

Reviewer 1

General Comments

This manuscript simulates the Antarctic sea ice minimum that occurred in February 2023 using two different atmospheric reanalysis datasets. It presents the differences in the simulation results and attributes them to variations in atmospheric forcing. This work highlights the importance of selecting appropriate atmospheric forcing data in Antarctic sea ice modelling. It points out that many previous studies on the 2023 summer sea ice minimum relied on ERA5 as the atmospheric forcing field; thus, the resulting attributions and mechanistic analysis may be heavily dependent on this specific dataset. The paper serves as a valuable reminder for future numerical modelling studies to carefully consider how different atmospheric forcing choices impact simulation outcomes and subsequent scientific conclusions. However, there are some shortcomings in the analysis and discussion of the results that need to be addressed before the manuscript can be considered for publication.

We thank the reviewer for their comments and feedback. These comments have been invaluable in improving the manuscript. We are glad the reviewer finds the manuscript valuable as a reminder for modelling studies to carefully consider how different atmospheric forcing choices impact simulation outcomes as this is one of the key messages we wished to convey.

We address each of the specific comments in turn below, with the original reviewer comment in black text, our response comment in blue text, and edited manuscript text as appropriate in green.

Specific Comments

1. The current title does not accurately reflect the content of the manuscript. It should explicitly indicate that this is a comparative numerical simulation study based on two different reanalysis datasets used as atmospheric forcing.

We agree, the title is too broad, so we have changed the title to more accurately reflect the manuscript:

Inferred mechanisms of the 2023 Antarctic sea ice minimum strongly dependent on atmospheric reanalysis choice

2. In the Introduction (Lines 63–94), the author introduces the application and performance of various reanalysis datasets in Antarctica. However, this section reads like a mere list of literature and fails to provide justification for selecting the two specific datasets used in this study. While Section 4 indicates that ERA5 is commonly used in numerical studies of the 2023 Antarctic sea ice extent minimum, there is a lack of background information on JRA-55-do. The manuscript would benefit from a brief discussion explaining why these two specific reanalysis datasets were chosen over others

Thank you, this is a useful point – it is worth explaining in more detail why JRA-55-do was selected. The text in the manuscript introduction is updated to include the following:

ERA5 is selected as it is commonly used in numerical studies of the 2023 Antarctic sea ice minimum, and JRA-55-do is selected as it designed specifically for driving ocean-sea ice models, and has become the replacement for standard Ocean Model Intercomparison Project (OMIP) forcing, and thus likely to become comparable in popularity with ERA5 (Griffies, 2016).

3. Conclusion 3 is derived from Lines 224–226: "By December, however, pronounced regional contrasts emerge. JRA-55 simulates higher SIC relative to ERA5 in the Amundsen, Bellingshausen, and Ross sectors, while ERA5 shows higher SIC in the Weddell and Indian Ocean sectors." This statement is presumably intended to correspond to Figure 2. However, the spatial distribution in Figure 2 for December does not entirely match this description; ERA5 still exhibits higher SIC across all marginal ice zones. The same discrepancy applies to the distributions in January and February. Furthermore, Conclusion 3 fails to specify which month this comparison refers to.

In Figure 2, the third column shows the difference plot of sea ice concentration between ERA5 and JRA-55-do – red regions correspond to regions where ERA5 has higher SIC, blue regions where JRA-55-do has higher SIC. In September, October and November 2022, there is a red ring around Antarctica, representing a higher latitude sea ice edge in ERA5. In December, blue regions appear particularly in the Ross, and slightly in the Amundsen-Bellingshausen sectors. These become more pronounced in January. We wanted to highlight the emergence of regions where the SIC is notably higher for the JRA-55-do forced simulation in December, however we recognise that this description is incomplete and that we should also highlight the behaviour in the marginal ice zone:

In December, regional contrasts begin to emerge. A region of higher SIC in JRA-55-do forced simulation starts to occur in the Ross sector (and to a lesser extent in the Amundsen-Bellingshausen sector). However, the SIC difference is still dominated by the marginal ice zone differences that persist from September, October and November. By January, the regional contrasts strengthen: the higher SIC in ERA5 at the sea ice edge diminishes in the Ross and Amundsen-Bellingshausen and West Pacific (disappearing entirely in February). The regions of higher SIC in the JRA-55-do forced simulation in Amundsen-Bellingshausen and Ross seas, as well as around the Weddel Sea near the Antarctic Peninsula, strengthen.

