The Stem Borehole Equilibration Method

Measuring Water Stable Isotopes in Tree Xylem in situ

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References

[1] Volkmann et al. 2016, *Plant Cell Env.iron.* 39
[2] Majoube 1971, *J Chim Phys* 68

Introduction

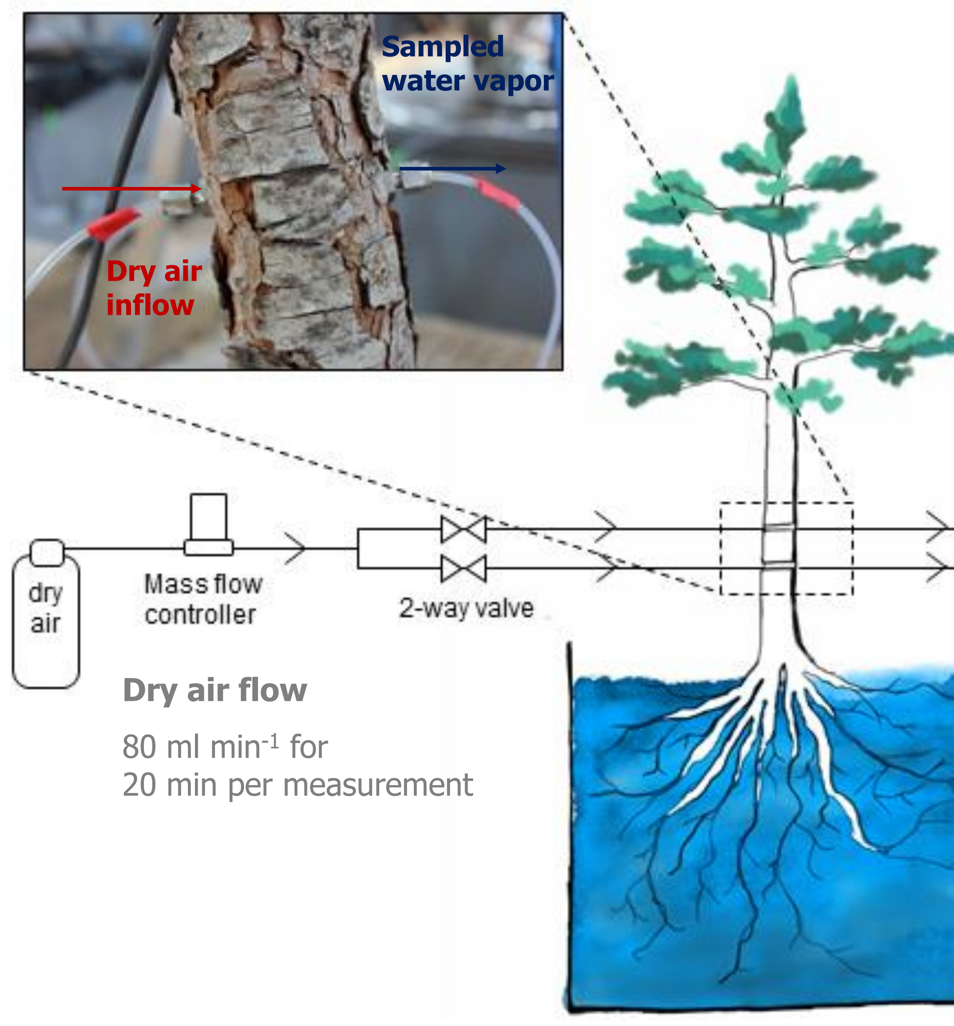
- Ecohydrological processes are highly variable in time
  → it is desirable to obtain high resolution data on parameters describing these processes
- *In situ* methods enabling high-resolution measurements of water isotopes in the tree xylem have already been tested [1] but are not yet widely applied
- Such methods would be tremendously helpful in understanding water uptake in plants, especially regarding short-term dynamics of root water uptake

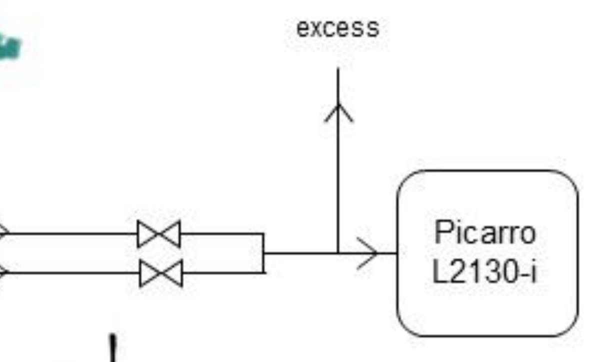
Testing a new method only using commercially available components for measuring the isotope composition of xylem water *in situ*

Methods

Borehole lengths

Tree	Ø top	Ø bottom
alder	9.2 cm	10.5 cm
cork oak	11.5 cm	12.3 cm
cork oak 2		8.8 cm
pine	8.0 cm	9.9 cm





