Comments on “Investigation of ice cloud modeling capabilities for the irregularly shaped Voronoi models in climate simulations” by Li et al.

Anonymous Referee #2

General comments

This paper addressed the important problem about the modeling capability of ice cloud radiative forcing in climate simulations. An irregularly shaped Voronoi ice cloud particle model which was proven to be effective and efficient in satellite remote sensing retrieval purposes has been implemented in the RRTMG RTM and CAM5 climate model. Comparisons of modeling results with the Voronoi model along with the other four previously proposed ice cloud models are carried out. Further comparison between model results and the CERES SYN1deg radiative fluxes indicates that the Voronoi model provides the closest cloud radiative forcing to observation. This study could be a good supplement to understand the influence of ice cloud optical properties on simulated cloud radiative effects. The topic of this paper is within the scope of the journal of Atmospheric Chemistry and Physics. But unfortunately, the paper is not acceptable in the present form due to various issues.

Response: Thank you very much for your significant comments.

Major comments

1. Overall, the quality of this paper does not meet the standard of ACP. The problem is all-round, from simple wording and sentence expressions to the quality of figures and tables, data analysis, conclusions, and so on. There are so many things to be improved to make the paper better (please see details below).

Response: Thank you very much for your significant comments. We have revised the manuscript accordingly.

2. The authors should be cautious about the definition and the use of abbreviations. Several abbreviations are defined again and again. While some other abbreviations are defined and never used again. Abbreviations like AGCM are used without definition.

This may be just subtle issue but it could be an indicator of how the paper is carelessly prepared …

Response: According to the suggestions, we have removed all irrational abbreviations.

3. The authors need to pay more attention to the way to cite papers. Some of the names of the authors are wrong! For example, Line 47, "Hulst" should be "van de Hulst"; Line 68, "Labonnote" should be "C.-Labonnote". Incorrect citation formats also exist, for example, at Line 61, 63, 83, 86, etc. This is another indicator that the paper undergoes insufficient examination before submission.

Response: According to the suggestions, we have corrected the citations throughout the manuscript.

4. It looks like the "Baum-Yang" scheme in this paper is different from the "Baum-Yang" scheme in Wang et al. (2018). It may be better to rename the schemes to avoid confusion when the readers are comparing the two studies.

Response: As you mentioned, these two schemes are different from each other. We have renamed the ice cloud parameterization scheme formed by Baum et al. (2005b) as "Baum-yang05 scheme" hereafter in the manuscript.

5. Among the various schemes, Fu scheme actually has different definitions of effective diameter (see Fu et al., 1997). So the question is how can the Fu scheme be compared directly with the other schemes?

Response: As you mentioned, the Fu scheme uses the generalized parameter D_{ge} (as shown below Eq. (1)), the other four schemes use the effective parameter D_e (as shown below Eq. (2)). As D_{ge} can be converted to D_e by a constant, D_{ge} is unified to D_e for consistency.

$$D_e = \frac{3}{2} * \frac{IWC}{\rho A}, \tag{1}$$

$$D_{ge} = \frac{2\sqrt{3}}{3} * \frac{IWC}{\rho A}, \tag{2}$$

6. These Line 89-92: What's the point of mentioning CIESM at this point? Since CIESM is no different from CESM regarding the ice cloud scattering properties, there seems no need to mention it at all. After all, the authors are actually using the original CAM5, isn't it?

Response: Yes. As you pointed out, we actually use the CAM5 model in this study. According to the suggestions, we have removed the Line 89-92 on Page 2 related to CIESM.

7. I don’t like the way the authors organized the figure panels. It’s strange to me to use panel a1, a2, … and b1, b2, … in a same figure. Please consider following the conventional panel naming habit of (a), (b), (c), …

Response: According to the suggestions, we have renamed all figure panels using (a), (b), (c).

8. I don’t like the organization of section 3 either. Particularly, Line 140-159 is a mess. It may not be a good idea to briefly referring to something you will mentioned in detail later. It makes no sense and just add to the confusion of the reader.

Response: According to the suggestions, we have rewritten Line 140-159 in section 3 as shown below.

