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On the survival of south-facing cliffs over debris-covered glaciers in the Himalaya: explaining the preferential orientation of supraglacial ice cliffs using energy balance model simulations

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Supraglacial ice cliffs exist over debris-covered glaciers worldwide and provide the only direct atmosphere-ice interface over the lower sections of these glaciers mantled in continuous rock debris. Low albedo and high longwave emissions from surrounding debris can cause very high melt rates, accounting for a significant portion of the total glacier mass loss. As a result, ice cliffs affect glacier downwasting and mass balance.
While conceptual ideas about the formation, evolution and collapse of ice cliffs exist, their life cycles have never been thoroughly investigated and quantitative, numerical energy balance models able to simulate their backwasting are scarce. Observational studies have suggested that supraglacial ice cliffs predominantly face towards north, whereas south-oriented cliffs are rare or of short duration (on northern hemisphere glaciers).On the other side, there is growing evidence that cliff aspect is independent of glacier orientation or flow direction.
Here, we simulate the evolution of selected ice cliffs over the debris-covered tongue of Lirung Glacier, Nepal, using a physically-based model of cliff backwasting. The 3D model calculates the energy-balance at the cliff scale and includes reburial by debris and the effect of supraglacial ponds coupled to the lower cliff sections.
We use the model to test the hypothesis that south-facing cliffs do not persist. Given the lack of observed cliffs with South orientation, we show that south-facing cliffs obtained by artificially rotating real north-facing cliffs demise after short period of time (few ablation seasons and at times within one season), because of high input of solar radiation on their upper sections, exceeding the longwave radiation receipt. For north facing features, the longwave radiation receipts on lower cliff sections balance shortwave radiation differences, preventing cliffs from flattening.