Interactive comment on “The Role of Cloud Contamination, Aerosol Layer Height and Aerosol Model in the Assessment of the OMI near-UV Retrievals over the Ocean” by Santiago Gassó and Omar Torres

Anonymous Referee #1

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The manuscript provides an assessment of the OMI OMAERUV algorithm over the ocean. This algorithm retrieves the AOD and SSA for cases with significant AAI, using assumptions on the aerosol layer height, the aerosol model (refractive index, size distribution and shape) and the surface albedo. By comparing the retrievals with AERONET, Modis and Calipso data, the impact of remaining clouds, of aerosol layer height and aerosol model are quantified using case studies. The main outcomes of the study a recommendation to the user to filter the data based on the number of successful neighboring retrievals, and a recommendation to implement a non-spherical dust model in the next version of the OMAERUV algorithm. Overall I find this a useful contribution to the literature. I like the work because it goes beyond the often presented comparisons between data product and tries to explain the causes for differences. My main criticism would be that the role of assumptions on the BRDF of the oceans are not discussed. I would suggest at least explaining what is assumed in the algorithm, and how this can effect the results. Furthermore, more information should be added in different places in the manuscript, see specific comments below.

A: We agree with the reviewer that the role of the background ocean surface within the algorithm is not well discussed in the text. The retrieval over the ocean is only carried out for conditions of high absorbing aerosol loadings (as determined by the AI threshold) in order to avoid pixels where the ocean surface effects (both BRDF as well as phytoplankton bloom) can bias the retrieval. In the version of the algorithm used in this paper, the possible remaining surface effects on the retrievals is addressed by the use of a climatology-based surface LER derived from TOMS long-term observations, and excluding sun glint affected areas based on viewing geometry considerations. The soon-to-be released new version of the algorithm will include additional corrections (a wind dependent correction) and a new databases (surface climatology based on OMI) to account for the surface effects. We have added additional information regarding the treatment of the ocean surface in the algorithm in section 2.1.2 (new) lines 199-205.

Line 21: “within the expected levels of uncertainty for the OMI AOD retrievals”: this shall be quantified
A: Added relevant information in the abstract.

Line 46 “singled” I think the authors mean “signaled” ?
A: no, it is correct as it is. "single out" is a phrasal verb meaning "distinguished from others"

Line 84-85 “OMI retrievals of SSA are the only global and daily operational retrievals of among all Earth viewing platforms.” I find this a very strange sentence, please revise. Note that the algorithm only provides a retrieval when the AAI is over a threshold, therefore it is clearly not a global product.
A: Sentence removed since it did not provide any meaningful information.

Line 93: “chiefly” should be replaced by “mainly”
A: replaced

Acronyms should be written out the first time they are used. For example AERONET (line99), MODIS (line 126), CALIOP (line 126), TOMS (line 145), GOME (line 145), SCIAMACHY (line 146).
A: acronyms clarified when first introduced

Line 105: I think the authors mean MODIS instead of AERONET?
A: See next answer.

Line 107-108: "it is assumed that a realistic and accurate AOD retrieval must have an associated realistic SSA as long as a realistic assumption on aerosol layer height has been made." I strongly doubt this assumption. From principal component analyses it is found that the dominant information in the wavelength pair is related to the AOD. In addition, the spectral slope of the radiance depends on the SSA, the aerosol vertical distribution and the aerosol microphysics (size distribution and refractive index). Given the fact that the system is very underdetermined, there is no guarantee that anaccurate AOD will result in an accurate SSA. The opposite is true: an accurate AOD is a prerequisite for an accurate SSA, given the dominance of the AOD in the information. content. Given the above, the authors should revise the statement, or delete it altogether.
A: we agree with the reviewer that this is a confusing statement and given this paper is focused on AOD over the ocean and not about SSA, we removed the paragraph.

