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Geoscientific Model Development Discussions

Interactive comment on "Representation of nucleation mode microphysics in global aerosol microphysics models" *by* Y. H. Lee et al.

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We thank the reviewer for their constructive comments and suggestions and have made several changes to the paper to address the issues raised. Reviewers' comments are shown in italics with our response shown after each.

In this manuscript the authors assess the errors committed by using different nucleation parameterization in the global aerosol microphysical model GISS-TOMAS. They explore the performance of two different version of GISS-TOMAS, with a cut-off for the particle size at 3nm (TOMAS-36) and 10nm (TOMAS-30), respectively, against a third version of GISS-TOMAS with a cut-off at 1 nm (TOMAS-40). While TOMAS-36 and TOMAS-30 parameterize the growth of the nucleating particles to the respective

cutoff with the Kerminen parameterization, TOMAS-40 explicitly simulates the whole size spectrum of particles, 1 nm being the critical diameter for molecular clusters to become stable.
This paper is clear and well written, and well suited for publication in GMD. I think, however, that some remarks about the computational burden should be added to the manuscript before publication in GMD. I have some suggestions that I feel would improve the manuscript.

General Comments
1. The title is pretty generic, and refers to "global aerosol microphysics models". How much do the authors think that their results depend on their particular model? Is it reasonable to assume that 3nm is a good choice of cut-off for other models, too? Have the authors investigated any other parameterization, beside the Kerminen parameterization? If not, I suggest that the authors change their title to refer specifically to GISS-TOMAS

RESPONSE) Our main results are limited to the sectional-based microphysics models, and the other referee also raises the similar concern. So the title is changed to "Representation of nucleation mode microphysics in a global aerosol model with sectional microphysics". We have investigated only the Kerminen parameterization.

2. As mentioned above, I think that the manuscript should mention the computational burden of the TOMAS-30, TOMAS-36 and TOMAS-40, both for the 10 minutes and 1-hour time-step.

RESPONSE) We understand that the computational burden is interesting quantity to show, and we estimated it by running the first month using the binary nucleation simulations – we were not able to obtain the information directly from the previously completed runs. We provided the information in Section 2.1 (see below). In the case of ternary nucleation, it takes a bit longer than binary nucleation simulations because it is likely to use a shorter internal adaptive time-step for the faster coagulation rates and larger areas (more grid cells) experience nucleation events.

"Regarding the computational burden of each model configuration, based on a one-month simulation with binary nucleation using a 600 Mhz single processor of an SGI Origin 300. For TOMAS-30, it takes about 58 hrs. For TOMAS-36, the 1-hour time step run takes about 73 hrs, and for the 10-min time step run, about 122 hrs. Finally, for TOMAS-40, the 1-hour time step run takes about 79 hrs, and for the 10-min time step run, about 123 hrs."

3. Could the authors add a figure or a table showing the vertical resolution of the model? Nine levels are quite few, and I was wondering if TOMAS spans troposphere and stratosphere or only the troposphere, as the pressure vs. latitude figures seem to suggest.

RESPONSE) We provided the pressure levels of the boundaries for the nine vertical layer in Section 2 in the revised manuscript as shown below. The top 1-2 vertical layers cover stratosphere.

"The GISS GCM II-prime has horizontal grid dimensions of 4 degrees latitude and 5 degrees longitude, with nine vertical sigma layers including the stratosphere to the 10 hPa level (Hansen et al., 1983); the pressure levels of the boundaries for the nine layers are 984, 934, 854, 720, 550, 390, 255, 150, 70, and 10 hPa."

4. Under which conditions are these results valid? Are they reliable in the stratosphere, too?

RESPONSE) Although we present the model results for whole model atmosphere, we have paid little attention on the model stratosphere (especially, their aerosols). The changes in the aerosols number predictions shown in the top 1-2 layers are only resulted from the uplifted aerosols/precursor gases from the surface layer through the tropics. Therefore, we feel more confident on our results within the troposphere. Additionally the GISS GCM II' has a coarse vertical resolution (i.e. only 1-2 layers), which may not be sufficient to simulate the stratosphere. We have added one line to the first paragraph of Section 2 to make this clear.

"Only 1-2 layers are in the stratosphere, so this model essentially treats only tropospheric aerosol."

5. Have the authors compared TOMAS-30 with any observation? An explicit calculation does not always lead to better results than a parameterization, if many assumptions are made for the calculation and if the parameterization has been well constrained.

RESPONSE) TOMAS-30 has been evaluated with various observations, and we mentioned this in Section 2 in the revised manuscript. Moreover, the parameterization is theoretical and is not tuned or compared to observations.

"The TOMAS model has been evaluated with ground-level measurements number and mass concentrations, deposition fluxes, and remote sensing observations (Adams and Seinfeld 2002; Pierce and Adams 2006; Pierce et al. 2007; Lee et al. 2009; Lee and Adams 2009). In addition, the TOMAS coagulation and condensation algorithms have been evaluated against analytical solutions and have shown excellent agreement (Jung et al. 2010; Lee and Adams 2011)."

6. Has GISS-TOMAS been used with higher vertical and horizontal resolutions, too?

RESPONSE) GISS-TOMAS does not have an option to run under a higher spatial resolution.

7. Fig. 3c: Why does Fig.3c show such a pattern, with few small areas with under-predicted CN10 concentration? What is the difference between those areas and the surrounding areas?

RESPONSE) The underpredicted CN10 areas in Figure 3c (ternary nucleation) show noticeably lower nucleation rates and free ammonia concentrations in TOMAS-30 compared to TOMAS-40 model. We think the nucleation rate in TOMAS-30 might be too low to lead higher CN10. Conversely, areas with about two times higher CN10 in TOMAS-30 in Figure 3c (ternary nucleation) show a higher nucleation rate than TOMAS-40. We would like to mention that the underpredicted CN10 areas in the binary nucleation simulations shown in Fig. 3a have no nucleation event. The following sentence is added in the revised manuscript. The new part is shown as bold.

"Unlike the 3 nm simulations, the 10nm simulations (shown in Fig. 3a, c) show underpredicted CN10 in some parts of the tropics for both binary and ternary nucleation schemes. **The underpredicted CN10 areas show no nucleation event for the binary nucleation and, for the ternray nucleation, noticeably lower nucleation rates and lower free ammonia concentrations in TOMAS-30 than TOMAS-40.**"

Interactive comment on Geosci. Model Dev. Discuss., 6, 893, 2013.