Dear Editor,

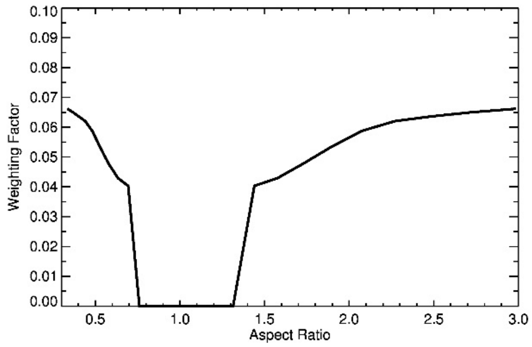
Following the review process, we have produced an enhanced version of the paper that addresses the issues raised in the review process. The main additions to the paper are listed below

-The introduction section was expanded to provide a more complete description of the OMAERUV retrieval algorithm. The following text was added:

"The algorithm, based on TOMS (Total Ozone Mapping Spectrometer) heritage, takes advantage of the interaction of molecular scattering and particle absorption in the UV to detect and quantify absorption properties of UV-absorbing particulate such as carbonaceous, desert dust and volcanic ash aerosols [*Torres et al.,* 1998]. The retrieval algorithm relies on forward calculations of angle-dependent upwelling near UV radiances whose accuracy depend on the correct characterization of both molecular and particle scattering. Aerosol scattering depends on particle size, shape and composition. In the OMAERUV algorithm, the aerosol scattering phase function is calculated using Mie Theory, which applies only to spherical particles. Erroneous scattering phase function characterization may produce large errors in retrieved AOD and SSA values [*Gassó and Torres, 2016*]. OMAERUV uses external ancillary data from other A-train sensors for characterization of aerosol type and information on aerosol layer height [*Torres et al.,* 2013]."

-Section 4.2 was expanded to provide a more detailed description of the modelling aspects of scattering by non-spherical particles. This addition includes two additional figures.

"A known difficulty in the treatment of non-spherical particles is the need of prescribing the fraction of non-spherical elements in the polydispersion, as well as making assumptions on the prevailing aspect ratio values. To address those issues, we follow the statistically optimized approach of *Dubovik et al.* [2011] to account for mixtures of spherical and non-spherical particles, as well as mixtures of spheroids of varying Ɛ values as suggested earlier by *Mishchenko et al.,* [1997]. In *Dubovik et al.* [2006, 2011], the aerosol polydispersion is modelled as a mixture of randomly oriented spheroids. Each size bin consists of a size independent distribution of Ɛ ranging from 0.33 to 2.98 which includes flattened oblate spheroids (Ɛ<1), elongated prolate spheroids (Ɛ>1), in addition to spheres (Ɛ=1). The aspect ratio is distributed in 25 bins, with each Ɛ bin having a fixed weight such that the sum of all weights equals unity as shown in Figure 4. This modelling approach, that closely reproduces the laboratory measured single scattering matrices of mineral dust (Feldspar) reported by *Volten et al* [2001], is currently applied in the operational AERONET (AErosol RObotic NETwork) inversion of measured sky radiances [*Dubovik et al.,* 2006]. The resulting spheroid scattering phase function and it sphere-equivalent representation at 388 nm for single scattering albedo 0.9 are shown in Figure 5. Additional calculations (not shown) as a function of aerosol absorption, indicate that in the near UV, the observed sphere-spheroid phase function difference in the 80°-150° scattering angle range is largest for non-absorbing aerosols, and reduces significantly for SSA values 0.82 and lower. "



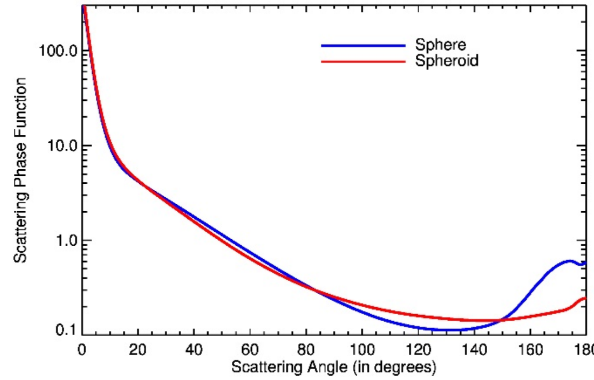


Figure 4. Spheroids aspect-ratio-weighted distribution

Figure 5. Sphere and Spheroid scattering phase functions

-A discussion section was added to the paper Section 6.0, including two more figures,

