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Outstanding Student & PhD candidate Presentation contest

High-mountain floods and landscape perturbation: Geomorphic and hydroclimatic insights of extreme flood events across the Upper Indus catchment in the NW Himalayas

Author's Affiliation: Indian Institute of Technology Kharagpur

Authors: Abhishek Kashyap, Kristen L. Cook, and Mukunda Dev Behera

Email: kashyap95abhishek@kgpian.iitkgp.ac.in

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Background of the Study

There is growing recognition that landscapes may evolve through the cumulative effects of extreme episodic events, particularly in rapidly eroding terrains. This study illustrates how the short-lived, high-magnitude flood events may substantially impact channel morphology over high-relief landscapes such as the Upper Indus Terrain in the NW Himalayas.

Regional Settings:

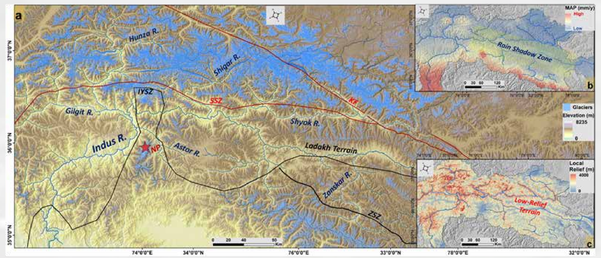
The upper Indus River is unique among Himalayan river systems due to its long passage through the Nanga Parbat-Haramosh massif (NP-HM), a highly tectonically active, high-relief region (~5000 m) with high rapid erosion potential, an 8th-9th-order antecedent drainage network, and a cut through the seismically active Indus River Gorge. The NP-HM region experiences the highest recorded rates of denudation and channel incision on Earth (~10-12 mm/y), as well as high rates of tectonic uplift (~4–10 mm/y), and forms river anticlines across extremely weak crust.

Data Used and Methodology:

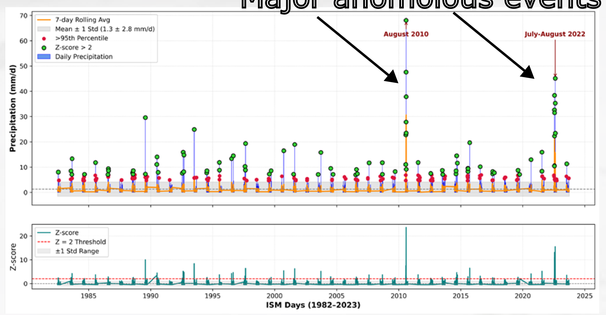
We have used the Copernicus 30m resolution DEM dataset for quantifying topographic metrics and employed geomorphic analysis using LSDTopoTools. We used daily precipitation data obtained from CHIRPS to investigate how the precipitation gradient that triggered this extreme flood event impacts regional erosion processes. This study utilized the HYSPLIT model to calculate the backward trajectory during the anomalous precipitation episodes.

Results & Discussion:

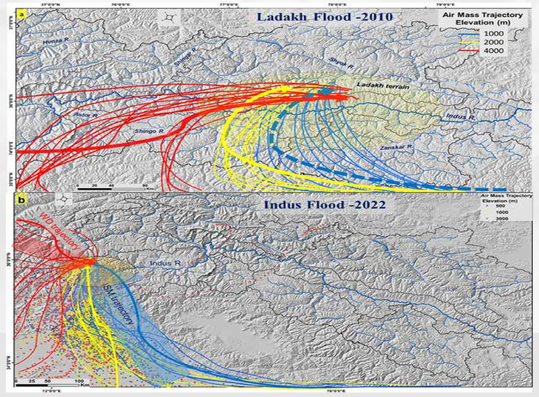
1. (a) Regional topographic setting of the upper Indus River catchment, along with its major tributaries, is overlaid with the outlines of major geological structures and glacier distribution. (b) Spatial distribution Mean Annual Precipitation (MAP) across Upper Indus Terrain. (c) Local relief across Upper Indus terrain.



