

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

Julia R. Andreasen and Peter D. Neff

We thank Referee 1 for their careful and constructive comments on our manuscript. 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 Gerlaro 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.accr.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 Figures A1–A4 are conceptual schematics depicting the large-scale Southern Ocean westerly wind belt and its modulation by SAM and ENSO, they are not representations of near-surface coastal wind directions at the ice rise locations. The wind arrows in those figures illustrate 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 Steig 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 Steig 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. We also note that Figures A1–A4 will be removed in the revised manuscript as they are not central to the quantitative analysis presented.

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 Steig 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.