Similarly, we will also update conclusion 3 to reflect this (conclusion 4 in revised manuscript):

In September, October and November, marginal ice zone differences are the primary difference between the forced simulations. However, in December, regional differences start to become evident in the spatial distribution of the sea ice between the two forced simulations. By January, the regional contrasts strengthen; with regions of higher SIC in the JRA-55-do forced simulation in the Amundsen-Bellingshausen and Ross seas, as well as around the Weddell Sea near the Antarctic Peninsula, and regions of higher SIC in the ERA5 forced simulation in the Weddell Sea.

4. Conclusion 5 is drawn from the last two paragraphs of Section 3.2. This conclusion appears to be a mere speculation based on the temporal evolution of the SIC differences between the two simulations from December to February. There is no additional supporting evidence provided for the ice-albedo feedback, such as changes in incoming shortwave radiation or

variations in ocean temperature. Such speculation is insufficient to serve as a formal conclusion. I recommend either removing this point or providing robust evidence to support it.

Thank you for this point. This will be moved from the conclusions to the discussion, as it is more of a speculative point than a formal conclusion.

5. Section 4 provides a detailed discussion of recently published numerical modeling studies on the 2023 summer Antarctic sea ice extent minimum. Most of these studies utilize ERA5 as the atmospheric forcing field, and this manuscript explores the potential implications of this choice. This discussion is highly instructive for future modeling efforts. However, the current discussion is somewhat fragmented. I recommend conducting a deeper analysis and synthesis to extract generalized insights, which could then be incorporated into the Conclusions.

Thank you; we are glad that the reviewer finds the discussion engaging and highly instructive for future modelling efforts. As suggested, we have substantially edited the discussion and introduced new subheadings to better organize the concepts discussed and to more effectively identify and convey insights. The edited discussion is shown in full below:

4 Discussion

Our study has broader implications for the interpretation of recent literature on the 2023 Antarctic sea ice minimum. Here, we discuss whether our results are consistent with mechanisms proposed in the literature to explain the 2023 extreme minimum, and assess the extent to which these mechanisms may be sensitive to the choice of atmospheric reanalysis. In this section, we look at implications for studies inferring mechanisms from reanalyses (Section 4.1), implications for studies using atmosphere forced ocean-sea ice simulations (Section 4.2), and finally limitations of our own study (Section 4.3).

4.1 Implications for studies inferring mechanisms from reanalyses

In this study, we investigate the differences between the atmospheric patterns between JRA-55-do and ERA5 in the lead up to the February 2023 minimum (Section 3.4), which have implications for studies that rely on a single reanalysis to infer mechanisms. A substantial proportion of the literature relies on a single atmospheric reanalysis, most commonly ERA5, to infer mechanisms driving the 2023 Antarctic sea ice minimum, and our results suggest that some conclusions are sensitive to this choice. Across both simulations, strong wind anomalies in October and February 2023 were consistently present in both ERA5 and JRA-55-do. The presence of both the strong wind anomalies, as well as the agreement between the two analyses, lends confidence to conclusions from studies using only one reanalysis that emphasise wind driven dynamical mechanisms. We do not show however that wind anomalies are necessarily the key, causal driving factor of the 2023 Antarctic sea ice minimum. Consistency in wind speed anomalies across the two reanalyses also does not necessarily imply that both reanalyses accurately represent wind speed, but it improves our confidence that this is the case relative to the scenario where the wind forcing is very different across the two reanalyses. Thermodynamic fields, particularly downwelling longwave and shortwave radiation, differed substantially between the reanalyses, whereas dynamical fields showed greater

agreement. These similarities and differences have direct implications for how conclusions drawn from reanalysis forced studies should be interpreted.

