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Critical zone evolution and the origins of organised complexity in watersheds

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The capacity of the landscape to store and transmit water is the result of a historical trajectory of landscape, soil and vegetation development, much of which is driven by hydrology itself. Progress in geomorphology and pedology has produced models of surface and sub-surface evolution in soil-mantled uplands. These dissected, denuding modeled landscapes are emblematic of the kinds of dissipative self-organized flow structures whose hydrologic organization may also be understood by low-dimensional hydrologic models. They offer an exciting starting-point for examining the mapping between the long-term controls on landscape evolution and the high-frequency hydrologic dynamics. Here we build on recent theoretical developments in geomorphology and pedology to try to understand how the relative rates of erosion, sediment transport and soil development in a landscape determine catchment storage capacity and the relative dominance of runoff process, flow pathways and storage-discharge relationships. We do so by using a combination of landscape evolution models, hydrologic process models and data from a variety of sources, including the University of Arizona Critical Zone Observatory. A challenge to linking the landscape evolution and hydrologic model representations is the vast differences in the timescales implicit in the process representations. Furthermore the vast array of processes involved makes parameterization of such models an enormous challenge. The best data-constrained geomorphic transport and soil development laws only represent hydrologic processes implicitly, through the transport and weathering rate parameters. In this work we propose to avoid this problem by identifying the relationship between the landscape and soil evolution parameters and macroscopic climate and geological controls. These macroscopic controls (such as the aridity index) have two roles: 1) they express the water and energy constraints on the long-term evolution of the landscape system, and 2) they bound the range of plausible short-term hydroclimatic regimes that may drive a particular landscape's hydrologic dynamics. To ensure that the hydrologic dynamics implicit in the evolutionary parameters are compatible with the dynamics observed in the hydrologic modeling, a set of consistency checks based on flow process dominance are developed.