#Response to the RC1

General Comments

In their theoretical analysis, the authors underestimate the importance of many physical mechanisms that contribute to the observed spectral dependence captured by the measured UVAI. Their analysis disregards the well-known UVAI dependence on factors other than ALH such as the spectral dependence of the near UV imaginary component of aerosol particle refractive index, also expressed as Aerosol Absorption Exponent (AAE), and the spectral dependence of surface albedo which over arid and semi-arid regions of the world and over the oceans(pure water, chlorophyll and CDOM absorption) contribute significantly to the UVAI signal.

These effects are clearly non-negligible. For instance, at a particular viewing geometry, a 340-380 defined UVAI value of 2.0 for an aerosol layer of AOD (550 nm) 0.5, can be explained by multiple combination of ALH values between about 3 km and 6 km and AAE values between 1 and about 3. Thus, to properly derive ALH information, AAE must be accurately constrained. AAE vary significantly between aerosol types, and even for a given aerosol type the AAE varies regionally depending on soil composition for dust particles, and on fuel composition for carbonaceous particles.

The simplified radiative transfer calculations used in this analysis are based on unrealistic representation of the aerosol scattering phase function. The assumed Henvy-Grennstein (H-G) phase function used in this work does not allow the accurate modeling of the role particle size distribution, particle shape, and complex refractive index. These properties vary significantly for different aerosol types. Accurate radiative transfer calculations using Mie Theory for spherical particles and T-matrix and Geometric Optics combinations for non-spherical particles, must be used to reliably interpret the information content of satellite near UV observations. The aerosol model used in the analysis based on simplified assumptions on asymmetry factor and single scattering albedo is a very crude representation unsuitable for the analysis of satellite data.

For the above stated reasons, this manuscript is not publishable it its current form. A realistic representation of the relevant aerosol types as well as accurate radiative transfer calculations are required to successfully extract the ALH information contained in the UVAI.

Author's response:

Thank you for your suggestion! UVAI is a qualitatively derived from level 1 radiance measurements. It depends on many aspects, among which the most important are the aerosol loading, aerosol vertical distribution and aerosol absorption. In this paper, we aim to find / build up an ALH data set that we focus on the UVAI's dependence on aerosol vertical distribution.

But there are two misunderstandings: (1) we are **not** using radiative transfer-based analysis of UVAI sensitivity to ALH. All the ALH-UVAI relationship analysis in this paper is only statistically based rather than physically based. In other words, we directly use the existing satellite UVAI product and co-located to the corresponding ALH data. For the MERRA-2 derived ALH variables (defined by us), the OMAERUV UVAI is co-located to the MERRA-2 and then make the analysis. For other satellite data sets (OMI, TROPOMI and GOME-2), the UVAI is combined with their corresponding ALH. (2) the radiative transfer simulations in this paper is **only used for sensitivity study** to present to provide some intuitions for readers who are not familiar with UVAI that how the UVAI is response to the aerosol vertical distribution. We have to admit that the setup of the sensitivity study is simplified. But as we will show, even using the Mie scattering scheme, wavelength dependent surface albedo and aerosol absorption, the conclusion will not change significantly. The HG aerosol models mentioned in other cases, are used in the (either official or not) ALH retrieval algorithms. Please see responses to specific comments for more details.

Specific comments:

Line 32. The term 'small' is ambiguous. Refer to agree-upon size ranges in aerosol definition.

Author's response:

Corresponding change has been done.

Change of the manuscript:

Atmospheric aerosols are liquid or solid particles with typical particle size ranging from 10^{-4} to 10 μm that originate from natural or anthropogenic sources.

Line 45. Define columnar ALH.

Author's response:

Corresponding change has been done.

Change of the manuscript:
ALH is a compact representation of aerosol profiles with a single value.

Line 58. Since POLDER does not have any near UV channels, this is a rather strange statement.
Author's response:
Corresponding change has been done.
Change of the manuscript:
The POLarization and Directionality of the Earth's Reflectance (POLDER) onboard PARASOL utilizes the distinct polarization difference between air molecules and aerosol particles (Dubovik et al., 2011).

Line 64. Clarify that EPIC does not involve spectrally resolved measurements.
Author's response:
EPIC does observe in several spectral bands, including in the O2 A and B bands.

Line 67. This is not a peer-reviewed work.
Author's response:
The ATBD is reviewed and contains useful information to readers. It is an ATBD of GOME-2 absorption aerosol layer height product that will be released soon.

Line 71. The beginning of the paragraph refers to active measurements, but the following discussion abruptly changes to passive measurements. Thus, the whole paragraph looks incongruent.
Author's response:
It is a matter of layout issue. They just look like a single paragraph but actually is not.
The paragraph about active measurements starts from "Aerosol vertical distributions are either described by…" to "…missing data in the measured profiles". The paragraph about passive measurements starts with "ALH is usually retrieved from…" to the end.

