Geophysical Research Abstracts
Vol. 20, EGU2018-13336, 2018
EGU General Assembly 2018

Studying soil water mixing processes and threshold behavior at the hillslope scale

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Prediction of temporal changes of both the soil water storage and the shallow subsurface runoff for hillslopes exhibiting high degree of subsurface heterogeneity remains a challenge. The extent of mixing of water of different temporal origin has a direct impact on the overall residence time of water in soil, hence influencing biogeochemical processes and mass fluxes of nutrients. The generation of stormflow, one of the most important runoff mechanisms in headwater catchments, was reported to be affected by a threshold behavior in respect to rainfall input. In this study, threshold behavior and mixing processes in a hillslope segment were studied by two-dimensional numerical model. The model is based on dual-continuum approach reflecting water flow and isotope transport through the soil matrix and preferential pathways. The threshold relationship between rainfall and stormflow as well as hysteresis in the hillslope stormflow–storage relationship were examined. The hillslope storage analysis was performed for selected individual rainfall–runoff episodes over the period of three growing seasons. Temporal and spatial variations of pre-event and event water contributions to hillslope stormflow were evaluated using two-component mass balance approach based on synthetic oxygen-18 signatures. The simulation results suggested significant mixing within the hillslope segment, within each of the two flow domains as well as between the domains (soil matrix and preferential pathways). Despite the dominant role of preferential stormflow in overall hillslope runoff response, a rapid and substantial contribution of pre-event water to the hillslope discharge was predicted. The spatially and temporally variable exchange of oxygen-18 between the soil matrix and preferential pathways exerted a primary control on the temporal origin of water in the hillslope runoff. The results also indicated that there was no single valued rainfall threshold responsible for the activation of preferential flow and initiation of stormflow.