Geophysical Research Abstracts
Vol. 12, EGU2010-2076, 2010
EGU General Assembly 2010

Representation of urbanized terrain and its use in quantifying hydrologic response with a morpho-climatic instantaneous unit hydrograph model

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Urbanization can affect landscapes in various ways that significantly affect their hydrologic behavior. In particular, imperviousness can increase runoff production, and pipes, streets, and artificial channels can modify the accumulation of flow. In stormwater models, large pipes and channels are commonly simulated with sophisticated hydraulic methods, but the subcatchments that feed these elements are usually modeled with hydrologic methods that neglect the presence of smaller pipes, streets, and artificial channels. Specifically, the subcatchment characteristics that are embedded in these hydrologic methods are often derived from digital elevation models (DEMs) that do not resolve such features. In this research, a new model called the U-McIUH (Urban Morpho-climatic Instantaneous Unit Hydrograph) is developed, which defines the IUH as the probability density function of the travel time from a random location in the urban terrain to the subcatchment outlet. Flow paths are extracted from a specially processed DEM that incorporates streets, pipes, and channels by reducing the elevation of the surface to match the known elevations of these elements. Each grid cell is then classified as a hillslope, street, pipe, or channel, and travel times are computed using the kinematic wave theory. The travel time expressions depend on the upstream contribution of flow and the excess rainfall intensity, so they incorporate the so-called climatic dependence (i.e. nonlinearity) of the IUH. Rainfall pulses are convoluted with their respective IUH and superimposed to generate the response to a given storm event. The application of the model to real catchments shows that the representation of urban terrain is better able to reproduce flow patterns than other available methods. In addition, the U-McIUH provides good reproduction of observed hydrographs. A detailed analysis of the model and results suggests that taking into account the nonlinearity of the catchment response is important and that artificial elements play a major role in determining the hydrologic response of urban watersheds.