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Interactive comment on "An upper-bound estimate for the accuracy of volume-area scaling" *by* D. Farinotti and M. Huss

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Through a series of resampling experiments, authors evaluate the maximum accuracies associated with total volume, volume change and area change that can be inferred from volume-area (VA) scaling. This research supports the existing belief that the scaling method performs better when applied to a large number of glaciers. Another key finding is that higher accuracies are obtained when the scaling parameters are generated using a large number of VA pairs. This implies that it is difficult to constrain the scaling parameters locally (i.e., on mountain scale, because no glacierized region has sufficient VA pairs known, at least, for a few dozens of glaciers), and hence the VA method is best suited for the global application. There are other useful findings regarding, for example, the suitability of VA inversion technique to estimate area change and

so forth.

This manuscript is well written, although I think certain portions can be trimmed to make it shorter and more concise. Before I list these below, I point out a simple error made throughout the manuscript: authors constantly use the phrase "coefficients of the scaling relation", which in my opinion should be "parameters of the scaling relation", because c is the coefficient and γ is the exponent (or power; not the coefficient) of the VA relation depicted in Eq. (2).

Once authors revise the manuscript by addressing most, if not all, of my comments, I recommend that the manuscript be accepted for publication.

Major comments

Section 3.2: I don't see the logic of having experiments on "transition between steady states". Theoretically, the subset of glaciers in the initial steady states (time t_1) and that in the final steady states (time t_2) should behave in an exactly similar manner. In other words, for sufficiently large number of VA pairs, the scaling parameters associated with initial or final steady states should converge. The differences that you are depicting between "single" and "multiple" scaling experiments are mainly due to the fact that in former one you have twice as many VA pairs to constrain the scaling parameters. More interesting experiment would be a transition between initial steady states and final transient states, as considered by Adhikari and Marshall (2012).

Even for "transition between transient states" experiments, more systematic way of comparing performances of "single" and "multiple" scaling parameters is possible. In the present analysis, you have constrained "single" set of scaling parameters by lumping VA pairs at different transient states altogether. I think "single" scaling parameters should represent for initial (t_1) or final (t_2) transient states one at a time. This way, you would have equal number of VA pairs for constraining both "single" (you will get two solutions here, associated with each transient state) and "multiple" scaling parameters. This might lead to the different conclusions about the importance of "multiple" scaling

parameters. Conclusions could be a function of "degree" of transition (i.e., how far the glaciers are off the steady states).

Section 3.4: Experiments presented in this section are interesting, but I don't think these make useful statements and deserve publication. Main reasons include: (i) the assumption that the scaling law parameters must be constant in time may not be entirely true (at least until there is sound mathematical justification available), (ii) this method demands unnecessarily large number of dataset (e.g., glacier area in two time stamps, corresponding change in volume) than the VA method itself and hence prone to poor performance, (iii) reasonable choice of c and γ themselves is needed (but I think you can initialize these with positive c and γ; after all, you are optimizing these), and (iv) this method yields no better results, despite the associated complication described above. I advise summarizing the whole section in a few sentences without actually describing the equation and experiments in details. Last paragraph of the section (p. 2341; l. 1-10), after a bit of rewordings, should be just enough.

Minor comments

Title: The title of the manuscript should be revised: (i) include the phrase "maximum accuracy" instead of "upper-bound of accuracy", and (ii) be explicit to write "glacier volume-area scaling".

p. 2294, l. 11: "all measurements" currently available measurements?

p. 2294, l. 21: Write "Direct measurement of. . ." instead of "Directly measuring. . .".

p. 2294, l. 26: "thinning rates" should be "rate of change in surface elevation"?

p. 2295, l. 20: Delete "Amongst these simpler methods. . ." because you have not actually discussed about "simpler methods" in the previous paragraph. Instead, you have described the applicability of VA method itself (e.g., l. 18-19). So, write "In VA scaling method, glacier V is related to A by means of a power law".

p. 2295, l. 25: "two coefficients" should be "two parameters". Only c is a coefficient; γ

is a power or exponent. Make necessary changes wherever needed.

p. 2296, l. 15: "Insights are won" sounds awkward to me. Rephrase it.

p. 2297, l. 2: Write "estimate of maximum accuracy" instead of "upper-bound estimate for the accuracy" here and elsewhere.

