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Hydrology and Earth System Sciences Discussions

Interactive comment on "A porewater – based stable isotope approach for the investigation of subsurface hydrological processes" *by* J. Garvelmann et al.

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Authors comment #2

First of all we would like to thank the anonymous referee for his thoughtful and encouraging review that will definitely help to improve the manuscript. Please find below the answers of the authors (AC) to the comments of the referee (RC)

General comments

RC: The current paper presents deuterium data obtained from several vertical soil

depth profiles along two hillslope transects of a small watershed in the Black Forest, Germany. The deuterium data was obtained using a new and innovative porewater extraction method developed by Wassenaar et al (2008). The study aims at investigating subsurface hydrological processes through the interpretation of the shape and statistical parameters of these vertical depth profiles. The results indicate that vertical percolation persist in the upper parts of the hillslopes, while the lower and wetter near stream areas show mixing of laterally displaced water. In general, the paper is well structured and written, follows a clear line of thought and contains adequate referencing. However, it has some limitations that should be addressed to warrant publication in HESS. While the paper is mainly focused on the interpretation of the vertical deuterium profiles through mixing processes and topographic features, it falls short of adequately presenting and interpreting the heterogeneity of encountered soils, soil hydraulic properties and the role of groundwater along these transects. This becomes evident in the very short catchment description and the complete lack of information about the encountered variability of soil and related soil hydraulic properties that could have been easily obtained from soil description and analysis of the drill cores. This is surprising since the subsurface structure can exert a strong control on the water displacement along the transects and might explain parts of the observed variability.

AC: The discussion of soil properties in the submitted manuscript is discussed very brief. In the revised manuscript, more information about the soil properties will be included. Information about soil texture analysis data of every soil profile and the gravimetric soil moisture for every soil sample will be included. The soil textures are quite homogeneous. In the upper parts of the study hillslope a cambisol with a sandy texture dominated and in the lower parts and the riparian zone alluvial soils with a loamy-sandy texture and hydromorphic features could be found. In addition, a more detailed description of catchment properties including the geology will be presented in the revised manuscript and a comprehensive figure will be added.

RC: In line with this, another major shortcoming of this study is the proper acknowl-

edgement of the groundwater component. Although a value of groundwater is reported in this study and its isotopic value plots near the stream water, it remains unclear where this groundwater sample was collected and which overall effect the apparently important groundwater component has on the smoothing of the deuterium profiles at the base of the hillslope at transect T2.

AC: The fact that the streamwater sample is very similar to the groundwater sample denote that the catchment was in base flow conditions during the soil sampling procedure. One of our aims was to show the importance of the groundwater component in catchments with the proposed sampling approach and the resulting profiles at the study hillslope foot. However, this needs to be made more clear in the revised manuscript since both reviewers were missing the link to groundwater. We can clearly show with the comparison of the deuterium profiles in the soil and the deuterium value of the sampled groundwater that groundwater flows through the soil in the riparian zone and this water dominates streamflow during baseflow. Of course, we will highlight this link more clearly in the revised manuscript.

RC: In this context the study also lacks a proper explanation why transect T1 appears to be less affected by mixing processes at the footslope.

AC: There is a simple reason why the lowest profiles at transect T1 shows no signs of mixing processes at the hillslope foot: The lowest profile at transect T1 (T1-7) was drilled about 20m horizontal distance and 6.5m vertical distance from the stream. Therefore this profile was still part of the hillslope and not the riparian zone. This circumstance will be more clearly mentioned in a revised manuscript.

Specific comments

RC: P9092 L20 onwards: This sentence is misleading as an objective as it might appear that the authors developed an entirely new approach of establishing vertical deuterium soil profiles. In fact, traditional approaches are refined with new extraction methods that were developed elsewhere. This should be made clear through appropriate

referencing in the introduction beforehand.

AC: The analytical technique used in this study has already been published by Wassenaar et al (2008), which we attributed accordingly in the method section. However, the investigation of soil water profiles at the hillslope scale is new. We will make this clearer in the revised manuscript.

RC: P9094 Study site: This whole section is way too short and needs to be entirely rewritten as it lacks essential information about the encountered soils and soil hydraulic properties that are crucial for infiltration, percolation and lateral water movement through the unsaturated zone. This also holds for the description of the geologic background setting that is important for a better understanding of the groundwater component later on.

AC: The section will be rewritten and additional information about the soil and the geology at the study site will be included.

RC: P9093 Fieldwork: It is nice to hear that the experimentalists had a “warm and sunny” field campaign with ”no considerable precipitation”. However, I would suggest rephrasing this sentence in more scientific terms. This whole section also lacks an adequate description about how long the field campaign took, how much of antecedent precipitation was observed prior to the extraction etc. However, such information is essential to answer the question if sampling conditions might have had an effect on the observed variability and might explain differences between the two transects.

AC: We will rephrase this sentence in more scientific terms. Nevertheless the information about the weather conditions during the soil sampling is important in terms of possible influences on the samples (e.g. contamination of the soil samples with rain water...). The soil sampling took two days of work. The field campaign took place in August 2009. The weeks prior and during the field campaign there was no significant precipitation.

RC: P9093 L21: If soil cores were extracted every 8cm, why do these samples only represent about a meter of depth in transect T1 and about 2m in transect T2? What was the rationale behind the sampling strategy?

AC: There is no rationale behind this sampling strategy. Indeed, a sound research sampling design would demonstrate equal depths of the soil cores along both transects. In this study the plan was to sample under the same environmental conditions to provide data consistency. Therefore one transect should be sampled in one day. Since we had no experience with the technique of the sampling approach and no idea about the time it takes to sample one transect, we started the first transect (T1) with soil core depths of one meter. What we learned from this day is that deeper soil profiles are feasible to sample within one day resulting in deeper soil cores for the second day.

