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Interactive comment on "Microwave and submillimeter wave scattering of oriented ice particles" *by* Manfred Brath et al.

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Discussion paper

Answers to Interactive comment on “Microwave andsubmillimeter wave scattering of oriented ice particles” by Manfred Brath et al. Anonymous Referee #1

January 31, 2020

General comments

Reviewer:

This article by Brath et al. presents a novel, highly valuable study and database of the properties of oriented snow particles in the atmosphere at low to high microwave frequencies. This has been a goal of the local research community for years, and the reviewer is rather glad that he came across it for review.

The resulting database is gigantic, and the complexities of assembling this database are discussed at length throughout the manuscript. Great care was taken to describe all of the conventions and equations involved in the scattering calculations, particle rotations and subsequent radiative transfer simulations.

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Discussion paper

The reviewer congratulates the authors on this achievement.

It is quite possible, however, for readers to become lost in this level of detail and lose the main thrust of the paper. Also, earlier sections of the manuscript (e.g. pp. 3 and 10) refer the reader to details in section 4 (p. 11). As such, the reviewer suggests that the authors attempt to simplify by moving some of these details into appendices and somewhat reordering the manuscript. There are also many small points (both scientific and formatting) that should be addressed. The overall recommendation is to revise and resubmit.

Answer:

As suggested, we shifted the details of section 4 to the Appendix. Furthermore, we revised the paper considering the comments of all three reviewers.

Section-by-section comments

Abstract

Reviewer:

The abstract is too vague. It states that you performed simulations and made adatabase for use with the upcoming Ice Cloud Imager. Your summary section con-tains information that should be emphasized here. Results from Sections 6 and 7 can further provide examples of why undertaking the construction of this database wasworthwhile.

Answer:

We revised accordingly.

Reviewer:

- Line 7: “The additional tilt angle adds an additional dimension” -> . . . adds an additional degree of freedom. Dimension can be rather confusing in the context of this paper.

Answer:

We changed it. We now write: “The additional tilt angle further increases the complexity.”

Reviewer:

- Line 8: dipol -> dipole

Answer:

Changed as suggested.

Reviewer:

- Line 9: Perhaps mention that these habits were first introduced in a previous paper. Mention that the database covers multiple temperatures.

Answer:

We now mention that the database covers multiple temperatures.

Reviewer:

- Line 10: The data is -> The data are

Answer:

We change it.

Introduction:

Reviewer:

You need information on why polarized scattering properties are important. What new information content would they provide for data assimilation / forecasting? Metop-SG-B's ICI instrument (launching in the early 2020s) will need better models of snow particle scattering to properly retrieve ice cloud properties. To provide for this, you need a few key components: accurate ice particle shapes, a polarized radiative transfer model, accurate orientation distributions, and polarization-sensitive dataset of ice particle scattering. Eriksson et al. (2018) provides the shapes, ARTS provides the radiation model, you assume the orientation distributions and generate the scattering dataset that studies / people / instruments can use.

Answer:

We revised the intoduction according to that. We now state, why polarization is important and why it is important to have scattering properties of oriented and realistically shaped particles. Furthermore, we rephrased the goal of the study and the idea behind the database.

Reviewer:

- Line 15: “channels of these passive” -> “channels of passive”

Answer:

Changed as suggested.

Reviewer:

- Lines 17 and elsewhere: “Currently, . . . GPM and MADRAS . . . are the only spaceborne microwave radiometer that measure polarization at ice cloud frequencies. GPM and MADRAS observe polarization around 160 GHz.” MADRAS was declared non-operational about two years after launch, and it is no longer collecting scientifically valid data. The sentence should reflect that.

Answer:

We corrected that and mention now that due to mechanical failure MADRAS measured only till January 2013.

Reviewer:

- Line 19: You might want to discuss the abundance of polarized data available at around 90 GHz. Polarized measurements are also available on Metop-C and on GCOM-W1, but are strongly affected by surface contamination.

