We thank the Editor and the Referees for their time and their positive and constructive feedback of the manuscript. In response to these reviews, we have edited the text to clarify our arguments and the results of the study. In particular, we have added text to the introduction that contextualizes the motivation of our study for a broader audience. Further, we have addressed all minor revisions suggested by the Referees. We believe that the revised manuscript is improved relative to the original.

In the following, we address each of the comments raised in the reviews and provide a detailed listing of the associated revisions to the text. We intersperse the reviewers' comments (black font) with our responses (blue font).

Referee #1

The authors present an analysis of the impacts of (predominantly) GIA on the grounding line stability of Antarctica's Ross Ice Shelf region when combined with high-resolution bathymetry. They do this by combining a range of GIA predictions with a computationally fast (and simplified) ice model. The work shows that specific regions have a greater likelihood of producing stable grounding lines at both 20ka and present-day and these are largely invariant to the exact GIA model employed. They also show that high-resolution (500m) bathymetry produces substantially different regions of grounding line stability than those computed after downsampling the bathymetry to 20km resolution as is typical in coupled ice-GIA models. The paper therefore reaches some important conclusions. The work is well described and the figures are nicely prepared.
We thank the Referee for their positive comments.

While I am not an expert on ice modelling, it appears appropriate and suitable for the task. A range of tests in the supplementary material confirm the results to be robust to various choices.

I have just a few comments where further clarification or discussion is required.

More substantial remarks

L110 - this section, do note that Nield et al 2016 GJI put some constraint on upper mantle viscosity in this region as >10^20 Pa s. That said, their work considered late Holocene flow switching but not the more recent finding of large-scale retreat and readvance, which may affect their conclusions. On that general topic, how does the absence of these large mid to late Holocene signals from the ice models change anything? Perhaps not at all, but maybe worth noting when introducing the ice models.
We now include the Nield et al 2016 reference (L 124-127):

> "Our Earth model is similar to the best fit 1-D Earth model used in Whitehouse et al. (2012), which was determined by inverting for the solid Earth rheology that best fit Antarctic deglacial sea-level data, and is consistent with local constraints on upper mantle viscosity (Nield et al., 2016).."

We do not consider any ice histories characterized by large-scale retreat and re-advance during the Holocene, and it is possible that such loading changes in the Holocene would impact our predictions of grounding line persistence zones at present day. Given the uncertainty in the timing and magnitude of Holocene readvance, such a consideration could be the subject of future research.

In general, I thought the importance of far-field sea level was emphasised more than the impact of the forebulge collapse (on the shelf break region). I didn't see evidence to suggest one was more important than the other. Please review all mentions or add some extra tests if the distinction matters.

We agree that this is an important point to make in our manuscript. To address this issue, we have added more detail to the text to compare the relative contributions of peripheral bulge collapse and sea level rise caused by global ice sheets melting (L 311-323):

> "There are two GIA mechanisms that cause the locations of zones of potential persistence to shift upstream over the last deglaciation: 1) sea-level fall caused by rebound of the solid Earth under the locus of ice mass loss (~250 m) and 2) sea-level rise caused by global ice sheet melt (~130 m), and secondarily by the collapse of the Antarctica peripheral bulge (~10 m; Figure S3). Within the interior of the Ross Sea Embayment, relative sea-level fall caused by isostatic rebound is nearly twice the magnitude of sea-level rise caused by global ice sheet melt. In contrast, near the continental shelf edge, relative sea-level rise is dominated by global ice sheet melt and peripheral bulge collapse contributes only <10% of the signal.
>
> Isostatic rebound shoals bathymetry within the interior of the Ross Sea Embayment, decreasing flux through the grounding line, thus increasing the potential for a "stable steady-state" grounding line at present-day. Sea-level rise caused by far field ice sheet melt and Antarctic peripheral bulge collapse causes increased grounding line flux, which decreases the likelihood of a "stable steady state" grounding line position near the edge of the continental shelf at present day (Figure 3)."

We now include a new Supplemental Figure (S3) illustrating the magnitude of sea level rise induced by the peripheral bulge.

