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The interactions between evolving soils and landforms, and the importance of relative response times

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The interactions between evolving soils and landforms are a question of relative response times. If soils respond/evolve quickly relative to the changing landforms then they will equilibrate quickly to the landform at any given time (e.g. soil catena). If soils respond slowly relative to landforms then landforms will evolve as if the soils do not change with time (e.g. evolving landforms stripping the soils in badlands). Only if the response times of soils are comparable to the response times of the landform will the deterministic details of the time-varying soils be important for the evolution of the landforms, and vice versa, leading to co-evolution. Thus to understand the evolution regime that landscapes reside in we need methods to estimate response times of both soils and landforms. The response times of soils can be determined in the field with dating methods (giving residence times which are related to response times) or by the use of pedogenesis models (such as our SSSPAM model). Landforms have been more difficult. As a first step this paper shows that a single landform has a spectrum of response times and the response time is a function of the location within the landform. This will be shown using a simple analytic model of landform response times that has been validated against a landform evolution model. The analytic model shows that response time (1) varies within the catchment (thus generating a spectrum of response times), (2) the spatial distribution of the response rate (relative to the spatial mean) is easily predicted based on catchment elevation, (3) is a function of whether climate or tectonics is the time-varying exogenic input, and (4) is independent of whether erosion is transport- or detachment-limited and is a function only of the erosion rate (for catchments at or near the dynamic equilibrium with the mean of the exogenic input). A simple example of a hillslope with time-varying soils evolution (using a calibrated pedogenesis model) will be shown. This example will demonstrate how this analytic model can be used in both modelling and field studies to simplify the interpretation and modelling of the combined evolution of soils and landforms.