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Where to measure point rainfall during extreme flash flood events in mountainous catchments?

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Despite the availability of weather radar data at high spatial (1 km$\hat{2}$) and temporal (5-15 min) resolution, ground-based rain gauges are still needed to accurately estimate storm rainfall input to catchments during flash flood events. This is especially true in mountainous catchments where estimating storm depth and intensity from radar data is more challenging than in flat terrain. Given economical limitations on the number of rain gauges, a long-standing problem in catchment hydrology is where to put the (limited amount of) rain gauges to best capture both storm rainfall depth and temporal variability of storm intensity during extreme events. This study addresses the question whether it is possible to predict the best locations for rain gauge installation given a basin's topography and dominant storm tracks. A network of 40 tipping bucket rain gauges was deployed in the Sabino Canyon catchment near Tucson, AZ, during the summer monsoon season of 2006. An extreme, multi-day rainfall event during 27-31 July 2006 caused record flooding and an unprecedented series of slope failures and debris flows in the Santa Catalina Mountains. Geostatistics (kriging with external drift, KED) was used to combine the tipping bucket rain gauge observations with NEXRAD weather radar to create rasterized rainfall maps with high spatial (1 km$\hat{2}$) and temporal (15 min) resolution over the entire multi-day rainfall event. We use these KED rainfall maps to determine the optimized locations for an installation of 1 up to 4 rain gauges considering all possible subsets of 1 to 4 grid cells over the entire rainfall event. Our optimization method minimizes both the residual percent bias and the coefficient of correlation between the mean areal rainfall obtained using the KED rainfall maps and mean rainfall determined using each subset. This method was applied to the entire record of rainfall observations to identify networks consisting of 1 to 4 rain gauges which represent the 'best' compromise between the two criteria. To determine the effect of the length of record of observations on the selected rain gauge networks, 'best' compromise networks were identified using the same method treating each single rainfall event (seven in total) independently. A semi-arid rainfall-runoff model (KINEROS2) was then used to evaluate each 'best' compromise rain gauge network. The performance statistics for model runs from all 'best' networks were evaluated against a calibrated simulation of KINEROS2 based on the full spatial extent of the KED rainfall map (representing an installation of 94 rain gauges). In addition, to test how each 'best' gauge network compared with random rain gauge configurations, average performance statistics for an ensemble of 1,000 randomly selected subsets of 1 to 4 grid cells were determined.