Author Response to Anonymous Referee #1

Manuscript: egusphere-2025-6301

Revised title: Antarctic Sea-Ice Anomalies and Global Hazard-Event Records: An Exploratory Analysis, 2010–2024

Dear Anonymous Referee #1,

We sincerely thank you for your careful, constructive, and encouraging assessment of our manuscript. Your comments identified the need to remove causal overstatement, address the limitations of the short observational record, strengthen the statistical safeguards, and recast the proposed pathways as conceptual rather than demonstrated causal mechanisms. We have therefore undertaken a substantial rewrite rather than a limited textual revision.

The revised manuscript has been reframed as an exploratory observational analysis of statistical co-variation. The title, abstract, introduction, methods, results, conceptual framework, discussion, and conclusions have all been rewritten. The revised line numbers cited below refer to the clean revised manuscript. Our point-by-point responses follow the summary of major revisions.

Major revisions

- **Causal interpretation removed.** The manuscript now consistently uses terms such as statistical association, co-variation, synchronization and conceptual pathway, and explicitly states that the results do not establish direct causal attribution.
- **Statistical analysis strengthened.** The exponential curve is retained only as a descriptive comparison. Linear fitting is now the primary model-form check, supplemented by Pearson correlation, Spearman rank correlation, detrended-residual correlation, leave-one-out sensitivity analysis and Benjamini–Hochberg false-discovery-rate adjustment.
- **Data object and scope clarified.** The China National Climate Center dataset is described as a record of major hazardous weather and climate events, not a complete objective census of all global extremes. Regional SIC maps are used only as contextual illustrations, whereas basin-wide annual mean SIE is the statistical predictor.
- **ENSO and SAM roles redefined.** ENSO is treated as a first-order quantified climate background. SAM is discussed only as a literature-supported potential co-modulating factor because it is not independently included in the quantitative tests.
- **Mechanistic discussion rebuilt.** The former causal mechanism narrative and unsupported numerical claims have been removed. The new framework separates plausible physical pathways, event-level statistical association and common modulation, and explicitly identifies the analyses needed for future attribution.

Point-by-Point Response to Anonymous Referee #1

R1.1 Overall interpretation, causality and confounding

> ***Reviewer comment:*** *The paper is well written and the experimental design is relatively clear, but the claims are overstated. The analyses are not sufficient to infer causality, particularly given the short temporal record and the absence of a more comprehensive treatment of confounding climate drivers.*

Response: We agree. The central interpretation has been changed from a causal or regulatory claim to an exploratory assessment of co-variation. The revised title now explicitly identifies the study as an "Exploratory Analysis". The abstract states that the results indicate statistical co-variation rather than direct causal attribution. The Introduction now distinguishes basin-wide SIE metrics from regional processes, describes the global-event question as unresolved, and states that current evidence does not demonstrate that Antarctic sea-ice retreat independently drives multiple types of global hazardous events. The Methods and Conclusions repeat these limits. We also acknowledge the short record, shared trends, individual anomalous years, event-recording limitations, ENSO and potential SAM co-modulation as sources of uncertainty.

> **Revised manuscript:** Title and Abstract, Lines 1–24; Introduction, Lines 40–71; Methods, Lines 98–139; Conclusions, Lines 470–477.

R1.2 Additional statistical safeguards

> ***Reviewer comment:*** *The short temporal record and incomplete treatment of confounding climate drivers make the regression results insufficient for strong conclusions.*

Response: To reduce the risk of overinterpretation, we added several robustness checks. The revised analysis now reports linear and exponential fits, Pearson and Spearman correlations, correlations between separately detrended residuals, leave-one-out sensitivity ranges and FDR-adjusted P values. These tests do not resolve causal identification, but they help distinguish associations that persist across model forms from results that are strongly influenced by common trends or individual years. The revised text explicitly treats these statistics as supporting evidence for robustness, not as evidence of causality. ENSO is used only to characterize a first-order quantified climate background, whereas SAM is not included in the quantitative regression or partial-correlation tests; neither should therefore be interpreted as having been causally controlled.

> **Revised manuscript:** Methods, Lines 125–139; Results and Table 1, Lines 193–226; ENSO/SAM qualifications, Lines 62–71 and 290–306.

R1.3 Conceptual rather than causal pathways

> ***Reviewer comment:*** *The causal language should be softened, the limitations of the correlation pathways should be acknowledged, and the pathways should be reframed as conceptual. The paper should make clear that it identifies patterns consistent with teleconnection mechanisms rather than proving direct causality.*

Response: We have fully adopted this recommendation. Section 3.3 is now titled "Conceptual pathways linking Antarctic sea-ice anomalies and recorded event frequency". The framework separates four elements: Antarctic sea-ice anomalies, plausible physical pathways, event-level statistical association and common modulation. Figure 8 explicitly states that the stronger/intermediate/weaker categories denote only statistical association strength and do not imply direct causality. The text further states that the framework is intended for future regional diagnostics, lagged tests and numerical modelling, not as a completed attribution result.

> **Revised manuscript:** Section 3.3, Lines 288–436; framework interpretation, Lines 307–323; Figure 8 caption, Lines 357–363.

R1.4 Recommendation to reframe and resubmit

> ***Reviewer comment:*** *If the paper can be turned into a more cautious, exploratory and correlation-based synthesis paper, revision and resubmission or major revision could be considered.*

Response: The manuscript has been reconstructed in precisely this direction. It is now presented as an exploratory observational analysis of recorded major-event frequencies, with explicit separation between statistical results, conceptual interpretation and unresolved causal attribution. Prediction and attribution claims in the original abstract and conclusions have been removed.

> **Revised manuscript:** Throughout the revised manuscript, particularly Lines 7–24, 54–79, 120–139, 288–323 and 437–477.

We thank you again for your constructive assessment. Your comments led us to reframe the study, strengthen the statistical evaluation, and state the inferential limits more clearly. We respectfully submit the revised manuscript for renewed consideration.

Sincerely, Shulin Tang and Yaozong Zhang