Response to reviewer 1

Authors appreciate reviewer's thoughtful comments and suggestions, which are greatly helpful for us to improve our manuscript. The manuscript has been revised to accommodate the reviewer's comments.

General comment:

This is a straightforward manuscript describing a WRF-CMAQ system with data assimilation adjustment for its initial condition, and shows that the data assimilation improve the predictions in most cases. Here are some specified comments.

Comments and response:

Comment: The data assimilation method mentioned mainly include AOD assimilation and surface measurement assimilation. Which one play a more important role for PM_{10} and $PM_{2.5}$ adjustment? Do these adjustments have any conflict?

Response: To clarify the impacts of the AOD and PM adjustments, assimilation was conducted in the following procedure. First, CMAQ simulated-AODs were assimilated with GOCI-retrieved AODs, and the assimilated AODs were then allocated into the PM concentrations, based on model-simulated concentrations. After that, the allocated PM was again assimilated using ground-based PM observations. Therefore, the assimilation using the surface measurements played a more important role in the entire PM adjustments. The reasons why the GOCI AODs were applied prior to using ground-based observations are two-fold: (1) GOCI slightly underestimates AODs compared to the AODs measured by the AERONET, which possibly leads to underestimated PM adjustments and (2) the allocation of AOD into PM concentrations based on model values has uncertainties. Despite these two reasons, we found that GOCI AODs are still useful for data assimilation (DA), because satellites provide meaningful information especially over the ocean areas where no surface-based observations are available.

Comment: Table 1 shows that CO's R and SO_2's MNB become worse after data assimilation, why?

Response: As listed in Table 1 (in this response), the model-calculated CO concentrations (BASE RUN) are by far lower than those observed by in-situ measurements. After conducting DA at 00:00 UTC, the CMAQ-simulated CO concentrations became closer to observations. Up to 6 hours, the DA RUN showed a better performance (R=0.56; MB=0.017) compared to the BASE RUN (R=0.40; MB=-0.27). However, the differences between the BASE RUN and the DA RUN were diminished as the prediction progressed, because model tends to go back to its original state. Because of this tendency, the scatter plot of the DA RUN became more widespread, i.e., smaller correlation coefficient, than those of the BASE RUN for 0 – 23 hours predictions.

In case of SO_2 (see Table 2 in this response), the DA RUN showed a better performance for 0 – 6 hours and 0 – 23 hours predictions compared with the BASE RUN in terms of R, IOA, RMSE, and MB. Unlike these statistical variables, MNB, a relative difference normalized by observations, was decreased in the DA RUN for 0 – 6 hours predictions and increased for 0 – 23 hours predictions. Figure 11(d) shows the discrepancy of MB between daytime and nighttime. The model-simulated SO_2 concentrations of both the BASE RUN and the DA RUN were much smaller than observations during the daytime, and became similar (BASE RUN) or larger (DA RUN) compared to observations during the nighttime. These over-predicted nocturnal SO_2 concentrations of the DA RUN lead to large positive MNB values. This can also be explained by the underestimated nocturnal mixing layer height (MLH) shown in Fig. 8. For further investigation, we are collecting and analyzing more lidar data available over South Korea. In the future, a further comparison study will be carried out using those lidar-measured MLH over South Korea.

Table 1. Statistical metrics for CO from BASE RUN and DA RUN with Air Korea observations at 00:00 UTC when the DA was conducted, 0 – 6 hr predictions after DA, and 0 – 23 hr predictions over the entire period of the KORUS-AQ campaign.

CO	At DA time (00 UTC)		0 - 6 hr prediction		0 - 23 hr prediction	
	BASE RUN	DA RUN	BASE RUN	DA RUN	BASE RUN	DA RUN
N	1024		27268		101764	
IOA	0.41	0.62	0.24	0.33	0.41	0.51
R	0.28	0.43	0.40	0.56	0.28	0.21
RMSE	0.35	0.16	0.31	0.17	0.31	0.19
MB	-0.31	-0.01	-0.27	0.017	-0.27	-0.04
MNB	-64.3	9.69	-62.52	17.11	-62.0	3.14

Table 2. Same as Table 1, except for SO_2.

SO_2	At DA time (00 UTC)		0 - 6 hr prediction		0 - 23 hr prediction	
	BASE RUN	DA RUN	BASE RUN	DA RUN	BASE RUN	DA RUN
N	1007		27258		101764	
IOA	0.36	0.44	0.34	0.37	0.34	0.35
R	0.097	0.27	0.13	0.15	0.14	0.15
RMSE	0.0061	0.0039	0.0074	0.0065	0.0068	0.0066
MB	-0.0019	-0.0009	-0.0021	-0.0014	-0.0009	-0.0004
MNB	-20.1	7.35	-29.87	-7.54	3.1	17.77

Comment: Line 276 (page 12), “Tang et al., 2017” cannot be found in the reference.

Response: “Tang et al., 2017” has been included to the references. Please, see pp. 34:830 – 834.

Comment: Line 282 (page 13), equation (7): the term “I” does not come with explanation in the text.

Response: The sentence of “I denotes the unit matrix” has been added to the manuscript. Please, see pp. 14:320 – pp. 15:321.