Round 1

Overall Comments

This manuscript addresses a scientifically important question about the sensitivity of Antarctic ice sheet projections to different sub-ice shelf melt rate treatments during model initialization. The core finding that the method of initialization of sub-ice shelf melt rates can lead to a significant difference in projected sea-level contributions is valuable for the ice sheet modeling community, and relevant to the scope of the journal.

General Comments

The research article presents novel insights by isolating the effects of sub-ice shelf melt rate treatment while maintaining identical model configurations, which addresses limitations of previous intercomparison studies that combined models of varying numerical complexities and initialization methods. The experimental design is well-motivated, and the writing is generally clear and well-structured.

The conclusions that West Antarctica dominates in driving projection uncertainties are potentially significant and well supported by the results, as are the substantial differences reported from previous studies. The comparison with CMIP6 and ISMIP6 projections raises important questions about model setup differences and other contributors beyond the melt rate parameterization that warrant further investigation. However, several methodological components require more detailed description to facilitate reproducibility, particularly the forward projection methodology, and the discussion of divergences from previous studies needs expansion.

Response: We thank the reviewer for the thoughtful and constructive comments, which have helped us significantly improve the manuscript. We are encouraged by the positive feedback on the novelty, experimental design, and significance of our findings. Below, we provide a point-by-point response to the specific suggestions raised.

1. In the model initialization, we have enhanced the description of both the similarities and differences between our model configuration and that of LOW21. To enhance the structural clarity of the manuscript, we hereafter refer to the initialization experiment using observed basal melt rates via Eq. 1 as experiment S1 (our study), and the experiment reproducing the LOW21 with Eq. 2 as experiment S2.
2. Furthermore, based on recent literature, we have provided additional justification

for using observed basal melt rates from Rignot et al. (2013). At coarse resolutions, the PISM utilizes a sub-grid grounding-line scheme to interpolate physical quantities within grid cells containing the grounding line. This approach ensures a smoother transition in the treatment of grounded and floating ice, resulting in a more accurate and physically realistic representation.

3. In the projection, based on whether the sub-grid scheme is enabled during simulation, we categorize the results into the more intuitive "sub-grid scheme on (SGO) scenario" and "sub-grid scheme off (SGF) scenario", replacing the original "high scenario" and "low scenario". Forthermore, we have added detailed information regarding the sources and temporal resolution of climate forcing.
4. Our results have been systematically compared against the ISMIP6 ensemble results, analyzing the strengths and limitations of our study. Furthermore, we have omitted the extrapolated AIS contribution beyond 2100 to maintain analytical rigor in the revised manuscript, as this projection was not substantiated by our simulation results.
5. We have added analysis on the key contributors to uncertainty in projections. Building on existing literature, we have also discussed potential future work directions aimed at better constraining the dominant drivers of model uncertainty. Additionally, we have analyzed the impact of errors in the observation for model validation. Specifically, we note that due to these uncertainties, the observed AIS state may potentially reflect an unstable condition, which could consequently affect the outcomes of model validation.

We have carefully addressed all the comments provided and believe the revised manuscript is substantially improved as a result. Once again, we thank the reviewers for their invaluable time and insightful suggestions.

Specific Comments:

Methodological Details:

Sub-grid interpolation:

p5, l107: *"... we conduct projection experiments, initiated in 2015, by employing "high" and "low" scenarios controlled by the sub-grid melt interpolation"*
This sub-grid melt interpolation requires clearer explanation. What constitutes this interpolation scheme, and why does activating it constitute a "high" scenario versus omitting it for "low" scenarios? Clarify the distinction between these scenarios.
Response: Thanks for your suggestions.

1. Simulating retreat processes of marine-terminating glaciers in coarse-resolution grid models, the sub-grid scheme calculates one-sided derivatives of the surface slope around the grounding line and interpolates key physical variables based on spatial gradients across the interface between grounded and floating cells. Assign 0 to ice-free/floating cells, 1 to fully grounded cells, and 0–1 to partially grounded cells (includes grounding line). The formula for basal melt rate adjusted using this scheme is:

$$M_{b,adjusted} = \lambda M_{b,grounded} + (1-\lambda) M_{b,shelf\_base}$$

   $M_{b,grounded}$, $M_{b,shelf\_base}$ denote the basal melt calculated for grounded ice grid cells and floating ice grid cells, respectively. λ indicates the value (0-1) of the mask corresponding to the grid cell. This scheme is also used to adjust the basal friction in the transition zone. For more accurate expression, we have revised the term "sub-grid melt interpolation scheme" to "sub-grid grounding-line scheme" throughout the manuscript.