Page 7, 8: “In this study, we develop the Voronoi scheme and assess its effectiveness in comparison with Mitchell, Baum-yang05, Fu and Yi schemes. The main flowchart of this study is described in Figure 2. Five schemes are derived first and evaluated through standalone simulations in the RRTMG and multi-year simulations in the CAM5. The simulations of cloud radiative properties from different ice cloud optical property parameterizations in CAM models are evaluated by CERES satellite observation products. The RRTMG is utilized to understand how the different optical properties of five schemes influence the upward/downward fluxes through standalone simulations. The CAM5 is employed to evaluate the ice cloud modelling performance of the Voronoi model compared with the other four schemes in the climate system.”

9. More details about the particle size distributions should be given. The authors may add a figure to show how the PSD looks like.

Response: According to the suggestions, we have added the figure of PSD (Figure 2) in the manuscript as shown below.

Page 29:

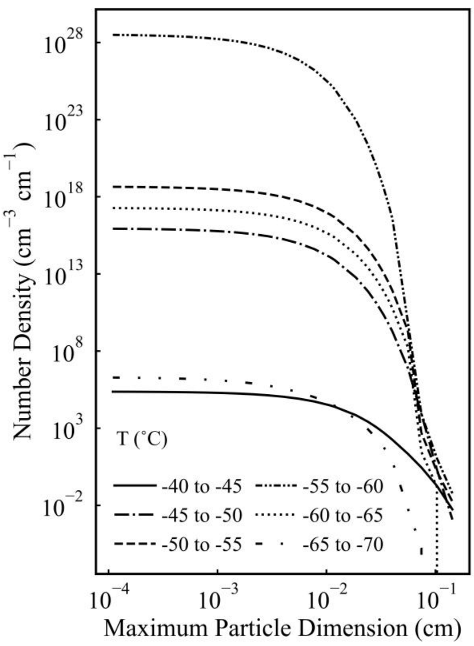

Figure 2. Ice cloud particle size distributions for different temperature.

10. Why do the authors choose to use CERES_SYN1deg_Ed4A products for comparison with GCM modeling results? What is the temporal range of data used? Usually, the CERES EBAF dataset is a better choice for this purpose. Since the authors' choice will apparently affect the evaluation results, it is quite necessary for the authors to elaborate the reasons more convincingly.

Response**:** According to the suggestions, we have used CERES EBAF Ed4.1 products from January 2001 to December 2010 for validation in this study.

11. The authors should do a better job of relating the optical properties of different ice cloud models with the simulated SWCF and LWCF. It is still confusing to me that why the Voronoi model possesses the lowest asymmetry factor in the SW but however exhibits the lowest SWCF compared with the other models? In short, why the Voronoi model could be the better choice?

Response**:** Firstly, the difference of asymmetry factor of different schemes is mainly attributed to different ice particle habits or shapes utilized in each scheme. Secondly, as shown in the Figure 1 below, the difference of ice cloud bulk optical properties between different schemes indicate that the Voronoi scheme possesses the lowest asymmetry factor compared to the other four schemes. The lowest asymmetry factor of Voronoi scheme can result in more reflected TOA radiation than the other four schemes. The difference of reflected radiation for cloudy and clear conditions are reduced, which can result in closer SWCF of the Voronoi scheme to the satellite observations.

