

## ***Interactive comment on “Retrieval of snowflake microphysical properties from multi-frequency radar observations” by Jussi Leinonen et al.***

### **Anonymous Referee #1**

Received and published: 7 May 2018

The paper is well-written and presents the results of research on an important topic and one that is perfectly suited for AMT. Only minor comments and suggested revisions are contained in what follows.

Comments:

0) The returned manuscript contains mark-up throughout the article. While some (much?) of it may not be easily readable, it may yet help to improve details here and there.

1) Page 2, Lines 13-14: Do two-frequency measurements constrain snowflake sizes when multiple populations of ice hydrometeors are present and one species dominates the reflectivity? Recent polarimetric results show that it is not uncommon for a large

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ice hydrometeor species to dominate reflectivity while a second smaller ice hydrometeor species dominates KDP. So the word "constrained" in these two lines is a weak constraint.

2) Page 4, Line 5: What does "cumulative" mean in "cumulative attenuation"? It was not clear what population of samples contributed to the R-M-S calculation mentioned on this line.

3) Page 5, Line 17: The comment "normalized cross sections are constant in the small-particle limit" is not strictly true. They can vary by about a factor of two depending upon the particle shape, even though the particles are small compared to the wavelength.

4) Page 5, Lines 17-18: "The samples used for the averaging are weighted using a Gaussian function of the distance from the bin center". Are the samples used in the averaging all associated with a single bin? If so, why does averaging of the samples within a bin require a weighting function? Is it because the bin widths are large and what is wanted is some sort of average representative of the bin center? Finally, what is the width of the Gaussian function? More information needs to be provided about this step so that others can reproduce it based on what is written.

5) Page 5, Line 23: "thus should" is weak. It either does or does not. Which is it?

6) Page 5, Line 28: How many "logarithmically spaced integration points" do you use?

7) Page 6, Line 9: "we appeared to us" -> "we found"

8) Page 6, Lines 28-33: Is the discussion here about errors overly optimistic? Assuming a mass-dimension relationship can lead to errors. In the case of this study do the two databases it uses have mass-dimension relationships built into them. If they do, what is the consequence of this in terms of retrieval results and errors based on a retrieval that uses the same/different mass-dimension relationships than those used in the databases? Why would you expect "their effect should be similar on each collocated radar frequency" to be true? Nothing much been mentioned about particle orienta-

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tion in the manuscript but we generally do not know much about it and the effect of having orientations wrong would not be expected to lead to similar errors at different frequencies. In summary, perhaps the structural errors in the retrieval need to be made perfectly clear. Because they are really difficult to deal with and no ideas seem to be out there to deal with them using available datasets, simply making them clear has to be sufficient at this point in time.

9) Page 7, Lines 7-14: What is your method for choosing a retrieved state vector  $x$  based on measurement  $y$ ? Is it the maximum in  $E[x|y]$  given  $y$ ? Perhaps this implicit but it needs to be stated directly.

10) Page 7, Lines 18-20: 10000 points scattered across a three-dimensional space is not that dense of a set of points. Are you sure that your sampling is sufficient? Where do the means and standard deviations of  $x_i$  come from on Line 19? Are they from your a priori data or some other place? Not sure from what is written.

11) Page 8, Line 17: Some might argue that a Voronoi based density is a much more meaningful "representative" density than a superscribing sphere. What might be a better word than "representative" here?

12) Page 9, Lines 26-27: Most aircraft in situ probes currently retrieve particle sizes based on a single two-dimensional image of them, which can lead to large biases depending upon the particle shapes and orientations as they fly through the probe sample volume. I would imagine there are similar issues with the PIP measurements discussed on the next page.

13) Page 10, Line 7: How was the value of the "linear scaling factor" set?

14) Page 10, Line 17: Is assuming that the "a priori distribution is multivariate normal" a good assumption? What is your justification for this assumption?

15) Page 11, Lines 22-24: "which identifies a change in the hydrometeor type at roughly the same altitude where a rapid increase in  $D_m$  is observed". What altitude is this?

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I do not see it clearly comparing Fig. 2a with Fig. 2d. Fig. 2e I mostly contains blue with purple and green speckle towards the top in the orange box region and no single altitude with a change jumps out.

16) Page 13, Fig. 2: The "NPOL" is hard to see in some of the figures. Perhaps arrows can be used to demarcate the location of the NPOL along the x-axis?

17) The words "good", "well", "seems", "should", "can", "appear to", "somewhat" are not informative. Replace them with quantitative statements or rewrite the sentences containing them in a more definitive, precise way. See Page 15, Lines 4, 28, 29, 30, 31, 32 Page 17, Lines 3, 20, 21, 26, 29 Page 18, Lines 1, 4, 11 Page 19, Lines 3, 16, 17 Page 20, Lines 2, 30

18) Page 15, Line 14: Particle imagers might be able to measure accurately the maximum dimension of a two-dimensional projection of a particle but this does not mean that particle imagers retrieve the maximum dimensions of the particles accurately. All depends upon the particle shape and orientation.

19) Page 16, Fig. 4: Squares would be better than rectangles in the subpanels.

20) Page 17, Line 27: "The multi-frequency retrievals... permit considerably more variation". Is this an advantageous feature of these retrievals if there is no improvement in correlation or any other objective measure of skill?

21) Page 20, Lines 27-29: The sentence contained in these lines is really problematic written in current tense. "Graupel occurs in relatively rare events" would mean that this is always true and everywhere. Do you mean this only for your datasets? If so, this would read much better as "Graupel occurred in relatively rare events". Most of the paper was written in present tense, including places describing things done, occurring, ..., in the past. The paper was sufficiently well-written that this use of present tense everywhere was not too distracting.

22) Page 21, Line 18: "The high cross-correlations found in this study". What are corre-

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lations are being referred to here and where did they occur in the manuscript. Not clear.

Please also note the supplement to this comment:

<https://www.atmos-meas-tech-discuss.net/amt-2018-73/amt-2018-73-RC1-supplement.pdf>

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Interactive comment on Atmos. Meas. Tech. Discuss., doi:10.5194/amt-2018-73, 2018.

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