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Deriving supraglacial debris thickness using satellite data on the Lirung Glacier in the Nepalese Himalayas

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Glaciers with debris-covered ablation zones are widely present in mountain ranges such as the Alps, the Himalayas and the Andes. An expansion of rock debris-covered areas has been documented in recent decades. It is therefore increasingly important to take the effect of debris cover into account in glacio-hydrological modelling. Debris thickness is a key control on a glacier's energy balance and it governs the melt rate beneath debris, hence the estimation of debris extent and thickness is crucial to predict melt. Data on debris thickness are scarce on most glaciers and thus simplified assumptions are commonly used.

In this study we test a new, recently developed physically based method to produce debris thickness maps from satellite imagery. The model is based on a solution of the energy balance equation at the debris surface to reconstruct debris thickness as a residual in each satellite pixel. This approach requires ASTER thermal images and reanalysis meteorological data and has the potential to map distribution of debris thickness without the need for detailed field data.

In a previous study we tested the model for glaciers with different characteristics and in different climatic regions of the world. The validation of debris thickness, however, is problematic due to data scarcity, the inhomogeneous debris distribution and the resolution of the ASTER product (90 m). The standard application of the model seems to work for glaciers for which debris characteristics such as the effective conductivity are known and reanalysis data are representative. In this study we additionally test the approach with a recently collected data set over the Lirung glacier in the Nepalese Himalayas, where initial application of the remote sensing method using reanalysis data led to a significant underestimation of debris thickness. Extensive field data were collected from May to October 2012 consisting of data from an AWS, spatially distributed air and surface temperature, effective conductivity and a large data set of debris thickness. Analyzing the data improved our understanding of spatial distribution of air temperature, the relationship of air and surface temperature and the thermal properties of the debris. We show how including this knowledge in the model changes the resulting debris thickness maps and we attribute the earlier underestimation of debris thickness mostly to the quality of reanalysis data and the use of literature values for debris characteristics and the air/surface temperature relationship. In particular we show that given the importance of turbulent fluxes, accurate knowledge of wind speed and temperature on the glacier is necessary. A sensitivity analysis identifies the most important inputs for the model and the method's applicability is discussed in relation to the quality of available field data.