Stable isotopes of water in the subsurface: Opportunities and challenges in method developments and applications

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Introduction

- Stable water isotopes (^2H and ^{18}O) are used to understand and predict water flow paths and different pools of subsurface water
- To evaluate the isotopic information preserved in soils, many pore water extraction methods exist

Aim: We went beyond the typical soil core approach and intercompared destructive and non-destructive water (in-situ) extraction methods on 3 outdoor mini-hillslopes:

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

Null hypothesis:

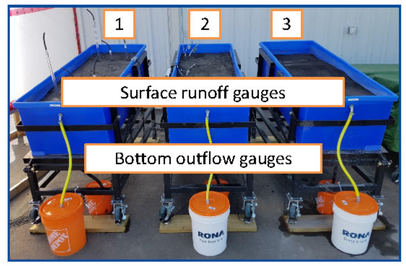
Destructive and non-destructive extraction methods sample isotopically the same soil water pool

Why do we care about differences in isotope results from water extraction methods?

→ Extracted isotopic compositions of water in both liquid and vapor phase are used to determine:

- Origin of water
- Soil water movement and mixing processes
- Evaporation fronts in soils
- Plant root water uptake depths
- Mean residence times

Materials and Methods

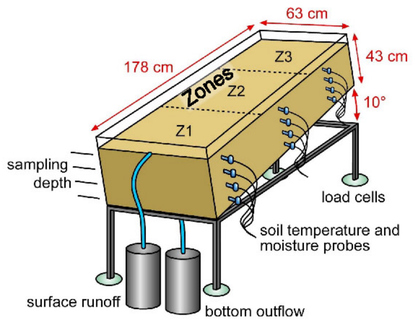


- Hillslopes (1-3) contained loamy sand textured crushed basalt (Biosph.2; UofA, US) and were initially filled with tap water
- Afterwards, natural precipitation was used as input function to study water flow paths over and through the hillslopes
- Measurement equipment: Climate station, soil moisture & temperature sensors, load cells under each hillslope, bottom outflow and surface runoff gauges

- 6 water extractions; 3 replicates per depth (4 depths) and zone (Z1-3)
- ^2H and ^{18}O analyses via laser spectroscopy
- Local Meteoric Water Line (LMWL) from regression analysis of local precipitation data
- lc excess as indicator for non−equilibrium fractionation:

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

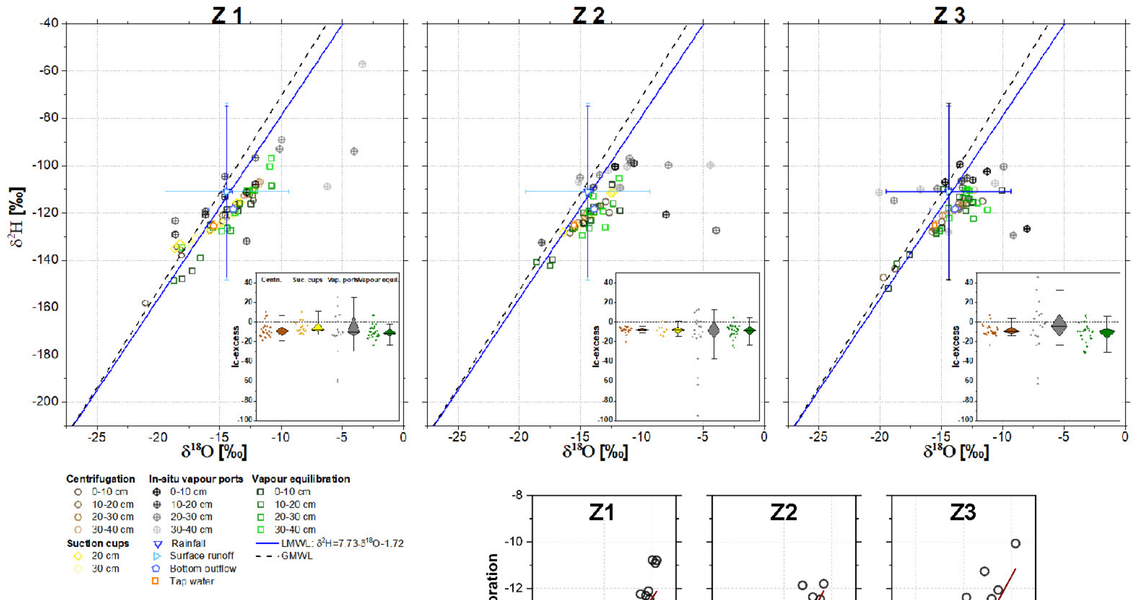
with a=slope and b=intercept

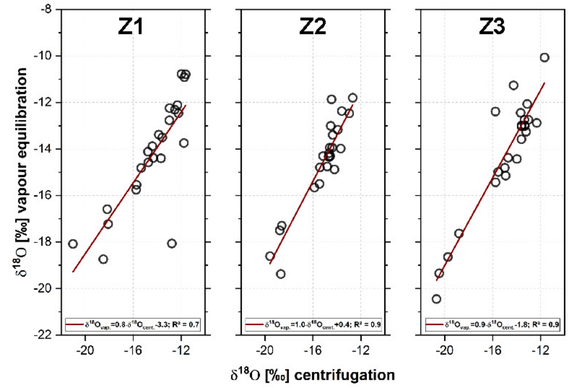


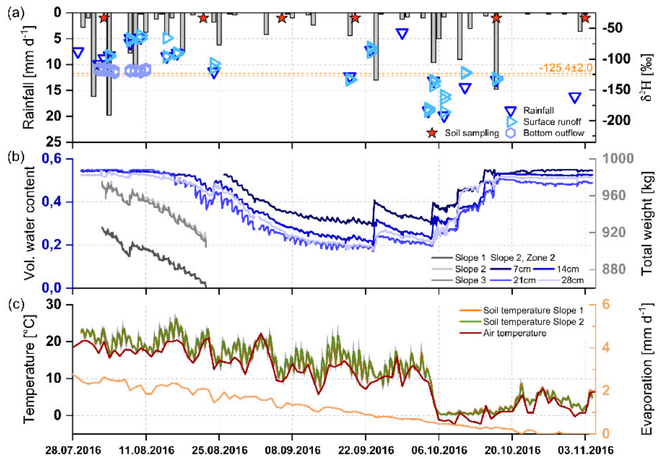
Results and Discussion

Dual isotope data

- All methods' isotope results plotted close to the LMWL, 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
- **Suction cups** failed when soils were dry and the porous material most likely became clogged by soil particles
- **Centrifugation and vapour equilibration** method plotted in the same isotopic range for all hillslopes and even showed a 1:1 relationship







Temporal variation

- Precipitation was isotopically more enriched in summer than in autumn (temperature-driven)
- Surface runoff followed the isotopic trend of the precipitation input and fell on the LMWL, whereas bottom outflow was isotopically more depleted
- Soil temperatures of both slopes were almost identical and followed air temperature trends

Opportunities and Challenges

- The applied water extraction methods most likely sampled the mobile soil water pool, but still showed isotopic differences among each other → **rejection of null hypothesis**
- Centrifugation and vapour equilibration were most reliable to sample the hillslopes' mobile runoff components
- Stable isotopes of water should be used in conjunction with other tracers to gain a holistic view on the linkages between different compartments of the hydrological cycle
- Non-destructive, in-situ methods open new opportunities for continuous, high-frequency isotope data and might overcome isotope fractionation issues observed with other techniques

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Orlowski et al. (2018): Intercomparison of soil pore water extraction methods for stable isotope analysis and interpretation of hillslope runoff sources (under review in Hydrological Processes)