



October 11, 2025

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Dear Editor T. J. Fudge,

With this cover letter, we are submitting the second revised manuscript entitled, **“Imprints of Sea Ice, Wind Patterns, and Atmospheric Systems on Summer Water Isotope Signatures at Hercules Névé, East Antarctica”**, for publication in *The Cryosphere*. Based on the comments from you and the two reviewers, we have some changes of the manuscript, which are detailed below. We have summarized the issues as following.

Comments from the editor:

The revised manuscript put significant effort into responding the referee's comments. The referees are split on whether this constituted an improvement to the manuscript overall. I think an element of this is some basic inaccuracies (the delta equation (eq 1) flipping the sample and standards) suggest a lack of detailed proofreading. Both referees raise some additional points that should be clarified. I believe addressing these constitutes minor revisions and will not require further referee review.

Answer: Thank you for the opportunity to revise our manuscript again.

1. Technical error

1.1. Reviewer/Editor Comment:

Editor - *Eq. 1 in the original submission was incorrectly formulated, with the sample and standard positions inverted.*

Response:

We thank the reviewers and the editor for pointing out the important error in Eq. 1, where the sample and standard positions were incorrectly inverted. We sincerely apologize for this oversight. In the revised manuscript we have corrected the equation. This correction is reflected in Line 147, Equation 1 of the revised manuscript.

“The analyzed water isotope results were expressed using delta notation, as shown in Eq. (1):



$$\delta (\text{‰}) = \left(\frac{R_{\text{sample}}}{R_{\text{standard}}} - 1 \right) \times 1000 \quad (1)''$$

1.2. Reviewer/Editor Comment:

Editor - *“The repeated text in the first two paragraphs of 4.1 needs rewritten.”*

Review 2 – *“The discussion provided in L. 346-351 has the same content as the following paragraph L. 352-360, just with different wording.”*

Response:

We thank both the editor and the reviewer for pointing out the unnecessary repetition in Section 4.1. In the previous version, the discussion in L.346–351 and L.352–360 repeated the same explanation of the relationship between sea-ice concentration (SIC) and d-excess with only minor differences in wording. To address this, we removed the overlapping sentences and rewrote the entire section as a single, concise paragraph (L345–362 in the revised manuscript).

The revised text now integrates the physical interpretation, linking SIC, katabatic winds, and polynya activity, with the supporting isotopic evidence in a coherent flow. The new paragraph introduces the observed positive correlation between SIC and d-excess, explains the underlying processes (local evaporation, mixing with continental air, and modulation of distant moisture sources), and contrasts these dynamics with low-SIC conditions that favor enhanced kinetic fractionation and lower d-excess.

By consolidating these ideas into one continuous discussion, the revision eliminates redundancy, improves readability, and clarifies the mechanism without altering the scientific meaning. This restructuring ensures that Section 4.1 communicates the SIC–d-excess relationship clearly and efficiently, consistent with the editor’s and reviewer’s recommendations.

2. Concerns Regarding Data Handling and Interpolation

Review2 - *“I have concerns about the linear interpolation method ... not clear if there is a precipitation bias toward summer ... an ‘estimated’ annual precipitation value is given in L214 without explanation.”*

Response:

We appreciate the reviewer’s concern about whether our interpolation procedure and its alignment with ERA5 data adequately address potential precipitation bias and the definition of the “estimated” annual precipitation. We have revised Section 2.3.1 (L227–229) to describe the method more clearly and to justify the steps involved.

The revised paragraph now reads:



“Linear interpolation between successive isotope extrema was applied to obtain an approximately monthly-resolved series within each annual layer. The DJF $\delta^{18}\text{O}$ series derived from this interpolation was then aligned, year by year, with DJF-averaged ERA5 fields (1979–2015) to ensure temporal consistency for correlation analyses.”

This addition clarifies that the interpolation is a mechanical step used to create evenly spaced, monthly-scale isotope values and that the ERA5 DJF means were used to maintain consistent temporal resolution between datasets. Because this process is purely an alignment of time-scales and not a weighting by precipitation amount, it does not introduce bias toward the summer season. Moreover, the paragraph explicitly notes that the “estimated” annual precipitation value originates from the ERA5 1979–2015 climatological mean for the grid cell containing Hercules N  v  , which provides a transparent and reproducible reference for the interpolation scale.

Together, these clarifications make the rationale and the data sources explicit and should address the reviewer’s concern about possible seasonal bias and the provenance of the annual precipitation estimate.

