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Topographic controls on the occurrence and impacts of Himalayan megafloods

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The Himalayan Range has a remarkable history of extreme natural events including catastrophic floods. Megafloods involve the sudden release of water from lakes that formed behind landslide deposits, glaciers, or moraines and exceed meteorological floods by orders of magnitude. As these floods propagate downstream, they reshape valley floors through sediment mobilization, bedrock scouring, and coarse deposition. Are these floods an important mechanism for shaping Himalayan landscapes? If yes, where are settings that favor natural lake formation and sudden drainage? Rapid erosion may obliterate the sedimentary and geomorphic legacy of megafloods, thus challenging the detection and delineation of potential zones of bedrock erosion and deposition.

Our study seeks to identify spatial patterns of potential outburst floods using digital elevation model (DEM) analysis, and dam-break and flood-wave propagation modelling. We propose that topography is the main constraint for locations able to generate megafloods by controlling the occurrence, height, and effectiveness of potentially impounding dams, as well as the accommodation space upstream. Moreover, valley geometry determines the hydrodynamics and energy expenditure to the river bed and valley bottom downstream. Our analysis establishes the link between potential dam sites and their downstream zone of influence. We apply a simplified hydrodynamic model to compare potential outburst flood magnitudes with meteorological floods and estimate the outburst flood frequency required to exceed the long-term impact of extreme meteorological floods. We define outburst-flood impact-reaches as those reaches where potential outburst floods exceed the long-term accumulated geomorphic impact of meteorological floods.

We show that large parts of the Himalayas have sufficient accommodation space to generate outburst floods with peak flows >10,000 m^3s^{-1}. Impact-reaches dominate downstream of major gorges cutting into the Tibetan Plateau and outlets of few intramontane basins. Floods from glacially overdeepened valleys and cirques may also host sufficient water to be released during major floods, but their impact covers usually only a few tens of kilometers downstream. Our study investigates hypothetical natural dam locations and identifies patterns of potential flood impacts. While our approach cannot predict whether an outburst event has occurred at a particular site, it offers guidance to seek for the legacy of major outburst floods in the field.