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Modelling the effect of debris cover on glacier response time

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Debris-covered glaciers are, in a warming world, increasingly common features of alpine landscapes. When a continuous layer of surface debris is thick enough, it reduces the ablation rate of the underlying ice, which in turn reduces thinning, surface evolution and, hence, affects the ice dynamics. Although the transient response of glaciers to climate variations is a well-studied problem for clean-ice glaciers, there is limited understanding of how debris cover changes the response time of glaciers. This is a relevant question given their role in future water supply and potential natural hazards in regions with frequent debris-covered glaciers such as the Himalayas.

In this work, we combine a numerical ice flow model with a physically-based debris transport model and include the insulation effect of the debris in order to examine the effect of surface debris cover on ice dynamics. In particular, we investigate the response time of debris-covered glaciers to changes in climate, by shifting the equilibrium line altitude (ELA), as a function of debris thickness, debris extent glacier thickness and glacier length. Since the standard glacier volume response timescales used for clean-ice glaciers are no longer appropriate here, we examine how the existing theory can be modified for debris-covered glaciers. We also compare our numerical results with observed glacial response to climate change for the case of Zmuttgletscher (Swiss Alps).