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Dynamics of runoff under stochastic rainfall in river networks

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We solve the linearized stochastic stream-based conservation equations in an arbitrary watershed forced by a steady Poissonian precipitation field of instantaneous rainfall events. The model describes the evolution of an interconnected network of linear reservoirs under the effect of random forcing. The resulting stochastic process tracks the streamflow and runoff for every stream link and hillslope. We provide a characterization of the invariant distribution of the streamflow in terms of the geophysical parameters of the river network and the statistical properties of the precipitation field. The invariant distribution encapsulates many emergent properties of the hydrological system, in particular the transfer of uncertainty from the precipitation input to the discharge, as mediated by the connectivity properties of the river network. We derive, for example, novel formulas for the invariant moments of the streamflow at the watershed's outlet, as well as the asymptotic behavior of extreme discharge events in terms of the geophysical properties of the watershed.