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Atmospheric Chemistry and Physics Discussions

Interactive comment on "A study on the aerosol optical properties over East Asia using a combination of CMAQ-simulated aerosol optical properties and remote-sensing data via a data assimilation technique" *by* R. S. Park et al.

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First of all, we thank the reviewer for the careful reading of the manuscript and constructive comments. We have revised the manuscript, following the reviewer's suggestions.

We have also removed/added/changed the words and sentences in the manuscript. The changed and added parts are painted in a red color in the text. In this revision, we have recalculated Table 7, and re-plotted Figs. 5 and 7. Please, check them out.

General Comments: This paper combined two models, CMAQ and ADAM (Korean

Dust Operational Model), to describe the detailed seasonal variations of aerosol optical depth (AOD) over Asia and made intensive analysis based on MODIS and AERONET observation data. This paper includes a lot of important messages to understanding the importance of sulfate, nitrate and other aerosols for Asian AOD field, and improving the aerosol radiative forcing estimation. The authors are using MODIS total AOD in order to evaluate the model results, however, MODIS fine-mode AOD could be another option for this purpose. It will be important to add some reasons why MODIS total AOD was used instead of MODIS fine-mode AOD. Otherwise, the paper is well written and I recommend for the publication in ACP after minor revisions as described below in details. Reply: As mentioned in introduction and summary, the primary purpose of this study was to enhance the accuracy in the estimation of aerosol optical properties (AOPs) over East Asia. The ultimate goal is to more accurately estimate the direct radiative forcing (DRF) by aerosols over East Asia. Taking this ultimate goal into account, we analyzed AOD, extinction coefficients (ïĄşext), and SSA (single scattering albedo) instead of fine-mode AOD (hereafter fm-AOD). These AOPs are now being used as input variables into the radiative transfer model (RTM) simulations. This was the main reason we chose these AOPs. Nevertheless, we agree with reviewer that MODIS-retrieved fm-AOD can also be used to evaluate the accuracy of the results from the CMAQ model simulations. But, in this case there are relatively large uncertainties in the estimation of fine-mode fractions (FMFs) from MODIS and AERONET. These uncertainties stem mainly from the assumptions made in the retrieval procedure of FMFs (e.g., refer to Kleidman et al., 2005; Lesins and Lohmann, 2006). In Fig. A below, we compared MODIS-retrieved/CMAQ-simulated fm-AOD with AERONET fm-AOD. The correlations, errors and biases are worse than those between MODIS-retrieved total AOD (t-AOD) and AERONET t-AOD for four seasons (refer to Table 8 and Fig. 10 in the manuscript), showing that both MODIS-derived and CMAQ-estimated fm-AODs are consistently underestimated, compared with the AERONET fm-AOD. In addition to the uncertainty in FMFs, there would have been uncertainties and difficulties in separately estimating fm-SSA and cm-SSA (coarse-mode SSA) for the RTM simulations, if we

had used the separate fm-AOD and cm-AOD. Therefore, we assumed that there would not be very large benefits from using the separate fine- and coarse-mode AOPs in this study. Please, refer to pp.16:21-17:4.

- Kleidman, R. G., O'Neill, N. T., Remer, L. A., Kaufman, Y. J., Eck, T. F., Tanré, D., Dubovik, O., and Holben, B. N.: Comparison of Moderate Resolution Imaging Spectroradiometer (MODIS) and Aerosol Robotic Network (AERONET) remote-sensing retrievals of aerosol fine mode fraction over ocean, J. Geophys. Res., 110, D22205,doi:10.1029/2005JD005760, 2005. - Lesins, G. and Lohmann, U.: Using MODIS and AERONET to determine GCM aerosol size, J. Atmos. Sci., 63, 1338–1347, 2006.

Minor Comments: 1. Page 23808 Section 2.2.1 Model description: How do you initialize CMAQ model? Reply: For the CMAQ initialization, we set up a spin-up period of 5 days, but, as we mentioned it in the text (see pp. 23:7-10), we did not import the boundary conditions from large domain simulations that could sometimes cause discrepancies between CMAQ results and observations, as discussed in Sect. 3.1 and in Fig. 6.

