

# ***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 #2**

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This manuscript presents an assessment of ice water content (IWC) retrieval algorithms based on KDP only and combined KDP-ZDR observations using measured IWC from aircraft in-situ probes. Results show that both the KDP-only and combined KDP-ZDR method works much better than the reflectivity-based retrieval algorithms. Although KDP-only and KDP-ZDR combined IWC retrieval algorithms are not new concept, an algorithm derived from quasi-collocated in-situ measurement and radar observations is a good addition to the existing literature. Some sections of the manuscript lack details and are somewhat difficult to follow, especially section 2. Modifications to the manuscript are needed before it can be recommended for publication. Major concerns and questions that needed to be addressed are outlined below.

## General Comments:

1. Combining KDP and ZDR in IWC retrieval is not new concept. For example, Eq. (13) in the current manuscript is very similar to Eq. (29) in Ryzhkov et al. (1998). In my opinion, the authors should discuss more on the relationships and differences between the current study and the other more theoretical studies.
2. Section 2 lacks detailed derivation and/or reference to existing literatures and is very difficult to follow. This section needs to be heavily rewritten. The author should provide detailed derivations or clearly refer to existing literatures for the equations. When doing so, the authors should make sure that the conventions of the equations are consistent.
3. The parameters (a, b) used in the Kdp only and Kdp-ZDR combined algorithm are obtained from linear fittings of data from 7 cases. By looking at Figure 12, it seems different values of (a, b) could be obtained if data from only one, or some of, the 7 cases are used in the fitting. What is the variability of the parameters (a, b)? How large the retrieval uncertainty will be due to the uncertainty in (a, b)?

Specific comments: P2, L14: What is the conclusion of Ryzhkov et al. (1998)?

P3, L11 and L14: Which convention is used for the back-scattering matrices and forward scattering amplitudes?

P3, L10 and L13: The radar observables, Zdr and Kdp, are usually integrated over a particle size distribution. Although Eq. (1) and Eq. (2) are OK if all the particles are of the same size and aspect ratio, this situation rarely happens. I think these equations can be removed since Eq. (5) and Eq. (6) are more general. Instead, the authors can discuss scattering properties in single particle level here.

P3, L15-17: This sentence is confusing. I guess the authors mean that Zdr does not change with increasing number of small particles while Kdp increases with increasing number of particles. The authors may want to rephrase this sentence.

P3, L20: Is the permittivity of particle based on solid ice?

P5, Eq. (9-11): By using symbol for “approximately equal”, do the authors really mean “proportional”?

P5, Eq. (11): Derivation for this equation is needed. Also, Eq. (9) and Eq. (10) use integration over a PSD, why Eq. (11) only use one mass?

P5, L7-9: Again, detailed derivation is needed. How to derive a closed form of IWC as a function of Kdp and ZDR? What does “particle mass variation is small within the radar volume” mean?

P5, L19-20: What are the physical meanings of the constants  $b_1$  and  $b_2$ ?

P10, L7: What does “initial observations” mean? Should the “include” be replaced with “indicate”?

P10, L8: “latter” is confusing. Better to clearly state which observations are weighted and biased towards Zdr.

P10, L20: No blue line in Fig. 5(c).

P10, L7-12: Are the polarimetric variables Kdp, Zdr, Zh, and  $\rho_{hv}$  shown in Figure (4) measured at a specific distance from the airplane or averaged over a range? How about those shown in Figure (5) and (6)?

P13, L6: What are the coefficients (a, b) used for Kdp-only and (Kdp, ZDR) algorithms? Are same values used for the other case?

P20, L12: I think the word “significantly” is too subjective and optimistic. For example, when  $K_{dp}=1$ , in panel (a), IWC varies by 50% of the maximum value (range 1~2 with maximum 2), and in panel (b), modified IWC also varies by 50% (range 0.15~0.3 with maximum 0.3). I would suggest remove the word “significantly”.

Technical corrections: P1, L9: Is the differential reflectivity here in linear scale or log scale?

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P2, L10: Aydin and Tang (1995) should be (1997).

P3, L8: The book of Bringi and Chandrasekar (2001) has over 600 pages. Detailed page numbers or equation numbers are needed. The same for P3 L22 and other places.

P4, L26: IWC is not sensitive to shape and orientation sounds strange. IWC is independent of them. The authors may want to rephrase this sentence.

P11, Figure 3 caption: “Bottom panel is shows” remove “is”.

P13, Figure 5 caption: using two values (0.1 and 0.05 degree) and “respectively” for three panels is confusing.

P12, L5: “blue” should be “black” for measured IWC.

P14, L5: “estimations” should be “estimation”.

P14, L5: The panels of Figure 6 are not labeled by ‘a’ or ‘b’. Same for Figure 11.

P15, Figure 6: Should vertical axis labeled as “Error” instead of “Bias”?

P18, L8: No ellipses in Fig. 11a.

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