Editor decision: Publish subject to minor revisions (review by editor)

Dear Authors,

First of all, apologies that it took so long (too long) for us to get back with a decision on your manuscript. But unfortunately, the responsible editor missed his deadlines numerous times. As he never responded to our editorial inquires, we have now canceled his assignment, and I have taken over as the sea ice Chief Editor. That said, I do agree that the initial start off the manuscript and the issues with the high similarity index make proper evaluation of the manuscript a bit more difficult than most of the manuscripts we receive. I would still ask you to better clarify, in the text, potential similarities with other versions in the internet and to explain what makes the present version unique.

We are grateful about the two constructive reviews we have received, and about your replies and suggestions. Therefore, I invite you to submit a revised version accordingly.

In addition to the reviewer comments, I agree with the one reviewer that it is unfortunate that your study ends/ended in 2014, when the action only happens afterwards. I appreciate that you have provided the additional results about future developments. But I don't understand why you suggest placing it into the appendix, instead of properly integrating it in the text and addressing the changes that happened since 2017, or at least the occurrence of similar events sometime in the time series (similar to ice depletion events (?) that are discussed in the Arctic)? I suggest considering integrating these results and discussion in the main text. I am looking forward to receiving your comments and revisions.

Thank you for your patience and apologies again.

Christian Haas

Response to Editor Comments (From the Authors):

We sincerely thank the Chief Editor, Dr. Haas, for taking the time to handle our manuscript and for the constructive feedback. We have revised the manuscript accordingly.

1. **Regarding the similarity index:**

We acknowledge the editor's concern regarding the similarity index. The overlap primarily arises from an earlier and much less scientifically developed version of this manuscript that was uploaded to open-access preprint repositories (ESS Open Archive), following a prior submission to *AGU–Geophysical Research Letters* (submitted in October 2024). That submission was not accepted, however the preprint remained publicly available, and despite multiple requests, the ESS Open Archive has not permitted its removal. To date, none of the information in that preprint has been published after peer review. Moreover, the version previously submitted to AGU–GRL and uploaded as a preprint, primarily focused on a preliminary comparison of Antarctic sea-ice thickness (SIT) across CMIP6 models using *historical* simulations (1979–2014). **That version "provided a brief analysis of SIT trends and inter-model variability but lacked a detailed assessment of model biases, seasonal behavior, model performances in warmer scenarios and connections with other sea-ice parameters".** We include the statement in quotes above in our text, **lines 84 – 89** as recommended by the Editor, in order to help differentiate between the manuscript under consideration by *The Cryosphere* and the preprint.

The current manuscript submitted to *The Cryosphere* presents a significantly expanded and refined study**.** It integrates new analyses using future projection experiments (SSP5-8.5), introduces multiple new figures and sections (including seasonal bias assessments, future scenario assessments and spatial distribution analyses), and offers a much deeper discussion of the physical mechanisms driving model discrepancies (a new discussion section). Moreover, the results have been completely restructured for clarity and supported by newly added references, updated datasets, and improved visualizations. Together, these enhancements make this current paper a substantially more comprehensive and original contribution than the GRL preprint.

Following are details of the major revisions which distinguish the current manuscript from the preprint. We do not compare these revisions and new work to the preprint in the text of the manuscript under consideration since that could interrupt the flow of the arguments presented in the manuscript:

- **Expanded dataset and methodology descriptions:** We started out with historical experiments of 39 coupled climate models (CMIP6). Our revised manuscript now also includes the selected 39 models for one of the future scenarios (SSP5-8.5) for an additional analysis. The dataset section provides a detailed and updated explanation of all datasets and analytical methods used.

- **Section 3.1 expanded:** This section now includes **Figure 2** (previously in the Supplement), illustrating the seasonal trends in SIT, SIV, and SIA across CMIP6 models and sea-ice products. The accompanying analysis is substantially expanded and newly written.
- **New Section 3.2 – "Future Projections under SSP5-8.5 (2015–2100)"**: This section (with new **Figure 3**) extends the analysis beyond 2014 to evaluate projected Antarctic sea-ice changes through 2100. This addition directly responds to the editor's and reviewer's suggestions and was not present in any earlier version.
- **Revised Section 3.3 – "Seasonal Variations and Inter-relationships"**: Now includes a **Taylor Diagram (Fig. 4;** previously in the Supplement**)** with updated visualizations and a more detailed interpretation than previous drafts.
- **New Section 3.4 – "Seasonality in SIT Biases"**: This section (with new **Figures 6–8**) presents original analyses of SIT bias seasonality, which did not exist in any earlier version or supplement.
- **Revised Section 3.5 – "Spatial Distribution of SIT"**: This section now uses **GIOMAS reanalysis data** (instead of Envisat–CryoSAT-2) as the reference, with entirely new figure (**Fig. 9**), visualizations, and interpretations, making it distinct from prior versions.
- **New Section 4 – "Discussion"**: This is a completely new section, distinct from the previous "Conclusion." It provides an in-depth discussion of model parameterizations, snow–ice interactions, and ice growth processes contributing to the observed discrepancies among models, expanding on reviewer suggestions.
- **Revised Section 5 – "Conclusions"**: The conclusion section has been rewritten and renumbered. It now focuses exclusively on summarizing findings and implications, with updated phrasing and clarity.
- **Updated references:** Newly published literature relevant to our study has been incorporated throughout the manuscript.

