A dual isotope approach using δ18O and δD for estimating past relative humidity: deuterium deviations from the global meteoric water line in leaf water (Δdl) and cellulose (Δdc)

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Cellulose δ18O and δD in preserved plant material can provide insights on climates and hydrological cycling in the distant past. However, most studies of plant cellulose have used only one isotope, most commonly δ18O, resulting in difficulties partitioning variation between changes in δ18O of precipitation versus the degree that evaporative conditions affect leaf water isotopic enrichment. Moreover, observations of pronounced diurnal differences from the predictions of the conventional Craig-Gordon (C-G) steady-state model of leaf water isotopic fractionation have cast some doubt on the use of this single isotope modeling approach for separating precipitation and evaporation drivers of cellulose δ18O or δD. We explore a dual isotope approach akin to the concept of deuterium-excess (d), to estimate past relative humidity influences while accounting for variation caused by isotopes in precipitation. We use paired δ18O and δD to establish deuterium deviations from the global meteoric water line in leaf water (Δdl). C-G models predict relative humidity (RH) will drive Δdl, while the influence of stomatal conductance or temperature should be negligible. To demonstrate this concept, we first survey studies of leaf water δ18O and δD and discuss the implications of these data for cellulose δ18O and δD in hardwood and conifer trees. We then use a mechanistic model of cellulose δ18O and δD to back-predict deuterium deviations from the global meteoric water line (Δdc) in Quercus macrocarpa, Q. robur and Pseudotsuga menziesii. For each species Δdc showed strong correlations with RH across sites. Δdc showed good agreement with C-G steady state predictions for Q. macrocarpa, and P.menziesii, but for Q. robur the relationship with RH was steeper than expected. These comparisons provide evidence that C-G steady state-models are appropriate for interpreting cellulose δ18O and δD and that Δdc can be used to establish variability in RH associated with past climatic cycles or across regional climates.