Supplement to: Calibration of a frontal ablation parameterization applied to Greenland's peripheral calving glaciers

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S1 MODEL RESULTS WITHOUT GLACIERS THAT HAVE A $q_{\text{calving}} = 0$ AFTER THE k CALIBRATION

Besides the 11% of PGs that do not produce a frontal ablation flux under any k value from the range 0.01 to 3.0 yr^{-1}, we have additional glaciers that have a $q_{\text{calving}} = 0$ after constraining the k parameter with the methods and data described in Sect. 4. In this section we show the calibration methods performance if we remove these extra glaciers from the results of Sect. 6. Figure. S1 shows the same data as Figure. 8 but keeping only glaciers that produce a frontal ablation flux after adjusting the k parameter. The correlation (r^2) between OGGM velocities and MEaSUREs velocity observations (Joughin and others, 2016) is now 0.72, when the calving parameterization is constrained using that same data input (see Fig. S1a). OGGM velocities correlates to the ITS_LIVE (Gardner and others, 2019) velocity observations with a r^2 =0.71, when using that same data set to calibrate the calving parameterization (the p-values of both correlations are smaller than 0.05) and there is no overestimation of the surface velocity at the calving front (see Fig. S1b). However, there is still an underestimation of velocities for some of the glaciers due to the model

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constraint of keeping the temperature sensitivity μ^* of the glaciers above zero. When the frontal ablation flux found by the calving law after constraining the k parameter is too large and cannot be sustained by the modelled surface mass-balance (m_{31}), μ^* is fixed to zero and the frontal ablation flux is obtained by closing the mass budget (using Eq. 1 and 6) instead of using the calving law (Recinos and others, 2019). In other words, even if the satellite velocity observations suggest that a higher flux at the terminus is needed for such PGs, the frontal ablation flux for each individual tidewater glacier in OGGM cannot be larger than its annual accumulation (P_i^{solid} in Eq. 5). This model constraint is not ideal, since it implies that all of the glacier's ablation in an equilibrium setting is due to frontal ablation and no surface melt can occur along the glacier, which might be unrealistic in some of the climate conditions for some PGs. However, in most cases it is possible to find $\mu^* > 0$ compatible with a frontal ablation flux, as shown in Figures. S1a and c for glaciers (blue and green circles) that fall on top of the grey regression lines, representing a perfect correlation. For RACMO derived model results, the coefficients of determination (r^2) are still low when compared to the velocity method if we remove this group of glaciers. Model surface velocities derived by constraining the calving parameterization with the RACMO method weakly correlate with MEaSUREs and ITS_LIVE observations, with OGGM mostly underestimating the velocity for such glaciers (Fig(s). S1b and d).

S2 GLACIERS WITH NO CALVING SOLUTION

The model does not produce a frontal ablation flux for ∼11% of the glacierised area of interest. These glaciers do not calve under any k value, from a range between 0.01 to 3.0 yr^{-1}. For these glaciers, the flux estimated by the calving law on any k value (Eq.7 of Sect. 3.3) is too large to be sustained by the surface mass balance and there is no solution to Eq. 9: $q_{\text{calving}} \neq q_{\text{deformation}}$. Like the glaciers in the previous section (S1), even without surface melt ($\mu^* = 0$), the total accumulation over the glacier is too small to close the frontal mass budget. This can be due to different factors, generally speaking either frontal ablation is overestimated (in all k values including those constrained by observations), or solid precipitation is underestimated. The frontal ablation can be overestimated, e.g., if k and/or the calving law does not represent the dynamics of that particular glacier, or if h_{f} is overestimated. Further investigation is needed for these glaciers, to determine the nature of the problem (input data errors or model concept errors). Such analysis requires more observations to constrain the model, such as terminus positions and/or bathymetric data as shown in Recinos and others (2019). Unfortunately, this falls beyond the scope of this study

