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Hydrology and Earth System Sciences Discussions

Interactive comment on "The effect of spatial throughfall patterns on soil moisture patterns at the hillslope scale" *by* A. M. J. Coenders-Gerrits et al.

Anonymous Referee #2

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This is an interesting paper on the effects of spatial patterns in throughfall on (simulated) soil moisture patterns. The authors use a throughfall pattern from one site and apply it in a modelling environment to another site. They study the effects of the selected throughfall pattern on the simulated subsurface flow response and soil moisture patterns. They also look at the effects of slope, storm size and soil depth in modulating the effects of the throughfall pattern on soil moisture. The proposed geo-statistical hydrograph is a novel and interesting concept. While this paper is interesting, I have several concerns.

The main difference between the spatial throughfall pattern used in the simulations of this study and those in Hopp and McDonnell (2011) is the higher standard deviation of the larger throughfall pattern. The authors explore the effects of storm size, slope and soil depth on the simulated soil moisture patterns, but not this important aspect. It is not clear why the authors did not explore the effects of the standard deviation of the throughfall pattern as well, especially because it can not be assumed that the standard deviation of the throughfall pattern remains constant when storm size or slope increase.

The authors mainly look at the effects of throughfall on depth averaged soil moisture. It should be discussed more clearly how the effect of the throughfall pattern is different for shallow soil moisture and deep soil moisture. One of the conclusions of this work is that soil moisture patterns before and after an event resemble the bedrock topography. However, this result is for depth averaged soil moisture and is thus highly influenced by ponding/saturation at the soil bedrock interface. The authors do not discuss if these results for depth averaged soil moisture are also observed for shallow (near surface) soil moisture. Other studies have shown that ponding at the soil-bedrock interface does not last much longer than a week after an event at the Panola hillslope, so it can be assumed that the depth averaged soil moisture pattern will change again after this 'remnant' ponding in bedrock hollows has disappeared. I expect the soil moisture pattern at depth or the depth averaged soil moisture pattern to be influenced less by the bedrock topography after this period. The results for the intra-storm conditions in this study therefore seem to be still influenced by the event. The pre-event results may also still be influenced by drainage from the initial conditions and may thus also not represent intra-storm conditions well.

When the authors do not look at depth averaged soil moisture, they compare soil moisture in the different slices. Since the slices have different thicknesses, they represent different depths below the soil surface. Thus soil moisture at for example 5-10 cm depth in one area is compared to soil moisture at 60-80 cm depth in another area. This is not well explained in the text and it is also not clear how this comparison of soil moisture at different depths influences the results.

Finally, the Panola hillslope has been used in other hillslope modelling studies. By more carefully comparing the results and assumptions of this study to those studies it will be easier for the reader to compare the different hillslope models and to understand the different assumptions.

Specific comments:

1.) P8628L10: Note that Keim et al (2006) also showed that throughfall has a small influence on the modelled subsurface flow responses. It is not just the amount of precipitation that is important but also the intensity. Perhaps explicitly mention this intensity effect somewhere in the text. Now it appears that the differences are attributed to the amount effect.

2.) P8628L20, P8629L1-2: If the variation in throughfall or the scale of the pattern is so important that it warrants a new study and adds something significant to the results of Hopp and McDonnell (which I agree it does), it is odd to study the effects of the throughfall pattern on the effective range (Fig 11) but not study the effects of the range of the throughfall pattern or the variability of throughfall on the responses and in fact assume that this range and variability remain constant when slope or rainfall amount change. This is a big assumption that needs to be addressed (and discussed) more.

3.) L8630L1-9: There is no need to describe this soil moisture data if it is not used anywhere in this study. If you used it, then you have to better describe how and when you used it.

4.) P8631L11-15: Better explain why these five classes are used if continuous data is available. The advantage of using classes is not clear and leads to extra smoothing of the data and the pattern.

5.) P8632L11: If the pattern with the largest influence on SSF is chosen, is it likely that this is also the pattern that leads to the largest effect on soil moisture? Does this

thus suggest that the modelling results represent a potential maximum effect since this specific pattern was chosen? The impact of choosing this pattern on the results should be discussed somewhere.

6.) P8633L10: Change the ordering of the methods paragraphs (3.1 and 3.2). You first need to describe the model as otherwise it is not clear what these layers are. Also explicitly state here that this is the depth averaged soil moisture.

