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Modeling subsurface stormflow based on catchment soil moisture connectivity.

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Application of Richards based catchment models is notoriously cumbersome in steep terrain with thin soil covers and high infiltration capacity relative to precipitation intensities. We argue that the connectivity of wet, hence conductive, patches of soil plays an important role in the spatio-temporal dynamics of soil moisture under these circumstances. The rough topography of the impeding layer causes connectivity to fluctuate with varying catchment soil water status. We developed a model framework to test hypotheses of preferential flow networks as well as convergence and divergence of subsurface flow. This model aims to bridge the gap that exists between the hydrologist's perception of subsurface stormflow and common model implementations thereof. It divides the catchment into grid cells with a certain soil depth. Infiltration is stored within the soil column until field capacity is exceeded. Inter-grid cell darcian flow of excess soil water occurs exclusively along preferential flow paths, local drainage direction determining the direction of flow. Intra-grid cell lateral transport is modeled by using Time Delay Frequency Distributions (TDFDs), describing the amount of time needed for the excess water to reach the nearest flow path. The shape and width of the TDFD depends on the configuration of flow paths in a cell. With increasing grid cell wetness, the cell switches to a drainage network of greater density, reducing time delays. This dynamic behavior of the grid cells allows for a wide variety of responses to incoming fluxes. The connectivity between patches of excess water determines the efficiency of the flow at a larger scale, as well as the non-linear behavior of catchment discharge. We consider this model a first step towards a new class of catchment models. We will critically test the model by applying it to several catchments with distributed subsurface stormflow observations in an inverse modeling framework.