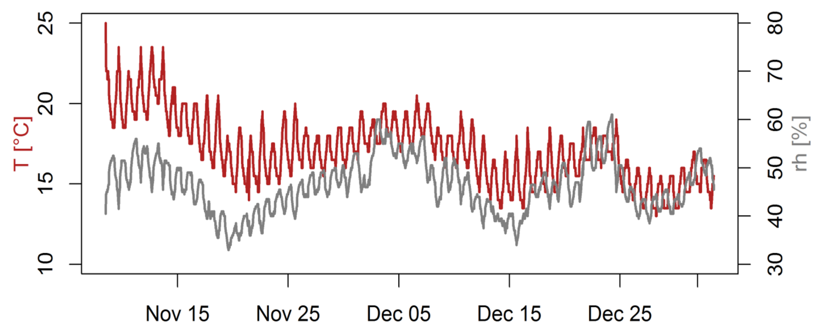
- Three tree species: Alder (*Alnus x spaethii*), Cork oak (*Quercus suber*) and Pine (*Pinus pinea*); Roots were submerged in water of known isotope composition
- Two stem boreholes (diameter 10 mm) in each trunk (distance: 50 cm), Swagelok connections were inserted at both sides and PTFE tubing attached
- Via a custom-made manifold system, dry air was directed through the selected borehole, the isotope composition of water vapor taken up by dry air was directly determined in a water isotope analyzer
- Temperature measured in boreholes was used to calculate liquid isotope composition from vapor values assuming equilibrium fractionation [2]
- Source water was exchanged with water enriched in ^2H and isotopic reaction in xylem observed
- Additionally, one sap flow sensor was inserted in each tree and twig xylem samples were collected for cryogenic vacuum extraction

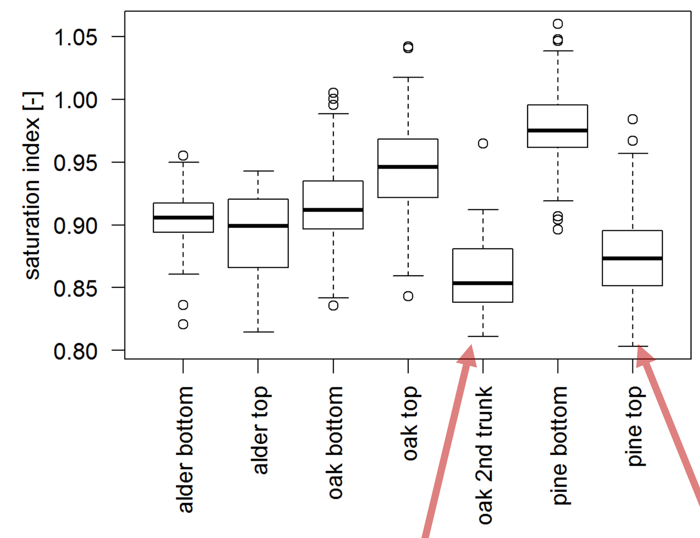
Results

With temperature recorded in the borehole, water vapor mixing ratio at full saturation can be calculated and compared to the value measured in the vapor sample

→ Used to evaluate if sample was fully saturated
→ Can isotopic equilibrium between phases be reached?
→ Data points with saturation index < 0.8 were excluded

