Physically-based modelling of ice cliff melt on a debris-covered glacier, Nepalese Himalayas

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1. Introduction

Debris cover reduces glacier melt through insolation (Østrem, 1959). Supraglacial cliffs are typical of debris-covered glaciers and may account for high mass losses by providing a direct ice-atmosphere interface. Their role has been investigated either in point scale studies of single cliffs (Sakai et al. 1998, Han et al. 2010, Reid & Brock, 2014, Steiner et al., 2015) or at the large-scale from satellite imagery, so that a gap in scale is evident. We suggested the first grid-based energy balance and ablation model for single cliffs, and demonstrated high variability in melt rates at the cliff scale (Buri et al., 2016). Building on that, we develop a dynamic 3D-backwasting model accounting for recovery/exposure of ice based on surrounding topography. Using this model approach we assess the importance of ice cliffs in terms of melt (Buri et al., under review).

2. Data

Manually derived from UAV-orthoimage – Cliff outlines

- Topography

- UAS-DEM (0.6m res., Immenez et al. 2016)
- ASTER (30m res.) for radiation modelling of far slope

AWS on Lirung Glacier (Tb, Td, SW-rad, JH, wind sp., AWS off-glacier Kyanjing (LW-Rad).

3. Methods

- Models

Static, distributed physically-based energy-balance model (Buri et al. 2016) considers shading/fluxes from surrounding topography

Dynamic, 3D-backwasting model (based on static model)
- Monthly cliff geometry corrections based on melt
- Considers recovering by debris and exposure of ice

4. Results

Modelled vs. observed cliff profiles:

- May vs Obs DEM – Oct vs Obs DEM – Oct vs Mod DEM

Modelled vs. observed cliff outlines:

5. Key points

1. We use high resolution digital elevation models to document the evolution of supraglacial ice cliffs over one ablation season
2. Reclining cliffs that flatten, stable cliffs maintaining a self-similar geometry, and growing cliffs that expand laterally are observed
3. We develop a 3D-model of cliff backwasting driven by atmospheric melt, reburial by surrounding debris, and the effect of adjacent ponds

Outlook: Application at the glacier scale using satellite products – Simulation of multiple melt seasons

References

Østrem, G., 1959. Ice melting under a thin layer of moraine and the occurrence of ice cores in morainic cliffs. GeografiskＡrmavirk.
Reid, T.D. and Brock, S.W., 2014. Assessing ice-cliff backwasting and its contribution to total ablation of debris-covered Moppa glacier, Mt Blanc massif, Italy. Journal of Glaciology