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Interactive comment on "A two-habit model for the microphysical and optical properties of ice clouds" *by* C. Liu et al.

C. Liu et al.

pyang@tamu.edu

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Responses to Dr. Bastiaan van Diedenhoven's comments (ACP MS No.: acp-2014-441)

We would like to thank Dr. Bastiaan van Diedenhoven for his valuable comments and constructive suggestions. In the revised manuscript, we have accommodated all the suggested changes.

Short Comment by Dr. Bastiaan van Diedenhoven

It is not my intent to provide a full review to the manuscript submitted to ACPD. There was one important comment that I missed in the previous reviews and I would like to

address that in this writing.

The manuscript by Liu et al. presents a two-habit model (THM) for the microphysical and optical properties of ice crystals in ice clouds. The authors show that this model represents the microphysical and remote sensing data rather well in general. This model could be useful for modeling and remote sensing applications. As they state in the manuscript, to better illustrate the advantages of the THM, they also consider a single hexagonal column model (SCM) for comparison. Based on the comparisons of the optical properties of the THM and SCM to measurements, the authors seem to suggest that a single column model cannot adequately represent the optical properties of ice clouds. However, that conclusion is not supported by the work in this paper.

The SCM used by the authors has aspect ratios that increasingly deviate from 1 with increasing size and does not assume any surface roughness, based on choices made many years ago. These choices of aspect ratio and roughness are largely determining the optical properties. Especially the difference in roughness is determining the differences in optical properties between the SCM and THM. The paper does not show that there are no other choices of aspect ratio and roughness possible that would lead to a similar agreement with the measurements as is reached with the THM. Indeed, Wang et al. (2014) show that the phase function data shown in Fig. 8 is sufficiently well fit by a rough solid column model, at least over ocean. Furthermore, Cole et al. (2013) show the POLDER data shown in Fig. 10 is well fit using a single rough hollow column model.

Thus, in my opinion, the authors should at least make clear throughout that their choice of SCM is a very particular one. Basically all recent literature on ice scattering models agrees that crystal surface roughness is prevalent in natural ice crystals. This paper once again shows that a pristine crystal model does not fit the data, which is not very relevant anymore. However, it does not show that a SCM with adjusted roughness and aspect ratio would not fit the data.

Response: Dr. van Diedenhoven's suggestions were followed and relevant revisions were made in the revised manuscript. To be more specific, in the conclusion we have added "It should be noticed that the SCM we used for this study is based on pristine particles with smooth surfaces, and the conclusions obtained with the present SCM should not be generalized to other single column models. Furthermore, models based on single column or plates are still widely used for radiative flux calculation and remote sensing implementations (e.g., Fu, 2007; van Deidenhoven et al., 2014), which are articulated to be rational with demonstrated success for some specific applications."

In addition, in the revised conclusion, we further emphasized the point that "Furthermore, we would like to emphasize that the SCM we used for comparison is based on pristine ice crystals with smooth surfaces and certain aspect ratio values, and the findings based on the assessment of the performance of SCM in remote sensing applications may not necessarily applicable to a different single column/plate model, particularly, when particle surface roughness is considered."

The microphysical data shown in Fig. 4 will likely not be fit as well using a single column model and this is an advantage of using a multi-habit model. However, for remote sensing this is not a concern and if a single particle model with adjusted aspect ratios and roughness produces correct optical properties, it would be adequate for remote sensing purposes.

Response: The advantage of the THM to consider both the microphysical and optical properties for the same model. This is one of our motivations to build the new model. The SCM we used in the study can not represent the microphysical properties of ice cloud regardless its performance in the optical property calculation.

I suggest removing the SCM results and any statements about the SCM from the paper. Alternatively, the SCM could be renamed "the single pristine column model" (SPCM) and the THM then should be renamed the "roughened two-habit model" (RTHM). It should then be clearly explained in the text that the differences in optical properties are

largely due to the differences in roughness and aspect ratio choices and not because one is a two-habit model and the other is a single habit model. The authors should acknowledge that this work does not prove that there does not exist any SCM (or single plate models) with adjusted aspect ratio and roughness such that it would fit all optical data presented here.

Response: We have clearly stated that smooth surface is used for the SCM, whereas the THM assumes rough surfaces. However, surface structure is only one factor of the model (it is definitely an important one), the aspect ratio, hollow structure, and aggregation configurations are all essential properties determining the model. We do not think there is any special reason to emphasize the importance of surface roughness and ignore the others. Historically, the SCM based on smooth surface and the aspect ratios that are the same as those used in our study were applied to remote sensing and radiative transfer simulations. However, the performance of the SCM has not been systematically evaluated. As a result, we prefer to keep the comparison of SCM and THM as they were used in the previous form of the manuscript. However, we added more detailed discussions in the revised manuscript to demonstrate the importance of surface roughness, and the limitation of the SCM used in this study.

Furthermore, at two places in the revised manuscript, we explicitly stated that the findings associated with the current SCM should not be generalized to other single habit models, particularly, those including the surface roughness.

Minor comment: Please change the x-axis label of Figure 6 to "effective particle diameter".

Response: Modified. Thanks for the suggestions.

Interactive comment on Atmos. Chem. Phys. Discuss., 14, 19545, 2014.