Geophysical Research Abstracts
Vol. 15, EGU2013-11226-1, 2013
EGU General Assembly 2013

Ice volumes in the Himalayas and Karakoram: evaluating different assessment methods

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Knowledge about volumes and the ice thickness distribution of Himalayan and Karakoram (HK) glaciers are required for assessing the future evolution, and estimating the sea-level rise potential of these ice bodies, as well as predicting impacts on the hydrological cycle. As field measurements of glacier thicknesses are sparse and restricted to individual glaciers, ice thickness and volume assessments on a larger scale have to rely strongly on modeling approaches. Here, we estimate ice volumes of all glaciers in HK region using three different approaches, compare the results, and examine related uncertainties and variability.

The approaches used include volume-thickness relations using different scaling parameters, a slope-dependent thickness estimation, and a new approach to model the ice-thickness distribution based only on digital glacier outlines and a digital elevation model (DEM). By applying different combinations of model parameters and by altering glacier areas by $\pm 5\%$, uncertainties related to the different methods are evaluated. Glacier outlines have been taken from the Randolph Glacier Inventory (RGI), the International Centre for Integrated Mountain Development (ICIMOD), and minor changes and additions in some regions; topographic information has been obtained from the Shuttle Radar Topography Mission (SRTM) DEM for all methods.

The volume-area scaling approach resulted in glacier volumes ranging from 3632 to 6455 km3, depending on the scaling parameters used. The slope-dependent thickness estimations generated a total ice volume of 3335 km3; and a total volume of 2955 km3 resulted from the modified ice-thickness distribution model. Results of the distributed ice thickness modeling are clearly at the lowermost bound of previous estimates, and possibly hint at an overestimation of the potential contribution from HK glaciers to sea-level rise.

The range of results also indicates that volume estimations are subject to large uncertainties. Although they are more labor intensive, distributed ice-thickness modeling approaches have the advantage of being based on simple but robust ice-mechanical considerations rather than on extrapolated statistical relations. Their major advantage is that they allow for more direct comparisons with in-situ measurements like, for instance, data obtained by ground penetrating radar. In combination with digital glacier outlines and DEMs with (near-) global coverage, they offer the possibility to improve ice-volume estimations of the HK region, but also of other glacierized mountain ranges.