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Interactive comment on "Constraining Chemical Transport $PM_{2.5}$ Modeling Using Surface Monitor Measurements and Satellite Retrievals: Application over the San Joaquin Valley" *by* Mariel D. Friberg et al.

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Author Comments (AC) to Referee Comments (RC) 1 – Anonymous Referee 2

RC1_0. In this paper, the authors conducted a case study for six days over San Joaquin Valley to constrain model simulated $PM_{2.5}$ using surface monitor measurements and satellite retrievals. They combined the aerosol products at 275 m spatial resolution from the MISR Research Aerosol retrieval algorithm, ground observations from EPA

and the 2 km resolution simulations from WRF/CMAQ to improve the surface estimates of $PM_{2.5}$, its major chemical component species estimates, and related estimates of uncertainty. The optimized results show good agreements with ground observations for both the total $PM_{2.5}$ and the species. The method is sound and the results look reliable. I recommend considering this paper for publication upon response to the following comments:
AC1_0. We thank the reviewer for the valuable comments to improve our manuscript. Please see our itemized responses below.

Major comments:

RC1_1. This work is a case study and the authors selected several days with requirements for the MISR data: (1) relatively cloud-free conditions for more MISR coverage; (2) mid-visible AOD exceeds 0.15. They have mentioned in the manuscript that applying this method in other polluted regions are likely to meet common condition with AOD exceeding 0.15. However, what about the coverage issue? For days with limited MISR coverage, the MAIAC AOD used to fill the gap will also have a lot of missing. Then how will this method be applied? This should be discussed in the manuscript.
AC1_1. Where satellite data are missing or where the AOD is too low to provide reliable aerosol type from MISR, we must rely on the emissions-based CMAQ model, tuned, to the extent possible by satellite and surface measurement. Nevertheless, the satellite provides vastly more spatial coverage than the surface stations alone, and this is especially important downwind of major pollution sources. As such, our approach provides improvements where possible, but does not resolve all possible problems. This is now emphasized in the Conclusions section of the paper. The plotting coverage in Figures 6, 7, and S4 has been addressed. Following Figure 5, when FillSAT is not available, the optimized dataset reflects the fused (model + surface measurements) results.

RC1_2. What are the major advantages of this study compared to previous studies that combined information from the satellite retrieval, CTMs and ground observations together? The optimized results in this study seemed not to take advantage of the full coverage of the CTMs.

AC1_2. The physical approach introduced in this study complements the statistical approaches now widely used to take advantage of satellite coverage for air quality applications. Statistical approaches rely on surface-based data training sets to constrain parameters in statistical models, which are then applied elsewhere. Where training data are limited or entirely absent, there is great uncertainty with this approach. In other studies where satellite data are used to constrain a CTM, only the AOD or very limited aerosol-type constraints from the satellite is considered. The physical approach we present makes use of surface data where available, but unlike other approaches relies primarily on both AOD and particle property information contained in the satellite retrievals to constrain a complex, physically based atmospheric dispersion model. This is especially helpful over the vast areas where surface measurements of aerosol concentration and type are not available. We now emphasize this in the Introduction and Conclusions, and mention it in the Abstract.

Minor comments:

RC1_3. Page 1, line 30: Why is that EC have much worse performance compared to other species?

AC1_3. Largely emitted from incomplete combustion, EC is a spatially heterogeneous primary species whose particulate phase chemistry and physics is very complex and difficult to model. This is reflected in Table S8, which shows low spatial correlation values and high root mean square error comparison between ground monitors and CMAQ outputs for EC. Appel et al., (2008) discuss overprediction of EC in January and August over western US by CMAQ. EC also relies heavily on the emissions inventory,

and although there have been great strides in the past five years or so to improve EC estimates in the emissions inventory (e.g., residential wood combustion), there are (or at least very likely) still large errors in the inventory relating to EC emissions.

RC1_4. Page4, line1: 1km or 275m?âĂÍ

AC1_4. Revised.

RC1_5. Page 6, line 19-20: Will this interpolation process introduce biases?

AC1_5. Yes, downscaling CMAQ outputs using any interpolation method inherently introduces biases. Three cross-validation techniques were employed to evaluate the biases of the optimized dataset with respect to ground observations.

RC1_6. Page 13, line 23: How is the MAIAC AOD scaled before gap-filling MISR AOD? This seems not to be mentioned in the manuscript.

AC1_6. We have revised Section 3.3 for clarity as follows:

"To obtain a spatially complete AOD map for each case-study day, we combine the MISR-retrieved, MAIAC-retrieved, and CMAQ-based reconstructed AOD products, as CMAQ can simulate values in all grid boxes, regardless of cloud cover, surface brightness, terrain, and aerosol optical thickness. The most relevant factor affecting spatially complete satellite-retrieved AOD in this study is missing retrievals due to the presence of clouds. The combined AOD product is more complete than the MISR or MAIAC product alone.

The Fig. S1 scatterplots show MISR-RA AOD retrievals are higher than those retrieved by MAIAC, and much closer to the AERONET ground-truth values, for the three case study days with highest AOD. These scatterplots reinforce the need to scale MAIAC-retrieved AOD before gap-filling MISR-retrieved AOD fields. Based on Fig. S1, a study-specific AOD adjustment was applied to the MAIAC data; in addition, a filter with an upper bound of 0.4 was used for MAIAC retrievals to reduce potential cloud contamination. On days when Aqua and Terra MAIAC C6v2 AOD retrievals on the 1 km fixed sampling grid were available, the MAIAC-Aqua AOD retrievals were used to fill in missing AOD in the MAIAC-Terra AOD maps (as MAIAC-Terra is closest in time to the MISR-RA retrieval) by linearly regressing values from a 15 x 15 MAIAC-Aqua grid cell region centered on the missing MAIAC-Terra cell value. The 1 km gap-filled MAIAC-Terra AOD maps were subsequently downscaled and spatially interpolated (via bilinear interpolation) to match the downscaled CMAQ 275 m $\times$ 275 m output grid, referred to herein as gap-filled MAIAC. Before combining retrieved AOD products, the 275 m $\times$ 275 m MISR-RA AOD at 558 nm was converted to 550 nm using the retrieved ANG product, and the dynamic sampling grid was re-gridded to match the downscaled CMAQ 275 m $\times$ 275 m grid. The gap-filled MAIAC product was then used to fill in gaps in the MISR-RA AOD product by linearly regressing values from a 15 x 15 gap-filled MAIAC grid cell region centered on the missing MISR-RA cell value. Larger gaps caused by cloud contamination in the satellite-retrieved AOD were filled using a 7 x 7 grid cell region of CMAQ-reconstructed AOD value, linearly regressed to the satellite-retrieved AOD. This procedure was repeated multiple times as needed until the satellite retrieval area within the SJV study region was filled, referred herein as $\tau_{FillSAT}$.

A unique component of this work involves the use of the MISR-RA aerosol species-specific groups. Consequently, we produce gap-filled, aerosol-type-grouped AODs from the original MISR-based AG AODs using the model-based grouped AODs from Step 1, and following the same gap-filling procedure used for $\tau_{FillSAT}$."

RC1_7. In Section 3.4, there are a lot of sentences (e.g. line 25-27 on page 14) reported the evaluation results, which should not belong to the Method section.
AC1_7. The sections 3.4.1 and 3.4.2 comparisons are AERONET validation, critical to the choices made in subsequent steps and, thus, were kept in the Methods section.

RC1_8. Figure 6: Although the OPT results had better agreement with ground observations, it still lacks of spatial coverage, even on the selected days with more MISR coverage.
AC1_8. Please see the response to comment RC1_1 above.