Ma et al. (2025) identified a dipole-like pattern of winter sea ice variability across the Weddell and King Haakon VII Seas, termed the East Antarctic Dipole (EAD), which they attributed to thermodynamic and dynamic processes associated with anomalous low pressure centred between the Weddell and King Haakon VII Seas. Atmospheric fields in that study were taken exclusively from ERA5. They identify sea ice motion as a primary driver, with geostrophic winds exporting ice westward from the King Haakon VII Sea and northward from the interior Weddell Sea, with temperature advection from cold southerlies over the Weddell Sea and warm northerlies over the King Haakon VII Sea providing a thermodynamic contribution. We find good agreement between ERA5 and JRA-55-do in wind speed and direction anomalies, suggesting that the associated dynamical forcing is robust, yet thermodynamic fields differ substantially between the reanalyses. In October, when the dipole persists (Ma et al., 2025), ERA5 exhibits stronger downwelling longwave radiation anomalies over the Weddell Sea and weaker anomalies over the King Haakon VII Sea than JRA-55-do. Because these differences project directly onto the two poles of the dipole, they could alter its thermodynamic component in ERA5-based analyses, potentially affecting estimates of the strength of the EAD and of the relative importance of dynamic and thermodynamic processes, even if the dipole itself is dynamically robust.

Similarly, Dou and Zhang (2025) attribute the February 2023 minimum in part to an Antarctic dipole pattern in spring 2022, associated with the co-occurrence of a positive SAM, La Niña, and a negative Indian Ocean Dipole. They use reanalysis data to explain the satellite observed sea ice dipole pattern, with increased sea ice in the northern Ross Sea and reduced ice in the Bellingshausen and northern Weddell Seas. The atmospheric processes invoked to explain this observed sea ice pattern, including a deepened and westward-shifted Amundsen Sea Low, and warm-air advection by north-westerlies over the Bellingshausen and Weddell Seas, are diagnosed exclusively from ERA5. We find strong air temperature differences in the Weddell Sea in October 2022, with much warmer air temperatures in ERA5 than JRA-55-do. Our simulations also show that regional sea ice behaviour is sensitive to the choice of reanalysis in precisely these regions, particularly the Weddell Sea, where ERA5 forcing produces substantially lower sea ice concentrations near the Antarctic Peninsula, and higher sea ice concentrations elsewhere in the Weddell Sea, compared with the JRA-55-do forced simulation. Given the close agreement in wind anomalies between the two reanalyses, the dynamical component of the proposed dipole mechanism is likely robust, but the relative contribution of thermodynamic forcing, and therefore the attribution of Weddell Sea ice loss to the processes identified in ERA5-based analyses, may depend on the reanalysis choice.

de Azevedo et al. (2025) likewise use ERA5 and attribute the February 2023 minimum to a positive SAM phase and La Niña conditions during September, which intensified winds and reduced sea ice in the Amundsen, Bellingshausen, and Weddell Seas while increasing ice in the Ross Sea; Jena et al. (2024) further show that storms and cyclones in the Weddell and Ross Seas are likely to have further contributed to the record low conditions, through episodes of exceptional slow ice expansion or even retreat. Our results lend confidence to the wind driven

component of these interpretations, given the consistency of strong wind anomalies across reanalyses, but the thermodynamic component remains more uncertain.

Swathi et al. (2025) uses the ERA5 reanalysis product, as well as ORAS5 ocean reanalysis, and NASA team passive microwave data for sea ice observations. They found that the Weddell and Amundsen-Bellingshausen Seas experienced the most decline in austral spring and summer, respectively, while the Ross Sea showed the minimum sea ice loss. They link these losses to a persistently positive SAM, reinforced by lower stratospheric cooling, and to a deepened Amundsen Sea Low associated with the transition from the 2020-2022 triple dip La Niña towards El Niño, which advected warm air towards the Antarctic Peninsula and drove ice towards the coast, particularly in the Bellingshausen Sea. Their thermodynamic interpretation relies on ERA5 net surface heat flux, including its longwave and shortwave components, attributing ice loss near the Antarctic Peninsula and in the Weddell Sea to anomalous surface heat exchange. These are the regions in which we find some of the largest differences in radiative fluxes between ERA5 and JRA-55-do, and in which our forced simulations produces substantially differing sea ice concentration patterns. This suggests that the attribution of the importance of thermodynamic forcing may be sensitive to the reanalysis used.