Line 85. Altitude dependence is just one of the several dependencies of UVAI: spectral surface albedo and aerosol absorption exponent are very important. Discuss those effects and their importance in UVAI interpretation.
Author's response:
As declared at the beginning of this document, we are aware of that the UVAI definitely only depends on ALH, but also other parameters as you mentioned. The UVAI's introduction and its dependence are detailed described later in section 4.1.

Line 114. The statement is not clear. Agreement of what with what.
Author's response:
Corresponding change has been done.
Change of the manuscript:
Improved agreement between MERRA-2 and observations is also found for aerosol optical properties and aerosol vertical distributions (Buchard et al., 2017)

Line 127. The validation shown in Appendix B uses CALIOP 532 nm extinction profiles. For smoke aerosols, 532 nm profiles are often truncated, and the derived aerosol height is overestimated [Torres et al., 2013] as a result of signal attenuation due to black carbon absorption (Kim et al., JGR, 118, 2013; Kacenelenbogen et al., JGR, 119, 2014; Liu et al., ACP, 15, 2015; Torres et al., AMT, 2013). Should use instead the 1064 nm channel.
Author's response:
It is true that lidar backscattering coefficient attenuation at 532 nm is stronger than 1064 nm. But we insist using profiles at 532 nm for the following concerns: (1) we are comparing CALIOP and MERRA-2, while the latter only report aerosol optical properties at 550 nm. Lidar aerosol properties is closer to compare; (2) the loss of measurement sensitivity near surface may affect the ALH determination, but here we are comparing the profiles rather than ALH. Besides, the common extinction weighed ALH suffers the problem of the lower sensitivity near surface, but for aerosol layer top height, its influence is small. Finding a representative ALH is one of the aims of this paper; (3) CALIOP level 3 monthly data does not provide profiles at 1064 nm. We use level 3 data as the time period is 2006-onwards in this study.
We will add this as a notice in the manuscript.
Change of the manuscript:

As the climatology reports aerosol optical properties at 532 nm only, one should keep in mind that extinction coefficient at visible has lower measurement sensitivity in the lower part of the atmosphere due to strong attenuation by smoke (Torres et al., 2013, Kim et al., 2015).

Line 152. Aerosol effective geometric height makes more sense.
Author's response:
Corresponding change has been done.
Change of the manuscript:
2.2.3 Aerosol effective geometric height

Line 255. The OMAERUV ALH climatology cannot be considered a single source ALH data base. This product is mainly based on a CALIOP climatology, but also includes model-based assumptions and spatial extrapolations developed to constrain the AOD/SSA retrieval. The authors should not use this data base. They should instead evaluate the CALIOP product on its own merits.
Author's response:
We have noticed that the OMAERUV ALH is not an operational product, as we discussed in section 3.1. The reason we still include it in this paper is because that the OMAERUV ALH is designed to retrieve accurate aerosol properties of absorbing aerosols in the UV channel (Torres et al., 2013), and it has a long-term global record since 2006. Furthermore, we want to use the relationship between UVAI and ALH that is found in the sensitivity study (section 4.1) to analytically examine whether the OMAERUV ALH and its corresponding UVAI has this relationship (and also for other satellite observations). If the UVAI-ALH relationship is found, then no matter the ALH is from observation retrievals or model simulations, we will consider it is worth analyzing UVAI.

The result is that the OMAERUV UVAI is highly dependent to OMAERUV ALH, even though we know this relationship is too 'optimistic', because the ALH is assigned according to aerosol types, the latter is (partly) determined by UVAI (section 4.4).

The CALIOP data, however, facing the problem we discussed in section 1 Introduction. Given a profile, which definition should be used to derive an ALH? On the other side, the CALIOP is subject to the signal attenuation due to presence of heavy clouds or aerosols, leading to missing data in profiles (incomplete profiles), which adds a lot of uncertainties on the retrieved ALH. Also, the coverage of CALIOP data is much less than that of OMI.

Thus, instead of using CALIOP, we use the AERONET to assure the quality of OMAERUV ALH by co-locating the two data sets and applying quality constraints on AOD and SSA retrievals as described in section 4.2.

Line 283. Scattering effects of HG idealized aerosols differ significantly from real aerosols. HG aerosols is a 1950's tool when computing tools were inadequate and, no actual satellite observations were available.
Author's response:
It is the aerosol models defined by Chimot et al. (2017) to retrieve ALH over O2-O2 band. Although the aerosol properties are simplified, but the HG is able to reproduce the Mie scattering function reasonably well for most aerosol types (Chimot et al., 2017). The HG assumptions is also applied in Oxygen-A band ALH retrieval (Sander et al., 2015) and aerosol corrections in AMF calculation when retrieving trace gases (Spada et al., 2006; Wagner et al., 2007; Castellanos et al., 2015).
The reason that HG is often used in the O2-A band retrieval is still computational efficiency. Even if the single HG phase function is replaced by a single Mie scattering phase function, this will increase computational effort significantly. Note that for example the TROPOMI ALH radiative transfer is based on a dataset that takes several months to produce on a computer cluster.

