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Comment on amt-2021-148

Anonymous Referee #3

Referee comment on "Coincident In-situ and Triple-Frequency Radar Airborne Observations in the Arctic" by Cuong M. Nguyen et al., Atmos. Meas. Tech. Discuss., https://doi.org/10.5194/amt-2021-148-RC3, 2021

Review of the article titled "Coincident In-situ and Triple-Frequency Radar Airborne Observations in the Arctic" by Cuong M. Nguyen et al.

This article shows promising results of triple-frequency radar observations from the Radar Snow Experiment (RadSnowExp). Part of the uniqueness of this article is that both in situ and remotely sensed observations were collected by the same aircraft. Some complications arise when combining these datasets for their analysis, but the authors carefully and thoroughly describe the methodology used for volume matching and range calibration.

The authors studied the relationship between in situ sampled cloud microphysical properties and radar triple-frequency signals particularly, they centered their analysis on the relationships between median volume diameters, effective bulk density and dual frequency ratios. Lastly, the authors suggest a path forward with the possibility for quantitative retrieval of particle size using measured DFR but more in-depth analysis is needed to reach that step.

This article is generally well written, it is interesting, and it will be of interest to the scientific community. Nevertheless, I have a few concerns I suggest be addressed before this article is published. Below are some general and specific comments.

General Comments:

The authors analyzed one flight (22 November) and divide it into 3 different segments (1948-2000 UTC, 2005-2028 UTC and 2121-2135 UTC) giving a total number of 49 minutes of DFR observations. Please consider this to put into context the overall findings that derive from this dataset that are stated in this article.

Figures need significant improvement, both in the actual quality of the figure (suggest improving ppi) and the legibility of axis labels and legends. For figure with more than one panel the different panels should be labeled. This was done for some of the figures but not

in all. I suggest a uniform way to address multipanel figures and their caption. Finally, figure captions need to carefully state what is plotted in each panel/figure.

I'm not sure figures 1 and 6 are necessary if the article centers around the Nov 22 flight (in case fig 1 is kept, I made I suggestion below to have all the flights drawn or the domain where all the flights took place). Similarly, I don't think figure 5 is necessary either, no extra analysis is done of how the overlapping sizes were treated or any extra analysis that would make this plot needed in the article, just stating in the text the size ranges each instrument measures should be sufficient.

Specific Comments:

Lines 14-16: Consider stating the amount of data that was used to reach the conclusions stated in the article and not the overall flight hours of RadSnowExp.

Line 18: I'm not entirely sure this article showed how to accurately derive the level of riming from the DFR plane, consider rewriting this sentence.

Line 26: Add the definition of GPM-DPR

Lines 29-31: Reference needed.

Line 34: Suggest modifying this sentence as "The GPM Core Observatory carries…" or similar.

Lines 39-41: Reference needed.

Lines 63-65: Figure 1 does not support this statement, a figure showing all the flight tracks, or the experiment domain would be more useful.

Line 71: Consider replacing 'uniquely' by 'unique'

Line 71: Figure 3 should be Figure 2, please reorder figures.

Line 110: Should be figure 3 when re-ordered.

Line 110: consider replacing 'points' by 'retrievals' or similar.

Lines 149-154: The second bullet point is not clear. What do you mean by 'three radar data'? How was it mapped into a common range axis? How 'reasonable' is the homogeneity assumption? Was any sensitivity analysis done to evaluate it? A schematic of all the smoothing methods could be valuable to assess the actual volumes that are being compared.

Lines 175-179: I consider this to be an important factor in the data analyzed here that could grant the inclusion of a figure showing these values to support this statement.

Line 180: Figures should be numbered in sequential order they are referenced in the text. Consider reorganize the figures or the text.

Line 181: Were there more than 1 flight on 22 Nov? How much data does this represent? i.e.: How many data points were used to reach this conclusion?

Lines 193-194: Consider adding sizes to contextualize 'small cloud droplets' and 'large

precipitation hydrometeors'.

Line 197: Consider replacing 'or' by 'and'.

Line 206: Is the difference between all the 9 groups and the subset of ice habits only the inclusion or not of the Drops and Artifacts category? How are small particles treated?