7.) P8633L19: It is not that clear to me why it would save computation time to assume a nugget of zero. Perhaps explain better.

8.) P8633L24: Again why not study the effect of the CV of throughfall as well, as according to the introduction this is the main difference with the Hopp and McDonnell paper. Furthermore, why keep the CV of throughfall constant when slope and storm size change (which in reality isn't true)? Explain this better - or preferably include additional simulation results.

9.) P8634L21 and P8643L4: Weiler and Tromp van Meerveld 2008 showed that it was crucial to run their hillslope model for longer time periods and that including preferential flow changed the saturation pattern at the soil-bedrock interface (and will thus change depth-average soil moisture patterns). You should acknowledge these results somewhere, even if preferential flow pathways aren't included in this model and you simulate a single storm event.

10.) P8634L28: The data is given in the WRR datanote and available online. James et al 2010 used this data in their hillslope model but showed that using this small core scale data did not lead to reasonable model fits. There are good reasons not to use small core scale data in a hillslope model but these should be given here rather than stating that the data is not available.

11.) P8635L26: Is Qbar the average of Q in time, or in space? Please explain.

12.) P8636L14-15: Which soil moisture pattern is described here? Depth averaged?

Shallow? For what time? Rewrite this sentence/section as it is not very clear.

13.) P8636L17-21; figure 5: Soil moisture in model layers that all have different thicknesses and are thus located at different depths below the soil surface are compared. A layer may be located at 20 cm or at 120 cm below the soil surface depending on the local soil depth. How can you then still compare soil moisture at different locations, and make sure that you are not comparing different things? How much of the pattern is due to the fact that these model grid cells are located at different depths below the soil surface vs how much is a true difference in for example shallow (0-10 cm or 0-30 cm) soil moisture? This is not clear.

14.) P8637L15: It is unclear how these results will be different for shallow or deep soil moisture. Do you expect shallow (surface) soil moisture to be dependent on bedrock topography? And deep soil moisture (near the soil bedrock interface) to only be dependent on bedrock topography when there is significant (lateral) drainage and ponding on top of the bedrock interface? Make this distinction between shallow, deep and depth average soil moisture patterns and responses.

15.) P8638L1-2: Does it asymptotically reach this range or does it start to deflect again if you wait longer/when lateral flow and ponding at the soil-bedrock interface have disappeared? Does it reach it more quickly for the shallow layers than for the deeper layers? What if the simulations lasted much longer and the soil dried out and ponding at the soil-bedrock interface disappeared? Does it start to decrease again? I do not expect soil moisture to be so dependent on the bedrock topography if there is no longer any saturation at the soil-bedrock interface. You should run your simulations for a longer period to test this. (see also the next comment).

16.) P8640L1-2: But what if the model was initialized for a much longer time and there was no more lateral flow and ponding at the soil-bedrock interface? Would the results have been different? Discuss if this is indeed a result of the wet initial conditions and if it would be different if the hillslope was much drier.

17.) P8640L3-8: Did these studies look at shallow or deep soil moisture or profile average soil moisture? Include this information as it will make it clearer how these results compare to your results.

18.) P8640L12-14: Weren't these results for summer when the soil was much drier than in these simulations and soil moisture was mainly influenced by ET? Also, it seems that that was a result of differences in soil depth, not bedrock topography per se. It is important to make the distinction between the effect of soil depth and bedrock topography. While they are related, they represent and influence different processes. More careful wording is thus needed (here and throughout the text).

19.) P8641L5: This requires more careful wording as this result depends on the time scale and season. Throughfall may be dominant when we look at the time scale of a few hours (in winter) while ET may be more dominant if we look at the time scale of a few weeks (in summer).

20.) P8643L20: I don't agree that this is a large control. You acknowledge this on P8642L19.

21.) Figure 10: How different are these results for the different soil layers? Is the deepest layer most affected by bedrock topography? Do the shallower layers respond earlier? Also perhaps flip the y-axis of this figure so that what you call a peak in the text is a peak (rather than the dip) in this figure. Plus add the scale for the precipitation.

22.) This paper is generally well written but needs some editing. Some of the sentences aren't very clear and there are several 1-2 sentence paragraphs that should be combined with other paragraphs.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 9, 8625, 2012.