Response to Reviewer 3

This study combines in situ aircraft data collected in summertime convective clouds over the UAE in 2019 with satellite data, ground radar, and reanalysis to adapt the development of a 5 microphysical zone categorization to said region and season. The 5 zones are: (1) diffusional droplet growth zone, (2) droplet coalescence growth zone, (3) rainout zone, (4) mixed-phase zone, and (5) glaciated zone. A case study is then presented for evaluation. The study presents a novel adaptation of the proposed categorization that presents a useful framework for future analyses. Said framework is specific to the season and environment of the aircraft data, however, so further efforts should be made to better categorize that environment to improve potential applicability to other seasons and regions. With revisions, the manuscript could be suitable for publication.

We appreciate the valuable comments from the reviewer.
Our responses are in blue below each comment from the reviewer.

Specific Comments:

1. The cloud droplet effective radius looks to be determined solely from the FCDP, when it should be determined as a composite from multiple cloud probes, not just the FCDP. Larger particles seen by the 2DS (and HVPS) should also be included, for both the liquid and the ice clouds. Discussion following from line 465 suggests that the FCDP is not sensitive to ice particles, when in fact it does measure ice crystals, albeit with more uncertainty in sizing than of water droplets. However, were the 2DS and HVPS measurements in the ice clouds included in the calculation of effective radius, one might anticipate improved agreement between the in situ and satellite estimates. The current statement that they disagree because the FCDP is insensitive to ice particles is insufficient.

We agree with the reviewer that there is value in including the 2DS and HVPS in the calculation of effective radius. As such, we plan to recalculate the effective radius (ER) in this study using the combined cloud particle size distribution from FCDP, 2DS, and HVPS. Following Fu et al. (2022), we use 40 µm as a fixed break point to combine the FCDP and 2DS particle size distribution. The break point between 2DS and HVPS is 1000 µm, given that the 2DS is a 10 µm resolution optical array probe and the HVPS is a 100 µm resolution optical array probe. Only size distributions with total number concentrations greater than 10 cm^{-3} are included in calculating ERs, to make sure that the cloud is not impacted by entrainment as cloud edges. According to our tests, the new ERs based on combined size distribution (FCDP, 2DS, and HVPS) tend to be slightly larger (around or below 5%) than the ERs based on FCDP for most cloud penetrations (CPs). Because the large particle size (>40 µm) concentration from 2DS is much lower compared to the particle size concentration from FCDP, and the concentration from HVPS is extremely low (close or equal to 0) for most CPs (e.g., Figures 6 and 13 in the manuscript). Meanwhile, the difference between the new ERs and FCDP ERs becomes larger for those CPs at a cold temperature (e.g., around -12°C), which is related to the increase of ice particles. In the revised manuscript, we will recalculate the ER to include the 2DS and HVPS, add a paragraph to describe the calculation of ER in Section 2 (Dataset and Methodology), and modify the text accordingly throughout the manuscript.

Fu, D., Di Girolamo, L., Rauber, R. M., McFarquhar, G. M., Nesbitt, S. W., Loveridge, J., ... & Scarino, A. J. (2022). An evaluation of the liquid cloud droplet effective radius derived from MODIS, airborne remote sensing, and in situ measurements from CAMP 2 Ex. Atmospheric Chemistry and Physics, 22(12), 8259-8285.

2. The analysis of the in-situ data is lacking in qualifying the environmental conditions and the cloud evolutionary stage of the selected cloud passes. For example:

Lines 591-594: Do we know that they are not all young turrets being sampled in SF07? Is there any indication of cloud age or development stage of these case studies?

The aircraft typically targets growing young turrets in the early stage of the cloud lifetime because they are most valuable to sample for studying the formation of precipitation and they are also safer to penetrate. Young growing turrets are also most valuable as targets for cloud seeding, which is the main application for developing the 5 microphysical zone characterization in this study. We reviewed the video of those flights and confirmed that the clouds sampled are young targets in the early- to mid-life cycle convection. The figure below is an example from flight SF03 showing that the aircraft was penetrating a relatively young turret.

Figure: Image from the aircraft video in flight SF03 on August 18, 2019. The aircraft was penetrating a relatively young cloud turret at 13:41:51 UTC. The temperature measured by the aircraft was -5.7°C at that time.