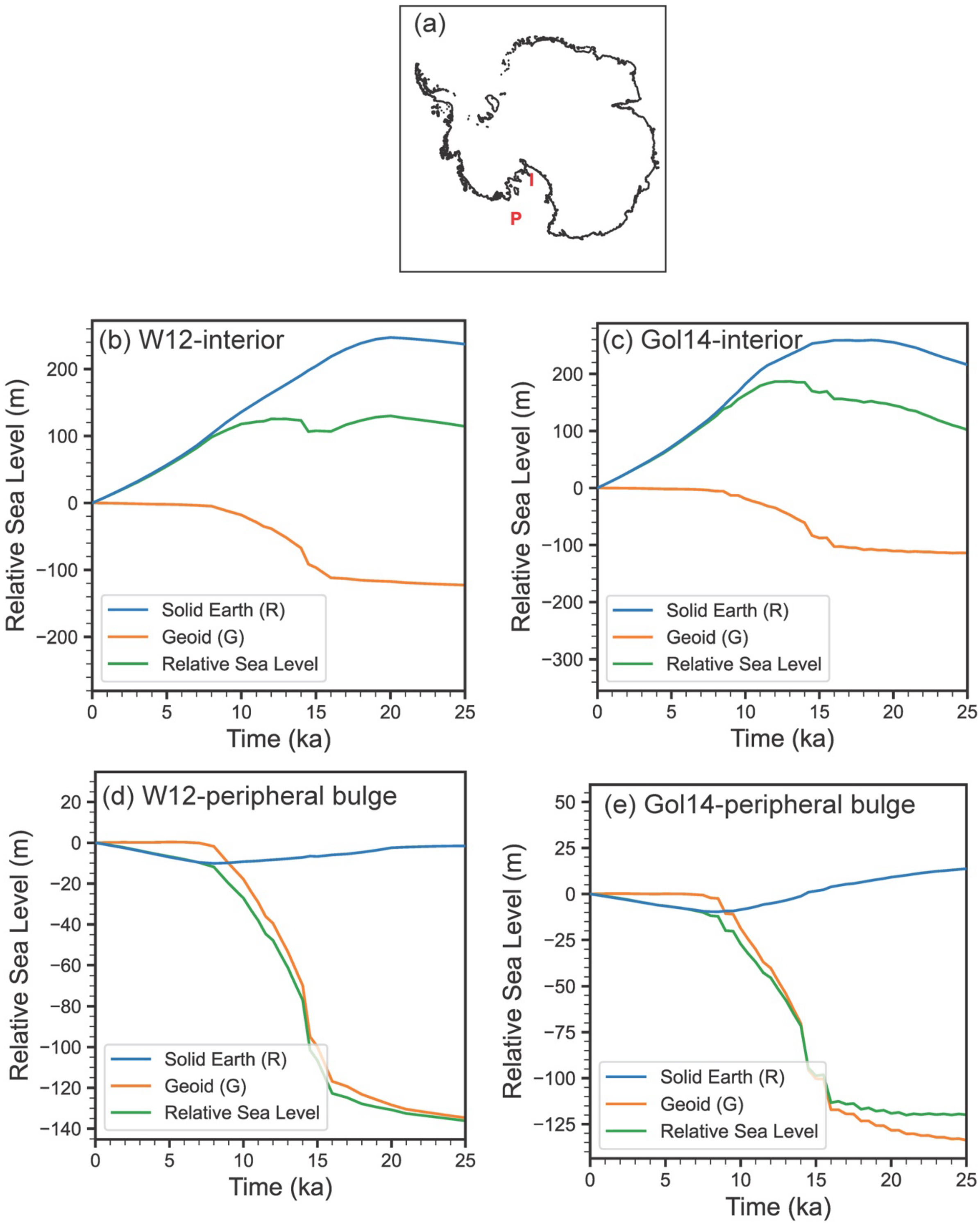


Figure S3 | Relative Sea Level (green) decomposed into solid Earth (R; blue) and geoid (G; including direct gravitational effect and global sea-level change; orange) components for a) Gol14 and b) W12 ice histories. a) Map of Antarctica showing location of relative sea-level curves for the interior (I) and peripheral bulge (P). b/d) Relative sea-level curves for W12 ice history. c/e) Relative sea-level curves for Gol14 ice history.

Minor remarks:

L75 please clarify the method for shifting the bathymetry to 20ka. Do you take model(PD)-model(20ka) and apply that to bedmachine? I guess that is the only approach one could use to adjust bedmachine but please clarify regardless

The Referee's interpretation is correct and we now specify in the main text (L 84-87):

> "To reconstruct Ross Sea Embayment 20 ka bathymetry we modify present-day BedMachine v1.38 bathymetry (500 m horizontal resolution; Morlighem et al., 2020) for the spatiotemporal patterns of GIA caused by the deformational, gravitational, and rotational effects associated with changes in ice load (i.e. $\text{bathymetry}_{20\text{ ka}} = \text{bathymetry}_{\text{pres}} - \text{relative sea level}_{20\text{ ka}}$)."

