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Coupling the delta-h parametrization with melt beneath a supraglacial debris cover: an evaluation across 54 glaciers in the southern European Alps

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Glacier mass balance is an essential component of the water budget of high-elevation and high-latitude regions, and yet this process is rather oversimplified in most hydrological models. This oversimplification is particularly relevant when it comes to representing two mechanisms: ice flow dynamics and melt beneath a supraglacial debris cover. In 2010, Huss et al. proposed a parsimonious approach to account for glacier dynamics in hydrological models without solving complex equations of three-dimensional ice flow, the so-called delta-h parametrization. On the other hand, accounting for melt of debris-covered ice is still challenging as estimates of debris thickness are rare.

Here, we leveraged a distributed dataset of glacier-thickness change to derive a glacier-specific delta-h parametrization for 54 glaciers across the Aosta Valley (Italy), as well as develop a novel approach for modeling melt beneath supraglacial debris based on residuals between locally observed change in thickness and that expected by regional elevation gradients. This approach does not require any on-the-ground data on debris cover, and as such it is particularly suited for ungauged regions where remote sensing is the only, feasible source of information for modeling.

We found an expected, significant variability in both the delta-h parametrization and residuals over debris-covered ice across glaciers, with somewhat steeper orographic gradients in the former compared to the curves originally proposed by Huss et al. for Swiss glaciers. At a regional scale, the glacier mass balance showed a clear transition between a regime dominated by active glacier flow above 2,300 m ASL and a debris-dominated regime below this elevation threshold, which makes accounting for melt in the debris-covered area essential to correctly capture the future fate of low-elevation glaciers. Implementing the delta-h parametrization and our proposed approach to melt beneath supraglacial debris into S3M, a distributed cryospheric model, yielded an improved realism in estimates of future changes in glacier geometry compared to assuming non-dynamic downwasting.