

Sensitivity of urban drainage models to the spatial-temporal resolution of rainfall inputs: A multi-storm, multi-catchment investigation

S. Ochoa-Rodriguez^{*1}, L.-P. Wang², A. Gires³, R. Reinoso Rondinel⁴, R. D. Pina¹, J. van Assel⁶, S. Kroll⁶, D. Murlà-Tuylls², G. Bruni⁵, A. Ichiba³, S. Gaitan⁵, E. Cristiano⁵, D. Schertzer³, I. Tchiguirinskaia³, C. Onof¹, P. Willems², J.A.E. ten Veldhuis⁵

1 Urban Water Research Group, Imperial College London, UK

2 Hydraulics Laboratory, KU Leuven, Belgium

3 Laboratoire Eau Environnement et Systèmes Urbains, École des Ponts ParisTech, France

4 Department of Geosciences & Remote Sensing, Delft University of Technology, the Netherlands

5 Department of Water Management, Delft University of Technology, the Netherlands

6 Aquafin NV, Belgium

*Corresponding author: s.ochoa-rodriguez@imperial.ac.uk

Abstract

Urban hydrological applications require high resolution precipitation and catchment information in order to well represent the spatial variability, fast runoff processes and short response times of urban catchments (Berne *et al.*, 2004). Although fast progress has been made over the last few decades in high resolution measurement of rainfall at urban scales, including increasing use of weather radars, recent studies suggest that the resolution of the currently available rainfall estimates (typically 1 x 1 km² in space and 5 min in time) may still be too coarse to meet the stringent requirements of urban hydrology (Gires *et al.*, 2012). What is more, current evidence is still insufficient to provide a concrete answer regarding the added value of higher resolution rainfall estimates and actual rainfall input resolution requirements for urban hydrological applications. With the aim of providing further evidence in this regard, a collaborative study was conducted which investigated the impact of rainfall input resolutions on the outputs of the operational urban drainage models of four urban catchments in the UK and Belgium (Figure 1).

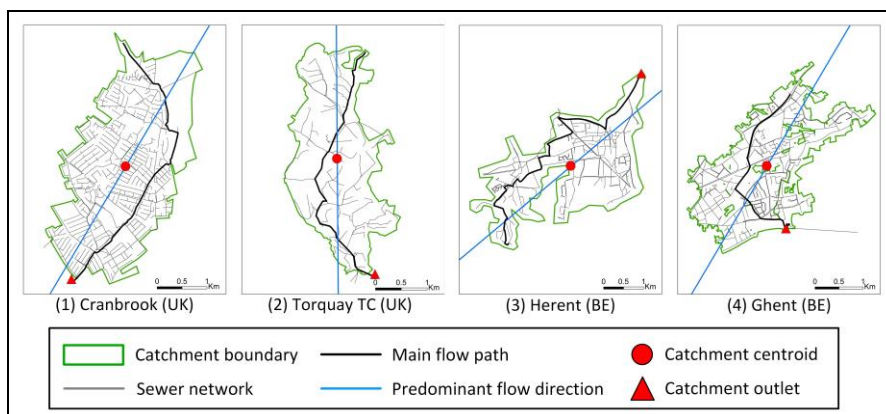


Figure 1: Boundary and sewer layout of the pilot urban catchments.

Nine storm events measured by a dual polarimetric X-band weather radar, located in the Cabauw Experimental Site for Atmospheric Research (CESAR) of the Netherlands, were selected for analysis. Based on the original radar estimates, at 100 m and 1 min resolutions, 15 different combinations of coarser spatial and temporal resolutions, up to 3000 m and 10 min, were generated. Coarser spatial resolutions were generated by averaging in space, whereas coarser temporal resolutions were generated through two different strategies: (1) by sampling radar images at the desired temporal resolution, thus replicating radar scanning strategies; (2) by averaging in time. The resulting rainfall estimates were applied as input to the operational semi-distributed

models of the urban catchments, all of which have similar size (between 5 and 8 km²), but different morphological, hydrological and hydraulic characteristics (Figure 1). When doing so, methodologies for standardising model outputs and making results comparable were implemented. Hydrodynamic response behaviour was summarised using dimensionless performance statistics and was analysed in the light of drainage area and critical spatial temporal resolutions computed for each of the storm events. The main features observed in the results are the following (Figure 2):

- The impact of rainfall input resolution decreases rapidly as catchment drainage area increases.
- In general, the coarsening of temporal resolution of rainfall inputs affects hydrodynamic model results more strongly than the coarsening of spatial resolution. This is particularly the case when coarser temporal resolution rainfall estimates are generated through sampling of radar images; however, in the case of averaging in time, temporal resolution still shows a dominant effect over spatial resolution.
- There is a strong interaction between the spatial and temporal resolution of rainfall input estimates and in order to avoid losing relevant information from the rainfall fields, the two resolutions must be in agreement with each other.
- For the storms, models and drainage areas under consideration, temporal resolutions below 5 min appear to be required for urban hydrological applications, whereas spatial resolutions of the order of 1 km appear to be sufficient.

