Which event produces the largest flash flood? Considering rainfall characteristics, initial soil moisture, retention and run-on infiltration

Markus Weiler, Hannes Leistert, and Andreas Steinbrich
University of Freiburg, Hydrology, Freiburg, Germany (markus.weiler@hydrology.uni-freiburg.de)

Local heavy precipitation regularly causes great damage resulting from flash floods in small catchments. Appropriate discharge records are usually unavailable to derive an extreme value statistics and regionalization approaches predicting peak discharge from discharge records of larger basins cannot consider the small-scale effects and local processes. In addition, forecasting flash floods from rainfall forecast requires to identify the event conditions under which a catchment is most prone to trigger flash floods. Therefore, factors influencing runoff formation and concentration need to be identified based on catchment characteristics in order to predict flood hydrographs, geomorphic processes and flood inundation.

We have developed a framework depending on the joint probability of soil moisture and rainfall and used the distributed, processed-based rainfall-runoff model RoGeR to predict the spatial explicit probability of soil moisture and linking this to overland-flow and subsurface flow generation assuming different scenarios of soil moisture and rainfall characteristics. Selected combinations result in a joint probability with a specified return period (e.g. 100 year), but are based on different probabilities for rainfall amount, duration and initial soil moisture. From this, the combination of a precipitation event and initial soil moisture condition can be determined which generates the largest runoff generation. In addition, we found, that accounting for the spatially and temporally controlled superimposition of runoff formation and runoff concentration, including the possible infiltration of overland flow (run-on infiltration) along the flow path and the retention in depression can have considerable influence on modelled peak discharge and discharge volume for a given catchment. For this purpose, various methods were developed and tested considering the effects of run-on infiltration and retention, from complex 2D hydraulic models coupled with RoGeR to simpler approaches considering run-on infiltration only locally or based on the difference between actual and potential infiltration. These approaches were tested in different catchments with different soils, geologies and land use. Also, the sensitivity of surface roughness was considered.

We developed an interactive spatial explicit method, which combines the joint probability of soil moisture and rainfall for runoff formation with hydraulic assumptions to determine runoff concentration and thus the corresponding design hydrographs and the specific conditions a catchment can trigger flash floods. This information can on the one side help to generate flash
flood risk maps, but should also be considered in order to provide adequate catchment specific information for heavy precipitation risk management. We could clearly demonstrate that only the combined consideration of factors affecting flood formation and concentration and its implementation into a statistical framework allows to predict floods for a specific return period (which is not equal to the return period of precipitation) for small catchments where different runoff generation mechanisms occur simultaneously.