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

A. I. Gevaert et al.

gevaertanouk@gmail.com

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We are grateful to the reviewer for his constructive comments. Here we address the specific points mentioned by the reviewer and we invite the reviewer to comment on our reply and additional analysis.

2.1 Subsurface flow and the formation of a groundwater ridge

We agree that once the infiltration front reached the impermeable boundary at the bottom of the hillslope, further accumulation of infiltrating water started to form a groundwater table. Part of the reason that this started earlier in the convergent area could be, as the reviewer suggests, the wetter initial conditions at the bottom of the central trough. However, the speed of the infiltration fronts in the convergent and upslope areas are very similar, so we expect that this is not the only factor. Based on simple column storage calculations we found that soil columns in the central trough saturated sooner than would be expected based on the initial conditions and rainfall rate alone. Similarly, storage in columns in the upslope area is less than would be expected, indicating that there was lateral flow between the upslope and convergent areas. We will add a few sentences to the Discussion section referring to these calculations.

2.2 Contribution of subsurface flow to overland flow

The estimation of overland flow based on the water balance indicates that overland flow may have started as early as 14 hours into the experiment, but the error bars show that we can only be expect significant overland flow after 20 hours. Before this time, error bars extend to 0 (Fig. 7) due to uncertainties in the water balance analysis used to estimate overland flow before the end of the rainfall event. We do not expect that Hortonian overland flow occurred for several reasons. Firstly, the constant rain rate is lower than the saturated hydraulic conductivity, both as determined in the laboratory and as determined by model calibration. Also, overland flow did not start until after many hours of rainfall and once it started, overland flow was limited to the central trough. In subsequent experiments with the same rainfall rate, but shorter duration, no ponding or overland flow was observed. Moreover, model simulations based on the 3D Richards' equation do not show overland flow due to infiltration excess (Niu et al., 2013, HESSD), but confirm overland flow due to saturation excess in the central trough. We will improve the quality of the graph showing the estimated overland flow and the error bars, so that it is clear that overland flow can only reliably be expected to start after 20 hours. We will also add a discussion on the runoff generation processes and list the reasons why Horton overland flow can be excluded.

While at some moment it is possible that tension saturation at the surface caused saturation excess overland flow to occur, the continuation of overland flow for almost a day after the end of the rainfall event (2218L17) indicates that it was mainly subsurface flow that contributed to overland flow. Though piezometric data would help justify this interpretation, we chose not to include the data in the initial version of the manuscript due to the temperature sensitivity of the vibrating wire piezometers installed in the hillslope. Though the temperature sensitivity prevents us from using the data quantitatively, the data can give us an idea about the timing of water table formation and when the water table reached the surface. This data is shown in Fig. 1 for different zones in the hillslope. Fig. 1a shows data from the central trough, or the piezometers along cross-section A as shown in Fig. 2 of the online manuscript. Fig. 1b shows the same data as Fig. 1a, but excludes the piezometer nearest the toe of the slope (at 2 m upslope and 6 m cross-slope as shown in Fig. 2 online manuscript). Fig. 1c and 1d show piezometer data from the convergent and upslope areas, respectively, as shown by the blue and green colors in Fig. 2 of the online manuscript. While the retrieved values should not be interpreted as accurate representations of actual groundwater levels (the values suggest groundwater levels extending below the hull of the hillslope as well as above the soil surface), the data support the timing of water table rise as seen in Fig. 7 of the online manuscript. Also, the data indicate that the water table reached the surface in the central trough (Fig. 1a and b).

2.3 Groundwater ridging and water table

We agree that the inclusion of piezometric and tensiometric data would be of great value. However, the MPS-2 sensors installed in the hillslope saturate at pressures of -6 kPa and therefore do not provide pore water pressure data under wetter soil conditions. The piezometric data, as mentioned earlier, are temperature sensitive and in future studies, the vibrating wire piezometers will be replaced by pressure transducers. However, the piezometric data (Fig. 2) support the presence of a groundwater ridge in the central trough. The development of the ridge as shown in Fig. 2 is similar to what was observed in soil moisture data (Fig. 6 of the online manuscript). We suggest including this and the previous figure in a revised manuscript to support our discussions and conclusions and are interested in learning the reviewer's opinion on this.

2.4 Physical processes involved in groundwater ridging

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Interactive Discussion

Discussion Paper

We agree that the discussion of groundwater ridging in the online version of the manuscript is limited. In this comment, the reviewer provides some very useful information and references to take into consideration. These will help improve the discussion in the revised version.

We considered air entrapment as an explanation for the decreasing water content after the passage of the infiltration front and other observations. However, there are a few reasons we deem it unlikely such as the scale of the hillslope and the fact that we did not observe any ponding. Also, the rainfall intensity distribution is not completely uniform over the hillslope, making air entrapment unlikely. At this time we think the decreasing water content in the second phase, yet constant infiltration rate can be explained by changes in water retention characteristics with depth.

The compaction of laboratory samples was similar to that of the hillslope: large barrels were filled with the soil material in layers, and after the addition of each layer the soil was compacted to a specific level. After this was done, samples were taken at different depths. Extra testing of the 5TM sensors showed that sensors overestimated soil moisture once the sensors were influenced by the capillary fringe or a groundwater table. Decagon confirmed that values above total porosity are due to calibration issues. Finally, when a cutoff value equal to the porosity is used for soil moisture, the storage estimates based on these values are almost identical to the mass accumulation measured by the load cells (Fig. 5 in online manuscript).

