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Stable oxygen isotopes in water from xylem and soil of alpine trees

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Tree-ring δ18O is a mixed signal influenced by the up taken water transported from the roots through the xylem, and fractionation processes at the leaf level. The xylem water is constrained by actual precipitation as well as water from deeper soil layers representing a lagged and dampened long-term precipitation signal and is the source for evaporative enrichment (Roden & Ehleringer 2000). Since no fractionation of oxygen isotopes takes place during water uptake by the root system, the water in the xylem should reflect the 18O-signature of the soil water and its seasonal variation.

Here we present a highly resolved data set of oxygen isotopes in precipitation, soil water and xylem water of Larix decidua and Picea abies at two alpine sites in the Loetschental/Switzerland, covering four growing seasons (2008-2011). This unique data set is used to test how far the sampled soil water reflects xylem water over the season and if a single isotope, two-source mixing model (Brunel et al. 1995; Phillips & Gregg 2001) using two soil depths can be applied to estimate xylem water δ18O.

Although the xylem water traced well the soil water during most of the season, we found significant offsets between both. They occur in early spring with a strong enrichment in the xylem water of larch particularly, which is uncoupled from the δ18O value in soil or precipitation water. This enrichment is approximately 10‰ higher than the δ18O value of soil water and decreases until mid-spring, where δ18O values reach soil water values. A sampling campaign during winter 2011 showed a successive development of this enrichment from the beginning of January. This effect might be related to freeze-thaw cycles of the twig xylem. While twigs above the snow surface experience strong radiation during day time in winter and can heat up accordingly (Mayr et al. 2012), the transpiration stream within the tree has stopped. This might lead to a slow enrichment, especially during late winter, where the daily radiation becomes stronger every day. During summer and fall, xylem water δ18O decreases below soil water indicating an acquisition from deeper soil layers. This is always accompanied by dry soil conditions and suggests a stronger influence of depleted water from the winter season.

These results improve our understanding of the effects that source water might have on δ18O of tree rings and may ultimately help to overcome some of the discrepancies observed between climate and oxygen isotopes in tree rings.

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