Wang et al. (2024a) attribute the Antarctic February 2023 sea ice minimum to different mechanisms depending on Antarctic region. They attribute the record December retreat in the Ross Sea to a deep Amundsen Sea Low, and southerlies associated with this that exported ice northward, opening coastal waters and triggering an ice–albedo feedback, which they identified from ERA5 net shortwave flux anomalies. Elsewhere, including the Weddell and Bellingshausen Seas, they attribute suppressed ice growth to warm-air advection holding back ice growth. In October 2022, we find close agreement between ERA5 and JRA 55-do in both wind and shortwave radiation anomalies over the Ross Sea, suggesting that this dynamical and ice–albedo mechanism is robust to the choice of reanalysis. In contrast, downwelling longwave radiation and near surface air temperatures differs substantially between the reanalyses over the Weddell Sea in October 2022, with warmer temperatures in ERA5, so the thermodynamic attribution of ice loss in this region, and its representation in ERA5-forced simulations, may be more sensitive to the forcing product.

Further to this, not all relevant studies focus on the causes of the 2023 minimum; some instead examine its consequences or longer term context, yet still rely on reanalysis forcing, so our results have implications for these studies too. Josey et al. (2024), using both ERA5 and MERRA-2, investigate not the causes of the 2023 minimum but rather its consequences for ocean–atmosphere interaction, a complementary focus to our study. They find that the strongest regions of sea ice retreat, located primarily in the Weddell, Bellingshausen and Ross Seas, provided an important new source of turbulent ocean heat loss, with ice concentration reduced by up to 80% and an unprecedented doubling of mid winter ocean heat loss. Crucially, they find close similarity in the pattern of net heat flux anomaly between ERA5 and MERRA-2, suggesting that in this case, the intensity of the ocean heat lost dominates any variations that may arise from differences in reanalysis physics and data assimilation. However, we find whilst there is strong sea ice retreat in the Ross Sea in both JRA-55-do and ERA5 forced simulations, the two simulations diverge on whether there is more remaining ice in Bellingshausen or Weddell Sea and Indian Ocean.

In summary, a significant number of studies use solely ERA5 reanalysis data, and particularly, attribute positive SAM phase as a contributing mechanism. We find good agreement in wind speed and direction between ERA5 and JRA-55-do, in both October 2022 and February 2023, lending confidence to dynamical mechanisms. However we find significant downwelling longwave flux and air temperature differences in October 2022, as well as significant shortwave flux differences in February 2023.

4.2 Implications for studies inferring mechanisms using atmosphere forced ocean-sea ice simulations

Our study also has implications for existing studies that use atmosphere forced ocean-sea ice simulations to infer mechanisms contributing to the February 2023 sea ice minimum. The two simulations produce divergent sea ice responses; the largest differences in sea ice concentration between ERA5 and JRA-55-do forced simulations occur near the ice edge, but as the season progresses, systematic anomalies also develop away from the edge. This amplification of both positive and negative anomalies is consistent with ice–albedo feedback, where initial differences in ice cover alter surface albedo, enhancing melt or growth and reinforcing spatially coherent differences. The two reanalyses produced markedly different regional sea ice responses; the Weddell Sea showed the greatest sensitivity to reanalysis choice, with ERA5 forcing producing substantially lower sea ice concentrations than JRA-55-do, while the exceptional loss in the Ross Sea was more robust across both simulations. Our JRA-55-do forced simulation more closely replicates the observed sea ice state during the 2023 minimum, but it is possible that there could be a compensation of a model error that masks errors with the JRA-55-do forcing data, not detected in our results, but potentially noticeable with a different sea ice or ocean model.

