Comment on amt-2022-247

Referee comment RC4 on "Retrieval of Terahertz Ice Cloud Properties from airborne measurements based on the irregularly shaped Voronoi ice scattering models" by Ming Li et al.

Anonymous Referee # 1

General comments

The paper assessed the capability of the Voronoi and sphere models in the retrieval of IWP and re using aircraft-based measurements of 380, 640, and 874 GHz brightness temperature. Based on the sensitivity analysis, the brightness temperature differences between 640 and 874 GHz are used for IWP retrieval, while brightness temperature differences between 380, 640 and 874 GHz are used for re retrieval. The authors find well correlations between the Voronoi-based retrievals and Evan's Bayesian retrievals using data from the CoSSI instrument. The comparisons of the retrieved IWP and re between Evan' s Bayesian retrievals using data from the CoSSIR instrument and the inversion algorithm among the Voronoi and Sphere models suggest that the Voronoi model outperforms the Sphere model. Overall, the highlight of this paper is that the Voronoi model has been previously applied to visible and infrared applications in satellite remote sensing and climate model simulations, and now it is being applied over the terahertz region to investigate how well the model performs there. The paper is relatively wellwritten, and the figures are also well-displayed. The analysis is quantitative and clear, with no obvious flaws. This paper could be a good supplement to the development of satellite remote sensing of ice clouds in the sub-millimetre regions. The topic presented in this study is suitable for Atmospheric Measurement Techniques, so I recommend Minor Revisions for publication.

Response: Thank you very much for your significant comments.

Specific comments

1. To ensure the effectiveness and representativeness of the Voronoi model in

terahertz region, I recommend the authors compare the retrievals against more other ice crystal scattering models, such as the column aggregate?

Response: Thanks for the comments. We have added the hexagonal column ice crystal scattering (ICS) model from the ARTS collection of models to compare with our results in this study. The descriptions of the hexagonal column ICS model are added in section 2.1 as shown below.

Lines 149-151: "The randomly-oriented hexagonal column (referred to as the Column hereafter) ICS model was defined by Yang et al. (2000a). Their aspect ratios *a*/*L* (defined as the ratio of the semiwidth *a* of a particle to its length *L*) of Column ICS models are defined as 0.35 and 3.48 respectively when *L* is less than 100 μm and greater than or equal to 100 μm. The single-scattering property database of the Column ICS model used in the study is developed by Hong (2007, 2009) using the discrete dipole approximation method at frequencies of 100-1000 GHz."

2. How about the accuracy of retrieved IWP and re in previous research in terahertz band? Please illustrate in the introduction.

Response: Thanks for the comments. We have added illustrations about the result accuracy of previous studies in the terahertz band in section 1 as shown below.

Lines 76-81: "For the accuracy of the BMCI method, validation results stated that for clouds with IWP greater than 5 g/m^2 the overall median retrieval error is about 30% for IWP and 15% for D_{me} (Evans et al., 2002). Jimenez et al. (2007) used the neural network method to retrieve the IWP and D_{me}. Results showed overall median relative errors of around 20% for IWP and 33 μm for D_{me} for a mid-latitude winter scenario, and 17% for IWP and 30 μm for D_{me} for a tropical scenario. Based on these studies, Buehler et al. (2007) proposed a formal scientific mission requirement for a passive submillimeter-wave cloud ice mission based on the background and early research. The requirements are the low IWP should be less than 10 g/m^2, the high ice water path should be less than 50%, and the particle diameter should be less than 50 μm. Lately, Liu et al. (2021) proposed an inversion method for the remote sensing of ice clouds at terahertz wavelengths based on a genetic algorithm. Results showed the absolute error of the low IWP (below 20 g/m^2) is small, while the relative error of the high IWP is generally maintained at around 10%, and the absolute error of the effective particle diameter is mostly around 4 μm."

3. Line 98: The "GOA" acronym has not been defined.

Response: We have added the definition of the "GOA" as shown below.

Line 98: ".. several improved Geometrical Optics Approximation (GOA) methods .."

4. I recommend the authors add more analysis and possible explanations in the result section. I recommend the authors relate the single-scattering results to the retrieval results.

Response: Thanks for the comments. In this study, we have added more analysis and explanations of the results in terms of the differences in the single scattering properties of three ice crystal models. The following description is added at the end of section 4.4.

