Reply to Referee Comment #2 (RC2):

The authors would like to thank the referee 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 *green italic* font and listed in paragraphs, with our reply following each paragraph separately. The revisions are also highlighted in the revised manuscript in green and marked by ***RC2***.

The Weddell Sea polynya, first observed in the mid-1970s through early satellite microwave imagery, is a highly intriguing phenomenon within the coupled atmosphere–sea ice–ocean system and has been the focus of several studies. However, it did not reappear for several decades, and due to a lack of observational data—particularly in situ measurements—research on the phenomenon remained limited. However, during the winters of 2016 and 2017, although on a smaller spatial and temporal scale, a region of open ocean re-emerged over the Maud Rise area, prompting renewed investigations from various perspectives.

This manuscript provides a comprehensive synthesis and integration of numerous previous studies on this fascinating natural phenomenon, resulting in a highly valuable review. To further enhance the quality of this review paper, I would like to provide the following comments.

P.1, L.1. "Abstract": Polynyas are generally described as open water areas within sea ice regions. However, in reality—particularly for coastal polynyas during winter—they are more often characterized by areas of frazil ice or new/thin ice. I believe this distinction should be described more precisely to reflect the actual conditions.
Reply: We agree and appreciate the clarification. We have revised the definition of polynyas in the abstract to read: "Open-ocean polynyas, areas with little or no sea ice,…"

P.2, L.32 "less frequent": Compared to coastal polynyas that appear almost daily during winter in the same region, sensible heat polynyas occur far less frequently and are regarded as extremely rare phenomena. Therefore, the term "less frequent" may be too mild, and a stronger expression such as "rare" or "very infrequent" would more accurately reflect the true nature of their occurrence.
Reply: We have replaced the phrase "less frequent" with "rarer" to better reflect the low frequency of open-ocean (sensible heat) polynya events, as compared to coastal polynyas.

P.2, L.51 "the current unprecedented decline in Southern Ocean sea ice": The rapid decline in sea-ice extent in the Southern Ocean has emerged as a particularly prominent topic in recent years. In this context, it would be valuable to also address the potential relationship between this decline and polynya occurrences, especially in connection with the future projections discussed later in the modeling results. Including such a discussion could provide a more comprehensive review and further strengthen the overall impact of the manuscript.
Reply: Thank you for this insightful suggestion. We added a brief discussion at the end of Introduction, acknowledging that although the 2016 MRP occurred during a period of sea ice decline, no similar polynyas were observed in 2022-2023 despite record-low ice extent. This suggests that extreme ice loss does not necessarily lead to polynya formation, possibly due to the lack of sufficient preconditioning or altered atmospheric patterns. We note the absence of dedicated studies on this topic and propose it as an important avenue for future research.

P.6, L.156 “Fig. 5”: Figure 5 is introduced prior to Figure 4, creating a mismatch between the figure numbering and the order in which they appear in the text. For clarity and to improve reader comprehension, it would be preferable to present the figures in the same sequence as they are referenced.
Reply: We have corrected the figure order in the text to ensure that Figure 4 is referenced before Figure 5.

P.6, L.163-164 “Taylor Cap” and “warm-water Halo”: If possible, visually indicating these characteristic structures in Figure 3 would greatly enhance reader understanding. In addition, labeling “Maud Rise” on the figure would help readers more easily connect the figure with the corresponding discussion in the text, making the illustration more informative and user-friendly.
Reply: We have updated Figure 3 to include annotations for “Taylor Cap,” “warm-water Halo,” and “Maud Rise.”

Paragraph beginning on P. 11, L. 320 – Comment: The melt–freeze cycle described in this paragraph appears to be a plausible process and likely plays an important role in the maintenance of the polynya. However, even with increased sea-ice production in such cases, the salinity of the underlying water may already be too low to allow the formation of sufficiently dense water necessary for Antarctic Bottom Water (AABW) formation. Including a brief discussion of this aspect could further enrich the overall argument.
Reply: We have expanded the paragraph to briefly note that despite enhanced sea ice production, the resulting brine rejection may be insufficient to increase surface salinity to levels required for effective AABW formation. This is especially true if the background stratification is strongly freshwater-influenced, a condition increasingly common under projected future meltwater input scenarios.

P.13, L.413 “A minor component of the observed abyssal warming since the 1990s (Purkey and Johnson, 2010) could be linked to recovery from the mid-1970s WSP event (Zanowski et al., 2015).”: This statement is quite intriguing; however, the roughly 20-year time gap between the events makes the proposed causal relationship somewhat difficult for readers to intuitively grasp. Including a brief explanation of the mechanism by which such an effect could emerge after such a long interval would help strengthen the argument and improve clarity.
Reply: We have clarified this point in the text by briefly explaining the proposed mechanism: the deep convective event during the 1970s WSP injected cold, dense water into the abyssal ocean. Over subsequent decades, as the anomalous cold water mass equilibrated and upwelled, it could have contributed to the delayed warming signal observed in the deep Southern Ocean. This lag is consistent with abyssal circulation timescales and has been simulated in multi-century coupled model runs (Zanowski and Hallberg, 2017).