Continuous, Near Real-time Observations of Water Stable Isotope Ratios during Rainfall and Throughfall Events

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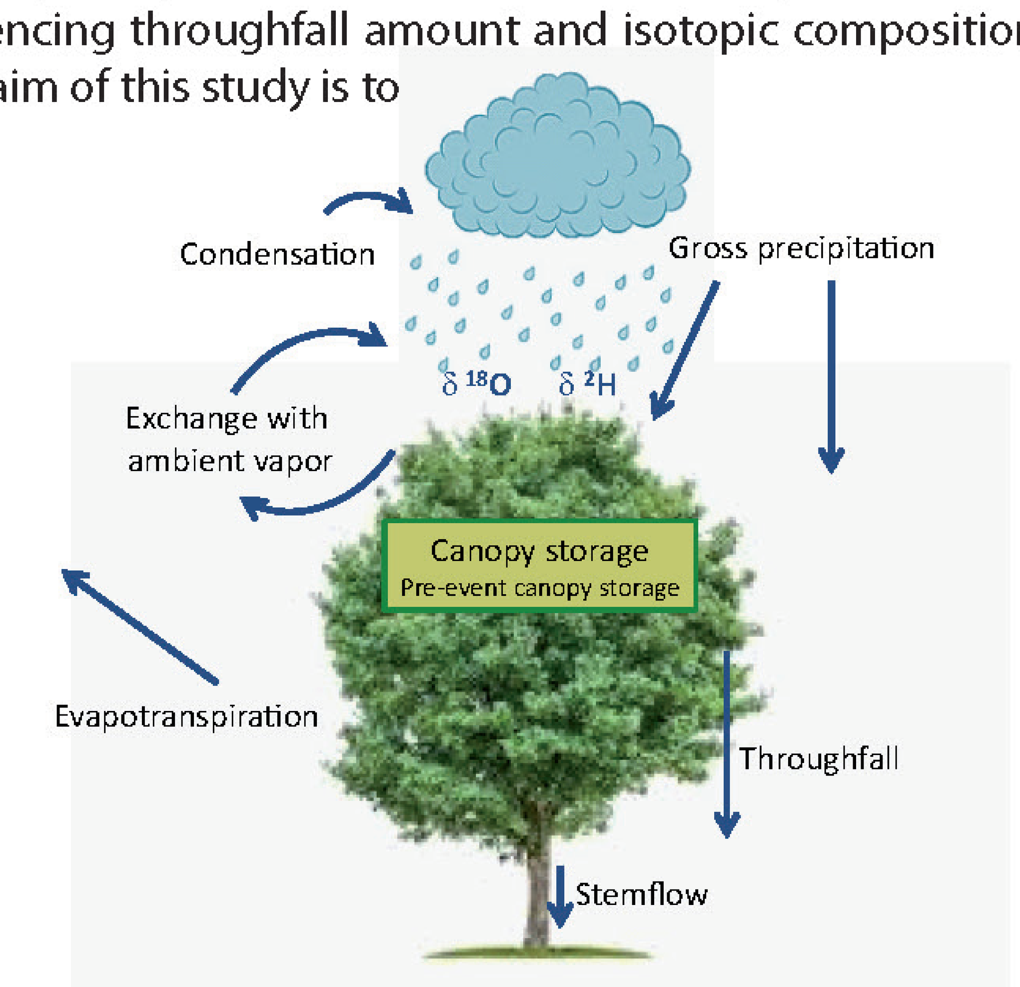
Motivation

The isotopic composition of throughfall is affected by complex exchange and mixing processes in the canopy. The differences between gross precipitation (P_g) and throughfall (TF) are driven by evaporation from the canopy during or between storms, isotopic exchange with ambient vapor and canopy storage effects, where water is differentially retained by the canopy during rainfall events. These interception processes occur simultaneously in time and space influencing throughfall amount and isotopic composition. Hence, the aim of this study is to

