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Bedrock river erosion measurements and modelling along a river of the Frontal Himalaya

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River incision is a key process in mountains denudation and therefore in landscape evolution models. Despite its importance, most incision models for mountain rivers rely on simplified, or quite empirical relations, and generally only consider annual average values for water discharge and sediment flux. In contrast, very few studies consider mechanistic models at the timescale of a flood, and try to bridge the gap between experimental or theoretical approaches and long term river incision studies.

In this contribution, we present observations made during 7 monsoon seasons on fluvial bedrock erosion along the Bakeya river across the Frontal Himalaya in Central Nepal. Along its lower gorge, this river incises alternation of indurated sandstone and less resistant claystone, at Holocene rates larger than 10mm/yr. More importantly, its upper drainage mostly drains through non-cohesive conglomerate which allows, in this specific setting, estimating the bedload characteristics and instantaneous fluxes, i.e. a pre-requisite to test mechanistic models of fluvial erosion. During the study period, we monitored and documented the channel bank erosion in order to understand the amplitude of the erosion processes, their occurrence in relation with hydrology, in order to test time-integrated models of erosion. Besides hydrologic monitoring, erosion measurements were threefold: (1) at the scale of the whole monsoon, plucking and block removal by repeated photo surveys of a 400m long channel reach, (2) detailed microtopographic surveys of channel bedrock elevation along a few sandstone bars to document their abrasion, (3) real time measurement of fluvial bedrock wear to document erosion timing using a new erosion sensor.

Results indicate that:

1. Erosion is highly dependent on rock resistance, but on average block detachment and removal is a more efficient process than bedrock attrition, and operates at a rate that permit channel banks downcutting to keep pace with Holocene uplift rate.

2. Both block detachment and attrition processes clearly increase with fluvial shear stress, but non-linearly, in particular through the existence of a minimum threshold. As a result of which bank erosion occur during only a few hours per year during short and very high flood events, which questions the use of average discharge (or drainage area) in many bedrock erosion models.

We then propose a semi-physical model of sandstone bars abrasion based on discharge history (HEC-RAS modelling), Rouse suspension model, and experimental measurements on dependency of abrasion rate vs impacting particle size. This model predicts well the timing and the amplitude of both real-time and monsoon average abrasion along the surveyed sandstone bars. This first validation of a model for bank erosion opens large perspective for future work on channel bottom incision modelling using physical models of erosion and their time- and gravel-size-integration, with the objective to introduce more physical rules in landscape evolution models.