Geophysical Research Abstracts,
Vol. 11, EGU2009-6065, 2009
EGU General Assembly 2009

Catchments as simple dynamical systems, at different scales and in different climatic regimes

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Catchment hydrologic processes are complex and spatially heterogeneous, seeming to defy simple characterization and prediction. Nonetheless, it has recently been proposed that one class of catchments (those in which discharge depends primarily on the volume of water stored in the subsurface) can be usefully characterized as simple first-order nonlinear dynamical systems, and that their governing equations can be inferred directly from measurements of their streamflow fluctuations.

Here we test this approach at several small catchments, including Erlenbach, Vogelbach, and Rietholzbach in northeast Switzerland and Caspar Creek in coastal California. The inferred storage-discharge relationships for all of these catchments are steep and nonlinear, consistent with their flashy storm response. At Rietholzbach there is a 3.14 m^2 weighing lysimeter that can be analyzed as a micro-catchment in its own right, with a drainage area one million times smaller than the 3.18 km^2 Rietholzbach catchment itself. Furthermore, the storage-discharge relationship can be directly measured by weighing the lysimeter, and can be tested against with the storage-discharge relationship that is inferred from fluctuations in the lysimeter outflow using recession plots.

The dynamical systems approach allows one to use fluctuations in discharge to semi-quantitatively infer time series of rainfall, snowmelt, and evapotranspiration at landscape scale. Discharge time series from these catchments exhibit transient responses to rainfall inputs, as well as diurnal cycles that vary seasonally, reflecting evapotranspiration fluxes. The Caspar Creek catchments span nearly two orders of magnitude in drainage area and a wide range of climatic regimes, from rainy winters to dry summers with several months of negligible precipitation. Considered together, data from Caspar Creek and the Swiss catchments allow us to test the dynamical systems approach across a range of drainage areas and climatic regimes.