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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Observations and modelling of microphysical variability, aggregation and sedimentation in tropical storm cirrus outflow regions" *by* M. W. Gallagher et al.

Anonymous Referee #1

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Review of ACPD manuscript titled "Observations and modeling of microphysical variability, aggregation and sedimentation in tropical storm cirrus outflow regions" by Gallagher et al.

Overall recommendation:

The authors show detailed microphysical data from tropical convective anvils acquired during ACTIVE. Differences in cloud microphysical properties as a function of distance from convective core are shown. By comparing observations with numerical simulations, a discrepancy between the aggregation efficiency obtained from observations and from models is addressed. This type of study is important because it acts as a

bridge between observations and models. However, there are several problems and weaknesses in the methodology used by the authors as shown below.

Major comments 1. Particle size distributions. See specific comments 1 and 18. i. Did the authors correct the PSDs measured by the CIP for shattering? ii. What is contribution of the small ice crystals to the total IWC? Can it be ignored? What are the errors in the parameterized PSDs due to these small ice crystals? iii. Why did the authors exclude measurements from the CDP when calculating the PSDs? iv. Why didn't the authors use the calibrated CPI PSDs to represent the small ice crystals (e.g., D < 100 um)?

2. m-D relationship. See specific comment 13. Is the m-D relationship used in this study applicable to the ACTIVE data? Since this study does not conduct a closure study with bulk measurements of mass content, what are the errors in calculated mass and how are they estimated?

3. Ice crystal habit. See specific comments 14, 22, and 24. Through the manuscript quantitative information about ice crystal habit is required.

4. Please show more parameters in the distance downwind plot. See specific comment 20 and 21. To show how aggregation and sedimentation vary with distance from the storm, additional parameters should be shown. For example, it is necessary to show an intercept parameter (no) because it is mentioned several times. Total number concentration, N, median mass dimension, and mean maximum dimension are also necessary to determine the importance of aggregation and sedimentation. Further, the ratio N of aggregate concentration to N of single ice crystals as function of distance from storm core is highly recommended.

5. Model results. See specific comment 32 and 34. It is hard to tell that E=0.02 provides the best agreement with the observed data based on the evidence shown in this study. E=0.02 shows good agreement with observations made within 30 km from the storm core, but shows disagreement for observations beyond 30 km. Further, there

is a large disagreement between the IWC predicted by the model with E=0.02 and the observation even inside 30 km. The authors suggest several possibilities to explain the disagreement between model runs and observations. Sensitivity tests with changing conditions, as the authors mentioned in the manuscript, are highly recommended.

6. Check all references and citation format carefully. Lots of references are missing or wrong. For example, all references on page 23777 are missing, so I could not get any background information for modeling material.

Specific comments 1. Page 23763, line 11-13 Please add reference for this sentence.

2. Page 23764, line 25 Sice < 1

3. Page 23765, line 27 Tropical Warm Pool-Ice Characterisation Experiment -> Tropical Warm Pool International Cloud Experiment

4. Page 23767, line 2 Please define ACTIVE

5. Page 23767, line 20 Please define ARA

6. Page 23768, line 12 Fig. 2c -> Fig. 2b

7. Page 23768, line 13 I think this feature is highlighted in Fig. 2c also highlighted -> also highlighted in Fig. 2c

8. Page 23768, line 22 Cloud Particle Imaging -> Cloud Particle Imager

9. Page 23769, line 7 depth of focus -> depth of field

10. Page 23769, line 23 we us -> we use

11. Page 23769, line 23-24 Did the authors correct the CIP PSDs? There are several well-known problems with CIP measurements, especially for D < 100 um, such as the presence of out of focus donut particles and shattered particles.

12. Pages 23790 and 23791 (Figs. 3 and 4) Figure captions of Figs. 3 and 4 need to be revised. What are (a) and (b) in Fig. 3? According to Figs. 3 and 4, (a) and (b)

indicate Fig. 3 and 4, respectively. What is the difference between L and Dp? Is it 1600 um instead of 1800 um? In this study, the microphysical properties of AE13 (9 Dec. 2005) are discussed, but PSDs of AE27 (10 Feb. 2006) are shown in Fig. 3 and 4. To be consistent PSDs obtained during AE13 should be shown.

