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Interactive comment on "Comparing calculated microphysical properties of tropical convective clouds at cloud base with measurements during the ACRIDICON-CHUVA campaign" *by* Ramon Campos Braga et al.

Ramon Campos Braga et al.

ramonbraga87@gmail.com

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Review of "comparing calculated cloud microphysical properties of tropical convective clouds at cloud base with measurements during the ACRIDICON-CHUVA campaign" by Ramon Campos Braga et al.

Anonymous Referee #1

Braga et al., use airborne measurements aboard HALO from a CCP, CAS-DPOL and CCN counter to derive cloud drop size distributions (DSDs) and cloud water content from various instruments via an inter–comparison. In this study parameterizations for

liquid cloud formation in tropical convection are validated, but for instance comparing the directly measured cloud drop concentrations (Nd) near cloud base to inferred values that are derived by combining the cloud base updraft velocity, CCN vs SS (supersaturation) spectra. In addition, Nd from cloud base was also compared to drop concentrations (Na) derived by assuming adiabatic expansion for vertical evolution of cloud drop effective radius above cloud base. Overall, this paper presents a good summary but it lacks a significant scientific finding or discovery. Rather it is verifying previous formulated parameterizations, which is valuable. However, the authors could do a better job of comparing the differences they observe between the parameterizations validated here with previous studies. Perhaps the paper can be re-worked to demonstrate the novelty of the work, which is lacking in the current version of the manuscript. Specific comments below should help achieve this. After such revisions have been made, the paper maybe considered for publication. There are small editorial issues and some grammatical errors throughout the manuscript, of which I have pointed out a few, but will leave it to the authors to check that more carefully upon submission of the revised version.

General comments

The authors thank the referee for the general comments and advices. Furthermore, the advices of the referee are highly appreciated as well as the very valuable and constructive suggestions to increase the quality of the manuscript. We tried to address the points requested by the reviewer to the paper be considered for publication. Overall, we have improved the focus of the paper highlighting our objectives and the novelty of our study.

The answers for specific comments are available after "A:" for each specific line.

Specific comments:

Line 29: Why not introduce CWC here like all the other acronyms in the abstract?

A: OK. Changed.

Line 46: “pursue” replace this word with something more suitable like “cloud microphysical models “aim” to reproduce or “The goal of cloud microphysical models is to reproduce. . ..”

A: OK. Changed.

Line 137 “account” should be “accounted”

A: OK. Changed.

The discussion in line 132 to 137 can be expanded upon to make the paper more scientifically novel. State in more detail what was unique about these measurements, are the convective clouds here unique? Related to this but later in the paper, are the results obtained here the same as other convective regions in the world? Could the authors comment or discuss this? If indeed this is the case, that the results are similar to other locations of convection globally, the authors may consider discussing this point and stressing this aspect.

A: The text was changed to address these comments. Thanks.

New text:

“The availability of these measurements collected by the same aircraft provides a unique opportunity to compare the data with model predictions and to test the sensitivity of the results to the differences between the measurements by the cloud probes.

This study is novel in several aspects:

It is the first study that validates the methodology of retrieving the adiabatic cloud drop concentrations Na (Freud et al., 2011) from the vertical evolution of re while assuming that re is nearly adiabatic. This is important because it supports the validity of retrieving Na from satellite-retrieved vertical profile of re (Rosenfeld et al., 2014a and 2016).

It is the first study that tests with aircraft the measured Nd with its parameterization that is based on NCCN(S) along with cloud base spectrum of updrafts weighted by the updraft speed itself, Wb*. It is done this way to be compatible with the recently developed methodology of retrieving CCN from satellites by means of retrieving Nd and Wb* (Rosenfeld et al., 2016).

It is the first study that compares observationally the old Twomey (1959) parameterization of the dependence of Nd on Wb (Eq. 2) versus the recent Pinsky et al. (2012) analytical expression for the same (Eq. 3).”

References:

Freud, E., Rosenfeld, D. and Kulkarni, J. R.: Resolving both entrainment-mixing and number of activated CCN in deep convective clouds, Atmos. Chem. Phys., 11(24), 12887–12900, doi:10.5194/acp-11-12887-2011, 2011.

Pinsky, M., Khain, A., Mazin, I. and Korolev, A.: Analytical estimation of droplet concentration at cloud base, J. Geophys. Res. Atmos., 117(17), 1–14, doi:10.1029/2012JD017753, 2012.

Rosenfeld, D., Fischman, B., Zheng, Y., Goren, T. and Giguzin, D.: Combined satellite and radar retrievals of drop concentration and CCN at convective cloud base, Geophys. Res. Lett., 41(9), 3259–3265, doi:10.1002/2014GL059453, 2014a.