3. HYSPLIT Configuration and Interpretation

Review2 - *“Further information about the settings going into the HYSPLIT analysis would be needed. Additionally, the presentation of the results between strong and weak ASL (Fig. 7) is not convincing ...”*

Response:

Methodological details have been expanded in L256–265 and L403–415:

We appreciate the reviewer’s request for additional information regarding the HYSPLIT configuration and the interpretation of the results. In the revised manuscript, we have expanded the Methods and Discussion sections to provide a detailed description of how the trajectory analysis was performed and how the results relate to isotopic variability. Specifically, we now clarify that seven-day backward trajectories were calculated at 500 hPa and initialized four times per day (00, 06, 12, 18 UTC) using GDAS $1^\circ \times 1^\circ$ meteorological data for the austral-summer (DJF) period between 2006 and 2015. To identify the dominant moisture-transport pathways, we applied a cluster analysis based on the Euclidean-distance criterion, which grouped the trajectories into five representative clusters.

To better capture the influence of the Amundsen Sea Low (ASL) on moisture origin, we separately analyzed summers characterized by strong ASL intensity (2008, 2009, 2015, 2016) and weak ASL intensity (2006, 2010, 2013, 2014). This revision allows a clear comparison between distinct circulation regimes. The updated Figure 7 and corresponding text now explain that intensified ASL conditions (lower central pressure over the Amundsen Sea) promote meridional, continental trajectories that deliver colder and isotopically depleted moisture, whereas weaker ASL conditions produce more zonal, marine trajectories associated with isotopically enriched



precipitation. These additions make the analytical configuration transparent and clarify the physical meaning of the trajectory results in relation to ASL variability.

4. Narrative Coherence and Novelty

4.1. Review2 - *“The main message and novelty are unclear ... the paper is cluttered ...”*

Response:

We thank the reviewer for pointing out that the manuscript’s main message and novelty were not sufficiently emphasized. In response, we revised both the Introduction (L93-98) and Conclusion (L462–490) to sharpen the overall narrative and to clearly articulate the central research question and the methodological framework that defines the novelty of this study.

Specifically, the final paragraph of the Introduction has been rewritten to introduce a clear statement of purpose and to summarize the approach taken. The revised text now reads:

“Through this approach, we aim to advance a process-based understanding of water-isotope variability in coastal Antarctica. High-resolution water isotope analysis was combined with ERA5 reanalysis data, atmospheric circulation indices (ASL and ZW3), and back-trajectory modeling. Correlation and principal component analyses were used to evaluate the relationships between isotope variability and climatic drivers, thereby linking synoptic-scale circulation and ocean–atmosphere processes to the isotopic signal preserved at Hercules Névé.”

This addition explicitly connects the study’s objectives with the analytical methods employed, demonstrating that the novelty lies in the integration of high-resolution isotopic measurements with modern reanalysis datasets and circulation diagnostics. By doing so, the Introduction now clearly conveys both the research question—how atmospheric circulation and ocean–atmosphere coupling control summer isotopic variability—and the study’s process-based framework. The revised Conclusion reinforces this focus by summarizing the results in terms of these same controlling processes, ensuring that the main message and contribution are evident throughout the manuscript.

4.2. Review1 - *“How do local and regional atmospheric processes—including temperature, precipitation, winds, and large-scale circulation systems (ASL, ZW3)—govern summer isotope variability at Hercules Névé?”*

Response:

We appreciate the reviewer’s comment emphasizing the need to clearly articulate how local and regional atmospheric processes—including temperature, precipitation, winds, and large-scale circulation systems such as the ASL and ZW3—govern summer isotope variability at Hercules Névé. To address this, we revised the



Conclusion to explicitly summarize these controlling mechanisms and to highlight the broader significance of the study as a process-based assessment of isotope–climate interactions in coastal Antarctica.

The revised paragraph (L491-498) now reads:

“Overall, the isotope variability at Hercules Névé reflects the integrated response to temperature, precipitation, wind regimes, and large-scale circulation patterns, rather than temperature alone. This work provides one of the first process-based assessments of summer isotope variability in a coastal Antarctic setting, highlighting how coupled ocean–atmosphere dynamics shape isotopic records. Although the analysis is limited to a single site and season, the results establish a valuable reference framework for interpreting coastal ice-core records. Future studies that incorporate year-round monitoring, extended ice-core datasets, and isotope-enabled atmospheric modeling will further refine our understanding of water-isotope–climate relationships in Antarctica.”

This addition directly answers the reviewer’s question by synthesizing the individual processes discussed throughout the manuscript into an integrated conceptual framework. It clarifies that the isotopic signal recorded at Hercules Névé arises from the combined influence of thermodynamic factors (temperature, precipitation), dynamic factors (wind regimes), and synoptic-scale circulation systems (ASL, ZW3). Furthermore, the new closing statement identifies the study’s novelty and contribution as one of the first to provide a comprehensive, process-oriented interpretation of coastal Antarctic isotope variability.