Answer:

We added some sentences about it. We now mention that there are polarized observations below $100\,GHz$. We further added that due to the low frequency, the sensitivity considering ice clouds is low Buehler et al.(2007), though there still can be enough sensitivity for precipitating ice, and that at theses frequencies surface contamination is an issue.

Reviewer:

- Line 22: The mentioning of particle orientations is rather abrupt. You need a few expository sentences here.

Answer:

Done as suggested. We restructured the introduction and gave some additional background considering polarization, see also answer to your first introduction comment.

Reviewer:

- Line 24: "realistically shape" -> "realistically shaped"

Answer:

Changed as suggested.

Reviewer:

- Line 24: “that also possess an orientation” – This dangles from the end of the sentence, and should be rephrased.

Answer:

Removed, due to restructuring of the introduction.

Reviewer:

- Line 28: “one orientations” -> “one orientation”

Answer:

Changed as suggested.

Particle orientation:

Reviewer:

This section can get rather technical, and so it is important for the reader to be guided through possible misunderstandings.

- Lines 49 and elsewhere: “spherical symmetry” is a bit confusing, and you seem to be using two competing meanings of this term throughout the manuscript. Consider a symmetric 6-bullet rosette. In Appendix A, line 592, spherical symmetry occurs when Ixx = Iyy = Izz. Contrast to line 49: “If the particle possesses spherical symmetry there is no particle orientation, because it does not matter from which side the particle with spherical symmetry is viewed or how it is rotated – it will always look the same.”: This seems more like radial symmetry.

Answer:

According to the American Meteorological Society Glossary of Meteorology radial symmetry and spherical symmetry is the same in three dimensions. “Radial symmetry in two dimensions is often called circular symmetry; in three dimensions, spherical symmetry.” http://glossary.ametsoc.org/wiki/Radial_symmetry Therefore, we did not change it.

Reviewer:

- Line 50: Last sentence of paragraph is cumbersome. How about “The particles considered in this paper are not radially symmetric and may be oriented.”?

Answer:

We changed it to “The particles considered in this paper are not spherically symmetric and therefore can be oriented.”

Reviewer:

- Lines 52-62: "In general, the orientation of a particle in a three dimensional space can be described by a set of three parameters. The three Euler angles are one such parameter set." - You need to assert in this section that your choice of rotation angles are not necessarily the same rotation angles used elsewhere. There are six pure Euler angle schemes (intrinsic rotations), six Tait-Bryan conventions (extrinsic rotations; some literature sources also consider these to be Euler angles), and several mixed approaches.

Answer:

We now state that there is no unique set of parameters and that there are different sets of them depending on the definition of the rotation axes.

Reviewer:

- Line 52: "three dimensional" -> "three-dimensional"

Answer:

Changed as suggested.

Reviewer:

- Lines 56,57 and in many places elsewhere: Something went wrong with the PDF rendering of some of the symbols used in your manuscript (e.g. zyz' notation is

displayed as z[box]z'). This happens on different machines (macs, Windows) and using different PDF readers.

Answer:

Unfortunately, there were some problems with the font. This happened when the manuscript was uploaded to AMT. We are aware of this.

Reviewer:

- Line 62: "important to know" -> "important to note"

Answer:

Changed as suggested.

Reviewer:

- Line 63: "Additionally to the Euler angles" -> "In addition to the Euler angles"

Answer:

Changed as suggested.

Reviewer:

- Line 66: You are considering only generally oblate particles (and your particle model is discussed later in the paper). You mention plates here, but it is good to explicitly state that you assume only oblate shapes. If you have something more prolate-shaped (i.e. columns), then its general alignment to vertical or horizontal becomes a very complicated function of drag and other local conditions (you can get preferential vertical instead of horizontal alignment).

Answer:

We revised that part and now discuss the validity of our assumption.

Reviewer:

- Lines 80, 81 and 98: Define the abbreviations (TRO, ARO) in lines 80,81 instead of in a subsequent figure caption (line 98).

