Author replies reviewer #2

Author replies are in blue

I appreciate the authors' efforts in responding to the previous comments and in improving the clarity of the results section, which is now much easier to follow. I also understand that, following the removal of the FEFI initialisation, the authors sought an alternative initial state that would allow them to preserve the key messages of the study.

However, I am puzzled by the current comparison between the simulations starting from the P05 and P1 initial states for the power law case. Because the power law is independent of N, and therefore of p, the P05 and P1 initialisations should theoretically produce identical initial states and thus identical forward simulations. The differences presented here stem entirely from the fact that the initial states were first generated using the Zoet–Iverson law (with p = 0.5 and p = 1), and only then rescaled to a power-law-equivalent friction field. While I understand that the authors aim to assess the influence of initialisation choices on the friction field and subsequent simulations, I am not yet convinced that this comparison is meaningful. I believe this point needs to be discussed and more clearly justified in the manuscript.

Once this issue is addressed, together with the specific comments listed below, I consider the manuscript suitable for publication in The Cryosphere.

We thank the reviewer again for their thorough look through our manuscript and agree that it needs to be better explained that we do two initializations, both with the ZI and start the powerlaw simulations from them by rewriting the free parameter in the powerlaw. This indeed implies that the P1 and P05 simulations done with the powerlaw differ because of their slightly altered initial state acquired through an initialization with the ZI law. We would also like to stress that these two distinct initializations and their subsequent evolutions are not intended to produce the most accurate possible future projections. Rather, they are designed to generate two physically plausible ice-sheet evolutions, plausible in the sense that, if the bedrock state matches current estimates, the simulated evolution is as realistic as current models allow. Together, they demonstrate that ice-shelf buttressing can, but does not necessarily, mitigate the influence of the basal sliding law on ice-sheet evolution.

We will add to Ln 282: 'Three of the friction laws evaluated in this study depend on the effective pressure, whereas one (the powerlaw) does not. As a result, any differences between continuation experiments initialized from either P1 or P05 using the powerlaw friction law arise solely from small variations in the initialized friction field, obtained with the ZI law. During a continuation experiment, the free parameter C_p can be regarded as analogous to the product of C_c and the effective pressure N in the other three friction

laws. While the product $C_c N$ evolves differently for different values of p, C_p remains unchanged.

We will also add to Ln 389: As shown in Fig. 8c, a distinct band near the TG grounding line exhibits higher friction under the P1 initialization than under P05, whereas the opposite pattern occurs near the PIG grounding line. This indicates that, when P1 is chosen, CISM tends to strongly stabilize TG while destabilizing PIG. This contrast has a profound impact on the sequence of collapse observed in the continuation experiments discussed in the next section, even for the effective-pressure-independent power-law friction law.

Specific comments:

l.12–13: I suggest rephrasing as:
"We find a geometry-driven connection between buttressing and basal sliding in the Amundsen Sea Embayment when performing multi-century future simulations based on the present-day observed imbalance of the Antarctic Ice Sheet, in which Thwaites and Pine Island glaciers eventually collapse."

This is a great suggestion, we will replace lines 12-13 with the suggested sentence.

l.23–24: Isn't it the present-day imbalance rather than the present-day ocean thermal forcing that drives the collapse?

Yes it is. However, including the present-day imbalance has an influence on the initialized present-day ocean thermal forcing: when using the present-day imbalance CISM needs less negative temperature perturbations in our treatment of the basal melt calculation compared to an initialization without the imbalance. Therefore, we argue that our 'imbalance' initialization produces ocean conditions better in line with the observations than our equilibrium initialization. In turn, those different initialized ocean conditions then produce the imbalance in a future simulations. We will add 'the present-day ocean thermal forcing, which is a product of the inversion using the present-day imbalance'

l.71–72: What is meant by 'for realistic collapse conditions'? Please clarify.

We meant compared to schematic or schematically-forced experiments (i.e. uniform warming in the ASE). We will replace 'for realistic collapse conditions' with 'for sustained present-day forcing'.

l.118: Replace the period with a comma in: "the bedrock height, and p a constant in the range …"

We will do this

l.167–169: The sentence about applying friction and/or basal melt scaled by the grounded fraction of a grid cell (PMP; Leguy et al., 2021) seems redundant, as this is already described in lines 219–221.

We will remove this sentence here

l.162–164: It should be explicitly stated here that p has no influence in the power-law formulation, since it does not depend on N (Eq. 1.2).

We will add to Ln 164 (Ln 139 in file uploaded in the TC upload system, due to some confusions with the manuscript versions): 'Note that the powerlaw does not depend on the effective pressure'

l.249: "DI" is no longer relevant and should be replaced with "P05."

We will replace 'DI' with 'P05'

l.246, Section 2.4.1: Again, it should be clarified in this section that the P1 initialisation will be similar to P05 for a power law.

We will add to Ln 230: 'These two initializations will serve as a starting point for continuation simulations done with the four different friction laws described above to produce a set of 8 forward simulations. We will rewrite free parameters in the friction laws to be able to start every forward simulations from a single initialization simulation.'

l.282: "We take the initialisations using the ZI law as initial states". Ok, I understand better now. I think that it is very important to explicitly acknowledge that your results are entirely dependent on this choice. If the power law had been used for initialisation, the P05 and P1 initial states would be identical. The fact that starting from the ZI law introduces differences between the P05 and P1 power-law simulations requires a much stronger justification.

We agree with the reviewer that this is not clear in our manuscript, and we hope that the addition to Ln 230 (previous comment), and Ln 389 and Ln 282 as our reply to the main comment will clarify this in the manuscript.

l.340–348: This discussion appears to refer to an initialisation performed using observed ice velocities. Since the current version of the manuscript no longer uses observed velocities in the initialisation, it is unclear what message is intended here. As written, this paragraph no longer seems relevant.

We will remove the parts about the ice surface velocities from this paragraph.

l.596: Again, I would say that it is the present-day imbalance accounted for in the initialisation that leads to the collapse of both glaciers under the present-day ocean forcing; not simply applying the present-day ocean forcing.

We will add ‘applying the inverted present-day ocean forcing’ to emphasize the effect of including the present day mass change rates on the inverted ocean temperatures.