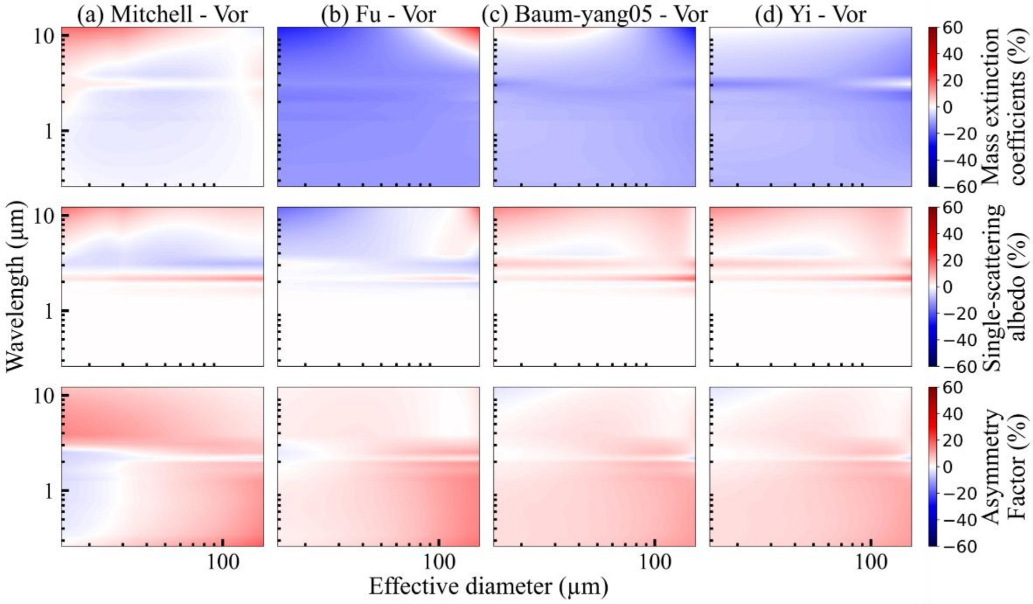

Figure 1. Relative percentage of differences of (top row) mass extinction coefficients, (second row) single scattering albedo, (third row) asymmetry factor as functions of ice particle effective diameters and shortwave bands in CAM5 between the other four schemes and Voronoi scheme.

12. Many grammar mistakes and sentence errors could be found in the manuscript. The authors should pay more attention to polish the English language. Several captions of figures and tables also need to be rephrased. For example, Table 3 and Figure 9 all miss the units. While caption of Figure 5 is too complicated to understand.

Response**:** According to the suggestions, we have proofread the manuscript, added units to the Table 3 and Figure 9 in the manuscript and rewritten the caption of Figure 5.

Minor comments

1. Line 17-18: "While abundant irregularly shaped ice particle habits present a challenge for modelling ice clouds." – please be clear about what challenge is the authors referring to.

Response**:** We have modified the sentence as "Complexities of ice particle habits/shapes and sizes make it difficult to select a representative ice scattering model for simulating the real ice cloud scattering properties.”.

2. Line 24: There may be no need to express the names of the other four schemes since they are not used again in the abstract, and the readers still could not understand what the names are referring to.

Response**:** According to the suggestions, we have removed the names of the other four schemes in the abstract.

3. Line 25, 27, 30: RRTMG, CERES, SW and LW are never used again in the abstract. May not need to define the abbreviations.

Response**:** According to the suggestions, we have deleted the unused abbreviation names in the abstract.

4. Line 91: “CAM5 in CIESM was modified with several new schemes”- what are the changes which relate to this study?

Response**:** Changes include cloud macrophysics including cloud fraction and condensation using PDF cloud scheme (Qin et al., 2018) and cloud microphysics using single-ice scheme from Zhao et al. (2017). The ice cloud parameterization scheme (Mitchell scheme) remains unchanged in the CAM5 in CIESM. However, according to the aforementioned suggestions, we have removed contents related to CIESM in the manuscript.

5. Line 101-105: Very complicated sentence which contains error.

Response: According to the suggestions, we have rewritten these expressions in the manuscript as shown below.

Page 5:

“Ishimoto et al. (2012) developed an irregularly shaped Voronoi model based on in situ microphysical measurements. Letu et al. (2016) compared the Voronoi model with the conventional general habitat mixture (GHM) (Baum et al., 2011), IHMs (C.-Labonnote et al., 2001), 5-plate aggregate (Baum et al., 2005a, 2011), and the ensemble ice particle model (Baran and Labonnote, 2007) through minimizing the difference between the observed polarized reflectivity and the simulations. The results indicated that the irregularly shaped Voronoi model outperformed with the measured polarized reflectivity from the POLDER observations."

6. Line 109: "has proven" should be "has been proven"

Response: According to the suggestions, we have corrected this irrational expression on page 5.

7. Line 138: It's very odd to see equation (1) here without any explanation.

Response: According to the suggestions, we have reorganized the layout of Eq. (1) as shown below.

Page 6:

"The definition of *SZP* is shown below,

$$SZP = \frac{\pi L}{\lambda}\ , \qquad (1)$$

where L is the ice particle maximum diameter."