2. **Regarding the integration of future scenario results:**

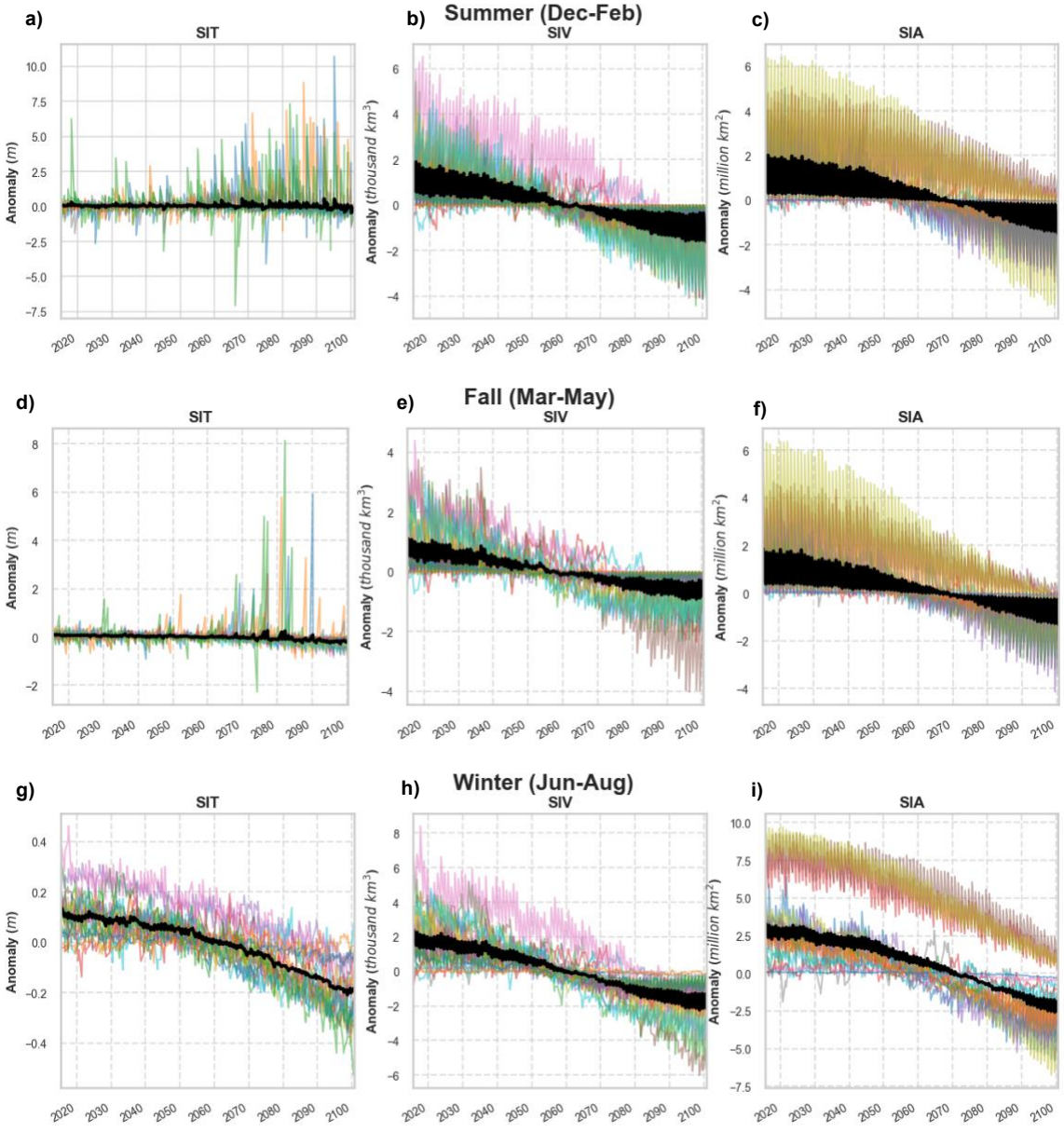
Thank you for your suggestion. We were concerned about exceeding the recommended length (and the number of figures in the main text) of the paper, hence we placed the figures for the future emissions in the supporting document and kept the discussion succinct.

