Dear authors,

Thank you for addressing the points raised in the previous round of reviews and for submitting a revised version of your manuscript.

This is an extensive study that addresses several important research questions using complementary information from the analysis of field data and numerical modelling. The manuscript is significantly improved from the previous version and the two strands of the study are now clearly linked. The inclusion of additional tables is very useful and the restructuring that has taken place in several sections has improved the flow and coherence of the text. You have included additional detail in the methods sections, but many points remain unclear, and you will see a large number of queries in relation to this section below. The results are generally clearly summarised but justification for a couple of the key points mentioned in the abstract require a little more care when interpreting and communicating the results – these are addressed in my major points below.

I know that you will be frustrated to receive another detailed review. None of the points should require additional work to be carried out and therefore my decision is 'publish subject to minor revisions', but addressing the points below will require some careful edits in terms of explaining your methods and interpreting and reporting your findings.

Pippa Whitehouse (Editor)

Major points

Drygalski Ice Tongue (abstract line 7, section 5.1): as far as I can tell, presence or absence of the ice tongue cannot be inferred from the flowline modelling because the ice tongue does not play a role in controlling the dynamics/thickness of the glacier, it does not provide any buttressing. To make statements about the history of the ice tongue you would need to demonstrate that the observed thinning history cannot be replicated unless the ice tongue was present from a specific time. Since the data/modelling presented in this study does not provide any insight into the history of the ice tongue, please review the relevance of any related text about local ocean conditions (e.g. lines 441-447).

Relative timing of retreat and thinning: the abstract (lines 8-9) states that 'simultaneous thinning along the Transantarctic Mountains occurred ~3 ka after the retreat of marine-based grounded ice'. I could not find any explicit support for this statement in the results, discussion, or conclusions. A good place to address this issue might be in section 5.3 (e.g. around lines 506-510), drawing on information presented in the results. See also comments relating to lines 512-514.

Modelling methodology: despite useful edits to the methods section, many aspects of the modelling remain unclear, as evidenced by the large number of minor queries below. As you address these queries, please review the order that information is provided to the reader and make sure that the following are clearly stated: which parameters or variables are fixed, which are tuned to fit modern/LGM constraints, which vary over time/space, what is the experiment duration, how/when are changes in model forcing implemented?

Data-model comparisons at Mt Kring: Section 3.1 states that bedrock at the summit of Mt Kring (~300 m above the ice) has an exposure age of ~550 ka and that the highest erratics are ~180m above the ice (exposure age ~7.2 ka). Text on lines 344-345 implies that you assume the site has experienced ~200 m of Holocene thinning, but text on line 434 implies that you assume the ice

surface was above the summit of Mt Kring at the LGM. Please clarify upper and lower bounds on the magnitude of Holocene thinning at this site to enable comparisons to be made with the modelling.

In various places (e.g. lines 391, 407) you state that the modelling agrees well with the data constraints at Mt Kring or modern observations (e.g. line 393). However, the final modelled ice surface at Mt Kring is several hundred metres below present in many of the experiments (this mismatch is acknowledged in relation to one of the experiments on line 401). I suspect the statements about a good fit are based on the fact that the modelled ice surface passes through the data constraints for some experiments (e.g. M3, fig. 9B; MS1-3, fig. 11B), but the continued thinning predicted by these experiments is in stark contrast with the fact that the present surface of the ice sheet is ~30 m below the lowest data point (fig. 4). Please review your assessment of the model fit to Holocene changes at Mt Kring.

Minor points

Abstract and Introduction

Line 14: text states that retreat and thinning is 'initiated by *interactions* between enhanced sub-ice-shelf melting and reduced lateral buttressing'. This is not supported by the results of experiments M2/M3/S2/S3 (see figures 9 and 10) which show that retreat and thinning can be initiated solely by enhanced basal melt or a reduction in buttressing. Edit text to remove the implication that interactions between processes are necessary to initiate retreat.

