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Multifractal analysis of the outputs of a fully distributed model for two case studies in urban hydrology

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Hydrological fields are known to exhibit extreme variability over wide range of spatio-temporal scales. In this paper, these features are investigated in the specific context of urban hydrology with the help of two case studies. The first one consists in a 144 ha flat urban area located in the Seine-Saint-Denis County (North-East of Paris, France), known for suffering occasional pluvial flooding. The second one is a 250 ha urban area with a significant portion of forest located on a steep hillside of the Bièvre River (Yvelines County, South-West of Paris, France). The catchments behaviour is modelled with the help of Multi-Hydro, a fully distributed physically based model (2D/1D) currently under development at Ecole des Ponts ParisTech. It consists of an interacting core between open source software packages, each of them representing a portion of the water cycle in urban environment. The rainfall data comes from the C-band radar of Trappes operated by Météo-France and located at respectively 45 Km and 13 Km of the studied catchments. The resolution is 1 km in space and 5 min in time. Three rainfall events that occurred in 2010 and 2011 that generated significant surface runoff and some local flooding are analysed.

First the uncertainty associated with small scale unmeasured rainfall variability (i.e. below the C-band radar resolution) is investigated. This is done through the analysis of the disparities among an ensemble of hydrological simulations performed with the help of downscaled rainfall fields. The downscaling implemented here simply consists in stochastically continuing the underlying Universal Multifractal cascade process observed on the available range of scales. This uncertainty is significant for both simulated conduit discharge and water depth, and therefore cannot be neglected, indicating the need to develop the use of X-band radars (which provide an hectometric resolution) in urban environment.

Second it appears that the outputs (maps of water depth and velocity, and discharge in conduits) of the hydrological model exhibit a scaling behaviour both in space and time. The Universal Multifractals are used to characterize this variability with the help of only 3 parameters which are furthermore compared with the one observed for rainfall. This hints at innovative techniques to quantify the extremes at very high resolution (typically 1 m) without having to run the model at these resolutions which would require to much time especially for real time applications.