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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Influence of ice particle model on retrieving cloud optical thickness from satellite measurements: model comparison and implication for climate study" *by* Z. Zhang et al.

Z. Zhang et al.

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Thank you for your thoughtful comments and suggestions, especially on the references. We have gone through all of references on your list and found most of them quite helpful for this paper. Below are the answers to the individual comments.

1) Firstly, it needs to be demonstrated that the Baum 05 model is an appropriate model to apply to the POLDER data. The authors should use the methodology outlined in Labonnote et al. (2001) to address this question. If it is proved that it is not appropriate for the particular case under consideration then there is little point in using that model to retrieve optical thickness using that instrument. This application would improve this

paper and would make their argument stronger; if it is proved that the Baum 05 model is appropriate. If it is proved that it is not applicable to POLDER for this particular case then that is also worthy of publication.

Response: We appreciate this suggestion. But we do not think the suggested task is necessary or appropriate for this paper, for the following reasons:

First of all, we do not have the ambition in this paper to evaluate appropriateness of the Baum05 or the IHM model or other models in the literature. The primary objective of this paper is to explore the relative importance of ice particle model in ice cloud τ retrieval in comparison with other factors.

Secondly, as discussed at the end of the "Summary and Discussion" section, the differences between the MODIS and POLDER instruments lead to the use of different retrieval methods, which in turn lead to MODIS's and POLDER's different perspectives on the appropriateness of ice particle model. The MODIS retrieves not only optical thickness, but also effective radius of ice clouds. Therefore, the top priority for the MODIS ice particle model is to account for the variability of the optical and microphysical properties of ice clouds with respect to effective radius. It is the reason for the use of a large number of ice cloud particle size distributions in the development of Baum05 model.

Furthermore, as pointed out by the referee, it has been demonstrated in many studies that the smooth and featureless scattering phase function similar to that of IHM model may be more appropriate to represent the majority of ice clouds, than the featured phase function of the Baum05 model. In future work, the ice particle surface roughness, which may lead to smooth and featureless scattering phase function, will be taken into account in the new ice particle models being developed for the next generation of the MODIS product. On the other hand, we have also pointed out in the paper that there is evidence indicating the existence of the smooth and pristine ice crystals in ice clouds. This evidence should not be ignored and further investigation of the ice particle

ACPD

9, S2199–S2204, 2009

microphysics, especially on the global scale, is needed.

2. The paper misses a further point, which is that solar intensity measurements by themselves are insufficient in testing the physical consistency of single-scattering models of cirrus and therefore their appropriateness for application to GCM simulations. It is important that ice crystal models are tested over a wide range of wavelength space using a simultaneously derived set of measurements. It was demonstrated in Baran and Labonnote (2006) [JQSRT 100, 382] that it is insufficient to use intensity alone measurements since intensity alone measurements could not differentiate between models which possess a high degree of randomization. Since their scattering phase function were very similar. This is why polarization measurements are also required. The forthcoming GLORY mission should be cited in regard to this point. Moreover, ice crystal scattering models with very similar phase functions do not necessarily have the same

Response: We agree with the referee on this point, although "testing the physical consistency of single-scattering models" is not the objective of this paper. We have added some discussion at the end of the paper on the synergetic use of A-train instruments to evaluate and improve the current ice particle models. Following the referee's suggestions, the "Baran and Labonnote (2006) [JQSRT 100, 382]" and the Glory mission have been cited in the discussion.

3. On page 1774 the author state, it is still controversial which assumption represents better the nature of ice clouds. What about the following series of papers, see for instance Foot (1988), Francis (1995), Francis et al. (1999), Baran et al. (1999),Baran et al. (2001), Boucher et al. (2000), Labonnotte et al. (2001), Field et al. (2003) and Jourdan et al. (2003) which all demonstrate that ice crystal models exhibiting strong optical features in their scattering phase functions do not generally describe aircraftbased or space-based measurements of the transmitted angular radiance or reflected angular reflection properties of cirrus, respectively. The authors seem to have ignored all these references which contradict their statement.

