**The Cryosphere
Discussions**

Interactive comment on "Density assumptions for converting geodetic glacier volume change to mass change" *by* M. Huss

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This manuscript presents a sensitivity study for the assumption of "Sorge's Law" for the densification of firn. The basis of the modeling study is to then compute the individual components that make up the conversion factor relating volume changes to mass changes, namely Δ, ΔV, and V. Dynamic changes are not accounted for (Pg 224/4-5) which would require coupling to an ice-flow model. The mass balance forcing is derived from mass balance gradients with elevation and then coupled with a simple H-L densification model. The experiment is mainly applied to idealized glacier geometries of a constant width. It is a very nice study that exemplifies the sensitivity of geodetic mass balance estimates to assumptions about the conversion factor especially relevant for

rather short-term geodetic measurements. Another interesting and re-assuring finding is that the sensitivity decreases significantly for longer-term geodetic measurements where the conversion factor (fΔv) approaches the density of ice.

There are however a number of reasons that make the title and conclusions of this study misleading.

- First, eq. 4 and the model applied only refer to land-terminating glaciers. This derivation of a conversion factor requires that mass is conserved and the modeling approach is basically solving for variations in the glacier wide average density through time. For marine terminating glaciers, a (often large) proportion of the volume change may be through calving which would raise the conversion factor.

- Second, since the idealized glacier geometry contains only constant glacier widths (slab of ice), it is difficult to assess how applicable these results are to geodetically measured volume changes of real glaciers with significantly varying geometries. For example, it is stated on Pg 233 (Line 6-7) that "the area-elevation distribution of the glacier has a minor influence on fΔv." How could these experiments lead to this conclusion when glacier width is held constant? It could be expected that the accumulation area ratio (AAR) has a large influence on this factor as it defines approximately the magnitude of the firn volume in relation to the total glacier volume and we assume that the larger the AAR the larger sensitivity on volume to mass conversions using a constant. Thus, the results obtained from idealized glacier geometry may not be explicitly applicable to geodetically measured volume changes of real glaciers.

- The abstract and conclusions of this study suggest (even recommend!) a constant conversion factor of 850 $\pm$ 60 kg m-3. Where does this number come from? Interpreting Figure 4 and 5 shows that the conversion factor is not at all constant, but rather varies significantly the shorter the time interval between geodetic acquisitions. In fact, the error bar on the conversion factor will also vary significantly with time. It would be beneficial, and possible with the data in this study, to calculate a variable error of

the density conversion dependent upon time. Then readers may get an idea of the magnitude potential of such errors in their data given the time span between geodetic surveys.

To summarize, it is difficult (and dangerous) to suggest and apply the constant conversion factor directly to any geodetically measured volume change. Results of this study show that the conversion factor varies greatly for short time periods between geodetic measurements and supposedly if more realistic glacier geometries and a more sophisticated densification model had been used, this variation may increase even more. In addition, only land terminating glaciers are represented in this study. Therefore, the title claiming to assess "density assumptions for converting geodetic volume changes to mass changes" does not describe what is actually accomplished in this study. One title suggestion: "Sensitivity of assuming Sorge's Law for converting volume to mass changes of land terminating glaciers".

We think the results would allow analyzing a hitherto unexplored point, namely to separate the effects on bulk glacier density related to changes in the firn volume, ΔV_{firn}, from those caused by changes in the firn density, $\Delta firn$. The outcome may have important implications: if changes in $f\Delta V$ were dominated by ΔV_{firn}, the costly (and uncertain, see comments by Referee #1) computation of $\Delta firn$ could be omitted. ΔV_{firn} may be estimated using remote sensing methods (at least the change of firn area). This would open possibility for a more accurate conversion from ΔV to ΔM than relying on a single constant $f\Delta V$.

Minor Remarks:

- Pg 226-227: Maybe list the experiments in bullets. This would aid the reader easily recover what exactly is being done in Figure 4.

- Section 3.2., Fig 5: Which mass balance series was used for Silvrettagletscher? Was it the homogenized series or the series that did not fit with the geodetic assessments? In both cases, I do not understand how then the conversion factor was calculated since

both series are either no longer independent, or that the two series are significantly different.