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High-resolution ensemble rainfall forecasts in urban hydrological applications

Sara Liguori (1), Miguel Rico-Ramirez (1), Alma Schellart (2), and Adrian Saul (2)

(1) University of Bristol, Department of Civil Engineering, Bristol, BS8 1TR, UK, (2) Pennine Water Group, Department of Civil and Structural Engineering, University of Sheffield, Sheffield, S1 3JD, UK

The use of Quantitative Precipitation Forecasts (QPFs) enables to improve the real-time control of urban drainage systems by extending the time available to prevent critical situations such as flooding or sewer overflow [1-5]. Often, these are caused by rainfall events developing within a short period of time, and therefore, short term rainfall forecasts with lead time less than 3 hours are most important in urban hydrological applications [6]. As opposite to single deterministic rainfall forecasts, ensemble QPFs are a number of forecasts valid at the same time, which can be expressed in probabilistic terms, thus providing information about the probability of occurrence of a given event. This might result relevant to the prediction of critical conditions within the sewer system in urban hydrological applications, while also modelling the QPFs inherent uncertainty.

QPFs can be achieved by extrapolating the future rainfall distribution from a sequence of radar images (i.e. radar nowcasting). Weather radars provide high resolution spatially distributed data. Therefore, radar rainfall estimates are suitable to be used for urban hydrological applications, which require data with high spatial and temporal resolution. However, inherent uncertainty affects weather radar measurements, thus limiting the use of radar rainfall estimates in urban hydrology. Radar-based forecasts show a high initial accuracy, as they are based on the assimilation of the initial precipitation state as provided by the radar rainfall estimates. However, the accuracy rapidly decreases with lead time, as radar nowcasting techniques do not model processes such as growth and decay of precipitation [7]. At longer lead times, higher accuracy QPFs are produced by Numerical Weather Prediction (NWP) models, which solve the dynamics and physics of the atmosphere. The scale of the features the model is able to predict decreases as the resolution of the model increases, but is limited by the structure of the model itself, which is able to reproduce only meteorological features on scale in excess of five times the grid length of the model [8]. Hybrid systems aim at merging the advantages of radar nowcasting and NWP models. A system of this sort is the stochastic probabilistic precipitation forecasting scheme (STEPS) [9], developed by the UK Met Office in collaboration with the Australian Bureau of Meteorology. The STEPS model merges an extrapolation radar rainfall forecast with a high-resolution NWP rainfall forecast. Ensemble rainfall forecasts are generated through the stochastic realization of a noise term, which attempts to model the uncertainty in the evolution of the precipitation field, whilst the uncertainty in the motion field is modelled through a random component added to the advection field at each ensemble realization.

The STEPS model has been tested for the prediction of flows in the sewer system of a small urban area. Deterministic and ensemble rainfall forecasts with spatial and temporal resolutions of 2 km and 15 min respectively and 6 hr lead time were produced for some events occurred in 2007 and 2008 having different meteorological characteristics. The NWP forecasts were provided on this occasion by the MM5 model [10-12].
The rainfall forecasts assessment has focused on the comparison of deterministic and ensemble rainfall forecasts and the analysis of the dependency of the forecast accuracy on the rainfall intensity. The results show that both deterministic and ensemble rainfall forecasts skill decreases as the rainfall intensity increases and that the ensemble rainfall forecasts are more skilful than the deterministic ones in predicting low rainfall intensities. The analysis of the implementation of the STEPS ensemble forecasts as input to the Infoworks CS model of the sewer system of a small urban area shows potential for improvements in real-time flow simulations within the sewer system.

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