Geophysical Research Abstracts
Vol. 13, EGU2011-4401, 2011
EGU General Assembly 2011

Climatic forcing of erosion rates in space and time – examples from the central Andes and Himalaya

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The windward flanks of the central Andes and the Himalaya are characterized by steep climatic and tectonic gradients. Here, orographic rainfall causes some of the wettest places on Earth that are closely linked with intensified surface processes and high erosion rates. However, the higher-elevation flanks of both orogens become progressively drier, until arid conditions are attained in orogen interiors (i.e. the Tibetan and Altiplano-Puna plateaus). Some of the world's largest rivers with high sediment loads emerge from these mountain belts, and understanding the relation between climate and erosion is key in predicting mass fluxes, assessing the effects of climate variability and long-term climate forcing of erosion on landscape evolution. In this study, we analyze the effect of climatic gradients on erosion rates through new, cosmogenic nuclide basin-wide erosion rates from the central Andes (n=40) and the western Himalaya (n=30).

We make three key observations that underscore the importance of climatic parameters on the voracity of surface processes in space and time. (1) First-order spatial erosion patterns can be explained by a simple specific stream power (SSP) approach. Importantly, we explicitly account for discharge by routing high-resolution, satellite-derived rainfall downstream. This is important as the steep climatic gradient of both orogens results in a highly nonlinear (and non-power law) relation between drainage area and discharge, one of the key assumptions for deriving energy expenditure in fluvial systems. This simple, but robust approach allows us to compare similarly steep catchments from wet, frontal with dry, internal parts of the orogens. (2) The derived relation between SSP and basin-wide erosion rates indicates that erosion (E) scales with $E \sim SSP^2$ on cosmogenic-nuclide timescales. (3) The use of late Pleistocene and Holocene sedimentary archives (lacustrine sediments related to landslide damming of river valleys) from both regions furnishes valuable information on the temporal variation of erosion rates. These records reveal that arid, but steep landscapes with low present-day and millennial-scale erosion rates may have increased sediment flux by an order of magnitude during wetter periods. Overall, these findings underscore (1) the fundamental importance of climate-driven processes in the long-term landscape evolution of tectonically active mountain belts; (2) the importance of climatic forcing on sediment production, mass transfer, and permanent vs. transient sediment storage in orogens; and (3) the importance of climate variability in intensifying erosion and sediment-flux rates on millennial time scales.