Response to Review of Climate Controls on Snowfall at Coastal West Antarctic Ice Rises - Potential Ice Core Sites

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We thank the editor for their careful handling of this manuscript and for their encouraging assessment of our initial responses. We also thank Referees 1 and 2 for their careful and constructive comments. Their feedback has meaningfully strengthened the work. Below, we respond to each comment in turn. Reviewer comments are shown in italics, and our responses follow in regular text. Where applicable, we note revisions made to the manuscript.

Reviewer Comment #1:

Overview Comments:

The authors use contemporary reanalyses to explore the relationship (primarily) between annual snowfall and the primary modes of variability affecting ice rise locations along with West Antarctic coast to the west of sites drilled by BAS. Ice core observations to extend the contemporary record of the "pole of variability" are really needed to provide a much longer-term perspective for this critical region for global sea level rise. The goal is to identify those sites that are more favorable to reconstructing specific modes going back decades to centuries (?) in the past. The challenges that reanalyses experience prior to 1979 (Bromwich et al. 2024) emphasize the need. The authors are suitably cautious about the fidelity of reanalyses along this coast post 1979 especially that has limited direct observations. Figure 3c verifies the need for caution, although the precipitation variations in Fig. 3d are very similar. Overall, I found this analysis interesting, significant, and well done apart from a few issues that need attention, constituting a minor-major revision.

We are grateful for this positive overall assessment and for the specific comments below, which we address individually.

Specific Comments:

1. *Line 15: Add "current" before "relative"*
    a. Thank you. We have revised Line 15 to read: "...and warrant exploration via climate reanalysis to assess the current relative balance of climate controls at any potential ice core site."
2. *Line 39: Proxy temperature seems more likely.*
    a. We agree. Line 39 has been revised to refer to "proxy temperature" rather than "temperature" in recognition that ice core temperature records are derived from geochemical proxies (e.g., stable water isotopes) rather than direct thermometric measurements.

3. *Line 54: A good reference to add here is doi: 10.1016/j.gloplacha.2017.04.008*
    a. Thank you for this suggestion. We have added this reference (Scambos et al., 2017) at Line 54, where we discuss the observational gap along the WAIS coast.
4. Line 72: weaken not deepen.
    a. Thank you for this correction. Upon review, we agree that El Niño phase of ENSO is associated with a positive geopotential height anomaly in the Amundsen Sea region, that is, a weakening of the ASL rather than a deepening. We have revised the text at Line 72 to read: "...with El Niño phase of ENSO occurring when warmer tropical Pacific waters send atmospheric teleconnections that weaken the ASL (Cook et al., 2016; Ding et al., 2011)..." This correction is consistent with the cited literature, with the broader regional pressure response to El Niño conditions, and with other sections of the paper (Line 80, Lines 319-321).
5. *Line 89: O'Conner et al. (2025) is just an abstract. More recent publication details where the details can be found?*
    a. Thank you for flagging this. We have updated this to reference the paper published from this abstract in September, 2025 (O'Connor, G.K., Nakayama, Y., Steig, E.J. et al. Enhanced West Antarctic ice loss triggered by polynya response to meridional winds. Nat. Geosci. 18, 840–847 (2025). https://doi.org/10.1038/s41561-025-01757-6).
6. *Line 106: I do not understand what "uniquely unbiased" means.*
    a. We apologize for the unclear phrasing. The intended meaning was that the WAIS coast, unlike other Antarctic sectors, has not been selectively sampled by researchers in ways that would bias the distribution of observations. We have revised this sentence to read: "...in fact, the WAIS coast is notably underrepresented in sustained human observations relative to other Antarctic sectors," which more clearly conveys the point without the ambiguous phrase.
7. *Lines 124 and 125: You need original references for ERA5 (Hersbach et al. 2020, https://doi.org/10.1002/qj.3803) and MERRA2 (Gerlaro et al. 2017, https://doi.org/10.1175/JCLI-D-16-0758.1).*
    a. Thank you. We have added the primary dataset references: Hersbach et al. (2020) for ERA5 and Gelaro et al. (2017) for MERRA-2, at Lines 124–125. Full citations have been added to the reference list.
8. *Fig. 3c: It is distressing to see the divergence of the temperatures in mid 2000s between ERA5 and MERRA2. Please do some more investigation as to how and why this occurs. Are particular sites to blame? Etc.*
    a. Thank you for highlighting this. As shown in Figure 3b, the lowest ERA5–MERRA-2 temperature correlations are spatially coherent along the coastline where the ice rises are located, rather than being attributable to individual outlier sites. The blue band of low correlation running along ~70–75°S corresponds directly to the strip where all 13 ice rise locations sit. This regional structure

