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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Linkage among Ice Crystal Microphysics, Mesoscale Dynamics and Cloud and Precipitation Structures Revealed by Collocated Microwave Radiometer and Multi-frequency Radar Observations" *by* Jie Gong et al.

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Unfortunately, I believe the writing quality for this article falls below the level necessary for publication. Grammatical errors are frequent (e.g. "collocation cases... are averaged separately considering they locate in different weather regimes at L228), articles/prepositions are often missing or used inappropriately, and word choices are often inappropriate, both in the sense of conventional English (e.g., "the biggest blob

of power" at L304) and in terms of formal writing (e.g., "more and more" throughout). Occasionally, it was enough of an issue that I found it difficult to understand the author's message. Please make sure that this paper is proofread more carefully before the next submission, with specific attention to formal word choices.

We highly appreciate Reviewer 3's in-depth review and constructive suggestions. The English/grammar errors pointed by this and other reviewers have been corrected. The revised draft has been carefully proofread by the 4th author, who is a native speaker. The missing colorbars have now been added back. Below are point-by-point responses (questions in black, and responses in blue).

Specific comments are below:

L40: It would be nice to have more detail here. I have never heard of Cloud Radiative Effect before, and I would like to know which microphysical properties you are referring to.

There was a brief summary of some of the highly related papers discussing about cloud microphysical property impacts on cloud radiative effect in one of our previous papers [Gong et al., 2017 in the reference list, first paragraph in the introduction section]. Some of the sentences are quoted here: "They are a major modulator of Earth's radiation and thus play an important role in weather and climate changes (e.g., Hartmann et al., 1984; Raymond Zeng, 2000; Waliser et al., 2009). Studies have shown that the cloud radiative effect (CRE) of the clouds strongly depends on physical details, such as cloud top height (Kiehl et al., 1994), thickness (Hartmann Berry, 2017; Hong et al., 2016), overlaying situation (Hartmann et al., 2001), and microphysical properties (Liou et al., 2002; Tang et al., 2017; Zeng et al., 2009a, 2009b). Fu and Liou (1993), for example, showed that the radiative heating rate for a layer of ice cloud with a fixed ice water path could differ by a factor of 10 when the mean effective radius of the ice particles varies by a factor of 5. Reducing the uncertainty of CRE requires a better understanding of ice cloud microphysical properties, which is essential not only to remote sensing of the bulk optical properties but also to the simulation of CRE (Tang et al., 2017). "

L17/87: PD is defined in two different ways (Polarimetric radiance Difference, Polarimetric Difference). I would suggest unifying these.

Sorry for the confusion and thanks for point that out. We now clarified in the revised manuscript that "polarimetric difference" is an abbreviation of "polarimetric radiance difference".

L163: Has the collocated GMI, DPR, and CPR dataset been used by "many" other researchers for published articles? Yin et al. (2017) was the only one I was familiar with before reading this paper.

We also added another two references: Gong et al., 2017; Zeng et al., 2019. Also, "many" has been changed to "some". This is a really nice dataset that tremendously reduced the amount of work for us. The version I used did not include the ECMWF-AUX, but the latest version contained all collocated CloudSat and GPM Level 2 data products as well.

L193: ". Compared with "high-PD" scenario, the "low-PD" one apparently has more high clouds that are thinner than those from deep convective scenes as the reflectivity magnitudes are smaller". Unsure of what you mean by "more high clouds that are thinner". According to the CloudSat CFAD, the distribution of reflectivities for clouds above 13 km appear to extend larger at low PD than high PD, so I feel like that would make the high clouds at low-PD thicker?

Apologize for not being very clear here. What we meant was clouds at 15 km for comparison, which are mostly cirri. These cirri are thicker (higher reflecitivities, likely from reminiscent from deep convective core or anvils) in the "deep convective" scenario than those in the "low-PD" scenario (reminiscent or in-situ formation). But now after rereading the sentences, we found such a different feature was not quite relevant to PD signals as neither GMI nor DPR could "see" cirrus cloud. So this sentence has

been removed in the revised paper.

L203: I don't understand how a mean could be "PDF-weighted". Consider rewording?

Sorry we didn't realize that "PDF-weighted mean" was not a mathematically predefined term. Now it's changed to "weighted-mean".

L203-L218: I don't agree with the interpretations of reflectivity used throughout this paragraph, and I would prefer if the authors would be more objective. Reflectivity is used to describe the "thickness" of clouds and the "presence" of clouds in the same sentence, even though these two traits are not directly comparable. Later it is used to describe the number of precipitation sized particles (less/more), even though reflectivity can also be indicative of precipitation particle size. I would prefer if the figures are discussed more literally in this section, just explaining which PD scenarios have larger average reflectivity at different altitudes, and then save the interpretation of reflectivities for the following paragraph.