Line 186: "steady" should be replaced by "stable"
A: corrected

Section 2.1.1: Given that the OMI pixel increases strongly towards the edge of the swath, are all the across track pixels used in this study?
A: The eastern edge OMI rows are included in the analysis whereas the western edge rows are not because MODIS swath is not wide enough to match OMI's. In the posterior analysis (section 4.1), it is noted that the pixels in OMI rows at the edge are probably so large that even the collocation with the closest and surrounding MODIS pixel cloud fraction is not enough to account for the observed excess in OMI AOD. We added the following paragraph in section 2.6 (instead of current 2.1.1), to make clear the collocation of MODIS and OMI edges: "*Both detectors are approximately aligned, and tend to have similar viewing geometries. However, while both eastern edges of the respective swaths align well, the western edges do not align because the detectors do not have the same swath (MODIS swath is approximately 2300km whereas in OMI, the swath is about 2600km). Consequently, OMI first few rows (typically rows 1 to 4) cannot be used in a collocation with MODIS. The eastern edge rows, however, are included in this analysis.* "

Section 2.1.2: I looked into the Torres [2013] paper to find a definition of the aerosol types (size distributions and index of refraction). However, Torres [2013] refers to two other papers. Because I think it is important for this manuscript, I recommend including a table with the specification of the aerosol types.
A: We added the following table with aerosol model information in Section 2.1.2 and moved the list of AERONET sites used for comparison with OMI to the Appendix.

Model	R1	R2	S1	S2	Fraction	Real
SLF 1-7	0.088	0.509	1.499	2.16	0.0004	1.40
SMK 1-3	0.087	0.567	1.537	2.203	0.0002	1.50
SMK 4-7	0.080	0.705	1.492	2.075	0.0002	1.50

DST 1-7	0.052	0.670	1.697	1.806	0.0044	1.55

Model	Imaginary 354nm/388nm
SULF	0.0,0.002,0.004,0.006,0.008,0.01,0.12
SMK	0.0/0.0,0.006/0.005,0.012/0.01,0.024/0.02, 0.036/0.03,0.048/0.040,0.0576/0.0480
DUST	0.0/0.0,0.0013/0.0001,0.0026/0.0018,0.0056/ 0.0040,0.0083/0.0060,0.0130/0.0092,0.023/0.017

Table 1: Number-Weighed Particle Size Distribution Parameters and Real Refractive Index for the Aerosol Types (Sulfate = SLF, Biomass Burning = SMK) assumed in the OMI Near-UV Algorithm. Number-weighed particle size distribution parameters: fine and coarse mode radii and variance, coarse mode fraction. The bottom table list nodal points in imaginary refractive index (wavelength independent for the sulfate and spectrally dependent for smoke and desert dust aerosols) (adapted Torres et al., 2007; Jethva and Torres, 2012)

Section 2.1.2: Add a description of the treatment of the ocean BRDF.
A: We have added additional information regarding the treatment of the ocean surface in the algorithm in section 2.1.2 (new) lines 199-205. Also, see answer to the main comment in page 1 of this answer to R1.

Line 202: add a reference for the CALIOP-based climatology.
A: reference added in section 2.1.2

Section 2.3. In this section it should be discussed that for the OMI-MODIS hybrid method to work, the MODIS and OMI aerosol types as used in the retrievals should be consistent. This is mentioned later on in the discussion of the results, but should be added here.
A: we added the following clarification in section 2.3 . “This method works best when the extrapolated MODIS AOD falls between AOD values included in the OMI LUT. When this is not the case (for example when MODIS assumes a spectral dependence of an aerosol type different than the aerosol type detected by OMAERUV), the retrieved aerosol height can be unrealistically high or low due the non-linear of the curve in figure 1.”

Section 2.3. Because the MODIS retrievals are very insensitive for aerosol absorption, it would make more sense to use the scattering AOD instead of the total AOD in the hybrid method. The absorbing part of the AOD in the MODIS product is fully based on a prior information. The scattering AOD is defined by SSA*AOD. Using the scattering AOD would result in a better separation of scattering and absorption effects, because these parameters are more orthogonal than the SSA and AOD.
A: we respectfully disagree with the premise of this statement. MODIS AOD retrievals are sensitive to aerosol absorption. This was first shown by the MODIS aerosol group using SAFARI observations (Ichoku, C. M., L. A. Remer, Y. J. Kaufman, et al. 2003. "MODIS observation of aerosols and estimation of aerosol radiative forcing over southern Africa during SAFARI 2000." Journal of Geophysical Research-Atmos. 108 (D13): 8499 [10.1029/2002jd002366]) and while some corrections have by implemented in the MODIS algorithm, it is still an issue that has been raised again in Eck et al 2013 (Eck , T. F. et al. 2013. "A seasonal trend of single scattering albedo in southern African biomass-burning particles: Implications for satellite products and estimates of emissions for the world's largest biomass-burning source." J. Geophys. Res. Atmos., 118 (12): 6414-6432 [10.1002/jgrd.50500]).

