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Simulating the Greenland ice sheet under present-day and palaeo constraints including a new discharge parameterization

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Total mass balance and mass conservation

We present here a short treatise on the total mass balance of our model to show that it is mass conservative. The total mass balance reads

$$\frac{dV}{dt} = P - R - D, \tag{S1}$$

where V, t, P, R and D are ice volume, time, total precipitation, total runoff and total ice discharge, respectively. In Eq. (S1), the total ice discharge can be decomposed as

$$D = D_{\mathrm{expl}} + D_{\mathrm{par}}, \tag{S2}$$

with the explicit total ice discharge D_{expl} simulated by SICOPOLIS and the parameterized total ice discharge D_{par}, as explained in the main text. Runoff is also comprised of different components

$$R = P_{\mathrm{r}} + M_{\mathrm{i}} + M_{\mathrm{s}} + M_{\mathrm{b}} - F \tag{S3}$$

where P_{r} is liquid precipitation, M_{i} is the total melted ice, M_{s} is the total melted snow, M_{b} is the total basal melt under the ice sheet, and F is the frozen water including the frozen rain and the refrozen melt.

We also define the residuum (or error) in total mass balance via Eq. (S1) as

$$\mathrm{Res} := \frac{dV}{dt} - (P - R - D). \tag{S4}$$

As we measure all quantities in Eq. (S4) in temporal change of mass (Gt/yr), the equation allows an assessment of mass conservation of our model.

Figure S1, displays the most important components of simulated total mass balance as given in Eq. (S1) and (S4). For simplicity and because D_{expl} is small – as supported by observations revealing that most ice discharge appears via narrow outlet glaciers (Rignot and Mouginot, 2012) – we display the sum of all ice discharge (Eq. (S2)), as for runoff. All displayed components of total mass balance can change considerably during the glacial cycles. While runoff becomes zero during glacial times, there is still ice discharge. During the Eemian, the ice volume changes remarkably. Not so for present-day, which justifies a steady state assumption for pre-industrial time. Most importantly, the residuum of all total mass balance components is always very close to zero. Although not absolutely perfect due to numerics, our model conserves total mass with sufficient accuracy.

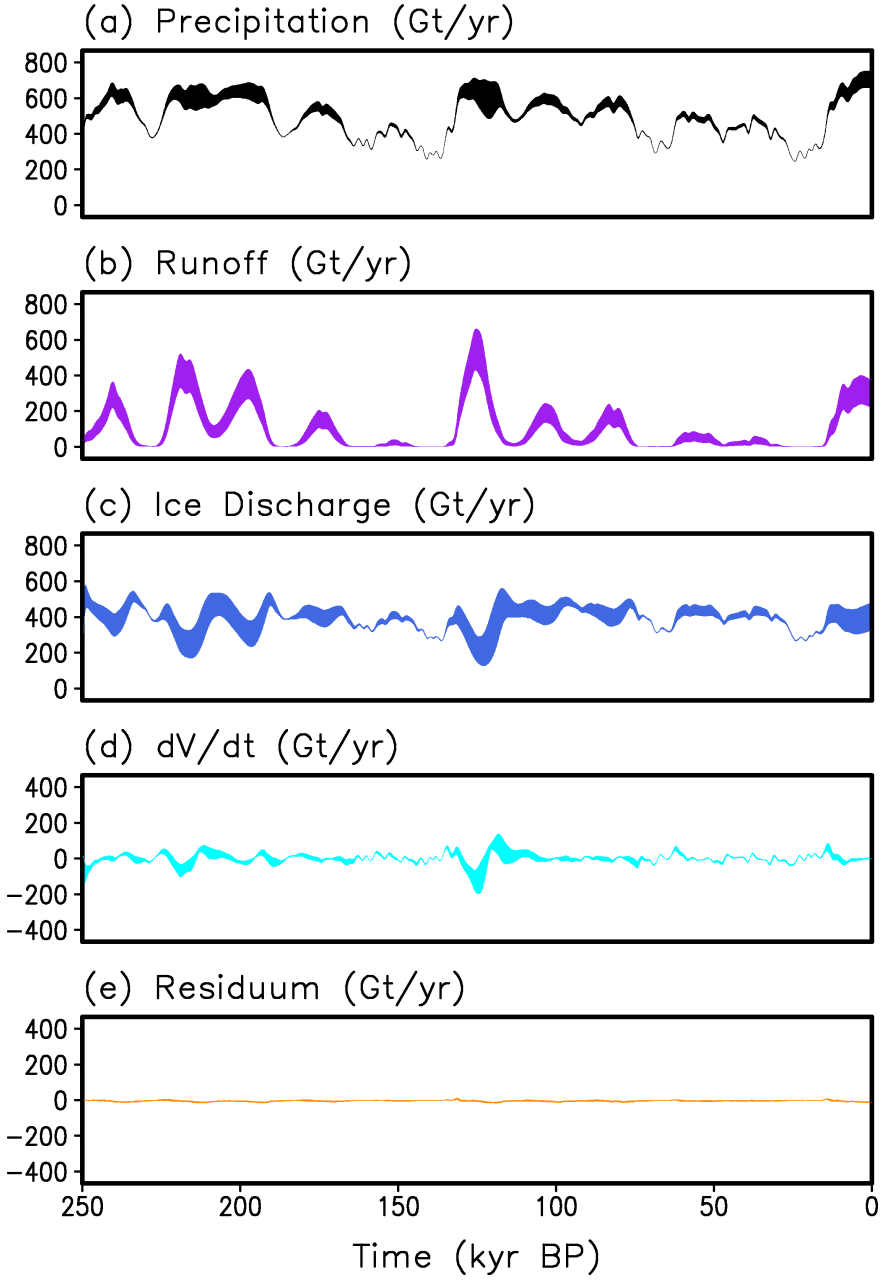

Fig. S1. Elements of total mass balance in Gt/yr during the last two glacial cycles from the valid simulation described in the main paper. The shaded areas in the respective panels are created via plotting a shading between the individual lines of each valid simulation. **(a)** Total precipitation, **(b)** total runoff, **(c)** total ice discharge, **(d)** temporal change in ice volume and **(e)** residuum of total mass balance, see Eqs. (S1) and (S4). For additional explanations, refer to text of this supplement.