Geophysical Research Abstracts
Vol. 16, EGU2014-11795, 2014
EGU General Assembly 2014

Modelling bed overdeepenings for the glaciers in the Himalaya-Karakoram region using GlabTop2

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Calculating ice thickness distribution and bed topographies for large glacier samples is an essential task to estimate stored ice volumes with their potential for sea level rise and to model possible future retreat scenarios of glacier evolution under conditions of continued warming. Modelling such bed topographies to become exposed in the near future by continued glacier retreat also enables modelling of future landscapes with their landforms, processes and interactions. As the erosive power of glaciers can form numerous and sometimes large closed topographic bed depressions, many overdeepenings are commonly found in formerly glaciated mountain ranges. Where such overdeepend parts are becoming exposed and filled with water rather than sediments new lakes can come into existence.

GlabTop (Glacier bed Topography) has been used to model ice thickness distribution and bed topographies of large glacier samples. It is an ice dynamical approach, based on the assumption of perfect plasticity of ice, which relates glacier thickness to its local surface slope via the basal shear stress estimated for each glacier based on an empirical relation between shear stress and elevation range as a governing factor of mass turnover. From comparison with radio-echo soundings in the Swiss Alps, the uncertainty range of local ice thicknesses calculated with GlabTop is estimated at about $\pm 30\%$. The spatial variability of ice depths, i.e. the glacier-bed topography, primarily depends on surface slope as provided by DEMs and is quite robust. For the entire Swiss Alps, GlabTop revealed a considerable number (more than 500) of (partly large) overdeepenings in the modelled glacier beds with a total area of about 50-60 km^2 and a total volume of about 1.5-2.5 km^3. A number of lakes have formed in such modelled overdeepenings during the past years and decades.

To calculate bed topographies with their overdeepenings for the 28'100 glaciers of the Himalaya-Karakoram region the GlabTop-approach was modified and named GlabTop2. While the original approach relied on so called glacier branch lines that had to be digitized manually, GlabTop2 is fully automated and requires only a DEM and glacier outlines as an input. The result is the same: ice thickness distribution and bed topographies, which can be used for volume calculations and for model simulations concerning glacier retreat scenarios and future landscapes. According to the model output there are about 15'000 overdeepenings covering an area of about 2000 km^2 and having a total volume of about 120 km^3 (3-4% of the now existing glacier volume) in the Himalaya-Karakoram region. In a statistical analysis concerning the morphological characteristics of these overdeepenings, mean and maximum values of the parameters surface area, length, width, depth, volume, frontal/adverse slope and their statistical interrelations are determined with their corresponding uncertainty ranges and compared with a corresponding analysis for the Swiss Alps. While the modelled overdeepenings based on model runs with different data input differ in shape, the locations of the overdeepenings are robust and the values for the extracted parameters are comparable.