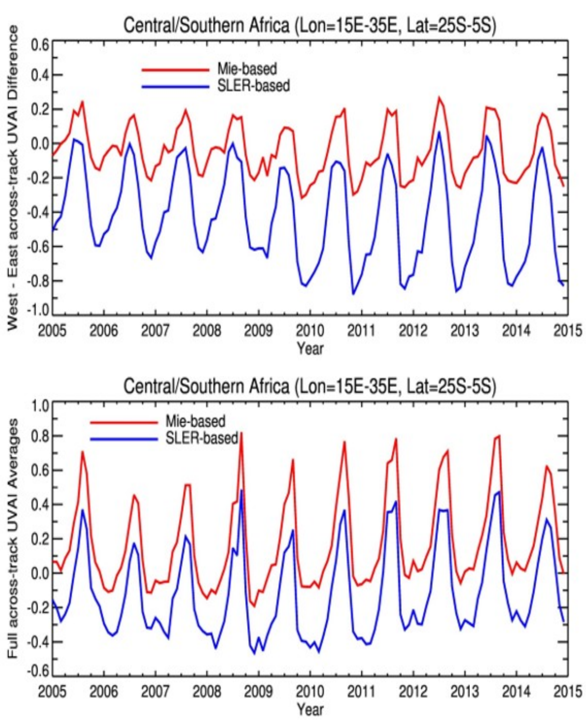
Section 6.0 Discussion

"The improved radiative transfer modelling in the presence of desert dust aerosols and water clouds, as discussed in this paper, was incorporated in a revised version of the OMAERUV algorithm. The effect of these upgrades on the global product, and the impact of the row anomaly on the long-term OMAERUV regional records are briefly discussed here. A more detailed discussion of the global long-term OMAERUV record will be given in a forthcoming publication.

A global comparison of resulting Mie and SLER based UVAI definitions under cloudy conditions are shown in Fig. 12 for August 20, 2007. The across-scan bias of the Mie-based UVAI map, shown on the middle panel, is significantly reduced in relation to the corresponding SLER-based UVAI map depicted in the top panel. To facilitate the comparison, the bottom panel of Fig 12 shows the associated reflectivity field. A clear reduction in across-scan Mie UVAI bias is observed over cloudy regions of reflectivity larger than about 20%.

Figure 13 (upper panel) shows the W-E differences between the monthly averages of UVAI obtained with the SLER (blue line) and Mie-based (red line) calculation approaches over the SAF region for the 2005-2014 period. Both results show repeatable seasonal cycles over the first four years of observations. The SLER UVAI across-track differences oscillate between about -0.6 in winter to about 0 in winter whereas the Mie UVAI W-E differences shows much less seasonal variability (-0.1 to 0.2). An overall drop of the W-E UVAI differences is apparent by the summer of 2009 when the row anomaly has fully developed. A decrease of about 0.2 is observed in the SLER UVAI data whereas a smaller change (~0.1) can be seen in the Mie-based UVAI definition. From then on, the winter W-E UVAI difference stabilizes at -0.8 for the SLER method, and at -0.2 for the Mie-based definition. The summer maxima, on the other hand, slowly increases with time after 2010 for both parameters but a more rapid increase is apparent for the SLER UVAI term. Overall, the effect of the row anomaly is larger and more noticeable in the SLER UVAI definition. Similar results (not shown) are also observed over the NEUS region. The eleven-year record of monthly average UVAI over the SAF region obtained by both definitions is shown in the lower panel of Figure 13. Overall, the Mie-based UVAI record is about 0.3 higher. This increase moves up the minima UVAI values associated with water clouds from negative (~ -0.3) in the SLER definition to nearly zero in the Mie-based calculation. The rapid decrease in the SLER UVAI annual minimum in early 2008, following the onset of the row anomaly, is not present in the Mie-based UVAI record. Both records show an increasing trend beginning in 2009. The SLER UVAI shows a 0.04/yr. increase, whereas the Mie-based UVAI is about half that value.

Upper panel of Figure 14 depicts the eleven-year temporal record of the across-track AOD bias for both spherical and spheroidal model representations of desert dust aerosols. The W-E differences for the spheroidal model (red line) oscillate around 0.05 but are never larger than 0.1, with no clearly observable effect of the onset of the row anomaly. The spherical model (blue line), on the other hand, produces across-track differences as large as 0.25 during the first two years, and a decrease to 0.15 coincident with the initial loss of viewing capability associated with the row anomaly. Following the row anomaly onset, the spherical model yields seasonal and inter-annual variability of across-track AOD differences as high as 0.2 towards the end of the shown temporal record. The resulting multi-annual records of AOD over the SAH region as calculated by the spherical and spheroidal models are shown on the bottom panel of Figure 14. During the first four years of the record, the spherical model underestimates spring and summer monthly averages by about 0.05 with respect to the spheroidal model. Starting in 2009, after the full development of the row anomaly, the bias goes down, and the spherical model results are closer to those of the spheroidal model. The reason for this bias reduction is the exclusion of observations from most of the rows in the East across-track segment of the orbits (yielding larger errors associated with the erroneous phase function assumption) as they are affected by the row anomaly."



