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Interactive comment on "Illustration of microphysical processes in Amazonian deep convective clouds in the Gamma phase space: Introduction and potential applications" *by* Micael A. Cecchini et al.

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Major comments:

1. (Comment) This paper describes an attempt by the authors to use gamma function fitted using cloud macro- and microphysical observations to analyze microphysical growing path and particle size distribution evolution within deep convective clouds. The data used in this study are from ACRIDICON-CHUVA field campaign over Amazon, primarily six flights focusing on cloud microphysics measurements over regions with

different aerosol background profiles. The findings of cloud properties under different environments appear to be very interesting. However, the method in using gamma function to interpret cloud microphysical growing path contains serious issues.

1. (Answer) We would like to thank Anonymous Referee #1 for the invaluable comments. Please find in this document the detailed answers to your concerns.

2. (Comment) The description of the closure of gamma function was firstly given by Eq. (2) - (4), where the closure variables were the zeroth, second, and third moment. The three undetermined parameters of gamma function would be defined by these moments. However, the actual closure variables, as described in Eq. (6) – (8) are liquid water content, cloud droplet number concentration, and effective droplet diameter. The former two were equivalent to the third and zeroth moment, respectively, while the effective droplet diameter was mostly equivalent to the first moment. To the least, these two descriptions are redundant. In fact, in many places of the paper including the Concluding remarks, the authors were still referred to the second moment. Indeed, the procedure of fitting gamma function with observations was never clearly described.

2. (Answer) The third paragraph and Equations (2) – (4) explain the methodology adopted to obtain the Gamma parameters. It is a relatively simple process and the method of moments has been extensively studied in the literature. From the Gamma parameters obtained with this methodology, we are able to calculate any DSD property of interest - note that the Gamma parameters fully define the respective Gamma DSD. In this study, we were interested in analyzing (among other things) the parameters given in Equations (6) – (9). Those are not closure parameters to obtain the Gamma DSD, instead are properties we obtain from them. Because we use moments of order 0, 2, and 3, Nd, LWC, and Deff obtained from the Gamma parameters will exactly match the observations. The relative dispersion, on the other hand, have dependency on the first moments and will be slightly different. However, as explained in the text after Equations (6) – (9), this parameters is still well represented by the Gamma fit used here.

3. (Comment) The most serious flaw of the proposed method exists in the procedure to interpret microphysics in the phase space of size distribution function. For a given air parcel, the ternary group of closure variables (mostly moments in different order) and undetermined parameters are bonded by mass conservation applied to the prognostic procedure of the former group, this defines the unique solution of both groups through the evolution of the air parcel, and they change accordingly due to the variations of the closure variables induced by dynamical and microphysical processes. Note also that the closure variables must be conservative ones with well-defined sink and source besides advection and mixing terms. When fitting gamma function with multiple observations, however, one should realize that these observations are multiple snapshots likely represent different air mass origin either unmixed or mixed, therefore, they mostly reflect different ternary groups of the closure variables and hence their paths in the phase space are irrelevant microphysically speaking unless a strong isentropic assumption (at least for any given horizontal plane) is made. This is why even in analyzing Eulerian modeling results, modelers usually derive microphysical and size distribution evolution within a parcel framework (can be conveniently derived from Eulerian grid parameters though), e.g., the “Twomey model”. Only within such a framework does the analysis of size distribution evolution become meaningful.

3. (Answer) We understand your concern because we are not strictly using a Lagrangian measurement setup (which is not possible using airplanes). As there is no way to follow specific air parcels with aircraft measurements, we had to steer our analysis to get as close as possible to the cloud evolution. Firstly, the flight patterns were specifically chosen as to measure growing convective clouds at their tops. Therefore, in each vertical step of the aircraft, we probed clouds that were “older” than the clouds probed on the last step (vertical steps were in ascending order). Additionally, the Gamma phase-space trajectories are only calculated for w > 0 m s-1, making sure we only capture the growing part of the convective elements. The flight strategy is now clarified in Section 2.1, where we added the following sentence (second paragraph): “The latter step was deployed as follows. After the cloud base penetration, the aircraft

performed several penetrations in vertical steps of several hundred meters. In each step, the aircraft penetrated the cloud tops available, thus avoiding precipitation from above. In this way, different clouds can be penetrated in the same altitude level and the vertical steps followed the growing cumuli field overall". This procedure was performed to allow interpreting the data (only w>0) as quasi-Lagrangian trajectories of the cloud parcels.

We also performed simple calculations with the help of a Lagrangian parcel model. For details of the runs, please refer to our answers to Anonymous Referee #2 (item 2). Overall, the model calculations show that the condensation and collision-coalescence pseudo-forces act in similar directions to what we show in Figure 3. Therefore, we not only provide further justifications for Figure 3, but also show that the trajectories in Figures 5-8 can also be explained by the physical processes in the Lagrangian model. Of course, the Lagrangian model we chose is relatively simple given that it does not consider advection or turbulent mixing. On the other hand, it is capable of isolating the effects of condensation and collision-coalescence growth on the DSDs (bin microphysics) and, therefore, on the trajectories in the Gamma phase-space. The fact that we observed similarities between the Lagrangian trajectories and the observed ones is a strong argument in favor of our approach.

4. (Comment) By the way, many comments made by the authors are not accurate. For example, in the Abstract, the opening statement seems attempting to link our lack of understanding of the "tropical clouds" solely to the model representation issue of certain physical processes. The statement of "there is almost no study dedicated to understanding the phase space of this function…" is not accurate too. The properties of Gamma function along with many other probability distributions have been well studied and documented in statistics and applied mathematics literature. In the cloud physics and modeling field, the evolution of conservative moments (mostly in the format of LWC, number concentration, and spectral disperse) have never been a rare topic in various mostly modeling studies.

The observations are invaluable for further our understanding of cloud physics and for evaluating models. Applying derivatives of these data, however, warrens special cautiousness.

4. (Answer) Yes, we agree that the phrasing regarding tropical clouds and their representation in models was not appropriate. The intended meaning is that, because of our lack of knowledge of tropical clouds, we still can't reproduce them adequately in models. We changed the first sentence in the Abstract to be: “The behavior of tropical clouds remains a major open scientific question, resulting in poor representation by models”.

We also updated the Gamma function reference in the Abstract to: “However, even though the statistical characteristics of the Gamma parameters have been widely studied, there is almost no study dedicated to understanding the phase space of this function and the associated physics. This phase space can be defined by the three parameters that define the DSD intercept, shape, and curvature. . .”.

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