

Additional comments on ‘Sensitivity of Totten Glacier dynamics to sliding parameterizations and ice shelf basal melt rates’.

Dear Yiliang Ma et al,

Thank you for this much improved manuscript, and taking many of our concerns into account. I would like to recognize the hard work (and computational expenses) the authors put in extending their simulations to 2100.

I have some additional minor comments, with the most emphasis on convincing me that your setup does not show, or shows very little, model drift. If there is drift (not unexpected when doing a data-assimilation initialization) I would like to see it quantified and discussed in how it affects your results and conclusions.

Ln 34: I would add (Schoof, 2012) as a reference to MISI here

Ln 126: You use time-varying SMB fields from CESM2 – CMIP6 ensemble, right? If so, please specify that you use 1995- 2100 CESM2 annually varying SMB fields (and, if space allows, include a plot to show what the SMB looks like over the modelled period)

Ln 146: ‘Version 9.0.’ should be mentioned before the citation and after ‘Elmer/Ice’

Ln 154 – 165: I am still seeing poorly-loaded question marks for the symbols used in your equations. I’ve added a screenshot below here. I double checked if this was due to my version of Adobe Acrobat and it was not. Please make very sure during the typesetting process that the symbols are represented correctly.

where $\mathbf{T}$ is the deviatoric stress tensor, p is the isotropic pressure, ρ_i is ice density, $\mathbf{g}$ is the acceleration due to gravity $(0, 0, -9.81) \text{ m s}^{-2}$, and $\mathbf{v}$ is ice velocity. The effective viscosity, η , for the ice-rheology,

$$\tau = 2\eta\dot{\epsilon}, \quad (3)$$

given by Glen’s flow law (Cuffey and Paterson, 2010),

$$\eta = \frac{1}{2} (E \cdot A(T))^{-\frac{1}{n}} \dot{\epsilon}_e^{\frac{1-n}{n}} \quad (4)$$

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is dependent on ice temperature via the flow rate factor $A(T)$, defined by an Arrhenius equation. We use an exponent of $n=3$. $\dot{\epsilon}$ denotes strain rate and the term $\dot{\epsilon}_e = \sqrt{tr(\dot{\epsilon}^2)/2}$ is the effective strain rate. The ice temperature distribution comes from the output of ice sheet model SICOPOLIS (Greve et al., 2020). We introduce $\kappa = \eta_0 / \eta$, to obtain

$$\eta = \frac{1}{2} E_0^{-\frac{1}{n}} \cdot A(T)^{-\frac{1}{n}} \dot{\epsilon}_e^{\frac{1-n}{n}} \quad (5)$$

which ensures $\eta > 0$ for any value of κ . We refer κ to as the 2D vertically constant stress enhancement factor which is set initially to unity everywhere, indicating no stress enhancement, before performing the viscosity inversion. The enhancement factor is often used to account for anisotropy effects (Ma et al., 2010). Values of $\kappa < 1$ indicate softer and faster deforming ice, whereas higher values, $\kappa > 1$, mean stiffer ice.

Ln 189: try to avoid starting sentences with a parameter symbol. You could change this to ‘The parameter A_s’

Ln 189: ‘is the sliding parameter without cavitation’ does not make it clear to me what the parameter does, what its value is, or what its units are. A general comment on this

section: consider adding a table at the beginning or end of this chapter where you list all parameters, their units, and their values used.

Ln 205 – Ln 210: the rewriting of free parameters in friction laws has been done by (Brondex et al., 2017), please refer to that paper here in this paragraph as well.

Ln 210 – Ln 234: The same questionmarks appear as shown in the screenshot earlier. Please pay special attention when compiling the final manuscript

Ln 265 – Ln 279: I would write this part directly after Ln 244 – Ln 250. In that way, the flow of text would be more logical e.g. ‘In shallow water we use...’, ‘in deep water we use ...’ and then ‘The WAOM estimates...’

Ln 298 – 315: could you quantify or show if there is any model drift in the final initialization you used? Is this setup robust? I would like to see a line added to Fig 9 representing a simulation starting from 2015 and remaining unforced, or, if you do not want to change your main text too much, see it added to the supplementary materials. I would like to see that your setup is not drifting from 2015 – 2100 and that you can attribute all changes in TG’s geometry to changes in basal friction and/or basal melting.

Ln 298 – 315: related to that, it would be good state in this section what happens with the basal melt rate during the initialization procedure of Gladstone and Wang (2022) and during your 1 year relaxation (I assume they are kept constant). In that way you can state explicitly (related to the previous comment): ‘during our initialization we used basal melt rates from ... /shown in supplementary material, and when starting a continuation run we immediately switch to Keeping the melt rates and the basal friction constant and running forward to 2100 did not introduce model drift, as shown in Fig (S) ...’

Ln 336: Please avoid starting sentences with parameter symbols

Ln 337: ‘show a rib like pattern’

Ln 337: ‘regions’

Ln 338: ‘it does not directly give us the cause’.

Ln 339: The dot after the references appears as red to me. Is this a track-change left in the document?

Ln 340: I would replace ‘unity’ with just ‘one/1’

Ln 342: Xi varies from 0.3 – 0.5 (what units?) and then increases to 0.3 – 0.5? This repetition of values seems like an error to me

Ln 393: You could also argue that the rib-like pattern is caused by other errors in the ice sheet modelling process and/or by the use of non-coherent datasets, as described by (Berends et al., 2023)

Ln 407: ‘might be because’

Ln 495: Did you also run with the same 1-year relaxation period?

Ln 510: Cluster specific details are not necessary here in my opinion. Stating that Blatter Pattyn is 15 times faster would be sufficient.

521: Or, the structures arise as compensating errors to other missing processes or uncertainties in datasets, see my comment on Ln 393

Ln 571: This is not true, the rewriting was done first by (Brondex et al., 2017)

References

- Berends, C. J., Van De Wal, R. S., Van Den Akker, T., & Lipscomb, W. H. (2023). Compensating errors in inversions for subglacial bed roughness: same steady state, different dynamic response. *The Cryosphere*, 17(4), 1585-1600.
- Brondex, J., Gagliardini, O., Gillet-Chaulet, F., & Durand, G. (2017). Sensitivity of grounding line dynamics to the choice of the friction law. *Journal of Glaciology*, 63(241), 854-866.
- Schoof, C. (2012). Marine ice sheet stability. *Journal of Fluid Mechanics*, 698, 62-72.