8. Line 148: What is the temperature used in the Planck function?

Response: We defined the Planck function assuming a cloud temperature of 233K according to Liou (1992).

9. Line 157: "to validate the cloud radiative properties" – do you mean "cloud radiative Forcing"?

Response: Yes, we have replaced "cloud radiative properties" with "cloud radiative forcing" on page 7.

10. Line 166-167: Sentence error.

Response: We have corrected the Line 166-167 as shown below.

Page 8:

"$\sigma_{e,s}$ is the extinction and scattering cross section, respectively (See Table 1 for a list of acronyms), and σ_a is the absorption cross section given by $\sigma_a = \sigma_e - \sigma_s$."

11. Line 197-198: What is "standard tropics"? How are the 60 vertical levels distributed? Please give a reference.

Response: The term "standard tropics" means a U.S. Standard reference atmospheric model profile consisting of vertical profile for temperature and gas mixing ratios designed for tropic cases (15N annual average) (Anderson et al., 1986). The 60 vertical profiles are distributed from bottom pressure 1013.0 mb to the top pressure 0.0003 mb.

12. Line 201: "the same with" should be "the same as"

Response: Corrected.

Page 11:

"LWCF is defined the same as SWCF but for LW spectrum."

13. Line 242: should be Zhao et al. (2018)?

Response: Agreed, we have corrected the citation.

Page 12:

"This highest asymmetry factor of the Mitchell scheme is also found when comparing among other schemes in the study of Zhao et al. (2018)."

14. Line 264-266: Please change a way to express the range of values since the present form easily cause confusion.

Response: According to the suggestion, we have rewritten the sentence as "Figure 5 shows 6-30 W/m^2 differences in TOA upward fluxes, 10-40 W/m^2 differences in surface downward diffuse flux, 10-30 W/m^2 differences in surface net fluxes, and 8-42 W/m^2 differences in TOA net fluxes owing to five different ice cloud schemes.".

15. What is the version of RRTMG used?

Response: The version of the RRTMG used in our study is the current radiative code applied in the CAM5 (Mlawer et al., 1997; Iacono et al., 2008; available from http://rtweb.aer.com).

16. Line 320: The authors may need to specify the contribution of all authors.

Response: According to the suggestions, we have added more specific contributions of each author as shown below.

Page 16: "Ming Li developed the ice cloud optical property parameterizations (Voronoi scheme) based on the single-scattering properties of Voronoi models, compared the band-averaged optical properties of the Voronoi scheme with the other four schemes (Mitchell, Yi, Baun-yang05 and Fu). Ming Li also compared the upward/downward flux profiles from five schemes through RRTMG standalone simulations and radiative properties of five schemes in CAM5 model simulations, as well as downloaded the CERES products and wrote the initial draft of this manuscript. Husi Letu designed the aims and structures of this study and assisted in developing the parameterization of ice cloud optical properties based on the Voronoi models. Husi Letu also provided the single-scattering property database of Voronoi models and helped in analyzing the single-scattering properties of Voronoi models, as well as guided the writings and revisions of the manuscript. Yiran Peng and Yanluan Lin assisted in developing the ice cloud optical property parameterization of the Voronoi scheme and provided the climate models, as well as guided the settings of climate model runs and reviewing the manuscript. Hiroshi Ishimoto developed the single-scattering property database of Voronoi models, provided the database of Voronoi models and helped in the parameterization of ice cloud optical properties based on the single-scattering properties of Voronoi models. Takashi Y. Nakajima provided the single-scattering property database of Voronoi models, especially assisted in guiding the flowchart of this study and reviewed the manuscript. Anthony Baran guided the development of the ice cloud optical property parameterization and reviewed the paper. ZengYuan Guo assisted with the runs and design of the climate model simulations and helped with the review of the manuscript. Yonghui Lei assisted in analyzing the results and guided the flowchart of the study, as well as reviewed the manuscript. Jiancheng Shi assisted in designing the aims and structures of this study, guided the writings of the paper and helped reviewing the manuscript."

17. Line 513: "Ice particle effective size" – please be specific. Is it diameter or radius?

Response: The ice particle effective size is defined as "effective diameter".

Reference:

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