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Ice thickness distribution of all mountain glaciers around the globe using the GLIMS database and SRTM/ASTER DEMs

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Mountain glaciers and small ice caps are expected to remain an important component of the eustatic sea level rise in the coming decades. The ice volume of these more than 100'000 glaciers is normally estimated using volume-area scaling relationships. Volume-area scaling does, however, not account for the characteristics of individual glaciers, and does not yield any information about the spatial distribution of the ice thickness which is required e.g. for the transient modelling of glacier ice flow dynamics.

The GLIMS glacier database essentially provides 2D information about most mountain glaciers and small ice caps on the earth. This study proposes and applies a method for adding the third dimension to glacier inventories by inverting global digital elevation model (DEM) data to distributed ice thickness. This allows inferring additional glaciological variables that are vital for assessing the future retreat of glaciers around the globe and their contribution to sea level rise.

The method to estimate ice thickness distribution is based on glacier mass turnover and the principles of ice flow mechanics. Using glacier elevation bands evaluated from a digital elevation model, volume balance flux is calculated and transformed into an initial guess of the local ice thickness using Glen's flow law. In an iterative procedure, the basal shear-stress distribution and the shape factor is determined along the glacier until convergence is reached. Finally, mean thickness in each elevation band is extrapolated transversal to the topographic gradient including local surface slope. Thus, for each glacier ice thickness on a regular grid can be calculated. The only input requirements are a glacier outline (given by the GLIMS glacier database) and a DEM.

DEMs between 60°N and 60°S are available from the Shuttle Radar Topographic Mission (SRTM) with a spatial resolution of about 90 m. North and South of 60° the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) DEM (30 m resolution) is used. Based on these readily available data sets, thickness distribution and ice volume of all mountain glaciers of the GLIMS database is evaluated.

Inferred thickness distribution is validated against in-situ measurements (radio-echo sounding) on about two dozens alpine glaciers, and against additional ice volume data indicating a good agreement with field data. We present estimates of the ice volume in different mountain ranges and analyze the characteristics of the spatial ice thickness distribution, and its implications for future glacier wastage.