Comment on amt-2022-247

Anonymous Referee # 2

Referee comment RC1 on "Retrieval of Terahertz Ice Cloud Properties from airborne measurements based on the irregularly shaped Voronoi ice scattering models" by Ming Li et al.

General comments

This paper investigated the ability of Sphere and Voronoi model in retrieving cloud microphysical properties such as ice water path (IWP) and effective particle radius (Re) using airborne measurements. Sensitivity results indicate that TOC BTDs between 640 and 874 GHz is used for IWP, while BTDs between 380, 640 and 874 GHz is used for Re. In addition, retrieved results of IWP and Re from Voronoi model are better than that of the Sphere model compared with airborne ones. Overall, this manuscript is clear. However, there are several issues that need to be taken care of before this paper becomes acceptable for publication.

Response: Thank you very much for your significant comments.

Specific comments

1. How about the previous research in terahertz band? In the introduction, I only saw Li's research (Li et al., 2016). How about the accuracy of retrieved IWP and Re of previous studies using different ICS models, like aggregates, hollow columns, flat plates, rosettes and spheres?

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."

2. The "Inversion results" part is too short, and the results and validation sections are not insightful. You simply present the validation metrics like MBE, RMSE, and R, etc. Why is the Voronoi better than the sphere model?

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 $BTD_{2\text{-}3}$ and $BTD_{1\text{-}3}$ 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."

3. For Figure 7, 2000 test data were generated by the RTSRA and plotted on the Figure 7 with black dots, why are there only 19 points?

Response: The 19 black dots shown in Figure 7 are only used to generally indicate that the selected test dataset is within the coverage of the look-up table. According to the comments, we have presented all 2000 test points using grey dots in Figure 7 as shown below.

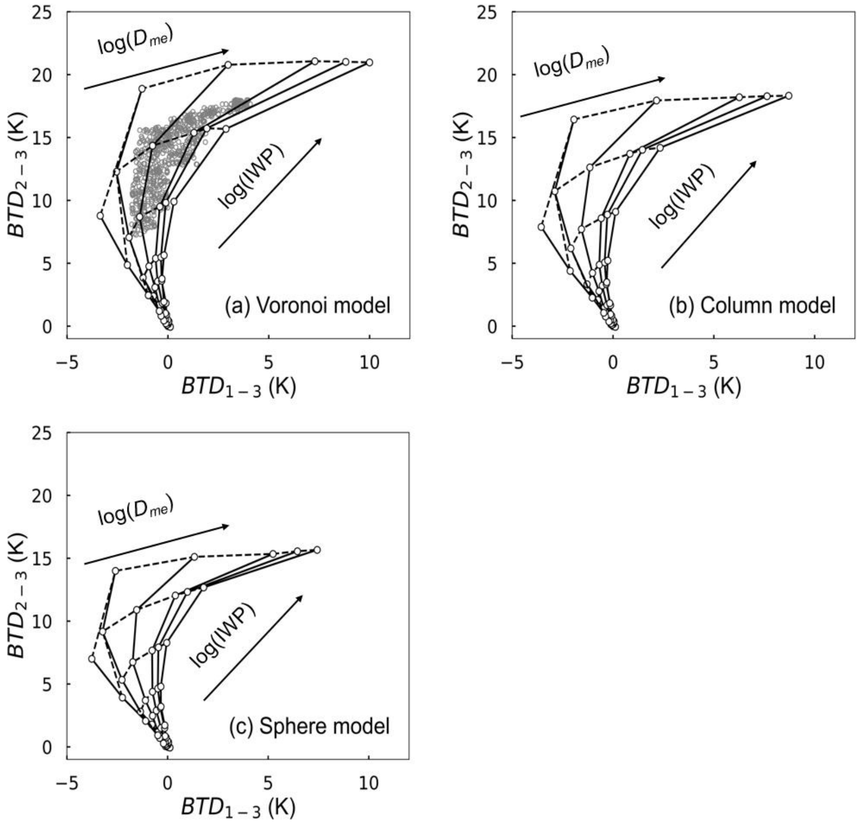

Figure 7: The LUTs of $BTD_{2\text{-}3}$ and $BTD_{1\text{-}3}$ for the (a) Voronoi, (b) Column and (c) Sphere ICS models varying with the logarithm of IWP and D_{me}. Grey dots in circles represent the randomly generated 2000 test data from RSTAR model.