Mezzina et al. (2024), using an ERA5 forced NEMO–LIM configuration, identify the Ross and Weddell Seas as the dominant contributors to summer minima, with thermodynamic processes outweighing dynamic ones at large scales. Although our results agree on the exceptional loss in the Ross Sea, we find that the Weddell Sea response is more sensitive to reanalysis choice, with ERA5 forcing producing increased ice concentrations in February 2023 relative to JRA-55-do, except near the Antarctic Peninsula, where the ERA5 forced simulation exhibits lower SIC compared with JRA-55-do. Stronger shortwave flux anomalies in the Ross Sea under ERA5 further suggest that reliance on a single reanalysis may overemphasise thermodynamic mechanisms at the expense of dynamical contributions.

Richaud et al. (2026), also using a NEMO-SI3 configuration forced by ERA5, investigates the sea ice mass budget during sea ice lows and find that reduced basal growth characterised the 2023 minimum, driven primarily by ocean conditions at the sea ice–ocean interface. They further find an increased importance of dynamics in the sea ice mass budget; since our results show that wind speeds are largely consistent between reanalyses, this lends some confidence to their dynamical conclusions. However, we find that downwelling longwave flux is stronger in ERA5 than JRA-55-do during October 2022 in the Weddell and Amundsen Bellingshausen Seas, suggesting that the use of ERA5 alone could underestimate the role of surface thermodynamic conditions relative to basal mass budget terms.

Kusahara and Tatebe (2025) use a sea ice–ocean model forced exclusively by ERA5 surface boundary conditions to investigate the broader 2016–2023 Antarctic sea ice decline, rather than focusing specifically on the 2023 minimum. Their numerical experiments reveal that thermodynamic boundary conditions, particularly increased sub-polar sea surface temperatures north of the sea ice edge, are the dominant drivers of the decline, with wind stress playing a secondary role. However, since their model relies exclusively on ERA5 forcing, and our results show that thermodynamic fields differ substantially between ERA5 and JRA-55-do, the magnitude and spatial structure of the SST driven signal in their study may be sensitive to reanalysis choice, particularly in regions such as the Weddell Sea where our simulations show the greatest thermodynamically driven differences in sea ice response.

Goosse et al. (2025) similarly use ERA5 forcing in a NEMO-SI3 configuration, but with a focus on the mean state relationship between Antarctic Circumpolar Current (ACC) frontal positions and the climatological winter sea ice edge rather than on interannual variability or the 2023 event specifically. They find that the latitude of all ACC fronts correlates strongly (above 0.85) with the mean winter ice edge position, with the Polar Front identified as the most consistent indicator, and attribute this relationship to heat transport via mesoscale eddies and atmospheric processes downstream of major bathymetric features. Since both the atmospheric fields and the NEMO simulation derived oceanic heat fluxes in their study are ERA5-forced, both components of this mechanism could be sensitive to reanalysis choice. Our results show that ERA5 and JRA-55-do produce notably different thermodynamic fields and mean sea ice edge positions, suggesting that the relative contributions of oceanic and atmospheric heat transport to the ice edge position in Goosse et al. (2025) may differ under alternative reanalysis forcing. Our study thus highlights that implications of reanalysis sensitivity extends beyond interannual variability and attribution of mechanisms of extreme events, and may also affect conclusions about the mean state processes governing Antarctic sea ice, underscoring the potential scope of impact from potential biases introduced by using a singular reanalysis product.

In summary, we find that ERA5 is also the most common reanalysis used for forced ocean-sea ice models studying the 2023 Antarctic sea ice minimum. As JRA-55-do grows in usage, there are implications for differences in the simulated sea ice state. We find that the spatial structure of the 2023 sea ice minimum, i.e. which Antarctic regions have higher or lower sea ice concentration anomalies, is sensitive to reanalysis choice, and therefore that conclusions drawn from this warrant caution. We particularly find that a number of studies rely on an accurate assessment of the sea ice edge, which we find to be affected by the choice of reanalysis forcing in the months leading up to the minimum (October, November, December). Similarly, whilst we do not investigate this in our study, the common use of NEMO as the ocean model of choice could present some biases in mechanisms when compared with other ocean models.

