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Incorporating moisture content in modeling the surface energy balance of debris-covered Changri Nup Glacier, Nepal

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Glaciers whose ablation zones are covered in supraglacial debris comprise a significant portion of glaciers in High Mountain Asia and two-thirds in the South Central Himalaya. Such glaciers evade traditional proxies for mass balance because they are difficult to delineate remotely and because they lose volume via thinning rather than via retreat. Additionally, their surface energy balance is significantly more complicated than their clean counterparts' due to a conductive heat flux from the debris-air interface to the ice-debris boundary, where melt occurs. This flux is a function of the debris' thickness; thermal, radiative, and physical properties; and moisture content.

To date, few surface energy balance models have accounted for debris moisture content and phase changes despite the fact that they are well-known to affect fluxes of mass, latent heat, and conduction. In this study, we introduce a new model, ISBA-DEB, which is capable of solving not only the heat equation but also moisture transport and retention in the debris. The model is based upon Meteo-France's Interactions between Soil, Biosphere, and Atmosphere (ISBA) soil and vegetation model, significantly adapted for debris and coupled with the snowpack model Crocus within the SURFEX platform. We drive the model with continuous ERA-Interim reanalysis data, adapted to the local topography (i.e. considering local elevation and shadowing) and downscaled and de-biased using 5 years of in-situ meteorological data at Changri Nup glacier [(27.859N, 86.847E)] in the Khumbu Himal. The 1-D model output is then evaluated through comparison with measured temperature in and ablation under a 10-cm thick debris layer on Changri Nup. We have found that introducing a non-equilibrium model for water flow, rather than using the mixed-form Richard's equation alone, promotes greater consistency with moisture observations. This explicit incorporation of moisture processes improves simulation of the snow-debris-ice column's temperature gradient—and, thus, energy fluxes—through time.