

## ***Interactive comment on “Investigation of ice particle habits to be used for ice cloud remote sensing for the GCOM-C satellite mission” by H. Letu et al.***

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Response to the comments of reviewer#1

The Voronoi model is compared to pristine hexagonal columns, plates, bullet-rosettes and droxtals. Already since the first POLDER publications in the 1990s that also used the SAD method, in addition to analysis of polarized reflectances, it is clear that pristine crystals with hexagonal parts are inconsistent with the measurements. Basically all the papers referred to on page 31669, line 21-23, and page 31670, line 5-6, come to this conclusion. Including pristine crystals in the analysis performed here is therefore pointless. Since discussion of the pristine models compared with the Voronoi model

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takes up most of the paper, either that analysis needs to be repeated with rough models or in my opinion the paper should be rejected in the current form. In figure 10, the rough 5-plate aggregate is shown. I assume the optical properties for that habit are obtained from the Yang et al. database. The authors may want to use the optical properties of other rough particles in that database instead of their own calculations. Otherwise, a shorter paper just focusing on the Voronoi particles may be suited for publication. Aside from this main comment, there are various other major shortcomings in this paper, as well as some minor issues. Below my other major and minor comments are listed. Should the paper be accepted in some form, I recommend these issues to be addressed. Both the conclusions and the abstract should also be revised accordingly.

Answer: The reason for using hexagonal column, plates, bullet rosettes, and droxtal habits in this study is to provide a sense of different optical properties and to determine the optimal habit model used in the ice cloud retrievals. As the reviewer mentioned, some pristine models employed in this study were already investigated in previous studies. We have reduced the description about the pristine models in the manuscript. However, I don't think it is a full replication of previous studies to include the results for pristine models because compared to previous studies we have more data processed and in a fully consistent manner so it does make sense in my view to keep the results for the other pristine models even if we emphasize and focus on the results obtained for the Voronoi. It can easily be justified that we want to maintain other results in the paper because it is the first publication that compares all models in a consistent way for the exact same observation dataset. Even if previous studies came to the same conclusion, it reinforces our analysis and provides a reliable basis for discussing the Voronoi model. So we want to reduce the discussion of the pristine models but still keep those in the current paper for full reference.

Major comments:

1) A model is searched to be used for optical thickness and size retrievals using the commonly used Nakajima-King approach as illustrated in Fig. 6. Such an approach re-

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quires the optical properties to be integrated over size distributions as shown by Baum et al. (2005). The authors define an effective radius in Eq 6., where a size distribution is used, although not specified. However, in their SAD analysis, as far as I understand, only single particle optical properties are used. To be consistent with their goal, I recommend using size-distribution integrated optical properties for the SAD analysis. It should be specified which size distributions are used. The conclusion that small bullet rosettes are consistent with the data is because these tiny crystals have size parameters well below 100 and therefore smooth phase functions. However, the contribution of these small particles to scattering properties for any realistic size distribution is probably negligible. Thus, I expect only the Voronoi model to be consistent with the measurements once size distributions are used, since the other models are pristine and have phase functions with features. Furthermore, it should be pointed out that for particle size retrievals, a model is needed that is consistent with measurements over a large range of sizes and not just a single size.

Answer: According to the suggestions, we have performed the size distribution integrated optical properties to SGLI scattering habit models using the particle size distribution (PSD) by Baum et al., (2005, 2011) for the SAD analysis.

The particle size distribution (PSD) of the effective radius defined by Nakajima and Nakajima (1995, JAS) is modified for simulating the data in Figure 6. The RSTAR radiative transfer model (Nakajima et al. 1986, 1988 and Sekiguchi et al. 2008) with single scattering properties database for various ice habit models is employed to simulate the graph in Figure 6.

In this study, except for Voronoi habit, various sizes of the hexagonal column, plates, bullet rosettes, and droxtal habits were chosen simply to provide a sense of different optical properties. The reason for using the various size of bullet rosettes is not only for investigating the shape of the bullet rosettes, but also for investigating whether the optical property of the bullet rosettes habits with varying size can satisfy the SAD measurements.

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#### Reference:

Nakajima, T., and M. Tanaka, 1986: Matrix formulations for the transfer of solar radiation in a plane-parallel scattering atmosphere. *J. Quant. Spectrosc. Radiat. Transfer*, 35, 13-21.