2. The "high scenario" and "low scenario" refer specifically to simulation results obtained by enabling or disabling the sub-grid scheme in PISM, respectively, and do not represent different climate (RCP/SSP) scenarios. For clarity, we have replaced the original terms "high scenario" and "low scenario" with the more descriptive expression "sub-grid scheme on (SGO) scenario" and "sub-grid scheme off (SGF) scenario". The "SGO scenario" activates the sub-grid melt interpolation, thereby accounting for basal melting in grid cells containing the grounding line. This results in higher overall mass loss because it accelerates grounding line retreat within the coarse-resolution grid; without it, the retreat would not be simulated. By contrast, the "SGF scenario" omits the scheme and applies no basal melting to any grid cell that is not entirely floating. These neglects melting in partially floating cells, leading to lower total mass loss and thus representing a more conservative (lower melt) scenario.
3. As noted in your comment on "**Projection uncertainties (p14, Table 2)**", limited computational resources prevented large ensemble simulations of AIS evolution for statistically significant projections. We therefore alternatively enabled/disabled this scheme to estimate the upper/lower bounds of the AIS sea-level contribution (Table 2).
4. As suggested, we have supplemented this section accordingly and modified the relevant description in the revision as follows:
   "The grounding line migration is optimized through a sub-grid scheme, which calculates one-sided derivatives of the surface slope around the grounding line and interpolates key physical variables—such as basal shear stress, basal melt rate, and basal friction—based on spatial gradients across the interface between grounded and floating cells (Feldmann et al., 2017; Nowicki et al.,2020). This approach reduces physical gradients across the grounding line and simulates a more realistic and dynamic representation of the ice margin (Leguy et al., 2014; Golledge et al., 2015).".

"Further, based on the initialized model state and the optimal parameter set from S1, we conduct projection experiments from 2015 by turning on or off the sub-grid grounding-line scheme in PISM. The "sub-grid scheme on (SGO) scenario" incorporated sub-grid melt interpolation near grounding lines, accelerating grounding-line retreat in our coarse-resolution model, while the "sub-grid scheme off (SGF) scenario" ignored melt in partially floating cells, yielding more conservative mass loss estimates (Albrecht et al., 2011; Golledge et al., 2015; Nowicki et al.,2020).".

Climate forcing implementation:

p5, l109-110: *"These experiments used climate forcing derived from the CMIP5 IPSL-CM5A-MR (Barthel et al., 2020; Payne et al., 2021) and the CMIP6 CNRM-CM6-1 (Nowicki et al., 2016; Kamworapan et al., 2021) to assess …"*

I could also not find details on the implemented climate forcings, consider specifying:

-How are the forcing fields (temperature, salinity?) used/derived from these models?

-What is the temporal resolution of the forcing data?

-How are the CMIP5 or CMIP6 forcings interpolated or downscaled to the PISM grid?

Describing this would be useful for reproducibility

Response: Thanks for your suggestions.

1. We directly utilized the "ISMIP6 21st Century Forcing Datasets" published by Nowicki et al. (2021), which provide 21st-century atmospheric and oceanic forcing datasets designed for standalone ice sheet model simulations over Greenland and Antarctica. The dataset incorporates output from six CMIP5 and four CMIP6 climate models, processed into a form readily applicable to ice sheet models. Each climate model contributes atmospheric forcing—including surface mass balance anomaly and near-surface air temperature anomaly—from 1995 to 2100, as well as oceanic forcing covering the same period, which includes salinity, temperature, and thermal forcing. So we can directly download the output forcing fields from these different climate models without the need for any additional processing.
2. The original temporal resolution of the atmospheric and oceanic forcing data is "daily". However, as PISM is not suited for high-temporal-resolution inputs, we pre-process the data into annual averages before using them in the model. Spatial grid resolutions are available in 2 km, 4 km, 8 km, 16 km, and 32 km, can be selected as needed.
3. PISM provides publicly available preprocessing scripts (https://github.com/pism/pism-ais) to convert model input data into a consistent resolution and a model-readable format. For our experiments, the input data were standardized to an 8 km grid resolution. Therefore, the 8 km horizontal resolution

forcing data can be downloaded directly from the "ISMIP6 21st Century Forcing Datasets" without the need for re-interpolation.

