An isotopic comparison of waters obtained by destructive and non-destructive methods to evaluate mixing and runoff processes at the mini-hillslope scale

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Introduction

- Technical developments have fostered the application of stable water isotopes (^2H and ^{18}O) to measure, understand and predict water flow paths and different pools of subsurface water
- To gain the isotopic information preserved in the soil, many pore water extraction methods exist, but their effects on natural soil water isotopic composition are poorly understood

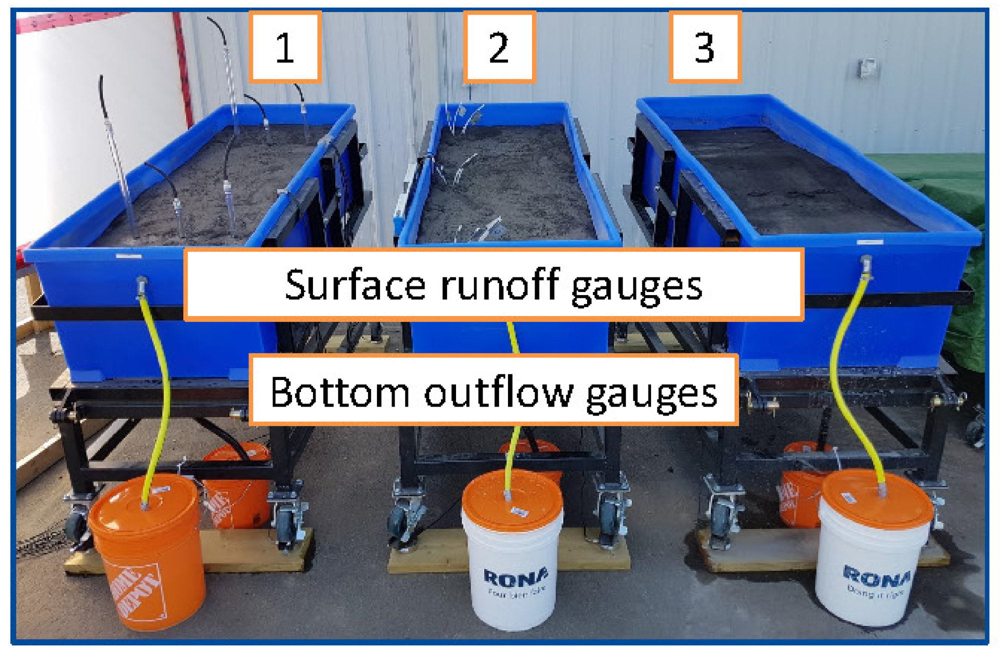
We intercompared destructive and non-destructive water extraction methods on an outdoor mini-hillslope:

- Non-destructive: Suction cups (Slope 1) and in-situ vapour ports (Slope 2)
- Destructive: Centrifugation and vapour equilibration method (Slope 3)

- Findings have major consequences for the use of a soil water component for hydrograph separation, mean transit time estimation or plant water uptake depth estimates

Null hypothesis:

Destructive and non-destructive extraction methods sample isotopically the same soil water pool