strongly suggests the mid-2000s divergence visible in Figure 3c reflects a known reanalysis artifact rather than a processing error or site-specific issue. We have added a sentence to Section 3.1.1 explicitly noting this spatial coherence to directly address this comment.

   b. This coastal disagreement is consistent with broader documented inter-reanalysis discrepancies in Antarctic temperature. Wang et al. (2025, doi: 10.1016/j.accre.2025.03.003), using an ensemble of five reanalysis products including both ERA5 and MERRA-2, show that these datasets can give substantially contrasting temperature signals in coastal Antarctic regions. Zhu et al. (2021) further note that while MERRA-2 can capture monthly temperature variability over Antarctic stations, its correlations with observations are generally lower than those of ERA5, attributable to differences in the dimensionality and input data of their respective assimilation systems. This dataset-level difference likely contributes to the inter-product divergence we observe here. Separately, Bromwich et al. (2024) demonstrate that ERA5 successfully captures interannual temperature variability at all Antarctic station locations after 1979, which is the period and variable type central to our analyses. Together, these considerations support our use of ERA5 as the primary reanalysis product for all subsequent analyses and further underscore the need for direct observational constraints from future ice core records at these sites.

9. Section 3.1.2: Looking at Figs. A1-A4 the zonal winds along the West Antarctic coast appear to be easterlies (U<0). If so, this will change your interpretation of the correlation coefficients between precipitation and the zonal winds.
   a. Thank you for this important observation. We note that the original Figures A1–A4 were conceptual schematics depicting the large-scale Southern Ocean westerly wind belt and its modulation by SAM and ENSO; they were not representations of near-surface coastal wind directions at the ice rise locations. The wind arrows in those figures illustrated the broad mid-latitude circulation, not the local surface wind field at the coast, where katabatic outflow and the polar anticyclone can indeed produce easterly surface winds.
   b. With respect to our correlation analysis, the broader Amundsen Sea box (55–72°S, 105–150°W) extends well into the mid-latitude westerly belt where the climatological mean U-wind is positive (westerly), so the sign interpretation of the negative U-wind correlations in Figure 4a remains valid: stronger westerlies in this domain suppress precipitation at West Sector sites. However, we acknowledge the reviewer's concern has more validity for the narrower S12 box (72–68°S, 125–100°W), which sits closer to the coast where easterly surface winds are more prevalent. The reversal to positive U-wind correlations in the S12 box for East Sector sites (Figure 4d) may in part reflect this mixed wind regime, where the box average simultaneously captures westerly open-ocean flow and

easterly coastal flow, potentially diluting or reframing the correlation signal. We have added language to Section 3.1.2 acknowledging this as a limitation of the box-averaging approach and note that a full spatial correlation analysis would be a more robust approach for disentangling these competing wind directions, representing a natural avenue for refinement in future work.

   c. The original Figures A1–A4 (conceptual wind schematics) have been removed from the revised manuscript as they are not central to the quantitative analysis presented. Note that the validation figures previously in Appendix B (ERA5-derived SAM and Niño 3.4 index comparisons with observational records) have been renumbered as Figures A1 and A2 in the revised manuscript's Appendix A.

10. *Lines 241-242: ..”high-pressure ridging..” Presumably this relates to the positive pressure anomalies at high latitudes when SAM is positive.*
    a. Correct, and thank you for the clarification prompt. We have revised Lines 241–242 to be more explicit: "...promoting high-pressure ridging associated with positive geopotential height anomalies..." This makes clear that the ridging is a feature of the high-latitude pressure response to positive SAM, not a mid-latitude phenomenon.

