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Accelerating recent mass loss from debris-covered Khumbu Glacier in Nepal, and projected response to climate change by 2200 CE

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Thick supraglacial debris covers the ablation areas of many large Himalayan glaciers, particularly those in the Everest region where debris is typically several metres thick. Sustained mass loss from these high-elevation debris-covered glaciers is causing supraglacial debris layers to expand and thicken. However, at the same time, regional satellite observations have demonstrated that debris-covered glaciers in High Mountain Asia are currently losing mass at the same rate as clean-ice glaciers. This greater than expected mass loss—sometimes referred to as the “debris-cover anomaly”—could be due to surface processes that locally enhance ablation, including the formation and decay of ice cliffs and supraglacial ponds.

We tested the hypothesis that the presence of ice cliffs and supraglacial ponds is responsible for the rapid decay of debris-covered Himalayan glaciers, using a numerical glacier model that includes the feedbacks between debris transport, mass balance and ice flow. We show that parameterising differential ablation processes in our higher-order ice flow model of Khumbu Glacier in Nepal does increase glacier-wide mass loss, but is not sufficient to match the observed glacier surface elevation change between 1984 and 2015 CE. Additional mass balance forcing is required to simulate the remaining mass balance change, which may represent the impact of rising air temperatures on englacial and supraglacial hydrology or englacial ice temperatures. Under a moderate future warming scenario (RCP4.5), Khumbu Glacier is projected to lose 59% of ice volume by 2100 CE, and 94% by 2200 CE accompanied by a dynamic shutdown that causes the death of this iconic glacier by 2160 CE.