Geophysical Research Abstracts, Vol. 9, 05001, 2007
SRef-ID: 1607-7962/gra/EGU2007-A-05001

Modelling fluvial incision and transient landscape evolution: reconciling theory and field observations

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Fluvial incision has been recognized as one of the primary processes that control landscape evolution in non-glaciated areas. Numerous fluvial incision laws have been proposed recently, which assign different roles to the sediments transported by the river. Whereas they all predict a quasi-power relationship between slope and drainage area when erosion is steady and uniform, they predict different types of transient behaviour when landscape is responding to a disturbance (tectonic or climatic). It has then been suggested that fluvial incision laws can be tested and calibrated by comparing their predictions with the transient response of natural systems which can be characterized in the field, where good constraints exist on the nature and amplitude of the disturbance. However, in order to predict realistically the transient response of the fluvial system, it is also crucial to capture correctly the dynamics of channel geometry adjustment (Whittaker et al., Geology, v. 35, no. 2, 2007). We use the Channel-Hillslope Integrated Landscape Development (CHILD) model to compare the transient response of a landscape to a tectonic disturbance using (1) the commonly assumed relationship which stipulates that the channel width scales with the square-root of the drainage area (W=k*Aˆ0.5), and (2) relationships that allow a channel's width to dynamically adjust to new boundary conditions (e.g. Finnegan et al., Geology, v. 33, no. 3, 2005). We demonstrate how using the commonly assumed hydraulic scaling relationship alters the predicted transient response in terms of river profile, landscape morphology and response time. For example, because the relationship W=k*Aˆ0.5 does not allow a channel to narrow following an increase in slope associated with an increase in uplift rate, it overestimates the new slopes necessary to produce erosion rate matching the

new uplift rate. It also largely underestimates the response time of the landscape and produces morphologies distinct from the ones predicted using a channel width which dynamically adjusts. In an area experiencing active normal faulting and fault linkage, the relationship W˜Aˆ0.5 does not allow the development of antecedent rivers, with implications in terms of predicting through time sediment routing from the range to the adjacent basins (Cowie at al., Basin Research, vol. 18, no. 3, 2006). This study emphasizes the need to integrate into models the changes in channel geometry which characterize transient state, in order to predict realistically how a landscape would evolve following any kind of disturbance - tectonic or climatic.