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Flow recession behavior of dendritic subsurface flow patterns

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Spring discharge curves can be seen as the fingerprint of an aquifer. In particular, the recession of flow after strong recharge events has been widely used for aquifer characterization. Several conceptual models for recession curve analysis were proposed. They either provide a mathematical fit to empirical relations or approximate a solution to the diffusion equation.

This study investigates the flow recession behavior of aquifers with preferential flow paths with a structure according to the concept of minimum energy dissipation.
Assuming a power-law relationship between hydraulic conductivity and porosity, the subsurface flow patterns used in our model are organized towards an optimal spatial distribution of these two parameters in a way that the total energy dissipation of the flow is minimized. This leads to two-dimensional dendritic network structures similar to river networks. Starting from a steady-state initial condition with a constant recharge rate we model the decrease of discharge over time, under the assumption of a linear storage behavior.

Our model produces recession curves that follow an exponential function at large time scales, which is a behavior often observed in nature and corresponds to many previous studies. The recession coefficient of this exponential decay shows a power law relation to the catchment size of each individual spring. This relation however is significantly less prevalent than for corresponding linear flow in 1 or 2D.
Projecting the exponential portion of flow over the complete recession time period shows that the majority of available water is drained in this baseflow component. The overall share ranges from 85-100% but is independent from spring catchment sizes.