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Geoscientific
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Discussions

Interactive comment on "Development of an OMI AI data assimilation scheme for aerosol modeling over bright surfaces – a step toward direct radiance assimilation in the UV spectrum" *by* Jianglong Zhang et al.

Jianglong Zhang et al.

jzhang@atmos.und.edu

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Responses to reviewer 2 comments

This paper develops a data assimilation scheme using the VLIDORT radiative transfer model and simulated aerosol information from the NAAPS model to assimilate OMI AI measurements into the NAAPS model. Including the OMI AI assimilation improves the NAAPS simulation compared to the OMI AI, and improves NAAPS simulated AOD compared to AERONET AOD, but it does not outperform the NAAPS reanalysis AOD

compared to AERONET. Overall the paper is well written and their data assimilation approach is well explained. I do have some comments.

We thank the reviewer for his/her comments

Question : My main issue with the paper is that the authors state in the abstract: "Improvements in model simulations demonstrate the utility of OMI AI data assimilation for improving the accuracy of aerosol model analysis over cloudy regions and bright surfaces." But this is not really shown anywhere in the paper.. On line 149 it is even stated: "As AERONET data require a cloud-free line of sight to the solar disk, the performance of OMI AI data assimilation over overcast regions is not evaluated." Yes there are AI measurements over cloudy regions and bright surfaces, but nowhere in the paper have the authors specifically evaluated the performance of their analysis over bright or cloudy surfaces compared to, say, the NAAPS reanalysis AOD from MODIS and MISR. The authors even state that their assimilation does not improve the NAAPS AOD compared to the reanalysis AOD, so where is the evidence of improvement over bright and cloudy surfaces? It is not explicitly stated which products from MODIS and MISR go into the NAAPS reanalysis, but both MODIS deep blue and MISR retrieve AOD quite accurately over bright surfaces, especially deserts, so this statement really should be backed up somehow.

Response: One of the advantages of OMI AI is its ability to detect UV- absorbing aerosols over cloudy skies as well bright surfaces such as over desert regions and snow/ice-covered regions. In this study, we examined the possibility of assimilating OMI AI data over cloudy regions as well as desert regions (bright surfaces). All quality-checked (excluding noisy data and data with row anomalies) OMI AI data over cloudy regions and desert regions were used in the assimilation process. In comparison, no reliable AOD retrievals are available over cloudy regions from traditional passive-based aerosol retrieval methods. Also, retrievals over the desert regions are also limited to select algorithms. Therefore, having the OMI AI data assimilation capability over cloudy regions and over bright surfaces is an advancement in aerosol data assimilation.

We agree with the reviewer that it is hard to evaluate NAAPS performance over cloudy regions. We also agree that OMI AI is an indirect indicator of aerosol properties, and assimilating OMI AI typically cannot out-perform assimilating of MODIS/MISR AOD over cloud free regions. Nonetheless, the improvements in NAAPS analyses over cloudy regions or bright surfaces through OMI AI DA can be directly or indirectly illustrated from three aspects.

First, our study suggests, based on the AERONET evaluation, that over cloud-free regions, in comparing NAAPS natural runs (without aerosol assimilation), the accuracy of NAAPS analyses is improved with the assimilation of OMI AI data. This suggests OMI AI data can be used to improve NAAPS performance. Also, OMI AI has comparable capability to detect UV absorbing aerosols over cloud-free skies as well over cloudy skies, thus, benefits in NAAPS analysis over cloudy regions or bright surfaces are expected through assimilating quality- controlled OMI AI data over cloudy and bright surfaces. Note, no passive-based AOD data are currently available for assimilation over cloudy regions.

Secondly, as the reviewer mentioned, there are AI measurements over cloudy regions and bright regions for evaluation. We have performed this approach in the paper. One of the steps for a data assimilation system is to check the difference between observation and analysis (O-A), as well as the difference between observation and background (O-B). OMI AI can be considered as observations. NAAPS data includes aerosol concentrations, and thus to perform O-A or O-B, we used the forward model and computed simulated OMI AI using NAAPS data. The two-month (July and August 2007) mean O-A is shown in Figure 4d and the two-month mean O-B is shown in Figure 4h. While near zero O-A values are found for the study region as shown in Figure 4d, large O-B values can be found in Figure 4h over heavy smoke and dust aerosol polluted regions. Note to compute two-month mean O-A and O-B, both NAAPS and OMI AI data over both cloudy and cloud-free skies were used. At the instantaneous level, Figures 3b and 3f show the O and A for 12UTC, July 28, 2007. Figures3b and 3e show the

O and B for 12 UTC, July 28, 2007 as well. Again, while observation and simulated AI using NAAPS analysis are similar over both cloudy regions and cloud free regions, large discrepancies can be found between OMI AI and simulated OMI AI using NAAPS natural run data. The O-A/O-B analyses at both two-month mean and instantaneous levels indicating NAAPS performance can be improved over cloudy regions.

