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Quantifying active tectonics in the case of dynamic and instable landscape: an example from the Bhutan Himalayas

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The quantification of active tectonics from geomorphological and morphometric approaches most often implies that erosion and tectonics have reached a certain balance. Such equilibrium conditions may however be seldom found in nature, as questioned and documented by recent theoretical studies, in particular because drainage basins may be quite dynamic even though tectonic and climatic conditions remain constant.

Here, we document this drainage dynamics from the particular case example of the Bhutan Himalayas. Evidence for out-of-equilibrium landscape features have for long been noticed in Bhutan, from major (> 1 km high) river knickpoints and from the existence of high-altitude low-relief surfaces within the mountain range. These geomorphologies were generally interpreted in the literature as representing a recent change in climatic and/or tectonic conditions, either related to the uplift of the Shillong Plateau (climate/tectonic change) or to the initiation of uplift over a blind ramp within the mountain range (tectonic change).

To further characterize these geomorphologies and discuss their origin and meaning in terms of regional tectonic or climatic evolution, we perform a detailed quantitative geomorphometric analysis using c plots and basin averaged aggressivity metrics, at various spatial scales, from large Himalayan rivers to local streams draining the low-relief surfaces. Our results first emphasize that the morphology of Bhutan does not result from a general wave of incision propagating upstream, as expected from most previous interpretations. Rather, we find that the river network is highly unstable and dynamic, in particular for the rivers draining the low-relief surfaces, hampering a proper quantification of tectonics from classical approaches based on denudation or incision rates. Finally, we discuss the origin and meaning of the observed dynamics, and from there draw some useful guidelines for future morpho-tectonic studies of active landscapes.

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