Rosenfeld D., Y. Zheng, E. Hashimshoni, M. L. Pöhlker, A. Jefferson, C. Pöhlker, X. Yu, Y. Zhu, G. Liu, Z. Yue, B. Fischman, Z. Li, D. Giguzin, T. Goren, P. Artaxoi, H. M. J. Barbosai, U. Pöschl, and Meinrat O. Andreae, 2016: Satellite retrieval of cloud condensation nuclei concentrations by using clouds as CCN chambers. Proceedings of the National Academy of Sciences, doi:10.1073/pnas.1514044113.

Twomey, S.: The nuclei of natural cloud formation part II: the supersaturation in natural clouds and the variation of cloud droplet concentration, Geofis. Pura e Appl., 43(1), 243–249, doi:10.1007/BF01993560, 1959.

Line 149: should read “Manaus City” not “Manaus city”

A: OK. Changed.

Line 193-194: Delete “was used additionally considering” and Line 194: add “was considered” after 10%. In total the sentence should read “For the CDP sample area of 0.22 mm2, an uncertainty of about 10% was considered (Molleker et al., 2014).”

A: OK. Changed.

Line 205: Delete extra periods

A: OK. Changed.

Line 267: “maximal” should be “maximum”

A: OK. Changed.

Line 269: should “probes” have an apostrophe after it i.e. probes’? it sounds like it is being used in the possessive.

A: OK. Changed.

Line 297: Why these specific flights being used (AC08 and AC20) for the CWC, why not data from the entire campaign? Also, why not use the same flights as were used in the effective radius comparison (line 278)?

A: The sentence is wrong. We used all flights, except AC07 which we have not hot-wire data. We have corrected the sentence.

New text: "The mean values of CWC estimated from the probes from flights AC08 to AC20 (AC07 had no hot-wire CWC data) and altitudes between 600 m and 5,000 m generally show an increase with increasing re."

Line 309-314: Why compare only with one hot wire probe when three of them were on board the aircraft?

A: There was only one hotwire operational aboard HALO. This one was mounted on the CAS-DPOL. Some DMT instruments are delivered with hot-wires. The CCP was indeed equipped with the hot-wire as well, but we do not operate it during flight as then the CCP’s overall power consumption would exceed the limits. It was physically disconnected and no part of CCP anymore.

Line 319: insert “the” before “hot-wire”

A: OK. Changed.

Line 320: Can you make it clearer that this is a decreasing number concentration with increasing effective radius

A: OK. Changed.

Line 322: insert “the” ahead of “CAS-DPOL” in general the grammar is really poor from lines 320-325, please rectify

A: The text was rewritten.

Line 326-333: Why not consider using only particles less than 40 microns in your CWC comparison?

A: The amount of CWC above 40 μm is negligible. However, it illustrates the difference in the shapes of the DSDs.

Line 406: replace “greater than or equal” with the symbol “$\geq$”

A: OK. Changed.

Line 471-479: Are these values presented here similar to literature values from other locations in the world? Can there be a comparison and discussion of this?

A: Ok. We added a new text:

“For some flights the values estimated for N0 and k parameters of Eq. 1 are similar to what was found by Pöhlker et al., (2016) for ground measurements (N0 = 1469 $\pm$ 78 and k = 0.36 ± 0.06) during the dry season in the Amazon. However, in the majority of the cases N0 and k are twice or three times greater than the values from Pöhlker et al., (2016). These differences are probably related to flying selectively to areas that had high aerosol concentrations to contrast the cloud behavior with the flights with low aerosol concentrations, as shown in Fig. 2. The high CCN measured in this study is more similar to previous aircraft measurements in smoky conditions over the Amazon (Andreae et al., 2004; Freud et al., 2008)."

References

Andreae, M. O., Rosenfeld, D., Artaxo, P., Costa, A. A., Frank, G. P., Longo, K. M. and Silva-Dias, M. A. F.: Smoking rain clouds over the Amazon, Science, 303(5662), 1337–42, doi:10.1126/science.1092779, 2004.

Freud, E., Rosenfeld, D., Andreae, M. O., Costa, A. A. and Artaxo, P.: Robust relations between CCN and the vertical evolution of cloud drop size distribution in deep convective clouds, Atmos. Chem. Phys., 8(6), 1661–1675, doi:10.5194/acp-8-1661-2008, 2008.

Pöhlker, M.L., Pöhlker, C., Ditas, F., Klimach, T., Hrabe de Angelis, I., Araújo, A., Brito, J., Carbone, S., Cheng, Y., Chi, X. and Ditz, R., 2016. Long-term observations of cloud condensation nuclei in the Amazon rain forest–Part 1: Aerosol size distribution, hygroscopicity, and new model parametrizations for CCN prediction. Atmospheric Chemistry and Physics, 16(24), pp.15709-15740.

