Geophysical Research Abstracts
Vol. 15, EGU2013-5517, 2013
EGU General Assembly 2013

Erosional response of active mountain belts to Milankovitch-cycle climate forcing : time lag and amplification

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We investigated the erosional response of a steady-state mountain belt (i.e. that has reached a balance between tectonic uplift and erosion) to variations in rainfall intensity using a simple stream-power law to represent river bedrock incision. In the stream power law, the erosion rate is assumed to be proportional to slope (to the power n) and discharge (to the power m) We show that, when precipitation is forced to vary periodically, the erosional response is offset by a time lag that depends on the period of the climate forcing and the value of both exponents (n and m). Furthermore, for large values of these exponents, variations in sedimentary flux are amplified with respect to the imposed climate variations, explaining why even small periodic variations in precipitation rate can lead to a large and thus observable signal in the sedimentary record. To support our findings we used geochemical observations from site ODP-758 in the Indian Ocean that show a clear offset between a record of climate variability at the Milankovitch periods (23, 41 and 100 ky) derived from Oxygen isotope measurements and the erosional response from the nearby Himalayan orogen measured by Nd seawater isotopic composition. Using this dataset, we were able to constrain the values of the exponents n and m that best reproduce the observed time lags as a function of the forcing period, and, from them, we estimated the amplification factor, which can be as high as 3 to 4. This finding may explain why small amplitude variations in climate (precipitation) can lead to substantial and thus measurable variations in sedimentary flux out of large-scale orogens such as the Himalayan system.