Geophysical Research Abstracts
Vol. 15, EGU2013-11621, 2013
EGU General Assembly 2013

Estimating sediment storage volume and residence time for the Himalayas using a morphometric approach

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Any assessment of sediment routing through mountain belts and their forelands remains incomplete without estimates of intermediate storage that decisively links erosion rates to sediment yields. Sediment storage can have a profound influence on mass balance studies through attenuating water and sediment flows; decoupling hillslopes from river-channel processes; protecting underlying bedrock from incision; and sequestering biogeochemical constituents. Sediment storage also provides intermontane sedimentary archives of environmental change and offers flat ground for settlements and land use. For the Indus and Ganges-Brahmaputra river systems, modern sediment fluxes delivered to the large submarine depocentres of Indus and Bengal fan have been determined, and the role of the floodplains as buffers in this system has been highlighted. However, the spatial distribution, the volumetric amount and the residence times of sediments within the Himalayan orogen, remain largely unclear. Here we quantify for the first time the sediment stored in >38,000 Himalayan mainly postglacial valley fills, based on unsupervised extraction and geometric scaling of digital topographic data. We find distinct differences between the Western, Eastern, and Central Himalayas. While most of the total volume of at least $\sim$600 $\pm$ 200 km^3 focuses around the Himalayan syntaxes, where erosion rates are high, and glacially scoured valley trains provide accommodation space for numerous large valley fills (>1 km^3), the Central Himalaya only features very few large valley fills. We compare the distribution of valley fills along the Himalayan arc to different influencing factors, i.e. precipitation pattern, distribution of glaciers, mean local relief, tectonic structures, and long-wavelength topographic gradient. We find that the step-like long-wave topography in the central Himalaya limits glacier extent, and thus any significant sediment storage. Our morphometrically based estimates of volume and residence time are in good agreement with published data from individual catchments, as well as new data we present here from the NW Himalayas. The estimated volume stored in Himalayan valley fills could potentially feed contemporary denudation rates for >10^3 yrs, and underlines the potential for residence times of eroded material of up to 10^5 yrs at the mountain-belt scale.