L85 sedimentation is mentioned along with sea level (and later far field sea level effects) but maybe it is worth adding other things that could contribute to sea level over LGM timescales such as changes in ocean dynamic topography and thermosteric effects.

The Referee raises an important point about other processes that might impact relative sea level in the Ross Sea. However, the other potential processes suggested by the Referee would be of second order (e.g. thermosteric effects would contribute a maximum of ~2.5 m of sea level rise since the Last Glacial Maximum; Simms et al., 2019), so we choose to omit them from the main text.

Simms, Alexander R., Lorraine Lisiecki, Geoffrey Gebbie, Pippa L. Whitehouse, and Jordan F. Clark. "Balancing the Last Glacial Maximum (LGM) Sea-Level Budget." *Quaternary Science Reviews* 205 (February 1, 2019): 143–53. https://doi.org/10.1016/j.quascirev.2018.12.018.

L114 check the wording of this sentence as I did not understand it

We rewrote the sentence to address this comment, and a comment from Referee #2 (L 128-130):

> "…VM5a Earth model (lithosphere thickness of 96 km, average upper and lower mantle viscosity of 0.5×10^{21} and 1.6×10^{21}, respectively (Peltier et al., 2015)"

L129 the use of 'geologic record' was confusing to me given the context is present day. That raised the question as to the meaning of 'present day' in the paper more generally. is it within the last few hundred years? Is there a definition you wish to use?

In our study "present day" refers to the time period over which the observations that led to BedMachine were taken over, or the period of time that BedMachine bathymetry is representative of, which is likely the past few years to decades. We agree that "observational record" is a more appropriate term than "geologic record", and now clarify the text to read (L 148-150):

> "…the observational record (e.g. predicting stable steady state grounding lines on present-day bathymetry offshore of the present-day grounding line)"

L150 should flow come before law here in L151?

Corrected.

Equation 5. I looked at the right side of Eq 1 and could not see how taking the derivative with respect to L would arrive at this equation. Please check but given the authorship's mathematical expertise, it is likely I was missing something. I note that h is defined only in table 1 and not in the text.

Part of the confusion may have been that h_g must first be moved to the right-hand side before taking the derivative. Additionally, h_g is a function of L (since bed elevation and therefore grounding line ice thickness vary downstream). We also now change h to b for clarity (since it references bathymetric depth) and refer to it in the main text. Here is the complete derivation, which we have now included in the Supplementary Text:

$$\frac{d}{dL}\left(PLh_g^{-1} - \Omega h_g^{\beta-1}\right) \tag{1}$$

Applying the chain rule to PLh_g^{-1}

$$Ph_g^{-1} - PL\frac{dh_g}{dL}h_g^{-2} \quad - \frac{d}{dL}(\ \Omega h_g^{\beta-1}) \tag{2}$$

Applying the chain rule to $\Omega h_g^{\beta-1}$

$$Ph_g^{-1} - PL\frac{dh_g}{dL}h_g^{-2} \quad - (\beta - 1)\Omega h_g^{\beta-2}\frac{dh_g}{dL} \tag{3}$$