RC: P9093 L24: Where and when was the groundwater and stream water exactly sampled? This is essential information that needs much more carefully explained!

AC: The streamwater (-58.15‰ VSMOW) and the groundwater (-59.47‰ VSMOW) were both sampled at the second field day on 20th August 2009. The streamwater was sampled at the foot of the study hillslope. The groundwater was sampled at a well about 200m distance from the study hillslope. We will include this information in the revised manuscript.

RC: P9094 Stable isotope analysis: It would be helpful to give a brief explanation why the study focused on deuterium values and not oxygen-18 values, although both were measured.

AC: With modern laser spectroscopy it is very easy to measure both deuterium and oxygen-18. There are two reasons why we used deuterium values for the depth profiles in this study: First, the relative measurement accuracy for deuterium is better than for oxygen-18. Second, deuterium is less sensitive to fractionation effects (e.g. evaporation). Therefor the overall relative accuracy of deuterium is better compared to oxygen-18.

RC: P9095 L1 onwards: This sentence sounds odd and is not clear, please rephrase!

AC: Sentence will be rephrased or even canceled since there is no important information for the research.

RC: P9096 L13 onwards: Why was the deuterium sampling only focused on the upper soil profile parts at transect T1? This allows almost only speculation about the deeper part of the profile, as a trend towards heavier deuterium values is hardly visible. At least this should be explained in more detail, including a short paragraph in the discussion section on the possible effects on the obtained interpretation results when dealing with this limited data series.

AC: The comparison among the slopes will also be done using data from the first meter only. The results are similar. We did not include this in the manuscript already since we thought this may confuse the reader. See also AC on RC P9093 L24.

RC: P9097 L3 onwards: There is no word on the much larger interquartile range that can be observed for transect T2 compared to transect T1. The larger scatter of values in transect T1 compared to transect T2 is also apparent when looking at figure 2 and when comparing standard deviations. What causes this? Are there different soil properties, measurement artefacts or is this just an effect of the limited sample size? Please elaborate on this in the discussion section!

AC: The larger IQR in transect T1 is an effect of the limited sampling depth at this hillslope transect. This will be clarified in the discussion part of the revised manuscript (see also last comment).

RC: P9098 L25 onwards: The conclusions that are drawn here completely neglect the actual soil hydraulic properties at the different vertical profiles that might vary considerably and might exert a strong control on the individual deuterium profiles. Please comment on this in detail!

AC: See also AC on referees general comments. The soil was very homogeneous

along the hillslope. To clarify this issue we will provide a figure with the textures of soil samples from every soil core as well as the information about the gravimetric soil moisture of these samples

RC: P9099 L29 onwards: This groundwater is essential and its influence needs to be discussed in much more detail! It is not enough to just mention it with one "outlook sentence" for future studies. . . Here also cross-references to earlier studies about the importance of the shallow groundwater components in Black Forest hillslope studies are advised.

AC: See also AC on referees general comments. The study took place in a different geomorphological region of the black forest. There are no periglacial drift covers. Therefore there is no relevance to reference other studies in the Black Forest that were done in catchments dominated by periglacial drift cover, since this will strongly influence the flow pathways and residence times (e.g. Uhlenbrook and Leibundgut, 2002; Wenninger et al., 2004).

RC: P9100 L15 onwards: This sentence sounds odd "..a good influence for the relative influence. . .". Please rephrase.

AC: Sentence will be rephrased in the revised manuscript.

Figures

RC: P9106 Fig: It would be helpful for the reader to show a figure of the seasonal deuterium dynamics in precipitation to allow a better interpretation of the vertical deuterium profiles and mixing processes. At least an indication of typical values encountered during winter and summer is required.

AC: A figure of the seasonal variability of typical deuterium values for the region in precipitation from January 2008 through December 2009 will be included in the revised manuscript.

RC: P9105 Fig. 1: Please indicate where the groundwater and stream water was

sampled.

AC: See AC on RC P9093 L24. Since, the location of the groundwater sample location is not anymore on this figure, the information will just be given in the text.

RC: P9107 Fig. 3: Isotope values of the vertical profiles appear extremely small in this figure and make it very hard to read. Please modify the figure that the "soildepth-deuterium box" is reduced or moved elsewhere (e.g., below), so that the actual figure has more space. Please also explain in the figure caption what the dashed line represents.

AC: Figure 3 will be adapted in order to achieve more clarity.

RC: P9110 Fig. 6: This figure appears redundant as the statistical information about the correlation in the text might be sufficient.

AC: The statistical information in the text might be sufficient. Nevertheless we think the information of the figure is important for the conclusions of the study in order to clearly show the decreased deuterium variability with increasing TWI.

RC: P9112 Fig. 8: This figure appears to be only valid for the case of transect T2 as no clear evidence of mixing can be found in transect T1. Please discuss and comment on this! "presented findings" in the figure captions sounds odd, please revise or rephrase e.g., "Perceptual model of hillslope processes".

AC: Indeed, the figure is a representation of the findings at hillslope transect T2 because of the limited dataset at transect T1. Nevertheless T1 gave important information on the proposed vertical subsurface flow at hillslope position with a weak affinity for saturation. See also AC on the general comments of the referee. Figure caption will be revised.

Technical comments

RC: P9094 L2: Please use a consistent way of referring to VSMOW or V-SMOW

throughout the paper.

AC: A consistent way of referring will be used.

RC: P9095 L 20: Please use a consistent way of proper labelling the isotope values throughout the paper e.g.:-12‰ 18O

AC: The labeling of the isotope values will be consistent in a revised version

RC: P9099 L20: “destroyed” is a strong word in this context, please revise.

AC: We will use damped in this context.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 8, 9089, 2011.