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Estimate on melt rates of debris-covered glaciers in the Himalayas using ASTER data

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The ablation areas of the large glaciers in the Himalayas are covered with supraglacial debris. The melt rates of such glaciers are necessary for revealing the expanding mechanism of glacier lakes, which often causes disastrous outburst floods. However, field measurements of the melt rates are difficult since they depend on thickness and thermal properties of the debris, which vary widely even on one glacier. Thus we propose an improved methodology for deriving the thermal resistance (thickness / thermal conductivity), which has been utilized as an essential index for melting of individual glacier so far. This study utilizes satellite remote sensing techniques, and discusses possibility of reducing parameters to estimate spatial distribution in the Himalayas.

The remote sensing data were used for elevation, albedo and surface temperature of the glacier surfaces, which were acquired by ASTER on 20 September 2002 and 21 July 2003. The present targets are ablation areas of three debris-covered glaciers in the Lunana region of Bhutan, which range in approximately 10 km square. We calculated spatial distribution of the thermal resistance by two methods. One used all of the heat balance components, which are net radiation, sensible heat and latent heat fluxes. Another used net radiation flux only to estimate heat balance on the debris. This approximation is based on less contribution of sensible and latent heat fluxes to the heat balance on the glacier surfaces as studied in the Himalayan glaciers. The ground meteorological data, which includes the ASTER data acquisition date, by an automatic weather station at 4524 m a.s.l., was used for the calculation by combining with albedo, surface temperature and altitude from ASTER data. The temperature in the debris was assumed to be in a linear profile and 0 degree Celsius at the bottom. The air temperature was calculated using an altitudinal lapse rate and the other components were represented by the observed values at the station. We solved the heat balance equation for the thermal resistance at each 90 m per pixel.

The two methods resulted in negligible differences in the thermal resistances compared to the potential errors. This means that thermal resistance in the Himalayan ranges can be derived by the approximation using the net radiation component, which is available as the remote sensing. Thus we conclude that the methodology can expand wider area in the Himalayas, and contribute to the studies for glacier melting and glacier lakes in the Himalayas.