4. As suggested, we have added the relevant content in the manuscript and supplemented the source description of the forcing data in the Data Availability Statement:

   "We employed the same daily-resolution climate forcing as LOW21 (Lowry et al., 2021), derived from the CMIP5 IPSL-CM5A-MR RCP2.6/8.5 (Barthel et al., 2020; Payne et al., 2021; Nowicki et al., 2021) and the CMIP6 CNRM-CM6-1 SSP1-2.6/5-8.5 product (Nowicki et al., 2016; Kamworapan et al., 2021; Nowicki et al., 2021) spanning 2015–2100, to assess and compare Antarctica's contribution to global mean sea-level rise by 2100.".

   "The forcing data under RCP and SSP scenarios were sourced from the dataset published by Nowicki et al. (2021). The data preprocessing tool used is the publicly available scripts pism-ais (https://github.com/pism/pism-ais).".

Model configuration:

p11, l226: *"consistent model configurations and climate forcings with LOW21.."*

It is not clear what consistent model configurations constitutes of, and the term is ambiguous. There is some clarification for this provided in Section 5, which would fit better in Section 2, where the experimental setup is first introduced. Consider establishing early on exactly which parameters remain identical between experiments and which differ.

Response: Thanks for your suggestions.

1. During initialization, our model configuration—including parameters, stress approximation, resolution, initial topography, and atmospheric conditions—is identical to LOW21. The only difference lies in the oceanic initial condition: our simulation uses observationally derived sub-ice-shelf melt rates, whereas LOW21 employed ocean temperature and salinity. To enhance the structural clarity of the manuscript, we hereafter refer to the initialization experiment using observed basal melt rates via Eq. 1 as S1, and the experiment reproducing the LOW21 with Eq. 2 as S2. In the projection experiments, both the model configuration and climatic forcing are the same.
2. Per your suggestions, we have clarified differences in the initialization and projection experiments and moved model configuration details from Section 5 to Section 2. We have revised the relevant description as follows:

   "During initialization procedure, to evaluate the specific role of oceanic conditions, we conducted two experiments using PISM: Experiment "S2" replicates the single simulation from LOW21 that used the best-fit parameter set (the one minimizing

mismatch with observations), employing a thermodynamic parameterization (Eq. 2) to estimate sub-ice shelf melt rates. Experiment "S1" uses the same model configuration—including all parameters, stress balance approximation, resolution, topography, and atmospheric conditions—but replaces the basal melting scheme with observed basal melt rates derived from satellite altimetry (ICESat-1), radar (OIB and ALOS PALSAR), and model outputs (RACMO2), based on Eq. 1.".

"We employed the same daily-resolution climate forcing as LOW21 (Lowry et al., 2021), derived from the CMIP5 IPSL-CM5A-MR RCP2.6/8.5 (Barthel et al., 2020; Payne et al., 2021; Nowicki et al., 2021) and the CMIP6 CNRM-CM6-1 SSP1-2.6/5-8.5 product (Nowicki et al., 2016; Kamworapan et al., 2021; Nowicki et al., 2021) spanning 2015–2100, to assess and compare Antarctica's contribution to global mean sea-level rise by 2100.".

Forward projection:

p12, l231: *"Prognostic simulations from 2015 to 2100 revealed divergent ice mass changes compared to LOW21, particularly in WAIS. Under various climate scenarios, …"*

The treatment of sub-ice shelf melt rates during the 2015-2100 projection period is unclear. Are the observational melt rates from Rignot et al. (2013) prescribed throughout the projections?

Response: Thanks for your suggestions.

1. The sub-ice shelf melt rates from Rignot et al. (2013) were used solely during the initialization in S1 to construct a new ice-sheet initial state under this oceanic condition, enabling comparison with S2 (LOW21) and analysis of resultant dynamic mechanism differences.
2. Furthermore, our study focuses on how variations in sub-ice shelf melt rates affect the initial ice-sheet state after spin-up and subsequently influence projected sea-level contributions. To maintain consistency with the LOW21 for comparative analysis in projection experiment, we used the same future oceanic forcing—specifically ocean temperature and salinity from CMIP5 and CMIP6 climate models—to project future ice-mass change.
3. To improve clarity, we have revised the expression to *"To ensure that differences in projections originated solely from the model spin-up, the basal melting scheme was parameterized using the same linear thermodynamic framework for the ice-shelf–ocean boundary layer as that employed in LOW21. This approach explicitly resolves heat and freshwater exchange processes at the ice–ocean interface, driven by oceanic forcing under different RCP/SSP scenarios from 2015 to 2100.".*

