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Modelling distributed mountain glacier volumes: A sensitivity study in the Austrian Alps

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Knowledge about the spatial ice thickness distribution in glacier covered mountain regions and the elevation of the bedrock underneath the glaciers yields the basis for numerous applications in geoscience. Applications include the modelling of glacier dynamics, natural risk analyses and studies on mountain hydrology. Especially in recent times of accelerating and unprecedented changes of glacier extents, the remaining ice volume is of interest regarding future glacier and sea level scenarios. Subglacial depressions concern because of their hazard potential in case of sudden releases of debris or water.

A number of approaches with different level of complexity have been developed in the past years to infer glacier ice thickness from surface characteristics. Within the FUTURELAKES project, the ice thickness estimation method presented by Huss and Farinotti (2012) was applied to all glaciers in the Austrian Alps based on glacier extents and surface topography corresponding to the three Austrian glacier inventories (1969 - 1997 - 2006) with the aim to predict size and location of future proglacial lakes.

The availability of measured ice thickness data and a time series of glacier inventories of Austrian glaciers, allowed carrying out a sensitivity study of the key parameter, the apparent mass balance gradient. First, the parameters controlling the apparent mass balance gradient of 58 glaciers where calibrated glacier-wise with the aim to minimize mean deviations and mean absolute deviations to measured ice thickness. The results were analysed with respect to changes of the mass balance gradient with time. Secondly, we compared the observed to modelled ice thickness changes. For doing so, glacier-wise as well as regional means of mass balance gradients have been used.

The results indicate that the initial values for the apparent mass balance gradient have to be adapted to the changing conditions within the four decades covered by the glacier inventories. The gradients flatten from the first to last inventory. This is consistent with the decreasing deviation between glaciological and geodetical glacier mass balance when a period with negative mass balances results in decreasing ice dynamics.

The comparison of mean ice thickness changes between the Inventories reveals the effect of changes in glacier mass transport in addition to changes in glacier area and topography. 93% of the mean observed ice thickness change could be reproduced using the glacier-wise optimized mass balance gradients. More than 85% of mean ice thickness change was calculated from modelled ice thickness distributions with inventory mean optimized mass balance gradients. The ratio decreases to 60% the same parameters for all three glacier inventories and can be attributed to changes in glacier extent. Thus, the actual glacier mass turnover has to be considered to model glacier volumes based on glacier topography more realistically.

Huss, M., and D. Farinotti (2012), Distributed ice thickness and volume of all glaciers around the globe, J. Geophys. Res., 117, F04010, doi:10.1029/2012JF002523.