# Referee #1: Mathieu Morlighem

First, we would like to thank Mathieu Morlighem for his insightful comments on our paper.

## General comments

This is a very important topic that has not received a lot of attention so far. The paper is well written and easy to follow. I don't have any major comment but a few suggestions outlined below.
First, three friction laws are used:

- Linear Weertman ($m = 1$)
- Nonlinear Weertman ($m = 1/3$)
- Nonlinear Budd ($m = 1/3$)
- Nonlinear Schoof ($m = 1/3$ and $C_{max} = 0.4$)
- Nonlinear Schoof ($m = 1/3$ and $C_{max} = 0.6$)

I understand that the authors cannot run every possible combination, but it would be great if they could include the friction laws that are commonly used in the ice sheet modeling community. The linear Budd law ($m = 1$), for example, is extensively used by multiple groups (ISSM, UW, etc), much more than the nonlinear Budd law. It would be great to see how it compares with respect to other laws. These experiments could also be useful for intercomparison projects such as ISMIP6 in order to better understand the differences in model projections, but this would only be possible if common laws are tested. Also, why is the Budd sliding law only tested with one of the inferred initial states? Is it a problem of computational resources? It feels like the analysis is incomplete.

We acknowledge that the linear Budd law is extensively used in the modelling community as well. Therefore, we have decided to test this law too, but for the inferred state $I_{R\gamma,100}$ only. Indeed, given the size of the domain and the mesh refinement required to capture the main flow features, we had to split the computational domain in 24 partitions and to affect 4 CPUs to each partition so that simulation durations were not too long. As a consequence, running a 100-year pronostic simulation for one particular combination inferred state/friction law/pronostic experiment (i.e. ABMB or CONTROL) costs around 11000 hours CPU. Since the Budd law induces a depence of $|\boldsymbol{\tau}_b|$ on $N$ over the whole ice sheet, even in its interior where a drainage system may not be present, and since it does not imply any upper bound on the value of $|\boldsymbol{\tau}_b|/N$, we consider the Budd law as being the least physically acceptable one among all the tested laws. This is the reason why we have decided that both the linear and non-linear Budd laws would be tested for $I_{R\gamma,100}$ only, which is the most physically acceptable inferred state. Information regarding the computational cost of transient simulations, as well as explanations regarding the reason why the Budd laws are tested for $I_{R\gamma,100}$ only, have been added to the manuscript.

## Specific comments

Lots of comma missing before "which" and "where".

Commas have been added before some of the "which" and "where".

- p1 l3: to a schematic perturbation → to a prescribed perturbation
- p1 l11: much higher → significantly higher
- p1 l21: trustworthy → reliable
- p1 l21: modelling of GL dynamics ...
- p1 l22: as close as possible to observations.
- p2 l1: have come up → have been developed
- p2 l7: have shown that, at large strain, the till ...

- p2 l13: behaves very similarly → behave similarly
- p2 l27: schematic perturbation → prescribed perturbation
- p2 l28: consider removing "To reach our goal,"
- p2 l33: we apply a synthetic perturbation to the basal melting rate under floating ice, to the different...

We followed your suggestions for all the points listed above.

- p3 Figure 1: label Cosgrove ice shelf on the figure (in green)

Figure 1 has been modified to add the name of all ice shelves (in black).

- p3 eq 1: double check but given your definition of $\tau_b$, the sign in front of $\tau_{b,x}$ and $\tau_{b,y}$ should be +.

You are right, this was a mistake, which has been corrected.

- p3 eq 2: Did you forget to divide the integral by the ice thickness H?

We think that the way $\bar{\eta}$ was defined in the first version of the manuscript was consistent with the way it was used in Eqs. (1) and (13). However, given your comment and the one of Referee #2, we have decided to redefine $\bar{\eta}$ as being the vertically averaged effective viscosity, which now reads $\bar{\eta} = \bar{\eta}_0 D_e^{(1-n)/n}$, with $\bar{\eta}_0 = \frac{1}{H}\int_{z_b}^{z_s} \frac{1}{2} A^{-1/n} dz$. Eqs. (1) and (13) have been corrected accordingly.

- p5 l6: I think $a_s$ should be defined as the surface mass balance instead of just the accumulation rate (it may be negative in some places). That's how it is defined in p6 l9
- p6 l12: these two pinning points ... to be critical because of the ...
- p6 l27: being submitted → undergoing
- p7 l18: impurity content
- p7 l18: the question is whether

We followed your suggestions for all the points listed above.

- p9 l22: initializing the friction based on driving stress was first proposed by Morlighem et al. 2013

The reference has been corrected.

- p10 l11: the coefficient of other laws, which ...
- p10 l30: all over the model domain
- p11 l14: rephrase "are submitted to", maybe "the 13 initial states are then run for 105 years under two different scenarios: (1) ..."

We followed your recommendations for all the points listed above.

- p13 l17 seldom exceeds 10 % → rarely exceeds 10% (no space between before a percentage sign)

This has been corrected and we have also removed all the spaces before percentage signs.

- p13 l24 significative → significant
- p13 l32: focus on → focuses on
- p14 l11: Independently → Irrespective
- p14 l16: all over the 105 a → over the entire 105 a
- p15 l32: as going further → as we go further

- p17 l10: the lower ... the higher
- p17 l18: an increase in ice velocities
- p17 l23: as going further → as we go further
- p17 l32: as Thwaites glacier is mostly unconfined
- p17 l35: a MISI likely initiates
- p19 l4: The perturbation experiments

We followed your suggestions for all the points listed above.

- p19 l16: You have not really shown that a subglacial hydrology model is needed here, maybe rephrase the sentence

The sentence has been modified.

- p17 figure 8: increase the width of the grounding lines

This has been done.