Projection uncertainties:

p14, Table 2:

The confidence intervals presented in Table 2 are not defined. Are these ranges derived from ensemble runs, sensitivity tests, or are a statistical treatment of the model output? Consider clarifying the source and methodology of these intervals and expand the table description/title accordingly

Response: Thanks for your suggestions.

1. The confidence intervals provided in Table 2 summarize simulation results obtained by either enabling or disabling the sub-grid grounding-line scheme in the prediction process. When using the sub-grid scheme, the model applies weighted adjustments to ice mass changes in the ice sheet–shelf transition zone. This results in the "SGO scenario", which defines the upper bound of the confidence interval for the sea-level contribution in Table 2. Conversely, when this scheme is disabled, the model neglects these ice mass changes, yielding the "SGF scenario" that defines the lower bound of the interval. This methodology follows the approach of Golledge et al. (2015).
2. In response to your feedback, we have supplemented the description of Table 2: *"Sea level contribution (m SLE) of Antarctic Ice Sheet Basins by 2100. The confidence intervals represent the range of sea-level contribution from the "SGO scenario" to the "SGF scenario" simulation across different RCP/SSP scenarios; the single value denotes the mean value of this range."*.

Initialization results:

Grounding line migration:

p11, l225: *"…discrepancy can be attributed to the reversibility of grounding line migration on a retrograde-slope bedrock, which is characterized by oscillatory shifts"*

The differences presented among the three regions of retrograde bed slope (TB, WL, GVL) are interesting, and Section 3.3 provides a well written mechanistic understanding of the processes involved. In Section 3.4, the grounding line analysis mentions "reversibility of grounding line migration on retrograde-slope bedrock", raising an important point, but remains brief. Further, the phrasing of that sentence makes it unclear, as it seems to conflate the mechanism of oscillatory shifts in the grounding line with the bed geometry. A clearer explanation of the physical processes underlying these patterns in GL migration would be useful.

Response: Thanks for your suggestions.

1. In Section 3.4, the physical mechanism behind grounding line retreat involves higher melt rates triggering MISI, leading to sustained retreat on a retrograde slope. This also highlights the role of bed topography in grounding line migration. So, the subsequent paragraph further emphasizes that the factors of grounding line motion, such as topography, ice velocity, and basal melt rates. Grounding line migration can be driven by either individual or combined factors. For example, the discrepancy in grounding line position on the Siple Coast is primarily influenced by topography (Figs. 3c, d), as evidenced by the agreement between S1 and S2 (Figs. 5d, e). In contrast, in the TB of WAIS (Section 3.4), grounding line retreat results from the combined effects of enhanced basal melt and retrograde bed topography.
2. The original manuscript did not clearly describe the cause of grounding line migration on the Siple Coast; the explanation was unclear and potentially confusing. Therefore, incorporating your feedback, we have revised the explanation to clarify why the simulated grounding line position on the Siple Coast is located closer to the open ocean compared to observational data:

   "In fact, the grounding line position varies across different ice streams depending on topography, neighboring ice shelf basal melt rates, and ice velocities (Martin et al., 2011).".

   "This discrepancy likely arises from the stabilizing self-limiting mechanism inherent to prograde slopes. As the grounding line retreats into shallower bedrock, the ice thins and flux decreases; this leads to ice re-accumulation that prompts grounding line readvancement, creating reversible shifts around an equilibrium point (Huybers et al., 2017).".