We agree with the reviewer that we put too many assertions in this paragraph which require many assumptions. In general, a single frequency radar reflectivity can only directly tell us about the mass at a given level, while larger mass could be associated with more particles, or larger particles (change of PSD), or denser particles (change of density). Here are the changes that have been made now in the revision:

Change "lesser present" to "thinner", and change "more and more thick" to "thicker". Here thinner and thicker correspond to the mass change according the weighted mean of reflectivity from different scenarios.

Change "suggesting" to "which might implicate", and change "indicates" to "might indicate", so the tone is weaken. This is our "hypothesis" that will be further elaborated using three frequency radar signals together, so we feel it necessary to raise up the idea step by step rather than just abruptly bringing it up after presenting all evidences.

Figure 3: I do not see any novel information provided by Ka band reflectivity in Figure

3b, so I think it could be removed.

We feel it's still worthwhile to keep Fig. 3b here, because our interpretation of GMI PD signals are mostly based on the triple-frequency radar reflectivity similarities and differences. The fact that Fig. 3b looks very similar to 3c but they both are quite different from Fig 3a indicate that 166 GHz PD signals are dominated by precipitation-sized particles, not cloud-sized particles.

On a similar note, Ka band reflectivity can be used to construct a Ku/Ka DWR. DWR can be used to provide information on ice particle size without being influenced by particle concentration, unlike the Z measurements used throughout the study. Comparison between DWR and Ku may also provide information on ice particle concentration. Considering the frequent discussion on ice particle aggregation, I think it could be valuable and relatively straightforward, to make figures similar to Figure 2 and 3 (and potentially Figure 8) with DPR-measured DWR. Keep in mind that DWR may also be influenced by liquid water attenuation, so a DWR profile should be interpreted with caution. This is more of a suggestion than a perceived requirement for publication, however.

As shown in Fig. 6 and Fig. 7c and 7d, DWR is not only a function of particle size, but also impacted a lot by density and multiple-scattering (also discussed in Battaglia et al., 2015), as well as liquid water attenuation as you mentioned here. Since Fig. 2 and 3 are in Section 3 that was intended for quantitative presentation of observations rather than discussions in Section 4, we think presenting Z instead of DWR will be more straightforward. Nevertheless, Fig.1 below is $DWR_{Ku/Ka}$ for Fig. 3. One can see the red line is consistently smaller than the other three lines above the melting level.

Battaglia, A., S. Tanelli, K. Mroz, and F. Tridon (2015), Multiple scattering in observations of the GPM dual-frequency precipitation radar: Evidence and impact on retrievals, doi:10.1002/2014JD022866.

Figure 6: I am having difficulty understanding this figure well enough to determine whether I agree with your interpretation. The combination of filled and unfilled contours

worked in Figure 2, but only because the zones of reflectivity were mostly separate. I think this figure would work better if both high PD and low PD were line contour plots of different colors, and regardless of whether that suggestion works, I would appreciate if this figure could be replotted to be more decipherable.

Now the colorbars have been added with rainbow color contours for "high-PD" and hue filled colors for "low-PD" scenarios. Hopefully now the contrasts between the two scenarios are clearer to see. Thanks for your suggestion.

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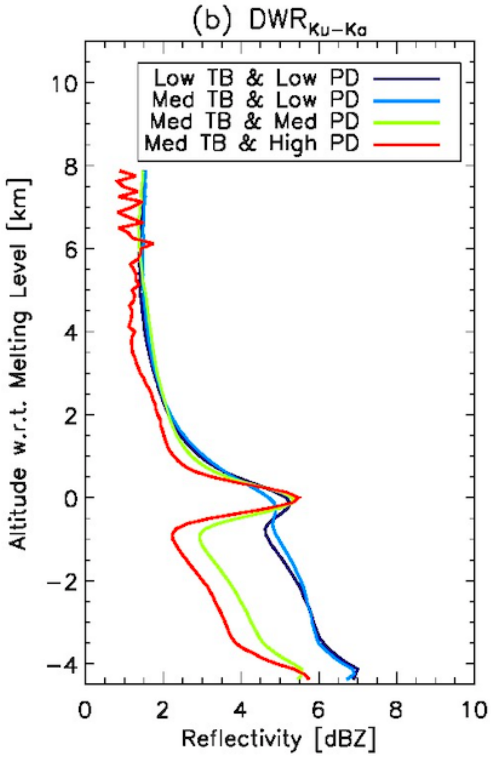
(b) DWR$_{Ku-Ka}$
Low TB & Low PD
Med TB & Low PD
Med TB & Med PD
Med TB & High PD
Altitude w.r.t. Melting Level [km]
10
8
6
4
2
0
−2
−4
0
2
4
6
8
10
Reflectivity [dBZ]

Fig. 1.