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

This study analyzes the in-situ observation of mixed-phase clouds collected during the SOCRATES field campaigns over the ocean. Each cloud segment is categorized into four phases: 1) liquid, 2) mixed-phase/liquid, 3) mixed-phase/liquid/ice, and 4) ice. The dependency of microphysical cloud properties, dynamical properties, and aerosol properties on each of these phases is examined. The paper introduces mixed and ice spatial ratios to describe the evolution of the phases.

This paper presents an intriguing approach for analyzing in-situ data of mixed-phase clouds. However, there are concerns regarding the equal treatment of cloud segments between 0.2 km and 180 km (see major comment). The quality of the presentation could be enhanced by focusing on fewer figures and discussing these figures more comprehensively (see minor comments).

Recommendation: I suggest reconsidering the paper after making major revisions.

Major:

Cloud segments vary in length from 0.2 to 180 km. What is the likelihood that a short cloud segment is incorrectly classified as liquid (phase 1) due to the low measurement volume missing ice crystals? Is there a possibility that the two edges of a long cloud segment interacted with each other? If not, what justifies treating them as one quantity in the analysis? How do the results depend on the length of the segments? Would splitting long cloud segments into smaller pieces (e.g., 1000 m), where cloud particles interact with each other, be advantageous?

Minor:

Abstract: Specify the dataset used and the types of clouds investigated.

Line 180: Figure S1 is crucial for understanding the approach and should be moved to the main manuscript.

Line 184: The introduction of M1, M2, M3 is confusing and unnecessary as it only appears in Table 1.

Line 215: It should be a second-by-second analysis. Could an analysis of larger intervals (e.g., 10 seconds) provide a better understanding of the cloud phases?

Line 225: "The lengths of cloud segments vary..."

Line 225: After the sampling statistic, I expected the number of samples, not a time.

Line 236 – 238: A mixed-phase cloud (MPC) consists of supercooled droplets and ice crystals. Which spatial fraction describes the macrophysical properties of MPCs? How do LCR, ICR, MCR, and TCR represent macrophysical properties, and why aren't they used in the analysis?

Line 240 – 245: Is it correct that the mixed spatial ratio equals the spatial ratio of MCR (M3), but the ice spatial ratio differs from the spatial ratio of ICR? If yes, try to find clearer names and perhaps add the definition of mixed spatial ratio and ice spatial ratio to Table 1.

Line 270 – 272: What is the percentage of observations over 1.25 m/s in phase 2 and 3? Is the difference significant? I suggest moving Figure 4 i-p to the appendix and Figure S4 b-d to the main manuscript.

Line 295 – 296: Which phase are you referring to? I suggest plotting all temperatures of the size distribution of this phase in one plot to emphasize the differences. As differences in temperature are not further discussed, I suggest moving the size distribution of the temperature interval to the appendix and showing only the size distribution of all temperatures in the main manuscript.

Line 305 – 306: What is the fraction of observations with ice particle number fraction > 0.1 in Figure 6b? Why was the linear regression calculated on the mean of each ice spatial ratio bin (which weighted each bin equally despite very different numbers of observations in each bin) and not based on individual observations? Please add more information on the calculation of the linear regression.

Line 315 – 320: I have difficulty following the argument. Are you referring to "ice crystals gradually dominating the total particle population" as high ice particle number fraction? How can "a particular TCR" be identified in the multiple subfigures? What is the spatial extent of the entire cloud segment?

Line 323 – 324: How can "ICR appear" when phase 3 always has some ICR?

Line 325: Please describe in more detail how you derived that "they experience similar rates of phase changes from liquid to ice" based on measurements of individual states of cloud microphysics?

Line 336: How do you conclude that generating cells contain lower ice particle number fractions? What is the uncertainty of the generating cells measurements?

Line 348-349: What do you mean by "... similar rate of increase between ice crystals embedded among supercooled liquid droplets..."?

Line 352: Should be Figure 7i.

Line 357 – 358: What effect would the formation and growth of ice particles have, and could the depletion of the liquid phase also play a significant role?

Line 405: Why should SIP be stronger in phase 3 when phase 2 has more large droplets (according to Fig. 5)?

Line 447-448: Please be precise if you are referring to MCR/ICR or phase 2/3.

Line 468- 476: Move this paragraph to the definition of the phases.

Line 480 – 484: Are you suggesting that once a small pocket of pure ice crystals appears in a cloud (phase 3), the rate of change from liquid to the ice phase accelerates for the whole cloud?