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Hydrology and Earth System Sciences
Discussions
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Interactive comment on "Hillslope experiment demonstrates role of convergence during two-step saturation" *by* A. I. Gevaert et al.

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We would like to thank Dr. Zehe for his positive review and constructive comments, which we address below.

Main points

- The reviewer points out that the results of the hillslope are dependent on the boundary conditions of the hillslope. Particularly due to the impermeable lateral boundaries the reviewer questions whether the results are typical of hillslopes or of small confluent catchments.

We expect that this system would behave similarly without the lateral impermeable boundaries, as is the case for natural hillslopes. The topography of the surface as well as the shape of the impermeable 'bedrock' as shown in Fig. 1 of the online manuscript suggest that even water falling along the outer edges of the hillslope will not flow along or over the lateral boundaries, but at a slight diagonal towards the trough. Once the groundwater table extends to the sides of the experimental hillslope, the impermeable lateral boundaries become relevant. In natural hillslopes, water would move across these boundaries to adjacent hillslopes. However, in natural rain events or storms, adjacent slopes will receive similar amounts of rainfall and thus the groundwater table may rise in a similar fashion, sustaining the no-flow boundary condition at the topographic divide. This suggests that the dynamics are in fact typical of small confluent catchments or zero order basins.

However, this does not mean the dynamics are not relevant for hillslopes. Consider a case where a planar hillslope is placed adjacent to the confluent B2-LEO hillslope and exposed to the same forcing. We would expect groundwater tables in the planar hillslope, where there is no significant lateral flow, to be higher than along the edges of the confluent hillslope, where there is lateral flow towards the central trough. This difference in groundwater level would result in flow over the boundary from the planar hillslope to the confluent hillslope. While the flow over the lateral boundary would change the magnitude and timing of the response, the overall dynamics in the confluent slope would be similar to what we observed during the experiment. This illustrates the relevance of the dynamics we observed to hillslopes.

- In the second point, the reviewer mentions that it would be interesting to benchmark TOPMODEL with the experimental data, which would improve the manuscript and underpin the potential of the B2 (LEO) hillslopes.

We agree that the hillslope setup has the potential to test the assumptions and concepts in hydrological models. This experiment has already been simulated by physically based models, based on the 3D Richards' equation (Niu et al. 2013, HESSD). Other colleagues are currently testing the hillslope-storage Boussinesq model with data from our experiment. However, so far no work has been done to benchmark TOPMODEL, and we believe this interesting idea is outside the scope of the current work. We agree that the hillslopes are very suitable for this and it would be interesting to work on this in the future.

- In the last point, the reviewer asks for an indication of how likely the experimental conditions are to occur in reality, such as providing the return period for the rain event in Tucson and other climates.

Though the B2 facility is located in Arizona, the experiment was not designed to be in line with the local extreme rainfall characteristics, but rather the aim was to bring the hillslope in a hydrologic steady state. The rainfall rate was chosen based on its relatively even spatial distribution and the irrigation was stopped when the (unplanned) overland flow was observed. The resulting event is comparable, at least in the magnitude of the 24h precipitation sum, to events that trigger floods and/or landslides around the world. However, the main focus of the research is not to reflect ambient conditions in certain natural hillslopes, but to observe underlying hillslope hydrological processes in great detail and under the simplified (but controlled) conditions of the artificial hillslope compared to natural hillslopes.

Technical points

- Figure 5: Might be instructive to plot cumulated storage against cumulative rainfall?

The suggested figure is shown below in Fig. 1. Due to the constant rainfall rate, the figure is very similar to Figure 5b of the online manuscript. At the beginning of the event, the storage closely follows the 1:1 line because runoff has not yet started. At the end of the event, the storage data increasingly deviates from this line as runoff increases. We propose that we add a line to the current Fig. 5b representing the constant rainfall intensity in the revised version.

- Please specify the error margins of your measurements.

The error of the 5TM sensors within the calibration range is ±2% volumetric water content. The load cells measure storage changes of ±0.05% of the total system mass, which is equivalent to less than 1 cm of precipitation. Piezometer errors are dominated by temperature sensitivity. Under normal applications these piezometers hang in deep wells where temperature is more or less constant. In our application, these piezometers are mounted from below the hillslopes and are subject to rather large diurnal temperature fluctuations. It was impossible to find reliable correction methods as the impact of T fluctuations on the piezometer readings kept changing between days. We will mention more details about the reliability of the piezometers in the revised version.

- You explain the overshoot of the soil moisture observations by the influence of the capillary fringe of the ground water table. Can you specify how this should work for a TDR or and FDR sensor with respect to the measurement principles?

