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Environmental signals in tree-ring δ18O from a temperate catchment in Switzerland

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Oxygen isotopes (δ^{18}O) in tree rings are a valuable proxy for past environmental conditions. Yet, the contribution of source water δ^{18}O versus signals generated at the leaf level as well as the influence of tree-physiological responses on tree-ring δ^{18}O differences between individual trees at a site remain uncertain.

To address this topic, we conducted a study at a catchment research site in northeastern Switzerland. Its unique long-term sampling design allowed for bi-weekly δ^{18}O measurements of precipitation and creek water for the 2002 to 2014 period. Four ash trees (*Fraxinus sp.*) situated at a creek and four on a nearby steep slope were selected for δ^{18}O measurements of tree-ring cellulose for the same 13 year period. δ^{18}O of soil water as well as cryogenically extracted stem and twig xylem water were determined for three days within the 2016 vegetation period for comparison of xylem and soil water δ^{18}O between the slope and the creek site. Gas exchange measurements with a LI-COR (Li-6400) allowed for comparison of transpiration rate, stomatal conductance and productivity between sites.

We calculated correlations to environmental variables and applied the mechanistic Péclet-modified-Craig-Gordon (PMCG) model to simulate observed δ^{18}O cellulose values while varying the parameterization of physiological and environmental variables according to the measured values.

Mean inter-series correlations between the tree-level δ^{18}O time series are similarly high at the slope and the creek locations, and both site-chronologies are tightly correlated (r=0.9) although offset by 0.9 ‰ on average. Both chronologies contain a similarly strong summer VPD/RH signal, but we find correlations to precipitation and creek discharge δ^{18}O are just as high. Our results suggest that i) both leaf-level and source water signals are imprinted in cellulose δ^{18}O, and ii) in addition to leaf-level evaporative enrichment the VPD signal at least partly results from its correlation to precipitation δ^{18}O (r=0.57).

The cellulose δ^{18}O values are on average 0.9 ‰ higher at the slope site compared to the creek site despite similar stem xylem and soil water δ^{18}O. Although it is commonly assumed that no fractionation occurs during transport from the roots to the twigs, we find that twig xylem δ^{18}O is about 1 ‰ higher than stem xylem δ^{18}O. Simulations with the PMCG model (which captured the overall behaviour in the δ^{18}O time series well) with varying parameterization for stomatal conductance and twig xylem δ^{18}O according to measured values show that about 50 % of the 0.9 ‰ offset between creek and slope is explained.

We conclude that i) it is unlikely that differences in source water δ^{18}O cause the 0.9 ‰ offset between both sites alone, ii) despite the proximity of both sites the transpiration rate and productivity of trees at the creek site is higher, and iii) according to the PMCG model tree physiological responses are important for site internal tree-ring δ^{18}O variability although interannual variations are only slightly affected.