11. *Line 264: Stronger southerly flow corresponds to $V > 0$ not $V < 0$.*
    a. Thank you for this correction. The reviewer is correct that by standard meteorological convention, $V < 0$ corresponds to northerly flow (from north toward south) and $V > 0$ to southerly flow. We have corrected Line 264 and all related text throughout the manuscript accordingly. The modified text now reads: "Both West Sector and East Sector sites show negative correlations with meridional wind (V-wind, Figure 4b-e), indicating that northerly flow ($V < 0$) is associated with drier conditions at the ice rises."
    b. To verify the directionality of this result, we inspected the climatological mean V-wind in both correlation domains as a diagnostic check. The mean V-wind is northerly (negative) in both the S12 box (−0.11 m/s) and the broader Amundsen Sea box (−0.39 m/s). The negative V-wind correlations therefore reflect a physically coherent and verified signal: years with anomalously stronger northerly flow correspond to drier conditions at the ice rises.
    c. We acknowledge that the mechanism linking stronger northerly flow to precipitation suppression is not fully resolved in the literature. Rather than over-interpreting the direction, we have revised the manuscript text to state the observed correlation clearly and note its consistency with the recognized importance of meridional winds as a regional climate signal, as demonstrated by O'Connor et al. (2025). The original manuscript text attributing the drying to "cold, dry air advection", written with southerly flow in mind, has been removed. The physical mechanism linking northerly flow anomalies to precipitation

suppression at these coastal sites represents an important open question that future ice core records from these locations will be well positioned to address.

Reviewer Comment #2:

Overview Comments:

This article presents the relationship between precipitation at Antarctic ice rises and several key atmospheric circulation or oceanic indicators (Southern Annular Mode, Amundsen Sea Low, and El Nino-Southern Oscillation). Section 1 summarizes previous Antarctic ice core sites, and presents the potential importance of future ice core drilling at Antarctic ice rises. Section 2 examines the reanalysis data and conclude to use ERA-5 in further analysis. Section 3 is the main results of the article, presenting the correlation between precipitation at 13 potential ice core sites from WAIS and atmospheric circulation indices. The analysis led to two main conclusions for the proposed ice core sites: [1] the West Sector of the WAIS coast, where precipitation is strongly influenced by Southern Hemisphere westerly winds; and [2] the East Sector, where precipitation is strongly influenced by synoptic-scale pressure systems along the Bellingshausen Sea.

I believe the methods used have not been sufficiently considered for the research purpose of assessing future ice core sites for climate reconstruction. The most critical point is that ice cores do not necessarily record precipitation; they record surface mass balance.
Surface mass balance is determined by several processes, including precipitation, refreezing of water, surface melting, sublimation of ice, and blowing snow erosion (e.g. Equation 2 of van Dalum et al., (2025)). At high annual-mean temperatures like those in Table 1, significant melting can occur during austral summer, which makes it very hard to reconstruct past precipitation. To address this issue, a global reanalysis like ERA-5 and MERRA-2 has very limited ability to address surface mass balance. Instead, I recommend that authors analyse regional climate model simulations. Recently, several regional climate simulations have been published (van Delum et al., 2025; Agosta et al., 2019). As these regional climate models have been evaluated by number of observed surface mass balance observations, These datasets have a certain degree of credibility. In fact, the Antarctic regional climate model, RACMO, has been used to examine ice-core data (Thomas et al., 2017). As those regional climate simulations were forced by reanalysis including ERA-5, I think the analysis in the current preprint can be utilized in the same manner.

We thank Reviewer #2 for engaging seriously with the methodological foundations of the study. We believe the concern, while worth addressing directly, does not undermine the core analysis, for the reasons we explain in detail below. The key point is that our study is focused on interannual variability between atmospheric circulation modes and local precipitation, a relationship that is robust in ERA5 and directly relevant to ice core site selection. The distinction between precipitation and SMB matters most for absolute magnitudes and long-term trends; it has a much smaller effect on the year-to-year correlation structure that we base our conclusions on, especially in coastal Antarctica where snowfall is highest anywhere on the continent. Additionally, Antarctic surface snow melt is limited particularly along the coast of West Antarctica and becomes even more so at locations elevated above low-lying ice shelves, such as the ice rises that are the subject here, all of which are elevated several hundred meters above sea level (see Table 1).