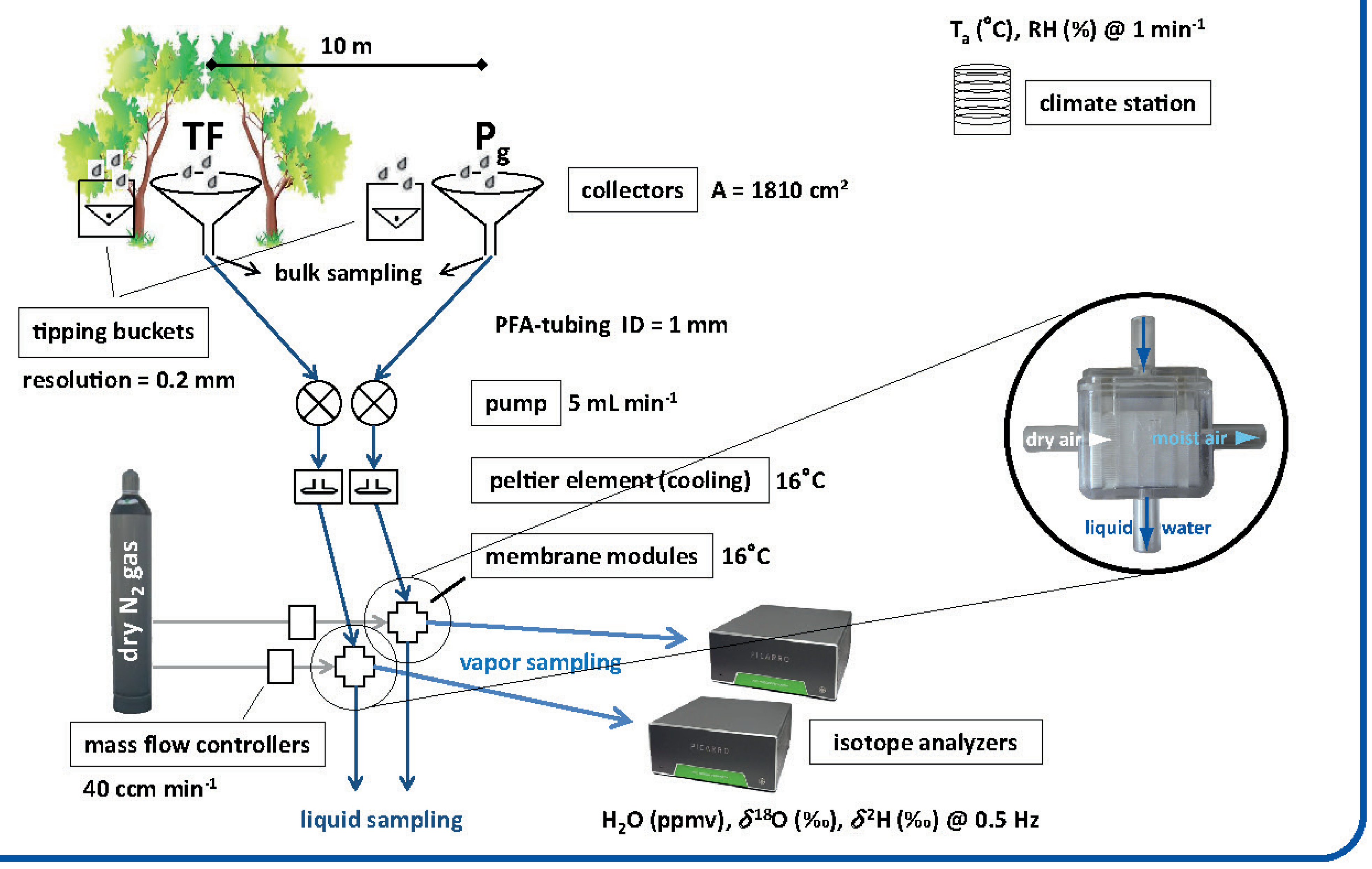


Canopy interception processes

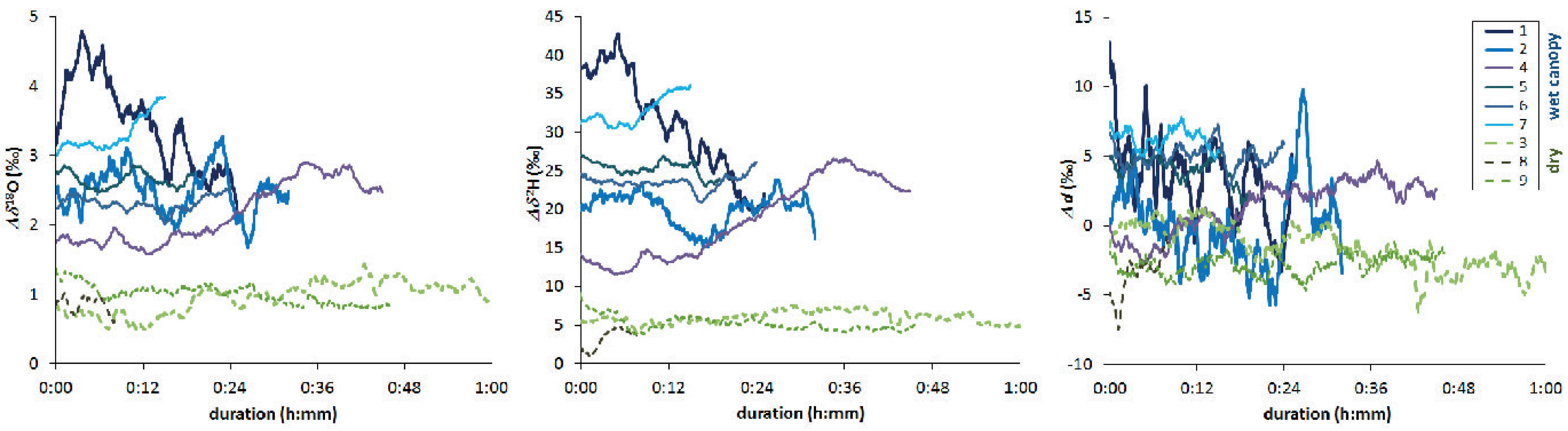
- develop a method to analyze rainfall and throughfall depth and isotopic composition in parallel and in high temporal resolution
- investigate interception processes
- evaluate continuous isotope measurements and compare with discrete liquid samples as well as with event-based bulk samples

Methodology

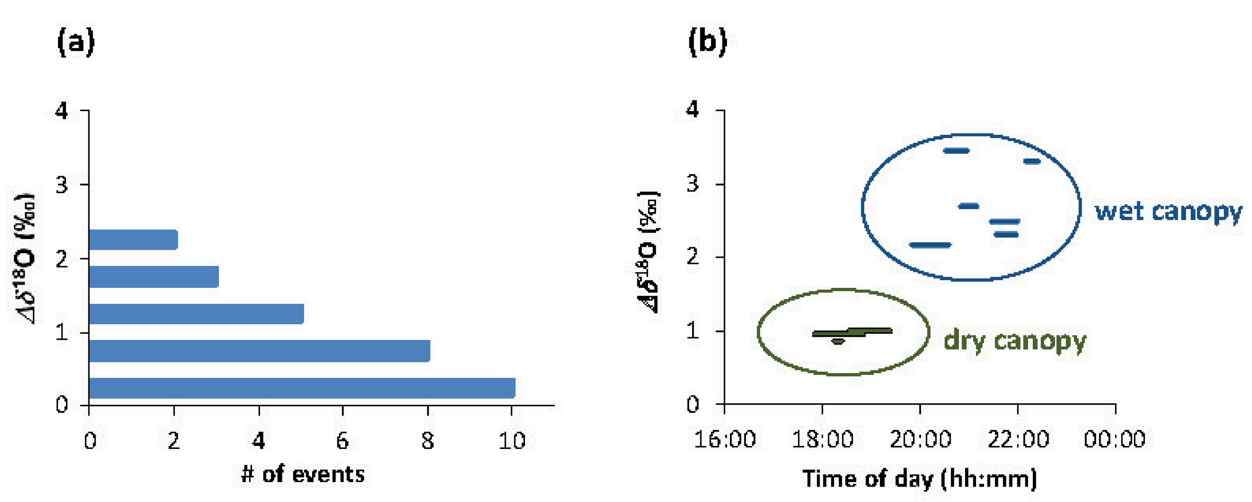
In combination with a CRDS instrument we established an in-situ method to transfer liquid water to water vapor within seconds (Herbstritt et al., WRR, 2012). Core of the method is an off-the-shelf microporous hydrophobic membrane contactor, originally designed for degassing liquids. It is used with nitrogen as carrier gas in order to produce a constant stream of water vapor which is then directly analyzed.
Based on this method, the isotopic composition of **throughfall (TF)** below a decidious tree canopy and **gross precipitation (P_g)** 10 m away were measured continuously (0.5 Hz) with two CRDS instruments in parallel. Liquid grab samples, representing rainfall sums of 30 sec were taken from time to time, as well as bulk samples for each event. Additionally, rainfall amounts were recorded every minute at both sites by tipping buckets. Meteorological parameters RH (%) and T_a (°C) were recorded every minute.