4.3 Limitations of our study

Our study focusses on simulations of the 2023 Antarctic sea ice minimum, by atmospheric reanalysis forced simulations, rather than fully coupled models. Atmosphere forced simulations are computationally cheaper than fully coupled climate simulations, and can compensate for sparse in situ observations in the Antarctic. Using forced simulations instead of

fully coupled models can also aid reduction of the carbon impact of climate science by using less resource intensive methods. Atmosphere-forced simulations are also often used for studies focused on sea ice model development or understanding how improvements in the representation of particular processes can impact sea ice evolution (Flocco et al., 2012; Roach et al., 2018; Li et al., 2025). In such studies, the use of a forced atmosphere can be beneficial to allow multiple simulations (e.g. sensitivity studies), and also makes it easier to understand particular changes in sea ice without the additional internal variability introduced with a coupled atmosphere. In the context of the continued utility of atmosphere forced simulations, it is therefore important to analyse the impact of reanalysis choice as we have done here.

However, even where multiple reanalyses are employed, atmosphere forced simulations still carry additional limitations that warrant consideration. The absence of a fully coupled atmosphere means that feedbacks involving the atmosphere cannot be captured. A further limitation, even when using multiple reanalyses, is the high sensitivity of the sea ice system to aspects of reanalyses with a high uncertainty, such as the representation of clouds and radiative fluxes, which are known to be uncertain in reanalysis products. Boehm et al. (2025) attribute a substantial fraction of the decadal decline in Antarctic sea ice to SAM associated clear-sky shortwave feedbacks, deliberately using satellite observations from CERES rather than reanalysis radiative fluxes, citing known uncertainties in the latter; for instance, moisture and energy budgets in ERA5 experience spurious trends (Mayer et al., 2021) and ERA5 has been shown to have biases in mixed phase clouds that could impact radiative fluxes (Silber et al., 2019; Lenaerts et al., 2017). Whilst Boehm et al. (2025) finds comparatively weak contributions from longwave radiation, in our simulations, notable differences in longwave radiation anomalies are evident between ERA5 and JRA-55-do, showing an influence of reanalysis choice on radiative flux anomaly strength. Together, these results suggest that caution is warranted when attributing Antarctic sea ice variability to specific radiative mechanisms based on reanalysis forcing, particularly in regions and seasons where cloud radiation interactions play a significant role. Clouds are also uncertain in fully coupled Earth system models, so the use of them does not necessarily bring advantages over reanalysis forced simulations (Schuddeboom and McDonald, 2021).

An additional limitation of our study is that we focus purely on the role of the atmosphere on the February 2023 sea ice minimum, whilst some studies emphasise the critical role of the ocean (Purich and Doddridge, 2023; Silvano et al., 2025). Future work could investigate secondary order effects, of the impact of atmospheric forcing choice on the ocean state that in turn lead to impacts on the sea ice state. Further to this, future studies could investigate the impacts of atmospheric forcing on Antarctic extreme events more generally, to further our study on specifically the impact on simulation of the extreme minimum of February 2023. As well as this, our study focusses on the impact of atmospheric reanalysis when used as forcing for a coupled ocean sea-ice model, as this is a popular methodology. To extend this, it could be beneficial to investigate the impact of reanalysis choice when used as the target of relaxation for winds or temperature in a fully coupled model setup.

6. Many studies emphasize the critical role of the ocean. Since the model outputs in this study include ocean variables, a comparative analysis of these oceanic fields should be conducted to

provide a more comprehensive understanding of the impacts caused by differences in atmospheric forcing.

