Delayed observation of tree water uptake using in-situ measurements of stable water isotopes

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Motivation

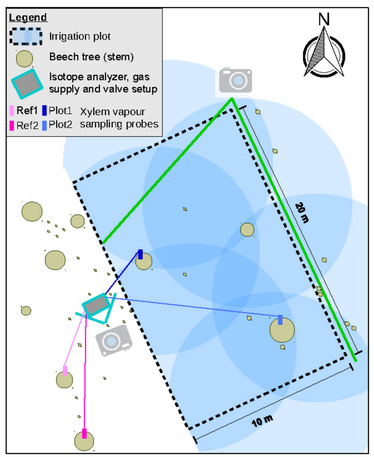
- Effort required to sample tree xylem water for stable water isotope analysis previously reduced feasible sampling frequencies
- Development of in-situ vapour sampling probes (Volkmann et al. 2016) promises new possibilities for long term and high frequency monitoring of stable water isotopes in the tree xylem
- Apart from proof of concept study over 12 days and close to the lab, applications of the new method are missing

Objectives

- First extended field application of the xylem water isotope sampling probe (XWIP)
- Monitoring tree water uptake during a sprinkling experiment using deuterium enriched water as an artificial tracer

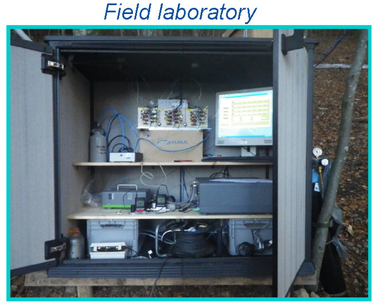
Study site

- Old growth beech forest in the Black Forest, Southwest Germany
- 12 h irrigation of 200 m² area with 60 m³ of isotopically labeled water (Deuterium-excess of 110 ‰)



Irrigation setup

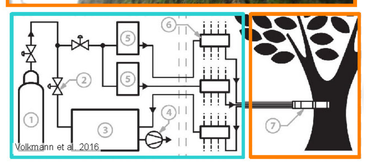
Field laboratory



Measurements

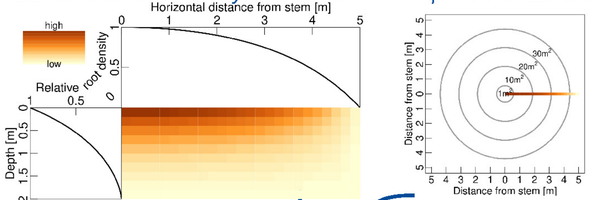
- Xylem water isotope probes (XWIPs) installed in two trees on the irrigation plot and two trees on the reference area
- Sap flow sensors (East 30 Sensors) installed close to each isotope probe
- Drilled soil cores analyzed for stable water isotopes with vapor equilibration method

XWIP: Xylem water isotope probe



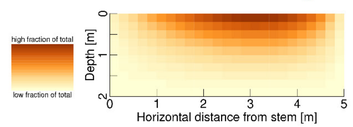
Thoughts on tree fine root distributions

2D-slice of root density distribution → *Top view of 2D-slice*



- Root densities declining with depth & horizontal distance to the stem
- Area within a certain perimeter grows with the square of the distance

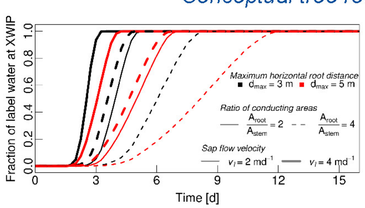
Effective root distribution



- Up to a certain horizontal distance from the stem, the increase of covered area outweighs the decrease of relative root density

→ In total, the most fine roots are found at a bigger distance from the stem

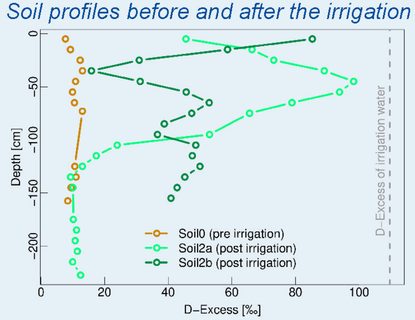
Conceptual tree root water transport model



- Explicit simulation of multiple “root pipes” (all combinations of depth and distance), represented as FIFO (first in first out) buffers, whose lengths are determined by depths and distances
- Number of input & output elements per time step determined by current sap-flow velocity
- Outputs of all “root pipes” weighted according to the effective root distribution

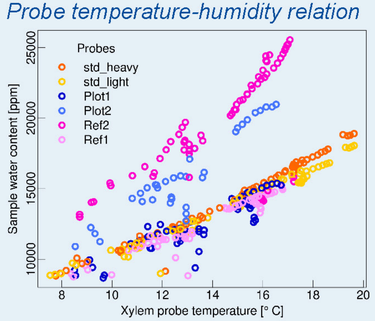
Results

Soil profiles before and after the irrigation



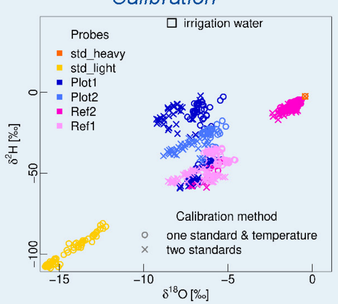
- Increased D-Excess of labeling water found in the soil depth profiles
- Strong soil heterogeneity leading to contrasting soil profiles within irrigated area **→ Is there a representative soil profile and how do we obtain it?**

Probe temperature-humidity relation



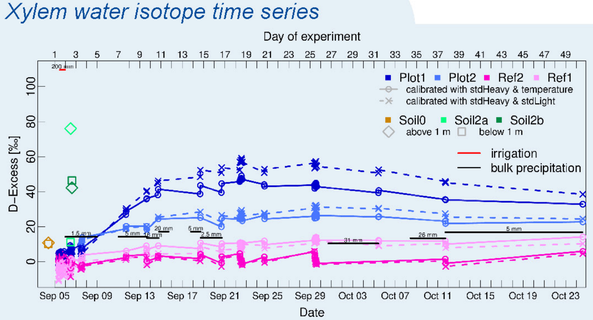
- Standard measurements most consistent
- All tree probes occasionally deviate from linear relationship **→ Are temperatures of nearby sap flow sensors representative enough?**
- “Plot2” and “Ref2” indicate malfunction of the intended dilution process

Calibration



- Different calibration approaches yield different isotope values, but overall patterns persist
- Drift of light standard, while heavy standard's raw values remained more stable → How do we ensure stability of standards?

Xylem water isotope time series



- 10 to 19 days pass until the maximum D-Excess is reached on the irrigated area
- Values on reference area always close to the natural D-Excess values measured in the precipitation bulk samples
- Calibration artifacts cause improbable short term signal variability

Conclusions

- XWIP probes allow for near real time (values available within minutes), high frequency (one value each 10 minutes) monitoring of xylem water isotopes
- Tree root distributions smooth isotopic signals
- XWIPs have proven to be applicable for monitoring tree xylem water isotopes for at least 50 days

Outlook

- Further applications: more regular measurements & longer periods
- Improvement of calibration procedure to reach accuracies required for monitoring of less pronounced natural isotopic signals
- Development of probes with integrated temperature measurement
- Replacement of on-site sample analysis by controlled sampling into gas tight bags

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References:
Volkmann, Till HM, et al. "A method for in situ monitoring of the isotope composition of tree xylem water using laser spectroscopy." Plant, cell & environment 39.9 (2016): 2055-2063.