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Permafrost in the Himalayas: specific characteristics, evolution vs. climate change and impacts on potential natural hazards

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Mountain environments are very sensitive to climate change, yet assessing the potential impacts of these changes is not easy because of the complexity and diversity of mountain systems. The Himalayan permafrost belt presents three main specificities: (1) it develops in a geodynamically active mountain, which means that the controlling factors are not only temperature but also seismo-tectonic activity; (2) due to the steepness of the southern flank of the Greater Himalaya and potential large scale rock failures, permafrost evidence manifests itself best in the inner valleys and on the northern, arid side of the Himalayas (elevations >4000m); (3) the east-west strike of the mountain range creates large spatial discontinuity in the "cold" belt, mostly related to precipitation nature and availability. Only limited studies have been carried to date, and there is no permanent "field laboratory", nor continuous records but a few local studies. Based on preliminary observations in the Nepal Himalayas (mostly in Mustang and Dolpo districts), and Indian Ladakh, we present the main features indicating the existence of permafrost (either continuous or discontinuous). Rock-glaciers are quite well represented, though their presence may be interpreted as a combined result from both ground ice and large rock collapse. The precise altitudinal zonation of permafrost belt (specifying potential permafrost, probable permafrost, observed permafrost belts) still requires careful investigations in selected areas.

Several questions arise when considering the evolution of permafrost in a context of climate change, with its impacts on the development of potential natural hazards that may affect the mountain population. Firstly, permafrost degradation (ground ice melting) is a cause of mountain slope destabilization. When the steep catchments are developed in frost/water sensitive bedrock (shales and marls) and extend to high elevations (as observed in Mustang or Dolpo), it would supply more mass-wasting and debris-flow events and may directly threat the infrastructures recently built to unlock these remote areas. Secondly, acceleration of permafrost degradation might also affect the steepest rock walls (as in Khumbu, Manang and Mustang Himals) and cause rock avalanches that could impact nearby settlements, as suggested by relicts of past events. Lastly, ground ice is a hidden source of water in areas without permanent glacial ice. In a context of global warming this non-renewable resource would be depleted and no longer available for the population living in these areas, all the more as growing tourism activities are increasing the demand for water consumption that may conflicts with irrigated agricultural uses down valley.

More in-situ observations and long-term monitoring studies should certainly be useful to understand climate trends hence permafrost evolution and their consequences in order to help mountain populations of the cold, arid Himalayas to adjust to progressive changes in their environmental conditions and resources.