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Envirodynamics on river networks: A minimal complexity framework for transport studies

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In this study we apply complex-network methods to the problems of environmental transport on river networks. Such problems involve the flux of water, sediment, pollutants and biota. We establish statistical properties of a flow along a directed branching network and suggest a compact representation for it. The downstream transport is treated as a particular case of nearest-neighbor hierarchical aggregation with respect to the metric induced by the branching structure of the river network.

Specifically, we describe the static geometric structure of a drainage network by a tree, referred to as the static tree, and introduce an associated dynamic tree that describes the transport along the static tree. It is well known that the static branching structure of river networks can be described by self-similar trees; we demonstrate that the corresponding dynamic trees are also self-similar, albeit with different values of the self-similarity parameters. Furthermore, we introduce and study a related object, which we call a dynamic network; this network reflects the actual physical mixing of fluxes that propagate along a static tree. Boolean delay equations (BDEs) are used to model the downstream transport along real and synthetic river networks. We report an unexpected phase transition in the environmental dynamics of real river basins, demonstrate the universal features of this transition, and seek to interpret it in hydrological terms.