Geophysical Research Abstracts
Vol. 14, EGU2012-5989, 2012
EGU General Assembly 2012

Numerical simulation of morphodynamic diversity in the World's largest rivers

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The World's largest rivers share many common properties, including gentle longitudinal bed gradients ($\sim$ 0.01-0.1 m per km), high mean annual discharges ($\sim$ >10,000 cumecs), and sand-sized bed sediment (D50 $\sim$ 0.1-0.4 mm), yet despite these similarities they are characterised by diverse planform patterns and morphodynamic behaviour (including meandering, braided and anabranching river styles). Recent studies have shown that this diversity cannot be explained using existing channel pattern classification schemes that apply to small rivers. Indeed at present, the causes of morphodynamic diversity in the World's largest rivers remain unclear. Moreover, elucidation of process-form interactions in large rivers is hampered by logistical difficulties involved in field data collection, and by the time period over which satellite imagery is available, which is short given the slow rates of channel change in many large rivers. Numerical models provide a further possible approach for investigating large river morphodynamics. However, although many such models exist, they have generally been developed or applied to simulate either meandering or braided rivers, rather than to investigate a range of channel styles. This paper aims to address this shortcoming using a new numerical simulation model, which is applied to explore the controls on morphodynamic diversity in large sand-bed rivers. This model is based on the 2D shallow water equations with secondary circulation correction, with model components representing total sand transport, suspended transport of silt and clay, bank erosion, vegetation growth and floodplain development. Numerical simulations representing time periods of c. 200 years illustrate how a wide range of channel morphologies, including meandering, braided and anabranching channels, may develop from the same initial conditions and external forcing (valley gradient and discharge regime). These results shed light on the process controls on morphodynamic diversity in the World's largest rivers and provide a possible explanation for the failure of channel pattern classification schemes when applied to such rivers.