Lines 212-213: It would be good to state the uncertainty values that are within the range presented by Baumgardner et al. (2017).

Lines 219-224: This paragraph is confusing, if the wiring had little effect on the estimated water content, then what was the factor that made the accuracy drop from 0.002 g/m3 to 0.05 g/m3? Was this value taken as a constant value regardless of the size of the hydrometeors sampled? How was the estimation of the accuracy of the Nevzorov probe done?

Line 226: If the minimum of 50 μm was used as lower bound then FCDP was not used in this analysis?

Line 229: Consider adding "(The definition of) several bulk…"

Line 232: Add year to Heymsfield et al.

Lines 242-248: I think this paragraph and figure 6 could be removed from the article. Just adding a sentence that states that 22Nov will be analyzed and why should be sufficient.

Line 258: Consider adding "In (current or past) literature…" and adding several references of this literature.

Lines 266-267: Convair average ground speed is 100m/s, this makes the volume for the in situ sampling of 200-500 m. How is this mismatch between the radar and in situ volumes handled?

Lines 271-272: I suggest analyzing if reflectivity shows a different signal comparing Nadir vs Zenith samples and then compare DFR.

Section 3.3.1: This paragraph and associated plot is confusing, the almost 500 m difference between the observations at nadir and zenith show that the vertical structure of the cloud has a large impact on DFR. This is particularly clear when comparing DFR X/Ka, where the Zenith ratio has an almost constant value regardless of the values measured at Nadir. Is there a reason for this? As mentioned before, joint distributions of reflectivity would be better to analyze this 500 m effect.

Line 288: Add 's' to Gans.

Line 294: Figures should be numbered in sequential order.

Lines 292-294: I'd consider regions where both the Nadir and the Zenith correlation coefficient are good. This will hint at a more homogeneous cloud in the vertical and thus a more reliable comparison between what is sample in situ and at a 245 m difference in height. For example, the 4th region marked in figure 10 shows a big difference between Nadir and Zenith (based on correlation coefficient) this is most probably hinting that the part of the cloud sampled has a notable vertical structure so, I'm not sure it is a good case to analyze DFR because this gives an extra reason for the differences between the DFRs.

Lines 296-305: How long was this flight? How many samples were analyzed?

Line 333: Replace ‘similarity measurements‘ by ‘correlation coefficient filter’ or cc threshold or similar.

Line 339: How where the different sections within segment 1, 2 and 4 defined? Was this breakdown into sections defined by the aircraft sampling pattern? Because figure 13 shows that there are different processes occurring in these different sections, for example, section D shows clearly different behaviors in DFR and CPI particle fraction near the beginning of the section when compared to the end of the section.

Lines 340-346: It’d be best if this description of the first segment has figure 13 as reference, it’d help contextualize the differences in the different segments.

Lines 345-346: The bimodality in the PSD distributions it difficult to see for all sections, especially the referred maxima at 1 mm. Please clarify.

Line 351: IWC should be TWC or is the legend in the figure incorrect?

Line 357: Why/How was the aircraft at 6 km height? I assumed the black line in Figure 10a is the aircraft path, so in sections b-d shouldn’t the aircraft be at around 2.4 km height? It would be extremely beneficial to have the different sections shown in figure 10a.

Line 364: Consider rewriting ‘remarkably mirrors’

Line 365: Similar to the comment before, from Figure 10a after the first few minutes of the first segment (first few minutes of section a that the aircraft descended) the aircraft seems to be flying at a constant altitude of ~2.4 km, is this not the case? Aren’t sections A-D correspond to segment 1 that is shown by the first box in figure 10a?

Lines 372-373: This sentence that the fraction of dendrites and rimed particles drops to its lowest level in section D can be misleading, this is the case near the beginning of the section, but by the end of the section this is clearly not the case. Consider rephrasing to avoid confusion.

Lines 390-391: Would it be possible to add to figure 14 the line representing graupel particles using discrete dipole approximation? It could be helpful to add the relevant curves from figure 2.

Line 405: Consider ordering figures in sequential order that are mentioned in the article (Figure 15 should come before Figure 16). Also, how where these different sections defined?

