Response to Anonymous Referee #1

We thank Referee #1 for these helpful comments (listed below in standard font). Our responses and changes to the manuscript are listed below in **bold font**.

Interactive comment on "Seasonal origins of soil water used by trees" by Scott T. Allen et al.

Anonymous Referee #1

Received and published: 5 December 2018

This manuscript describes a seasonal index developed using stable water isotope data from precipitation to characterize the seasonal water source origin (i.e., winter or summer) of soil water or tree xylem water. The data represent almost 200 forest sites in Switzerland, which is an impressive sample of systems. Using the seasonal origin index, the authors describe that winter precipitation was the predominant water source that was stored in soil water or that trees were using during the mid-summer. This manuscript contributes to the ongoing discussion in the ecohydrological community about how plants extract water from the soil storage and the so called ecohydrologic separation between plant water and water that contributes to streamflow or groundwater recharge. In my opinion, this is an important paper and will generate discussion.

The manuscript is very well written and the analysis is pretty thorough. I also appreciate the detailed information that is provided by the supplemental information. I would recommend publication of this work. I have a few comments, mostly editorial, that I hope will help improve the manuscript.

Thank you for your kind remarks and your editorial comments.

One minor issue is that the authors consider that suction lysimeters sample mobile water. In a relative sense compared to other sampling methods this is largely true. However, mobility is a continuum and it might be better to relax that dichotomy. For one, the suction that is used is rather high compared to other studies that are attempting to sample "mobile" water (e.g., -10 to -30kPa, especially considering that many use the somewhat arbitrary definition of field capacity as ∼-30 kPa). Also, it should be noted that even though the suction was applied for a month or so, most of the water was likely sampled within the first day or so and that the longer suction is maintained, the more the sample water represents the applied tension (i.e., finer pore space; see Severson & Grigal, Everett & McMillion, and Weihermuller et al. for example).

We agree that mobility is a continuum. The conceptual discretization of this continuum into more and less mobile fractions can facilitate communication, although there is some risk of over-simplifying. We have followed the reviewer's advice, and relaxed the binary language. On page 4, we change "To determine the δ^{18}O and δ^{2}H ratios of mobile soil waters, samples were collected from suction lysimeters" to "We also determine the δ^{18}O and δ^{2}H ratios of soil waters accessed by suction lysimeters, which tend to sample the more mobile soil waters (i.e., in contrast to water under high tension or in tight pore spaces)". In the other instance where we referred to "the mobile fractions", we change it to "the more mobile fraction" (page 4 and 8) so that we do not imply that there is a strict partitioning. In the revised manuscript, we also elaborate upon the likely timing implications of the lysimeter sampling (and now add citations).

The analysis with rooting distribution is interesting and it was certainly an achievement to collect observations from so many sites. The method, however, is likely biased by coarse roots and may not reflect the finer roots that participate in water uptake. Some discussion of this is encouraged. It also wasn't clear what depths were involved in the root survey, i.e., only that it was by horizon. I understand that horizon depths vary by site, but please provide more information, for example, were O horizons surveyed? In general, there are more fine roots and root distribution is highest in the upper 10 cm of soil, which would typically include the O horizon.

The root density metric that we report is actually fine root density, which we have now clarified. We also now comment on the possibility of missing roots on page 11, and we now mention that not all roots transport water equally. The depth information is provided in Figure S2, which we now refer to in the Methods section.

For the reviewer: approximately 1/3 of the soils were recorded to have an O horizon, which generally occupied the top 1-10 cm (median of 5, among sites with O horizons) and had fine root densities that were generally classified under categories "strong", "very strong" or "extremely strong". These data will be available in the archived data files.

Line comments:

P2, Line 6, comma after thus

A comma has been added.

P2, Line 14: after water ages, perhaps cite a study where storage selection functions are used to describe how ET is selected from storage and hence represents water of varying age. The Sprenger et al. citation in the sentence above is close by there might be something else that work better (e.g., Botter et al. 2011 show this idea conceptually with eqn. 6, but maybe there is a field study showing something similar). Also, it's not just fast/slow pathways, but as is discussed later, it is dependent upon rooting distribution.

Botter et al's equation 6 is relevant, and we suggest that our findings here could be considered with respect to age conservation concepts. We now cite it as recommended.

P2, Line 23: more mobile relative to what?

