> We appreciate the reviewers and editor for investing their time and providing helpful feedback on our manuscript. Below, we explain the detailed changes we have made, and we hope these revisions are satisfactory and that the revised manuscript meets the journal's criteria. Our responses are tabbed and blue, following individual comments. The line numbers we refer to are those of the revised manuscript.

RC1: 'Comment on egusphere-2025-5820', Anonymous Referee #1, 21 May 2026

The authors have made significant changes to their manuscript in response to the review comments and I thank them for responding so constructively to the reviews. In particular, I find the index they derive much more understandable and defensible in this version. The paper represents a novel way of detecting past polynya activity. While it is a proxy study and therefore not perfect, I believe it is a good step forward and should be published. I have only minor comments, which do not require me to review the paper again if the authors make minor changes.

> We appreciate the reviewer's positive assessment of our revision and thank them for supporting the publishing of our manuscript.

1. In the abstract, line 22 the ratio Na/SO4 is still mentioned but in fact this was removed. This needs an edit.

> We have now removed Na/SO4 from the abstract.

2. Line 257, just a typo, "Satellite imagery is crucial" or "Satellite imageries are crucial"

> Changed as suggested

3. Line 284. The authors answered one of my review questions in reverse. They state that "our study site receives approximately 2% of all trajectories originating from the MRP region". But I asked something different: what proportion of trajectories passing the drill site have also traversed the MRP region. This is interesting because if it is for example 5% then 95% of airmasses (but perhaps not most moisture laden airmasses) cannot record the MRP, making it all the more remarkable that the MRP presence/absence rises above the noise. I don't insist if it is difficult but it would be interesting to see this number.

> We apologise for the confusion. We have now added the requested detail in the main text (Line 293 – 296):
>
> > *Our back-trajectory analysis (Fig. 6) further confirms the findings from the forward trajectory patterns, with ~19% of all trajectories reaching our ice core site having also traversed over the polynya prone region.*

4. Line 358. "Negative z-scores were set to zero to prevent them from cancelling out physically significant peaks in other proxies". This doesn't seem justified to me - there is no logic to ignoring one of the contributors to the index if it is below average but not if it's above average. However, I don't want to make a lot of work making new calculations,. I'd just like the authors to give an assurance that this decision has not made a large influence on the result.

> We thank the reviewer for this insightful comment and appreciate the opportunity to clarify the logic behind this design choice.
>
> Our primary objective with the polynya index is to identify periods of active, positive anomalies across multiple proxies. Because different proxies respond to different environmental thresholds, a negative z-score in one proxy does not necessarily represent a physical state that should actively cancel out a strong, positive signal in the other three proxies. Instead, a negative z-score often simply represents a baseline or quiescent state. Treating negative values as zero allows the index to function as an activation index, highlighting coherent peak events without allowing baseline noise or differing proxy sensitivities to artificially mute significant signals. We can assure the reviewer that this decision does not fundamentally alter our results or conclusions. The timing, frequency, and relative strength of the major polynya (including the 1964 and 1974 – 76) events remain highly robust between both formulations; however, the zero-truncation simply improves the signal-to-noise ratio, gives a clearer background fluctuation and prevents artificial dampening during periods of highly localized proxy responses.

5. Figure 9 is very hard to understand and not in my view much of an increase in information for the reader compared to Figure 8. I would recommend moving it to the supplement and explaining it better. You could then just refer to it briefly in the main text where it currently distracts from the interesting results you show.

> As suggested, we have moved the figure and the text to the supplement.

RC2: 'Comment on egusphere-2025-5820', Anonymous Referee #2, 20 May 2026

I am happy with the author responses to my suggested revisions.

> We thank the reviewer for their positive assessment of our work and accepting the manuscript for publication

Editor: 'Comment on egusphere-2025-5820', 13 July 2026

The manuscript presents a compelling multi-proxy approach to reconstructing the historical footprint of the Maud Rise Polynya (MRP), providing valuable multi-century

context that extends beyond the satellite era.

I request several unclear sections be addressed, including meteorological data limitations should be more transparently acknowledged, and the physical mechanism underlying the stable isotope choices needs a sharper defense.

> We thank the editor for investing their time in reviewing our manuscript and providing the constructive feedback.

Comments:

1. Re-evaluate the physical basis for positive deuterium excess (d-excess)

Lines 323–326 and 356–357: It is stated that MRP openings are linked to positive anomalies in d-excess.

Classically, evaporation from open water under high relative humidity conditions (such as a local maritime moisture source exposed to the polar boundary layer) tends to lower the d-excess of the resulting vapor, while distant, low-humidity, or warm-subtropical moisture sources yield higher d-excess values. Conversely, intense kinetic fractionation during rapid evaporation driven by very cold, dry katabatic/cyclonic winds passing over warm open water can occasionally elevate it.

