Interactive comment on "Isotopic approaches to quantifying root water uptake and redistribution: a review and comparison of methods" by Youri Rothfuss and Mathieu Javaux

M. Sprenger (Referee)

General comments

The manuscript by Rothfuss and Javaux on quantifying root water uptake by the means of isotopic approaches aims to provide both an overview of methods and a comparison of the methods with regard to their limitations for the interpretation. They further propose to include modeling approaches to better estimate the root water uptake patterns.

The manuscript is generally well prepared, with mostly sufficient references, in depth information, and proper visualizations. Due to its nature as a review, it is pretty long and I am not sure if the sections 2.1 and 2.2 are really necessary. I agree that it is necessary to understand the soil water isotopic composition in order to interpret the root water uptake with the means of stable isotopes. The authors focus on evaporation fractionation as one process to alter the soil water isotopic composition. From my point of view, also the precipitation input (and its variability in time) would then need to be considered. However, this has been reviewed recently and would blow up the manuscript.

I think that the manuscript is a good contribution to current issues in ecohydrology and will be of interest to a broad readership. Therefore, I suggest a publication after a minor revision.

Specific comments

On page 5, where you introduce into the theoretical backgrounds, I do not think that the isotope depth profiles are solely a result of fractionation effects. It seems that you miss the importance of the variability of the isotopic signal of the precipitation input and its consequences for the spatial variability of the soil water isotopes over depth.

> *Dear Matthias, we fully agree with this. In a revised version, a text will be added on how soil upper-boundary isotopic condition (i.e., δ_{surf}) - one of the determinants of the soil water isotopic composition profile – is highly impacted both spatially and temporally by input precipitation isotopic composition.*

As you write, the evaporation fractionation has been reviewed by Horita et al. (2008) and it was more recently reviewed by Soderberg et al. (2012). In order to streamline the manuscript and keep its focus on the root water uptake, I doubt that the section 2.1 and 2.2 are really necessary. However, I agree that it is necessary to account for the spatial and temporal variability of the soil water isotopes, but this is influenced by more than soil evaporation (see also my review Sprenger et al. (2016)).

> *The authors still think that sections 2.1 and 2.2 are necessary for the readers who, for instance, already study RWU yet are interested in using water stable isotopes to characterize it. These paragraphs will however be significantly shortened. About the remark that "spatial and temporal variability is influenced by more than soil evaporation", please refer to our answer to your specific comment below.*

I am wondering if the authors are aware of the work by Ogle et al. (2004) and Ogle et al. (2014), where they suggest to include biophysical conditions in a process-based mixing model ("root area profile and isotope deconvolution, RAPID"). I think it would be worth including this in the review of methods, since it goes in the same direction as the author's proposal of including more physical basis of the root water uptake estimates.

> *The authors are aware of the work of Ogle et al. (2004) where they could reconstruct "active root area" and RWU profiles from isotopic measurements (assuming, amongst other things, normal a priori distributions for the xylem water oxygen and hydrogen isotopic compositions and considering prior knowledge on x). Since we wanted to focus on the most used and cited methods for partitioning plant water sources, we choose not to incorporate that of Ogle in the model comparison (and for that same reason neither that of Romero-Saltos et al. (2005)). Nevertheless, we propose that in the revised version of the manuscript mention of Ogle et al. study is made in Section 5 (Challenges and progresses) as it nicely fits there as you point out.*

Please state that the recently published dependency on the carrier gas was found for a WS-CRDS (Picarro); I did not find this CO_2 dependency for Off-axis ICOS (Los Gatos) (currently in review).

> *Done. Thanks!*

Technical corrections

P1 L12/13: I suggest using “studies” rather than “authors”

Done

P3 L11: Insert “and” for “in space,” and replace “but also on the root’s” with “and their”

Done

P3 L25: Not sure what you mean with “by reference”

We meant that the letter “S” makes reference to the “sink term”. We will use the correct formulation “in reference to” instead of the incorrect “by reference to”.

P3 L32: I suggest “distribution of S” instead of “S distribution

Done

P3 L23: Introduce RLD here.

Indeed, this was not properly introduced in the original manuscript. Done.

P4 L21: Why not stating directly that Zarebanadkouki et al. (2012) used deuterated water?

Done

P4 L29: I suggest (or artificial enriched/depleted)

Since “artificial” stands for “isotopic abundance”, it cannot be followed by “enriched or depleted” but only “higher of lower” but then it reads a bit funny. We would like to keep the more general “artificial”

P5 L1: Please state here once again what “these methods” will be.

Done

P5 L8: Is this not a bit too simplified at this point? You would always also need some kind of info about vegetation isotopes. I don’t think the first sentence is necessary here.

The authors write that for reconstruction of S profiles, one needs both soil and <u>plant</u> isotopic information (“within the soil-plant system”).

P5 L9: Are you referring to S profiles or isotope depth profiles? I do not think that the isotope depth profiles are solely a result of fractionation effects.

We are referring to isotopic variations. It is implied here that these isotopic variations are solely due to the difference of physical properties of the different isotopologues (ultimately leading to isotopic fractionation) <u>only in-between precipitation events</u>, i.e., we rule out the partial to total reset of the isotopic profile due to each rain event.

We added “in-between precipitation events” at the beginning of the sentence and “isotopic” before “variations” to clarify the sentence.

P5 L 16: Consider splitting this long sentence.

We moved “are expressed in ‰ relative to the Vienna Standard Median Ocean Water international (VSMOW) isotope reference scale (Gonfiantini, 1978)” to the introduction of section 2 to lighten this long (!) sentence. Thanks.

P6 L 30: This line is not black anymore.

Thanks! Done

P7 L5: I think it would be worth including the definition by Barnes, Allison (1983) for the vapor region to be of total water potential about 15bar, while at lower potential there would be little connected water.

