Hydrol. Earth Syst. Sci. Discuss.,
https://doi.org/10.5194/hess-2018-301-AC2, 2018

Hydrology and Earth System Sciences
Discussions

Interactive comment on "Real-time observations of stable isotope dynamics during rainfall and throughfall events" *by* Barbara Herbstritt et al.

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Received and published: 21 August 2018

Response to reviewer comments RC2

We thank you for your thoughtful comments and making us aware of open questions. Please find below a list of specific responses to the individual points.

The manuscript "Real-time observations of stable isotope dynamics during rainfall and throughfall events" by Herbstritt et al. presents and discusses an experimental setup designed to monitor in parallel the stable isotope composition of rainfall (Pg) and throughfall (TF) at high resolution during several summer rainfall events. High resolution stable isotopes in rainfall have already been observed and documented in previous studies. Yet, this study is the first I am aware of that compared the rapid dynamics of

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rainfall and throughfall and looked into their mass weighted average difference over several rainfall events. In the abstract and the introduction, the authors summarize the importance, extent, and main reasons of the difference between isotopic composition of throughfall and that of rainfall. The authors justify the need for a comparison of these signatures at a higher resolution than in the past, which reflects their measurement setup. This is described in the method section and well-illustrated in Figure 1. The results show time series of stable isotopes in TF and Pg, differences between them (dynamics and means), and an attempt to find correlations between such differences and meteorological variables. The discussion essentially deals with some of the limitations of the approach. The manuscript is clear and concise, and the figures are of good quality. Yet, no or only minor mechanistic understanding is provided. It will be a good contribution to isotope hydrology, after having addressed several comments and after some questions are clarified. The introduction and the discussion need to state clearer in what way this measurement setup can provide a more accurate estimate of the isotopic recharge in the catchments for typical applications in isotope hydrology. Why is it not enough to just consider the average mass weighted difference between isotopes in TF and Pg? What is a necessary detail of measurement? One figure that would improve in the manuscript in that regard is the relationship between precipitation intensity and Dd for each measured storm. Are isotopic differences larger for higher intensities during a single event? A more detailed description of the applications of tracers in isotope hydrology is also needed in the introduction. The discussion needs to argue for which application this time-varying difference really is important. For instance, are End Member Mixing Analysis (Hooper et al., 1990), isotope hydrograph separation (Klaus & McDonnell, 2013), or travel time modeling (McGuire & McDonnell, 2006; Rinaldo et al., 2015; Hrachowitz et al., 2016) able to incorporate such high-frequency data and distinguish between Pg and TF? Some clarifications of details in the method sections will be necessary (see details below), as some important information was skipped. Furthermore, the English is somewhat bumpy especially in the first half of the introduction, and should be carefully revised before the manuscript is resubmitted. Eventually, one may

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consider to change the manuscript into a technical note, since many of the hydrological aspects are discussed rather briefly and the key contribution is the measurement of high-frequency variations in stable isotopes of Pg and TF and their characteristics. No mechanistic understanding is provided by the manuscript. The main conclusion also starts with the technological aspect.

Specific comments: Abstract line 15 The 4 min time-lag information can be confusing with respect to the 2 sec reading interval. Please make it clearer that the time-lag is the transfer time from the collector to the laser in the instrument. How does dispersion/diffusion potentially influence this?

Response: We inserted "...from rainfall collector to isotope analyser..." after "...four minutes...". Dispersion in the small funnel must be assumed which is why we calculated a moving average. Dispersion and diffusion can be considered neglectable in the tubing given the small diameters.

page 1: line 1ff. Please tighten up and do a better job in pointing out the relevance of isotopes from here until page 2 line 12.

Response: We rephrased the first part of the introduction as suggested.

line 20 I would omit the word "signature", since the stable isotopes are the tracers, while their signatures are measurements.

