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# Nonlinearity in subsurface stormflow generation: comparison of an explicitly nonlinear model to a Richards equation based approach.

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The hydrological behavior of a distributed catchment model should reflect our knowledge of hydrologic behavior at the element scale. In the special case of modeling subsurface stormflow using models based on Richards' concepts, assumptions crucial to the successful application of this concept have been shown to be invalid. One of the most important issues is the heterogeneous but strongly organized spatial distribution of soil water at the sub-element scale, combined with the strong nonlinearity present in the relation between flow and relative saturation. We compare model elements as used within two different concepts: model element type E1 represents an element based on the well-known Richards equation for saturated-unsaturated flow through porous media using a Van Genuchten-Mualem approach. E2 represents a model that explicitly accounts for nonlinear behavior often observed in the hydrological dynamics of subsurface stormflow-dominated hillslopes and small catchments. The E2-type element uses a numerical approach to residence time distributions at the element scale to model the shape of the unsaturated zone in terms of travel time of soil water. Element discharge occurs through a flow path, whose direction is that of steepest bedrock descent. Lateral transport is governed simply by the Darcy equation for saturated flow. We assume that the saturated zone is heterogeneously distributed over the spatial domain of the element and that it grows and shrinks in a nonlinear way. With the growing and shrinking of the saturated zone within the element, the residence time distribution changes. This effectively constitutes a positive feedback between soil water present

at locations away from the saturated zone and flow at the element scale. We assessed whether the explicit recognition of nonlinearity leads to improved process representation. To do so, we calibrated E2 to an artificial hydrograph, where precipitation intensity and duration were included as calibration parameters besides the model structural parameters. We subsequently applied the best-fit parameter set to E1 and tried to reproduce the artificial hydrograph. We compared results from the two concepts in terms of peak timing, rising limb steepness and magnitude.