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Sediment transport dynamics in the Central Himalaya: assessing during monsoon the erosion processes signature in the daily suspended load of the Narayani river

Guillaume Morin (1), Jérôme Lavé (1), Christian France Lanord (1), and Ananta Prassad Gajurel (2)

(1) CRPG-CNRS, Vandoeuvre les Nancy, France (jlave@crpg.cnrs-nancy.fr), (2) Department of Geology, Tribhuvan University, Kathmandu, Nepal (apgajurel@gmail.com)

The evolution of mountainous landscapes is the result of competition between tectonic and erosional processes. In response to the creation of topography by tectonics, fluvial, glacial, and hillslope denudation processes erode topography, leading to rock exhumation and sediment redistribution. When trying to better document the links between climate, tectonic, or lithologic controls in mountain range evolution, a detailed understanding of the influence of each erosion process in a given environment is fundamental. At the scale of a whole mountain range, a systematic survey and monitoring of all the geomorphologic processes at work can rapidly become difficult. An alternative approach can be provided by studying the characteristics and temporal evolution of the sediments exported out of the range. In central Himalaya, the Narayani watershed presents contrasted lithologic, geochemical or isotopic signatures of the outcropping rocks as well as of the erosional processes: this particular setting allows conducting such type of approach by partly untangling the myopic vision of the spatial integration at the watershed scale. Based on the acquisition and analysis of a new dataset on the daily suspended load concentration and geochemical characteristics at the mountain outlet of one of the largest Himalayan rivers (drainage area = 30000 km2) bring several important results on Himalayan erosion, and on climatic and process controls.

1. Based on discrete depth sampling and on daily surface sampling of suspended load associated to flow characterization through ADCP measurements, we were first able to integrate sediment flux across a river cross-section and over time. We estimate for 2010 year an equivalent erosion rate of 1.8 $+0.35/-0.2$ mm/yr, and over the last 15 years, using past sediment load records from the DHM of Nepal, an equivalent erosion rate of 1.6 $+0.3/-0.2$ mm/yr. These rates are also in close agreement with the longer term ($\sim$500 yrs) denudation rates of 1.7 mm/yr obtained from cosmonuclides in Narayani river sands (Lupker et al. 2012). Such stability of the erosion rates suggests that either buffering behaviour of this large watershed or broad spatial integration dampen the variability in monsoon strength or the sporadic nature of extreme mass-wasting events.

2. Paradoxically, the relatively high variability of the daily geochemical signature in suspended load and the apparent absence of delay between high rainfall episodes and sediment export suggest very short transfer time for silt and medium sand load, despite fluvial transfer distance of hundreds of kilometres between the sediment sources and the mountain outlet. This implies the absence of a buffering behaviour of the fluvial network and a very reactive fluvial system, which would be strongly supply limited relative to the fine sediment fraction.

3. By analysing sediments fluxes and using geochemical compositions in deltaD, carbonates content and TOC, which we propose as possible tracers for glacier- and soil-derived material, we show that glacier and soil erosion contribute to annual erosion budget to less than 10% and a few % respectively. Their imprints in Narayani sediment is only visible during the pre- and early monsoon before being overwhelmed by landslide-derived material during the monsoon.

4. Hillslope erosion by landslides appears therefore as the dominant erosional process in central Himalaya, and by comparing the sediment export history to a rainfall/runoff model, we confirm Gabet et al.'s (2004) inference that sediment export and possibly landslide triggering on Himalayan hillslopes are controlled both by pore pressure (depending on cumulated precipitation) and daily rainfall intensity.