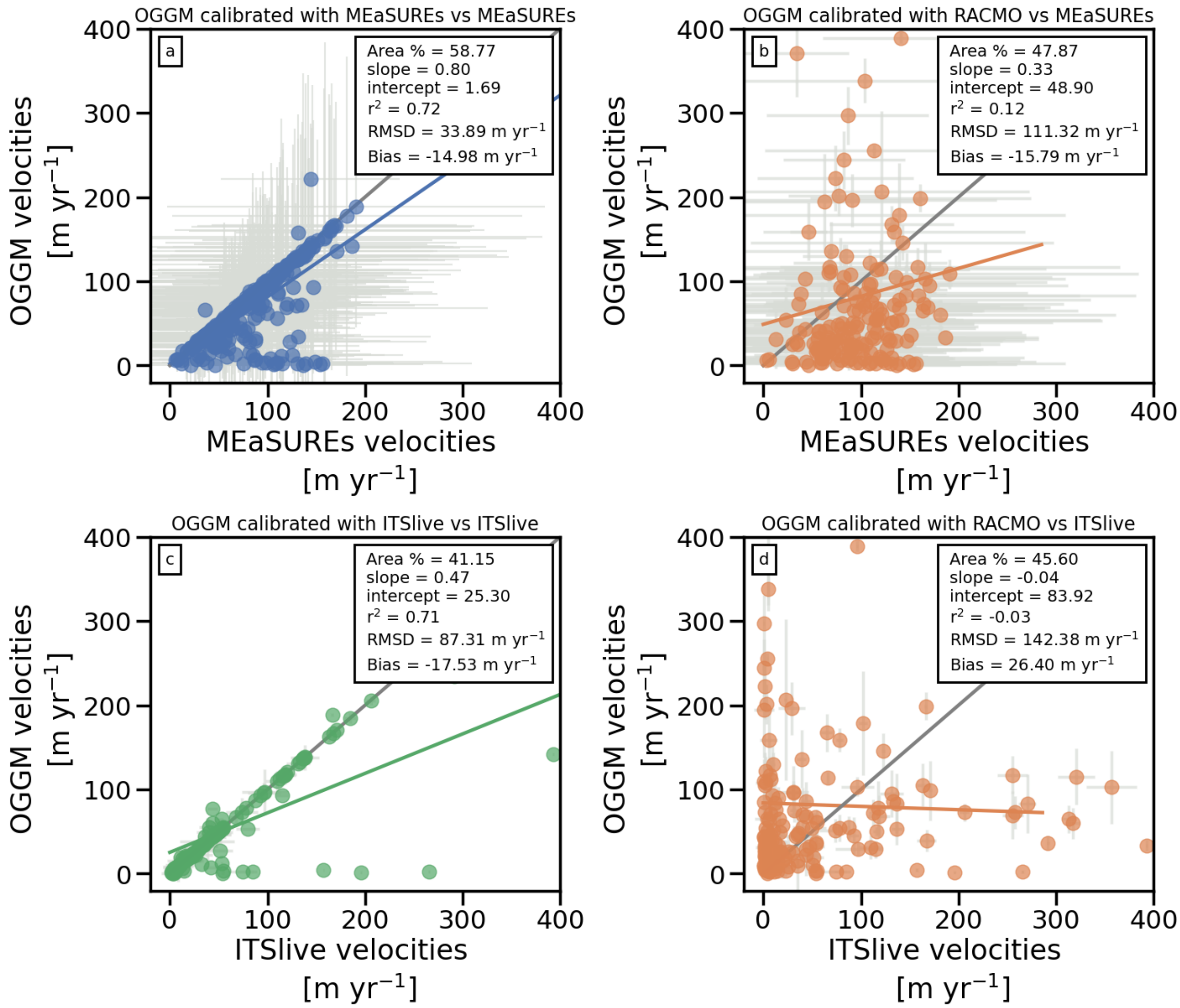

Fig. S1. Model performance. **a and c:** comparison of modelled (after calibrating k with the velocity method) and observed surface velocities from MEaSUREs (**a**) and ITS_LIVE (**c**). **b and d:** comparison of modelled (after calibrating k with the RACMO method) and observed surface velocities from MEaSUREs (**b**) and ITS_LIVE (**d**). Regression lines (solid lines) and statistics are shown in the upper right corner, i.e. % of study area represented in the graph, regression slope, intercept, coefficient of determination (r^2), RMSD and bias. P-values are all smaller than 0.05. Grey solid lines represent slopes equal to 1 and intercepts equal to zero and in all scatter plots uncertainty bars are plotted in light grey.

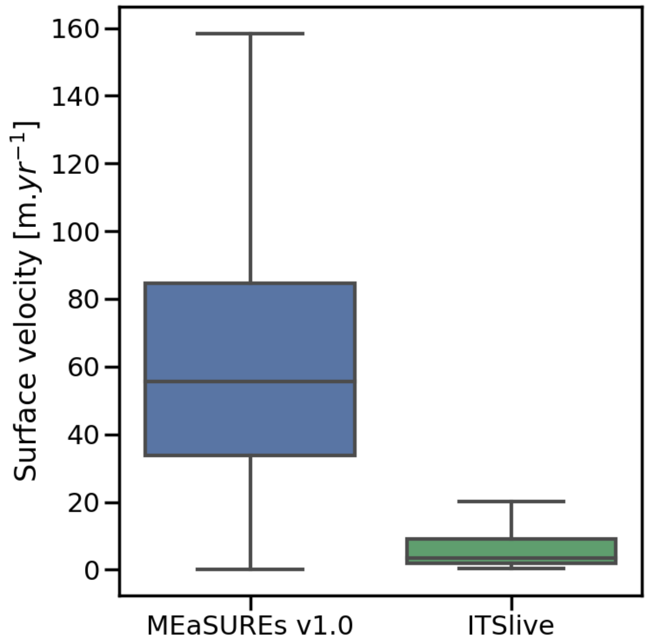

Fig. S2. Surface velocity estimates at the last one third of the glacier flowline extracted from MEaSUREs (blue box plot) and ITS_LIVE (green box plot) for glaciers which have no calving solution to Eq. 9. The width of the boxes represents the inter quartile range (IQR) of the data values. The line dividing the boxes represents the median. The whiskers represent the range of values for 99.3% of the data. Points outside this range only contain 0.7% of the values distribution and are not shown in the figure.

but it will be addressed in future versions of OGGM. Finally large uncertainties might also arise from the fact that the calving parametrization implemented here is mostly representative of tidewater glaciers with a grounded terminus. PGs might also include extensive shelf ice areas, with floating parts, such a setting is not accounted for in the current frontal ablation parameterization of OGGM. For these glaciers we also extracted velocity observations along the last one third of the flowline, Figure. S2 shows that for the ITS_LIVE data set, the majority of these PGs have observed surface velocities within 1.83 to 9.06 $\mathrm{m\,yr^{-1}}$, which implies that frontal ablation fluxes in reality for these PGs should be equal or close to zero, as suggested for the model and the ITS_LIVE data. On the contrary, the MEaSUREs data set shows different velocity estimates for the same group of glaciers, suggesting these PGs should produce a frontal ablation flux.

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