Projection results:

p12, l238-239: *"which is relative to the hysteretic response of ice sheet dynamics to climate forcing…"*

The lack of scenario dependence with significant overlap in the prediction ranges is consistent with the delayed/hysteretic response of ice sheet dynamics in that the current ice sheet state and near future (as during this 2015-2075 period) reflect historical forcing, but it is unclear from this sentence. Consider explaining/rephrasing

Response: Thanks for your suggestions. This sentence indeed did not clearly explain the reason for the overlapping projections across scenarios before 2075. This is because the ice sheet's hysteretic response means that its full reaction to new climatic forcings takes considerable time to appear. Therefore, changes during this period primarily reflect the ice sheet's response to past historical forcing, rather than to divergent future emission scenarios. In response to your comment, we have revised the statement as follows:

"This is consistent with the hysteretic response of ice sheet dynamics, meaning that the ice sheet's state in the near-term (2015-2075) is largely determined by historical forcing, masking the influence of divergent future scenarios (Garbe et al., 2020).".

p12, l244-246: *"...2100 trajectory extensions, persistent ice mass ....beyond 2100. "*

Are these extended projections beyond 2100 provided anywhere for this particular study, or does this statement refer existing literature? Consider expanding on this, particularly, which SSP scenario and which RCP simulations correspond to persistent ice mass and stabilizing trends.

Response: Thanks for your suggestions. We did not conduct extended projection experiments of ice sheet evolution beyond 2100, as climate forcing datasets after 2100 are not publicly available in the "ISMIP6 21st Century Forcing Datasets". As such, we have removed the corresponding speculative statement from the manuscript to maintain rigor. All analyses and conclusions in the revised text are now strictly based on simulations ending in 2100.

p15, l295-300: *"... Compared to ISMIP6 (Ice Sheet Model Intercomparison for CMIP6) Antarctic projections under RCP 8.5 (Seroussi et al., 2020), our WAIS contribution exceeds it by approximately 0.15 m SLE, with AP showing a slight increase (~0.002 m SLE) and EAIS exhibiting a minor reduction (~0.02 m SLE..."*

The substantial differences from ISMIP6 projections raises important questions. To strengthen this section, please clarify whether the comparisons are made against the full ensemble or PISM-based runs alone. (e.g., from the description in LOW21, the model setup here would be most comparable to the VUW-PISM from ISMIP6). It would also be helpful to highlight and discuss any other model differences apart from the melt rate parameterization that could contribute to the divergences. If possible, a short comparison on the strengths/limitation of either this observationally constrained approach or the ISMIP6 approach would add significant value.

Response: Thanks for your suggestions.

1. The comparisons presented in this section are made against the full ensemble simulated results of the ISMIP6 projections (Seroussi et al., 2020), rather than against any single model. We did not perform a direct comparison solely against the PISM-based simulated results from ISMIP6 because the sea-level contribution projections for individual ice sheet models were not separately provided in the main

ISMIP6 ensemble publications. The published results primarily offer the multi-model ensemble results, which formed the basis for our comparative analysis.

2. The uncertainties in the projections are related to the physical processes represented in the model, the model initial conditions, the forcing data, and the model parameterization schemes. We have addressed these aspects in Section 5 ("Model Uncertainties") and have revised the discussion in response to your comments.
3. The ISMIP6 ensemble, which combines ice-flow model simulations from 13 international groups, provides a more comprehensive representation of the full spectrum of potential AIS behaviors under given climatic forcing. Results indicate that, among the three major sources of uncertainty in sea-level contribution, the parameterization of oceanic conditions into basal melt rates is the dominant contributor. However, the ensemble-based simulated results inherently cannot reveal the specific physical mechanisms driving these differences. A limitation of our single-model study is its dependency on the parameterizations of the PISM, which can only represent a subset of potential future sea-level contributions and do not provide statistically robust uncertainty ranges. However, by following the same single-model approach and climatic forcing as LOW21 ensemble experiments, and by comparing simulations using both observationally derived basal melt rates and parameterized ocean thermal forcing, S1-based projection identifies the specific regions and dynamic mechanisms underlying the ISMIP6 finding that "the parameterization of ocean thermal forcing into basal melt rates is the largest source of projection uncertainties".
4. As suggested, we have included a short section comparing the strengths and limitations of our approach versus the ISMIP6 methodology. The content we have supplemented is as follows:

   "Compared to the full ensemble results of ISMIP6 (Ice Sheet Model Intercomparison for CMIP6) Antarctic projections under RCP 8.5 (Seroussi et al., 2020), S1 simulated sea-level contribution from WAIS is approximately 0.15 m SLE higher, while AP showing a slight increase (~0.002 m SLE) and EAIS exhibiting a minor reduction (~0.02 m SLE).".