Major Comments

1. *Section 2 presents the correlation between ERA-5 and MERRA-2, but this analysis does not guarantee that these models have sufficient ability in simulating precipitation. I recommend using the surface mass balance from the Antarctic regional model(s), as these models have been evaluated by observations. The same applies for surface air temperature.*

We appreciate the depth of this comment and address the following three points: the precipitation–SMB relationship at these specific sites, the independence (or lack thereof) of regional climate models (RCMs), and the melting concern.

1. Precipitation as a proxy for SMB at high-accumulation coastal ice rises. The reviewer correctly notes that ice cores record SMB rather than precipitation directly, and that SMB is determined by multiple processes including precipitation, refreezing, surface melting, sublimation, and blowing snow erosion and redeposition (Lenaerts et al., 2019, doi: 10.1029/2018RG000622). We agree this distinction is important and have added clarifying text to Section 2.1 and the Discussion to address it explicitly.

At the high-accumulation coastal ice rises studied here (mean annual accumulation 0.58–1.06 m w.e. yr^{-1}, Table 1), precipitation is the dominant SMB term and non-precipitation losses are small in relative terms. Surface sublimation depends on the surface-to-air humidity gradient and wind speed and is suppressed when near-surface air moisture is high (Lenaerts et al., 2019); frequent precipitation and proximity to the Southern Ocean maintain persistently moist near-surface conditions at our sites. Drifting snow sublimation, the largest ablation term continent-wide, removes approximately 6% of annually precipitated snow when integrated across the ice sheet (Lenaerts & van den Broeke, 2012, doi: 10.1029/2010JD015419), and this fraction is further reduced in high-accumulation coastal regions where near-surface air is frequently near saturation and summer melt consolidates the snow surface, limiting the potential for snowdrift (Lenaerts et al., 2012b, doi: 10.1029/2011JD016145). Runoff is negligible at these sites because nearly all meltwater refreezes (Lenaerts and van den Broeke, 2012). As a consequence, interannual SMB variability largely follows the interannual variation in snowfall (Lenaerts et al., 2012a, doi: 10.1029/2011GL050713).

Furthermore, Lenaerts et al. (2019) explicitly identify the Amundsen-Bellingshausen region as exhibiting the largest intra-annual and interannual SMB variability on the Antarctic continent, driven primarily by southward moisture transport, the same atmospheric circulation signal captured by our ERA5 precipitation correlations. This supports our contention that ERA5 precipitation captures the dominant driver of interannual SMB variability at these specific sites.

This equivalence is well established in the literature: Medley and Thomas (2019) use reanalysis P−E as a proxy for snow accumulation across the grounded Antarctic Ice Sheet, restricting this framework to regions of positive SMB, the same regime characterizing our sites. In the revised manuscript, we compute ERA5 P-E at each site and confirm that the correlation structure with climate indices is not meaningfully affected by the inclusion of the evaporation term, providing further support that precipitation captures the dominant interannual SMB signal at these locations.

2. ERA5 is appropriate for assessing interannual variability, and RCMs are not independent. We agree that RACMO (van Dalum et al., 2025) and MAR (Agosta et al., 2019) are valuable datasets and have been evaluated against observed SMB and used in ice core studies (Thomas et al., 2017). Therefore, we have added citations to both in the revised manuscript. That said, we want to flag two points to discuss whether switching to RCM-derived SMB would actually change our conclusions.

First, as the reviewer notes, these regional climate simulations are themselves forced by ERA5 lateral boundary conditions. This suggests that their large-scale circulation patterns, and therefore their interannual precipitation variability, are not independent of ERA5. The added value of RACMO and MAR is primarily in representing local surface energy balance, orographic precipitation, and blowing snow at fine scales, not in providing an independent check on the large-scale forcing we explore here.

