Atmospheric
Measurement
Techniques

**Discussions**

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# Interactive comment on "Determination of Ice Water Content (IWC) in tropical convective clouds from X-band dual-polarization airborne radar" *by* Cuong M. Nguyen et al.

Anonymous Referee #3

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General Comment

The manuscript compared three radar measurement based IWC retrieval methods (Z only based, Kdp only based, and Kdp and Zdr based) using X-band polarimetric observation and in-situ observation and demonstrated that the Kdp and Zdr based method can provide better IWC estimates. The retrieved IWC agreed very well with the observed IWC from the in-situ measurement. The methods are based on observations, and I would expect to extend the techniques to other places in future; however, the manuscript did not mention effectiveness of the methods for other cloud types at different locations. The subject and results of the manuscript are suitable for the scope of

the journal. However, this manuscript lacked detailed descriptions about how to estimate coefficients. In particular, estimated coefficient values were not presented. Some figure captions lacked explanations. I recommend major revision in terms of comments below.

Specific comments

1. The manuscript lacked detailed descriptions about how to estimate coefficients (a1, b1, a2, and b2) and their values. Information below is at least needed. 1) The estimated coefficient values. 2) Were the coefficient values estimated for each case or constant for all cases? 3) How did you sample radar data? In-situ data was valid near the aircraft, while the radar could not collect data below a range of 1000 m from the aircraft. What are locations of the radar data used for the coefficient estimations? How did you match the radar data and the in-situ data? The sampling method may control the accuracy of the linear regression technique. 4) How many cases (how many hours) were used for coefficient estimates? 5) Is there a dependency of the estimated coefficients on cases? 6) It is very worth to add a flow chart of the IWC retrieval technique.

2. Details about the radar data are needed. What are the beamwidth, radar range gate spacing, and time resolution? Did the radar point at a fixed direction during the flights or scan some directions (in that case, what are the elevation and azimuth)? Did the radar sampling volume match the in-situ measurement sampling volume?

3. A more description about IWC from PSD is also needed. What D-M parameterization was used? How was it tuned using IKP2 measurements? Again, a flow chart of the IWC calculation should be useful. Did the image probes scan particles at a horizontal plane (parallel to the horizontal plane) or vertical plane (perpendicular to the horizontal plane)? Can the scan direction cause some errors in the IWC calculation?

4. Is the technique presented in the manuscript valid for cases where graupel existed? Graupel particles generally have aspect ratio ~1, which are not sensitive to Kdp or Zdr. Deep convective cases could include supercooled liquid droplets and heavily-

rimed particles. Were there effects of supercooled liquid droplets and heavily-rimed particles in the cases used in the analysis? Was the case dependency of the proposed technique? More case descriptions would be needed to help understanding the case dependency.

5. P. 14, lines 2-3: This sentence does not make sense to me. Please give more description about why Kdp can improve large aggregates effect, although it is sensitive small crystals. Just before the sentence, it was stated that "ðİŘ¿ðİŚŚðİŚİ is more sensitive to the oriented small ice crystals." Why Kdp can improve large aggregates effect? How did you know the orientation of ice particles?

6. P. 18 lines 10-11 "On the other hand,...": This sentence does not make sense to me. Why the modified IWC was less sensitive to the particles' shape and orientation, even though the Zdr constraint well worked for the IWC estimate?

7. Evaluations for mode error sources should be discussed; how could Kdp estimation resolution, Zdr bias, and in-situ instrument limitation (difference between IWCmeas and IWCpsd) affect the IWC retrievals?

8. Fig. 12: I do not know the meaning of Fig. 12. Why can you see "the modified version of IWC is better replicated by a simple linear regression model" from this figure? "Modified IWC" is the just measured IWC scaled by Zdr. Why is this better replicated by a simple linear regression model then measured IWC? In both Fig. 12a and Fig. 12b, it seems that there is ∼50% variability in IWC at Kdp = 1. There is no significant difference between Fig. 12a and Fig. 12b. If you wanted to say that Eq. 13 can provide better correlations between IWC and polarimetric variables (Kdp and Zdr), this has been already shown by $R^2$ values in Fig. 5.

9. "Modified IWC" is a confused phrase. In the manuscript, "modified IWC" represents the left hand side of Eq. 13. (1-ZDRˆ-1)*IWC. This is IWC scaled by [1-ZDRˆ-1], not actual IWC. Use an appropriate phrase through the text.

Minor comments

1. Did you do attenuation corrections for reflectivity and Zdr? Attenuation corrections may not be needed for pure ice precipitation, but it would be good to mention about this.

2. Did you do calibrate Zdr values for systematic offset?

3. What was the window size for calculating Kdp? What is the special resolution of Kdp?

4. P. 10, lines 1-2 "The radar estimates...": This sentence is unclear. Please add detailed descriptions.

5. P. 10, line 8 (2): This feature is unclear in Fig. 4. Scatter plots of MMD, RHOhv and Zdr should be helpful.

6. P. 10, line 9 and p. 14, line 2: How did you know the orientation of small crystals? Kdp should also be sensitive to larger crystals with aspect ratio /= 1. How did you know the particle aspect ratios?

7. P. 10, lines 10-11: In Fig. 5, it seems to me that the break point where Zdr started increasing and RHOhv deceased was at Kdp∼1.5 deg/km.

8. P. 10, line 20: I cannot see any blue line Fig. 5.

9. P. 10, lines 20-21: I cannot see measured IWC or modified IWC in Fig. 5.

10. Fig. 3b and Fig. 7b: Why is there a break line at 6-7 km range in reflectivity fields?

11. Please give height information for Figs. 3, 7, 9, 10.

12. Please give information about height, range, and temperature for Figs. 4, 5, 6, 8, 11, 13.

13. Unit of Kdp should be degrees / km through the manuscript?

14. Fig. 5: What do red lines represent?

15. Fig. 5: I confused 'scatter plots' with red and black dots. I guess that 'scatter plots' here meant color shades representing frequency distributions. I recommend using 'frequency distribution' instead of 'scatter plot.'

16. Fig 5: missed (a), (b), and (c)

17. P. 18 line 8: I cannot find ellipses in Fig. 11.

18. Caption of Fig. 3: Delete "is"