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Environmental transport on self-similar networks: A dynamical approach

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The theory of self-similar drainage networks, based on the Horton-Strahler and Tokunaga branching statistics, commonly focuses on a static structure (topology) of a given network. At the same time, understanding the transport of environmental fluxes along a river network requires a setting that would reflect the carrier network dynamical properties; the latter might, in fact, change depending on the transport process of interest. This study introduces the concept of a time-oriented dynamic tree which describes a downstream flow—from the leaves to the root—along a given static tree. We show that under some natural assumptions: (i) transport on a self-similar static tree generates a self-similar dynamic tree; and (ii) the Horton-Strahler and Tokunaga parameters of a dynamic tree may significantly deviate from those of the original, static tree. We illustrate this approach using several real river networks. We also report an unexpected phase transition phenomenon in the network dynamics and attempt its interpretation. The new concepts and tools introduced herewith are explored with a view towards developing simple predictive models of river network transport.