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A European vision for hydrological observations and experimentation

Towards the mechanistic understanding of plant-source water isotopic offsets

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In recent years, the widespread use of laser-based analyzers of the isotopic composition of water ($\delta^{18}O$ and $\delta^{2}H$) resulted in an increase in the temporal and spatial resolution of measurements of plant water and their sources. Such datasets revealed previously undetected mismatches between the isotopic composition of subsurface water pools and bulk xylem water usually extracted by cryogenic distillation. To understand the underlying cause of these isotopic mismatches, plant ecophysiologists and ecohydrologists have conducted numerous experiments to address a range of hypotheses. Measurement artifacts produced by water extraction techniques in both bulk xylem water and soil water were claimed to be behind the observed mismatches. However, there is not yet a consensus on a sole mechanism to explain all cases. On the other hand, our research demonstrated the existence of isotopic heterogeneities between the water in different xylem compartments, which also have contrasting degrees of hydraulic connectivity with the transpiration stream. Analogous isotopic patterns were observed in soil water pools and attributed to physicochemical interactions with soil particles. Altogether, it seems that the water pools that are measured matter, and that not all isotopic mismatches can be attributed to methodological artifacts. Given the widespread occurrence of these isotopic mismatches, it is urgent to identify the cause, either natural, artificial, or both. This will allow us to make informed choices of the extraction techniques in each situation and eventually, we could be able to correct potentially biased old datasets. In this regard, we will summarize the most recent findings and suggest research strategies to unravel the underlying mechanisms of isotopic mismatches. In addition, we will outline how such strategies can also provide important insights for closely related disciplines such as plant hydraulics or isotopic analyses of tree-ring archives.