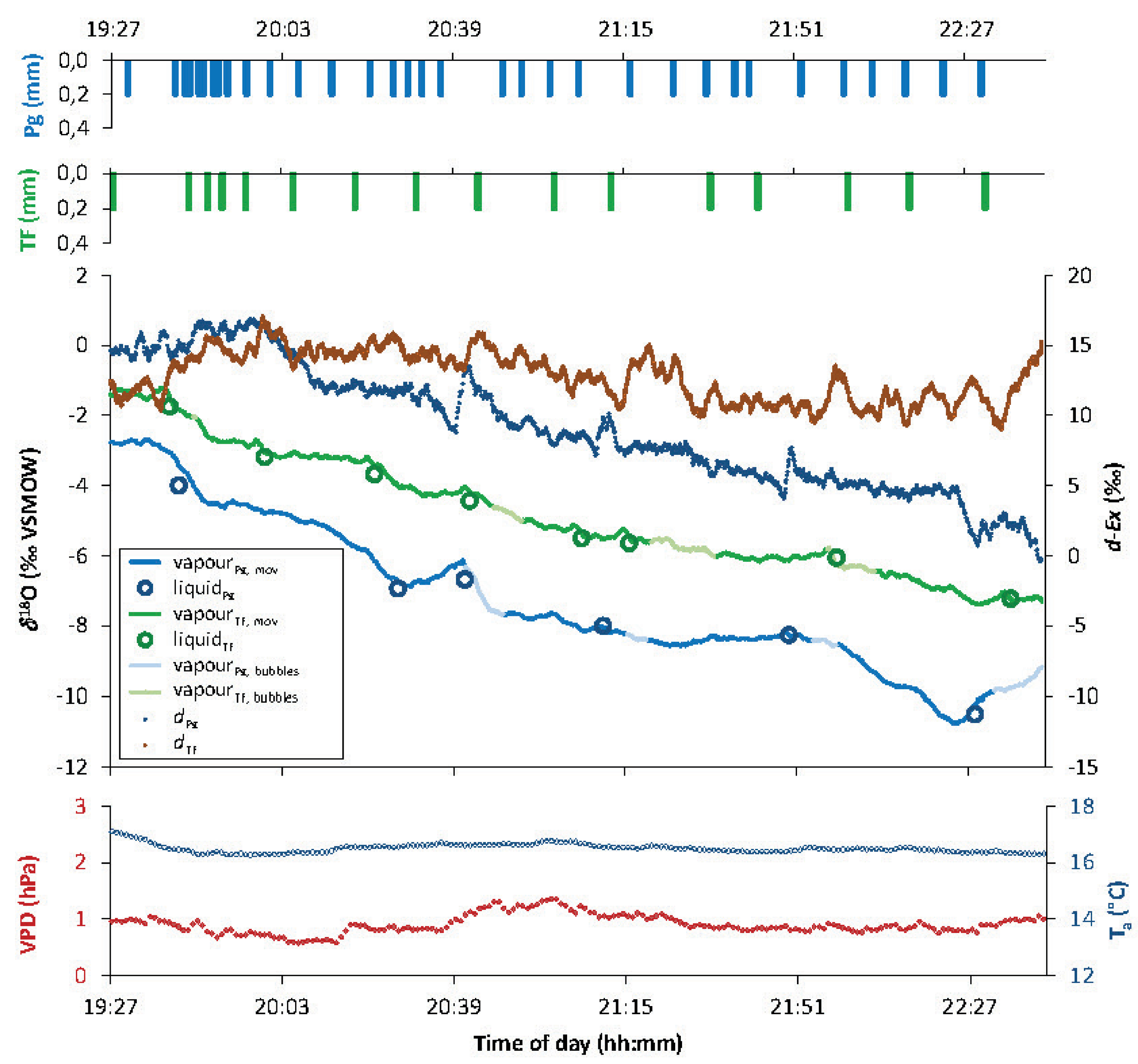
Results



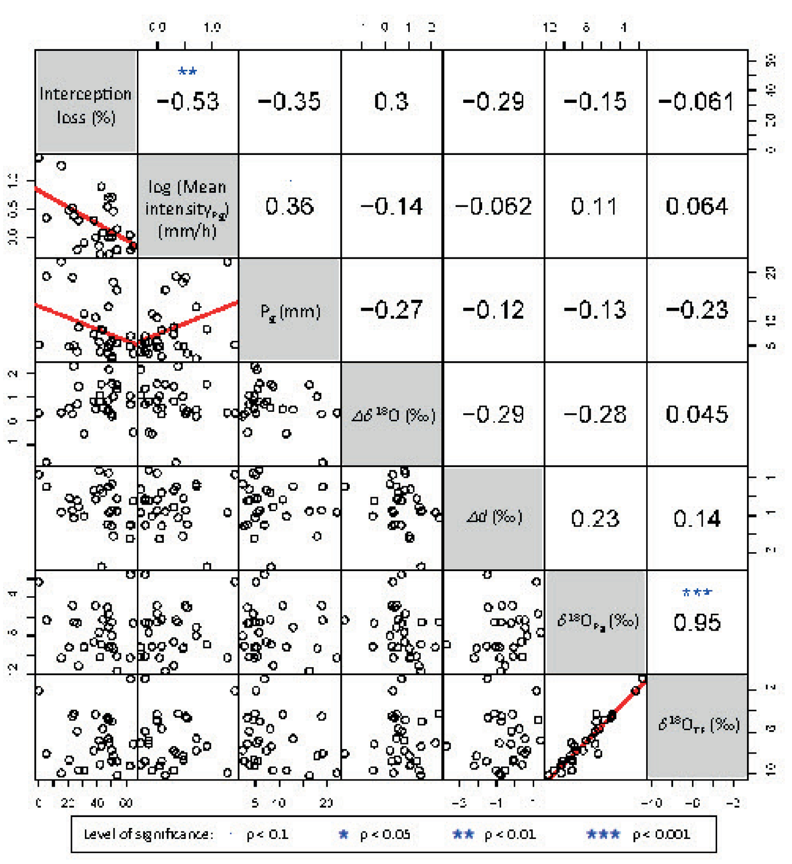
Time series of differences between $\delta^{18}O$ (left), δ^2H (middle), and d-Ex (right) of TF and P_g: events on initially dry (dashed line) and wet canopy (solid lines)



Difference of the isotopic signature ($\Delta\delta^{18}O$) between TF and P_g for (a) 28 event-based bulk samples and (b) 9 continuously analyzed events of the same period



Time series of continuous data of $\delta^{18}O$ and *d-Ex* (*d*) in Pg and TF, periods of intensities below threshold for continuous sampling (bubbles at membrane contactor) in light blue (Pg) and light green (TF); 5 min discrete liquid samples; rainfall and throughfall depths, air temperature (Ta), and vapor pressure deficit (VPD)



Lower left: scatter plots and linear regressions of meteorologic and isotope-related characteristics of bulk samples (n=28); upper right: Pearson correlation coefficients and level of significance

Key findings

Stabilized water temperature enables simplified calibration and operation.

Continuous data were in good agreement with discrete liquid samples.

$\delta^{18}O$ signal of TF was dampened and systematically enriched in heavy isotopes compared to Pg.

Significant correlation between interception loss and rainfall intensity exists.

Although expected, neither significant positive correlations between interception loss and $\Delta\delta^{18}O$ nor between interception loss and Δd were found in bulk samples.

Antecedent conditions have an impact on isotope enrichment of throughfall.

Direct comparison with high resolution meteorological data possible.

Conclusions

- Approach is suitable to continuously observe water stable isotope dynamics in Pg and TF.
- Huge increase of temporal resolution and time lag of only four minutes from collector to analyzer.
- Approach supersedes taking liquid samples, data are instantaneously available.
- Due to selected setup dimensions, minimum rainfall intensities are ~ 0.03 mm/min.
- Missing siginificant correlation between loss and $\Delta\delta^{18}O$ indicates complex evaporation pattern.
- Postitive Δd values cannot be explained with classical evaporation or intra canopy mixing.

Reference

Herbstritt, B., B. Gralher, and M. Weiler (2012): Continuous in situ measurements of stable isotopes in liquid water; Water Resour. Res., 48, W03601; doi:10.1029/2011WR011369
Herbstritt, B., Gralher, B., and Weiler, M. (2018): Real-time observations of stable isotope dynamics during rainfall and throughfall events, HESSD, https://doi.org/10.5194/hess-2018-301

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