Geosci. Model Dev. Discuss.,
https://doi.org/10.5194/gmd-2020-359-AC1, 2021


Geoscientific Model Development Discussions

# *Interactive comment on* "snowScatt 1.0: Consistent model of microphysical and scattering properties of rimed and unrimed snowflakes based on the self-similar Rayleigh-Gans Approximation" *by* Davide Ori et al.

**Davide Ori et al.**

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Received and published: 1 February 2021

**Reviewer** This paper describes a new modeling system for computing the radiative properties of snow particles in the microwave band. As such, it has the potential to move the field of microwave radiative transfer from its earlier (though still relatively recent) numerical experiments and databases for a limited set of frequencies and particle shapes to a practical community resource that appears to be both easy to use and of wide potential applicability. It includes an impressive database of modeled snow aggregates, both rimed and unrimed, and it utilizes a computationally efficient and flexible



numerical methodology – the self-similar Rayleigh-Gans Approximation (SSRGA) – for the single-particle scattering calculations. I don't know of any other research group undertaking something comparably ambitious and versatile, and I predict that this will quickly become a go-to tool for radiative transfer calculations and as a foundation for inverse methods related to both passive and active microwave remote sensing.
Except for a few specific instances noted below, the paper is well-written and quite thorough in describing both the methods and the limitations of the tool. I visited the github repository and found that the software is convenient to download and install, though I haven't tried using it yet. There's a good start on documentation, though some sections appear not to have been written yet. My overall recommendation is to publish after considering the comments below.

**Author** *Thanks for the very encouraging words and the insightful comments. We agree that the initial code documentation was not exhaustive. We have expanded and completed it in our revised submission.*

**Reviewer** Minor comments:

**Reviewer** lines 54, 131: The SSRGA is introduced here with appropriate citations, but for readers who haven't read those other papers yet, an additional sentence or two explaining what "self-similar" means in this context could be helpful.

**Author** *We have introduced the concept of snowflake self-similarity.*

**Reviewer** line 61: Offhand, at least, I don't know what a "Rayleigh distribution of polarimetric components" is, so maybe a slight elaboration would be useful here as well.

**Author** *The term has been avoided entirely and substituted with a more clear statement about the polarimetric components of RGA Rayleigh scattering.*

**Reviewer** line 77: "parametrized" should be "parameterized"

**Author** *Corrected*

**Reviewer** Eq. (3): The RGA yields a symmetric scattering phase function, as shown by this equation. But I believe that for diameters D (where D is the dimension in the direction of the propagating wave) much greater than about $0.1\lambda$, the phase function quickly shifts toward stronger forward scattering owing to consistently constructive interference in the forward direction (irrespective of size) and varying degrees of destructive interference in the backward direction. Since this is mainly a geometric effect, I'm not even sure whether small $|n - 1|$ eliminates that asymmetry, so I'm wondering whether Eq. (2) tells the whole story. In other words, a particle with kD âĹij 1 or greater, should not, I don't think, conform to Eq. (3) regardless of whether it satisfies Eqs. (1) and (2). If I'm mistaken on this, please disregard this comment, but it would be worth checking and clarifying, if needed.

**Author** *Eq. (3) yields a symmetric scattering phase function only if one does not consider the angular dependency of the form-factor. The sin(theta/2) in the argument of the form-factor in equation (3) takes into account the angular dependency of the phase delays of the various scattered waves from 0 in the forward direction to the maximum (2*k*D) in the backward. Of course, if D«$\lambda$, this effect is not relevant and the phase function appears symmetric.*
*The condition on |n-1| does not change this feature and the reviewer is totally correct on this. The point of misunderstanding was on the symmetric nature of the phase function which is actually not symmetric. As pointed out also by Reviewer 2, this passage in the theoretical formulation was unclear and needed to be written more carefully. We hope that the new version helps avoiding possible points of confusion. In particular, we stressed more on the relevance of the angular term in the argument of the form-factor.*

**Reviewer** line 119: Is V the spherical-equivalent volume?

**Author** *We would prefer to avoid the term spherical-equivalent volume since V is the volume of the particle occupied by the dielectric material regardless of its shape. In the case of snowflakes, it is the mass of the snowflake divided by the ice density. We have specified that to avoid confusion.*



**Reviewer** line 148: Fig. 1 is not completely convincing as regards the purported convergence of $\beta$ and $\gamma$. Any curve starts to look flat as it approaches zero on a linear axis. The point might be made more convincingly if a log vertical axis were used in the plot.

**Author** *We have switched to a log vertical axis as suggested.*

**Reviewer** line 467: For what it's worth, Petty and Huang (2010) found that neither Bruggeman nor Maxwell-Garnett dielectric mixing formulas gave the best fit to DDA calculations for soft spheres but rather Sihvola (1989) with an exponent of 0.85.

**Author** *We have computed again the T-matrix solution using the Sihvola generalized mixing formula with the nu parameter set to 0.85 as suggested. The plots and the data have been updated accordingly.*

**Reviewer** General: Several references are made to the computational cost of the DDA method. While true, note that Petty and Huang (2010) demonstrated a variation on the method that at least avoids the extremely large memory requirement of DDSCAT in the case of low density aggregates and effectively allows smaller dense linear systems to be solved rather than very large sparse ones. In other words, I think DDSCAT might not be the ideal benchmark for evaluating the viability of the DDA approach in a resource-limited computational environment. DDA calculations can be run inexpensively on desktop workstations using the alternative approach.

**Reviewer** *We are aware of the Coupled Dipole Approximation (CDA) approach used in Petty and Huang (2010). The DDA implementation we used is actually ADDA and not DDSCAT. ADDA implements a "SPARSE" mode which, despite its name, is analogous to the CDA method https://github.com/adda-team/adda/issues/98. Davide Ori also explored the possibility to leverage on the low memory footprint of the method to accelerate the computations further using GPU computing http://amsdottorato.unibo.it/7521/ https://github.com/adda-team/adda/tree/sparse_ocl*
*Although the approach is very interesting for the mentioned application (computing*

*the microwave scattering properties of low-density aggregates) it becomes not feasible when the number of scattering elements is large. This is a problem for our application that involves either rimed particles (high density) or high frequency (increased requirements with respect to particle shape resolution).*
*Despite the memory footprint being low, the computational complexity of CDA is O(n**2), where n is the number of volume elements composing the aggregate shape. This leads to a rapid increase in the computing time needed to solve the system of linear equations as the number of scattering elements increases.*

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