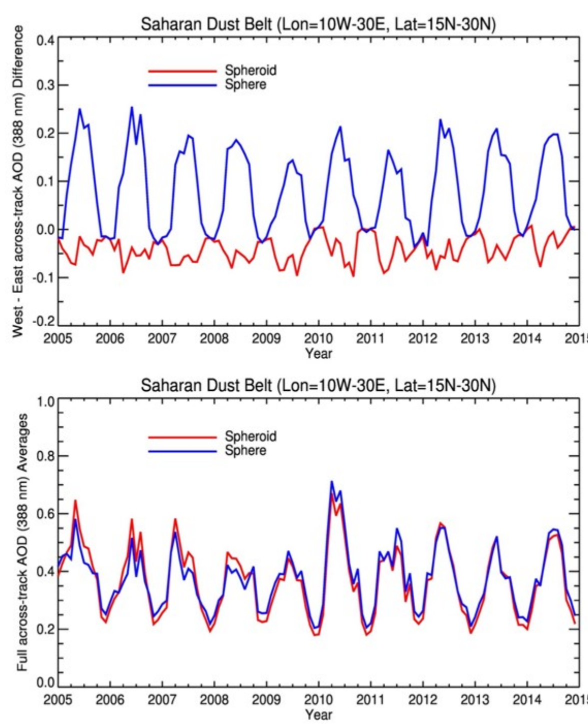


Figure 13. Figure 14

- The Summary and Conclusions section has been enhanced

"The OMI sensor is currently affected by a loss of spatial coverage commonly referred to as row-anomaly. Although an unequivocal explanation of the row anomaly does not exist, it is believed to be the result of an internal obstruction affecting the sensor's across-track viewing capability. Prompted by the loss of angular coverage associated with OMI's row anomaly, we carried out a detailed examination of the effect of the reduction of OMI's angular sampling capability on the accuracy and statistical representativity of retrieved aerosol parameters, and the consequences of the row anomaly on the long-term record derived from OMI observations. "

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"The analysis discussed here has uncovered important algorithmic deficiencies associated with the model representation of the angular dependence of scattering effects of desert dust aerosols and cloud droplets. In addition to the documented east-west asymmetries in the magnitude of the retrieved aerosol parameters, the use of inaccurate scattering phase functions of desert dust aerosols and clouds introduces spurious features in the long-term record when a range of scattering angles is no longer available because of the row anomaly. The more accurate representation of the scattering patterns of water clouds, and the spheroidal particle shape assumption in the retrieval of desert dust properties eliminates the observed inconsistency of aerosol retrieval results associated with the separate use of east-of-nadir or west-of nadir observations. The recommended improvements in the modelling of scattering by cloud droplets and desert dust aerosols also reduces the magnitude of row-anomaly related discontinuities in the long-term record of the OMI aerosol products. "

Reply to Comments by Anonymous Referee #1

The paper describes the characterization and correction of view-angle dependent OMI retrieval results of AOD, SSA, and UVAI. Particularly in view of the loss of data from certain OMI detector rows due to the so-called row anomaly, a dependence of retrieval results on view angle (or row number) causes biases in temporal and spatial averages. Torres and co-workers identified the spherical particle assumption to be the reason for the observed view-angle dependency of AOD and SSA retrieved over desert and were able to strongly decrease the bias by using phase functions more appropriate for mineral dust. The UVAI view-angle dependency was found to be mainly caused by the commonly used approximation of clouds as opaque LER surfaces. The UVAI bias over regions affected by clouds could be strongly reduced by adapting the UVAI algorithm to incorporate a more realistic cloud parameterization.
This manuscript is in a very good condition: the results are impressive and well presented, and the conclusions are of importance to the scientific community, particularly to users of OMI data. My recommendation to the editor is to publish the manuscript as soon as the minor and technical comments below have been addressed in a satisfactory way.

Minor Comments

1. Several sentences are extremely long and hard to read (e.g., lines 7-10 on page 4). Please read the manuscript critically and try to make the sentences shorter, thereby improving readability.