   "The ISMIP6-Antarctica projections improve a more comprehensive representation of potential Antarctic sea-level contribution under climatic forcing, with the parameterization of oceanic conditions into basal melt rates being the dominant source of uncertainty (Seroussi et al., 2020). However, this approach cannot identify the specific physical mechanisms behind the inter-model differences. A key limitation of our single-model research is its reliance on PISM-specific parameterizations, which restrict the range of projected sea-level contributions and

provide limited statistical uncertainty. By comparing observationally derived and parameterized basal melt rates under a consistent single-model framework, our simulations identify the specific regions and dynamic mechanisms underlying the ISMIP6 projection uncertainty associated with representation of oceanic conditions.”.

p16, l318-321: *“Compared to other prior studies, our sea level projections differ due to variations in ice sheet model configurations, including model resolution, ice dynamics (particularly stress balance schemes), represented physical processes (calving, hydrology, or bedrock uplift), and initialization methods (data assimilation or spin-up)”*

These lines address my above comment about detailing the potential reasons for the differences. Is there evidence to suggest which of these factors might be most important, and how it could be addressed in future work?

Response: Thanks for your suggestions.

1. According to the ISMIP6-Antarctica projections (Seroussi et al., 2020), the parameterization of ice melt dynamics contributes most significantly to the uncertainty in sea-level estimates, surpassing variations arising from differences in climate model forcing, initialization methods, and the physical processes included. This implies that ice-model-related uncertainties dominate throughout the simulation period (Seroussi et al., 2019; Seroussi et al., 2023).
2. Therefore, continual model improvement, further exploration of the broader parameter space covered by initial state ensembles and their extended sampling (Coulon et al., 2024; Klose et al., 2024), and the acquisition of more observations for verification and validation are essential to reduce uncertainties in future projections of dynamic mass loss from the AIS (Favier et al., 2019; Seroussi et al., 2020; Seroussi et al., 2023).
3. As suggested, we have incorporated this content as follows:
   “Of these factors, the parameterization of ice melt dynamics contributes most significantly to the uncertainty in sea-level estimates, surpassing uncertainties arising from differences in climate model forcing, initialization methods, and the selected physical processes. This implies that ice-model-related uncertainties dominate throughout the simulation period (Seroussi et al., 2019, 2023). Therefore, continual model improvement, further exploration of the broader parameter space covered by initial state ensembles, and its extended sampling are essential to reduce uncertainties in future projections of dynamic mass loss from the AIS (Favier et al., 2019; Coulon et al., 2024; Klose et al., 2024).”.

Technical Comments:

p1, l30-31: This sentence on ice shelf susceptibility could be streamlined for clarity.

Response: Thanks for your suggestion. We have revised it as follows: *"Ice shelves are highly vulnerable to oceanic forcing due to both basal melting from warm seawater and their near-flotation elevations (Bindschadler et al., 2013; Depoorter et al., 2013; Li et al., 2023).".*

p3, l74: "(Rignot et al., 2013; Fig. 2; Table 1)" Should this reference be "Fig. 1"?

Response: Thank you for your suggestion and correction. Yes, we have changed "Fig. 2" to "Fig. 1".

p3, l90: What is the depth of the ocean water temperature, T_s? Is it taken close to the bottom?

Response: Thanks for your suggestion. We have supplemented the definition of T_s according to the relevant literature: *"T_s is the vertically averaged ocean temperature between 200 m and 1000 m depth along the continental slope (assigned T_s=271.45 K, Beckmann and Goosse, 2003; Martin et al., 2011)".*

p3, l92: Define S_o (ocean salinity?) in Equation (3)

Response: Thanks for your suggestion. We have supplemented the definition of S_o: *"S_0 denotes the specified ocean salinity (35 psu).".*

p8, l166-170: In Fig. 5 caption, clearly define ΔRMSE (Is it RMSE (current vs. obs.) – RMSE (LOW21 vs. obs.)?)

Response: Thanks for your suggestion. Yes, ΔRMSE is the result of RMSE (current vs. obs.) – RMSE (LOW21 vs. obs.). We have added a calculation formula to clarify the method for determining ΔRMSE: "$\Delta RMSE = RMSE_{S1\ (our\ study)} - RMSE_{S2\ (LOW21)}$".

p9, l175: The percentages mentioned (0.5%, 0.2%) appear to conflict with the values presented in Table 1. Clarify whether these refer to overall ice volume biases or volume above flotation biases.

Response: Thanks for your suggestion.