p. 2297, l. 8: What value of c and γ did you use to generate v_{true} of $n_{true} = 171000$ synthetic glaciers? I don't think you have specified these.

p. 2297, l. 18: Is M a subset of T? I think so; specify clearly.

p. 2298, l. 5: "Note also that" instead of "Note as well that".

p. 2298, l. 15: Use Q or other symbol, instead of M' so that you will have $p \in T$ and $Q \in M$? Also define whether M' is subset of P? I think yes (refer l. 23).

p. 2299, l. 6: What is M'^c? I don't think intersection symbol is appropriate here.

p. 2299, l. 17: Suggest rephrase: "Example results of this experiment are shown in Fig. 1a, in which. . .".

p. 2299, l. 19: May be show a 30% accuracy line in the figure, to facilitate reading.

p. 2299, l. 23 onwards: It is perhaps the uncertainty noise has a normal distribution with zero mean? Too long a sentence to understand for me. Lines 1-2 on the next page is too puzzling to grasp. Please rephrase.

p. 2300, l. 9: "as" instead of "since"?

p. 2300, l. 27: For clarity, write ". . ..considered glacier population P".

p. 2301, l. 2: Write "(results not shown)" here and elsewhere.

p. 2301, l. 8: For clarity, write ". . . their assessment is based on. . ."

p. 2302, l. 5 onwards: "For example. . ." I don't think this statement can be made based on Fig. 1b. If I am correct, be explicit to include "(results not shown)" at the end of the

statement.

p. 2304, l. 1: How do you control ELA in ice flow model, such that you get AAR = 0.57?

p. 2304, l. 4-14: Bring this discussion up on the page 2303 (l. 17) where you first talk about the ice-flow model.

p. 2304, l. 15: "declared?" I think "considered" would be better term.

p. 2306, l. 14: For sufficiently large number of steady-state VA pairs, I don't think you would obtain different set of scaling parameters no matter at what time (i.e., t_1 or t_2) glaciers attain steady states.

p. 2306, l. 16: I don't think intersection symbol is appropriate here. Again, what is superscript ^{C} for?

p. 2307, l. 14-15: This sentence is incomplete. You have used all data set to determine "time independent" scaling parameter. Adhikari and Marshall (2012) compare "time varying" parameters vs. those based on steady-state VA pairs.

p. 2308, l. 10: The discussion #2 should be mostly based on Fig. 3b instead of Fig. 3a.

p. 2309, l. 8: But, the point is that the so-called constant parameters you have used are based on the VA pairs of glaciers at both time stamps. If you use VA based on one time-stamp and assume it constant, results and conclusions may be other way around.

p. 2309, l. 8: "a positive effect on the accuracy"? You mean increase in accuracy? Rephrase it.

p. 2309, l. 24: Delete "some".

p. 2311, l. 14: "between steady-state geometries than between transient states". Plot Fig. 4a and 4b in a single plot. This makes comparison easier.

p. 2311, l. 16: Write "100 % (or 10%)" instead of "100% (10%). Make necessary

changes in other places as well.

p. 2311, l. 20: To depict this more clearly, use same x- and y-axis range and draw a diagonal in Fig. 4.

p. 2311, l. 22: "within a factor of two"? 100% uncertainly may correspond to a factor of half as well, right? To avoid potential confusion, just write "uncertainty %" instead of a "factor" here and elsewhere.

p. 2311, l. 26: Write "(or with an uncertainty. . .)".

p. 2311, l. 28: Write "Thus, in general, . . ." instead of "rule of thumb".

p. 2313, l. 27 "volume changes".

p. 2314, l. 15-16: "the previously estimated confidence. . . . . .confidence intervals need widening" is too difficult to understand. I would suggest rephrasing it.

p. 2315, l. 23: Worth citing Adhikari and Marshall (2012) here, who demonstrate that the stable values of scaling parameters are obtained only for large sample size (>100).

p. 2317, l. 18: Write ". . .seems to be reasonable only when. . .".

p. 2317, l. 20: Write "corresponding" in place of "according".

References

Adhikari, S. and Marshall, S.: Glacier volume-area relation for high-order mechanics and transient glacier states, Geophys. Res. Lett., 39, L16505, doi:10.1029/2012GL052712, 2012.

Interactive comment on The Cryosphere Discuss., 7, 2293, 2013.