Lines 409-412: From figure 16 top right panel it seems like the fraction of dendrites is higher in C than in B?

Line 419: MDV does not reach 6 mm in section A, please clarify.

Lines 420-421: ZDR was not mentioned before in the article, was there not any ZDR signature in the previous segment?

Line 421-423: Consider rewriting this sentence, variables do not mimic other variables. Also, MDV is not > 8 mm for all the times that DFR is ~ 10 dB, this occurs just for the second maxima in DFR in section B.

Line 423: consider adding a time series of ZDR to figure 16.

Lines 426-427: What do you mean by 'fluctuations in the DFRs'? Also, what datapoints correspond to section A, B or C is not clear from the plot, consider making the markers edge a different color linked with each section. Also, I suggest adjusting the limits of the plot to better fit the data plotted this will make the differences in the markers size and colors clearer.

Lines 429-435: These few sentences are confusing consider rewriting. The hook feature is present in data from section C not B. Also, remove parenthesis for the references inside the larger parenthesis, like in the Petty and Huang, 2010 reference.

Line 444: Why was this segment chose to be analyzed in depth? Please consider the previous comment regarding the difference between observations at Nadir and Zenith with respect to the vertical structure of the cloud and how different processes can be playing a role at different heights of the clouds that could give difference in DFRs that are not exclusively related to the factors analyzed here. This variability in height can clearly be seen in figure 10a where different microphysics might be acting between the lowest trusted range sampled by the radar and the in situ observations sampled 245 m below.

Lines 484-485: This sentence is misleading as a summary and discussion part of this article where 1 day was analyzed and 3 segments of that flight that resulted in 49 minutes of DFR observations.

Lines 488-490: This sentence is confusing, please consider rewriting it.

Lines 496-499: Add 'for the flight we analyzed' or similar phrase here as the results described could be case dependent.

Lines 503-504: Figure 22 should be figure 21?

Line 503: I'm not sure I understand how figure 22 (or 21) is a first attempt for quantitative retrieval of particle size using measured DFR Ka/W and DFR X/Ka. There are a lot mean MVD and density values that are linked with different DFRs values. This looks more like a qualitative analysis.

Line 505: Figure 21b shows that equivalent density increases with decreasing both DFR

Line 510: Remove extra '.'

Lines 515-517: Change 'demonstrated' by 'shown', otherwise, this is too strong of a statement based in the case analyzed in this article.

Lines 523-524: This sentence is not clear, consider rewriting it for clarity.

Fig. 1: please improve figure 1a, it is very difficult to visualize the location of the flights, what is the color in the track representing? Not sure how convoluted a figure showing the path of all the flights done in RadSnowExp, but it'll sure be useful to see such figure.

Fig. 4: Consider center this figure around the heights that are referenced in the article. For example, if the ground is not referenced why extend the y-axis all the way 5 km?

Fig. 7: Please add in the figure caption what is shown in the figure (what is the dashed line and the error? bars).

Fig. 8: Consider adding lat and lon to the plots and make the maps larger the synoptic

map is not very useful in the context given for people not familiarize with the area the flights took place to easily link all 3 maps.

Fig. 9: What is the F9 legend? What do you mean by 'the ground to air temperature' ground temperature is ~ -23C and why is this important information to have?

Fig. 10: Improve figure caption to add what are the red, blue and black lines in panel (b) and also improve the legibility of the legend in panels b-d. Also, please consider not using similarity measurement and just use correlation coefficient.

Fig. 12: Please correct what figure is referencing the five sections. Also, I don't see a reference in the article that requires panel b to be part of the figure.

Fig. 13: Please label each panel of the figure for an easier read and to improve the connection between the text and each plot in the figure.

Fig 14: Consider modifying the colorscheme of the scatter plot to improve the readability of the figure (pinkish colors represents both low and high values).

Fig. 15b: I don't see a mention to this panel in the article.

Fig. 16: Similar to Figure 13 please label each panel.

Fig. 21: A joint distribution with number of samples would give reference to the mean MVD and density.

Fig. 22: Add what the black line and vertical black lines are in the figure caption.