2. Page 23809 Section 2.2.2 I believe that REAS inventory only covered up to the year 2005. How do you extend REAS emission for year 2006 ? Reply: The REAS emissions for the year of 2006 were downloaded from the REAS official web site (http://www.jamstec.go.jp/frcgc/research/p3/reas_h_b.html). We mentioned this in acknowledgement at pp. 33:12-14.

3. Page 23810 Section 2.2.3 Dust emissions and transport. Kim et al. (2011) reported the ADAM validation for the dust 2007. Do you have another ADAM model validation reports for the 2006 dust or more general evaluation papers? Reply: The capability of the ADAM model has been improved continuously, since it was started to use as an operational dust generation and transport model at KMA. However, unfortunately there was no ADAM model validation study or report "for the year of 2006". The evaluation

and validation of the ADAM model forecasting (and/or hindcasting) for several dust cases were described in In and Park (2003), Park and In (2003) and Park and Lee (2004). The model capability was also evaluated in the Dust Model Inter-comparison Project (DMIP) (Uno et al., 2006). We added some further explanation on this point. Please, see the modified manuscript at pp. 11:22-12:2 and a new reference at pp. 40:16-19.

4. Page 23819 Section 3.1 Figure 5 seems very interesting. Do you use the model and MODIS results for all model grid points? MODIS AOD sensor might have a different sensitivity over land and ocean. Is it possible to separate the symbol (or color) of data point for land and ocean grid? Reply: Based on your comments, we have used CMAQ-simulated and MODIS-retrieved AODs for all grid points, employing different color scheme over the ocean and land (please, refer to modified Fig. 5 in the manuscript). The correlation between MODIS-retrieved and CMAQ-simulated AODs over the ocean (yellow triangles) was better than that over the land (blue circles). This may be due to the following facts: (1) MODIS AOD sensor might have a different sensitivity over the land and ocean and (2) there are different levels of uncertainties in the AOD retrieval algorithm over the ocean and land. In the revised manuscript, Fig. 5 was replaced (re-plotted), and explanations were also added into Sect. 3.1. Please, check out pp. 21:20-22:4.

5. Page 23820 Lines 10 – 14. The authors indicate the several important factors (or problems) to get the better results from CMAQ simulation. I wonder the order of importance to improve the model results. Reply: We have improved several factors to better estimate the AOPs from the CMAQ model simulations over East Asia: (1) meteorology; (2) emission; (3) CMAQ model simulation; (4) grid resolution in the CMAQ model simulations; and (5) algorithm to convert the aerosol composition to the AOPs. Obviously, the impacts of each component on the enhancement of AOPs should be evaluated individually. But, this would be another big work to be done. Our best guess is that the order of importance would be emissions> algorithm> meteorological fields

= grid resolution = CMAQ model simulation. But, again this should be investigated in a separate study, and it is also very important how much each factor was improved. In addition, in order to minimize these uncertainties from the above-mentioned components, we conducted the data assimilation, using the MODIS-retrieved AODs. We emphasize this point at pp. 28:14-20 & pp. 29:22-30:2 in the revised manuscript.

6. Page 23823 Lines 25 – 26. From Figure 8, I cannot read this message. Sea salt seems only important wintertime over the East-China Sea and east part of Sea of Japan. Reply: The original sentence could be misleading. We have rephrased it. Please, see pp. 26:11-20.

7. Page 23833 Line 5. Reference of In and Park is duplicated. Reply: We removed one. Thank you for this correction!

Interactive comment on Atmos. Chem. Phys. Discuss., 11, 23801, 2011.

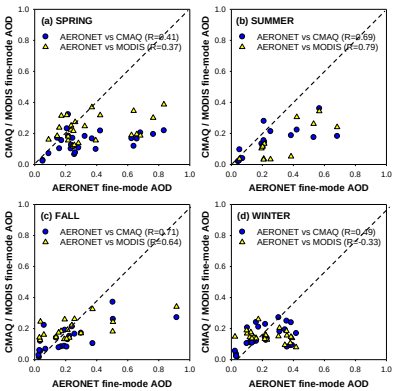

Figure A-1. Scatter plots of the CMAQ-simulated, MODIS-retrieved and AERONET fine-mode AODs for four seasons, 2006. Blue circles and yellow triangles indicate CMAQ-simulated and MODIS-retrieved fine-mode AODs, respectively: (a) spring, (b) summer, (c) fall and (d) winter.

Fig. 1.