**Atmospheric Chemistry and Physics**

Discussions

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# *Interactive comment on* "Resolving ice cloud optical thickness biases between CALIOP and MODIS using infrared retrievals" *by* R. E. Holz et al.

## Anonymous Referee #2

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This is a review of the manuscript "Resolving ice cloud optical thickness biases between CALIOP and MODIS using infrared retrievals" submitted to ACPD by Holz et al.

The paper describes comparisons of ice cloud optical thickness of thin clouds retrieved with several different algorithms in order to evaluate the ice model assumptions in MODIS collection 5 and 6 retrievals and operational CALIOP retrievals. This is an important paper since the ice model has a profound effect on ice cloud optical thickness and size retrievals. The ice model adopted for MODIS collection 6 is very different from the collection 5 selection and this paper mostly justifies this update. Furthermore,

previous indications that the lidar ratio used by CALIOP is causing biases in extinction estimates are confirmed here and a correction is suggested.

The paper is generally written well, although some things can be clarified more. Also, I suggest some restructuring of the sections, as explained below. I certainly recommend publication in ACP after these minor corrections are made.

Minor comments:

Page (294)58, line 15: Please indicate the section describing the details of the data shown in Figure 1.

Page 60, line 19: Please give a short outline of the paper here, as is commonly done.

Page 61: line 9: What is the sensitivity to assumed effective radius? 40 micron is rather large, as also can be concluded from Fig. 8.

Page 63, Eq. 1: Which wavelengths are used for wl1 and wl2?

Page 63: The retrieval procedure is not entirely clear to me. Equation 2 does not contain the 11-micron emissivity. How is tau_abs retrieved from the measurements? And why are the cloud boundaries not needed here as they are for the other approach using 11-micron measurements? I realize that details are given in the Heidinger et al. paper, but please improve the explanation here.

Page 65, line 15: The notation 25+-10 sr is not clear. My interpretation is the CALIOP uses Sc = 25 sr everywhere and 10 sr is the uncertainty on it. If correct, I suggest rewriting this sentence to something like this: "the CALIOP V3 unconstrained retrievals use a globally constant default value of Sc = 25 sr with an estimated uncertainty of about 10 sr."

Page 68, line 22: Please give an explanation or a reference for these quality flags.

Page 71, line 12: Please indicate the scattering angle ranges corresponding to the left, center and right parts of the granule.

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Page 71, line 12: I suggest pointing out that the scattering angle dependency of the retrieved ice optical thickness is caused by the relatively strong angular variation of the C5 phase function.

Page 72, line 1: Please include a reference to the Yang et al. paper giving details about the models.

Page 72, line 1: Please describe the applied size distributions.

Page 72, line 4: These differences are an interesting result and I would suggest to add some more discussion. My interpretation would be that the various ice models have different relations between maximum diameter, volume and area, so that the size distributions, that are defined as a function of maximum diameters, applied to the various models lead to different distributions of volume and area associated with a given effective radius. This would imply that these differences really indicate more general uncertainties in the effective radius retrievals due to uncertainty in size distributions.

Page 72, line 11: Please add a note that the size dependency of certain models is due to the assumed ice crystals geometries varying with size, whereas the geometry of the aggregate of columns does not vary with size.

Page 72, line 13: Please add references to Yang et al. (2008) and Van Diedenhoven et al. (2014) related to the larger CER retrieved using the C6 model with smaller asymmetry parameter. The latter paper showed that the CER retrievals approximately scale as (1-g1)/(1-g2), i.e. as the inverse of the optical thickness retrieval sensitivity to assumed asymmetry parameter.

Page 72, last paragraph: I suggest to include the figures for the other ice models as supplementary material (similar to Fig 7a and 4b).

Page 73, line 26: "More recent investigations": Please add some references.

Page 74, line 6: I suggest removing "a modified gamma distribution" as the aggregate of columns model does not change with size.

Page 74, line 14: "are" is missing in first sentence.

Page 76, line 8: I suggest changing "randomly oriented ice clouds" to "ice clouds with randomly oriented crystals".

Page 76, line 7: I wonder whether the updated lidar ratio is consistent with the value derived from the rough aggregated columns phase function at 532 nm. Please discuss in the paper.

Sections 5.2 and 5.3: Section 5.2 is an assessment of the newly derived optical properties for C6 and CALIOP retrievals. It should be placed after 5.3, since it also discusses the updated lidar ratio. Also, I suggest renaming (current) section 5.2 to something like "Final assessment of updated ice models".

Page 77, line 12: Please point out here that maybe the most notable limitation of the dataset is that it only samples clouds with optical thickness below about 3.

Page 77, line 14: Variations of inferred ice models with region, cloud type, dynamics and cloud top height are shown by Cole et al. (2014) and van Diedenhoven et al. (2014).

Page 77, line 26: It seems like "yield" or "lead to" is missing from this sentence.

REFERENCES

Cole, B. H., P. Yang, B. A. Baum, J. Riedi, and L. C.-Labonnote (2014), Ice particle habit and surface roughness derived from PARASOL polarization measurements, Atmos. Chem. Phys., 14(7), 3739–3750, doi:10.5194/acp-14-3739-2014.

Van Diedenhoven, B., A. M. Fridlind, B. Cairns, and A. S. Ackerman, 2014: Variation of ice crystal size, shape, and asymmetry parameter in tops of tropical 640 deep convective clouds. 641 J. Geophys. Res., 119 (20), 11,809–11,825, doi:10.1002/2014JD022385.

Yang, P., G. Hong, G. Kattawar, and P. Minnis (2008), Uncertainties associated

with the surface texture of ice particles in satellite-based retrieval of cirrus clouds: Part II-Effect of particle surface roughness on retrieved cloud optical thickness and effective particle size, IEEE Trans. Geosci. Remote Sens., 46(7), 1948–1957, doi:10.1109/TGRS.2008.916472.

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