Answer:

Done as suggested.

Reviewer:

- Line 90: Total scattering angle is a function of the angle between incoming and outgoing direction, and it might be useful to include the equation here.

Answer:

Done as suggested.

Reviewer:

- Lines 94+, and 70-79: You seem to be aligning your ensemble of particles in the same way, regardless of the different moments of inertia, sizes and aspect ratios of the particles. Why not allow for different particles in your ensemble to have different preferential alignments, perhaps using von Mises-Fisher or Fisher-Bingham-Kent distributions? It's worth discussing, especially since related work has been presented by the GPM team. This also relates to my comment in section 5 – can the raw (per-orientation) data be made available for users to manipulate independently?

Answer:

Considering your comment and after reading the specific lines again, the lines 70 - 79 may be misleading, because it was not stated clearly in manuscript what is the basic idea behind the database and its usage, which we now do. Our main assumption is that there is no preferred orientation of the particles in azimuth direction. Based on that we want the users to decide, which tilt angle β (zenith orientation) or tilt angle distribution they need. That is why we calculate the scattering properties for several tilt angles β for all particle sizes and shapes.

In the revised introductions, we now state: "The idea behind the scattering database is that the users can use scattering data of a desired zenith orientation or combine the data of different zenith orientations to mimic any desired distribution of zenith orientations." We also rephrased the goal of the study, see answers to section-by-section

comments for introduction.

Reviewer:

- Lines 100-116: The paragraph is wordy and would be hard to understand for someone outside of the immediate field. Lines 101 and 111 state, "to get a better picture of it" and "to get a better idea of it". You might need to add in a descriptive figure here.

Answer:

Done as suggested.

Basic setup and shape data

Reviewer:

This section reads well.
- Line 118: Amsterdam DDA's name was changed. See a recent version of the manual for their rationale.

Answer:

Changed as suggested.

Reviewer:

- Lines 125-126: As described elsewhere in the manuscript, the two hydrometeor habits have multiple shapes in each habit. The text here is somewhat misleading and should be rephrased. Or, prefix with the sentences in lines 127-128.

Answer:

We reordered it as suggested and further revised that section considering your and the other reviewers' comments.

Reviewer:

- Line 134: Volume equivalent diameter should be defined. It has multiple meanings in the field, and I am assuming that you mean the diameter of an equal-volume sphere made of solid ice, later used in line 310.

Answer:

We added the definition of the volume equivalent diameter to the text. The volume equivalent diameter is defined as the diameter of a solid ice sphere with the same mass as the particle.

Reviewer:

- Line 134: Same with maximum diameter. Assuming you mean in three dimensions.

Answer:

We added the definition of the maximum diameter to the text. The maximum diameter is defined as the diameter of the minimum circumscribed sphere of a particle.

Reviewer:

- Line 135: Why are the sizes slightly different?

Answer:

The plate type 1 habit in our study has slightly different sizes than the plate type 1 in Eriksson et al. (2018), because an older version of shape data was used than in Eriksson et al. (2018) and given the high computational costs of the scattering calculation a recalculation was not feasible. We added previous sentence to the text.

Reviewer:

- Line 142: Why are the frequencies slightly different?

Answer:

Due to a rounding mistake when the simulation was set up, the frequencies of the plate type 1 habit slightly deviate from the frequencies of the large plate aggregate habit by at maximum $0.5\,GHz$. We added previous sentence to the text.

Reviewer:

- Page 7: 886 GHz is quite high! What interdipole spacing did you use when calculating these results?

Answer:

For all particles considered in our study holds

$$|m|\, kd < \frac{1}{2} \tag{1}$$

with m the refractive index of ice, k the wavelength and d the dipole size. With the microwave refractive index of ice this result in roughly 22 dipoles per wavelength. Furthermore, all simulated particles consist of at least $1,000$ dipoles so that small particles are reasonable resolved. We added a similar statement to Section Basic setup and shape data.

