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A stochastic methodology for pluvial flood mapping in urban areas with a fast-processing DEM-based flooding algorithm

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High-intensity and short-duration storms can generate pluvial floods in urban areas. Currently, 2D hydrodynamic models are recognised to be the best tool to simulate pluvial floods. The T-year synthetic design storm is usually assumed to generate the T-year pluvial flood. However, synthetic design storms cannot represent the variability in duration, precipitation and intensity temporal distribution of real storms that should be considered to account for their influence on water depths in pluvial floods. A more sound approach consists in estimating the T-year water depth in a given location from the frequency curve of water depths generated by a long series of possible rainfall events similar to the real storms.

However, 2D hydrodynamic models require high computation times that are not well suited with stochastic simulations. The Safer_RAIN tool is a rapid hydrostatic flood model based on a filling-and-spilling technique that has been developed within the SAFERPLACES project funded by the EIT Climate-KIC (Samela et al., 2020). Depressions and links between them are identified from a digital terrain model. The continuity equation is used to simulate how depressions are filled and spill to downstream depressions. Infiltration is simulated by using a distributed implementation of the Green and Ampt model that accounts for ponding time.

In this study, a stochastic methodology to delineate pluvial flood hazards is proposed in the Pamplona metropolitan area in Spain. First, the Safer_RAIN tool has been benchmarked by using spatially distributed high-resolution quantitative precipitation estimates (QPE) at time steps of 10 minutes for three real pluvial flood events. QPEs were obtained merging the data recorded at a set of automatic weather stations from the Spanish State Meteorological Agency (AEMET), the Regional Government of Navarre and crowdsourced networks, with continuous fields of radar observations. The Safer_RAIN tool has been benchmarked with the 2D hydrodynamic IBER model.

In Barañáin, the results show a bias of -0.17–0.18 m and a RMSE of 0.22–0.49 m between water depths, as well as an accuracy correlation coefficient (ACC) of 0.87–0.99. In Zizur Mayor, the bias is -0.19–0.20 m, the RMSE is 0.29–0.55 m and the ACC is between 0.88 and 0.98.

Second, a long set of 10 000 synthetic storms has been generated by using a stochastic rainfall generator based on a bivariate copula approach fitted to data recorded at four rainfall-gauging stations located close to the case study. The 10 000 synthetic storms generated with a Gumbel copula fitted to the real rainfall events have been used as input data of the Safer_RAIN tool. Safer_RAIN preprocessing was done in 112 seconds and each simulation lasted around 45 seconds. A Generalized Pareto distribution function was fitted to the 10 000 water depth values in each cell of the grid. Pluvial flood hazard maps were obtained by estimating the T-year water depth in each cell of the grid.

Samela et al. (2020). Safer_RAIN: A DEM-Based Hierarchical Filling-&-Spilling Algorithm for Pluvial Flood Hazard Assessment and Mapping across Large Urban Areas, Water, 12, 1514.