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A Monte-Carlo Bayesian framework for urban rainfall error modelling

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Rainfall estimates of the highest possible accuracy and resolution are required for urban hydrological applications, given the small size and fast response which characterise urban catchments. While significant progress has been made in recent years towards meeting rainfall input requirements for urban hydrology –including increasing use of high spatial resolution radar rainfall estimates in combination with point rain gauge records– rainfall estimates will never be perfect and the true rainfall field is, by definition, unknown [1]. Quantifying the residual errors in rainfall estimates is crucial in order to understand their reliability, as well as the impact that their uncertainty may have in subsequent runoff estimates. The quantification of errors in rainfall estimates has been an active topic of research for decades. However, existing rainfall error models have several shortcomings, including the fact that they are limited to describing errors associated to a single data source (i.e. errors associated to rain gauge measurements or radar QPEs alone) and to a single representative error source (e.g. radar-rain gauge differences, spatial temporal resolution). Moreover, rainfall error models have been mostly developed for and tested at large scales. Studies at urban scales are mostly limited to analyses of propagation of errors in rain gauge records-only through urban drainage models and to tests of model sensitivity to uncertainty arising from unmeasured rainfall variability. Only few radar rainfall error models –originally developed for large scales– have been tested at urban scales [2] and have been shown to fail to well capture small-scale storm dynamics, including storm peaks, which are of utmost important for urban runoff simulations. In this work a Monte-Carlo Bayesian framework for rainfall error modelling at urban scales is introduced, which explicitly accounts for relevant errors (arising from insufficient accuracy and/or resolution) in multiple data sources (in this case radar and rain gauge estimates typically available at present), while at the same time enabling dynamic combination of these data sources (thus not only quantifying uncertainty, but also reducing it). This model generates an ensemble of merged rainfall estimates, which can then be used as input to urban drainage models in order to examine how uncertainties in rainfall estimates propagate to urban runoff estimates. The proposed model is tested using as case study a detailed rainfall and flow dataset, and a carefully verified urban drainage model of a small (∼9 km2) pilot catchment in North-East London. The model has shown to well characterise residual errors in rainfall data at urban scales (which remain after the merging), leading to improved runoff estimates. In fact, the majority of measured flow peaks are bounded within the uncertainty area produced by the runoff ensembles generated with the ensemble rainfall inputs.

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