Climatic conditions

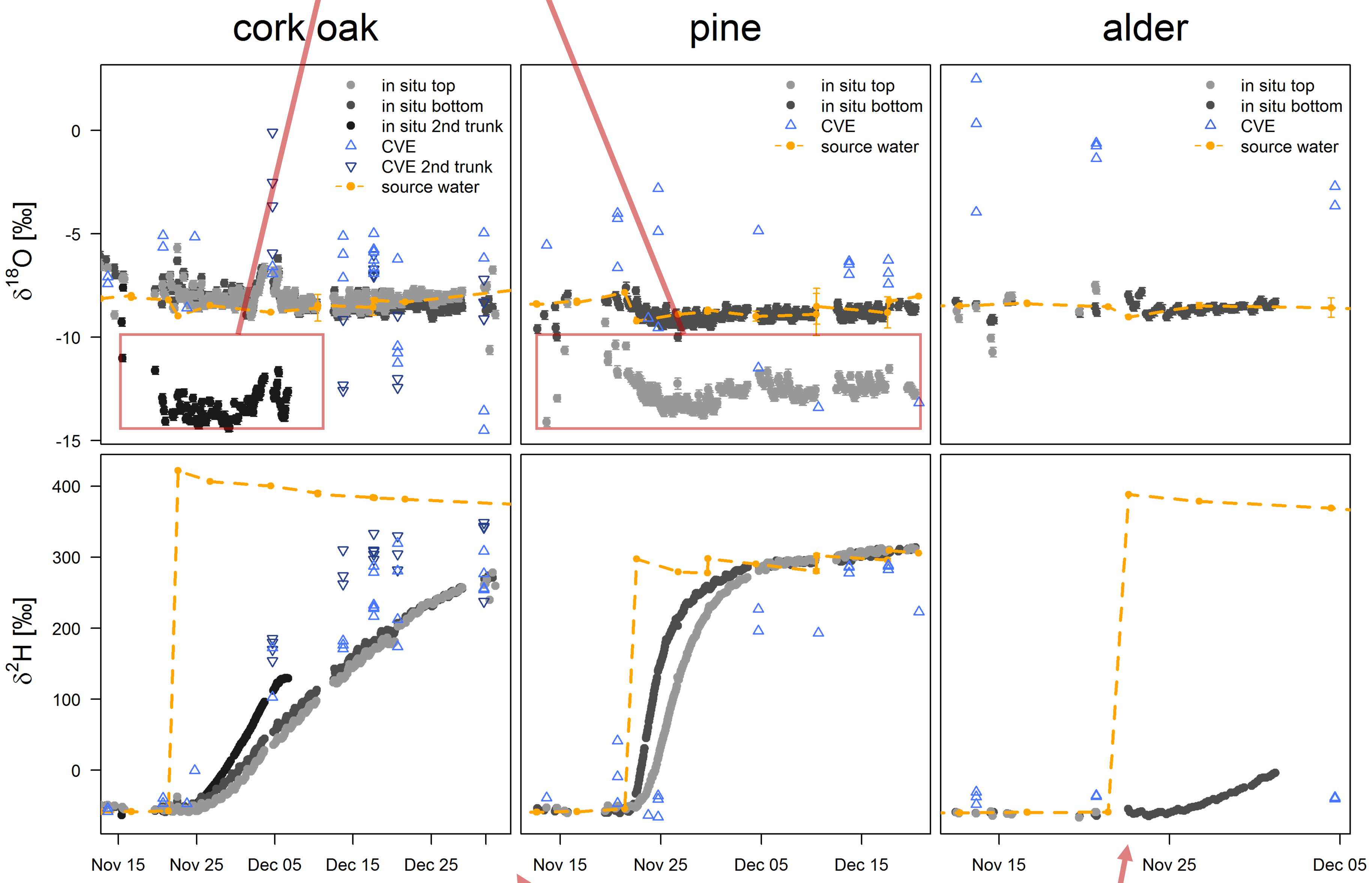




Deviation from source water $\delta^{18}O$ due to incomplete isotopic equilibrium
→ Relation to borehole diameter

Isotope measurements

Comparison of *in situ* data with source water isotope composition and values from destructive sampling and following cryogenic vacuum extraction (CVE)



time lag between top and bottom borehole
Cork oak: 40 h
Pine: 60 h

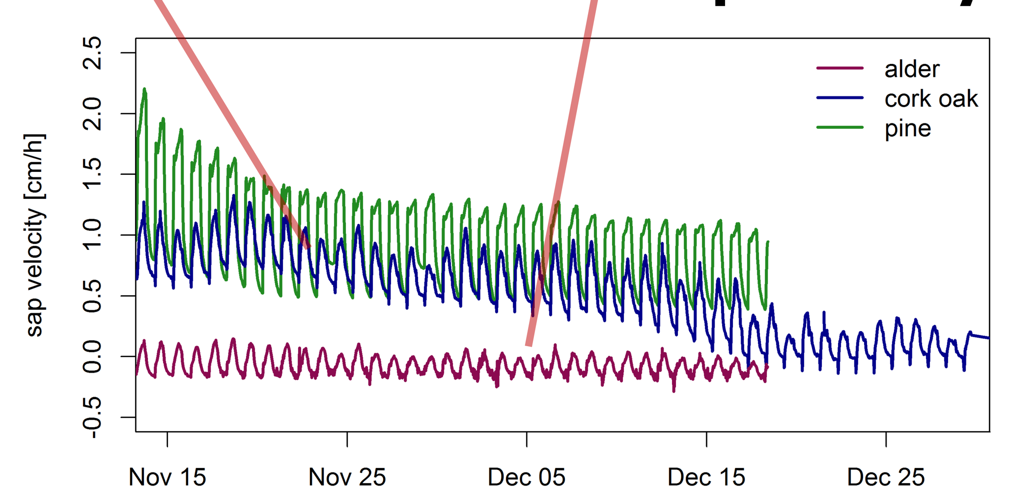
Distance between boreholes: 50 cm

Sap velocity calculated
Cork oak: 1.25 cm h^{-1}
Pine: 0.83 cm h^{-1}

Lower sapflow in cork oak compared to pine explains slower reaction after change of ^2H in source water, also results in lower slope

Due to leaf drop, the alder tree stopped transpiring, nevertheless sap water δ^2H increased in reaction to irrigation
→ Still some exchange of tree xylem water with source water?
→ Diffusion due to isotopic gradient?

Sap velocity



Calculated sap velocity from isotopic time lag **higher** for cork oak than pine
BUT
Measured sap velocity is higher for pine than for cork oak

→ Dispersion of tracer signal may be dependent on sap velocity

→ Uncertainties about isotopic mixing in stem (e.g. isotopic differences between sapwood and heartwood), might also explain observed differences between *in situ* and CVE data

Conclusion

- Natural abundance data is in an acceptable range for field measurements
- A pronounced change in xylem water δ^2H was detected both in pine and cork oak; For pine, values stabilized at the new source water composition
- If and how isotope data can be used to cross-validate sap flow probes has to be further investigated

→ **If applied carefully, the method can be used to obtain high-resolution information on xylem water isotope composition *in situ***

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