Response: Changed as suggested.

line 25 Move the citations (Kendall and McDonnell [. . .]) to line 22 after "water cycle" line 25 "There is. . . hydrology" I would omit that sentence which looks somehow too isolated, see previous comment.

Response: Changed as suggested.

line 26 "residence times" is vague. Is it canopy, soil, or catchment residence times? Please be more precise.

Response: We inserted “catchment”.

Line28 New sentence after “Allen et al. . .”. Delete “Since” Line 28 Citations after “forested” needed.

Response: We rephrased to “Many studies have used the temporal dynamics in the isotopic composition of precipitation for estimating catchment residence times, but especially in forested catchments interception losses and accompanying isotope effects have a significant impact on the input function (Xu et al., 2014; Stockinger et al., 2015; Allen et al., 2017). The importance of understanding rainfall interception processes is presented in a thorough review by Allen et al. (2017).”

page 2: line 1 must be . . .”Allen et al. (2017).”

Response: Changed as suggested.

line 13 delete “Typically”; found for what? Precip? TF? Runoff? References needed and line 15 “spatial variability in general” is to general. Please elaborate

Response: We rephrased l. 13 - 15 to ”High spatial intra- and inter-storm variabilities have been found in depth and isotopic composition of TF. A synthesis study analysed the spatial variabilities of TF from 18 selected studies at a global scale. The study showed that the spatial patterns of TF, when related to leaf area index (LAI) as well as to spatial variability in general, were very heterogeneous and ecosystem dependent (Levia, 2011).”

line 17 Ref needed after “diameters”. Replace “They” by “The authors” or “Keim et al.”

Response: Ref. added, “They” replaced by “The authors”

page 3: line 18 in-situ

Response: Changed as suggested.

line 24,27 SPACE between numeric value and unit needed

Response: Changed as suggested.

page 4: lines 2-4 What is the dead volume inside smaller funnel just before the pump? How is it made sure that all the water exceeding the pump flowrate Qp is spilled into the bulk sample?

Response: after "...was spilled. . ." in l. 3 we inserted ". . . and collected via an additional funnel into a sampling bottle. This overflow was volume-weighted, contributing. . ." In my perception, if Vd is the dead volume of the smaller funnel (let's assume Vd = 3 mL), then assuming complete mixing, the isotope signature effectively recorded is a moving average of the precipitation, with a time window of length Vd/Qp, i.e. about 36 sec. Please elaborate on this!

Response: We see your point and agree. However, time windows shorter than 90 s yielded quite "noisy" data.

lines 14-16 Were these discrete samples analyzed later in the lab?

Response: Yes. We changed the sentence to ". . .discrete liquid samples were taken every five minutes at the liquid outlet port of the membrane module and anlysed later in the laboratory."

line 19 Is 10 m really sufficient to make sure that there are no effects of the trees at all on the gross precipitation? Did you see an effect of wind direction etc?

Response: Due to the height where the samplers were installed and the size of the tree the distance was considered sufficient (45°, WMO guidelines). We didn't observe meaningful effects of wind direction.

line 20 How many events were recorded in total? It is never mentioned in the text. It also makes it difficult to follow the results. Add also more details about the events in tables.

Response: Number of recorded events is added as suggested. Table will be added.

page 5: lines 2-9 How was calibration applied? Did you apply an individual correction for each rainfall event based on the 3 measured standards? More details are needed here. Also, how did you ensure that there were no memory effects between standards when measuring them consecutively?

Response: Yes, we applied an individual correction for each rainfall event. l. 5: For clarification after "...each rainfall event..." we added "...until a plateau in the isotope readings was reached ($\sim$ 10 minutes)..."

line 6 What is meant by "long term changes in the membranes"? Please elaborate

Response: Small particles could be removed by back flushing, whereas the built-up of biofilms or mechanical changes of the membrane ("membrane fouling") would change its characteristics over time. We inserted "...e.g. built-up of biofilms or mechanical changes (small cracks, fissures) at the membrane..." after "...long term changes"

line 17 It should be mentioned here already why the VPD is calculated.

