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Perspective – Open problems in earth surface dynamics require innovative new methodologies from graph theory and non-linear analysis

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Are the dynamics of meandering rivers non-linear? What information does the shape of an oxbow lake carry about its forming process? How to characterize self-dissimilar landscapes carrying the signature of larger-scale geologic or tectonic controls? Do we have proper frameworks for quantifying the topology and dynamics of deltaic systems? What can the structural complexity of river networks (erosional and depositional) reveal about their vulnerability and response to change? Can the structure and dynamics of river networks reveal potential hotspots of geomorphic change?
All of the above problems are at the heart of understanding landscape evolution, relating process to structure and form, and developing methodologies for inferring how a system might respond to future changes. We argue that a new surge of rigorous methodologies is needed to address these problems. The innovations introduced herein are: (1) gradual wavelet reconstruction for depicting threshold nonlinearity (due to cutoffs) versus inherent nonlinearity (due to underlying dynamics) in river meandering, (2) graph theory for studying the topology and dynamics of deltaic river networks and their response to change, and (3) Lagrangian approaches combined with topology and non-linear dynamics for inferring sediment-driven hotspots of geomorphic change.