However now, following your suggestion, we have moved the SSP5-8.5 future scenario results (2015–2100) from the Appendix into the main Results section (Section 3.2). We also added a brief discussion connecting these findings to post-2015 Antarctic sea-ice minima, as suggested. The following section has been added to accommodate the comments:

Lines 304-341:

“3.2. Future Projections under SSP5-8.5 (2015–2100)

Since our study uses *historical* experiments in climate models which ends in 2014 (due to the cut-off limits of the *historical* simulations), this section acknowledges the importance of assessing future sea-ice developments, particularly in the Antarctic where pronounced declines in the sea-ice have been observed since 2016 (Raphael and Handcock, 2022; Wang et al., 2022; Turner et al., 2022; Eayrs et al., 2021).



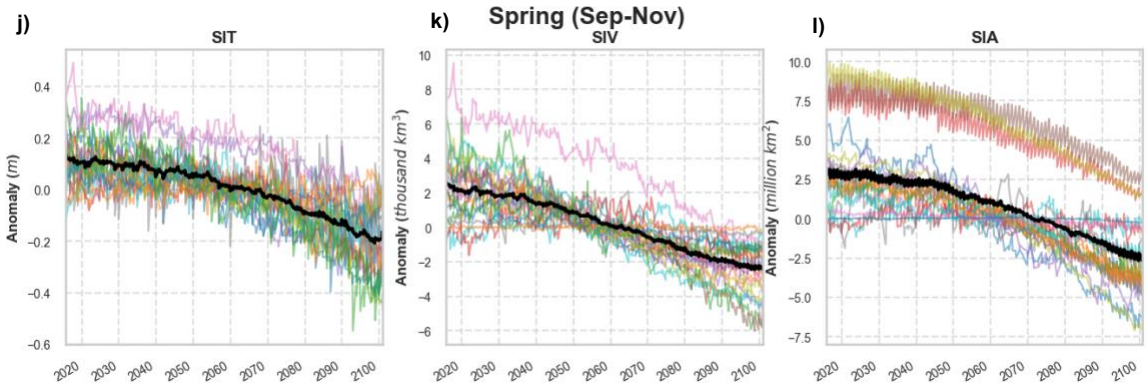


Figure 3: Anomalies for four seasons: Summer and Fall (a-f; Warm Seasons), Winter and Spring (g-l; Cold Seasons) of SIT (left), SIV (middle) and SIA (right) of the circumpolar Antarctic. All the CMIP6 models are shown as colored lines, and the Multi-model Mean in black line. The time-period is 2015-2100 for the SSP5-8.5 scenario. Since sea ice products end in 2014, they could not be included here. Note that 3 models (namely ACCESS-CM-2, ACCESS-EM2-1 and CESM2-WACCM show slightly higher anomalies (especially for SIA), particularly evident during the cooler seasons (i and l).

We examined the seasonal anomalies in sea-ice variables under the high-emission SSP5-8.5 scenario for the period 2015–2100 (Fig. 3). The results are consistent with those in Fig. 2, showing pronounced seasonal trends in SIT, particularly during the cooler seasons (winter and spring). Under the warmer scenario, all CMIP6 models project a notable decline in SIT during these cooler months, while trends in SIT are largely absent during the warmer seasons (summer and fall). In contrast, SIV and SIA exhibit a persistent year-round decline, with negative anomalies becoming more pronounced from approximately 2060 onward (Fig. 3).

When assessing the Antarctic sea ice distributions in the post-2014 period, it is expected that under warming scenarios, models will show reductions in sea ice owing to their response to increasing temperatures. However, our results reveal a seasonally asymmetric pattern of decline: SIA and SIV decrease persistently throughout the year, while SIT exhibits notable thinning only during cooler seasons. This indicates that the overall reduction in Antarctic sea ice projected under warmer scenarios is likely driven by sustained losses in area and volume as actual thinning is not consistently observed across all seasons. Consequently, much of the reduction in simulated sea ice likely arises from changes in surface coverage rather than from widespread structural thinning. These projected declines also correspond well with the observed post-2016 record-low Antarctic sea-ice extents (Turner et al., 2017; Schlosser et al., 2018), indicating that the recent losses may represent the early onset of the long-term downward trend simulated under high-emission scenarios. Such consistency between observations and projections highlights the increasing vulnerability of the Antarctic sea ice system to ongoing atmospheric and oceanic warming. Future studies are needed to investigate this in detail."

Following lines have also been added in the manuscript:

Lines 199-201 in the Dataset Section:

"In addition to the *historical* experiments, we also analyze a warmer scenario, SSP 5-8.5 (Shared Socio-economic Pathway; 2015-2100) to compare with the sea-ice variability in future."

Lines 658-668 in the Conclusion Section:

"To place the historical findings in a broader climate context, we further examined future projections under the high-emission *SSP5-8.5* scenario (2015–2100). These results provided valuable insights into how the observed post-2016 declines may evolve in a warming climate and help link present-day variability to long-term Antarctic sea-ice vulnerability."

We believe these revisions have strengthened the manuscript, and we are grateful for the opportunity to revise and resubmit.