Interactive discussion on AMTD-2017-286 "Spatial distribution analysis of the OMI aerosol layer height: a pixel-by-pixel comparison to CALIOP observations"

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We thank Referee #2 for his / her comments. Below we address them one by one (Referee #2 comments in blue, author and co-authors in black).

The paper presents the retrievals of aerosol layer height from OMI O_2-O_2 absorbing band and evaluate the retrievals with CALIOP. The retrieval method was published already, which is based on neutral network algorithm trained with data from radiative transfer calculation. Overall, the paper is interesting, and I recommend it be published after the following comments are addressed.

We took into account all the comments and questions asked by Referee #2 below. We reformulated where necessary according to the remarks and question, in order to ensure a better clarification. More details on these reformulations are given below where appropriate.

1) The introduction part discussed pros and cons O_2 A band. how about O_2 B? Both Xu *et al.* (2017, cited already) and Ding *et al.* (2016, see below) showed from real data and theoretical calculation that O_2 A and B are complimentary to each other for retrieving ALH at different altitude. This is because their combination provides a wider range of different O_2 optical depth, thereby allowing to characterize aerosol layer at different altitude. I recommend that both Xu's paper and Ding's paper should be added in the introduction to talk about O_2 B band.

Ding, S. *et al.*, 2016, Polarimetric remote sensing in O_2 A and B bands: Sensitivity study and information content analysis for vertical profile of aerosols, Atmospheric Measurement Techniques, 9, 2077-2092, doi:10.5194/amt-9-2077-2016.

Thank for the reference. We, the authors, have much less experiences with the O_2-B spectral band than the O2-A for now. However, the paper of Ding *et al.* (2016) suggests, like Xu *et al.* (2017), that there is indeed a possibility to exploit it in synergy with the O_2-A. Its proximity with the O_2-A may suggest similar difficulties (high surface albedo over land, low AOT compared to the O_2-O_2). Moreover, Ding et al. (2016) suggest a lower optical depth and thus signal. However, we are very much in favor and encourage all studies investigating the amount of information on aerosol height that can be derived, and the corresponding approaches necessary for that purpose.
We added a sentence mentioning this reference and this band in the introduction, on Page 3.

2) Equation 1. Comparing ALH with CALIPO. Xu *et al.* (2017) used the same method to evaluate ALH retrieved EPIC/DSCOVR, and their better found a better statistics, although their analysis over the over ocean. In case of O_2-O_2 method, this reviewer is curious how well the final results (using AHL and AOD for forward calculating) can agree with OMI spectra in O_2-O_2? Because O_2-O_2 absorption optical depth is small, it has the disadvantages to retrieve high altitude aerosol layer. Is there any limit where retrieval uncertainty is too large? Regardless, some discussion on how the results compare with some existing techniques can be more helpful to the readers.
As investigated in Chimot *et al.* (2017) and mentioned in this manuscript in Sect2.2., reliable OMI ALH is available over scenes with a minimum AOT(550 nm) value of 0.5. Below this threshold, the aerosol load has too little effects on the absorption by the dimers at 477 nm. Moreover, since the O_2 collision complex absorption scales with the pressure-square instead of being linear with pressure, there is very little sensitivity for aerosol layers located at high altitude: *i.e.* approximately above 5 km (Park *et al.*, 2016). Also, cloudy scenes and too bright surfaces such as deserts and snow should be discarded.

A direct comparison with other techniques would deserve a rigorous study in itself. At high level, we can say that the 477 nm O2-O2 spectral band present the advantages of higher AOT values, and lower surface albedo over land surfaces. The lack of contrast between surface reflectance and scattering layers in the Near-InfraRed (NIR) usually leads to several challenges over non dark surfaces such as vegetation. We briefly discussed these advantages in the Introduction, Page 3 Lines 16-20.

3) How the shape of aerosol profile is defined? Is it Gaussian distribution, and how the width of profile is assumed? In Xu et al. (2017), the assumption of the width is based on field data. Globally, will the width have any effect on retrieval?
The aerosol profile shape is described in Chimot *et al.* (2017) and already repeated in the present manuscript in Sect.2.2 Line 31: "Aerosol profiles are assumed as one single scattering layer (also called "box-layer") with a constant geometric thickness (100 hPa, or about 1 km). The particles included in this layer are homogeneous (*i.e.* same size and optical properties). ALH is then defined as the mid-altitude (above sea level) of this scattering layer.". A different profile shape such as Gaussian or 2 separate layers as investigated in Sect.4.2. and Fig.s.11-12 could indeed impact somehow the ALH retrieval. Overall, we show in this manuscript that ALH is a weighted average of the aerosol extinction coefficients, in the visible, distributed along the vertical atmospheric layers. Overall, all our analyses demonstrate that aerosol model, and then potential cloud residuals, are the most crucial assumptions affecting the quality of the OMI ALH derivation.

4) In several plots, the retrieved AHL appears to be for aerosols above clouds (such as Figure 7 -14 - - 12 degree). In such cases, how AHL from CALIOP is computed? Cloud contamination seems very high in all cases showed.
The ALH of CALIOP is exclusively computed from the CALIOP L2 aerosol product, which does not contain the layers identified as clouds by the CALIOP processing chain. Therefore, the CALIOP ALH is only based on aerosol layers. In all the cases we have selected and analyzed, we tried as much as possible to detect and filter-out collocated OMI-MODIS cloud scenes following the methodology described in Sect.2.3. Of course, we acknowledge that, in spite of these efforts, some cloud residuals may persist, and this is why we studied the potential impacts in Sect.4.5 and Fig.14.
However, given the reasonable agreement we obtained between OMI and CALIOP ALH and our analyses, the number of selected OMI pixels with aerosols above clouds is expected to be quite minimal in this manuscript.

5) Non-spherical dust phase function. It is surely important, but in many cases, especially in Asia, dust and spherical particles can co-exist, and only consider non-spherical particles are not sufficient as shown in the following paper. Does the difference bewteen AHL vs. CALIOP counterparts as a function of scatting albedo show any indication of dust non-spherical effect? It will be interesting to see if the difference as scattering angle is flat or random for smoke particles.
As discussed in our manuscript and our precedent study, the aerosol model accuracy plays a crucial role in the quality of the OMI ALH retrieval. This covers the optical properties such as scattering *vs.* absorption (*cf.* single scattering albedo), but also the realism of the scattering phase function.
Dust can be often mixed with nitrate and sulfate, especially over large industrialized and urban area such in East-Asia, and in Spring and Summer during the dust transport episodes from the deserts. However, anthropogenic particles still dominate the measured signals in these regions. As stipulated in our outlook, we advised indeed in future studies to consider more aerosol models and detailed scattering phase function modelling (*e.g.* Mie scattering for spherical particles and T-Matrix for pure dust outbreak). New neural networks should be then trained based on these new datasets and their performances on smoke cases could be then compared in detail with the present performances.

Wang, J. *et al.*, 2003, The effects of non-sphericity on geostationary satellite retrievals of dust aerosols, Geophys. Res. Lett., 30, 2293.

We thank the Referee for informing us about this last reference.