1. The value of 0.5% represents the difference between the bias in S1 simulated ice volume above flotation relative to observations (-4.61%) and the bias in S2 simulation relative to observations (-5.14%), calculated as -4.61%-(-5.14%) =0.53%. And the 0.2% corresponds to the difference in the simulation results for

the GVL region: -5.23%-(-5.42%) =0.19%. (Note: The final values 0.53% and 0.19% are retained for accuracy, while the text acknowledges the rounded reference "0.5%" and "0.2%" from the original context.)

2. The term "volume" refers to volume above flotation biases. We have revised the statement to: *"the bias in ice volume above flotation decreases by approximately 2.8%, while the biases for WL and GVL reduced by 0.5% and 0.2% (Table 1), respectively."*.

p9, l186: "enhanced oceanic forcing" needs a clearer definition in this context.

Response: Thanks for your suggestion. We have modified the relevant expressions in the revision as follows: *"In this study, enhanced oceanic forcing (Fig. 2), which is represented by higher basal melt rates, intensifies ice-shelf basal melting, leading to geometric thinning and reduced buttressing effect of upstream ice flow (Gudmundsson, 2013; Miles et al., 2022)."*.

p9, l195: "elevated basal water consent": Should be "…content"

Response: Thank you for your suggestion and correction. We have changed "consent" to "content".

p11, l211-212: Line colors mentioned here are inconsistent with Fig. 7 description. (purple/orange in text vs. grey (dashed/solid) in figure)

Response: Thank you for your suggestion. We have revised the description in the text based on Fig. 7: *"Cross-sectional analysis of Thwaites Glacier (Fig. 7) demonstrates this mechanism, with enhanced basal melting, causing an approximately 30 km grounding line retreat from its stabilized position (S2, dashed grey line in Fig. 7) to a new quasi-stable state (S1, solid grey line in Fig. 7)."*.

p12, l243: "persistent ice mass": Should this be "ice mass loss"?

Response: Thank you for your suggestion. Based on your comment in the **Projection results (p12, l244-246)**, we have revised the entire paragraph by replacing "ice mass loss" with "*the AIS contribution*".

p12, l243-247: There seems to be a causal gap between the two sentences. Consider adding a brief description in between to establish the causal link between persistent ice mass (loss?) / stabilizing trends and "amplified ice-climate feedback" or modifying the sentence.

Response: Thank you for your suggestion. We have modified the description and logic of this passage as follows: *"These differences between RCP 8.5 and SSP 5-8.5* *projections are largely due to the SSP scenarios in CMIP6 climate models simulate higher warming magnitudes (averaging +0.14-0.25 ℃) than RCP scenarios in CMIP5 at equivalent radiative forcing (Tokarska et al., 2020; Wyser et al., 2020; Rounce et al., 2023). Consequently, under anthropogenic warming, the sea-level commitment of AIS under SSP high-risk scenarios demands heightened scientific attention.".*

p12, l250: Fig. 8 caption should specify which RCP scenarios are used for panels (a) and (b).

Response: Thank you for your suggestion. Fig. 8 (a) shows the spatial differences in projected mean ice thickness based on S1 and S2 under RCP 2.6 and 8.5 scenarios, while (b) displays the spatial differences of the ensemble mean for the year 2100. We have revised the description in Fig. 8: *"Spatial differences in the projected mean ice thickness between the multi-scenario (RCP 2.6 and RCP 8.5) ensemble means from S1 and S2 in 2050 (a) and 2100 (b).".*

Secondary comments:

The below comments are merely secondary suggestions for the authors, and I leave it to them whether to address these or not.

Use of Rignot et al., (2013) melt rates:

The reliance on Rignot et al., (2013) melt rate observations is understandable given their wide use in the modeling community. At the same time, this data now reflects conditions around a decade old, and more recent work, has further revealed interannual variability in ice shelf basal melt rates (Adusumilli et. al., 2020), and even slowdown in melt-driven thinning for certain sectors (Paolo et. al., 2023). I encourage the authors to briefly discuss and frame the use of this dataset within the context of more recent observational work.

Response: Thanks for your suggestion. We agree that acknowledging the temporal limitations of the Rignot et al. (2013) melt rate dataset is important.