In addition, we also examined the vertical profiles of radar reflectivity associated with those CPs (at the same time and same location as those CPs), which suggests that these clouds are relatively young in their lifetime. The figure below shows the vertical profiles of radar reflectivity for the CPs in SF01 and SF03. The radar reflectivity ranges from 0 to ~30 dBZ, indicating characteristics of early- to mid-life cycle convection. Our radar observations do not show the high reflectivity (higher than 40 dBZ) typical of mature convection (Zipser et al., 2006; Feng et al., 2018).

Zipser, E. J., D. J. Cecil, C. Liu, S. W. Nesbitt, and D. P. Yorty, 2006: Where Are The Most Intense Thunderstorms on Earth? Bulletin of the American Meteorological Society, 87, 1057–1072, https://doi.org/10.1175/BAMS-87-8-1057.

Feng, Z., Leung, L. R., Houze, R. A., Jr.,Hagos, S., Hardin, J., Yang, Q., et al., 2018: Structure and evolution of mesoscale convective systems: Sensitivity to cloud microphysics in convection-permitting simulations over the United States. Journal of Advances in Modeling Earth Systems, 10, 1470–1494. https://doi.org/10.1029/2018MS001305.

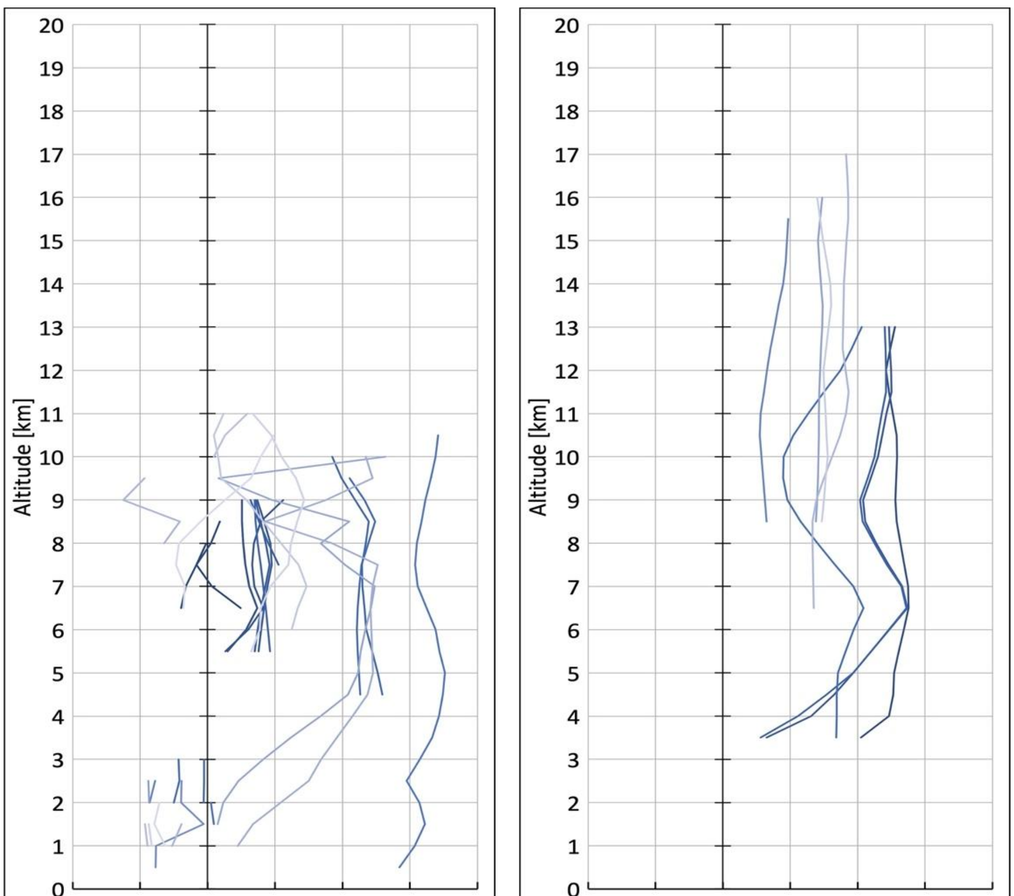

Figure: The vertical profiles of radar reflectivity associated with the CPs in SF01 (left) and SF03 (right) from the C-band weather radar at Al Ain. Each trace corresponds to the vertical profiles of radar reflectivity (above and below the aircraft) at the same time and same location (Lat & Lon) for each CP.