We thank the reviewer for this comment as this is an interesting point- it is true that many studies emphasise the role of the ocean. However, we focus on the role of the atmosphere on the Antarctic sea ice minimum in 2023, and the impact of reanalysis forcing on this. We did not produce ocean outputs from our simulations. We have focused our analysis on the atmospheric forcing, which drives the differences between the two simulations, and the sea ice state, which is the key metric of interest in this study. Some atmospheric impacts on sea ice state will act indirectly via interactions with the surface ocean, but these impacts are still a result of differences in the atmosphere.

It would be interesting to further study impacts of atmospheric forcing on the ocean state (and the impacts of this on the sea ice), and to reflect this we have added a paragraph addressing this suggestion for future work to the discussion (limitations section) – please see updated text of discussion in point 5.

7. The authors mention melt ponds in both the model setup (Lines 124–127) and the results section (Lines 195–196). However, melt ponds are rare on Antarctic sea ice and their impact on simulations and satellite remote sensing is not significant. The relevant model setup and the cited literature (Aparício et al., 2025) are specifically tailored for Arctic sea ice.

The model setup includes topographic melt ponds as part of our standard setup, and the methods section must include all details of the model setup, regardless of strong impact or weak impact on the Antarctic sea ice state. It is true to say that the impact will be less than that of Arctic focussed simulations, however, melt ponds do still occur in the Antarctic, and thus it is worth mentioning their inclusion. We agree that is worth explicitly emphasising however that the choice of melt pond scheme is unlikely to be an important aspect of our model setup, so as the reviewer suggests we edit the text to emphasise this:

Activate topographic melt pond scheme: This is an explicit melt pond parameterisation scheme that represents meltwater accumulation. Melt ponds evolve via realistic processes: input from snow melt, ice melt, and rain, drainage through ice permeability or floe-edge spillover, refreezing, and snow infiltration that modulates radiative effects. This scheme has been shown to enhance realism in simulated summer sea ice evolution, although the choice of melt pond scheme is unlikely to have a strong impact on Antarctic sea ice).

We also remove the reference to melt ponds in lines 195-196.

8. Line 265: The text states "negative anomalies in the northern sea ice edge and Ross Sea", but this is inconsistent with what is shown in the corresponding figure.

Thank you for this point, it is worth improving our description of the EOF spatial patterns:

When EOF1 is positive (red in Figure 4), this corresponds to a region of enhanced February sea ice concentration in ERA5 compared to JRA-55-do. This occurs in the majority of the Weddell Sea, and weakly near the ice edge in the Amundsen Bellingshausen sector. Where EOF1 is negative (blue in Figure 4), this corresponds to enhanced sea ice concentration in JRA-55-do

compared to ERA5. This occurs across most of the Amundsen Bellingshausen region, as well as part of the Weddell Sea (near the Indian Ocean sector, and at the ice edge).

9. Lines 268–269: "The PC1 time series remains weak during December–February (DJF) 2022/23, while PC2 exhibits a pronounced peak." This description contradicts the features in Figure 4. Furthermore, Figure 4 only presents results for February. A similar issue occurs at Lines 285–286.

Thank you for raising this, as it is a similar issue to the previous point, so we amend the text to more accurately reflect Figure 4.

Lines 268–269: PC1 is weakly negative during February 2023. In contrast PC2 remains strongly positive in 2021, 2022 and 2023.

Lines 285–286: PC2 remains high during February 2023

10. Section 3.4 primarily discusses atmospheric anomalies in October, with only a brief mention of February at the very end. Please clarify the rationale for this approach. Additionally, the paragraph starting at Line 323 discusses "a modest positive sea ice concentration anomaly in October." Given that the focus of this manuscript is on the sea ice extent minimum, shouldn't the emphasis be on negative SIC anomalies? Finally, the term "circulation" mentioned at Line 340 does not appear to have been introduced or discussed previously in the text.

Thank you, we should clarify further why we use this approach in section 3.4.

We discuss atmospheric anomalies in both October 2022 and February 2023, in order to study atmospheric differences both during the extreme minimum as well as in the months leading up to the minimum. October is the month just after the sea ice maximum (i.e. the onset of seasonal sea ice retreat) so allows us to study differences at both extremes of the sea ice state and understand whether differences in October lead to differences later in February.