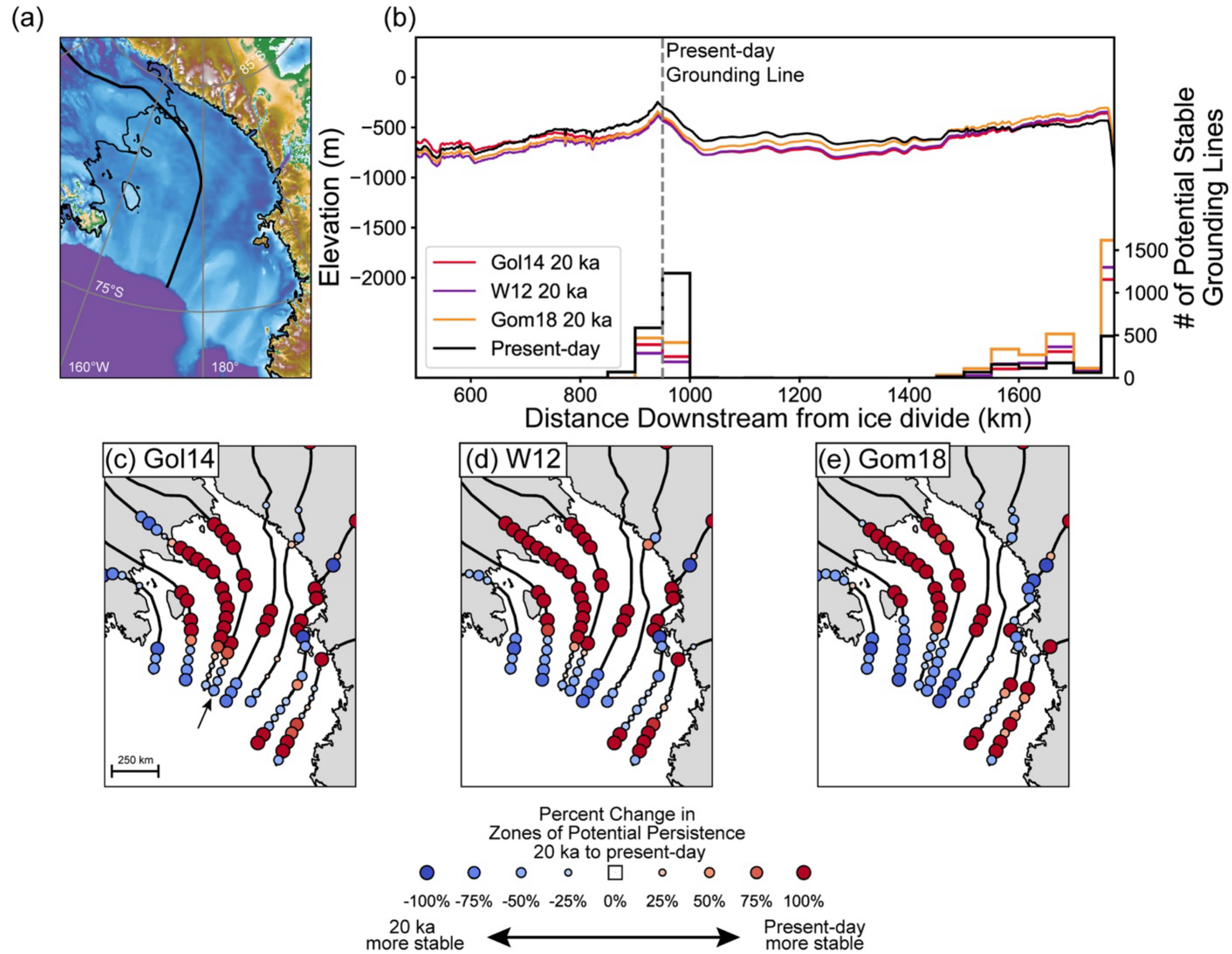
Applying that $h_g = -\frac{\rho_w}{\rho_i}b$, where b is a function of L

$$Ph_g^{-1} + \left[PLh_g^{-2} + (\beta - 1)\Omega h_b^{\beta-2}\right]\frac{\rho_w}{\rho_i}\frac{db}{dL}$$

The original manuscript contained a $\Omega h_b^{\beta-1}$, but now correctly contains $\Omega h_b^{\beta-2}$.

Fig 2. a) Please add some distance markers so one can understand the profile in b). In b) xaxis distance from where?

Thank you for this suggestion. We now include a scale bar and an arrow indicating which flowline is shown in panel b. Distance from the ice divide is shown on the x-axis.



L246 some comment on the forebulge change on the right side of 2b would be appropriate.
We have now added a supplemental figure (Figure S3; see above) that identifies the magnitude of peripheral bulge collapse, and include a discussion in both the main text (L 311-323; see above) and the supplementary material (Text S5):

> "On the peripheral bulge RSL is predominantly caused by global sea level rise due to global ice sheet melt, which causes ~130 m of sea level rise. Peripheral bulge collapse only causes ~10 m of RSL rise, an order of magnitude smaller. However, these forcings occur at different times. RSL rise due to changes in global sea level occur primarily from 20-10 ka, while changes in RSL due to peripheral bulge collapse occur from 8 ka to present-day"

L339 T-test to t-test
Corrected

L358 the methods used to resample are missing. I presume this is some sort of mean. I wonder if using something other than the mean (like first quartile or max) may produce more realistic subsampling and useful advice to those running lower-resolution models out of computational necessity. maybe that messes with ice-ocean melt in those models.
We describe our sampling in the methods section (L 213-215):

> "We resample by smoothing the transect using a windowed mean of the desired resolution and then resampling the smoothed bathymetry at the desired resolution."

The Referee raises an interesting point about more realistic ways of down-sampling or subsampling bathymetry that could be interesting to explore in future work.

