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Are hydrologic systems complex, or just complicated, or maybe simpler than we thought?

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Hydrologic time series have provided some of the earliest and clearest examples of power-law magnitude-frequency relationships and spectral scaling in nature. The discovery that the spectra of passive tracers in streamflow exhibit 1/f scaling over three orders of magnitude would seem to confirm the view of catchments as complex dynamical systems. Nonetheless, at least some of these behaviors can be adequately explained by relatively simple, even prosaic, theories.

At face value, this is surprising. Catchment hydrology is controlled by processes and material properties that are known to be complicated, highly coupled, heterogeneous on all scales, and poorly characterized by direct measurement. This observation raises the question of how one can identify the appropriate constitutive equations that describe the large-scale behavior of these complex heterogeneous systems. Here I show that some small catchments can be usefully characterized as first-order nonlinear dynamical systems, and that one can infer their nonlinear governing equations at catchment scale, directly from field data. This approach assumes that discharge depends on the aggregate volume of water stored in the catchment, but makes no a priori assumption about the functional form of this storage-discharge relationship, instead estimating it from rainfall-runoff data.

This approach not only allows one to predict streamflow from measurements of rainfall, but also allows one to "do hydrology backwards": that is, to infer effective rainfall

and evapotranspiration at whole-catchment scale, directly from fluctuations in streamflow. This approach also directly explains the relationship between the power spectra of the incident precipitation and the resulting streamflow fluctuations. Thus it allows one to understand how catchments filter rainfall fluxes that are complex in space and time, yielding streamflow fluctuations that are predictable over wide ranges of time scales.