Second, our central question is which climate modes (SAM, ENSO, ASL, regional winds) drive year-to-year variability in accumulation at these sites, not the absolute magnitude of SMB. For that purpose, ERA5 precipitation is appropriate: Medley and Thomas (2019) show that reanalysis products capture a significant fraction of interannual accumulation variability across Antarctica even where absolute magnitudes are biased and explicitly favor reanalyses over regional climate models for this purpose. We have added RCM comparison as a recommended next step for evaluating absolute SMB values and site-specific surface processes, rather than treating it as a prerequisite for the correlation analysis presented here.

3. Surface melt at these sites is limited. We take the melt concern seriously but note that the evidence consistently points to it being negligible at the specific sites studied here. A high-resolution (5.5 km) RACMO2 simulation of coastal West Antarctica, the very RCM the reviewer recommends, finds that surface melt does not frequently occur over most of the grounded ice sheet and is confined to ice shelves (Lenaerts et al., 2018, doi: 10.1017/aog.2017.42). Where melt does occur on ice shelves, it is concentrated in a narrow band near grounding zone margins where warm microclimates develop due to katabatic wind compression (Lenaerts et al., 2018). The elevated summits of the ice rises studied here (397–659 m a.s.l.) are well above these low-lying melt zones.

This is further supported by satellite-based melt flux estimates showing that the Amundsen Sea and Marie Byrd Land coast experiences some of the lowest surface melt rates on the Antarctic continent, consistently near or below several tens of mm w.e. yr^{-1} throughout the 1999–2009 record (Trusel et al., 2013, doi: 10.1002/2013GL058138). The continent-wide survey of Kingslake et al. (2017, doi: 10.1038/nature22049) similarly documents widespread surface meltwater drainage as an ice-shelf phenomenon, occurring on floating ice at or near sea level; none of the 696 drainage systems identified originate on elevated grounded ice features of the type studied here. The mean annual temperatures at our sites (−8.3°C to approximately −14°C in ERA5, Table 1) provide an additional thermodynamic constraint: even under anomalously warm summer conditions, the surface energy available for sustained melt at these elevations is minimal. Additionally, we have direct field experience at Canisteo Peninsula (RAICA project, January 2024, unpublished) and observed no evidence of significant melt in the recovered core stratigraphy, only periodic melt or sun crust layers no thicker than 1–2 millimeters.

On the question of whether RCM melt parameterizations offer a more reliable picture: the Lenaerts et al. (2017) RACMO2 simulation already demonstrates that melt is negligible at grounded, elevated coastal sites in this region. More broadly, melt schemes in existing Antarctic regional models remain poorly constrained in coastal West Antarctica precisely because of the absence of in situ observations, the same gap this manuscript and the RAICA ice core initiative are designed to fill (Lenaerts et al., 2018; Neff, 2020). We have added a paragraph to the Discussion addressing melt, noting the modeled temperature ranges at each site and the Trusel et al. (2013) satellite evidence, while acknowledging that melt will need proper evaluation once cores are recovered.

2. *Table 1: The method used to calculate climate information for each ice rise point is not explained. Is the elevation the elevation of the observed terrain, or the elevation from the ERA-5 reanalysis? Also, the temperature and precipitation should have been calculated from ERA-5, but how were they calculated? Are they calculated by bilinear interpolation based on the latitude and longitude? Also, are these annual average temperatures and precipitation values calculated at a single point in the table, or are they averaged over the ice rise? Please clarify.*

Thank you, we agree that the table was insufficiently described. We have added the following clarification to Section 2.1 and the Table 1 caption: Maximum elevation values are from MEaSUREs BedMachine Version 3 at 500 m resolution (Morlighem, 2025), representing observed ice surface topography, not ERA5 model orography (which at ~35 km resolution substantially underestimates the height of individual ice rises). Annual temperature and precipitation time series are extracted from ERA5 at the single nearest grid cell (~0.25°) to each ice rise summit coordinate, without bilinear interpolation or spatial averaging over the ice rise. This point-extraction approach is appropriate because ERA5's resolution already represents a spatial average that encompasses the full extent of these relatively small features. Temperature values are ERA5 2-meter air temperature annual means (1979–2022). We have also added °C to the temperature column header and specified precipitation units as m w.e. yr^{-1} (meters water equivalent per year).

