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170 years of debris covered glacier surface evolution

Nico Mölg (1), Tobias Bolch (1), Andreas Vieli (1), and Andreas Bauder (2)

(1) University of Zurich, Geography, Switzerland (nico.moelg@geo.uzh.ch), (2) Versuchsanstalt für Wasserbau, Hydrologie und Glaziologie (VAW), ETH Zürich, Switzerland

The local effect of debris layer thickness on ice melt can be studied considering short time periods and is quite well known to date. How the reduced melt, the additional weight of the debris, and the formation of ice cliffs and lakes are linked with the flow behaviour of the glacier is less well understood and much longer time periods are required for such investigations, typically in the order of the response time of the respective glacier, if possible even longer.

For this reason we selected to study Zmuttgletscher in the Western Swiss Alps, which today is a heavily debris covered valley glacier. We produced a time series of glacier area, debris cover and surface elevation changes on the basis of 14 old maps and aerial images, 11 orthoimages and additional terrestrial photographs starting at the end of the little ice age (LIA) in 1859. During these 170 years the glacier lost a volume of ∼52.9*106 m^3 (mean thickness change of -89 m) at its tongue while its debris covered area increased from about 14 to 20%. Several periods of variable retreat rates can be discerned and spatially varying change patterns become visible. Commonly the glacier has been retreating, but we can discern locally different elevation change, and also stable to positive periods in the 1980s become visible on different dynamical section of the glacier.

Surface features that are commonly linked to debris cover and ice flow have emerged after the end of the LIA. For example, supraglacial thermokarst features become visible in 1880 and are widespread in the lower area of the glacier tongue in 1946. Considering big ice cliffs that are typically related to a realtively high, steep elevation difference and a large surface area, their number has increased somewhat from zero in 1859 to about 15 today. However, it′s the small ice cliffs, lakes and surface water channels that have emerged and also contribute to stronger melt through either exposed clean ice or ice in contact with water. Elevation differences from DEMs demonstrate that the position of ice cliffs is clearly driving a large share of the total volume loss through melt. Currently, the extraction of surface features has been done manually, but we will also present an attempt to automatically extract ice cliffs and lakes.

Further investigations will concentrate on studying the relationship of debris cover, surface features and flow velocity in more spatial detail using more and higher resolution DEMs and in-situ information on debris and glacier surface flow velocity.