As suggested, we have revisited the manuscript to improve readability.

2. Please add one or two literature references to phase functions of small spherical particles (Mie Theory).

The section 4.1 of the paper dealing with the issue of small spherical particles has been revisited. References on the subject has been added.

Text added to section 4.1:

The outcome of these comparative analyses suggests that the particle size distributions, spherical shape, and refractive index used in conjunction with Mie Theory for calculating the scattering phase functions of sulphate and carbonaceous aerosols in the OMAERUV algorithm [Torres et al., 2007] adequately reproduce the observed scattering patterns of small spherical particles [*Kaufman et al.,* 1994; *Dubovik et al.,* 1998].

3. On page 4, line 9, you mention that ”the angular variability of the scattering phase function of aerosols and clouds” is the ”ultimate driver of the angular distribution of scattered radiation”, but that is disregarding Rayleigh scattering, which is also very anisotropic. This is of course taken into account in your RT calculations and should not cause any trouble within your retrieval, which is probably why it is not mentioned here. But the statement as it is given here is inaccurate.

The statement has been rewritten to eliminate the inaccuracy identified by the referee.

Text added to section 3:

The observed angular distribution is associated with the combined effect of the scattering phase functions of Rayleigh scattering, and scattering by aerosol and cloud particles. Unlike Rayleigh scattering, whose scattering phase function can be unambiguously calculated with great accuracy, the scattering phase functions of aerosols and clouds require detailed information on particle size, shape and optical properties of the scattering elements.

4. On page 5, starting from line 30, the calculation of new dust phase functions is described, but it is kept rather short. Please be more specific, e.g. by mentioning the assumed fraction of non-spherical particles. How realistic is the selected set of parameters? Regarding the results (particularly in Fig. 4), how representative are they, and what happens if you try different fractions of non-spherical particles? Or different shapes? It would be nice to see this analysis for different particle mixtures (like that shown for different SSA), and in the best case a plot with the range of retrieval errors found for all particle mixtures used by the retrieval algorithm.

The discussion on the non-spherical phase function has been expanded to include additional detail on the choice of spherical/non-spherical particles mixtures. In this work we have adopted the analysis of Dubovik et al [2006, 2014] in which a distribution of spherical/non-spherical particles that closely reproduce laboratory measurements of scattering phase function of Feldspar. To our knowledge, the Dubovik et al approach is the most comprehensive analysis that involves actual observations of phase function. Since our purpose was to account for the non-sphericity effect using an accurate approach, we have done so by adopting the well documented approach of Dubovik et al [2006. 2014]. A detailed sensitivity analysis examining variations of the observation-based formulation of Dubovik et al is beyond the scope of this manuscript.

See Text added to section 4.2 above

5. On page 6, lines 5-6, it says "Retrieval errors transition from overestimations to underestimations at about 155° scattering angle". But this is not the case for SSA = 0.97. Any thoughts on why this is so?

The statement cited by the referee makes reference to the resulting AOD retrieval error depicted in the top panel of Fig. 4. The modelled AOD error does indeed transition from overestimation to underestimation at a scattering angle of 155° for all SSA values. The reviewer may be referring to the bottom panel of Fig 4, illustrating the SSA retrieval error for particles of varying absorptivity. The angular dependence of the obtained SSA error varies with aerosol absorption as described in the manuscript.

6. In the last paragraph of Section 5.3 (page 9), the improvement of the modified Mie UVAI algorithm with respect to the old version is pointed out. However, the positive UVAI artefacts that appear in the Southern part of each orbit appear to have increased in the new version. Can you comment on that?

The Mie-based UVAI definition is about 0.3 larger than the SLER-based definition. This increase moves up the minima UVAI values associated with water clouds from negative (~ -0.3) in the SLER definition to nearly zero in the Mie-based calculation. As a result, the Mie-UVAI UVAI is in general about 0.3 larger everywhere.

Text added to section 5.2

The calculated value is sensitive to the choice of COD for which a value of 10 has been assumed in this work. Except at high solar zenith conditions, the calculations are insensitive to assumed cloud top and bottom levels. Accounting for the spectral dependence of surface albedo is also an important difference that will affect the magnitude of the calculated radiances and resulting UVAI values. For the COD value used here the resulting Mie-UVAI is generally 0.3 larger than the SLER definition. This difference increases with assumed COD.

7. The modified-Mie UVAI algorithm varies from the SLER algorithm in more than one aspect. In keywords: cloud phase function, cloud opacity, cloud height, surface albedo. Although introducing a more appropriate cloud phase function intuitively seems to be responsible for the decrease in view-angle dependence, the other changes may also have an effect. Did you investigate that?

