Geophysical Research Abstracts
Vol. 14, EGU2012-10599-1, 2012
EGU General Assembly 2012

Hysteresis in transient landscape topography recorded by hillslopes.

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On hillslopes considered to be at steady-state, hillslope morphology reflects the rate of denudation and the processes transporting sediment. Roering et al. [2007] expanded the commonly implemented non-linear sediment transport law to predict steady-state hillslope morphology as a function of erosion rate in a non-dimensional framework. This framework allows dimensionless erosion rate and relief to be predicted on the basis of topographic parameters readily predicted from high resolution digital elevation models (LiDAR). Here we extract hilltop curvature (Laplacian), hillslope gradients and hillslope lengths throughout a landscape with a well constrained uplift field in order to search for deviation in hillslope morphology when the steady-state assumption is violated. The Dragon's Back Pressure Ridge, immediately adjacent to the San Andreas Fault (SAF), is a series of south-west trending valleys, approximately perpendicular to SAF, generated as dextral fault motion carries the Pacific plate of a 'knuckle' of uplift which is pinned to the North American plate [Hilley and Arrowsmith, 2008]. As such the topography has been generated by passing through the zone of uplift and subsequently relaxing as it comes out the other side. This facilitates a space-for-time substitution and allows extraction of a time series of hillslope evolution in response to active uplift and erosion and subsequent landscape relaxation during tectonic quiescence over a period of 130 ka. We find that the morphological response of hillslopes to increased surface uplift is markedly different from the response to cessation of uplift. During increased uplift, hillslopes steepen, and hilltops get sharper. This morphological response is near instantaneous, implying that the response time scale for hillslopes to increased valley incision is extremely rapid. Subsequent drainage reorganisation occurs as uplift continues so that hillslopes tend to get longer with time spent in the uplift zone; possibly due to increased landslide frequency escalating the efficiency of hillslope sediment transport relative to valley erosion. During relaxation hilltop curvature and hillslope gradient decline gradually over 50 ka, implying that response time is much longer when a hillslope is responding to a reduction in surface uplift. Non-dimensional analysis reveals that hillslope morphology is markedly different for similar erosion rates depending on whether the landscape is being rejuvenated or relaxing. Hence our ability to interpret rates of tectonic processes based on topography alone may require a priori interpretation of the history tectonic conditions.