ACPD

9, S2199–S2204, 2009

Response: We have added a detailed discussion on this issue to the "Summary and Discussion" section. Most of the above references and many others are cited to show that "there is increasing evidence supporting the predominance of smooth and featureless phase function in ice clouds". At the same time, we also point out that "it should be kept in mind that the frequently observed halos, as well as a recent study by Sherwood (2005), indicate the existence of a considerable amount of pristine and smooth ice crystals, such as the hexagonal columns and plates, with phase function similar to that of Baum05 model. Given the substantial impact of ice particle model on ice cloud retrieval and climate studies as shown in this study, further assessment of the appropriateness of the current ice particle models on a global scale is needed."

References

4. Cirrus climatology, the Sassen and Comstock (2001) [JAS 58 2113] should be cited. Discussion on radiative forcing using GCMs should include Donner et al. 1997, Kristjansson et al. 2000, and more recently the paper by Edwards et al. 2007 should also be cited. The references on ice crystal habits are only a few, more recent work by Lawson et al. (2008) amongst others should also be cited and the reader should be given an indication of the occurrence of particular habits, for instance Korolev et al. (2000) and others. The references cited for some of the campaigns miss out other tropical campaigns such as EMERALD. These references should also be included.

Other references concerned with the development of ice crystal models applied to retrieval of cirrus properties on page 1760 should also include McFarquhar et al. (2002), Baran and Labonnote (2007), Baran et al. (2001), Macke et al. (1996), and Noel et al. (2006), and a number of others. Other references that have studied the impact of ice crystal models on retrieval of cirrus properties, such as the optical depth, should also include Baran et al. (1999). The influence of the phase function on retrieval of cirrus properties was also noted in Boucher et al. (2000).

As regards the impact of ice crystal shape on CRF the following references such as

ACPD

9, S2199–S2204, 2009

Kristjansson et al. (2000), Edwards et al. 2007, Liou and Takano (1994), Schlimme et al. (2005) and the more recent paper by Fu (2008) are also deserving of citation in this regard.

Response: We found most the suggested references helpful for the paper. We have cited most of them that are suitable for the context in the revised version of the manuscript.

Other comments *5. The word photon is used repeatedly throughout this paper when in fact the phase functions have been computed using ray-tracing or a physical optics approach. Suggest remove the word photon and replace with ray or rays. We would like to keep the word "photon". It has been extensively used in the literature.*

6. The discussion on optical thickness on page 1761. Here it would be appropriate to introduce the asymmetry parameter as this of course also influences the bulk reflection properties of cirrus, whilst stating that w0732; 1, since the bulk reflected flux back to space is determined by 732; w0(1-g)tau.

Response: The suggestion is taken. We have added the following discussion to the end of section 3."it has been shown that the observed cloud reflectivity at a non-absorbing wavelength, such as the 0.86μm, is generally proportional to the scaled optical thickness, , (King, 1987; Stephens et al., 1990). In other words, the retrieved is proportional to . Therefore, since the IHM model has a smaller than the Baum05 model, an ice cloud is more reflective if it consists of IHM particles rather than the habits assumed in Baum05. In other words, from the perspective of the retrieval, smaller (larger) will be retrieved from the same observation if the IHM (Baum05) model is assumed in the algorithm. "

7. Also Eq. (2) was not derived originally by Liou (2002). Please re-write as, see for instance Liou (2002).

Response: Corrected

ACPD

9, S2199–S2204, 2009

8. The IHM model also included a distribution of aerosol as well as spherical air bubbles?

Response: We have changed the sentence to “all ice particle habits in the Baum05 model have smooth surfaces and no inclusions of air bubbles, while the IHM model assumes that all ice particles contain many randomly distributed small air bubbles inside.“

9. Also in figure 1 please state the range of scattering angle sampled for the case under consideration.

Response: The range has been added to the figure caption.

Interactive comment on Atmos. Chem. Phys. Discuss., 9, 1757, 2009.