In more practical terms, it is difficult to estimate MODIS scattering AOD for each pixel. To achieve this, the SSA of each fine and coarse models found by MODIS is needed. Then, the total SSA (ie the combined contribution by the two modes) needs to be estimated by using the MODIS Fine Mode Fraction parameter, which is only available over the oceans and is only reliable at moderate to high AODs. To our knowledge, this operation has not been explored even by the MODIS aerosol team.

Section 2.4. It is unclear why CALIPSO and AERONET are described in one section.
A: Both Aeronet and CALIPSO data descriptions were separated each in different sections.

Line 296. The impact of distance between two satellites for cloud clearing has been quantified in Genkova, et al AMT, 5, 595-602, doi:10.5194/amt-5-595-2012, 2012. This reference can be used to quantify the impacts of the time difference between OMI and MODIS described here.
A: thanks for pointing us to this paper. We incorporated the reference and added sentence regarding the time difference in this section 2.6 : "A 7-8 minute difference is in the upper end of acceptable time difference for using a high spatial resolution instrument collocated with a coarser resolution instrument (Genkova et al., 2012)."

Line 314: I think it is meant "closest MODIS AOT retrieval to the OMI pixel center .."
A: yes, correction added.

Line 322-323 "detector anomaly" should be replaced by "row anomaly"
A: Correction added.

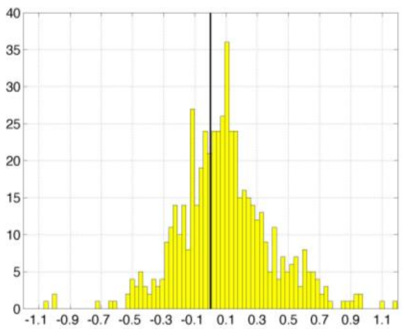
Section 3. Please include if the AERONET observation closest in time is used, or if the AERONET observations are averaged over the time window.
A: it is the average of AODs during the 20 min window. A clarification was added

Section 3. It should be discussed that by comparing with AERONET an additional implicit cloud clearing is performed. Can you provide statistics on the percentage of cases for which an OMI retrieval was present, but no AERONET observation was available due to the cloud flags used for AERONET?
A: As any good comparison with ground data requires, the existence of both a satellite and surface measurement requires an initial cloud screening. The comparison on itself does not represent a test of the performance of the algorithm under all conditions and in particular, comparisons with AERONET are useful for quantitatively evaluating the satellite retrievals and not for algorithm's cloud screening capabilities. While the fact that the existence of coincident observations from the satellite and the sunphotometer implies a cloud screening, this is only valid when the satellite's ground pixel is comparable with the area of observation scanned by the ground sunphotometer (for example, Aeronet-MODIS). In the case of AERONET-OMI comparisons, OMI's pixel size may well exceed AERONET area coverage and in this case, the existence of observations from both sensors is not necessarily an effective cloud screening. In a more practical sense, we do not think that the suggested computation can be done without much additional work and we think it deviates from the main objective of the paper.

Line 350: The criterion of 8 surrounding pixels selects spatial homogeneous cases, not necessarily "fairly clear sky conditions".
A: In the same paragraph we added a clarification on the use of the 8 surrounding pixel (see third paragraph in Section 3).

Section 3. In addition to the scatter plot shown in Figure 2, I strongly suggest to also include histograms of absolute and relative difference between AERONET and OMI. The shape of the histograms (e.g. modal, long tails) can provide additional information on the behavior of the algorithm, that cannot be extracted from the presented scatter plots.