<u>Specific comments:</u>

1. *L34: I think Barr & Lovell (2014) does not fit here because the study is Antarctic Morraines.*
    a. Thank you, we agree. We have removed Barr & Lovell (2014), which examines topographic controls on moraine distribution and is not relevant to the WAIS ice dynamics context of Line 34. We have replaced it with Shepherd et al. (2018, doi: 10.1038/s41586-018-0171-6), which is a comprehensive review of satellite-era trends across the Antarctic cryosphere and includes grounded ice mass loss, ice shelf thinning, and ocean-atmosphere forcing in the Amundsen Sea sector, which directly supports the statement at this line.
2. *L111: Why were these 13 ice rises selected from 30 ice rises (L109)? Is it based on the size of the ice rises? Please clarify.*
    a. Thank you for this question, we will clarify this in the revised manuscript. From the full Matsuoka et al. (2015) inventory of ~30 coastal WAIS ice rises, we selected the 13 sites based on three criteria. First, we applied a minimum total area threshold, Dean Island (~699 km^2) is the smallest included site, to ensure sites are large enough to sustain a stable summit divide over the timescales relevant to paleoclimate reconstruction (millennia). Second, we required sufficient elevation above the surrounding ice shelf to ensure the ice rise developed independent flow divides with slow horizontal ice flow (which is necessary for undisturbed stratigraphic layer preservation and ice core paleoclimate reconstruction). Also, adiabatic cooling dictates that ice rise summits elevated several hundred meters above sea level will be several degrees Celsius cooler and thus less likely to experience significant surface melting than surrounding ice shelves (the shortest ice rise is Dean at 397 m). Third, we selected sites to span the full longitudinal range of coastal WAIS (~91°W to ~162°W), since one aim of the study is to characterize how climate controls on snowfall vary across this sector. We have added these sentences to Section 2.1 to clarify these selection criteria.

3. *L37: What does "considerable (poorly observed)" indicate? Maybe contradicting to L36.*
    a. We agree that this may seem contradictory. We have revised Line 37 to: "…in addition to substantial spatial and interannual variability that remains poorly constrained due to the scarcity of direct observations in coastal West Antarctica."

4. *L150: "steig box" is not a frequently used word. Maybe changed to "S12 box" or relevant in this article. In addition, Steig et al., (2012) proposed the box as an indicator of U-wind but not analyzed V-wind, so there seems to be limited reason to analyze the V-wind and discuss its relationship with Steig et al., (2012).*
    a. Thank you, we have renamed this domain to the "S12 box" throughout the manuscript. Regarding the V-wind analysis, the reviewer is correct that Steig et al. (2012) defined this domain specifically in the context of zonal wind anomalies linked to CDW upwelling. We have revised Section 3.1.2 to clearly separate the S12-box U-wind discussion (which follows the Steig et al., 2012 framework) from the V-wind analysis (which addresses broader meridional transport questions brought up by studies in the intervening decade since S12, like O'Connor et al., 2025). We have removed any implication that V-wind results within the S12 box are directly connected to the CDW upwelling context established by Steig et al. (2012).

5. *Table 1: unit [degC] missing in temperature. And please clarify the unit of precipitation, [freshwater mm/a, or ice mm/a].*
    a. Thank you for this suggestion. We have added °C to the temperature column header and specified precipitation as m w.e. yr^{-1} (meters water equivalent per year) in the Table 1 caption.

6. *Figure 1 caption: [1] What does "remaining" ice core sites really means? Does it mean the site is not drilled yet? Please clarify. [2] Please clarify that red dots indicate "existing" or "previous" ice core sites (if I understand correctly).*
    a. We agree with this clarification and have revised the Figure 1 caption to: "…red dots indicate ice rise locations where ice cores have previously been recovered; orange dots indicate previously drilled ice core sites at non-ice-rise WAIS locations; and blue dots indicate previously drilled ice core sites at Antarctic Peninsula and East Antarctic Ice Sheet locations." This removes the ambiguous term "remaining" and clarifies the status of each category.

