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Converting geodetic glacier volume change to mass change – an uncertainty assessment

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Determination of glacier mass balance via the comparison of two terrain elevation models is one of the most popular, and most accurate methods to monitor glacier mass change over periods of a few years to some decades. However, the differencing of elevation models provides a change in glacier volume instead of a mass change which is the relevant quantity for climate impact studies. Observable glacier volume change is usually converted to a mass change using a straight-forward density assumption that has received little attention so far, and can represent a significant uncertainty in geodetically determined mass balance.

This study investigates the factor to convert geodetic volume change to mass change based on a firn compaction model applied to simplified glacier geometries with idealized climate forcing, and two glaciers with long-term mass balance series. It is shown that the 'density' of geodetic volume change is not a constant factor and is systematically smaller than ice density in most cases. This is explained by the accretion/removal of low-density firn layers, and changes in the firn density profile with positive/negative mass balance. Assuming a value of $850\pm60\,\mathrm{kg\ m^{-3}}$ to convert volume change to mass change is appropriate for a wide range of conditions. For short time intervals ($\leq$3 years), periods with limited volume change, and/or changing mass balance gradients, the conversion factor can however vary from 0-2000 $\mathrm{kg\ m^{-3}}$ and beyond, which requires caution when interpreting glacier mass changes based on geodetic surveys.