Response to Reviewer1

This paper sets out a methodology and presents summary results for assimilating aerosol index measurements in to an aerosol forecasting model. This is relevant and interesting for the modelling community as it is effectively aerosol radiance assimilation. Radiance assimilation is common place in the NWP data assimilation community but has still to be explored for aerosol assimilation. For NWP it provides improved results compared to a level 2 retrieval and it has not yet been established whether the same may be true for aerosol assimilation. The article is very nicely written and provides a clear and precise overview of the work carried out. The detail of the forward model and assimilation procedure used is thoroughly covered but the clear structure of the article means the overall message of the paper is not lost in all the detail. The results of the assimilation experiment are succinctly presented in easy to understand figures without inflating the results or claiming more than is shown. This well written paper presents an advance to modelling science and deserves publication. I do, however, have a few minor comments that I list below

We thank the reviewer for his/her constructive comments

Minor comments

Question 1. It was not quite clear to me from the article whether the three models whose results are compared were the same version of the NAAPS model? I understand that the NAAPS reanalysis v1 was used to show the results with AOD assimilation (pg 8, paragraph 1) and that a free running version was used to provide the results without any aerosol assimilation at all (line 176). You also state that the assimilation system is based on variations of aerosol particles from NAAPS (line 106). Are all three the same version at the same resolution or are there differences between them? It would be beneficial to clarify this in the article as any differences will also impact on the results of the three experiments compared to Aeronet.

Response: *The same research version of the NAAPS model is used for all three experiments. For the natural runs, only the NAAPS forecast model was used, that is, without any form of data assimilation. For the NAAPS reanalysis version 1, NAAPS was run with additional assimilation using MODIS and MISR AOD data. For the OMI AI data assimilation as presented in the study, NAAPS was run with the newly developed OMI AI assimilation. All three runs are at the same spatial and temporal resolutions, and are driven by the same meteorology and model physics. We expect that differences among three model runs resulted from the different aerosol data assimilation schemes implemented versus the natural run. We have added the following sentence to clarify the issue:*

"Note that the same version of the NAAPS model with the same temporal and spatial resolutions, and driven by the same meteorological data, were used in constructing Figure 5 and thus the differences in Figures 5a, 5b and 5c only result from different aerosol data assimilation methods implemented (no data assimilation for the natural run)."

Question 2. Related to this, I'm slightly confused by your description of the post-processing system in lines 209-211. I would consider the construction of a new NAAPS analysis based on the background NAAPS aerosol concentrations and increments as derived from the assimilation system to be part of the assimilation process itself. In fact I would assume that this updated analysis state would be forecast forward in time to create the background state for the next cycle of the data assimilation process. Is this not the case?

Response: *Post-processing as mentioned in lines 209-211 is a part of the typical data assimilation process. In a typical data assimilation method, increments are constructed based on the differences between observations and modeled parameters (innovations), as well as error characteristics of both model and observations. These increments include new changes that need to be made for each model grid. At the last step of a typical data assimilation process, the modeled background is updated by adding those increments (or corrections) to construct a revised background state (analysis). The revised background state is then used as the initial state for the forecast for the next time cycle.*

In another word, analysis = background + increments. Note that a similar post-processing step is also included in the NAVDAS-AOD for MODIS and MISR AOD assimilation (Zhang et al., 2008).

Zhang, J. and J. S. Reid, D. Westphal, N. Baker, and E. Hyer, A System for Operational Aerosol Optical Depth Data Assimilation over Global Oceans, J. Geophys. Res., 113, D10208, doi:10.1029/2007JD009065, 2008.

Question: 3. Your Figure 7 is a comparison of the vertical profiles of the NAAPS natural and AI DA runs. Assuming that the AI DA runs are as described above, so an analysis model state that is used as the initial condition for a short forecast to create the background state for the next assimilation cycle, then I don't believe you can draw the conclusions that you do in lines 493-498. There is no guarantee that the profile before assimilation is the same as the nature run profile and so you can not disentangle what profile differences come from previous assimilation versus what is due to the assimilation of the AI data in the current cycle. To look at the impact of assimilating AI data in one specific cycle you would need to plot the background model state versus the analysis state, rather than the nature run.

Response: *Both natural and OMI AI DA runs were performed with the same version of the NAAPS model, at the same spatial and temporal resolutions, with the same initial conditions at the beginning of the study period (00Z, July 1, 2007). The only difference between the two-month natural and OMIAI DA runs is that OMI AI data assimilation was implanted in the OMI AI DA run, while OMI AI data assimilation was not implanted for the natural run. Therefore, the differences between the two model runs arise uniquely from the OM AI data assimilation process.*

Note that for a given cycle, once the model has begun integrating forward in time, the differences in vertical profiles between the natural and OMI AI DA runs will also be impacted by increments from previous cycles (after the starting date of the study period). So the differences between

OMI DA and natural runs as shown in Figure 7 can be considered as an integrated effect of OMI AI DA from 00Z, July 01 to 12 Z, July 28, 2007.

We added the following sentence to avoid confusion: "Note that the differences between OMI DA and natural runs as shown in Figure 7 are essentially an integrated effect of OMI AI DA from 00Z, July 01 to 12 Z, July 28, 2007."

Question 4. What do you think is the impact of using gridded OMI data (line 130-133) versus the higher resolution (I assume) AOD data of the reanalysis. Do you think that the results would change if you were able to use the AI data at its native resolution and that it would closer match the results of the reanalysis?

Response *: I assume the reviewer meant to say "high resolution (I assume) AI data" based on the second sentence. Changes are definitely expected with the use of AI at its native resolution. This is because each data point included/removed will introduce changes in the computed increments. Still, for a given grid, the gridded OMI data represents the averaged properties for that grid. Thus, we expect the difference between using gridded data or OMI data at the native resolution to be marginal.*

Question 5. It is interesting and useful to have an idea of the computational burden of the call to the radiative transfer model in Section 4.4, but it would add perspective if this could be compared to the equivalent computational burden for AOD assimilation.

Response: The time scale for running AOD assimilation for 1 month is at the hourly level, depending on the machines used. We have added the following remark:

"In comparison, the time scale for running AOD assimilation for 1 month is at the hourly level."

Typos

Question: Pg. 7, line 147: AERONET

Response: *done.*

Question: Pg. 8, line 169: precipitation data are used to constrain the wet removal process

Response: *done*

Question: Pg. 18, line 405-407: It is unclear to me which figures you are talking about in this sentence. I assume it is Figure 3c, but coming directly after discussion of a comparison of 3b to 3d it needs further clarification.

Response: *We added Figure 3c in the text.*