A: We plotted a histogram of the absolute differences for the case of figure 2b (OMI vs AERONET AOD at coastal sites). The plot of OMI minus AERONET AODs is shown below (and included as a new figure 2c in the main text). It shows an asymmetric distribution and it emphasizes that OMI AODs tend to be larger than AERONET AODs. Descriptive text was added in the respective section. It replace the old figure 2c which was the scatter plot for island sites.

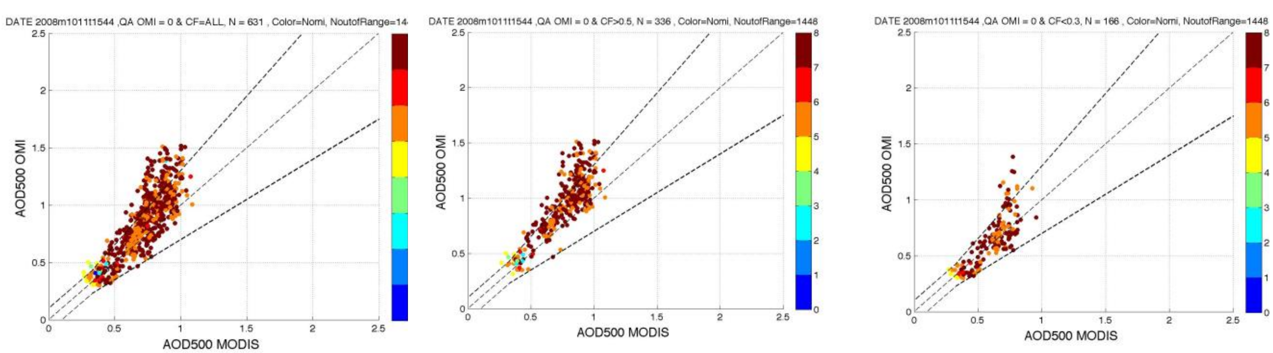


Line 414 "stretching" this is not clear, I think the authors mean the effect of the increasing size of OMI pixels towards the end of the swath.

A: the word was removed and replaced with this text: "the increase of pixel size at the edge of the swath"

Lines 432-442. It is unclear to me why the results of section 3 are not used in section 4. How does the comparison with MODIS change when the 8-neighbour criterion is applied to OMI. This should be investigated in this section.

A: We carried out the suggested analysis. The resulting image is shown below.



Figures: Similar to Figure 6 in manuscript. Comparison of OMI and MODIS AOD 500 nm colored by the number of successful OMI AOD retrievals around the selected pixel. OMI pixels have flag 0. Left: All points where a successful MODIS and OMI retrieval occurred regardless of the Cloud Fraction value in the MODIS retrieval. Center: only points with CF>0.5. right: only points with CF<0.3

The data points are the same as in figures 6 from the manuscript but color coded by N_{OMI}. Most of the pixels are surrounded by 6-8 successful OMI retrievals. In this case, the approach did not work to screen out possible contaminated OMI pixels. A possible reason of the failure is that the cloud field in the scene has a large area covered by small fair weather clouds which are not bright enough to be rejected by the OMAERUV algorithm (figure 4 A and C). This cloud field is similar to the one shown in figure 7 where very small clouds are present in contiguous OMI pixel and these pixels all have AOD retrievals. Thus , this case points to a limitation of the usage of number of OMI retrievals around the selected pixel as tool for possible cloud contamination.

This case does not preclude the conclusions drawn from the comparison of OMI with AERONET (section 3). As noted earlier, when using AERONET data, there is an implicit cloud clearing (i.e. the fact there is an AERONET AOD implies that at least there is some clear sky in the area) and probably the cloud field around the selected site is inhomogeneous. These are the conditions where the use of the number of OMI retrievals should perform the best.

It should be pointed out that this method may not an effective method for implementation in an operational algorithm (Level 2 data). Such approach would add a double loop over the orbit: first for computation of parameters in each pixel and then a second loop to evaluate the retrieval in each pixel and its surroundings. However, we currently investigating possible applications of this method in Level 3 data.

We have additional text to the manuscript in new lines 477-481 (section 4.1) and lines 509-519 (section 4.2).