Lines 597-599: Do we know if the cloud passes at these levels were in a similar age of cloud life cycle? Were they at similar distance from cloud top and cloud base?

As we mentioned above, the aircraft typically targets convection in the early- to mid-life cycle. The aircraft usually penetrates the cloud near the cloud top, usually 1000 ft below the top of growing turrets. Since this procedure was followed consistently during the experiment, it can be assumed that their distance from cloud tops and bases across the cases are fairly similar.

Line 608: "...implies that the droplet growth in the cloud cases SF01 and SF07 is suppressed", are the cloud passes under consideration consistent enough to make this conclusion? What were the cloud base temperatures? What are the cloud top temperatures/heights? What are the environmental conditions for the various days?

Based on the CPs observed by aircraft, those cloud cases have similar cloud top temperatures as shown in the table below; for the cloud bottom, SF06 and SF07 have a relatively colder cloud base (lowest CP) compared to SF01 and SF03. As discussed above, the life cycles of those convective cloud cases are similar, at the early- to mid-life cycle.

	Top Alt (ft)	Top T (C)	Bottom Alt (ft)	Bottom T (C)
SF01	23121	-13.5	12018	9.3
SF03	22750	-13.0	11674	9.2
SF06	23294	-16.1	15983	-3.3
SF07	20155	-12.1	13403	1.8

Table: the cloud top (highest CP) and cloud base (lowest CP) for the four cases (SF01, SF03, SF06, and SF07) according to the definition of a CP in the aircraft data.

Figure 12 and associated case studies: were the temporal measurements of these cloud cases all from the same convective turret, or could they have been different turrets (differing potentially in cloud top height, cloud age, etc.)?

During the flight, if the turret was growing, then the turret was profiled vertically through subsequent cloud penetrations in vertical increments in its early- to mid-life cycle stage. Once the cloud top was reached and the cloud transitioned to the past mid-life cycle (or rainout stage), a different and younger cloud target within the same cloud field was selected. This can be distinguished from a change in the altitude of the aircraft within a relatively small radius from the previous location. We also checked the video from the flights to confirm that.

Line 603 states the coldest observed temperature was -12 C in all four flights. Is this the coldest temperature because it was near cloud top, or was there another sampling reason? How close was sampling performed to cloud top?

The CPs at -12°C in those flights are close to the coldest CP observed by the aircraft. Satellite imagery shows colder temperatures, but those colder clouds were not penetrated because they usually transitioned to a mature life cycle stage. As mentioned above, the aircraft typically targets the clouds at the early- to mid-life cycle stage.

All of the utilized cloud passes should be better qualified to improve usefulness and applicability of the analysis, and perhaps the analysis revised to include only cloud passes of comparable nature (it is currently unclear if they are comparable or not from the lack of context for the chosen cloud passes).

These clouds are comparable because the aircraft videos confirm that they are within the same cloud field and sampled by the aircraft in their early- to mid-life cycle stage. In addition, the radar reflectivity of those CPs confirms that those CPs are relatively young. We will include a few snapshots from the aircraft videos and a description of the cloud lifetime to clarify the cloud environment in the revised manuscript.

Minor Comments:

Figure 10. and 11. are cramped and very difficult to read

We agree with the observation regarding Figures 10 and 11. To improve readability, we will revise these figures by increasing the spacing and font size and reorganizing the layout to ensure all elements are clear and easy to interpret. We will include the updated figures in our revised manuscript.

Figure 12. The font of the x-axis needs to be bigger to be able to read the times.

We will revise the figure to increase the font size of the x-axis in our revised manuscript.

Figure 12. Black text on purple background is nearly illegible.

We will change the colors to improve the readability of this figure in our revised manuscript.

Figure 14. For clarity, would suggest numbering the zones in the figure.

We will add the numbers of the zones in the revised Figure 14.

Lines 692-695. For clarity of discussion, would suggest using zone microphysical names rather than numbers here.

We will add the microphysical names of the zones in the discussion section.