Based on these results, initial models to quantify the impact of rainfall input resolution as a function of catchment size and spatial-temporal characteristics of storms are proposed and discussed.

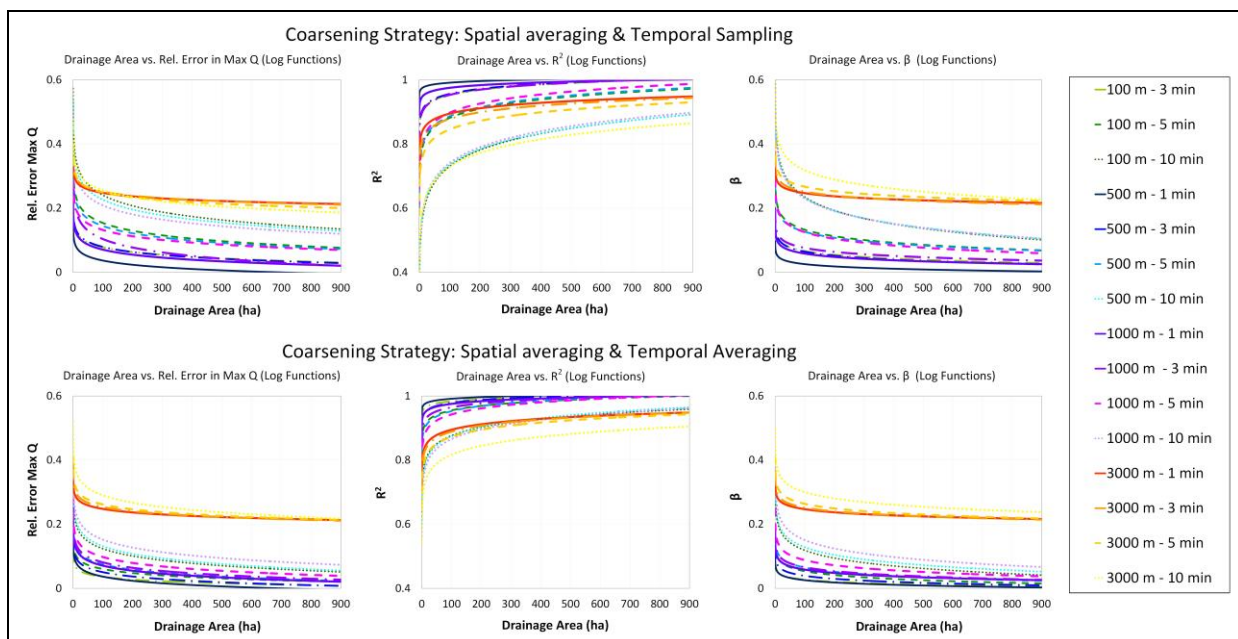


Figure 2: Logarithmic functions fitted to performance statistics of hydraulic outputs (relative error in maximum flow peak, coefficient of determination (R^2) and regression coefficient (β)) as a function of drainage area size, for different space-time resolution combinations.

Line type denotes different temporal resolutions (1 min = solid; 3 min = dash-dot; 5 min = dashed; 10 min = dotted) and colour range denotes different spatial resolutions (100 m = green; 500 m = blue; 1000 m = purple; 3000 m = orange).

References

- Berne, A., Delrieu, G., Creutin, J.-D. & Obled, C. (2004). Temporal and spatial resolution of rainfall measurements required for urban hydrology. *Journal of Hydrology*, **299**, 166-179.
- Gires, A., Onof, C., Maksimović, Č., Schertzer, D., Tchiguirinskaia, I. & Simoes, N. (2012). Quantifying the impact of small scale unmeasured rainfall variability on urban runoff through multifractal downscaling: A case study. *Journal of Hydrology*, **442**, 117-128.