Shredding of Environmental Signals by Autogenic Transport Fluctuations

Jerolmack, Douglas [1]; Paola, Chris [2] (1) Earth and Environmental Science, University of Pennsylvania, Philadelphia, PA. (2) Saint Anthony Falls Laboratory, University of Minnesota, Minneapolis, MN.

Sediment transport is an intermittent process. Even under perfectly steady boundary conditions, sediment flux in systems as diverse as rivers and rice piles undergoes wild fluctuations as a result of the inherent nonlinear dynamics of transport. This variability confounds geologic interpretation and prediction: “mean” transport rates may be dominated by rare but extreme events such that short-term measurements are not directly comparable to longer-time integrated measurements; and autogenic erosion and deposition events may be mistaken for changes in climate and tectonics where their temporal and spatial scales overlap. We hypothesize that the presence of a strong process threshold, and a high degree of internal friction (or “stickiness”), are sufficient conditions to generate intermittent sediment transport behavior. We present experimental data showing similarities in transport fluctuations from three very different systems: gravel bed load transport in a large flume, avalanching in a table-top pile of rice, and shoreline fluctuations in an experimental river delta. Numerical models reproduce these fluctuations, and are used to explore both their origin and also their influence on environmental perturbations. We impose an environmental perturbation on our model systems in the form of cyclically-varying sediment supply. Physical and numerical experiments demonstrate that these external signals are destroyed when their time and magnitude scales fall within the range of autogenic fluctuations. Thus, sediment transport can act as a noisy, nonlinear filter that “shreds” signals of environmental forcing so that they are not merely masked but entirely lost. Results suggest that the nonlinear dynamics of sediment transport sets a hard lower limit on our ability to resolve environmental forcing in sedimentary systems. We suggest that Earth's sedimentary archives could be dominated by transport “noise” on time scales up to ~10 kyr. This time scale range overlaps in particular with known climatic time scales, meaning that in many systems the physical signature of these signals may be lost. The ubiquity of autogenic sediment storage and release in river systems, however, suggests a new interpretation for common stacking patterns of stratigraphic sequences.