1. We clarify that the melt rates from Rignot et al. (2013) were adopted herein because they align more closely with the ocean thermal forcings in the Schmidtko et al. (2014) dataset (1975–2012), as used in experiment S2. We note, however, that these rates represent a six-year mean (2003–2008) from ICESat observations and thus do not capture interannual variability or more recent changes, as highlighted in Adusumilli et al. (2020) and Paolo et al. (2023). So we consider experiment S1 use of this dataset as a general representation of long-term mean ice-shelf basal melt

conditions, while also emphasizing the need for future work to incorporate time-varying melt forcings to better understand ice-ocean interactions.

2. In response, we have added a discussion paragraph in the manuscript: *"It is important to note that the ice-shelf basal melt rates applied here, derived from Rignot et al. (2013), were selected for use because the ocean thermal forcing they represent corresponds closely to the 1975–2012 mean state of the Southern Ocean captured in Schmidtko et al. (2014) dataset (used in S2). However, as these data reflect conditions from approximately a decade ago, they inherently represent a temporal average and do not capture interannual variability in ocean forcing (Adusumilli et al., 2020). Furthermore, Paolo et al. (2023) observed a widespread slowdown in ice-shelf thinning across the Amundsen, Bellingshausen, and Wilkes sectors, attributing it to changes in ocean forcing and internal ice-dynamic feedbacks. Therefore, S1 simulated results should be interpreted as a response to a steady-state, general ice-shelf basal melting field. Future work would benefit from incorporating time-evolving melt rates to better constrain the sensitivity of the AIS to oceanic variability on interannual to decadal timescales."*.

Validation against observations:

p16, l321: *"...the present-day AIS may not have been in a steady-state during the observational period, and thus, some of the misfits could be attributed to uncertainties in the observational data used for validation"*

The authors note that the present-day AIS may not have been in steady state during the observational period. A brief discussion of the uncertainties and potential biases in the datasets used for validation would strengthen this argument

Response: Thanks for your suggestions.

1. We have supplemented the discussion on the uncertainties and potential biases in the observational data used for validation. As noted in the context of BedMachine v.3 (Morlighem et al., 2019), approximate calculations or inversion methods introduce errors across various regions—including fast-flowing sectors, slow-moving zones, ice-free land, ocean bathymetry, and sub-ice-shelf cavities—with estimated biases ranging between 10 and 30 m depending on the area. Similarly, for the MEaSUREs velocity product (Mouginot et al., 2019), ice surface velocity inevitably incorporates errors arising from speckle-tracking and phase data during SAR data processing, along the direction of ice flow. These inherent errors and biases in the observed ice sheet state—which itself may not be in steady state—contribute to the apparent mismatch between model simulations and observational data.
2. As suggested, we have expanded the discussion on ice sheet non-steady-state behavior in the revision. *"Notably, the present-day AIS may not have been in a*

steady-state during the observational period (Martin et al., 2011). This inference, while primarily based on discrepancies between model simulations and observations, may also be influenced by uncertainties inherent in the validation datasets. For example, the BedMachine v3 dataset relies on approximate calculations in regions such as ice-free land, ocean bathymetry, and cavities under ice shelves, potentially introducing spatial biases in thickness estimates (Morlighem et al., 2019). Similarly, the MEaSUREs velocity map inevitably contains errors in flow direction derived from phase data and speckle tracking during SAR data processing (Mouginot et al., 2019). Thus, the apparent model–data mismatch not only demonstrates the non-steady-state of AIS but also reflects the challenge of validating model simulations against modern records that contain their own uncertainties and potential biases.".

Paolo et al., 2023, which constructed 3 km resolution datasets of ice thickness also revealed a slowdown in thinning from around 2008, specifically in the Amundsen, Bellingshausen and Wilkes sectors. Following from my earlier comment about melt rate observations, in addition to the citations in the introduction for accelerated thinning of ice shelves, this article may be worth including as a reference. The specific paper I'm referring to is:

Paolo, F. S., Gardner, A. S., Greene, C. A., Nilsson, J., Schodlok, M. P., Schlegel, N.-J., and Fricker, H. A.: Widespread slowdown in thinning rates of West Antarctic ice shelves, The Cryosphere, 17, 3409–3433, https://doi.org/10.5194/tc-17-3409-2023, 2023.

Response: Thank you for your suggestion. We agree that the study by Paolo et al. (2023) provides a highly relevant and updated observational context for the discussion of ice shelf basal melt rates and their variability. We have now included a citation to this important work in the revised manuscript. This addition strengthens our discussion on the recent temporal variability in ice-shelf basal melting.

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