THERMAL PROPERTIES OF SUPRAGLACIAL DEBRIS, NGOZUMPA GLACIER, NEPAL

Background

Improved estimates of ablation rates of debris-covered glaciers in the Himalayas are needed for: (1) long-term hydrological management (Nakawo and Rana, 1999) and (2) predicting the future growth of supraglacial lakes associated with debris-covered glaciers. Such lakes pose a significant threat in mountain regions where glacier lake outburst floods are becoming increasingly common (Richardson and Reynolds, 2000a).

Due to the difficulties of obtaining and extrapolating direct ablation measurements over debris-covered glaciers, mathematical modelling of melt rate from meteorological variables is commonly employed (e.g. Nakawo and Young, 1982). Such models assume that heat transfer is conductive only, and that conduction is determined by a temporally stable temperature gradient (Conway and Rasmussen, 2000), with the average heat flux, Qc, given by:

$$Qc = \frac{\delta q}{\delta t} = k.\frac{\delta \bar{T}}{\delta z}$$

Where q is the heat flux, t, time, k is the conductivity of the medium, $\bar{T}$ is the mean debris temperature and z is the vertical distance.

Previous work (also funded by the QRA) suggested that over short time scales and within particular debris fabrics, the effects of both convection and freeze-thaw processes may be significant (Nicholson, 2002). Furthermore, existing data of supraglacial debris temperatures in the Himalayas covers limited time periods (Conway and Rasmussen, 2000) and uncertainty remains about how the Indian monsoon affects heat flux and melt rate beneath debris covers.

Aims and methods

This research aimed to use debris temperatures and concurrent meteorological data to assess the stability of debris temperatures and potential significance of non-conductive processes over a full annual cycle.

Debris temperatures were recorded using TinyTag loggers attached to thermistors emplaced in typical supraglacial diamicton at intervals to a depth of 0.8 m. Meteorological measurements were made using a Kipp & Zonen CC48 logger.

The sampled site was at ~4,800 m.a.s.l on the Ngozumpa Glacier, in the eastern Nepalese Himalayas. Continuous debris temperatures were recorded from November 2001 to October 2002, and meteorological data spans the same period, although this record is incomplete due to power failures under cold conditions.

Results

The thermal regime of the debris responds rapidly to changes in both surface conditions and ambient meteorological conditions. Snow-covered periods, identified in Figure 1(b) where surface temperature shows no diurnal fluctuations (mid January, and 2 shorter periods in early February and March), cause rapid cooling throughout the debris, with a very short lag time.

The ablation season can be identified as the period through which daily mean vertical temperature gradient is positive. This becomes fully established in the middle of May, and continues until early October. The winter season, during

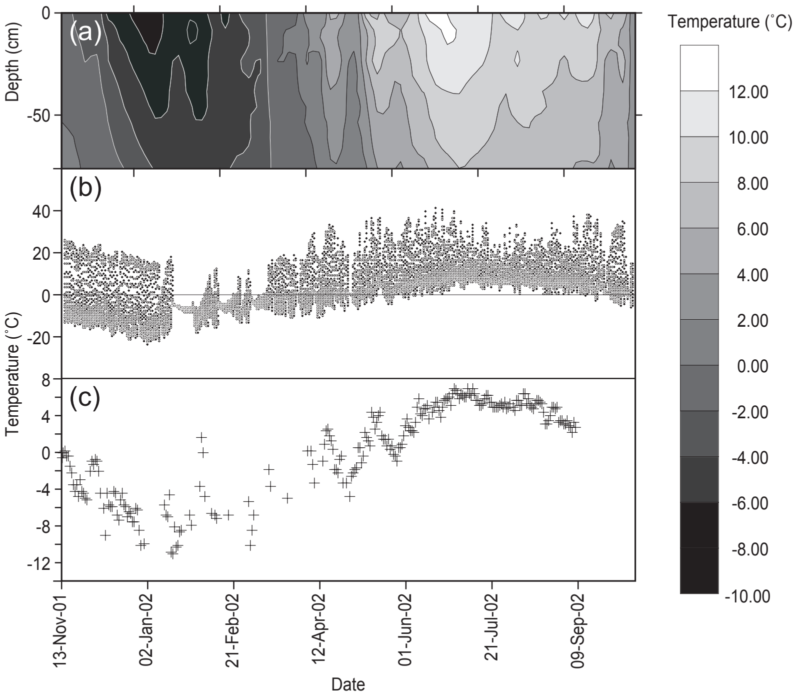

Figure 1. (a) Debris surface temperature, (b) mean daily air temperature.

which the mean vertical temperature gradient is negative, spanned a shorter period from November until early February (possibly also the missing section of late October).

Within both of these stable seasons the mean daily temperature profiles approximate linear gradients, with R^2 values >0.95. Given that on a day-to-day basis in these established seasons the temperature of the debris can be assumed to be temporally stable, this linearity is indicative of dominant conductive heat flux.

In the seasonal transition period (mid February to mid May) the gradient of mean temperature profiles deviates from linear due to progressive warming of the debris layer. In the daily temperature profiles a zone of latent heat exchange can be identified penetrating onto the debris from the surface. During this time calculations of heat flux through the layer cannot be made on the basis of a stable conductive thermal gradient. Taking mean debris temperatures over the duration of this transitional period to be representative of overall heat flux regime at a coarse scale, the mean profile gradient is slightly positive suggesting that over this period melt may be occurring, but it is likely to be negligible.

Non-linearity of daily mean temperatures also occurs periodically through the monsoon. This may be due to advection of heat by infiltrating precipitation. However, as no precipitation data is available for the site, due to failure of the rain gauge, this interpretation is not conclusive.

The data show that the transition to an ablation gradient begins during springtime and is established by the onset of the monsoon in May, and suggest that periods of marked temperature transition in the debris layer are more complex than represented in models of conductive heat flux.

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