Third, as a qualitative check, as highlighted in red ellipses in Figure 3, the NAAPS AOD patterns after OMI AI DA show a very similar spatial pattern to OMI AI over both cloudy and non-cloudy regions. This can be considered as an indirect indicator that NAAPS AOD patterns match OMI AI patterns after OMIAI DA, even over cloudy regions.

However, we have revised the sentence along the lines suggested by the reviewer:"Improvements in model simulations demonstrate the utility of OMI AI data assimilation for aerosol model analysis over cloudy regions and bright surfaces"

Other comments: Question: - In section 4.3 Sensitivity Analysis, the authors discuss how varying smoke SSA affects the AI and conclude that there is a need for regionally varying SSA values for smoke to be included for future studies. However, the issue is not necessarily varying smoke SSA, it is the fact that the model used in this paper treats all "smoke" as one aerosol type with a single SSA value. In reality, "smoke" is composed of both black and organic (that is, brown) carbon, which have different SSA values, and different areas have different contributions of black and brown carbon to the overall "smoke". So really what the authors are showing is a major limitation in modelling absorbing aerosol with the particular model they chose.

Response: Agreed. However, the problem we are encountering is very similar to that faced by the passive-based AOD retrieval community. Dust/smoke aerosol properties vary as a function of region and season, creating a problem not only for this study but for AOD retrievals using passive sensors. To deal with this problem, regional-based aerosol properties are used in some algorithms (e.g MODIS Dark Target). Similar methods may be also adopted for this study, as we have mentioned. However, this is outside the scope of our paper and is the subject for a future study.

Question:- Also in section 4.3, the authors state: “Interestingly, although simulated AI values are significantly affected by perturbing SSA values as shown in Figure 6, less significant impacts are observed for NAAPS AOD.” However, this is to be expected, because AOD is a measure of the total extinction due to the presence of aerosols, so changing the fraction that is either scattering or absorbing would not change the overall extinction.

Response: NAAPS-modeled UV-absorbing aerosol (dust and smoke) concentrations are corrected based on OMI AI observations. We agree that dust and smoke aerosols are only a fraction of the total aerosol concentration.

Question: - Lines 136-139: “Isolated high AI values are removed as follows. First, for a 4x4 pixel box, if the mean AI is less than 0.7 but an individual AI value is larger than 0.7, then that one value is removed. Second, if the standard deviation of AI values for a 3x3 pixel box surrounding a pixel is larger than 0.5, that individual AI value is likewise removed” It is not explained how the authors came up with this criteria, and it might be helpful for them to include a bit of an explanation.

Response: Both approaches are essentially homogeneity tests that are used for identifying outliers. The thresholds are estimated empirically through visual inspection.

We added this sentence: “Note that both approaches are essentially homogeneity tests that are used for identifying outlies. The thresholds are estimated empirically through visual inspection.”

Technical comments:

Question: - Lines 80-86 are worded a little confusingly: “AI retrievals are currently computed using observations from sensors with ozone-sensitive channels. For example, the Ozone Monitoring Instrument (OMI), Ozone Mapping and Profiler Suite (OMPS), TROPOspheric Monitoring Instrument (TROPOMI) and the future Plankton, Aerosol,

Cloud and ocean Ecosystem (PACE) mission can detect UV-absorbing aerosol particles, such as black carbon laden smoke or iron-bearing dust, over bright surfaces, such as desert, snow and ice covered regions, and aerosol plumes above clouds (e.g. Torres et al., 2012; Yu et al., 2012; Alfaro-Contreras et al., 2014; 2016).” At first it is being discussed how AI retrievals use ozone sensitive channels, then the “for example” is talking about detecting absorbing aerosols.

Response: We revised the sentence to read:“For example, the Ozone Monitoring Instrument (OMI), Ozone Mapping and Profiler Suite (OMPS), TROPOspheric Monitoring Instrument (TROPOMI) and the future Plankton, Aerosol, Cloud and ocean Ecosystem (PACE) mission include ozone-sensitive channels that can detect UV-absorbing aerosol particles, such as black carbon laden smoke or iron-bearing dust, over bright surfaces, such as desert, snow and ice covered regions, and aerosol plumes above clouds (e.g. Torres et al., 2012; Yu et al., 2012; Alfaro-Contreras et al., 2014; 2016).”

Question: - Line 276: dust “plums” should be “plumes”

Response: Done.

Question: - Line 453: “proving” should be “providing” Response: Done.

Please also note the supplement to this comment:
https://gmd.copernicus.org/preprints/gmd-2020-216/gmd-2020-216-AC3-supplement.pdf

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