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On the Relationship between Rainfall, Recharge, Unsaturated Storage, and Hillslope Subsurface Flow Processes

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In this work we present the coupling between the one-dimensional Richards equation for vertical unsaturated flow, and the one-dimensional hillslope-storage Boussinesq equation (hsB, see Troch et al., 2003) for lateral saturated flow along complex hillslopes. This coupling allows for a quantitative investigation of the interactions between the unsaturated and saturated flow and storage processes. Specifically, in this paper the role of unsaturated storage in the relationship between rainfall and recharge is analyzed. Our modeling results indicate that the unsaturated zone not necessarily dampens the rainfall signal, but can also amplify it, causing recharge rates to exceed rainfall rates.

The coupled model is compared to the original hsB model (without unsaturated zone) and a three-dimensional Richards based model on a set of seven synthetic hillslopes, ranging from convergent to divergent. The comparison shows a reasonable agreement between both HSB models and the Richards-based model. However, the outflow rates are mostly underestimated, and water tables are mostly overestimated compared to the Richards-based model.

The capillary fringe is then included into the Boussinesq flow domain. Results show a clear improvement and a remarkably good match between the coupled model with inclusion of the capillary fringe and the Richards-based model in terms of hydrographs and water tables, stressing the importance of the capillary fringe on hydraulic

groundwater models. We conclude that for this test case it is possible to reproduce hydrographs and water table dynamics with a good degree of accuracy, using a low-dimensional hydrological model.