Line 520: Figure 14a shows the LWC? The Na that is stated in Figure 14a is also mentioned here in Line 523, not sure why the reference to Figure 14a is needed here.

A: Yes, LWC for adiabatic fraction > 0.25. A: Ok.

Line 530-534: The scaling of 1.3 works quite well, perhaps mention it here since this is a new data set.

A: Ok. Thanks.

Line 558: Here the authors should make a case for why their work was novel, interesting or what is new about their work.

A: The conclusions now clearly show the novel aspects of this study.

New text:"This study is focused on testing novel parameterizations that are used for the recently developed methodology of satellite retrievals of Na, Wb*, and CCN in convective clouds, based on aircraft measurements during the ACRIDICON-CHUVA campaign in the Amazon. It is the first time that these new parameterizations are tested com-prehensively alongside old parameterizations. Liquid water content measurements from a hot-wire device were taken as a reference for the quality assessment of estimated CWC from cloud probe DSDs near cloud base. The intercomparison of the DSDs and the CWC derived from the different instruments generally shows good agreement within the instrumental uncertainties. The values of Nd near cloud base were comparable within the measurement errors with their inferred values based on the measured Wb* and NCCN(S). The values of Wb* were calculated from the measured spectrum of W* using the parameterization of Rosenfeld et al. (2014a), which is also used for retrieving cloud base updraft from satellites (Zheng et al., 2015). In addition, Nd near cloud base was favorably (within ±20%) compared with Na, obtained from the vertical evolution of cloud drop effective radius (re) above cloud base. The values of Na in this study were obtained with the same parameterization that has been recently developed for satellite calculated Na based on the satellite retrieved vertical evolution of re in convective clouds (Freud et al., 2011; Rosenfeld et al., 2014a). These results support the methodology to derive Na based on the rate of re growth with cloud depth and under the assumption that the entrainment and mixing of air into convective clouds is extremely inhomogeneous.

The measured effective droplet numbers (Nd*) at cloud base were also compared against NdT* which is its predicted value based on the old parameterization in Eq. 2 (Twomey, 1959), which uses Wb* and the NCCN(S) power law. A newer parameterization calculates NdCCN* by substituting S into the power law NCCN(S), where S is obtained from Eq. 3 (Pinsky et al., 2012). The agreement between Nd* and Nd-CCN* was only within a factor of 2, underlying the yet unresolved challenge of aircraft measurements of S in clouds.

In summary, the measurements of NCCN(S) and Wb did reproduce the observed Nd. when using Twomey's parameteri-zation, while using measured in cloud S remains a challenge. Furthermore, the vertical evolution of re with height reproduced the observation-based adiabatic cloud base drop concentrations, Na. The combination of these results provide aircraft observational support for the various components of the satellite retrieval methodology that was recently developed to retrieve NCCN(S) below the base of convective clouds (Rosenfeld et al., 2016). This parameter-ization can now be applied more confidently and with the proper qualifications to cloud simulations and satellite retrievals."

Line 570-574: Was there any doubt about the validity of the parameterization prior to this study? What is new about the work here other than the fact that the measurements were all taken during this campaign on one/the same aircraft?

A: Most of the tested parameterizations are new, and it is the first time that they are tested comprehensively alongside old parameterizations.

Figures Fig 4: Consider editing the plot so that the legend matches the sub=plot where the quantities are shown

Fig 4 (lower left panel for CWC): Why is it necessary to have a log scale? The data just cover one order of magnitude and are all squeezed to the bottom half of the panel. There is no need for the scale to extend to 10. And no need for a log scale either. This artificially downplays some of the differences between the probes.

A: We changed the Figure 4 as you suggest. It is available at supplementary material.

Fig 6a and 6b: is it necessary to have zeros in front of the micron sizes, i.e. 05 instead of 5. Also, can both scales be made linear for consistency and clarity? It is hard to

compare presented in the manner here. A: The others referees also have requested some changes in figures 6. We have changed the figures 6 and captions to address the suggestions. Following these suggestions we have changed the DSDs figures using histograms of binned detection channels. The data points are shown with size bin limits in x-direction (to cover the Mie-ambiguity ranges, providing an approach to have the channel-wise sizing error superimposed by the size-bin limits) and uncertainty in y-direction. We also eliminate the zeros in front of micron sizes. New figures 6 are available at supplementary material.

Line 1134: Italicize “m” A: Ok. Thanks.

Fig 12 (all panels): Shouldn't Nd be in red? A: Yes. Thanks.

Fig 13 (line 1190): reference to Fig 7-8 is not consistent with text, should be Figure 11 and 12 A: Yes. Thanks.

Please also note the supplement to this comment:
http://www.atmos-chem-phys-discuss.net/acp-2016-872/acp-2016-872-AC1-supplement.pdf

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