

## **Changes in the Mountain Cryosphere and Potential Risks to Downstream Communities: Insights from the Indian Himalayan Region**

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Mountain environments around the world are often considered to be amongst the most sensitive to the impacts of climate change. For people living in mountain communities, there are clear challenges to be faced as their livelihoods and subsistence are directly dependent on their surrounding natural environment. But what of the wider implications for societies and large urban settlements living downstream – why should they care about the climate-driven changes occurring potentially hundreds of kilometers away in the snow and ice capped mountains? In this contribution we address this question, drawing on studies and experiences gained within joint Indo-Swiss research collaborations focused on the Indian Himalayan states of Himachal Pradesh and Uttarakhand. With the Intergovernmental Panel on Climate Change currently embarking on the scoping of their 6th Assessment Cycle, which includes a planned Special Report on Oceans and the Cryosphere, this contribution provides a timely reminder of the importance of mountain regions, and potential far-reaching consequences of changes in the mountain cryosphere.

Our studies highlight several key themes which link the mountain environment to the lowland populated areas, including the role of the mountain cryosphere as a water source, far-reaching hazards and disasters that can originate from mountain regions, the role of mountains in providing essential ecosystem services, the economic importance of tourism in mountain regions, and the importance of transportation routes which pass through mountain environments. These themes are intricately linked, as for example demonstrated during the 2013 Uttarakhand flood disaster where many of the approximately 6000 fatalities were tourists visiting high mountain pilgrimage sites. As a consequence of the disaster, tourists stayed away during subsequent seasons with significant economic impacts felt across the State. In Himachal Pradesh, a key national transportation corridor is the Rohtang pass and tunnel, linking Kullu with Lahual and Spiti districts in the north. Our studies have shown that this corridor is threatened by a range of climate related hazards, including debris flows, flash floods, and snow avalanches, highlighting the need to consider climate change scenarios to ensure the long-term sustainability of vital transportation networks in mountain regions. Often a transboundary perspective is required. For example, in 2000 a landslide dammed lake located in Tibet breached, causing the loss of at least 156 lives in the Indian district of Kinnaur located 100 km downstream, with infrastructural damage and loss of revenue estimated at up to \$US 222 million.

Considering the wide-ranging ways in which downstream societies interact with and depend upon mountain environments, systematic monitoring and assessment of changes in the high mountain cryosphere is essential to ensure that adaptation decisions are evidence-based, and well supported by latest scientific understanding.