Optimizing plant water uptake source depths estimation by stable water isotope labeling

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Motivation
Naturally occurring stable water isotope depth profiles in the soil may not be ideal for accurate estimations of the source depths of plant water uptake (PWU).

In order to increase the informational content of isotope depth profiles, they can be altered by irrigation with isotopically distinct water pulses.

But which points are most important for the experimental design of isotope labeling studies?

Objectives
This study aimed to assess the effects of different decisions regarding an isotope labeling for the purpose of PWU pattern estimation.

In particular, we wanted to assess the influence of:
- amounts of labeling water
- isotopic signatures of labeling waters
- order of labeling pulses
- isotope measurement depth schemes
- isotope measurement accuracies

Methods
Virtual experiments simulating different experimental scenarios
Richards equation based, single pore 1-D simulation of soil water household and isotopic signature
Same initial conditions for all simulations
Multiple irrigation schemes with varying amounts of different labeling waters
Model simulation until four weeks after last irrigation pulse

Evaluation of measurement accuracies

Isotopic signatures of virtual labeling waters

Simulated isotopic depth profiles for different labeling schemes

PWU source depths estimation

Evaluation of labeling schemes

Evaluation of measurement depth class schemes

Results
Improvement of PWU pattern estimation through isotopic labeling

Natural profile

PWU patterns

Evaluation of measurement accuracies

Differences between medium and high accuracies are smaller than between more and less suitable labeling schemes.

At lower measurement accuracies, some labeling schemes can become more suitable than at high measurement accuracy.

Conclusions

Higher depth resolutions (VIII_a and XII_a) for soil isotope measurements only pay off for high measurement accuracies.

Increasing the depth resolution at the top of the profile (VII_b and XII_b) may decrease estimates slightly.

For lower measurement accuracies, a lower depth resolution (V_b) may lead to better estimates.

Good knowledge of actual soil properties and the initial isotopic depth profile is essential!