Added text in 480-484 (section 4.1) : "*Also, inspection of the number of OMI retrievals around the pixels used in figures 6 showed a high number of OMI AOD retrievals around the selected pixel (i.e. $N_{OMI} > 4$) and there was no difference in N_{OMI} between those pixels inside or above the uncertainty envelope (not shown). In this case, it appears that discrimination of OMI pixels by using the number of surrounding retrievals did not help to remove cloud contaminated pixels.*"
Added text in lines 511-522 (section 4.2): "*This scene demonstrate a situation where the evaluation of number of OMI retrievals around the selected pixel (N_{OMI}) may not be effective at determining possible cloud contamination. In this case, several contiguous pixels with clouds in them have successful AOD retrievals (i.e. N_{OMI} is high). The cloud field has clouds fairly well so that the combined radiance from clear and cloud sectors within the OMI pixel is not high enough to be rejected for retrieval by the OMAERUV algorithm. A similar type of cloud field (low altitude fair weather marine cumuli) was also present in figure 4a in the areas with several contiguous OMI AOD retrievals. The contrast in using N_{OMI} between this case and the comparison with AERONET AODs (Section 3) highlights the relative utility of this parameter as a tool for cloud contamination discrimination. Clearly additional analysis is needed to determine its usefulness.*"

Line 440. A closing parenthesis ")" is missing.
A: corrected

Line 468 "the instrumental inability to resolve the subpixel contamination due to the coarse spatial resolution." This is a strange sentence because no instrument will resolve subpixel clouds. However, the OMAERUV algorithm doesn't seem to use the higher spatial sampling available in the OMI data through the so-called small pixel data. These data could be used to construct a better cloud mask.

Given the importance of the cloud clearing, this should be a recommendation for a future version of the algorithm and mentioned in the conclusions section.

A: The reviewer brings up an interesting point. OMI reports measurements at two wavelengths (342.5 in the UV2 channel and 388 nm in the VIS channel) at a slightly smaller size in the flight direction than standard ground pixels. However, because the intrinsic field of view of the sensor in the flight direction is about 10 km, the resulting small pixels overlap and, therefore, repeated contain information from the same scene. For this reason, small pixel measurements are of limited value for cloud masking purposes.

Line 523-525. I miss the point of this sentence. Please clarify what you mean.
A: we removed the sentence since it did not add any additional information.

Line 580-583. The effect of the choice of the aerosol models shall be discussed when describing the hybrid method. See my earlier comments.
A: we think we answered this in our previous comment regarding the hybrid method in section 2.3 above

Line 606-607. I don't understand this sentence, please revise.
A: The sentence "It is hypothesized that assumptions made by the retrieval algorithm are probably not fulfilled in the cases with underestimates." was replaced with :
"The origin of the underestimated AODs by the OMAERUV algorithm noted in the previous section are analyzed here. In this section, some of the assumptions made by the retrieval algorithm are specifically tested to verify if they are fulfilled for the pixels under observation"

Line 610 Apart from aerosol shape, also the assumed aerosol size distribution is important.
A: see condition 2) in the same paragraph.

Line 645 add a comma: ". . . samples, but . . ."
A: corrected

Line 699. Although in this case the results of the SSA do not depend on the aerosol model, it does have a very strong effect on the Absorption AOD, which is a measure for the radiative effect on the atmosphere. This should be mentioned.
A: good point . We now mention this fact in the respective paragraph.

Line 707-711 "This . . . aerosols." This section can be removed as it adds nothing.
A: we prefer to leave it as it is. The logic is that many readers choose to read the Abstract, then jump to the conclusions and if there is further interest, then they would read the rest of the paper. This sentence provides guidance to the reader on where to look for the information of interest.

Line 724 "This" should be replaced by "The".
A: corrected

Section Acknowledgements: there is missing information in this section.
A: We added information in this section.

Figures 8, 9, 10 and 11: please use consistent terminology. In these AAI is referred to as UVAI and UV Aerosol Index. This is confusing. By the way, I have a preference for UV-AI instead of AAI, but that is up to the authors.

A: we kept the AAI terminology and corrected respective figures accordingly.