7. *Figure 4: sentences "To reconstruct…" are unnecessary in this figure caption.*
    a. Thank you, we have moved the interpretive guidance from the Figure 4 caption into the main body of Section 3.1.2, condensing the caption to focus on describing the figure content. The interpretive text is retained in the manuscript, as it directly serves the applied site-selection purpose of the paper.

8. *Figures 4, 5, 7, 8: Bottom figure panel showing climate index locations can be unnecessary (figure caption is sufficient).*
    a. Thank you for this suggestion; however, we kept the bottom panels for Figures 4,5,7, and 8 because they contain the red boxes which define the regions that the correlating variables are averaged over.

9. *Figures A1-A4, I don't understand why A1-A4 are necessary in this research article, because the figures seem to present a summary of previous research. Also, the caption lacks the information of red dots.*
    a. We agree and have removed Figures A1–A4, and have renamed Figures B1 and B2 to A1 and A2.

10. *Data availability: The data used in B1 and B2 (the SAM index and the ENSO index) can be specified.*
    a. Thank you for noting this. We have updated the Data Availability section to specify: (1) the Marshall (2003) SAM index used for Figure A1 (formerly B1) validation is available from the British Antarctic Survey at https://legacy.bas.ac.uk/met/gjma/sam.html; (2) the observed Niño 3.4 index used for Figure A2 (formerly B2) validation is from the NCAR Climate Data Guide (Trenberth et al., 2025); and (3) ERA5-derived fields are available through the Copernicus Climate Data Store (doi:10.24381/cds.adbb2d47).

<u>References for new citations:</u>

1. Lenaerts, J. T. M., Medley, B., van den Broeke, M. R., and Wouters, B.: Observing and modeling ice sheet surface mass balance, Reviews of Geophysics, 57, 376–420, https://doi.org/10.1029/2018RG000622, 2019.

2. Lenaerts, J. T. M. and van den Broeke, M. R.: Modeling drifting snow in Antarctica with a regional climate model: 2. Results, J. Geophys. Res., 117, D05109, https://doi.org/10.1029/2010JD015419, 2012.

3. Lenaerts, J. T. M., van den Broeke, M. R., van de Berg, W. J., van Meijgaard, E., and Kuipers Munneke, P.: A new, high-resolution surface mass balance map of Antarctica (1979–2010) based on regional atmospheric climate modeling, Geophys. Res. Lett., 39, L04501, https://doi.org/10.1029/2011GL050713, 2012a.

4. Lenaerts, J. T. M., van den Broeke, M. R., Déry, S. J., van Meijgaard, E., van de Berg, W. J., Palm, S. P., and Sanz Rodrigo, J.: Modeling drifting snow in Antarctica with a regional climate model: 1. Methods and model evaluation, J. Geophys. Res., 117, D05108, https://doi.org/10.1029/2011JD016145, 2012b.

5. Lenaerts, J. T. M., Ligtenberg, S. R. M., Medley, B., van de Berg, W. J., Kuipers Munneke, P., van Meijgaard, E., van den Broeke, M. R., and Malles, J. H.: Climate and surface mass balance of coastal West Antarctica resolved by regional climate modelling, Ann. Glaciol., 59, 29–41, https://doi.org/10.1017/aog.2017.42, 2018.

6. Trusel, L. D., Frey, K. E., Das, S. B., Kuipers Munneke, P., and van den Broeke, M. R.: Satellite-based estimates of Antarctic surface meltwater fluxes, Geophys. Res. Lett., 40, 6148–6153, https://doi.org/10.1002/2013GL058138, 2013.

7. Kingslake, J., Ely, J. C., Das, I., and Bell, R. E.: Widespread movement of meltwater onto and across Antarctic ice shelves, Nature, 544, 349–352, https://doi.org/10.1038/nature22049, 2017.

8. Shepherd, A., Fricker, H. A., and Farrell, S. L.: Trends and connections across the Antarctic cryosphere, Nature, 558, 223–232, https://doi.org/10.1038/s41586-018-0171-6, 2018.