Whilst it is true that our manuscript focusses on the extreme sea ice minimum, this means that positive SIC anomalies are still interesting, in that they show the regional differences in the sea ice behaviour, and how they occur in the JRA-55-do and ERA5 forced simulations. Notably, this region where the positive SIC October anomaly occurs, in the marginal ice zone of the Amundsen-Bellingshausen and Ross sectors, is also a region with significant negative sea ice concentration anomalies later in February. Furthermore, the Amundsen-Bellingshausen region is one where major differences occur between the two forced simulations, with a region of enhanced SIC in JRA-55-do compared with ERA5 nearer the sea ice edge.

It is a good point that we do not previously mention 'circulation' in the text, so we will remove the reference to this word in line 340.

Technical Corrections

1. Figures should generally be placed immediately after the text where they are first mentioned. Please adjust the positions of Figures 1, 5, etc., accordingly.

Figure positions adjusted to ensure they are correct (generally at the start of the section, before the text)

2. Several abbreviations (e.g., ERA, JRA) are not defined at their first occurrence. Please provide their full names.

The text has been amended to define the abbreviations.

3. Please ensure consistency in naming the two datasets throughout the manuscript: use ERA5 and JRA-55-do.

The text has been adjusted to ensure all mentions of ERA5 are consistent, and all mentions of JRA-55-do are correct and not mistakenly JRA-55.

4. Line 30: Does "1979-" refer to "1979–2023"? Please specify the end year.

Corrected to say 1979-2023.

5. Line 111, "We use two coupled NEMO - SI3 (Vancoppenolle et al., 2023) ocean sea ice model simulations." Could it be changed to "We use two coupled ocean-sea ice model simulations performed with NEMO-SI3 (Vancoppenolle et al., 2023)."

Thank you for the suggested wording change, and we have changed the text to reflect this.

6. Line 112, "2 degree": The spatial resolution of the model is unlikely to be so coarse. Is this a typographical error?

Our simulations do use the standard NEMO ORCA2 grid configuration (nominal 2° resolution).

7. In Figure 1d, the satellite remote sensing results are plotted with a solid line, which does not match the line style indicated in the legend.

We will amend panel d to use dotted line for the observations

8. Line 214: The unit "km" should not be italicized.

We have corrected this error.

9. The statements in the beginning of Section 3.2 should be supported by referencing the corresponding figure numbers.

We amend the text to ensure the statement at the beginning references the Figure numbers

10. In the last sentence of the caption for Figure 2, should "JRA-55-do" actually be "ERA5"?

Yes, thank you for pointing out that error, which we have corrected

11. Section 3.3 states: "The analysis was applied to the annual series of each monthly mean separately, in order to minimise the influence of the seasonal cycle and to instead emphasise inter-annual variability." However, both the text and Figure 4 only present results for February. This limitation should be explicitly stated in both the main text and the caption of Figure 2.

We rephrase that paragraph, and the Figure caption to explicitly mention that February monthly means are used.

12. Line 261: The phrase "the EOF is positive" is an inappropriate expression. Please rephrase.
We use the alternative phrase 'EOF signal'

13. Line 300: The term "the Amundsen-Bell region" has not been defined previously. Should this be standardized to "the Amundsen–Bellingshausen and Ross sectors"?

We change all references in the text to Amundsen Bell to Amundsen Bellingshausen

14. Line 315: The description "the West Pacific sector" is inaccurate.

Changed to Western Pacific Ocean sector

15. Line 321: For the phrase "sea ice concentration by February 2023", please add the corresponding figure number.

Added Figure number

16. At Lines 9–11 and other locations, sentences contain parenthetical insertions starting with hyphens or em-dashes ("- " or "— "). I feel this specific writing style is strongly indicative of AI-generated text. Please revise the phrasing to ensure a natural academic tone.

No AI has been used to write this manuscript. Referring to the Cryosphere style guide, dashes, including en dashes, are permitted for separating clauses. However, we have modified the text (including line 9) where a comma or semicolon can improve the readability and tone.