Done

P7 L8: This line is not grey anymore

Thanks! Done

P7 L15: Is this supported by data? I don’t see it like that in Rothfuss et al. (2015), where you have shown that the slope for the depths above the EF (max -0.06 m) is still clearly below 8.

We write that “As a result, an intermediate value for the slope is expected, depending on the mixing ratio of atmospheric water vapor to evaporated soil vapor at a given soil depth.” (P7

L16-18), meaning that the value for slope should lie between 2 and 8 (which is in accordance with Rothfuss et al. (2015)).

P7 L16: I have shown that for several studies in Sprenger et al. (2016).

Indeed. The list of three references has been simply replaced with your review "Sprenger et al. (2016)".

P10 L8: delete second "is".

Thanks! Done

P10 L12: I summarized the uncertainty of the different methods to derive soil water isotope data in Sprenger et al. (2015).

The reference is cited now. Done

P14 L25: I assume this is for $\delta^{18}O$? Please clarify.

Yes. We added "(δ_S)" after "soil water oxygen isotopic composition" (as well as "(T)" after "actual transpiration rate") above in section 4.1.1

P14 L24: It would be interesting which rooting depth and density profile was assumed for the modeling. Please provide.

This is explained P14 L5-6:

"[All scenarios] relied on a common measured root length density vertical distribution of Festuca arundinacea",

and in Appendix B2 (Running the model for the inter-comparison):

"For this, H_S, δ_S, and RLD input data were interpolated at a 0.01 m vertical resolution…"

P16 L2: cases

Done

P17 L28: What about the study by Dawson (1993) who provides volumes?

To the authors' understanding, Dawson (1993) provided a lateral gradient of the proportion of hydraulically-lifted water from maple trees used by neighboring plants, not HL water volumes.

P18 L27: Why do you not include the direct-equilibration method by Wassenaar et al. (2008)?

Done

P19 L7: I did not use in-situ in that study, but consider including a recent paper by Oerter et al. (2016).

Done

P19 L14: Please not that this is the case for a WS-CRDS (Picarro); I did not find this CO_2 dependency for Off-axis ICOS (Los Gatos) (currently in review)

Done

P19 L25: I suggest referring to Farquhar et al. (2007).

Done

Table 1: I believe there are more studies than the listed ones. I suggest considering the following: Meinzer et al. (1999); Kulmatiski et al. (2010); Kulmatiski, Beard (2013); Evaristo et al. (2016); Goldsmith et al. (2012); Liu et al. (2011); Bertrand et al. (2012); Meißner et al. (2012); Dawson (1996); Bijoor et al. (2012)

The authors agree! However we had to make a choice and focus on the non-exhaustive list of papers that were reviewed here… Note that, on the other hand, another reviewer says that Table 1 is too long in its current form.

Table 2: Why did you limit your analysis here to $\delta^{18}O$, while emphasizing that dual isotope approaches would be preferable on page 12 L4?

In the text, we write that a dual isotopic framework is only interesting when oxygen and hydrogen stable isotopic composition profiles are disconnected from each other, i.e., when they are not linearly linked, which is the case in between rain events. Therefore with think that *a dual isotopic framework only adds value in the context of isotopic (^{18}O and ^{2}H) labelling pulses across the soil profile to artificially deconvoluate oxygen and hydrogen stable isotopic composition profiles (see, e.g., study of Bachmann et al., 2015).*

As we wanted to compare the different approaches at natural isotopic abundance, we choose to consider one of the isotopologues (i.e., $H_2^{18}O$) only.

Figure 1: Caption “negative towards the surface”

Done

Figure 2: Update the caption according to the color of the lines (blue).

Done

Figure 4: Caption “a detail is is presented for”

Done

Figure 5: Why standard deviation and standard error for the different approaches?

Error bars for the RWU analytical model refer to the standard deviation associated with relative contributions to transpiration (x) across the 1000 model runs. For the TM approach, error bars are standard error of x as calculated with Equation (8b). This is now specified in the caption of the figure.

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Dawson, T. E.: Hydraulic lift and water-use by plants - implications for water-balance, performance and plant-plant interactions, Oecologia, 95, 565-574, doi: 10.1007/BF00317442, 1993.

Farquhar, G. D., Cernusak, L. A., and Barnes, B.: Heavy water fractionation during transpiration, Plant Physiol., 143, 11-18, doi, 2007.

Gonfiantini, R.: Standards for stable isotope measurements in natural compounds, Nature, 271, 534-536, doi: 10.1038/271534a0, 1978.

Oerter, E. J., Perelet, A., Pardyjak, E., and Bowen, G.: Membrane inlet laser spectroscopy to measure H and O stable isotope compositions of soil and sediment pore water with high sample throughput, Rapid Commun Mass Spectrom, doi: 10.1002/rcm.7768, 2016. doi: 10.1002/rcm.7768, 2016.

Ogle, K., Wolpert, R. L., and Reynolds, J. F.: Reconstructing plant root area and water uptake profiles, Ecology, 85, 1967-1978, doi: 10.1890/03-0346, 2004.

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Wassenaar, L. I., Hendry, M. J., Chostner, V. L., and Lis, G. P.: High resolution pore water delta2H and delta18O measurements by H2O(liquid)-H2O(vapor) equilibration laser spectroscopy, Environ. Sci. Technol., 42, 9262-9267, doi, 2008.

Zarebanadkouki, M., Kim, Y. X., Moradi, A. B., Vogel, H. J., Kaestner, A., and Carminati, A.: Quantification and modeling of local root water uptake using neutron radiography and deuterated water, Vadose Zone J., 11, doi: 10.2136/vzj2011.0196, 2012.