Responses to the Reviewers

Format: The reviewers' comments are quoted in italic

Section number in the response refers to the revised manuscript with tracked changes

Quotation in red color stands for revised/added text in the revised manuscript

Overall comment:

We thank the two reviewers for the detailed, helpful comments. We have addressed individual comments as shown below and revised the manuscript accordingly.

Response to comments from Reviewer 5

The authors have made commendable revisions to the main text of the manuscript. However, these changes need to be reflected in the Discussion and Conclusion sections. Ensure that figures are referenced appropriately in both the Discussion and Conclusion sections to support the findings and arguments presented.

We appreciate the helpful comments from Reviewer 5. We checked through the entire manuscript to make sure all descriptions directly follow the most up-to-date version of the figures and tables. We also made a few revisions in Section 5 Discussion and Conclusions as the reviewer recommended below.

Revise argumentation:

Line 455: Elaborate on how this method can investigate the (temporal) evolution of cloud properties.

We revised this sentence to avoid using the terminology of evolution in Section 5 Discussion and Conclusions: "This method allows an investigation on ~~the evolution of~~ cloud macrophysical and microphysical properties as well as the related aerosol indirect effects at different levels of partitioning between supercooled liquid water and ice particles, as the phase change occurs among vapor, liquid, and solid phase of water molecules."

Lines 510-514: Remove or revise these lines, as the argumentation of growth rate has been removed from the main text.

We revised this section and removed the terminology of growth rate in Section 5: "This study illustrates that the mass and number partitioning between liquid and ice hydrometeors in mixed-phase clouds are not only correlated with the mixed spatial ratio or ice spatial ratio which reflects the spatial fraction of ice-containing regions, but also are correlated with the existence of pure ice segments (Figures 7 and 8). Future model parameterization is recommended to quantify the varying rates of phase change throughout a cloud's lifetime by considering two main factors – the type of phases (especially phase 2 versus phase 3 depending on the existence of pure ice segments) and the spatial fraction of ice-containing region."

Clarify specific terms:

Lines 462-463: Clarify what is meant by "all three microphysical properties". In line 350 four microphysical properties (IPNF, LWC, IWC, and ice mass fraction) are listed.

We thank the reviewer for pointing this out. We revised this sentence in Section 5 to: "Comparing phases 2 and 3, the latter phase shows higher rates of changes in four microphysical properties with increasing ice spatial ratio, including faster increase of IPNF, faster increase of IWC, faster decrease of LWC, and faster increase of ice mass fraction (Figures 7 and 8)."

We also revised one sentence in the abstract to mention all 4 cloud microphysical properties: "The results show that the exchange between supercooled liquid water and ice crystals in a macrophysical perspective, represented by the increasing spatial ratio of regions containing ice crystals relative to the total in-cloud region (defined as ice spatial ratio), is positively correlated with the phase exchange in a microphysical perspective, represented by the increasing ice water content (IWC), decreasing liquid water content (LWC), increasing ice mass fraction, and increasing ice particle number fraction (IPNF)."

Line 465: Specify that the higher rate of phase change is in respect to the spatial ratio, not time, to avoid confusion.

We agree that it would be helpful to clarify this point. We revised this sentence in Section 5 to: "These results indicate that when ice crystals become more dominant and pure ice segments start to appear, both the mass and number partitions between liquid phase and ice phase experience a higher rate of phase change with respect to the spatial ratio of ice-containing regions (note that this rate of change is not with respect to time)."

Response to comments from Reviewer 6

Manuscript Title: "Partition between Supercooled Liquid Droplets and Ice Crystals in Mixed-phase Clouds based on Airborne In-situ Observations"

Key Scientific Question: The manuscript addresses the question of how the macrophysical and microphysical properties of mixed-phase clouds, and the factors controlling their formation and evolution, impact their radiative forcing over the Southern Ocean. This research aims to understand the interaction between supercooled liquid water and ice crystals within these clouds and how aerosols influence these properties. The study introduces a novel method for categorizing mixed-phase clouds into four distinct phases based on spatial relationships among segments containing pure ice (ICR or phase4), pure liquid (LCR or phase1), or both, liquid dominated mixed-phase (MCR or phase 2) and ice-dominated mixed-phase MCR or phase3). Key findings include positive correlations between ice particle number fraction and ice water content (IWC) with mixed and ice spatial ratios in phases 2 and 3, with phase 3 showing faster changes. All methods identified a significant phase transition around -17.5°C. Larger aerosols were found to be more likely to act as ice nucleating particles (INPs), with phase 3 exhibiting weaker aerosol indirect effects due to secondary ice production. Higher updrafts and stronger in-cloud turbulence were observed in mixed-phase conditions, particularly in phase 3. These insights suggest that future climate models should account for varying phase change rates and spatial fractions of ice-containing regions. However, the method has limitations, including its idealized nature, reliance on 1-D aircraft data, and potential lack of comprehensive spatial representation. Future research should integrate 2-D and 3-D observations (remote-sensing) and simulations to validate and refine the phase categorization method, enhancing our understanding of mixed-phase cloud dynamics and their climate impacts.

We appreciate the helpful comments from Reviewer 6. Below is our response to each of the comments.

Minor Comments:

- Line 266: Typo → – 0.1 – km → 0.1 – 1 km

We thank the reviewer for catching this typo. We revised it to “0.1 – 1 km”.

- Line 280: Typo → Wegner → Wegener

We thank the reviewer for catching this typo. We revised it to “Wegener”.

- Line 485: "Because of this, aerosol indirect effects on various stages of clouds can also be examined separately." - Because of what? Consider rephrasing for clarity!

We agree that this former sentence can cause confusion. We revised this sentence in Section 5 to: “Aerosol indirect effects on mixed-phase clouds during different levels of phase partitioning can also be examined separately.”

Conclusion

The manuscript presents significant advancements in the understanding of mixed-phase clouds and their classification. The novel method proposed is promising and provides valuable insights into cloud microphysical and macrophysical properties. Addressing the major remarks and refining the methodology could further enhance the impact and robustness of the study. Overall, the manuscript is a valuable contribution to the field of cloud physics and climate science and is recommended for publication with minor revisions.

We thank the reviewer again for these helpful and valuable comments.