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Oxygen isotope variations in needles and tree rings of Scots pine exposed to varying water supply

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In many regions, drought is suspected to be a cause of Scots pine decline and mortality, but the underlying physiological mechanisms remain unclear. Because of their relationship to ecohydrological processes, δ^{18}O ratios in tree rings are potentially useful for deciphering long-term physiological responses and tree adaptation to increasing drought. However, a better understanding of needle- and stem-level isotope fractionations in mature trees is necessary. Although δ^{18}O in tree rings have often been used to reconstruct past environmental conditions, these studies mainly relied on statistical relationships with climate variables and thus may not always adequately account for all processes. It would be important to apply mechanistic, process-based models for better understanding the factors controlling the isotope fractionation in foliage and tree rings related to various environmental conditions, including drought. In this study, we investigated a drought-stressed Scots pine population from one of the driest parts of the European Alps (Valais, Switzerland) that has been subjected to a long-term irrigation experiment since 2003. We measured δ^{18}O values in water extracted from different soil depths and needles of the control and irrigated trees sampled multiple times between 2013 and 2015. At the same site, we analyzed the δ^{18}O values in tree-ring cellulose from Scots pine trees that had recently died and compared them with the signal from living trees over the period 1900-2014. Our first aim was to identify the factors controlling leaf-level isotope fractionation, owing to environmental and physiological changes, including evaporative leaf water enrichment, gas-exchange and needle morphological properties. Particularly, the basic Craig-Gordon model, Péclet and the two-pool correction were explored. As a second aim, we compared measured tree-ring δ^{18}O values with predicted ones using a fractionation model corrected with a similar approach as for needles to determine the driving factors of tree-ring oxygen isotope variability in drought-stressed trees. The results improve our understanding of the effect of long-term differences in tree physiology on δ^{18}O and shed light on drought-induced tree decline.