

Interactive comment on “Improving air quality forecasting with the assimilation of GOCI AOD retrievals during the KORUS-AQ period” by Soyoung Ha et al.

Anonymous Referee #1

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General comments

The focus in the present study is to implement AOD derived from satellite observation over East Asian region with the Korean Geostationary Ocean Color Imager in attempt to improve air quality forecast. The preprocessed data were assimilated with three-dimensional variational data assimilation technique for the Weather Research and Forecasting model coupled with Chemistry. The impact of GOCI AOD on the air quality forecasting is examined by comparing the obtained results with AOD derived from MODIS observation as well as against in-situ PM_{2.5} at the surface. In the present study, the assimilation of purely surface PM_{2.5} concentrations systematically underes-

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timates surface PM_{2.5} and prediction hold only for 6 hours. When the present GOCI AOD retrievals are assimilated with surface PM_{2.5} observations the forecasts are improved up to 24 h, with the most significant contributions to the prediction of heavy pollution events over South Korea.

The present study is very interesting and it is based on a comprehensive method, which is also very well described in the manuscript. In addition, the discussion of the results hold very well and this is also the case when uncertainties and limitations in the present study are discussed, as well as possible future improvements that could result in more realistic forecasts. However, there are two important questions or major comments that are in dispute and must be settled before this study can be accepted for publication in ACP.

Major comments

1. There is an issue when introducing information of GOCI AODs in the approach to simulate forecasts of air quality when the improvement of the latter is caused by an overestimation in GOCI AOD. For me this is not a correct approach and uncertain to rely on. One reason for the latter is that it seems not to be robust, considering that you will have differences in the statistics, (differences in the weights), when performing forecasts of air quality. The main reason for that is the cloudiness, thus, diverse cloudy conditions means differences in the availability/statistics in GOCI AOD from case to case.

2. There are issues with the language, which need to be improved. In the section Technical corrections below suggestions are given in an attempt to improve the language and clearness of the manuscript. However, my review and corrections of the manuscript concerning the language has only been carried out for the abstract and Introduction to show that the clearness of the text need to be improved. Therefore, I recommend that the full text needs an English proof-check.

Specific comments

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Page 5 Line 17. MODIS is not a satellite and which version is used here, 6.1? I guess version 6.1 is used in the present study, otherwise it is necessary to switch to this latest versions, since there are biases in the previous versions. Line 22. It is not correct to write that AOD measures something. This sentence need to be rewritten.

Page 7 Line 15. Which version of MODIS? Line 17. "Observation errors" are not the best name to use here and there is a later estimates from the MODIS aerosol team of the expected error in the MODIS retrievals of AOD. Suggestion: "The MODIS land and ocean retrievals give AOT at 550nm with expected error envelopes of $\pm 0.05 \pm 0.15 * AOT$ (Levy et al., 2010) and $\pm 0.04 \pm 0.1 * AOT$, $\pm 0.02 \pm 0.1 * AOT$ (Levy et al., 2013), respectively, which arise from combined errors in assumed boundary conditions (e.g. surface reflectance, instrument calibration) and type of aerosol model (such as in single scattering albedo)."

Page 9 Line 1. And the sentence beginning with "Because the difference." If the difference is so small should you not then go for thinning? Lines 5 and 6. The word "validation" can be used when comparing satellite derived AOD against ground-based sun-photometer measurements. However, you cannot validate AOD obtained from passive remote sensing against AOD derived from observations with another satellite sensor used in passive remote sensing. Line 15. Concerning the sentence "When these different observation errors were applied to GOCI retrievals in the assimilation, the smallest error (ϵ_2) produced slightly better fits to observations specially for the high values ($AOD > 2$)." This statement seems not hold, since ϵ_2 is not better than ϵ_1 over land for the situations with lower AOD. Line 26. Concerning this statement "This is partly because AOD is not directly associated with surface PM2.5 and partly because large uncertainties in the forecast model and the emission forcing can dominate over the analysis error during the model integration." how about uncertainties may also be induced in the forecasts of PM2.5 since here we have to deal with ambient AOD while dry conditions for PM2.5?

Page 11 Line 1. Is data used both from MODIS Aqua and Terra?

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Section 5 and page 15 Line 1 and first sentence. I think too strong positive words are used here when describing the GOCI AOD retrievals.

Line 15 and the sentence "However, the forecast error grew very quickly over the next 12 hours, underestimating PM2.5 at the surface, especially in the heavy pollution events where the forecast accuracy dropped from over 70% to ~30% only in four hours. Meanwhile, the GOCI AOD retrievals alone tended to overestimate surface PM2.5 but significantly contributed to improving air quality forecasts up to 24 h when assimilated with surface PM2.5 observations." Thus, the improvement increase for the wrong reason and one of the problems with that seems to be that the approach is not robust, considering that you will probably get variations in the amount of data/statistics you get from GOCI AOD when investigating different cases. This is because of cloudiness, which means no data when clouds are presented. Thus, the GOCI AOD statistics will varies between different forecasts investigated, thus the latter will be dependent on this. Why is not the results obtained with MODIS included in the discussion of Section 5?

Figures

Figure 1 It is not clear how the two domains are connected to the solid box in the figure. Neither the text in the beginning Section 3.1 is clear about this. The number of the in-situ stations at Korean peninsula that deliver PM2.4 data for the present study are so much more than is shown by the dots in this figure. This could be improved somewhat by reducing the size of the current Figure 1 (the right part/eastern part) and include instead at this place on the right an enlargement of Korean peninsula? The size of Korean

Figure 2 It is not correct to write that AOD is retrieved at this time, since it is the observations that is carried out at this time and it is a very long way to come up with an estimate of AOD, for example you have to introduce a model that describe radiation transfer in the atmosphere. Change "retrieved" to "corresponding" in the first sentence

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of the figure caption to Figure 2. Describe in the figure caption the solid black box introduced.

