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Key physical ingredients affecting the critical-zone reactor on a slope

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Recent theoretical advances together with field measurements suggest that coupled biogeochemical and physical soil-transport processes on hillslopes yield predictable, systematic downslope variations in catena features manifest in both topography and soil constituents. A key result of this work is that local soil conditions on a hillslope reflect effects inherited from the transport of soil materials from upslope sites, and from variations in downslope boundary conditions (e.g. channel incision) that propagate upslope. In addition, climate directly enters this problem via it influence on hydrological and biological conditions, which in turn influence the biomechanical processes that are responsible in many places for downslope transport and mixing of soil material, as well as soil production, in concert with geochemical processes. Within this context, a key ingredient of models describing coupled soil-hillslope evolution at the catena scale is the diffusion-like coefficient appearing in both linear and nonlinear transport formulae. This coefficient represents the depth-integrated 'rate constant' of transport and mixing, and is the one parameter in this class of models that is most closely related (albeit indirectly) to climate. A formulation of soil particle motions as a stochastic process indicates that the ingredients of this coefficient include the active soil thickness, the vertical porosity structure, and the frequency of particle activation due to biomechanical disturbances as a function of depth. This suggests that transport and mixing of soil material in sloping critical-zone reactors are tuned to the characteristic timescales of the biological communities inhabiting them.