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Discussions

Interactive comment on "Hillslope experiment demonstrates role of convergence during two-step saturation" *by* A. I. Gevaert et al.

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We thank Anonymous Referee #2 for the constructive comments. We address these below.

Main points

- The reviewer states that despite the high density of sensors, many state values are unknown. These factors could affect the results. Given the differences in volumetric water content and hydraulic conductivity as measured in the laboratory and observed in the experiment as well as the time that has passed since the hillslope was filled, the reviewer questions whether the hillslope can be regarded as homogeneous.

Even though the soil was packed on the hillslope in such a way as to create homogenous hydraulic properties, the scale of the hillslope prevents true homogenous conditions. We expect the subsurface structure to constantly change as more experiments will be executed. Actually the observation of this evolving subsurface structure and its effect on hydrology is one of the main objectives of the long-term experiment of LEO. The measured water content values exceeding the maximum porosity are a sensor issue. We tested the volumetric water content sensors and found that the sensors measure values exceeding the maximum porosity when under the influence of a capillary fringe or groundwater table. The overshoot is due to limitations of the calibration curves, which will be made clearer in the revised manuscript. In the experimental data, this is supported by the similarity of the storage estimate based on load cell data and the estimate based on water content data capped at 39% (see Fig. 5b of the online manuscript).

- The reviewer points out that some traditional models conceptualize the observed two-step saturation process by a tension water reservoir and a free water reservoir.

As suggested by the reviewer, conceptual models that have a tension and free water reservoir which interact as described can represent the two-step saturation process. However, this is only possible if the model allows the tension reservoir to become saturated, which is typically not the case. We thank the reviewer for the references and will add this point and the references to the Discussion section. However, lumped conceptual models cannot simulate the effect of convergence and lateral flow that played such an important role during the experiment.

- Finally, the reviewer suggests that more data be collected on soil structures and hydraulic characteristics, for example by performing dye tracer experiments.

We are performing additional soil characterizations in the lab to determine the K(theta) relationship. In the revised version of the paper we will add piezometric data to support our observations based on soil moisture data regarding soil saturation (see response

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to George Waswa).

Other concerns

P2L11-14L: In some conceptual models, similar two-step soil saturation has been considered like the Sacramento model and the Xinanjiang model. This point and the references will be included in the Discussion.

P3L12-14: Can the filled homogeneous material represent the highly heterogeneous soils of natural hillslopes?

The aim of the Landscape Evolution Observatory is not to reflect conditions in certain natural hillslopes, but rather to study the underlying hydrological processes in great detail. This is facilitated by the controlled conditions and simplified design. We expect subsurface heterogeneity to develop over the course of the 10-year experiment. This will be added to the Introduction where we describe the Landscape Evolution Observatory project.

P4L5: Since 2009, have the overall shape and relief of the hillslope been changed under sprinkler tests? Do you re-shape the micro-terrain every time after a rainfall experiment?

As mentioned previously, the hillslope was completed in 2012. After completion, a small number of sprinkler tests were performed to characterize the rainfall distribution. After these tests, the surface was reshaped once to restore the initial condition of the surface before performing the experiment. The surface is not reshaped after every rainfall event because the aim of the Landscape Evolution Observatory is to observe the evolution of the hillslope through time.

P4L15: Could the large difference between measured saturated hydraulic conductivity and the effective value be due to preferential pathways like soil cracks within the soil material? If you could provide more soil hydraulic experiment, e.g., a 1D soil column test, it will help readers understand your observations.

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We do not expect the difference in hydraulic conductivity estimates to be due to preferential pathways due to the care that was taken in filling and compacting the hillslope. Also, soil cracking is unlikely because the soil is classified as loamy sand, with a clay fraction of 3%. In Fig. 7b, the confidence interval of the median as shown by the error bars is very narrow, showing that the propagation of the infiltration front was uniform over the hillslope. Finally, the subsurface runoff starts after the infiltration front reaches the bottom of the hillslope in the convergent area. If preferential flow paths would be an important factor, we would expect the deepest sensors to saturate before the arrival of the infiltration front as shown in the figure and/or the subsurface runoff to start before the infiltration front reached the bottom of the hillslope. We will expand the discussion of preferential flow paths in the revised Discussion section.

P5L9: Did you only carry out one rainfall experiment?

Yes, only one rainfall experiment was performed for this study.

P5L24: In Figure 5a, the volumetric water contents in Phase 3 exceed the maximum porosity. Could it be the reason that there are some macropores which lead to higher hydraulic conductivity and water contents?

The overshoot in water content values is a sensor issue, as discussed in response to the first main point.

P6L27: In figure 7, it is better to add the rainfall line in the legend.

We will include the rainfall line in the legend as suggested. Thank you.

P8L14-21: The discussion that lateral distribution of water was a major contributor to groundwater table and overland flow generation in this part is not sufficiently supported by present data. Because justly in L10-13, the authors admit that the volume water content will not exceed the maximum soil porosity at the bottom of the soil profile at the toe of the slope, where should mostly tend to be saturated due to lateral subsurface flow.

The importance of lateral redistribution of water can be seen by the differences in the response of the convergent and upslope areas as seen in Figures 6 and 7. In addition, simple column storage calculations show that soil columns in the central trough saturated sooner than would be expected by initial conditions and rainfall rate alone. In upslope areas the storage was lower than would be expected. Although Figure 6a suggests that the soil is not saturated at the toe of the hillslope, we expect that this is not what really happened. The measured water contents reached 36-37%, within a few percent of the maximum porosity, and the sensors have an error of $\pm$2%. Also, the rate of subsurface runoff collected from the two central sections at the lower end of the hillslope (both 50 cm wide and one to either side of the central trough) was higher than the runoff rate in the other sections. Therefore we expect that in reality these locations were saturated. These points will be added to the discussion section.

P9L5-8: Could you really exclude macropore flow? Soil macropores can be shaped through vegetation roots, worm holes as mentioned by the authors. While other factors like the processes from wetting to drying, freeze thawing... also cause soil cracks. So I suggest a dye tracer experiment may help to verify it.

We do not believe macropore flow to be significant at this stage (recall that the construction of the hillslope was completed less than two years ago). The low clay content makes soil cracking unlikely, as mentioned previously under the comment of preferential flow paths. The hillslope is bare soil and was never vegetated and no worms have been observed. These points will be made clearer in the revised discussion section. A dye tracer experiment is not practical because this would disturb the hillslope.

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