By adding the word "fraction", we believe it is now clear that "more" is in comparison to the other fractions of water held in a given soil.

P3, Line 8: In addition to texture, some additional characteristics related to soil (e.g., all same soil order or type?) and parent material would be helpful.

While this is a fair question, it goes beyond the scope of our study because there are so many different soil types and parent materials across our domain. It would require considering these sites on a case-by-case basis, which is not our objective. For example, some are calcareous, some are highly clayey, not all have B horizons, and not all have O horizons. Geologic substrates include moraine deposits, river gravels, marl, loess, clay deposits, sandstone, dolomite, gneiss, and limestone. These soils span numerous soil orders and parent materials. Last, there are also reporting challenges that arise from subjectivity and language-specificity of soil classifications.

Because information related to soil type may be of interest to those interested in reusing our isotope data, the data file will also include taxonomic characterizations of the horizons (from which soil types can be inferred) and by-horizon data on soil textures and root densities. Coordinates for these sites are included in the open-access data, and they can be linked with publicly available geologic data from SwissTopo (Swiss Federal Office of Topography, Wabern, Switzerland).

P4, Line 10: Please give range of depths here.

I think that the reviewer is referring to the following paragraph (line 15), and requesting the depths of the lysimeters. We have elaborated and added a summary description of the depths. We also refer readers to data file that will show the lysimeter depths for each site.

P6, Line 22: Perhaps note parenthetically that Pearson is only in the supplemental information.

We have added a note that the Pearson coefficients are in the supplemental information.

P7: Line 9: Could snow canopy interception make the difference here?

It could certainly have an effect, but we are not aware of any studies showing snow interception effects that could have this large of an influence. Thus we prefer to not speculate here. No changes have been made.

P7, Lines 21-22: Surprising that most roots are not nearer the surface. Jackson et al. suggest that the top 10 cm contain about 25% of the roots. Could this be the bias of survey more coarse roots than fine?

Maybe our original text was not clear enough; our results are actually consistent with those of Jackson et al. The quoted depth of 15-40 cm is not the depth that contains most of the roots, but the threshold above which most roots are located. We have revised our language to clarify that "Most roots occur above 15-40 cm, depending on the site".

P7, Line 33: There are about 8-9 places in the manuscript where using the possessive seems awkward and the sentence could be recast. Please consider reducing the use of the possessive.

We have removed about half of them, as recommended. Some have been retained in the interests of clarity.

P8, Line 4: There are other soil properties that could be quite relevant, e.g., structure.

We agree, but unfortunately no structural traits have been characterized in these soils. No changes have been made.

P8, Line: Be specific and refer to suction cup lysimeters and perhaps give a few sampling methods that do in fact sample water that is less mobile.

Now in several places throughout the manuscript, we remind readers that "lysimeter soil water" refers to waters sampled by *suction* lysimeters.

P8, Line 24-25: Could this be related to litter interception since spruce litter is quite different than the broad-leaved species? Also, here and the next sentence are two more examples where the sentences could be slightly recast to remove the use of a possessive.

In this paragraph, we are referring to mixed forest sites, where their root distributions likely overlap (at least in a lateral domain). However, it is likely that differences in the evaporation of water prior to its infiltration to the depths of roots could cause inter-site variations that we observed (as described in the following paragraph). We now mention interception in the next paragraph to cue the readers towards considering that interception and soil water evaporation occur differently.

References:

Botter, G., Bertuzzo, E., & Rinaldo, A. (2011). Catchment residence and travel time distributions: The master equation. Geophysical Research Letters, 38(11).

Everett, L. G., & McMillion, L. G. (1985). Operational ranges for suction lysimeters. Groundwater Monitoring & Remediation, 5(3), 51-60.

Jackson, R.B., J. Canadell, J.R. Ehleringer, H.A. Mooney, O.E. Sala, and E.D. Schulze. 1996. A global analysis of root distributions for terrestrial biomes. Oecologia 108:389–411.

Severson, R. C., & Grigal, D. F. (1976). Soil solution concentrations: effect of extraction time using porous ceramic cups under constant tension. JAWRA Journal of the American Water Resources Association, 12(6), 1161-1170.

Weihermüller, L., Kasteel, R., Vanderborght, J., Pütz, T., & Vereecken, H. (2005). Soil water extraction with a suction cup. Vadose Zone Journal, 4(4), 899-907.