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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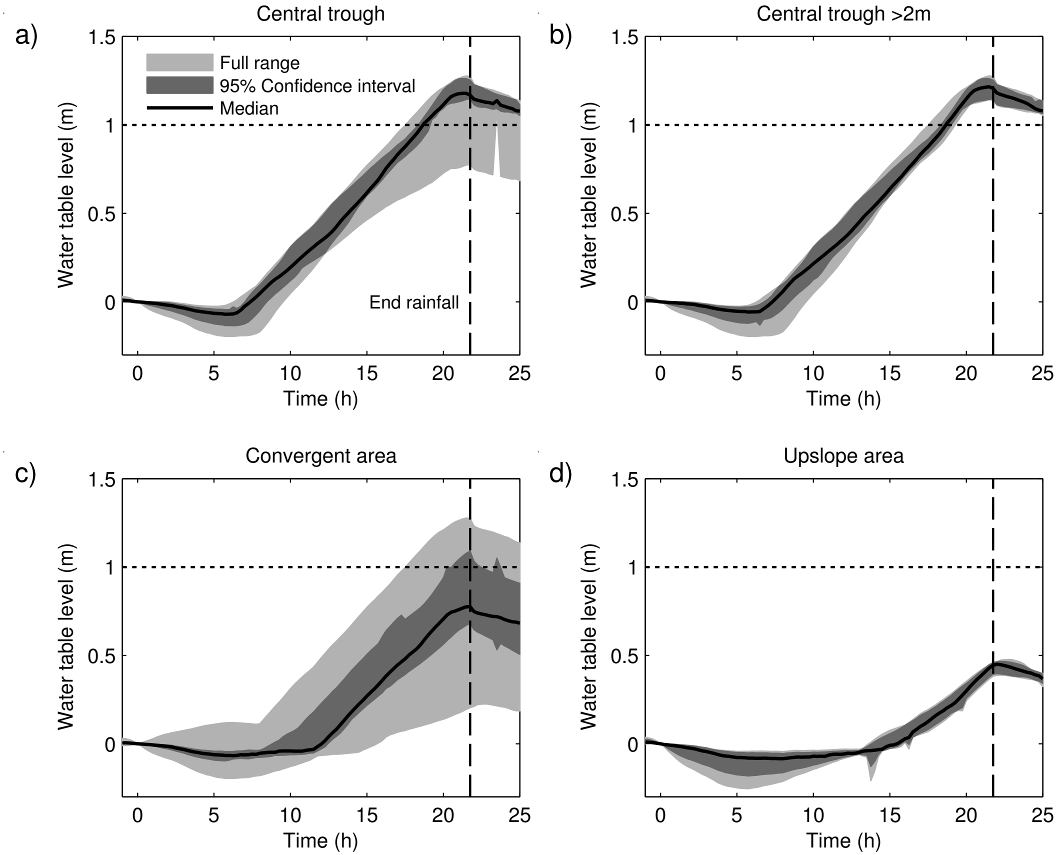

Fig. 1. Median groundwater levels, their 95% bootstrap confidence interval and the full range of water level data are plotted for several hillslope zones. The dotted line represents the soil surface.

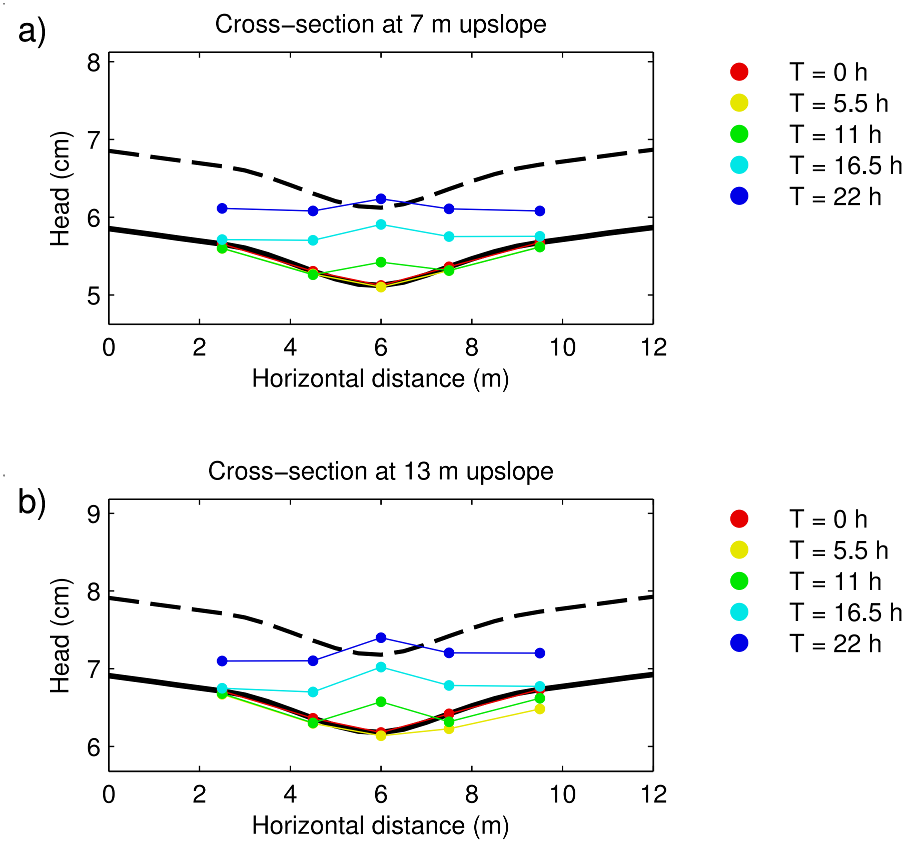

Fig. 2. Piezometric data along two cross-slope transects at 7 and 13 m from the toe of the slope are shown at several time steps between the start and end of the rainfall event.