Figure 3 What is it on the y-axes? Should it be AODo – AODa and AODo – AODb ?

Figure 4 In the figure caption you have to refer to the body text about the three different types of observation errors. Take the color blind persons in consideration and use the three colors in combination with solid, dashed and dotted lines and separate land and ocean with heavy and normal lines, respectively.

Figure 5 R² is squared correlation coefficient.

Figure 6 Keep the color for the lines but use solid and dashed lines. Why is not the results discussed more than for is included as phrase in the bracket? A suggestion, skip the figure and write “(not shown)”.

Figure 7 It is a lot of space in the figure and therefore write the names of the species in all figures.

Figure 8 Write “Model levels” connected to the y-axes.

Figure 9 The title (above the figures) is problematic both considering the language and that it is actually not 100% monthly mean values that are presented. I suggest to remove it and change the figure caption to. “Horizontal distribution of analysis increments in PM_{2.5} (analysis-minus-background) at the lowest model level (k=1) in domain 1, averaged over the period 4 – 31 May 2016. Maximum and mean values corresponding to the domain in each experiment are shown in the upper right corner of each panel.”

However, text describing the different figures are also needed in the figure caption. Since no alphabetic characters, a – d, have been included in these four figures then you have to include the more complicated “upper left, upper right” etc. In addition the x-label text should be “dry PM_{2.5} [µm m⁻³”

The results presented in Figure 9 are somewhat difficult to understand, since including

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result of GOCI AOD means that the final scene (All) abrupt get higher PM_{2.5} values in the upper part of the figure (Figure 9d). Is this realistic? In addition, how could the MODIS AOD results that are so limited in available values/statistics for the investigation area contribute to an improved forecast? It seems also that the MODIS AODs are only available east of the Korean peninsula, while the aerosol sources are located in west, over China.

Figure 10 Writing “9-km simulations” is not clear, explain what it is. Suggestion for the figure caption “Root-mean-square-error (rmse, upper figure) and bias error (lower figure) obtained for forecasts, with respect to the investigation area of 9-km (domain 1), verified against surface in-situ PM_{2.5} from 361 stations in South Korea of the period 4 – 31 May 2016. Average values of the forecasts (24 hours with increment of 1 hour) is shown next to each experiment name, where also mean absolute error is presented.” Should the latter be presented in the upper figure instead? Please adjust the suggested figure text above if needed.

Figure 11 Suggestion “Figure 11. Same as Fig. 10, while here the results of forecast accuracy (%) for categorical forecasts are presented, subdivided according to classification of air quality in Tables 2 and 3.” Include “Model level” on the y-axes.

Technical corrections

Abstract Line 2. Suggestion “The Korean Geostationary Ocean Color Imager (GOCI) satellite provide, based on daily high temporal and spatial resolution data, unprecedented information on air pollutants over the upstream region of the Korean peninsula for the last decade.” Line 3. “the GOCI aerosol” Line 6. “.assimilated with three-dimensional.technique in the Weather.” Line 9. Sensors are not observations, probably better with “.(MODIS) AOD.”, but better with “. Moderate Moderate Resolution Imaging Spectroradiometer (MODIS) AOD and in-situ ground-based fine particle matter (PM_{2.5}).” Line 11. “. underestimates predicted surface PM_{2.5}.” Line 11. What is meant by “positive impact” Is it better with “and the

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prediction hold only for about 6 h.” Line 13. The last part beginning with “with the most. . .” of this sentence is not clear.

Introduction Page 1 Line 19. “Complicated aerosol chemistry and due to its multiscale interactions.” Line 21. “Surface concentrations” of what ? Line 22. If line 21 is corrected then it hold to write “they” in line 22. Line 23. “The latter is highly dependent on.” Line 24. Take away “via aerosol-meteorology” and write “. . . meteorology due to interactions directly with solar radiation in the cloud-free atmosphere (scattering and absorption) and indirectly by acting as cloud condensation nuclei.”

Page 2 Line 3. “. . . performs chemical simulations according to 3-km horizontal resolution at present day.” Line 4. What is meant by “these fast-varying complex mechanisms” or what is it pointed to? Lines 9-10. This sentence need to be rewritten. Line 12. Not clear written: “(usually in the optical properties)” Line 12. Change “observed information” to “information” or “results” Line 15. Change “for” to “of” Line 16. “. . . conducted in Korea between 1 and 12 June 2016.” Line 17. Remove “a field campaign” Line 18. “of the major factors that highly influenced the air quality in Korea in the period 1 – 12 June 2016. Line 21. “occurred due to long-range.” Lines 25-27. Based on the Korean Geostationary Ocean Color Imager (GOCI) onboard the Communication, Ocean, and Meteorology Satellite (COMS) retrievals of hourly AOD scenes, for multiple spectral bands, are centred with respect to the Korean peninsula during daytime (Kim et al., 2017). AOD scenes with high spatial and temporal resolutions are available since 2010.” Line 28. “It has been demonstrated” Line 31. “assimilating AOD derived from MODIS observations (Remer et al., 2005)” Line 34. “forecasts of a dust storm” Line 34. When did the dust storm occurred? Line 35. “. . . widely used for air quality forecasting. The system has been extended for.”

Page 3 Line 5. “MOdel.” Line 8. “. . . assimilation of AOD improved.” Line 9. “In the present study, the assimilation. system has been extended to be better used in the GOCI AOD retrievals during the current investigation period.” Line 10. Not clear what is meant by this “careful investigation of data characteristics.” Lines 10-13.

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The last part in this sentence is not clear “. compared to that of other observations.” Line 13. “data and examine” Line 18. “conclusions are presented”

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