Geophysical Research Abstracts, Vol. 8, 02309, 2006
SRef-ID: 1607-7962/gra/EGU06-A-02309

Channel sinuosity: another angle on steady state and transient response in bedrock rivers draining active mountain belts

J.D. Jansen, A.T. Codilean, P. Bishop, T.B. Hoey, C. Persano

Earth Surface Dynamics Research Group, Department of Geographical & Earth Sciences, University of Glasgow, Scotland (jjansen@ges.gla.ac.uk)

We explore the potential of bedrock channel sinuosity for providing insights to fluvial adjustment in bedrock rivers draining the Sierra Nevada, a 3.5 km high tectonically-active mountain belt in southern Spain. Akin to other active orogens, the Sierra exhibits pronounced topographic asymmetry—a concave N-flank is coupled with a convex S-flank. Based on analyses of river profile steepness and concavity indices, we infer that smoothly-concave N-flank river profiles indicate that rates of erosion match rock uplift, whereas perturbed, irregular S-flank profiles indicate transient response as rates of rock uplift outpace erosion.

Channel sinuosity (P) is calculated as the ratio L_c/L, where L_c is channel length and L is straight-line valley length over a chosen distance. As with alluvial channels, bedrock channel sinuosity is a function of river discharge, channel gradient, sediment flux, and substrate erodibility, and rivers remain straight if little or no lateral erosion is possible. We interpret the development of bedrock channel sinuosity to indicate high lateral (bank) erosion relative to bed (vertical) incision, and that increasing sinuosity is a key mechanism by which rivers widen their valleys either downstream or over time. For example, increasing rock uplift promotes high bed incision potential leading to deep, narrow and straight channels; whereas, declining incision rate (usually coupled with reduced bedload flux and channel alluviation) favours bank erosion and increased sinuosity. We postulate that channel sinuosity is a mechanism for dissipating energy in excess of that required to transport sediment supplied from upstream. Conversely, by decreasing sinuosity (i.e. increasing gradient and therefore bed shear stress) bedrock rivers optimise erosional efficiency in response to either increasing rock uplift rate or more resistant rocks, and that low sinuosity prevails while rivers 'prioritise' vertical incision and little excess energy is available for lateral erosion. As steady state is approached, this priority is relaxed and excess energy becomes available for lateral erosion via increased sinuosity. It is likely that this process begins downstream, where excess energy will first arise, progressing upstream in the absence of further perturbations.

In all parts of the Sierra Nevada, steep low-order channels exhibit low sinuosity. However, downstream of a critical drainage area, where gradient varies as an inverse power function of drainage area, channel sinuosity in several streams increases to a maximum near the rangefront outlet. This tendency is particularly well developed in some N-flank rivers, where a steady state balance between rates of erosion and rock uplift is inferred. Elsewhere, sinuosity is not a simple function of drainage area; discontinuities reflect lateral sediment inputs, resistant rocks, or propagating knickpoints triggered by base level fall.

In light of our results, we propose a new empirical index for describing bedrock river morphology: the sinuosity index (ς) derived from regression analysis of channel sinuosity (P) and drainage area (A), and defined by $(P–1) = kA^{\varsigma}$, where k is a constant, and ς represents the rate of change in channel sinuosity with increasing drainage area to the catchment outlet. In addition to river profile analyses, bedrock channel sinuosity may provide useful insights to fluvial adjustment following perturbation and the extent of steady state conditions in river networks.