Reviewer:

- Line 158: Spacing. "Fig. 4 b" -> "Fig. 4b" to match "Fig. 4a" on line 156.

Answer:

Changed so that they now match.

Reviewer:

- Line 158: "This approach is analogue to the analytic T-matrix method, only in a much more numerical way." I am uncertain if many readers will appreciate the analogy.

Answer:

We removed it.

Reviewer:

- Line 168: "stokes" -> "Stokes"

Answer:

Changed as suggested.

Reviewer:

- Line 195: The number of incidence angles seems to be rather low. The reviewer recognizes that adding more would be prohibitively expensive, and that the manuscript is already a substantial improvement on what was available before. However, it might be worth commenting on in the text.

Answer:

We agree that it can seem to be, but the number of incidence angles is not low. Unfortunately, we forgot to mention in the text what accuracy we aim for the database. We now state in Section Basic setup and shape data that we aim for an accuracy of the scattering database in the order of a few percent. Relative to this, the number of incidence angles is sufficient. We further added some sentences considering the number of incidence angles.

Reviewer:

- Line 202: “appendix” -> “Appendix”

Answer:

Changed as suggested.

Reviewer:

- Section 4.1: Particle rotation: No comments here.
- Lines 252, 253, 256: “stokes” -> “Stokes”

Answer:

Changed as suggested.

Reviewer:

There were 69 particles overall, and 7245 cases, with over a million core hours, and about 1.5 TB or raw data. However, are users of the database are restricted to the orientationally-averaged set? The summary section, line 517, implies that only the summarized data are available.

Answer:

Yes, only the averaged data is publicly available, because it is not feasible for us to host the non-averaged data, but the data can be given to anyone who is interested by contacting us. We added a similar statement to the text.

Reviewer:

- Line 290: spacing. “scattering matrix Zaroand” -> “Zaro and”

Answer:

Changed as suggested.

Reviewer:

- Eqn 33: there is a spurious dot between the two lines of the equation. Was this supposed to be a comma?

Answer:

We corrected it.

Reviewer:

- Line 295: Wrong font for absorption vector “a”.

Answer:

We corrected it.

Reviewer:

- Line 307: “3” -> “three”

Answer:

Changed as suggested.

Reviewer:

- Lines 337-350, 375, Fig. 8,9 captions: PDF rendering problem with the asymmetry parameter.

Answer:

We corrected it, see answers to section-by-section Particle orientation.

Reviewer:

- Line 361: “Eqn.” -> “Eq.” to match how you abbreviate everywhere else.

Answer:

Changed as suggested.

Radiative transfer simulations

Reviewer:

No major comments.
- Line 456: “addionally” -> “additionally”

Answer:

Changed as suggested.

Reviewer:

- Line 487: “sphere like” -> “sphere-like”

Answer:

Changed as suggested.

Summary

Reviewer:

Good section overall. Some of the information here should be highlighted in the abstract.

Answer:

Done as suggested.

Reviewer:

- Line 552: fix opening quote before Climate

Answer:

Done as suggested.

Appendices

Reviewer:

No major comments.
- Lines 569, 577, 614, 616, 617: fix rendering

Answer:

We corrected it, see answers to section-by-section Particle orientation.

Reviewer:

- Line 592: See comment in Particle Orientation section.

Answer:

See first answer in answers to section-by-section Particle orientation.

References

Reviewer:

Various formatting typos.
- Line 666: “in: 2016” -> “in 2016”?

Answer:

No, it is correct as it is. It is the official citation from IEEE.

Reviewer:

- Line 670: “157?GHz”

Answer:

Corrected it.

Reviewer:

- Line 700: “let”?

Answer:

Changed to”IET”.

Reviewer:

- Lines 701-704: Title capitalization is inconsistent with other references.

Answer:

Corrected it.

Reviewer:

- Line 706: Cambridge University Press (capitalization)

Answer:

Corrected it.

Reviewer:

- Line 726: "ADDA: Capabilities". Capitalization in contrast to line 662.

Answer:

Corrected it.

References

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