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Interactive Comment

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#2

1) In the big picture, this is the sort of study that should be done more often. The authors make a good faith effort to compare the ice cloud bulk scattering models currently developed by different groups in the scientific community for use with a variety of satellite (and other) programs and make the case for how the GCOM-C team is choosing its own ice cloud bulk scattering model. There is some interesting material in this article, but a close reading of the text also led to a number of questions that need to be addressed before publication. To me, it seems that the paper was submitted a bit too

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quickly as there are some loose ends that need to be tied up. The scientific issues will be listed below. I would also urge the authors to submit their revised paper to someone, perhaps a co-author or colleague, who will carefully edit it to improve the grammar. Further, the verb tenses need to be more consistent throughout the manuscript. The authors tend to jump between present and past tense. Because of the numerous grammatical changes I found in reading this manuscript, I will not attempt to list them and will confine my comments to the scientific questions. Answer: according to the suggestion, we are going to submit the revised manuscript to the co-authors and to a proofreading service company for improving the grammar before finally re-submitting the manuscript.

2) Section 2, page 7, a lot of questions on my part: I am puzzled by the choice of habits chosen for comparison with the Voronoi particle for this study: hexagonal column, plates, bullet rosettes, and droxtals. In a given particle size distribution, is there any thought given to whether the choice of habits makes sense from a microphysical point of view, or was a habit chosen simply to provide a sense of different optical properties? For example, droxtals were employed in the Collection 5 MODIS models to represent only the very smallest particles in a given size distribution. This habit was never meant to be used for any particle larger than a few tens of microns in size. In this study, droxtals of all sizes seem to be employed - why did the authors choose this habit for comparison? It should also be stated that for Collection 6, MODIS now uses only an aggregate of solid columns for its operational retrievals, not a habit mixture. Answer: In this study, the hexagonal column, plates, bullet rosettes, and droxtal habits were chosen simply to provide a sense of different optical properties. The reason for adopting the droxtal habits with large sizes in the SAD analysis is not only for investigating the shape of the droxtal, but also for investigating whether the optical property of the Droxtal habits with varying size can satisfy the SAD measurements. Comparing with 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, although we will be emphasizing the results obtained for the Voronoi.

3) With regard to the choice of plates: plates do not tend to grow to sizes larger than about 500 microns and are not generally employed in bulk scattering models to represent large particles. What is the reasoning for using this habit at larger sizes?

Answer: Similar to the above answer, we employed the large particle (>500um) of the plate in this study to provide a sense of different optical properties and to further investigate the optimal particle model for ice cloud remote sensing.

4) With regard to the columns: are these hollow or solid? That is, are there hollow cavities at each end of the particle, or air bubbles within the particle?

Answer: The simple solid column models do not include air bubbles, were employed in this study. In the revised paper, we now use the term "solid" hexagonal ice column to avoid any confusion.

5) With regard to the bullet rosette: exactly what form of the bullet rosette did you use for your calculations? How many branches? Were the branches solid or did they have hollow cavities at the end of each branch?

Answer: As described in Line 25-27 Page 7, the definition of bullet rosettes in this study is same as the definition used in the scattering database by Yang et al., (2000).

6) I also have a number of questions about the Voronoi particle - this is a very interesting habit but little information is provided about it. Among the questions I have about this particle are the following:

(1) is a single particle adopted for each maximum diameter, or is a distribution of particles assumed from which an effective radius is calculated? This is not discussed.

Answer: Thank you very much for your valuable comments. The effective particle radius is defined as the radius of the equivalent volume sphere (See Line 18-20, Page 8).

(2) I would like to see a figure that shows the total volume and total projected area as a

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function of particle size for the Voronoi particle, and for comparison show a more well-known particle such as the column. further, it would be interesting to see asymmetry parameter, single-scattering albedo (at a slightly absorbing wavelength) and maybe extinction efficiency as a function of effective radius/diameter.

Answer: According to the suggestion, we have added the variations of the total volume, total projected area, asymmetry parameter and single scattering albedo (at a slightly absorbing wavelength) for Voronoi and well-known particles of column and plate at 2.2um in the revised manuscript. Please see Figure 1 in the attached file.

[Figure 1: Variations of volume, projected area, single scattering albedo and asymmetry factor as function of the maximum distance from the center of mass (half of the maximum dimension) for Voronoi, plate and column particles at a wavelength of 2.2um]

(3) if the Voronoi particle is used to represent all sizes, from the smallest to the very largest particles in a size distribution, what does it look like for very small particles? It would be illustrative to show a representation of this habit for very small, medium, and large sizes.

Answer: According to the suggestion, we have added the illustration of the Voronoi particles with various sizes in the manuscript based on the description by Ishimoto et al. (2012).

7) Section 3, questions regarding the use of SAD analysis: The authors are making heavy use of the SAD approach, and POLDER/PARASOL data, in their analysis for the optimal choice of ice habits/models for use by GCOM-C. As noted by the authors, the assumption in the SAD is that the ice clouds under analysis have a high optical thickness, generally having values greater than 5. So here are some questions relating to this:

(1.) Right away, this means that cirrus clouds are excluded as this subset of ice clouds generally has a much lower optical thickness. So I would suggest replacing "cirrus

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clouds” with “ice clouds” throughout the manuscript.