Figure 5 The definition of misfit is in the caption but missing from the text. Including it would help the reader avoid confusion

Thank you for this suggestion. We now also include the definition within the main text (L 422-425):

> "Figure 6a shows the percent misfit for change in zones of potential persistence of 20 km resolution compared to 500 m resolution ($\frac{ZPP_{500m} - ZPP_{20km}}{ZPP_{500m}}$)."

L390 add cross reference to Fig 6b

Added.

L389 is 'logarithmic' strictly or is this by eye?

This interpretation was by eye. We now reword to be more specific:

> "We also vary the coarseness of the grid resolution and find that as grid resolution coarsens, percent misfit converges towards ~80-90% (compared to 500 m bed resolution; Fig. 6b)…"

L396 there's already a median misfit of 25% at 1km so is it robust to say 1km? There does not appear to be convergence evident in Fig 6b and so I think you could argue that 500m may not be a high enough resolution. Correct? You could test that with some simulated higher-resolution topography. I guess.

In response to this comment, we have edited the text accordingly. Since "robust" could be interpreted differently, we instead specify the range of misfit and let the reader decide what level is appropriate for their research. While we could test a higher-resolution bathymetry, we feel that limiting our analysis to 500 m is appropriate given the resolution of BedMachine and realistic computational constraints. Assessing the effects of finer scale topography could be interesting, but as the reviewer notes this would have to be synthetic topography, which would in turn require observations or assumptions about the roughness of the true bathymetry and is beyond the scope of our study (L 439-441).

> "Based on our analysis, compared to 500 m grid resolution, a grid resolution of 20 km leads to a ~95% misfit, while a grid resolution of 1 km leads to a ~25% misfit (Fig. 6b)."

L415 'offshore Victoria Land' could be Ross Sea or Southern Ocean. please be more specific

Thank you for pointing out this confusion. We have now removed this reference to location so that the text reads (L 459-460):

> "The grounding line then retreated throughout the Holocene (Bart et al., 2018; Halberstadt et al., 2016; Prothro et al., 2020)."

L444-447 I found this sentence unclear as to its meaning.

We rephrase to clarify (L 486-490):

> "In this study we have shown that, in addition to impacting transient grounding line retreat, glacial isostatic adjustment promotes stability across ice-age timescales by shifting zones of potential grounding line persistence from near the edge of the continental shelf toward the present-day grounding line across the deglaciation."

Supp Material

S2 'marine ice sheet evolution' does not make sense to me

We now clarify:

> "we run a 1-D marine ice sheet, shallow-shelf approximation, flowline model"

Supp Table I think should be labelled Table S1 rather than STable 1.

Corrected.

Relevant here and in the main paper, where do these values come from and does it matter if they are not realistic? I think so. I presume for instance that the SMB present-day is actually about 0.1m/yr (ice? water?)

We now cite references to justify out choice of SMB values in the main text (L 170-171):

> "averaged surface mass balance 0.01–0.3 m/yr (Buizert et al., 2015; Cavitte et al., 2018)"

Present-day SMB within the Ross Sea Embayment is ~0.1 m/yr, however, rates can be as high as 0.3 m/yr (Lenaerts et al., 2012). To isolate the role of GIA, we consider the full range of SMB inferred from ice core and radar records for the time period spanning the LGM to present-day (Buizert et al., 2015; Cavitte et al., 2018).

Buizert, C., K. M. Cuffey, J. P. Severinghaus, D. Baggenstos, T. J. Fudge, E. J. Steig, B. R. Markle, et al. "The WAIS Divide Deep Ice Core WD2014 Chronology – Part 1: Methane Synchronization (68–31 Ka BP) and the Gas Age–Ice Age Difference." *Climate of the Past* 11, no. 2 (February 5, 2015): 153–73. https://doi.org/10.5194/cp-11-153-2015.

Cavitte, Marie G. P., Frédéric Parrenin, Catherine Ritz, Duncan A. Young, Brice Van Liefferinge, Donald D. Blankenship, Massimo Frezzotti, and Jason L. Roberts. "Accumulation Patterns around Dome C, East Antarctica, in the Last 73 Kyr." *The Cryosphere* 12, no. 4 (April 17, 2018): 1401–14. https://doi.org/10.5194/tc-12-1401-2018.

Lenaerts, J. T., Van den Broeke, M. R., Van de Berg, W. J., Van Meijgaard, E., & Kuipers Munneke, P. (2012). A new, high-resolution surface mass balance map of Antarctica (1979–2010) based on regional atmospheric climate modeling. *Geophysical research letters*, *39*(4).

Fig S4 define ZPS on yaxis label

Corrected.