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[Long-term memory loss of urban streams as a metric for catchment classification by *Dusan Jovanovic, Tijana Jovanovic, Alfonso Mejía, Jon Hathaway, and Edoardo Daly]*

Jovanovic et al (2017) present a case study for the use of Hurst exponent to evaluate the impacts of increasing urbanization on stream hydrological responses. This approach represents an alternative way to analyze the long-term correlation between rainfall and streamflow time series. Increasing urbanization (e.g., impervious area; engineered drainage networks) contributes to increasing "flashiness" of stream flow, with loss of landscape "buffering" through infiltration, ET losses, and slow recession. Previous studies (Yang et al. 2010) have shown that for impervious surface area (ISA) between 5-35%, a linear increase in frequency of high-flow events; beyond this range, urbanization impacts on stream hydrologic regime are expected to be nonlinear. In a hypothetical case of 100% impervious area and highly connected urban drainage infrastructure network, rainfall events are quickly translated to stream discharge, assuming minimal storage. Thus, time series of rainfall and discharge are highly correlated, especially for the larger events. Yang and Bowling (2014) examined changes in hydrologic system memory for sixteen basins with varying degrees of urbanization in the Great Lakes region. They concluded that decrease in long-term memory in simulated streamflow with increasing urbanization relates to a decreased low-frequency power and amplitude of soil–water storage. Kim et al [2015] used power spectral analyses for several urbanizing watersheds in South Korea, to show that slopes of power spectra for discharge time series converge to that of rainfall with increasing urbanization, a clear evidence for loss of “memory” or “landscape buffering”. In un-impacted streams, discharge time series is characterized as *$1/f^{\alpha}$* noise, with α ~1 (Godsey et al., 2015).

In the analyses Jovanovic et al (2017) presented here, Hurst exponent (*H*) approaches 0.5 for time-series of uncorrelated, independent, random variable; this is usually the case of rainfall aggregated at daily scale (white-noise signal) with *stationary patterns*. Larger H values are related to long-term correlation (memory, persistency), that are typical of discharge in non-urbanized streams. It is then expected that with increasing urbanization, *H* for urban stream flows would shift towards *H* for rainfall, as illustrated in Figures 1 and 2 of Jovanovic et al (2017) for urban watersheds with impervious area up to ~50%. It would be interesting to examine other urbanized watersheds with imperviousness are much larger than 50%, as was the case for Kim et al (2015). Figure 3 in Jovanovic et al (2017) reveals weak correlations between *H* value for stream discharge and catchment size, annual rainfall, and area-normalized mean discharge. Thus, the dominant control on dampening of rainfall time series – introducing “memory” -- is landscape storage and loss dynamics.

Hurst exponent for rainfall time series would allow comparisons between *H* values for natural, peri-urban and urban catchments. That is, does urbanization not only impact the stream flow but also rainfall patterns over the urbanized area, relative to the non-urbanized or peri-urban areas? Furthermore, non-stationarity of rainfall patterns (e.g., seasonality; or long-term shifts) will also result in $H \neq 0.5$. It is well known that urbanization modifies local atmospheric conditions enough to alter rainfall patterns and total amounts (Niyogi et al., 2017; Sheng et al., 20??). Thus, the rainfall *H* values might be different for the urban, peri-urban and rural areas.

Literature Cited

Godsey, S., Aas, W, Clair, T., deWit, H., Fernandez, I, Kahl, S., Malcolm, I., Neal, C., Neal, M., Nelson, S., Norton, S., Palucis, M., Skelkavale, B., Soulsby, C., Terzalff, D., and Kirschner, J. Generality of fractal *1/f* scaling in catchment tracer time series, and its implications for catchment travel time distributions. *Hydrol. Processes,* 24(12): 1660-1671.

Kim, D.H., Rao, P.S.C., Kim, D., and Park, J. 2015. 1/ f noise analyses of urbanization effects on streamflow characteristics, *Hydrol. Processes*, 30(11):1651-1664. DOI: 10.1002/hyp.10727.

Niyogi, D., Lei, M., Kishtawi, C., Schmid, P. 2017. Urbanization Impacts on the Summer Heavy Rainfall Climatology over the Eastern United States, *Earth Interactions*, June 2017, *https://doi.org/10.1175/EI-D-15-0045.1*

Sheng, C., Li, W., Du, Y, Mao, C., and Zhang, L. Urbanization effect on precipitation over the Pearl River Delta based on CMORPH data. *Advances in Climate Change Research,* 6(1): 16-22.

Yang, G., and L. C. Bowling, 2014. Detection of changes in hydrologic system memory associated with urbanization in the Great Lakes region, Water Resour. Res., 50, 3750–3763, doi:10.1002/2014WR015339.

Yang, G., Bowling, L.C., Cherkauer. K.A., Pijanowski, B.C., Niyogi, D. 2010. Hydroclimatic response of watersheds to urban intensity: An observational and modeling-based analysis for the White River Basin, Indiana. Jour. Hydrometeor. 11:122-138. DOI: 10.1175/2009JHM1143.1