

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

**Anonymous Referee #1**

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### General comments

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. The reviewer congratulates the authors on this achievement.

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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.

### Section-by-section comments

#### Abstract:

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

- 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.

- Line 8: dipol -> dipole

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

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

#### Introduction:

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 parti-

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cle 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.

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

- 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.

- 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.

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

- Line 24: “realistically shape” -> “realistically shaped”

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

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

Particle orientation:

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

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- 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  $l_{xx} = l_{yy} = l_{zz}$ .

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.

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

- 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.

- Line 52: “three dimensional” -> “three-dimensional”

- 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  $z[\text{box}]z'$ ). This happens on different machines (macs, Windows) and using different PDF readers.

- Line 62: “important to know” -> “important to note”

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

- Line 66: You are considering only generally oblate particles (and your particle model

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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).

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

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

- 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?

- 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.

#### Basic setup and shape data

This section reads well.

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

- 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

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be rephrased. Or, prefix with the sentences in lines 127-128.

- 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.

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

- Line 135: Why are the sizes slightly different?

- Line 142: Why are the frequencies slightly different?

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

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

- 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.

- Line 168: “stokes” -> “Stokes”

- 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.

- Line 202: “appendix” -> “Appendix”

- Section 4.1: Particle rotation: No comments here.

- Lines 252, 253, 256: “stokes” -> “Stokes”

#### Results of the scattering simulations

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

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orientationally-averaged set? The summary section, line 517, implies that only the summarized data are available.

- Line 290: spacing. "scattering matrix Zaroand" -> "Zaro and"
- Eqn 33: there is a spurious dot between the two lines of the equation. Was this supposed to be a comma?
- Line 295: Wrong font for absorption vector "a".
- Line 307: "3" -> "three"
- Lines 337-350, 375, Fig. 8,9 captions: PDF rendering problem with the asymmetry parameter
- Line 361: "Eqn." -> "Eq." to match how you abbreviate everywhere else.

#### Radiative transfer simulations

No major comments.

- Line 456: "addionally" -> "additionally"
- Line 487: "sphere like" -> "sphere-like"

#### Summary

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

- Line 552: fix opening quote before Climate

#### Appendices

No major comments.

- Lines 569, 577, 614, 616, 617: fix rendering
- Line 592: See comment in Particle Orientation section.

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#### References

Various formatting typos.

- Line 666: "in: 2016" -> "in 2016"?
- Line 670: "157?GHz"
- Line 700: "let"?
- Lines 701-704: Title capitalization is inconsistent with other references.
- Line 706: Cambridge University Press (capitalization)
- Line 726: "ADDA: Capabilities". Capitalization in contrast to line 662.

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Interactive comment on Atmos. Meas. Tech. Discuss., doi:10.5194/amt-2019-382, 2019.

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