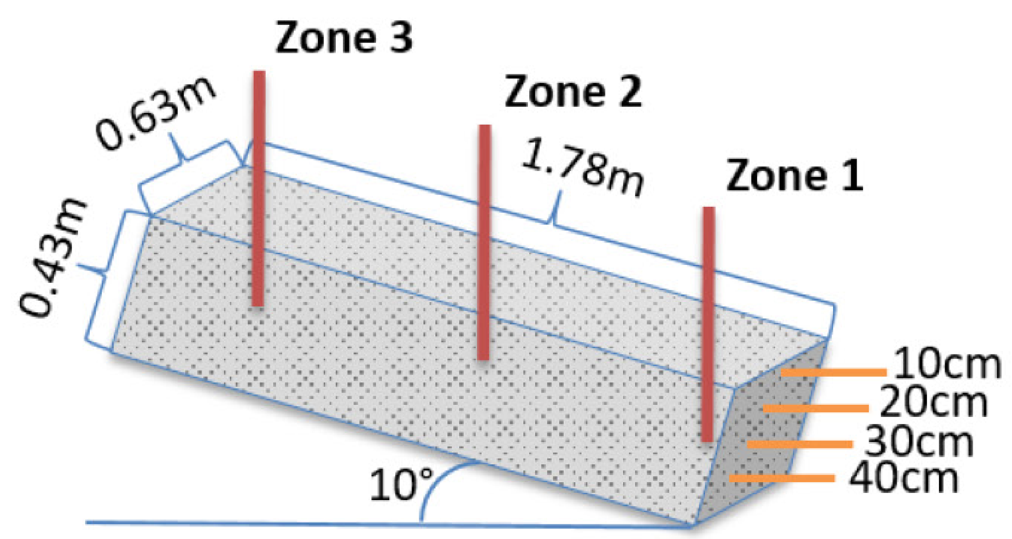
Materials and Methods

- Hillslopes contain volcanic basalt rock of loamy sand texture (Biosph.2; U of A, USA)
- Slopes initially filled with tap water
- Afterwards, natural precipitation used as input function to study water flow paths isotopically over and through the soil profile of the hillslopes
- Measurement equipment: Climate station, soil moisture & temperature sensors, load cells under each hillslope, bottom outflow and surface runoff gauges
- 6 non-/destructive samplings; 3 replicates per depth and zone
- ^2H and ^{18}O analyses on a laser spectroscope (IWA-45EP Analyzer, LGR Inc., US; precision: ±0.5‰ for δ^2H and ±0.1‰ for $\delta^{18}O$ for liquid water; ±0.2‰ for δ^2H and ±0.05‰ for $\delta^{18}O$ for water vapor)

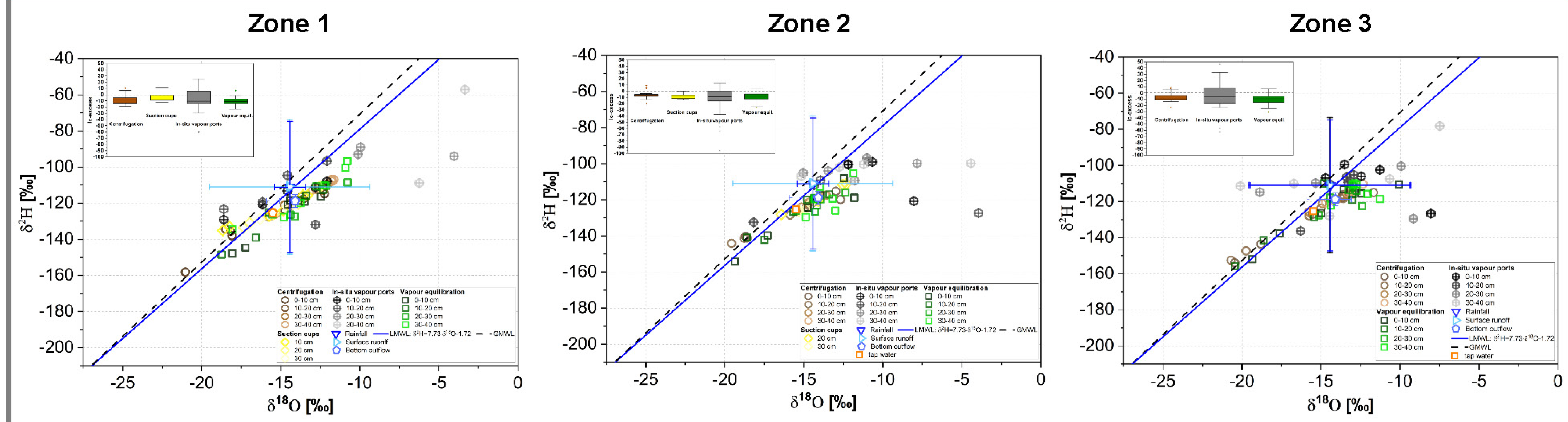
- Local Meteoric Water Line (LMWL) from regression analysis of local precipitation data
- lc−excess as indicator for non−equilibrium fractionation:

$$lc-excess = \delta^2H - \delta^{18}O * a - b$$

with a=slope and b=intercept

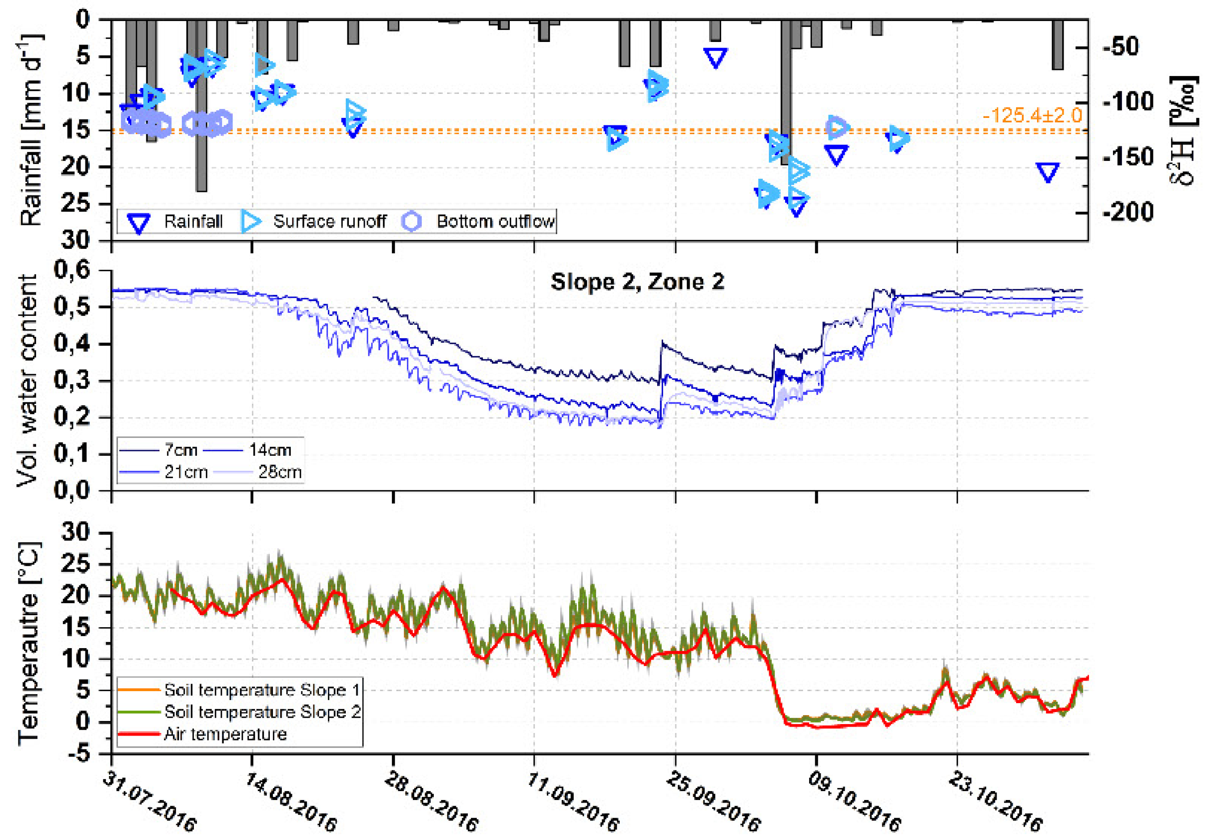


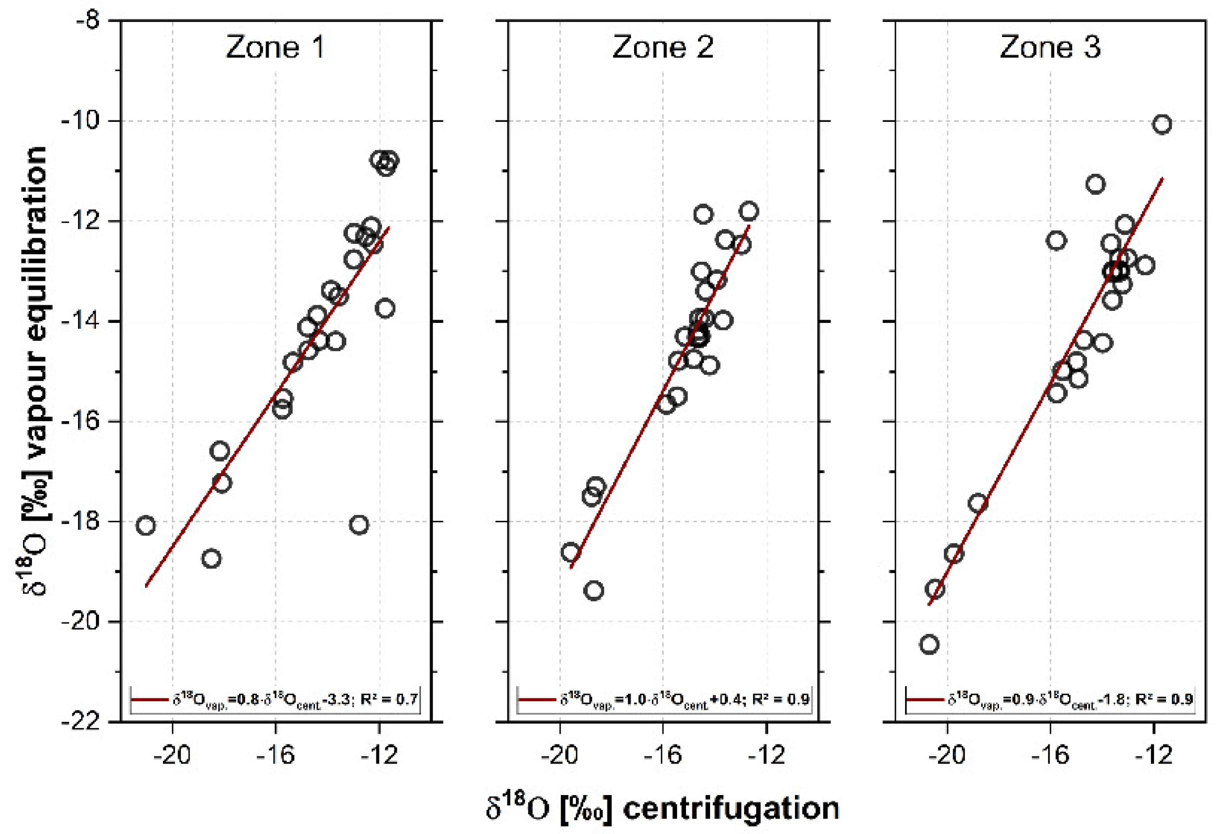
Results and Discussion



Dual isotope data

- All methods' isotope results fell within the range of precipitation and runoff, except for the in-situ vapour ports
- Isotope results from the in-situ vapour ports showed the greatest offset from the LMWL and the input signal, especially for the lowest depth (30-40cm)
- Issues with in-situ vapour ports were most likely due to high water contents causing condensation in the tubing
- Suction cups failed when soils were dry and pores most likely became clogged with soil material
- Centrifugation and vapour equilibration method plotted in the same isotopic range for all hillslopes and even showed a 1:1 relationship
- Destructive and non-destructive extraction methods did not sample the isotopically same soil water pool





Temporal variation

- Precipitation was isotopically more enriched in summer than in autumn as air temperatures dropped below zero
- Surface runoff followed the isotopic trend of the precipitation input and fell on the LMWL
- Bottom outflow was not always present and was isotopically more depleted
- Soil temperatures of both slopes were almost identical and followed air temperature trends

Conclusions

- Centrifugation and vapour equilibration were most reliable
- Applied extraction methods most likely sampled the more mobile soil water pool as results fell within the range of precipitation
- Aim of individual study dictates which method is suitable for particular results, sample types and properties, timeline, cost, and precision

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