-> Clarify the thermodynamic mechanism driving this positive d-excess anomaly. I.e., is the signal is dominated by wind-driven kinetic effects during cold-air outbreaks over the open polynya? The unexplained positive anomily in d-excess has the potential to weaken the physical robustness of the multi-proxy index.

> Thank you for the valuable suggestion. We completely agree with the Editor's physical assessment. The positive d-excess anomalies associated with MRP openings in our core are indeed driven by intense, non-equilibrium kinetic fractionation at the open water and cold and dry air interface from the strong katabatic/cyclonic wind events. We have revised the manuscript to explicitly clarify this thermodynamic mechanism (Line 327 – 338):
>
> > *During winter and spring, the opening of the MRP exposes open seawater (SST ≈ -1.5°C) directly to extremely cold polar air masses (T < -15°C) blowing off the ice sheet or driven by cyclonic circulation. Because these polar air masses are cold and dry, the actual atmospheric vapor pressure (e_a=$0.0611\ x\ RH\ x\ 10^{\frac{7.5\ x\ T}{237.3\ +T}}$) is exceedingly low. As a result, the relative humidity normalized to the sea surface temperature ($rhs = \frac{e_a}{e_{sat}(SST)}$) drops drastically. This large humidity deficit at the air-sea boundary layer drives rapid, highly kinetic, non-equilibrium evaporation, which is further amplified by the high-wind environments typical of DML cyclonic activity and katabatic flow, which sweep away the boundary layer and maintain this dry, highly undersaturated state. This results in higher*

> *d-excess in the evaporating moisture, injecting a localized vapour plume with positive d-excess anomalies directly into the coastal precipitation during polynya openings.*

2. NCEP/NCAR Topographic Limitations

Lines 239–240: The HYSPLIT modeling utilizes the coarse 2.5° x 2.5° NCEP/NCAR reanalysis.
Coarse-resolution reanalyses notoriously struggle to capture the sharp coastal escarpments and complex katabatic flow fields of coastal Dronning Maud Land, often smoothing out the precise boundaries of ice rises like Djupranen. While the overall trajectory corridors are likely robust at a regional scale, add a sentence in the discussion or methods acknowledging that the spatial resolution of the meteorological forcing data introduces an inherent smoothing effect on coastal airflow dynamics.

> We agree with the editor that the 2.5° × 2.5° spatial resolution of the NCEP/NCAR reanalysis data introduces an inherent smoothing effect on complex, localized coastal airflow dynamics, such as katabatic winds and flow diversion around ice rises (e.g., Djupranen). We have added a sentence to Section 2.5 to explicitly acknowledge this limitation (237 – 240) :
>
> > *While these coarse-resolution meteorological fields inherently smooth sharp coastal topographical features and complex local wind patterns around them, which are characteristic of coastal DML, they are still sufficient for resolving regional-scale atmospheric transport pathways.*

Minor comments:

* Text duplications, e.g., l229–233 contain a literal back-to-back duplication of a sentence.
Current"providing insights into their formation mechanisms and potential impact on regional oceanographic processes. The combination of these metrics allows us to characterise both the temporal persistence and spatial extent of polynyas, providing insights into their formation mechanisms and potential impact on regional oceanographic processes."
-> Delete l231–233.

> Deleted as suggested

2. Improve on the articulation:

L160–161: Change (≈approximately 85 °C) to either (~85°C) or (approximately 85°C).

> Changed to ~85°C (Line 159)

L383: There is a typo: "` corresponding to know halo years" to "corresponding to known halo years".

> Changed as suggested (line 398)

L408: There is a typo: "eight at 0.9 ad seven polynya years" to "eight at 0.9 and seven polynya years".

> Changed as suggested. Paragraph moved to supplementary materials as per Review 1's suggestion (Line 66, Supplementary materials)

L514: Update and provide details for data are "being prepared for submission."

> This section has now been updated in the revised manuscript (Line 508 512):
>
> > *The polynya index calculated in this study and the ice core proxy records used for the index calculation have been submitted to the NCPOR Polar Data Centre (https://data.ncpor.res.in, last access: 14 July 2026) and can be accessed at https://data.ncpor.res.in/static/datasets/MF131768238_evolution_of_maud_rise_polynya_during_the_last_250_years.xlsx (last access: 14 July 2026).*

L526: There is a funky line-wrap/formatting in the text blocks of the references at l500–517 with random fragments across the margin.

> All references have been formatted to follow the journal guidelines