Geophysical Research Abstracts
Vol. 17, EGU2015-1372, 2015
EGU General Assembly 2015

Transient runoff-runon model for a 1-D slope with random infiltrability: flow statistics and connectivity

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Despite the recent research focused on runoff pattern connectivity in hydrology, there is a surprising lack of theoretical knowledge regarding hillslope runoff generation and dynamics during a rainfall event. The transient problem is especially unaddressed. In this paper we propose a model based on queueing theory formalism for the infiltration-excess overland flow generation on soils with random infiltration properties. The influence of rainfall intensity and duration on runoff dynamics and connectivity is studied thanks to this model, numerical simulation and available steady-state results. We limit our study to a rainfall intensity that is a rectangular function of time. Exact solutions for the case of spatially random exponential distributions of soil infiltrability and rainfall intensity are developed. Simulations validate these analytical results and allow for the study the rising and recession limbs of the hydrograph for different rainfall characteristics. The case of a deterministic uniform rainfall rate and different infiltrability distributions is also discussed in light of runoff connectivity. We show that the connectivity framework contributes to a better understanding and prediction of runoff pattern formation and evolution with time. A fragmented overland flow is shown to have shorter charge and discharge periods after the onset and offset of rainfall compared to well connected runoff fields. These results demonstrate that the transient regime characteristics are linked with connectivity parameters, rainstorm properties and scale issues.