Lines 15-16: Figure 8 demonstrates that rapid thinning *is* captured in previous large-scale modelling efforts; perhaps clarify what you mean by 'this period' (line 16)

Lines 41-48: simplify this bullet point. Suggest starting at "Ice load reconstructions constrained by cosmogenic dating…" and say that the reconstructions are needed to model GIA, which (i) may play an important role in controlling ice sheet grounding line dynamics, and (ii) is needed to interpret gravity-based estimates of contemporary ice mass balance

Line 72: text in this paragraph repeats and expands on earlier material. Consolidate the text and review the overall structure and flow of the Introduction.

Line 82: 'evidence of a lingering ice shelf' – when?

Methods

Line 109: 'sufficient erosion' – sufficient for what?

Line 114: 'would have been elevated to the former ice margin prior to deposition' – text is a little ambiguous, please clarify the process described here

Line 151: equations 5 and 6 are revised versions of equation 3 – which version is used in this study? In general, try to be more specific about how the equations presented here are used in your study.

Equation 2: define all terms as soon as they are used

Line 163: '…equation *3* is modified…'

Line 172: how is the statement about mapping geomorphic features related to the equations?

Line 180: MISI does not consider the role of the ice shelf, so it is not clear what sort of feedbacks are described here. Do you seek to understand how ice shelf buttressing can modify the MISI process?

Line 180-181: how is a reduction in lateral buttressing implemented within your model?

Line 190: method used to define the onshore flowline-parallel width is unclear and not replicable

Line 195: somewhere, it would be useful to explicitly state which parameters are tuned in the modern experiments. Some information is in Table 1, but this could be better signposted in the text

Line 214: should basal melt rate be listed as a user-defined parameter on line 197? How is basal melt implemented within your model? (no mention of this in section 2.2)

Line 219: what is the modelled time period? Stated later, but reader needs to know before this point

Line 222-224: you state that you model basal stresses of 100 kPa, but then go on to say that Zoet et al. (2012) predict higher values which are consistent with your modelled values. The logic does not hang together.

Table 1: (i) units are missing for temperature and sub-ice-shelf melt rates. (ii) What is implied by a negative melt rate? (iii) Please expand on the fact that you only list 'maximum' basal melt rates. (iv) Clarify whether the values listed in the final column relate to glacial or deglacial conditions – it may be useful to document in the caption how/when the different conditions are applied in the model.

Line 230: need to explicitly state that the model does not account for isostatic deformation (along with other model limitations that only become apparent on line 412)

Lines 235-236: In the authors' rebuttal, it is explained that this text describes the approach used to ensure a stable grounding line during the first 7,500 model years. However, that is not what is implied by the text, which includes confusing information about tuning transient changes to ensure a stable LGM (how does this relate to model time?) configuration. How can applying transient changes in temperature and accumulation result in a stable configuration? How is the tuning carried out? What is 'the modelled period'?

Line 243: why are we told that accumulation was 75% of modern at 15 ka BP? How does this information relate to the forcing applied in the numerical experiments?

Line 244: 'we increase this value' – what value?

Line 246-247: it is not clear how accumulation changes over time are applied within the model

Line 247-248: 'we are able to demonstrate…' – this result (which perhaps belongs in the results) is not robust because you do not investigate the impact of varying the temperature or accumulation values within the model, despite acknowledging (line 254) that they are poorly constrained

Line 250: 'user-defined parameters…' – explicitly state what these are and what values they take

Line 250: 'optimised…forcings' – how are they optimised?

Line 257: it is not clear how progressive changes in forcing are applied – over time within a single experiment or by running a suite of experiments, each with different boundary conditions?