Response: We inserted "...to indicate potentially high or low evaporation..." after "...is calculated..."

line 20 What date did the event happened? This also needs to appear in the caption of Figure 2. Why not show directly the comparison between isotopes in Pg and TF in Figure 1, as in Figure 6?

Response: We added the date to the figure and the caption as suggested. In Fig. 2 we intended to show the temporal variability in both isotope ratios (d18O and d2H) during one 'long' (2 h) event without bubbles at the contactor, the continuous readings, the noise reduction by the moving average, and to illustrate the stepwise loss of information with discrete liquid samples and moreover with the one event-based bulk sample.

page 6: line 1 It looks like the isotopes in Pg are getting lighter while rainfall intensities are getting lower. Is that not contradictory with the amount effect?

Response: At the end of this specific rainfall event air temperature dropped which could explain this effect. For clarification we added the temperature data to the figure.

lines 3-4 I suppose the interception loss is (Pg-TF)/Pg*100. It should be stated clearly how you calculated it.

Response: This is correct. We added this equation to chapter 2.2 Analyses.

line 13 Were the interception losses and the Dd18O greater with time and plant growth from May to September? A plot with Dd18O in time during the growing season could be useful here. Any data on LAI?

Response: We had no data on LAI. We looked at the effects of the growing season without finding meaningful relationships.

line 15 Is this mean difference flux weighted? I think this is important to emphasize.

Response: Yes, the mean of each event (Pg and TF separately) was flux weighted and the difference was calculated from the flux weighted means. We added this information to the manuscript.

Line 21 “all events”, see above, more information needed

Response: We inserted “nine”

line 29: cm3 should be cm2

Response: Changed as suggested

page 7: lines 1-2 Why is the TF signature more damped than the Pg signature?

Response: We assume that this is due to mixing in the canopy. We rephrased this section to make our point clearer.

Lines 2-4 Maybe it is because of the scale, but it does not seem like the VPD is decreasing on figure 6. Please clarify. Also, why not look at the relationship between VPD, Ta, and time-variable Dd for all events? Some meaningful correlation could exist.

Response: We already looked at these relationships without finding meaningful relations.

lines 10- 11 Some statistics about the differences between continuous measurements and the single liquid samples would be nice here to emphasize that point, even though it looks valid just when looking at the figures. For example, what was the average difference between the single liquid samples and the corresponding moving average values for each event? For all events? Does that vary a lot between events?

Response: Will be added as suggested.

lines 17-18 How are “wet”, and “dry” canopies defined?

Response: We defined “dry” by inserting “i.e. 6 hours without rainfall” on p. 6 l. 17.

line 25 So, why are the average differences in bulk samples and continuous samples so different? I think this is a crucial part of the manuscript showing why the measurement protocol proposed here is valuable!

Response: We inserted in l. 25 after “(Fig. 4)” “. . ., which is not surprising. Bulk samples represent a mean isotopic signature, whereas higher resolution measurements capture the extreme values. Furthermore, in the continuously analysed dataset. . .”

line 27 What process could explain that a wet canopy leads to an even stronger enrichment?

Response: Will be extended in the discussion accordingly

Figure 1 Is the beginning of the event missed because of the stabilization of T? That info would be nice in the figure caption.

Response: We inserted “. . .starting after temperature at the contactor was stable”.

Figure 5 A legend with the date of each event and the corresponding lines would be nice here.

Response: Will be included.

Figure 6 The points for d_Pg and d_TF in the legend are too small and hard to distinguish. The date of the event is missing.

Response: Will be changed accordingly.

Thanks for the interesting contribution to isotope hydrology! :-)

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Please also note the supplement to this comment:
https://www.hydrol-earth-syst-sci-discuss.net/hess-2018-301/hess-2018-301-AC2-supplement.pdf

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