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Effects of small-scale throughfall patterns on the generation of subsurface stormflow at the hillslope scale

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Forested hillslopes are subject to pronounced heterogeneity in landscape properties and complexity of their responses to fixed hillslope attributes (e.g. slope, soil depth etc.) and temporally varying throughfall. One widely reported spatio-temporal pattern of hydrological response at the hillslope scale is the threshold nature of subsurface stormflow production. In many upland systems, this is linked to the development of connected patches of subsurface saturation at the soil-bedrock interface - a pre-condition for the initiation of fast lateral flow at many experimental sites examined around the world. One pressing issue that is difficult to assess with single-realization hillslope ecohydrological studies is how spatially varying throughfall inputs interact with static hillslope attributes, such as slope angle, soil depth or bedrock topography, and affect the development of connected patches of subsurface saturation necessary to drive flow.

Here we describe a new study where we examine how patterns of throughfall, applied to a hillslope with variable soil depth and irregular subsurface topography, influence the hydrologic response of the hillslope to a storm event. We present a number of virtual experiments using Hydrus-3D, a Richards' equation-based finite element model. Topography and hydrologic field observations from an existing study hillslope are used to calibrate and test the base case scenario. For the virtual experiments, slope angle and soil depth of the flow domain are varied in conjunction with applied throughfall patterns. We also explore which effect an increasing complexity of the hillslope geometry has on the sensitivity of the hillslope hydrologic behavior to spatially variable input. The analysis of spatio-temporal patterns of subsurface moisture shows how different realizations of throughfall patterns interact with the underlying soil mantle and subsurface topography, controlling the formation of subsurface saturation connectivity at the soil-bedrock interface and the generation of subsurface stormflow.