The overshoot is due to limitations of our calibration curves. We are in the process of recalibrating the sensors. Meanwhile we know that capping the sensors at an average porosity of 39% yields good results compared to the load cell readings, which we consider to be reliable (see Fig. 5b of the online manuscript).

- How did you measure the retention curves?

Retention curves were measured in the laboratory. Soil cores were taken from several depths of a barrel that had been filled with the same material as the hillslope and also compacted similarly. In the laboratory, the retention characteristic was made for these cores using Tempe cells and a WP4-T Dewpoint Potentiameter for the wet and dry ends, respectively. This information will be included in the revised version of the manuscript.

- Please specify the hydraulic conductivity curve of the material. Do you expect ks to be anisotropic (now and in the long term future)?

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Based on the water retention characteristics, the K(theta) curve is described by the following parameters:

theta sat = 39

theta res = 0.08

alpha = 1.86

n = 1.76

m = 0.43

We are also planning to determine the curve experimentally. We do not expect ks to be anisotropic now because the material and compaction are homogeneous and because this was the first experiment performed on the hillslope. However, we expect anisotropy to play a more important role in the future as hydrological pathways develop, especially after vegetation is planted.

- Subsurface hydrological dynamics at chicken creek (a large artificial hillslope) turned out to be pretty much contaminated by artificial structures (capillary barriers between cones when the site was filled). Do you expect B2-Leo to be free from this? If so I would expect symmetric patterns of saturation in Cross section B. This is not the case for the early stage of the experiment. Where does this come from - fingering?

During construction of the LEO hillslopes, great care was taken to fill and compact the material homogeneously. Instead of flattening and filling soil cones as was done in Chicken Creek, loose material was spread over a cross-slope strip of the hillslope to a certain depth. Then the material was compacted to another specified depth. This process was repeated for several (vertical) layers and (horizontal) cross-slope strips moving from the tow of the slope to the upper end. Also, great care was taken in choosing and preparing the source material for the hillslopes to ensure a homogeneous texture, whereas the material at Chicken Creek was from a natural source and therefore

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heterogeneous.

We agree that the early stage of Cross section B is not entirely symmetrical, as would be expected. However, this is likely due to small-scale variation due to the indicated time and location of the cross section shown in Fig. 6 of the online manuscript. The evolution of the early phase, with the propagation of the infiltration front, is in fact quite similar at hillslope scale. This is evident from the small error bars on the timing of the first step as shown in Fig. 7.

References

Niu, G.-Y., Pasetto, D., Scudeler, C., Paniconi, C., Putti, M., and Troch, P. A.: Analysis of an extreme rainfall-runoïňĂ event at the Landscape Evolution Observatory by means of a three-dimensional physically-based hydrologic model, Hydrol. Earth Syst. Sci. Discuss., 10, 12615–12641, doi:10.5194/hessd-10-12615-2013, 2013. 2213, 2214

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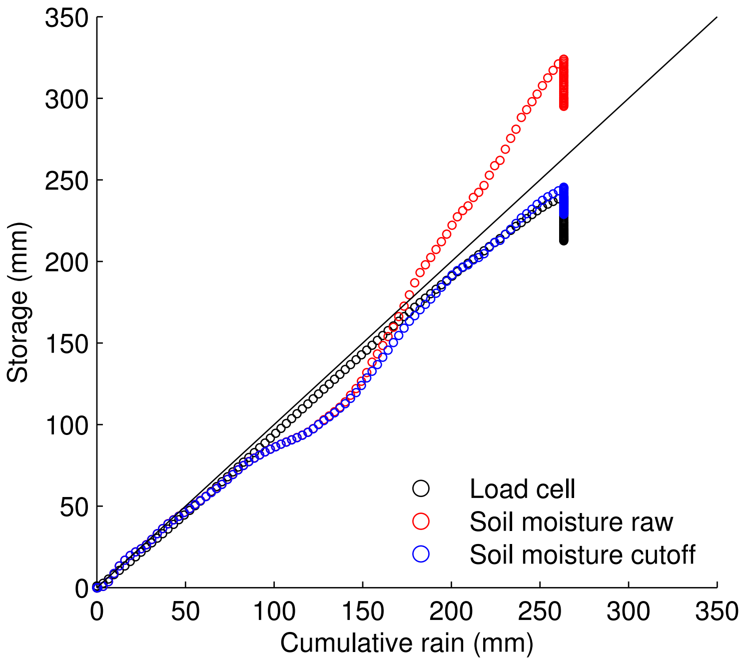

Fig. 1. Storage estimates based on load cell data and soil moisture data with and without the 39% cutoff value are plotted against cumulative rainfall.

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