

## **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  $-17.5^{\circ}\text{C}$ . 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.

### **Minor Comments:**

- Line 266: Typo  $\rightarrow -0.1 - \text{km} \rightarrow 0.1 - 1 \text{ km}$
- Line 280: Typo  $\rightarrow \text{Wegner} \rightarrow \text{Wegener}$
- 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!

### **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.