Line 265: 'a forcing perturbation is applied' – be more explicit about what this entails

Results

In a few places, additional information is needed to explain your interpretation of the field data:

- Line 296: 'Two bedrock exposure ages … suggest significant wet-based glacial erosion' – the reason for inferring wet-based erosion from these ages is not clearly stated
- Line 298: '…displays extensive glacial erosion which suggests the ice thickness at the LGM was considerably greater than 230m' – again, more information is needed to explain why such erosion could not have been carried out by a thinner ice sheet
- Lines 311-312: '…suggest either a thin cover of cold-based ice or ice-free conditions…' – not clear how you reach this conclusion (noting that you didn't mention the potential for a thin layer of cold-based ice when discussing bedrock ages from the summit of Mt Kring)
- Lines 312-313: 'High elevation bedrock samples are much younger… suggests burial by non-erosive ice' – several aspects of this sentence are unclear: which 'high elevation' samples are you referring to, where is the 'nearby' site with older bedrock ages at a similar height and which site do you suggest was buried by non-erosive ice?

Line 362: in this context, ICE-6G is an ice sheet reconstruction, not a post glacial rebound model

Line 366: how do you determine the ice thickness change for each model? Do you calculate the thickness change over a specific time period, or do you calculate the difference between the minimum and maximum ice thickness at any time during the model run?

Line 367: figure 4b implies that the highest Holocene erratic at Mt Kring is ~170m above the present ice surface, i.e. there has been at least 170m thinning during the Holocene (not 144m). Similarly, where does the value of 181 m come from for Hughes Bluff (line 368)?

Lines 387-390: text implies that experiments are carried out for melt rates between -2 and -10 m/yr, but such experiments are not listed in table 2 or shown in figure 9. The results presented here do not provide convincing evidence that -11 m/yr is the threshold value for triggering grounding line retreat

Model M1: text on lines 389-391 implies that M1 predicts rapid grounding line retreat and that the results agree well with Mt Kring data constraints, but this is not supported by figure 9

Line 397: does the 'further ice shelf debuttressing' take place after the 4% reduction in buttressing, i.e. during the same experiment, or in a completely separate experiment? Also, is a reduction by 40% the minimum value required for grounding line retreat to modern, or is this is simply an example of an experiment that showed full grounding line retreat?

Line 401: 'this simulation' – which simulation?

Table 3: (i) over what time period is 'modelled grounding line retreat rate' calculated? (ii) suggest listing the data-constrained thinning rates at each site, to allow comparison with modelled rates

Discussion

Line 424: take care when talking about 'matching periods of thinning' – the numerical experiments simply explore the response to an instantaneous perturbation to the boundary conditions. Your comparison could be taken to imply that Holocene change along the David Glacier was driven by a

single, sudden change in local conditions. Also, it is not clear what it means for modelled retreat to 'match' the onshore thinning, are you implying that they occur at the same time?

Line 508: does the two-phase grounding line retreat result in two phases of onshore thinning?

Lines 512-514: the text implies that thinning initiated prior to grounding line retreat. However, text on lines 515-517 implies that grounding line retreat preceded onshore thinning. Which is correct?

Lines 528-530: be more explicit about the fact that you apply an instantaneous change to boundary conditions rather than applying time-evolving forcing

Figures, grammar etc.

Check for minor grammatical issues, e.g. words missing, singular/plural errors, sentences that do not make sense, use of hyphens in compound adjectives (e.g. sea-level rise, sub-ice-shelf melt)

Ensure that any new text is carefully incorporated into the existing text

Figures are very clear. Check the use of brackets when including citations in figure captions. Support the text in the Results and Discussion with more references to figures. I don't think the Drygalski Trough is labelled on any figure.

Figure 2: Aviator Glacier (AG) is not labelled on the figure, REG is not defined in the caption

Figure 8: it is not possible to identify the source of all the lines, e.g. what is the difference between Kingslake2018 and Kingslake2018_WDC; what is Lowry2019_EMV? Check y-axis label on lower plot

Figures 9-11: (i) label the field sites on one of the panel A plots, (ii) consider indicating the position of the present-day grounding line and labelling the 'prominent sill' on one of the panel A plots, (iii) state which axis each of the lines in the top plots of panel B relate to and make it clear that there is no relationship between melt rates and % buttressing, (iv) why do melt rates seem to vary randomly through time in the top plots of panel B?