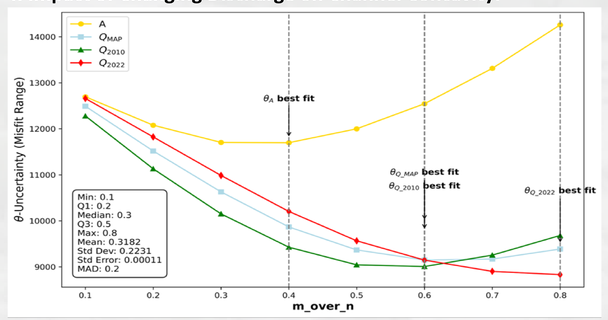
2. Daily max-value composite of precipitation intensity during the Indian Summer Monsoon (ISM) period across the Upper Indus catchment.



3. Moisture pathways (Backward trajectories) for Anomalous precipitation event (2010-2022) across the Upper Indus catchment. : (Blue and yellow dot lines exhibits the ISM pathways, whereas Red dot lines exhibit the WD pathways).

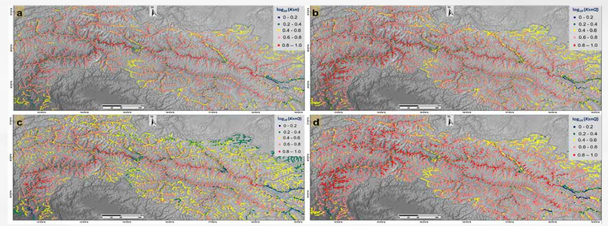


4. Impact of Changing Discharge on Channel Concavity:

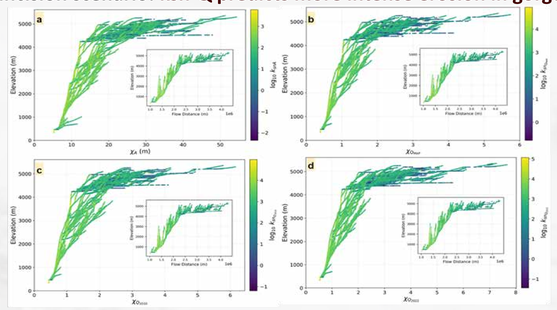


5. Drainage Area (A) or Discharge (Q) driven incision.

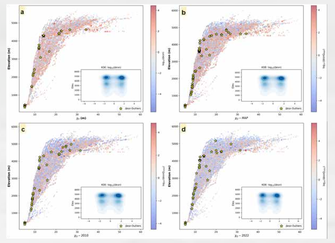
Spatial distribution of normalized channel steepness index weighted over drainage area and changing discharge:



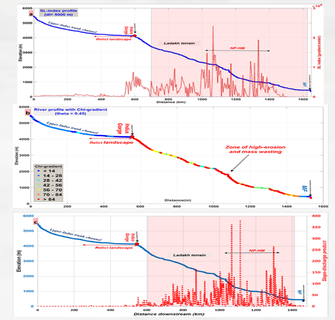
6. Illustration of how χ and ksn profiles change based on the choice of incision scenario: ksn-Q predicts more intense erosion in gorge



7. Illustration of knickpoint distribution based on the changing Δksn magnitude:



8. The longitudinal trunk channel profile of Upper Indus river plotted with (a) SL-index; (b) Chi (χ)-Gradient profile; (c) The Stream power profile (Slope-discharge product).



Concluding Remarks:

The synoptic observation of moisture pathways indicates that these anomalous precipitation incident is linked to the interaction of southward-moving midlatitude westerly troughs and eastward-advancing southwestern monsoon circulation.

These catastrophic floods may act as efficient geomorphic erosion agents, serving a significant role in the interaction of climatic extremes and topography, which are consequently among the main drivers of landscape evolution.

Significant research is needed to understand the influence of these high-magnitude events on long-term fluvial processes in the region.

References

Kashyap, A., Cook, K.L. and Behera, M.D., 2025. **Geomorphic imprint of high-mountain floods: insights from the 2022 hydrological extreme across the upper Indus River catchment in the northwestern Himalayas.** Earth Surface Dynamics, 13(1), pp.147-166

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