Answer: According to the suggestion, we have replaced “cirrus clouds” with “ice clouds” in the revised manuscript.

(2.) as a suggestion, use of the CALIPSO/CALIOP polarization lidar data would help to provide insight for optically thin ice clouds. It would be interesting to see how the Voroni particle behaves at low optical thickness values in direct comparison with the CALIOP retrievals. This could be done in future work, but it should be mentioned.

Answer: The suggestion by the reviewer is very important for further investigating the impact of the Voronoi particle on cirrus cloud retrievals. According to the suggestion, we have added the description about the suggested issue in the “conclusions” section of the revised manuscript as future work.

(3.) Are there other factors that could be influencing the SAD analysis that could lead to less agreement in the icebox region for example? Or can we assume that the choice of habit is the key factor here?

AnswerïijŽYes. Except for the particle habit, the surface roughness and whether the air bubbles included in the particles also influence the SAD analysis. For investigating the applicability of the Voronoi model, we compared it to the conventional ice particle models with surface roughness and air bubbles as shown in Figure 10. In the improved version of the manuscript, we have added the new description about the factors that influence the SAD analysis.

8) Section 4.1, page 12: The authors noted that the ice models currently in use now adopt particle roughening so that the solar-wavelength phase functions no longer have halos. Yet in Figure 4, results are shown for smooth ice particle habits in comparison with the Voronoi. The results in this figure should be changed so that all particles adopt roughening. Roughening is employed in other results, and the same assumption should be adopted with this figure too.

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Answer: In the previous study, it was reported that some complex aggregate ice habit models, column particle including air bubbles and particle model with rough surface showed good agreement with the SAD analysis. However, it is difficult to say that the research of the single ice particle model with smooth surface has been investigated enough. In this study, we adopted the four smooth ice particle habits (column, plate, droxtal, bullet rosette) with various sizes for comparison with the Voronoi as shown in Figure 4.

9. Page 13, Figure 6: why show results at a wavelength of 1.05 microns rather than at 0.67 or 0.87 microns?

Answer: Normally, the wavelengths of 0.68μm and 0.86μm are useful for retrieving the cloud optical thickness. However, the 0.68μm and 0.86μm channels of the SGLI were designed to observe the vegetation, ocean color and aerosol in GCOM-C satellite program. The maximum radiance (MRad) in these channels is lower than that of the cloud observing channels. Thus, observed radiance in these channels easily saturate when observing thick cloud. The wavelength of 1.05μm in the SGLI is designed to observe the cloud in GCOM-C mission. From Figure 6 we can also confirm that this channel is efficient for retrieving cloud properties.

10. Conclusions, page 17, line 10: as noted earlier, the use of the droxtal habit really does not make much sense. But my question for this conclusion is whether the results are based on smooth or roughened particles, or whether these particle model scattering properties are based on size distributions or simply a single particle for each given size - it's not clear to me.

Answer: As we stated in answer 1), the reason for using all sizes of the droxtal model is to provide a sense of different optical properties and to further investigate the optimal ice particle habit for retrieval of ice cloud properties.

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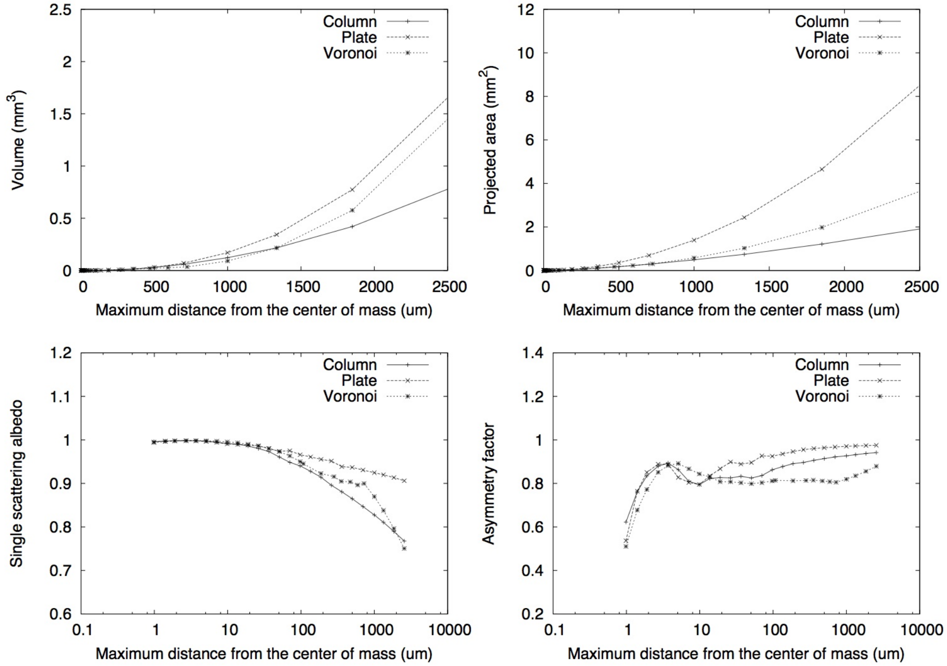

Fig. 1. Variations of volume, projected area, single scattering albedo and asymmetry factor as function of the maximum distance from the center of mass (half of the maximum dimension) for Voronoi, plate and c

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