13. Page 23770, line 5 This m-D relationship from Heymsfield et al. (2004) is limited to analysis of particles with median mass diameters smaller than 200 um or lambda > 150 cm-1. According to Figs. 5 and 6, it seems that some of the derived slope parameters are out of range to apply this m-D relationship. Since there is ambiguity in Figs. 5 and 6, a clearer explanation of the applicability of the m-D relationship should be made. This m-D relationship was derived using data obtained during CRYSTAL-FACE. Can a closure study be applied to derive the m-D relationship for the ACTIVE data? Alternative, a simple suggestion would be to test the similarity of ice crystal habits observed during CRYSTAL-FACE and ACTIVE since m-D relationship is strong function of ice crystal habit.

14. Page 23770, line 16 and throughout the manuscript A habit comparison with other field campaigns for convective system (e.g., EMERALD-II (Connolly et al. 2005, QJRMS) and TWP-ICE (Um and McFarquhar 2009, QJRMS)) would be useful for this study. Is there any difference or similarity between campaigns?

15. Page 23770, line 18 Since an exponential distribution is also used to represent PSD, “gamma distribution” would be better than “exponential model distribution”. Eq. (1) is a gamma distribution.

16. Page 23771, line 17 What is “mis-sizing”?

17. Page 23771, line 23-24 Please add a corresponding reference

18. Page 23772, line 6-9 Is it possible that the con of ice contributions of ice crystals smaller than 50 um are large enough not to be ignored? Can the authors calculate the contributions of ice crystals smaller than the CIP measurement range during ACTIVE?

19. Page 23773, line 15-16 Figures 5 and 6 are same.

20. Page 23773, line 17-21 Need more evidence. There is not enough evidence that the general decrease in IWC and slope parameter is caused by aggregation and sedimentation. Effect of evaporation due to entrainment of environmental air might be another possibility. Evaporation would become stronger with distance from convective core. Thus, small ice crystals evaporate quickly and large ice crystals become larger. It is recommend to calculate the ratio between Nsingle_particle / Naggregates to see the aggregation effect.

21. Page 23774, line 5-20 When the overall ice crystal size spectrum is explained with a slope parameter, an intercept parameter (no) should be addressed to test the ontributions of small ice crystals. However, since PSDs are parameterized with the CIP PSD in this study, the small ice crystals not detected by the CIP could cause errors. Thus, it is recommended to test the contributions of missing small ice crystals on IWC.

22. Page 23774, line 9-10 and Section 5.1 habit variation The authors show some habit information, but the information is not statistically significant. Quantitative information, such as fractional contributions of different habits to the total number or total area should be shown. Based on these numbers, dominant habit can be determined.

23. Page 23775, line 11 Where is the ice crystal size distribution? Fig. 8 shows images of ice crystals. The intercept parameter is necessary to interpret Fig. 8.

24. Page 23775, line 21-27 This comparison tends to be subjective unless quantitative information is shown. What is the fraction of aggregates of hexagonal plates and bullet rosettes during ACTIVE and EMERALD-1? Please show habit fraction information.

25. Page 23777, Eq. (3) What do x and y stand for?

26. Page 23777, line 16 Please define CFD

27. Page 23778, line 25 What is the contribution of small ice crystals that the CIP cannot capture?

28. Page 23779, line 4, size distribution equation Is it the same as Eq. (1) shown before? If this is not the case, please use different symbols for no and lambda0 to be distinct from the gamma distribution, i.e., Eq. (1). Do authors use both exponential and gamma distribution in this study?

29. Page 23780, line 6-7 Is this mass-velocity relation for a particular habit or is it habit independent?

30. Page 23780, line 10 Is it an exponential distribution or gamma distribution?

31. Page 23780, line 22 ice mixing ratio -> IWC

32. Page 23780, line 27-28 There is not enough evidence here. It is highly recommended to do several more runs with different sedimentation assumptions as the authors stated.

33. Page 23781, line 5 ice-mixing ratio -> IWC

34. Page 23781, Section 7. Discussion It is hard to tell that E=0.02 provides the best agreement with the observed data based on the evidence shown here. E=0.02 shows good agreement with the data within 30 km from the storm core, but shows disagreement beyond 30 km. Further, there is a large disagreement between the IWC predicted by the model with E=0.02 and the observations made even inside 30 km. The authors suggest several possibilities to explain this disagreement. It is highly recommended that some sensitivity studies changing initial conditions and fall speeds of small ice crystals be conducted as mentioned in the manuscript.

35. Page 23781, line 12 initalisation -> initialisation

36. Comparing Fig. 11 and 13, it seems that the inclusion of sedimentation in the model shows a worse result in terms of slope parameter. Is it true and why?

37. Page 23798, Fig. 11 (a) Please show IWC predicted by the model as a function of E as shown in Fig. 13 (a)

Interactive comment on Atmos. Chem. Phys. Discuss., 11, 23761, 2011.