}\Delta$ were generally observed during dawn and dusk, and lowest $^{13}\Delta$ during midday. Morning and afternoon $^{13}\Delta$ commonly displayed intermediate values. Day-to-day variations were summarized with flux-weighted daily means of $^{13}\Delta$, which ranged from 15‰ to 23‰ in 2009 and from 18‰ to 29‰ in 2010. If trees were not water-limited, branch gas exchange, and hence $^{13}\Delta$, appeared to be mainly driven by changes in incident PAR. Woody tissue CO_2 efflux was measured with two independent approaches to assess its potential bias on branch bag measurements. We estimated that its contribution to branch net CO_2 assimilation was < 0.1 µmol m^{-2} s^{-1} per total leaf area during the time of our field campaigns.
Using data from the 2010 field campaign only, we explored the applicability of the comprehensive ($^{13}\Delta_{comp}$), the simplified ($^{13}\Delta_{simple}$) and the revised ($^{13}\Delta_{revised}$) versions of the Farquhar et al. (1982) - model for predicting observed diurnal and day-to-day $^{13}\Delta$ variabilities. $^{13}\Delta_{comp}$ predicted the mean diurnal variability of $^{13}\Delta$ much better than $^{13}\Delta_{simple}$ ($RMSE_{simple} \approx 3.4$; $RMSE_{comp} \approx 2.5$). Furthermore, $^{13}\Delta_{comp}$ was more suitable than $^{13}\Delta_{simple}$ for predicting flux-weighted daily means of observed $^{13}\Delta$. For model calibrations, a Bayesian inference approach was used. This approach allowed us to reliably quantify uncertainties in the model parameter estimation and to reveal the amount of model-relevant information present in our field dataset.

Reference

Farquhar GD, O`Leary MH, Berry JA (1982) On the relationship between carbon isotope discrimination and the intercellular carbon dioxide concentration in leaves. Aust. J. Plant Physiol. 9:121-137