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Interactive comment on "Ice volume estimates for the Himalaya–Karakoram region: evaluating different methods" *by* H. Frey et al.

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Congratulations for a most useful paper, which provides important quantitative information about a large number of glaciers in Asia and presents an instructive intercomparison of presently available methods for estimating thicknesses and calculating volumes of unmeasured glaciers. The study stimulated the following additional thoughts, which the authors may wish to consider.

Concerning slope-related models, Figure 9 documents the generally good agreement between flux-related estimates (HF-model) and stress-related approaches (GlabTop). This confirms the result from an earlier comparison by Linsbauer et al. (2012) between similar model calculations for the Swiss Alps calibrated by local GPR measurements. The uncertainty range of about $\pm$ 20 to 30% can be compared with the scatter in the

thickness-area plot (Figure 8), which appears to be at least twice to three times this amount. The final paper could elaborate a bit more and quantitatively on this important aspect as it seems to indicate a remarkable improvement with respect to the long-used area-related approaches.

A quantitative inter-comparison between numerical values of the thicknesses used for the volume calculations could also be informative. The volumes reported in Figure 5 indicate that area-related estimates result in mean thicknesses, which are considerably higher than those from slope-related approaches, which use or reflect average basal shear stresses for large glaciers of up to about 200 kPa. As mean thickness is proportional to the average basal shear stress for given glacier areas and mean slopes, the average basal shear stresses resulting from the here-reported area-related estimates are likely to be much higher than those from slope-related estimates, i.e. between 200 and 400 kPa. Such values appear to be extreme, even for high-stress maritime-type glaciers with large mass turnover (cf. the stress values calculated for Taku glacier in Figure 3 of Huss and Farinotti, 2012). Comparing mean glacier thicknesses rather than, or in addition to, comparing glacier volumes also facilitates the comprehension of what the differences mean in nature, for instance, with respect to the accuracy of ice depth measurements. The mean thicknesses resulting from the slope-related approaches seem to differ within a narrow range, possibly even within the uncertainty range of field measurements and corresponding inter/extrapolations, while area-related approaches appear to produce glacier thicknesses which are systematically beyond this range. It would be useful if the authors could add a table with mean thicknesses and briefly comment on it.

Glacier volumes are not measured – as reviewer 1 appears to assume – but calculated from quantitative information about glacier thickness determined at points or along profiles by drillings or geophysical soundings inter- and extrapolated, averaged or integrated over defined glacier areas. Independently of any theory or methodology, all glaciers used in area-related considerations evidently have a defined area, which is

contained in volume. To use volume/area relations, therefore, means to unnecessarily use glacier area in both variables of statistical correlations, in both axes of corresponding scatter plots and on both sides of predictive equations. The popular equation (1), for instance, primarily predicts glacier area from itself. Going back to thickness/area relations as originally used decades ago already (for instance, Müller et al., 1976) avoids corresponding artefacts and provides a much better impression of how quantitative estimates are done (weak statistical correlation) with what type of measured information (thickness and area) and what the quality of the applied data and their interrelationship may be. The authors are to be thanked to make this step (cf. also Cogley, 2012). Their example should be followed in general. Most importantly, however, slope-related approaches should now be recognized to probably provide more accurate results and to certainly offer much more promising perspectives (detailed bed topographies, comparison with local thickness measurements) than area-related estimates.

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