Geophysical Research Abstracts
Vol. 19, EGU2017-9178, 2017
EGU General Assembly 2017

Hydrodynamic controls on the long-term construction of large river floodplains and alluvial ridges

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Floodplain construction involves the interplay between channel belt sedimentation and avulsion, overbank deposition of fines, and sediment reworking by channel migration. Each of these processes is controlled, in part, by within-channel and/or overbank hydraulics. However, while spatially-distributed hydrodynamic models are used routinely to simulate floodplain inundation and overbank sedimentation during individual floods, most existing models of long-term floodplain construction and alluvial architecture do not account for flood hydraulics explicitly. Instead, floodplain sedimentation is typically modelled as an exponential function of distance from the river, and avulsion thresholds are defined using topographic indices that quantify alluvial ridge morphology (e.g., lateral:downstream slope ratios or metrics of channel belt super-elevation). Herein, we apply a hydraulically driven model of floodplain evolution, in order to quantify the controls on alluvial ridge construction and avulsion likelihood in large lowland rivers. We combine a simple model of meander migration and cutoff with a 2D grid-based model of flood hydrodynamics and overbank sedimentation. The latter involves a finite volume solution of the shallow water equations and an advection-diffusion model for suspended sediment transport. The model is used to carry out a series of numerical experiments to investigate floodplain construction for a range of flood regimes and sediment supply scenarios, and results are compared to field data from the Rio Beni system, northern Bolivia. Model results, supported by field data, illustrate that floodplain sedimentation is characterised by a high degree of intermittency that is driven by autogenic mechanisms (i.e. even in the absence of temporal variations in flood magnitude and sediment supply). Intermittency in overbank deposits occurs over a range of temporal and spatial scales, and is associated with the interaction between channel migration dynamics and crevasse splay formation. Moreover, alluvial ridge construction, by splay deposition, is controlled by the balance between in-channel and overbank sedimentation rates, and by ridge reworking linked to channel migration. The resulting relationship between sedimentation rates, ridge morphology and avulsion likelihood is more complex than that which is incorporated with existing models of long-term floodplain construction that neglect flood hydraulics. These results have implications for the interpretation of floodplain deposits as records of past flood regimes, and for the controls on the alluvial architecture of large river floodplains.