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Characterization of the rainstorm and runoff uncertainties in a tropical volcanic catchment (Tuauru river, Island of Tahiti, French Polynesia)

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The tropical high volcanic Island of Tahiti in French Polynesia, as a few similar Polynesian islands, experiences intense rainfall leading to flash-flood episodes within its numerous small size catchments. Due to the steep slopes and dissected orography in the island, the rainfalls exhibit high space and time variability. Our objectives were first to characterize the rainfall uncertainties through a sub-hourly spatial rainfall generator, and second to evaluate the impact of such uncertainties in predicting floods using an event-based rainfall-runoff model. Our study case is the medium size (26 km^2) Tuauru catchment. We adopted the following 3-step modelling strategy:
The first step consisted in calibrating the rainfall-runoff model from a set of selected events, for which both rainfall (here 4 rain gauges in or near the Tuauru catchment) and stream flow observations were available. We applied a distributed event-based hydrological model combining the Soil Conservation Service production function and the lag-and-route transfer function scheme (referred as SCS-LR in ATHYS; cf. www.athys-soft.org). An optimization procedure gave for each event the best values of the model parameters, here reducible to CN the curve number (or equivalently the S maximal water storage capacity) and V0 the average streamflow velocity. The median value of the Nash-Sutcliffe criterion was 0.75 and a significant relationship between S and the base flow preceding the flood was found (R^2 = 0.60), whereas the V0 was constant (1.5 m/s).
In a second step, to account for precipitation variability, we used the SAMPO (Leblois & Creutin, 2013) stochastic rainfall simulator running in conditional mode. This technique can provide any number of plausible rainfall fields restituting both the actual rainfall measured at the rain gauges in or near the Tuauru catchment and the spatio-temporal variability inferred from the available event data, at sub-hourly time scales. As an example, the cumulated rainfall over the Tuauru catchment can vary in a ratio of 1:3 or 1:4.
In the final step, we simulated the discharge response for selected events for which hydrological model set of best parameters were available from the first step, and by taking a set of rainfall field realizations as model inputs. This exercise aims to estimate levels of uncertainties reached for discharge reconstructions owing to all these plausible precipitation fields, especially for extreme events. The range of plausible peak flows appeared to be as large (or even larger) as the one of the plausible rainfalls.
Our findings confirm that the rainfall uncertainties can be very high in Tahiti, considering the density of rain gauges. The rainfall generator was an efficient way to characterize these uncertainties in a limited network configuration; in addition, the generated scenarios led to a consistent probability distribution of the predicted runoff. Uncertainties in rainfalls can also strongly reduce the efficiency of the model calibration, and may be one of the main causes which weakens the relationship between the S parameter and the base flow preceding the flood.