Answers to anonymous Referee #2 comments, received and published on 26 February 2015, on the manuscript:

"Using the OMI Aerosol Index and Absorption Aerosol Optical Depth to evaluate the NASA MERRA Aerosol Reanalysis"

We thank the reviewers for providing comments that helped to improve the quality of the paper. The detailed responses to comments are listed below (text in black shows comments from the reviewers, and the text in blue is our answer):

Review of "Using the OMI aerosol index and absorption aerosol optical depth to evaluate the NASA MERRA aerosol reanalysis" by Buchard et al., submitted to Atmos. Chem. Phys. This study compares extinction and absorption aerosol optical depth and aerosol index in the MERRA aerosol reanalysis against remote-sensing retrievals from satellite sensors and AERONET. The authors build on the results of the comparison to improve the optical properties of selected aerosols in their model, namely mineral dust and biomass-burning.

The paper is well written, and relies on a large number of figures which give a thorough view of the skill of the MERRA aerosol reanalysis at simulating aerosol optical properties. The results are interesting, and I particularly like the fact that the authors act upon the results of the comparison. There is room for improvements, however, as detailed below. For those reasons, I recommend revisions before the paper is published.

1 Main comments:

• In Section 5.1.4, the authors update the refractive index of mineral dust from the OPAC dataset (which is indeed outdated) to an observation-based dataset. But why do they carefully ensure that the values at 354 and 388 nm are not changed? This means that the AI remains virtually unchanged (Page 32192, line 12 and Figure 7 and 8), but I cannot see the point. Later on, the authors show that AAODs now agree better against AERONET (Page 32192, line 22). But that is hardly surprising, since the "observation-based" dataset is mainly based on AERONET retrievals of mineral dust absorption in the first place.

In the analysis presented in the paper, in all cases we begin from a baseline of using aerosol mass mixing ratios (including their vertical distribution and aerosol speciation) that arise from the MERRAero reanalysis. Therefore, our sensitivity studies can only adjust assumed aerosol optical properties, not aerosol vertical distribution or, for example, the ratio of organic carbon to black carbon. These aerosol properties are determined by the forecast model (GOCART) and during the analysis process, and we do not attempt to adjust them here.

Over the Saharan dust region, our approach is to first compare MERRAero with OMI AI and AAOD. During the assimilation process, we used optical properties from the OPAC

database for dust. Thus, our aerosol masses are constrained by this set of optical properties. For a baseline comparison, we evaluate the resulting AI and AAOD compared to OMI. We found best agreement in AI, with less agreement in AAOD relative to OMI.
Having first constrained aerosol mass through the assimilation process using assumed OPAC optical properties, we can now use this observationally-constrained mass to try and revise our optical database. We chose to first consider the observation-based database from Colarco et al. (2014), and made exactly same comparisons with OMI. These 2 datasets have different spectral absorption dependencies. With the observation-based database, we improved our AAOD (388 nm) comparison but AI got worse. Therefore, we decided to revise the observation-based optical properties by adjusting the refractive index at 354 nm while keeping 388 nm the same. This insured that we would not make our AAOD comparison (388 nm) worse while trying to improve our AI comparison, which relies on the spectral contrast between 388 and 354 nm.

We agree that the "observation-based" dataset is mainly based on AERONET retrievals, nevertheless we think that this comparison of AAOD with AERONET is still useful to evaluate the model due to the fact that AAOD depends not only on optical properties, but also strongly on aerosol mass.

• On a more general note, the authors seem to use AAOD and AI interchangeably, using the variable that best suit their analysis. This is especially apparent when comparing section 5.2.3, which discusses both AI and AAOD, and section 5.2.4, which drops AI in the sensitivity analysis. I would argue that a more powerful approach is to improve both together: AAOD and AI constrain different aspects of the model (AI being also sensitive to altitude). Could the paper adopt such an approach?

We are trying to improve our optical properties, given the aerosol masses and their vertical distributions/speciations available from the MERRAero reanalysis product. For the biomass burning sensitivity analysis case (section 5.2.4), considering both south America and southern Africa, our AAOD seemed reasonable compared to observations from OMI (AAOD is biased slightly low over southern Africa compared to OMI, and biased slightly high over South America). Given this, we chose to focus on improving the AI. So as to not alter the AAOD comparison at 388 nm, we only adjust the optical properties of OC at 354 nm. This is reasonable because OC becomes more absorbing at lower UV wavelengths (e.g. Kirchstetter et al., 2004).

• Sections 5.3.1 ends with a discussion of the possibility that emissions are underestimated, thus explaining why AODs are biased low in Asia. But it would seem that the comparison to CALIOP vertical profile is not consistent with that hypothesis: if emissions were underestimated, how can backscatter be too large near the surface (section 5.3.2)?

We have corrected p 32198 lines 16-18 from:
"However, as seen in the biomass burning region in southern Africa, the model tends to have more aerosols than the observation in the lowest layers of the atmosphere."

to read:

"However, as seen in the biomass burning region in southern Africa, the model tends to have more **attenuated backscatter** than the observation in the lowest layers of the atmosphere."

Notice that this is the attenuated backscatter coefficient and not the backscatter coefficient.

Attenuated backscatter coefficient depends on the amount of aerosol and it's extinction/backscatter properties as well as the amount of extinction above. Thus, a large surface backscatter could be caused by (1) more aerosol mass, more backscatter or (2) less extinction above the surface implying more near-surface backscatter. If extinction at higher levels is lower, more radiation is available near the surface to be backscattered.