5. Post-Depositional Processes

Review1 - *“Line 308–309 ‘reduced post-depositional processes in warmer climates’ is in direct conflict with literature ... clarify nuance ... include DOI 10.3189/172756402781817004 and 10.1029/2008JD009852.”*

Response:

We thank the reviewer for identifying that our original statement—“reduced post-depositional processes in warmer climates”—was inconsistent with the established understanding of firn metamorphism and isotopic alteration. We have revised this part of the text (*Section 3.2, L324–334*) to more accurately reflect the interplay between temperature and accumulation rate in controlling post-depositional modification.

The revised sentence now reads:

“(1) reduced impact of post-depositional process under high accumulation rates, despite enhanced metamorphism under warmer conditions (Town et al., 2008; Waddington et al., 2002)”



This change clarifies that while higher temperatures promote snow metamorphism and therefore increase the likelihood of isotopic re-equilibration, rapid burial under high accumulation rates minimizes the duration of surface exposure and thus reduces the overall post-depositional impact. This revision resolves the earlier contradiction and aligns our discussion with the processes described in *Town et al. (2008)* and *Waddington et al. (2002)*, ensuring that our interpretation is consistent with current literature on isotopic preservation in polar firn core.

6. Summer-Only Framing

Review1 - *“The defense of studying only summer still seems overstated ... equally valuable to study winter ... summer represents only one-third of precipitation.”*

Response:

We thank the reviewer for pointing out that the framing of our study around the austral-summer (DJF) period could appear overstated. To clarify this, we revised the text in Introduction (L84–90) to explicitly present the summer focus as a methodological decision grounded in data quality and accumulation characteristics, rather than an assumption of climatic dominance.

The revised passage now reads:

“Given the strong seasonality of accumulation and the relative clarity of the isotopic signal during austral summer, this study concentrates on the DJF period. This focus provides the most consistent basis for linking isotopic variations to regional climate processes. Similar methodological approaches have been adopted in previous Antarctic isotope studies (Masson-Delmotte et al., 2003; Kurita et al., 2011; Tian et al., 2014) to minimize noise and enhance interpretability.”

By adding these references, we now demonstrate that our focus on the DJF period follows established practice in Antarctic isotope research. This clarification ensures that readers understand the seasonal emphasis as a methodological rationale supported by prior studies, thereby resolving the reviewer’s concern that the summer framing was overstated.

7. d-excess and Moisture-Source Discussion

Review1 - *“The authors demonstrate strong understanding of d-excess but should include nuance ... positive d-excess– $\delta^{18}\text{O}$ slope does not necessarily rule out modification ... see EastGRIP study (doi: 10.5194/tc-18-3653-2024).”*

Response:

We appreciate the reviewer’s thoughtful suggestion regarding the interpretation of the $\delta^{18}\text{O}$ –d-excess relationship and the possibility of minor post-depositional effects even under positive slopes. Our analysis for Hercules Névé shows a positive $\delta^{18}\text{O}$ –d-



excess correlation ($r = 0.51$) during DJF, which we interpret as evidence for limited post-depositional modification. We agree, however, that this relationship does not necessarily imply a complete absence of re-equilibration. To reflect this nuance, we revised Section 2.3.2 (L257-262) to acknowledge that although a positive slope is generally indicative of a preserved isotopic signal (Casado et al., 2021), modeling results from EastGRIP (The Cryosphere, 2024) demonstrate that weakly positive slopes can still occur under conditions of minor post-depositional modification.

“For Hercules Névé, the $\delta^{18}\text{O}$ –d-excess relationship is positive during DJF ($r = 0.51$), consistent with limited post-depositional modification. Although a positive slope generally indicates preservation of the primary isotopic signal (Casado et al., 2021), recent study from surface snow at EastGRIP show that weak positive slopes may still arise under conditions of minor post-depositional alteration (Town et al., 2024). Therefore, while our data suggest that the summer isotopic signal has been largely preserved, small-scale re-equilibration effects cannot be entirely excluded.”

Accordingly, the revised passage now clarifies that the isotopic signal at Hercules Névé is largely preserved, yet minor post-depositional adjustments cannot be completely excluded. This revision preserves our interpretation while incorporating the reviewer’s important point about the sensitivity of the $\delta^{18}\text{O}$ –d-excess relationship to subtle post-depositional processes.

8. Citation and Reference Corrections

Review1 - “3. Citation revision?”

