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Atmospheric
Chemistry
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Discussions

Interactive comment on “Numerical modeling of Asian dust emission and transport with adjoint inversion using LIDAR network observations” *by* K. Yumimoto et al.

K. Yumimoto et al.

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Reply to Reviewer #2:

Thank you very much for appropriate and adequate comments. We have deliberately confirmed and considered your comments. We believe that we have made sufficient changes in consideration of all comments in the revised manuscript. Below we will provide a point-by-point response to his/her comments.

Replay to comments:

1) 4D in the term of "4D-Var" means that the method can assimilate observations in space and time (3D space + 1D time) simultaneously; 3D-Var can assimilate only those

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observations measured at the same time (3D space). Actually, 4D-Var seeks the initial condition (3D space) or model parameters such that the forecast best fits the observations within the assimilation interval (in space and time). In our study, we applied the 4D-Var method to a dust transport model, used LIDAR observation (3D space + 1D time), and optimized dust emissions to produce a modeled dust concentration (3D space + 1D time) that fits the observations during the assimilation window. However, as the referee described, the term "4D-Var" occasionally reminds readers of a forecasting system with the 4D-Var data assimilation. It leads to confusion and misinterpretation in our system. For that reason, we shall use "adjoint inversion" or "variational inversion" instead of "4D-Var".

2) We will remove such words, and change into more concrete expressions.

3) We will add those citations of the literature to the revised manuscript.

4) We removed that statement from the manuscript.

5) As the referee mentioned, the statements might lead to misinterpretation about 3D-Var. We will improve the statements related to 3D-Vars in the referee's opinion as follows. "however, unlike the 4D-Var approach, 3D-Var can not use observation data of different observation times simultaneously."

6) In the adjoint equation (Eq. (3)), the emission term (i.e. Edt) does not appear (e.g., Eq. (6) in Hakami et al. (2007), Eq. (2) in Chai et al. (2007), and Eq. (8) in Elbern et al. 2007). Equation (3) is derived from both Eqs. (1) and (2); therefore, it has J (e.g., Eq. (7) in Hakami et al., 2005, Eq. (6) in Hakami et al., 2007, and Eq. (2) in Chai et al., 2007). We will change the vague description of Eq. (3) to "An adjoint equation corresponding to Eqs. (1) and (2) is derived as follows"

7) In Hakami et al. (2005), the term is described as "observation-driven forcing term for the adjoint system". In Hakami et al. (2007), the term is explained as a "forcing term for the adjoint equation". We will change the statement to a simpler description:

"dJ/d(HC) drives the adjoint model as a forcing term"

8) In order for meteorological fields to have some feedback from the tracer field, we need an adjoint model of a meteorological model (i.e. RAMS) and require several integrations of both forward and adjoint models in on-line manner. Development of the adjoint RAMS coupled with the adjoint of CTM takes a great deal of work. Furthermore, the iteration procedure of the adjoint inversion in the on-line manner requires considerable computational time and loading. An adjustment of meteorological fields through assimilation of dust observations is not the main purpose of this study. Development of an adjoint meteorological model conjunction with CTM will be the next step of 4D-Var applications for air quality simulation.

9) Considering only the relative error causes extremely small observation errors, and prevents the assimilation procedure from converging on the optimized solution. In this study, to avoid such a case, we introduced a minimal absolute error and defined the observation error as Eq. (6). We will add these descriptions related to Eq. (6) into the rivesed manuscript. "Using only the relative error leads to extremely small observation errors and prevents the assimilation procedure from converging on the optimized solution. In this study, we introduced a minimal absolute error and defined the observation errors as follows."

10) As the referee has mentioned, air particles from different regions might have the same potential temperature. Figures 2 and 6 show that the dust loading targeted in this study was caused and trapped by the low-pressure and its cold front hitting eastern Asia in early April 2007. The dense dust loadings, which were observed from 31 March to 1 April at Seoul and from 1 to 2 April at Matsue and Tsukuba, follow decreases in the potential temperature by the cold front, and are captured theta = 285 - 295 K. Therefore, we presumed that those dust layers were transported from the same source region. We will improve the statements as follows "A heavy dust event occurs from 31 March to 1 April at Seoul (dust extinction coefficients exceed 2 km-1), and from 1 to 2 April at Matsue and Tsukuba. Figure 2 shows that the dense dust loading was

caused and trapped by the low-pressure system and its cold front, which hit Mongolia and north-central China on 30 March 2007 and traveled eastward. The dust events observed at each LIDAR site are presumed to be transported by this low-pressure system and its associated cold front."

11) In this study, we used a smaller value of S1 in the CALIOP extinction retrieval to obtain the overall semi-quantitative aerosol profile. Consequently, the CALIOP extinction coefficient might be smaller than that retrieved from NIES LIDAR by a factor of ca. 0.6 (=30/50) for the optically thinner case. Furthermore, the dust layer is so dense that lidar signals of CALIOP might not penetrate into the surface, which might engender an underestimation of the column amount (i.e. AOT derived from CALIOP extinction coefficient). However, this difference is not critical because we used the CALIOP measurement for semi-quantitative analysis of the model results (i.e. a comparison of dust vertical and horizontal (in latitude direction) structures). A new version of CALIOP data (version 2), to be released 2008, will support analyses that are more quantitative.

12) In this study, the background error was assigned as 500% from results of the dust model inter-comparison project (DMIP: Uno et al., 2006). This means that dust emission fluxes have uncertainties of factor 5. Therefore, as the referee described, from the aspect of the quantitative amount of dust flux, places where the fluxes are already high have larger uncertainties of the amount of dust flux. However, the consistency between optimized emissions of Experiments A and B could not be derived from the choice of the background error. For example, when observation sites of Experiment A cannot capture important information of the dust loading, which an additional observation site of Experiment B (i.e. Beijing or Seoul) can measure, the assimilation results might not be the same (i.e. Experiment A might not obtain the optimized emission consistent with that of Experiment B). Experiment A is done in the absence of observation information that Experiment B captures. For that reason, we believe that the conclusion does not need to be changed. As the referee described, background error is an important part of the assimilation procedure. Unfortunately, it is quite difficult to

estimate the background error of dust emission flux because we have no quantitative observations related to dust emissions. In this study, we assign the background error from results of DMIP. In the development stage of our system, we performed several sensitivity experiments changing the uncertainty of the dust flux from 1000% to 50%. Uncertainty of 500% engendered reasonable and realistic results that were appropriate for the variations of dust fluxes of DMIP models.

Interactive comment on Atmos. Chem. Phys. Discuss., 7, 15955, 2007.

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