Hypsographic modelling as a tool for assessment of future glacier extent in the Swiss Alps

Paul Frank*, Maisch Max*, Rothenbühler Christine**, Hoelzle Martin* & Haeberli Wilfried*

*Glaciology and Geomorphodynamics Group, Department of Geography, University of Zurich, Switzerland
**Academia Engiadina, Quadratscha 18, CH-7503 Samedan, Switzerland

The strong reaction of glaciers to small changes in climate (mainly temperature and precipitation) designates glaciers as a unique demonstration object of ongoing climate change for a wide public (Zängl & Hamberger 2004). Under current scenarios of atmospheric warming for this century, many Alpine glaciers are likely to disappear within the coming decades (Zemp et al. 2006). The future evolution of glacier size and volume is of major importance for many purposes, including hydro-power production, run-off (agriculture, transport), tourism or natural hazards (rock fall, lake development). In consequence, there is an urgent need to quantify future glacier evolution on an Alpine-wide scale. As current models for calculation of future glacier length or area require input data that are generally not available for most glaciers (e.g. the bedrock), simpler approaches have to be found. We have developed such a simple modelling scheme that calculates future glacier geometry using digitized glacier outlines and a digital elevation model (DEM) only (Paul et al. in press). The model assumes a steady-state equilibrium line altitude (ELA_0) that is based on a constant accumulation area ratio (AAR) for all glaciers (e.g. Maisch et al. 2000) and a constant sensitivity of the ELA_0 to temperature changes of 140 m for a 1 °C increase. By calculating a 10 m hypsography within a GIS for all 3062 glacier entities in our sample, we can easily calculate the new accumulation area (and thus total area) for any given shift of the ELA_0 (we use six values in steps of 100 m) within a few seconds. In order to account for a certain variability of the AAR_0, we run the model with four different AAR_0 values (0.5, 0.6, 0.67, and 0.75). The model neglects any changes in glacier thickness, curvature or the size of the accumulation area.

In Fig. 1a the results of the model are shown. Overall, the AAR_0 has little effect on the general trends and the glacier number decreases most strongly due to the high amount of very small glaciers. For an ELA_0 rise of 200 m (400 m) we calculate a total area loss of -54% (-80%) and a corresponding volume loss of -50% (-78%) compared to the year 1973. Currently, about 20% of the area loss already occurred (Paul et al. 2004). The hypsographic curves in Fig. 1b illustrate the strong area loss at lower elevations and the 600 m upward shift of the mean elevation. In Fig. 2 we visualize the area loss for the Bernina Region, indicating the rapid loss of large glacier tongues and the fast disappearance of the small glaciers. Future versions of the model will be enhanced by including glacier specific ELA_0 (AAR_0) values and ELA_0 sensitivities as obtained from distributed mass and energy balance modelling.

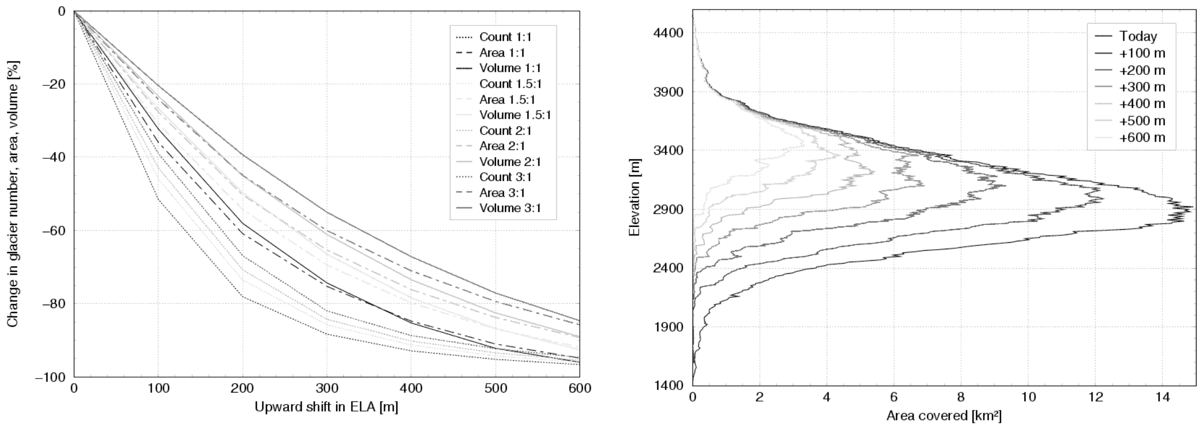

Figure 1. a) Modelled changes in glacier number, area and volume for six shifts of the ELA_0 and four AAR_0 values (1:1=0.5, 1.5:1=0.6, 2:1=0.67, 3:1=0.75). b) Overall changes in glacier hypsography due to six shifts of the ELA_0 using an AAR_0 of 0.6.

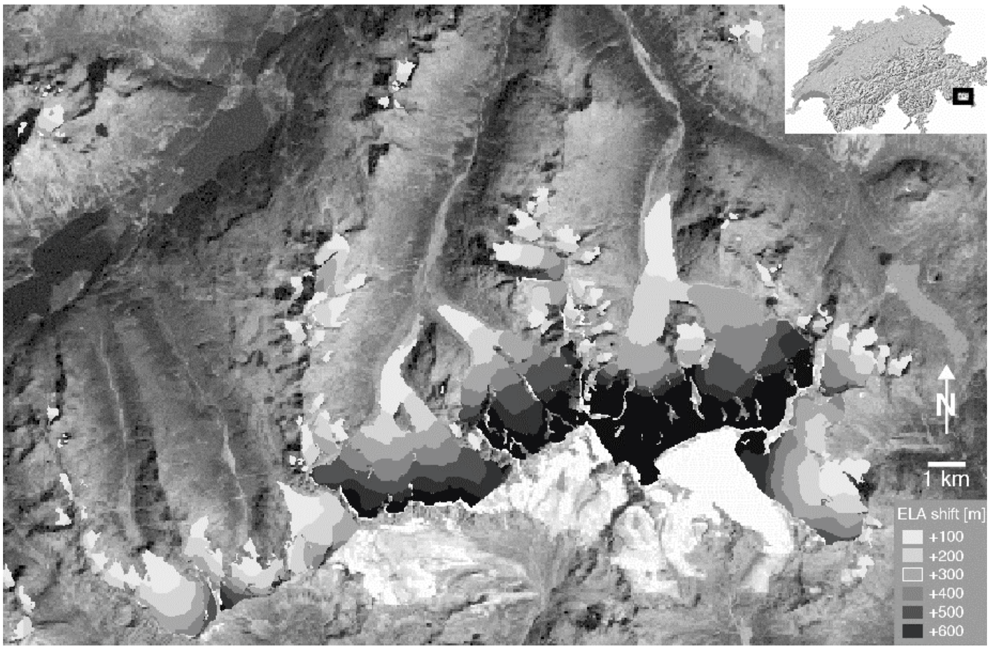

Figure 2. Glacier extent for the year 1973 (all grey shades) from the digitized inventory and modelled extent for six shifts of the ELA_0 (AAR_0 =0.6) for the Bernina Group (see inset for location). The legend gives the grey shade for the region that will disappear due to the corresponding ELA_0 shift. For an ELA_0 rise of 600 m only the nearly black regions will remain. In the background is a Landsat Thematic Mapper satellite image acquired at 13.9. 1999.

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