2 Other comments:

- Page 32181, line 13: Please list the years covered by the aerosol reanalysis here.

The years will be added in the new manuscript.

- Page 32183, line 1: I'm confused: the abstract and introduction say that MODIS AODs are assimilated. But the text says here that reflectances are assimilated. Which is it?

Bias corrected MODIS AOD (not the official product) are assimilated in MERRAero. To obtain these bias corrected MODIS AOD, a neural network approach has been used to translate cloud-cleared MODIS reflectances into AERONET calibrated AOD.

Page 32183, line 1 is part of the description of the neural network scheme saying that MODIS reflectances are one of the input into the neural network and not the official product MODIS AOD.

Page 32182, line 21, we have added "bias corrected" in the text: "GEOS-5 also includes assimilation of bias corrected AOD observations from…" and line 22: "The bias correction algorithm involves…"

- Page 32183, lines 26–27: Please summarise what modifications were made to the sulphur dioxide injection heights. Also, there is no mention of dust emissions. Why?

More details about the modifications made to the sulfur dioxide injection heights will be added to the new manuscript.
Page 32183, lines 26-27: " Parameterizations of natural and anthropogenic emissions in MERRAero reflect several noteworthy updates compared with the previous version of the GEOS modeling system (Colarco et al., 2010). Emissions of SO_2 from anthropogenic

sources come from the Emission Database for Global Atmospheric Research (EDGAR) Version 4.1 inventory, and the injection scheme was modified to account for the differences in injection profiles of emission sources from energy and non-energy sectors. The non-energy emission (from transportation, manufacturing industries, residential) are emitted into the lowest GEOS-5 layer and the energy emissions from power plants are emitted at higher levels between 100 and 500 m above the surface (Buchard et al., 2014). Biomass burning emissions are from the NASA Quick Fire Emission Dataset (QFED) Version 2.1. QFED is a~global fire radiative power based inventory of daily emissions of aerosol precursors and trace gases (Darmenov and da Silva, 2014)."

Dust emissions have not changed since Colarco et al., (2010). A line will be added in the new manuscript: Dust emissions follows from Ginoux et al., (2001) and are explained in more details in Colarco et al., 2010.

• Page 32184, lines 16–17: In addition to the requirement on AOD, the AERONET inversion of SSA requires that the solar zenith angle be large enough. That requirement means that absorption is sampled in mornings and afternoons, which introduces another bias in the AERONET absorption dataset, especially in regions where the aerosol diurnal cycle is large (e.g. biomass-burning regions).

This notification will be added in the AERONET description section 3.1: "In Level 2.0, SSA is only retrieved for AOD greater than 0.4 and solar zenith angle greater than 50º."

• Page 32186, lines 18–20: The paper does not seem to rely on polarisation, so that sentence is not relevant to the paper.

We are doing the AI simulation using the vector mode of VLIDORT to consider particle non-spericity for dust aerosols. It is part of the description of VLIDORT that can be used for other applications.

• Page 32187, line 10: In the calculation of AI in VLIDORT, do the concentrations and vertical profiles of ozone and water vapour matter? If so, how were they prescribed?

In our AI simulation, we did not consider profiles of ozone and water vapor.
According to Torres et al., (1998), "Derivation of aerosol properties from satellite measurements of backscattered ultraviolet radiation: Theoretical basis", JGR). For the wavelength considered in AI calculation, the ozone absorption is weak and does not affect the interaction between the aerosols and the molecular atmosphere.

• Page 32188, line 2: What are the white and grey areas in Figure 1?

The grey means no data (or OMI quality flag = 0), and is here to differentiate with the white color used in the differences (OMI-MERRAero) colorbar.
This will be added in the caption of the figure.

• Page 32188, lines 23–26: It would be useful to show the regions on one of the maps on Figure 2 or 3.

The regions will be added on Figure 1 in the new manuscript.
Page 32188 line 22: (shown on Fig. 1).

• Page 32190, lines 20–22: Do the authors have an explanation for the large surface backscatter in MERRAero?

Unfortunately we don't have at this time an explanation for the MERRAero value of attenuated backscatter coefficient higher than CALIOP at the surface. It potentially could be due to the amount of aerosol and it's extinction/backscatter properties as well as the amount of extinction above.

• Page 32191, lines 14–16 and page 32192, lines 14–16: What point are the authors trying to make here by giving all those numbers? That there are hints that aerosol composition is not right and explains the bimodality of the differences between MERRAero and OMI?

These numbers are just the statistics (r and bias) resulting from the comparisons between MERRAero AAOD and OMI AAOD like we have done for the AOD comparisons with MISR. We provide these numbers in the purpose to give more information about the comparison.

• Page 32192, lines 1–2: Please be more quantitative: what is the new SSA, for example?

These lines have been added to the new manuscript: " For example in Colarco et al., (2014), Table 1 summarizes SSA values at 550 nm resulting from simulations using several dust optic tables at Cape Verde, a site strongly influenced by dust. A SSA value of 0.88 is found assuming the OPAC database while a value of 0.92 is found with the observation-based database, both assuming a spheroidal shape distribution.

• Page 32192, line 19, and similar sections for other aerosol species: Are modeled AODs sampled as in AERONET absorption retrievals (at least AOD > 0.4)?

Not necessarily, if one AERONET data is available, MERRAero is sampled at AERONET location and time.

• Page 32193, line 2: More specifically, iron oxides.

This change has been made.

3 Technical comments:

• Page 32192, line 20: rephrase to "for which AERONET retrieves SSA..."

This change has been made.