Lines 323-328: "According to the sensitivity results of Figures 6 and 7, the Voronoi ICS scheme has higher BTD_{2-3} and BTD_{1-3} compared to the Sphere and Column ICS schemes, especially for large particles and IWP. This characteristic is also shown in Figure 8. This can be explicitly explained by the larger asymmetry factor of the Voronoi ICS model compared to the Sphere and Column ICS models. Thus, stronger forward scattering energy can be detected for the Voronoi ICS model than the other two models. The look-up table of the Voronoi ICS model can cover more IWP and D_{me}. The brightness temperature variations of the Voronoi-shaped ice clouds are more prominent and sensitive to the IWP and D_{me}. Therefore, the results of the Voronoi ICS model are better than the other two models."

5. In Figure 9, the scattered dots are hard to statistically measure the accuracy. Figure 9 might be better plotted as a PDF of the retrievals.

Response: Thanks. We have modified the scatter plot in Figure 9 to a PDF plot, as shown below.

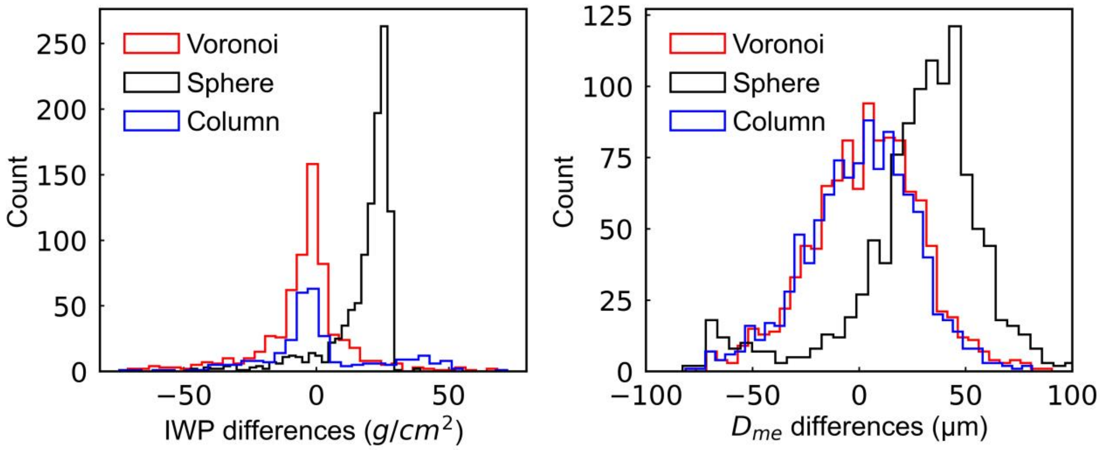

Figure 9: The joint histogram of differences of (a) the IWP and (b) D_{me} between the retrieved results and the CoSSIR-MCBI algorithm results for the Voronoi (red line), Sphere (black line) and Column models (blue line), separately.

6. Line 117: “Mo.,del” should be “Model”.

Response: We have corrected this error as shown below.

Line 117: “the Community Integrated Earth System Model (CIESM).”

Reference:

Buehler, S., Jimenez, C., Evans, K., Eriksson, P., Rydberg, B., Heymsfield, A., Stubenrauch, C., Lohmann, U., Emde, C., John, V., Tr, S., and Davis, C.: A concept for a satellite mission to measure cloud ice water path and ice particle size, Q J Roy Meteor Soc, 133, 109-128, 10.1002/qj.143, 2007.

Evans, K. F., Walter, S. J., Heymsfield, A. J., and McFarquhar, G. M.: Submillimeter-Wave Cloud Ice Radiometer: Simulations of retrieval algorithm performance, Journal of Geophysical Research: Atmospheres, 107, AAC 2-1-AAC 2-21, doi:10.1029/2001JD000709, 2002.

Hong, G.: Parameterization of scattering and absorption properties of nonspherical ice crystals at microwave frequencies, Journal of Geophysical Research, 112, 10.1029/2006JD008364, 2007.

Hong, G., Yang, P., Baum, B. A., Heymsfield, A. J., Weng, F., Liu, Q., Heygster, G., and Buehler, S. A.: Scattering database in the millimeter and submillimeter wave range of 100–1000 GHz for nonspherical ice particles, Journal of Geophysical Research: Atmospheres, 114, doi:10.1029/2008JD010451, 2009.

Jimenez, C., Buehler, S., Rydberg, B., Eriksson, P., and Evans, K.: Performance simulations for a submillimetre wave cloud ice satellite instrument, Q J Roy Meteor Soc, 133, 129-149, 10.1002/qj.134, 2007.

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Remote Sensing, 13, 735, 10.3390/rs13040735, 2021.
Yang, P., Liou, K. N., Wyser, K., and Mitchell, D.: Parameterization of the scattering and absorption properties of individual ice crystals, J Geophys Res-Atmos, 105, 4699-4718, 2000a.