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

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The point raised by W. Colgan is an interesting question indeed. However, I don't think I am able to address it in a well founded way with the available data basis and methods presented in this paper.

To estimate bulk density changes due to crevassing, one needs to know the *increase* in crevasse volume (voids inside the glacier ice that are invisible (!) to the geodetic survey) over long time scales (i.e. the period between repeated digital elevation models) which seems to be quite difficult to measure. An increase (or a decrease) in crevasse volume implies a change in glacier dynamics. Furthermore, the crevasse frequency and the approximate ice thickness would need to be known to estimate changes in bulk ice density. The estimation of density changes due to crevassing is thus strongly variable

between sites and depends on the characteristics of the individual glacier. Providing a general, "theoretical" number is not possible. As stated in the paper, this effect would need to estimated for each study site specifically based on direct field observations of crevassing.

For these reasons, I do not intend to include a more quantitative assessment of this topic in the paper. However, I try to provide some rough order-of-magnitude estimates in the following:

Let us consider a glacier with an average thickness of 100 m and a crevasse frequency of 0.05 m^{-1}. Crevasses are assumed to have a width of 1 m decreasing to 0 m at a depth of 20 m. The bulk glacier density change for a 0.5% a^{-1} growth of the crevasses (an upper bound according to Colgan et al., 2011) and a 10-year time period equals $\Delta\rho$=–0.225 kg m^{-3}. This assumes that crevasses everywhere on the glacier have grown, i.e. also in the accumulation area. The value thus again represents an upper bound.

By introducing $\Delta\rho$ into Eq. 4 of my paper, the impact of changes in crevasse volume on $f_{\Delta V}$ can be estimated. First, no changes in the firn density profile and firn thickness are assumed. $f_{\Delta V}$ is higher than ρ_{ice} in the case of crevasse enlargement, and smaller than ρ_{ice} for a reduction in crevasse volume. Depending on the magnitude of ΔV, the effect is small ($f_{\Delta V}$=920 kg m^{-3} for mean annual mass balances of –0.1 m w.e. a^{-1} and crevasse enlargement) to almost negligible for more important volume changes. Furthermore, if we superimpose firn volume and density changes in the calculation of bulk density in Eq. 4, it becomes evident that the firn densities will dominate the effects due to opening/closure of crevasses.

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