4. Why do the problems of 1 and 2 in the figure occur, see below?

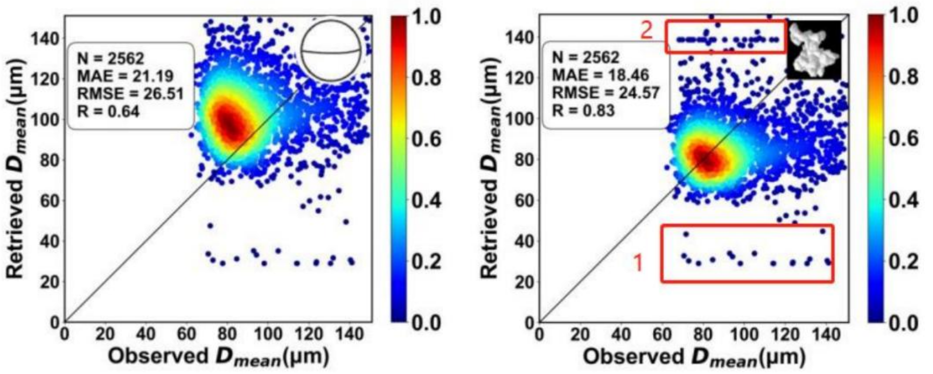

Figure 10: The scatterplots of the retrieved IWP (top row) and D_{me} (bottom row) against the CoSSIR-MCBI results for the Sphere (right column) and Voronoi (left column) ICS models.

Response: Thanks. According to the look-up table as shown above, there are overlapping lines when D_{me} is small (D_{me} < 40 μm) and large (D_{me} > 140 μm). When

BTD$_{2\text{-}3}$ and BTD$_{1\text{-}3}$ data fall under such overlapping lines of the look-up table, this overlapping region can lead to obtaining the same IWP and D_{me} when searching the look-up table. That is why the “horizontal line” problem occurs for $D_{me} < 40$ μm and $D_{me} > 140$ μm.

5. Increase the drawing range of Y in Figure 10, from currently 0~145, to 0~160. I want to see the sphere have the same horizontal line problem.

Response: According to the comments, we have increased the range of D_{me} from 0~145, to 0~160, and redrawn Figure 10 as follows. As shown below, the “horizontal line” problem does not exist for the Sphere and Column ICS models when $D_{me} > 40$ μm. That is because BTD$_{2\text{-}3}$ and BTD$_{1\text{-}3}$ do not fall where the lines overlap in the look-up tables for the Sphere and Column ICS models when $D_{me} > 40$ μm.

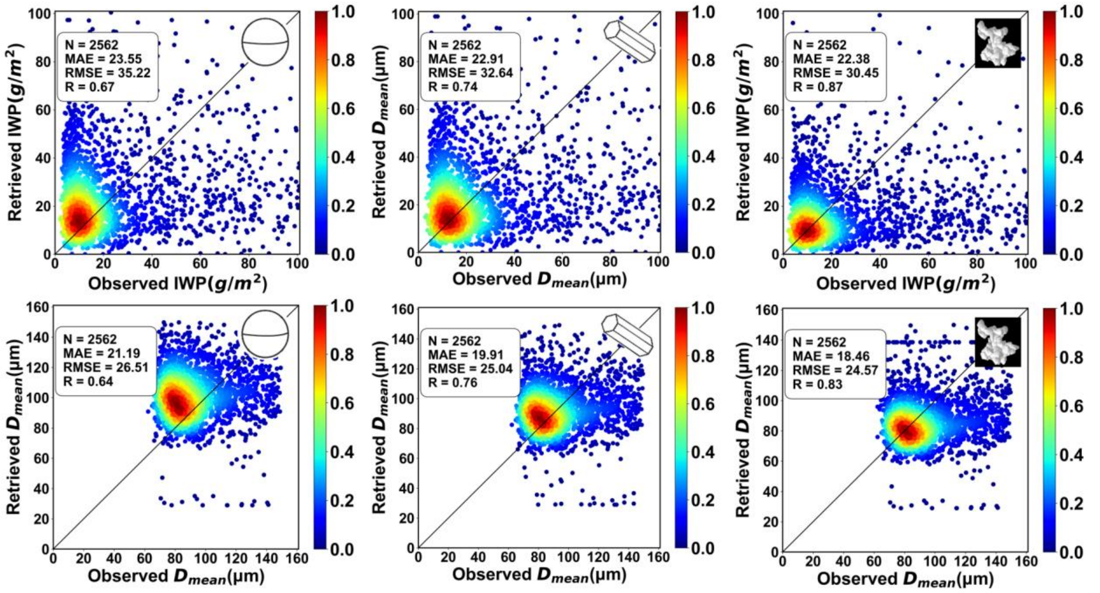

Figure 10: The scatterplots of the retrieved IWP (top row) and D_{me} (bottom row) against the CoSSIR-MCBI results for the Sphere (right column), Column (middle column) and Voronoi (left column) ICS models.

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.

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.

Liu, L., Weng, C., Li, S., Letu, H., Hu, S., and Dong, P.: Passive Remote Sensing of Ice Cloud Properties at Terahertz Wavelengths Based on Genetic Algorithm, Remote Sensing, 13, 735, doi:10.3390/rs13040735, 2021.