Nakajima, T., and M. Tanaka, 1988: Algorithms for radiative intensity calculations in moderately thick atmospheres using a truncation approximation. *J. Quant. Spectrosc. Radiat. Transfer*, 40, 51-69.

Sekiguchi, Miho, and Teruyuki Nakajima. "A k-distribution-based radiation code and its computational optimization for an atmospheric general circulation model." *Journal of Quantitative Spectroscopy and Radiative Transfer* 109.17 (2008): 2779-2793.

2) Several definitions are unclear in the paper. On page P316672,  $r^*$  is named the effective radius, but it is defined as the radius of an equivalent volume sphere. Effective radius for a single particle is usually defined as three-fourth of the volume over the projected area, which is a relevant size definition for determining the single scattering albedo. Using the term "effective radius" for  $r^*$  is confusing and should be avoided. I suggest to name  $r^*$  "volume-equivalent radius".

Answer: In order to avoid the confusion, we have used the name  $r^*$  "volume-equivalent radius" instead of "effective radius" according to the suggestions.

In equation 6, a size-integrated effective radius is defined, which adds to this confusion as it is unclear which "effective radius" is meant in the following parts of the paper. Furthermore, the effective radius defined in Eq. 6 is based on the size distribution weighted integration of  $r^3$  and  $r^2$ . If I am correct this is not consistent with the usual definition of effective radius for non-spherical ice, which is three-fourth of the total volume over the total project area. Please use the common definition of effective radius or rename it and use a symbol other than  $r^*$ .

For the calculation of effective radius as defined in eq. 6, size distributions are needed.

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What size distributions are used here? For non-spherical particles it is not trivial to choose a size distribution to obtain a specific effective radius (as it is for spheres). For example, this problem was described and tackled by Baum et al. (2005, 2011) by applying about 14000 size distributions and sorting them for effective radius afterwards. It seems that here  $r_e$  is only used for figure 6 in the current version, but the authors should discuss the size distributions applied as also remarked in my previous comment.

Answer: As the reviewer pointed out, the calculation of effective radius as defined in Eq. 6 is not consistent with  $R_e$  in Eq. 4. Thus, we have modified the Eq. 6 based on the paper by Baum et al (2005,1011). Furthermore, we have removed Fig. 6 from the manuscript (The reason is described in answer 1).

On page 31679, the comparison to other models from “conventional studies” is described. The optical properties of GHM model are provided by Bryan Baum. If I am correct, the optical properties available for the GHM are already integrated over size distributions and are given for specific effective radius (defined in the traditional way). However, here the authors say they compare the model using a single particle equivalent volume radius  $\hat{r}$  of 30 micron. I doubt that this is correct. Although this may not matter much for the analysis, it is all very confusing and inconsistent.

Answer: As we answered in question 1), we have performed the size-distribution integrated optical properties on the SGLI habit models as shown by Baum et al., (2005, 2011) for the SAD analysis in the revised manuscript.

3) The calculations for the SAD analysis are very unclear. Equation 3 on P316674 is technically incorrect. The right part is an observed quantity, while the left part is a modeled quantity since the  $\tau$ ,  $\omega$  and P11 dependency is included. In the following it is very unclear what is modeled and what is measured. The SAD analysis compares measurements with simulations, but nowhere in these equations there is a difference taken between measurements and simulations. Also, the step-wise description on page P316674-75 suggests that this is applied on a pixel-by pixel basis, while

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the model evaluation is done on globally, temporally averaged data. The SAD analysis is probably better explained in some previous Baran et al. papers, so I suggest to correct the equations and description based on such previous work. It should also be pointed out that simulated  $R_{cld}$  is a function of  $\tau$ ,  $\omega$  and P11, but then not also of  $r_e$ . The  $r_e$  dependency of  $R_{cld}$  comes from the dependency of  $\omega$  and P11 on  $r_e$ .

Answer: According to the suggestion, we have modified Eq. 3 in the manuscript and have added the new description about it in the improved manuscript.

Aside, the SAD analysis is described here in terms of  $r_e$ , while the applied SAD analysis is in terms of  $\hat{r}$ . This should be made consistent. As pointed out in my previous comment, the SAD analysis should also be performed using size-integrated phase function.

Answer: According to the suggestion, we have re-analyzed the SAD analysis by applying the size-integrated phase function.

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Interactive comment on Atmos. Chem. Phys. Discuss., 15, 31665, 2015.

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