After the cloud phase function, the Mie-UVAI is sensitive, in that order, to cloud opacity, surface albedo and cloud height. Increasing the opacity above the adopted value (10) will increase the UVAI, while lowering it will produce a lower UVAI value. The sensitivity to surface albedo varies regionally. It is largest over arid and semi-arid areas where surface reflectance is spectrally dependent and lowest over densely vegetated areas. The sensitivity to cloud height is negligibly small. A brief discussion of these issues has been added to the paper. A more detailed discussion will be given in a forthcoming publication currently in preparation.

See answer to comment 6 above

Did you compare results from the MLER (as described in the appendix) to the Mie algorithm?

Yes, the comparison was made.

Text added to section 5.1

The above analysis was also carried out using the Modified LER UVAI definition described in Appendix A (not shown here for the sake of brevity). As with the SLER UVAI definition, a clear, although slightly reduced in magnitude, across track bias effect was observed.

8. In Fig. 8, there is a large difference between the blue line at row number 20 and the red line at row number 0, although the scattering angle is nearly the same. Is this within the statistical error, or could there be another reason?

The two lines are representative of summer and winter conditions. Although the scattering angles are similar, there is no reason to expect exact agreement as the geophysical conditions of the observations are different. Factors such as the presence of aerosols above clouds, presence of ice clouds (instead of water clouds), etc could results in different UVAI values.

9. Please improve the readability of the appendix and add some references (e.g. to Herman et al., JGR 1997 / Torres et al., JGR 1998).

Done

The term on the right in eq. A-1 is only equivalent to the term in the middle if the calculated and measured radiances at lambda0 are equal. This requirement is mentioned later in the section, so I suggest to split the equations.

Done

It might be more useful to replace the description of the MLER algorithm by one of the Mie algorithm, as the MLER is not used in the presented study.

Since the Mie Algorithm is central to the focus of the paper, we prefer to keep its description and discussion in the main body of the paper. We also want to keep the MLER definition in the appendix, since it is referred to in the revised version of the manuscript.

Technical Corrections
p.2, l.4 and 17 global daily— daily global

p.2, l.16 row-anomaly — row anomaly

p.2, l.18 two-days— two days

p.2, l.33 making use of — consisting of

p.3, l.23 slow— slowed

p.3, l.32-33 no detection — missing

p.4, l.3 The NEUS region (...) representative— The NEUS region (...) is representative

p.4, l.15 using separately observations— treating observations East and West of the nadir separately

p.4, l.18 monthly average — average monthly or monthly averaged

p.4, l.21 minima — minimal or minimum

p.4, l.21 take place— occur

p.4, l.24 sulphate aerosols is the most commonly observed aerosol type.
— sulphate and secondary organic aerosols are most common.

p.4, l.26 produce— produces or provides

p.4, l.30 region from February through September— region, particularly from February through September

p.4, l.34 are in good agreement with each other at the annual minima AOD values — are in good agreement.

p.5, l.1 Minima — Smallest

p.5, l.20 reproduce — reproduces

p.5, l.22 Move the citation to the end of the sentence, after the term in brackets.

p.6, l.16 aerosol models in the— aerosol models as in the p.6, l.18 take place — occur

All technical corrections listed above have been addressed

p.8, l.14 Which water cloud model? C1?

Yes, we refer to the C1 model. References to Deirmendjian [1964, 1969] have been added to document the source of the models and its nomenclature

p.8, l.14 wavelength-dependent refractive index— Does the refractive index vary so much between lambda and lambda0 that you need to take the wavelength dependence into account?

Ignoring the spectral dependence of the refractive index introduces departures as large as 0.2 UVAI units at certain scattering angles. Thus, since the data is available we decided to account for it.

p.8, l.15 prescribed top and bottom levels — What does this mean?

We refer to the pressure of cloud top and bottom. We rephrased it in the manuscript for clarity.

p.8, eq.(1) and following — Put some space between the equation and the equation number. It's confusing.

Done.

p.8, l.24-26 The treatment of surface albedo is also an important change.

Yes, it is mentioned in the revised version of the manuscript. See answer to comment 6 above.

p.9, l.22 set — sets

Done

p.9, l.25 actual angular scattering— actual scattering p.10, l.4 were — where

Done

Fig. 6-8 UVAI is written UV-AI in the figures and the caption. In Figs. 6 and 7, the UVAI method is called LER-based, whereas in the text and in the appendix it is abbreviated SLER. Please be consistent.

Revisited as suggested.