Geophysical Research Abstracts
Vol. 19, EGU2017-2286, 2017
EGU General Assembly 2017

Geomorphic feedbacks between hillslopes and valley glaciers – implications for climate reconstructions and landscape evolution (GM Division Outstanding ECS Award Lecture and Penck Lecture)

Dirk Scherler (1,2)

(1) German Research Centre for Geosciences GFZ, Telegrafenberg, 14473 Potsdam, Germany, (2) Institute for Geological Sciences, Freie Universität Berlin, Malteserstr. 74-100, 12249 Berlin, Germany

Glacial landscapes respond rapidly to global warming: glaciers retreat, permafrost degrades, and snow cover diminishes. These changes affect the stability of glacial landscapes, manifested by enhanced rockfall activity and more frequent catastrophic slope failures. Similar changes have accompanied deglaciation after the last glacial maximum, albeit of much greater magnitude, and with potentially important feedbacks between the dynamics of mountain glaciers and the landscapes they reside in. Here, I summarize recent observations from debris-covered valley glaciers and put them into context with a more general conceptual model of how glacial landscapes respond to warming periods. I will identify key research problems and provide preliminary results from ongoing studies.

Ice-free areas that are located above glaciers generally consist of steep bedrock hillslopes (headwalls), where ambient temperatures are low enough to form bedrock permafrost, but the topography is too steep to accumulate significant amounts of ice on the surface. Because headwalls erode by rockfalls and rock avalanches that mobilize fractured bedrock, the rate-limiting factor is the growth of bedrock fractures. Current theory posits that bedrock fractures in cold regions primarily expand by segregation ice growth at subfreezing temperatures, which is known as frost cracking. Because frost cracking is temperature sensitive, there exists a temperature window of high frost-cracking intensity, which is thought to correspond to an elevation zone of enhanced sediment production. During warming periods, changes in the frost-cracking intensity combine with permafrost degradation and changing stresses due to ice thinning to destabilize steep headwalls and likely increase the flux of rocks that is shed to valley glaciers below.

Even if temporarily buried in the ice, most rocks eventually melt out at the ice surface and form a supraglacial debris cover. Because debris cover thicker than $\sim$2 cm reduces conductive heat transport and thus ice melt rates, heavily debris-covered glaciers are longer and extent to lower and warmer elevations compared to debris-free glaciers, all other things being equal. Therefore, if warming induces an increase in headwall erosion rates, the increased supply of rocks should lead to an increase in supraglacial debris cover, which would reduce ice melting and slow down glacier retreat. Theoretically this effect could offset part of the warming-induced glacier shrinking. Large slope failures that result in a sudden increase in debris cover may even trigger glacier advances, as has been proposed for a few glaciers already.

Such geomorphic feedbacks between headwalls and valley glaciers ought to be most pronounced in steep landscapes like the Himalaya, where existing glacial chronologies often lack spatial coherence. Some heavily debris-covered valley glaciers can be found to lie entirely below the regional climatic snowline where they are sustained by snow avalanches. Such glaciers typically flow at low velocities and their key role in glacial landscape evolution may lie in keeping the base of headwalls free from talus deposits and thereby sustain a steep and retreating headwall.