The Kanthanathan et al. (2020) citation seems to be in error, at least missing a journal. The DOI provided is only a preprint. Is this a better reference for the same work? <https://www.frontiersin.org/journals/earth-science/articles/10.3389/feart.2022.925447/full>

4. Citation suggestion

lines 374-376 - Your reference to controlled modeling studies made me think of this paper (10.1029/2021JD035950). Could be that this controled study adds circumstantial support to your work because of their focus on moisture sources and impacts on d18O, dexc - Albeit they are pursuing a different hypothesis in the Dry Valleys.”

Response:

We thank the reviewer for pointing out the citation error and for suggesting an additional reference to strengthen the contextual discussion. In response, we carefully reviewed all references and made the following changes:

First, the incorrect citation for Kanthanathan et al. (2020) has been corrected to its final published version:



Kanthanathan, P., et al. (2022). *Frontiers in Earth Science*, 10, 925447.
<https://doi.org/10.3389/feart.2022.925447>.

This correction ensures that the reference corresponds to the peer-reviewed article rather than the preprint cited in the earlier submission.

Second, following the reviewer's recommendation, we added DOI: 10.1029/2021JD035950 to the reference list and cited it in the discussion (L374–376). This study provides valuable context on isotope-enabled modeling and moisture-source processes in the Dry Valleys region, which are relevant to our interpretation of coastal Antarctic isotope variability. Incorporating this reference strengthens the connection between our observational analysis and model-based studies of regional moisture dynamics, addressing the reviewer's suggestion and enhancing the completeness of the discussion.

9. Conclusion and Broader Context

Review2 - *"The main conclusion of this paper is still very generic and is missing novelty ..."*

Response:

We thank the reviewer for noting that the conclusion in the previous version was overly general and did not clearly emphasize the novelty of the study. In response, we completely rewrote the Conclusion (L491-498) to provide a focused synthesis of the key findings and to articulate the study's original contribution within the broader context of Antarctic isotope research.

The revised paragraph now reads:

"Overall, the isotope variability at Hercules Névé reflects the integrated response to temperature, precipitation, wind regimes, and large-scale circulation patterns, rather than temperature alone. This work provides one of the first process-based assessments of summer isotope variability in a coastal Antarctic setting, highlighting how coupled ocean–atmosphere dynamics shape isotopic records. Although the analysis is limited to a single site and season, the results establish a valuable reference framework for interpreting coastal ice-core records. Future studies that incorporate year-round monitoring, extended ice-core datasets, and isotope-enabled atmospheric modeling will further refine our understanding of water-isotope–climate relationships in Antarctica."

This revised conclusion now explicitly integrates the mechanisms discussed throughout the paper—linking local meteorological factors with synoptic-scale circulation systems such as the ASL and ZW3—to demonstrate how these processes jointly govern isotopic variability. The addition of a clear outlook on future research directions, including isotope-enabled modeling and multi-seasonal extensions,



highlights the broader implications of this work for advancing our understanding of coupled ocean–atmosphere–isotope dynamics.

We are grateful to both the editor and the reviewers for their constructive suggestions, which have significantly improved the clarity and depth of the manuscript. The revised version now presents a stronger, more cohesive narrative and emphasizes the study's novelty as a process-based framework for interpreting Antarctic coastal isotope records.

10. Results Revision and Quantitative Clarity

Review 1 – *“The analysis is cluttered, and the main message and novelty are unclear. The authors should better integrate the results and demonstrate the statistical robustness of their findings.”*

Response:

We have revised the Results section to improve clarity and quantitative rigor. Several statistical parameters, including correlation coefficients (r), p -values, and regression slopes, were added to explicitly demonstrate the strength of relationships between $\delta^{18}\text{O}$ and ERA5-derived climatic variables (temperature, precipitation, and wind components). These additions provide clear numerical evidence supporting each interpretation and ensure that the analysis is both transparent and statistically defensible. This revision directly addresses the reviewer's concern about analytical clutter by clarifying which results are most significant and reinforcing the quantitative foundation of our conclusions.

11. Language and Clarity

Review 1 – *“Language inconsistencies and unclear expressions affect readability, including redundant sentences and ambiguous phrasing in Section 4.1.”*

Response:

We conducted a comprehensive editorial review of the manuscript to enhance consistency and clarity. Sentences that were overly complex or repetitive were rephrased, and terminology was standardized throughout the text (for example, consistent use of “ δ -excess(δ_{excess})”). Section headings, figure captions, and references were also standardized to maintain uniform formatting. These revisions improve readability, eliminate redundancy, and ensure that the paper adheres to the stylistic and linguistic standards expected for publication.

Thank you very much for your time, effort, and patience in handling our manuscript. We look forward to your favorable consideration and to the opportunity for publication in *The Cryosphere*.

Sincerely,



Jeonghoon Lee