

## ***Interactive comment on “In situ investigation of rapid subsurface flow: Temporal dynamics and catchment-scale implication” by L. Angermann et al.***

### **Anonymous Referee #3**

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General comments. This study is designed to investigate subsurface flow processes, and in specific preferential flow, at two different scales. The authors chose a multi-method approach including quantitative soil moisture measurements using TDR (time domain reflectometry) and qualitative soil moisture measurements using GPR (ground penetrating radar) during an irrigation experiment at the hillslope scale. The experiment was complemented with common hydrometric and tracers techniques (interpretation of the rainfall runoff graph and stable water isotopes of rainfall and runoff) at different catchment scales. The study addresses an important topic in the hydrological sciences. The manuscript is clearly structured following common scientific standards. The data are presented in (mostly) clearly arranged, high quality figures. The combi-

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nation of TDR and GPR measurements provide a very promising approach to monitor subsurface processes. While this approach is relatively novel, it bears a number of uncertainties and disadvantages, which are discussed at length (although the methodological discussion lacks a bit in references). However, I do have some concerns. First of all, clear objectives were not formulated in the beginning of the manuscript and it follows that the rest of the story misses a central theme. I do understand though, that the catchment scale analyses revealed that the system responded with a double-peak hydrograph to water input with the first, steeply and quickly responding hydrograph consisting of a mixture of new and old water and the second, dampened hydrograph consisting dominantly of old water. The results from the irrigation experiment were then used to explain the hillslope processes that may potentially lead to this catchment scale response. This leads to my second and third concerns: (2) I feel that only one hydrograph separation to calculate the event and pre-event water fractions of a catchment is not representative. Many studies have shown in the past that the event water fraction may vary largely in one catchment depending on various factors, e.g. water input and/or antecedent moisture conditions [e.g. Munoz-Villers & McDonnell, 2012]. Hence, I suggest including more data and/or an uncertainty analysis to add representability to the HS. And (3) the authors clearly point out that they did not intend to mimic natural conditions with the irrigation experiment, however, they use the results to explain the natural response at the catchment scale. While this shortcoming is mentioned in the methodological discussion, I don't feel that this justification is sufficient to link the observed processes in the irrigation experiment to the natural conditions at the catchment scale. At last, I feel that the novelty of this study is not clearly conveyed to the reader. I think it is the combined use of TDR and GPR measurements which bear a large potential to move forward in subsurface flow process understanding. However, this message needs to be presented more clearly. Specific comments. Objectives and experimental approach: I think that this subsection needs a bit more structure and/or more precise phrasing. Maybe name all objectives at the beginning of the paragraph and then list the approaches that you chose to address them in addition to the explana-

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tions why you chose said approaches (advantages vs disadvantages of others). Page 3, line 24: the role of what? Please add information because otherwise this sentence and subsequent paragraph come a bit out of the blue, i.e. raise further questions, e.g. why is it necessary to use a multi-scale approach? Line 25: What are the conventional hydrological methods that you mention? I suppose the TDR measurements that you chose as approach in your experiment? Please add this information to the text or rephrase. Line 27: you only propose GPR, why do you not mention the other techniques? (Maybe use this 3 comments to elaborate your objectives.)

Methods. Hydrological response monitoring: Page 6, line 22: How exactly was rainfall water sampled for isotope analysis? Was a sequential sampler used or is it a bulk sample? Please add information. Line 24 (and everywhere else in the ms): I suggest to use “hydrograph separation” instead of “mixing model”, the latter implies that an EMMA was performed which is not the case.

Process monitoring: Page 8, line 3: Please add information why different TDR sensors were used. Page 8, line 6: Which 3 TDR tubes were used? Sounds like they were mentioned before which they aren't. Please rephrase or add information for better understanding.

Results. Figure 3: there is too much information in this Figure. I suggest moving some of the information to e.g. a separate table. For example, the information of the catchment sizes and the % of the precipitation amount should be placed somewhere else, maybe together in one table. You may mark the 7th and 72th hr in the RR-Graph and refer the reader to the table. It also remains unclear to me why the information about the irrigation experiment (i.e. the mean structural similarity attribute) are placed in the rainfall-runoff and chemographs of the headwater catchments. Which y-axis does the mean structural attribute refer to? And what do the vertical bars mean? Please provide this information in the legend. I suggest considering making two different graphs, for example below each other in the manner of Figure a) catchment scale and b) hillslope scale. This should help to understand this figure faster and identify/extract important

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information more easily. Please also provide information about where groundwater was sampled for d18O, e.g. in section 2.2. Page 12, lines 7: Since there are several peaks in Figure 3, it would make it easier for the reader if you added the date of the described rain/hydrograph event. Page 13, line 5: What is an “overshoot” in mass recovery? Please add a bit more information to explain this. Page 14, lines 19-20 and Figure 5: The weak signal of soil moisture dynamics in TDR 13, 6 and 14 is apparent in Figure 5. While an explanation is provided for the signal in TDR 6, I am missing explanation for TDR 13 and 14. How do you explain this? I suggest including this in the discussion section 4.1. Figure 5: Soil moisture change is interpolated over time for visual reasons (according to figure caption), I think it would be helpful to add this information somewhere in the methods section (e.g. 2.4.1. TDR data analysis).

Discussion. Process interpretation: What is the novelty about this study? I suggest elaborating this e.g. add a paragraph to emphasize this a bit more clearly. Page 22, lines 22 – 25: I do not understand the link between delayed signal in the intermediate depth and the network of preferential flow paths. Please add a bit more text. Page 23, lines 22 – 29: So, does that mean that the first peak is generated by overland flow (as observed by Wrede et al.) AND shallow subsurface flow? Or is all of the event water conveyed via subsurface flow? Please express your interpretation a bit more clearly.

Technical corrections. Figure 4: Can you move the y-axis name and unit away from the numbers, e.g. to the very top or remove 140 and insert 120 instead? Typing errors: Throughout the whole manuscript use either one of Fig. X, Fig X or Figure X. Page 3, line 8: empirically Page 9, line 23: Add “of” in “In case of the vertical profiles...” Page 12, line 19: use “to” instead of “of” in “... up to 67.6 % to the event runoff...” Page 13, Figure 3, legend: “attribute” instead of “atribute” Page 14, line 3: delete “to” in “... returned to similar to initial conditions...” Line 15: insert “(“ in “Fig.5)” Page 15, line 2: use plural instead of singular: “flow paths” Page 19, Figure 6 caption, line 1: time-lapse GPR Page 22, line 13: I suggest to use “...match...” instead of “...fitted with...” Page 24, line 22: delete redundant “the” Page 27, line 17: substitute “is” with “are” in “The dynamics of preferential flow are often characterized...” Page 29, line 14:

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stable isotopes instead of staple isotopes

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