Geophysical Research Abstracts
Vol. 19, EGU2017-15464, 2017
EGU General Assembly 2017

Geomorphic effectiveness of long profile shape and role of inherent geological controls, Ganga River Basin, India

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River long profile is one of the fundamental geomorphic parameters which provides a platform to study interaction of geological and geomorphic processes at different time scales. Long profile shape is governed by geological processes at 10ˆ5 – 10ˆ6 years' time scale and it controls the modern day (10ˆ0 – 10ˆ1 years' time scale) fluvial processes by controlling the spatial variability of channel slope. Identification of an appropriate model for river long profile may provide a tool to analyse the quantitative relationship between basin geology, profile shape and its geomorphic effectiveness. A systematic analysis of long profiles has been carried for the Himalayan tributaries of the Ganga River basin. Long profile shape and stream power distribution pattern is derived using SRTM DEM data (90 m spatial resolution). Peak discharge data from 34 stations is used for hydrological analysis. Lithological variability and major thrusts are marked along the river long profile. The best fit of long profile is analysed for power, logarithmic and exponential function. Second order exponential function provides the best representation of long profiles. The second order exponential equation is Z = K1*exp(-β1*L) + K2*exp(-β2*L), where Z is elevation of channel long profile, L is the length, K and β are coefficients of the exponential function. K1 and K2 are the proportion of elevation change of the long profile represented by β1 (fast) and β2 (slow) decay coefficients of the river long profile. Different values of coefficients express the variability in long profile shapes and is related with the litho-tectonic variability of the study area. Channel slope of long profile is estimated taking the derivative of exponential function. Stream power distribution pattern along long profile is estimated by superimposing the discharge and long profile slope.

Sensitivity analysis of stream power distribution with decay coefficients of the second order exponential equation is evaluated for a range of coefficient values. Our analysis suggests that the amplitude of stream power peak value is dependent on K1, the proportion of elevation change coming under the fast decay exponent and the location of stream power peak is dependent of the long profile decay coefficient (β1). Different long profile shapes owing to litho-tectonic variability across the Himalayas are responsible for spatial variability of stream power distribution pattern. Most of the stream power peaks lie in the Higher Himalaya. In general, eastern rivers have higher stream power in hinterland area and low stream power in the alluvial plains. This is responsible for, 1) higher erosion rate and sediment supply in hinterland of eastern rivers, 2) the incised and stable nature of channels in the western alluvial plains and 3) aggrading channels with dynamic nature in the eastern alluvial plains. Our study shows that the spatial variability of litho-units defines the coefficients of long profile function which in turn controls the position and magnitude of stream power maxima and hence the geomorphic variability in a fluvial system.