Reply to Editor Comment:

The authors would like to thank the editor for the invaluable comments and suggestions. The following are the replies to each point raised, together with specific revisions that are made. The original comments are in *blue italic* font and listed in paragraphs, with our reply following each paragraph separately. The revisions are also highlighted in the revised manuscript in blue and marked by ***REV editor***.

Dear Authors,
Thank you for submitting this revision of your manuscript. Unfortunately, no external reviewers were able to be secured for this round; therefore, I am providing general and detailed comments based on my own editorial review of your latest version. Please consider these points carefully before proceeding. - I would like to call out that the ms has been lifted significantly from the integration of biogeochemical flux data and the updated context regarding the 2023–2025 Antarctic sea-ice minima have significantly strengthened the paper's impact and relevance.

General Comments

● *Review Classification & Scope: My main concern is whether the manuscript currently meets the criteria for a "Review" article. There appears to be an insufficient balance of existing work and a lack of a clear "vision" or future roadmap for the field. Please ensure the synthesis goes beyond a summary of events and provides an outlook on remaining gaps.*

● *Polynya Differentiation: The manuscript needs to more clearly differentiate between Weddell Sea Polynyas (WSP) and Maud Rise Polynyas (MRP). While related, their triggers and frequency warrant distinct treatment.*

● *Atmospheric Context: For a comprehensive review, a dedicated section on general atmospheric circulation, atmospheric properties, and their variability relative to polynya changes is required. The current introduction to atmospheric processes needs to be extended and deepened.*

● *Paleoclimate Signal: Please address whether one should expect a discernible signal in the sediment record beneath or near major polynyas, comparable to the signals found in (East) Antarctic glacial ice core records (l125).*

● *Terminology: The phrase "roadmap to polynya formation" is not suitable for a scientific review. Please replace this with more formal terminology (e.g., "Mechanisms" or "Evolutionary Stages").*

● *Visuals: Some key figures are missing that would be essential for a review. Please include schematics or data plots that synthesize the cross-disciplinary nature of these events.*

Technical Corrections – Text & Citations

● *Section 3.4 (Biogeochemical Fluxes): Please double-check the units for Dissolved Inorganic Carbon (DIC) and pCO2 in lines 442–445. Ensure consistency between µmol kg−1 and ppm throughout the paragraph.*

Reply: We confirmed that standardized DIC set to µmol kg^{-1} and standardized pCO2 set to ppm throughout the paragraph.

● *Reference Updates: Several citations listed as "In Press" or "2024" (notably Ayres et al. and the latest Southern Ocean State of the Climate) now have final DOIs and publication years (2025). Please update these in the bibliography.*

Reply: We confirmed that Ayres et al. citation is correct.

● *The "Salinity Paradox": In Section 4.2, please add a brief (1–2 sentence) clarification regarding the net buoyancy effect. Specifically, note that if sensible heat prevents ice formation without sufficient salt rejection, the resulting water mass may be ventilated but less dense than traditional Antarctic Bottom Water (AABW).*

Reply: We added two sentences in Section 3.3.2 stating that if sensible heat limits sea-ice formation (and thus brine rejection), the resulting ventilated waters can be less dense than canonical AABW, even if convection/ventilation occurs.

Technical Corrections – Figures & Formatting

● *Figure 4 (Convection Depth): The font size for the labels indicating the "Maud Rise Halo" and "Warm Deep Water (WDW) Core" is currently too small for print. Please increase these by at least 2pts.*

Reply: We increased the front size in Figure 3 (schematic figure).

● *Acronym Consistency: Ensure "WSP" (Weddell Sea Polynya) is defined at first use in the Abstract and again in the Introduction, and used consistently thereafter.*

Reply: We confirmed that WSP is defined at first use.

● *LaTeX Check: Ensure all chemical species (e.g., O2 , CO2) and mathematical variables used in the text are properly formatted using LaTeX math mode for the final typeset version.*

Reply: We confirmed that standardized DIC to μmol kg^{-1} and Standardized pCO2 to ppm throughout the paragraph.

Minor comments

Location	*Requested Correction*
Global	*Correct spelling of "in situ" to be in italics and without a hyphen.*
l5	*Replace "they could play" with "they may play".*
l78	*Use lower case for "seas": "Ross, Amundsen and Weddell seas".*
l88	*Update dated references. Suggest adding: (Turner et al., 2020; Abram et al., 2025).*
l148	*Replace "becomes relatively shallow" with "shoals".*
Location	*Requested Correction*

Reply: Corrected and updated as suggested in the manuscript.