Geophysical Research Abstracts
Vol. 18, EGU2016-575, 2016
EGU General Assembly 2016

Investigating ice cliff evolution and contribution to glacier mass-balance using a physically-based dynamic model

Pascal Buri (1), Evan Miles (2), Silvan Ragettli (1), Fanny Brun (3), Jakob Steiner (1), Francesca Pellicciotti (4,1)

(1) Institute of Environmental Engineering, ETH Zürich, Zürich, Switzerland (buri@ifu.baug.ethz.ch), (2) Scott Polar Research Institute, University of Cambridge, Cambridge, UK, (3) LGGE LTHE, Université Joseph Fourier, Grenoble, France, (4) Department of Geography, Northumbria University, Newcastle upon Tyne, UK

Supraglacial cliffs are a surface feature typical of debris-covered glaciers, affecting surface evolution, glacier downwasting and mass balance by providing a direct ice-atmosphere interface. As a result, melt rates can be very high and ice cliffs may account for a significant portion of the total glacier mass loss. However, their contribution to glacier mass balance has rarely been quantified through physically-based models. Most cliff energy balance models are point scale models which calculate energy fluxes at individual cliff locations. Results from the only grid based model to date accurately reflect energy fluxes and cliff melt, but modelled backwasting patterns are in some cases unrealistic, as the distribution of melt rates would lead to progressive shallowing and disappearance of cliffs.

Based on a unique multitemporal dataset of cliff topography and backwasting obtained from high-resolution terrestrial and aerial Structure-from-Motion analysis on Lirung Glacier in Nepal, it is apparent that cliffs exhibit a range of behaviours but most do not rapidly disappear. The patterns of evolution cannot be explained satisfactorily by atmospheric melt alone, and are moderated by the presence of supraglacial ponds at the base of cliffs and by cliff reburial with debris. Here, we document the distinct patterns of evolution including disappearance, growth and stability.

We then use these observations to improve the grid-based energy balance model, implementing periodic updates of the cliff geometry resulting from modelled melt perpendicular to the ice surface. Based on a slope threshold, pixels can be reburied by debris or become debris-free. The effect of ponds are taken into account through enhanced melt rates in horizontal direction on pixels selected based on an algorithm considering distance to the water surface, slope and lake level.

We use the dynamic model to first study the evolution of selected cliffs for which accurate, high resolution DEMs are available, and then apply the model to the entirety of Lirung and Langtang glaciers to quantify the total contributions of cliffs to glacier mass balance.

Observations and model results suggest a strong dependency of the cliffs' life cycle on supraglacial ponds, as the water body keeps the cliff geometry constant through a combination of backwasting and calving at the bottom and maintenance of steep slopes in the lowest sections. The absence of ponds causes the progressive flattening of the cliff, which finally leads to complete disappearance. Modelled volume losses from May to October 2013 range from 2650 to 9415 m^3 w.e., in agreement with the estimates with the SfM-approach. Mean error of modelled elevation within the cliff outline ranges from -1.3 to 0.6m.

This work sheds light on mechanisms of cliffs' changes by quantifying them for the first time with a physically-based, dynamic model, and presents the first complete estimate of the relevance of supraglacial ice-cliffs to total glacier mass-balance for two distinct glaciers.