Line 292. What is the point of using non-accessible data?
Author's response:
Because the OMI O2-O2 ALH is not an official level 2 product, although Chimot et al. are making efforts on that. If interested in the data, one can contact with Chimot directly. We have mentioned this in section Data availability.

Line 296. Reference wavelength? How much aerosol is then rejected? At 550 nm only a small fraction of AOD is larger than 0.5. How much data is available after AOD lower than 0.5 is rejected?

Author's response:

The 0.5 threshold applied to AOD is at 550 nm. About 2% of data is available after AOD lower than 0,5 is rejected. It is a quality control suggested by Julien Chimot, who is mainly in charge of the OMI O2-O2 ALH data set. As we mentioned in the manuscript, the aerosol shielding effect on O2-O2 absorption is too low for low AOD cases. Nevertheless, even though only 2% data left, there are still around 50.000 samples left to analysis, which is statistically sufficient.

Line 314. Same comment as above. HG aerosol type does not exist in the real world.

Author's response:

It is the aerosol models defined in Sander et al. (2015) and Sander and de Haan (2016) for the official TROPOMI Oxygen A-band ALH product. Same explanation as previous.

Line 321. This statement is not correct. CALIOP measures the actual aerosol vertical distribution.

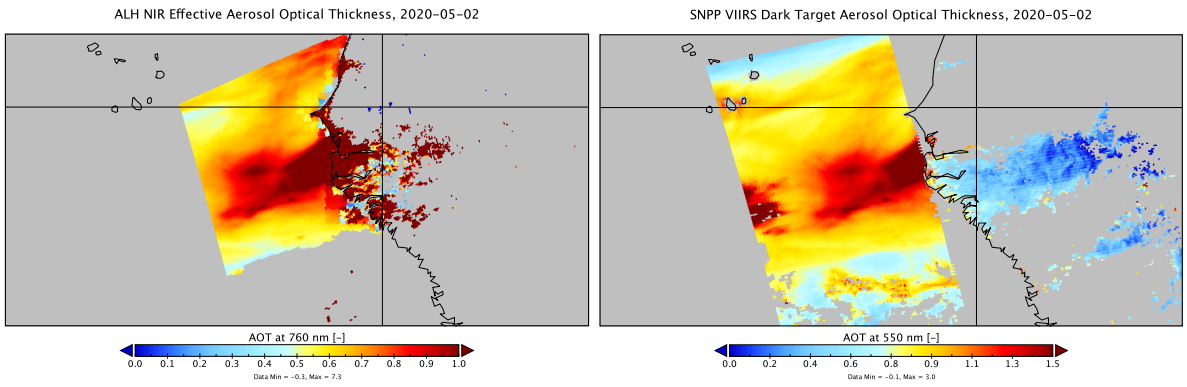
Author's response:

CALIOP measures the actual aerosol vertical distribution. But due to the presence of heavy clouds and aerosols, the lidar signal tends to attenuate, which may lead to missing data in the measured profiles. Considering that CALIOP lidar signal passes from the top of the atmosphere to the surface, the sensitivity should be higher at upper clean atmosphere than that passes through clouds or aerosol layers.

Line 324. Need to explain better the diagnostic role of AOD. AOD must be accurately known to retrieve realistic ALH. How accurate is the retrieved AOD, and how this accuracy translates in accuracy of retrieved ALH? It can be evaluated by comparison to ground-based observations or to MODIS-MiSR products.

Author's response: s

The TROPOMI ALH algorithm is an iterative optimal estimation scheme that fits the ALH and an effective AOD. The AOD is an effective quantity, that is based on single phase function assumption. As such, it is treated as a by-product of the retrieval, which because of the use of a single-phase function is not optimized to be close to the truth. A typical example of the effective AOD is given in the figure below, comparing the ALH AOD at 758 nm with the NPP-VIIRS AOD at 550 nm for a Saharan dust plume (note that the color scales are optimized to show the spatial similarity over the ocean). This figure shows that the spatial correlation of the two products is very high. Over land the ALH AOD shows overestimates, which is due to the high surface albedo in this region and limited accuracy of the used albedo climatology, which makes the ALH retrieval over such high surface albedo regions very challenging.



Left Panel: Effective AOD from the TROPOMI ALH retrieval at 758 nm. Right panel AOD from NPP-VIIRS dark target retrieval at 550 nm. Data are off the coast of Africa for 2020-05-02.

In this manuscript, we use the ALH data that are quality filtered according to the recommendations. It is therefore beyond the scope of this manuscript to perform a full validation of the effective AOD in the ALH product. A validation of the ALH product is described in Nanda et al. (2019, AMTD). The TROPOMI ALH generally can

captures the aerosol layers presented in CALIOP extinction coefficient profiles. CALIOP ALH is generally higher than TROPOMI by 1-2.4 km (but it also depends on how you calculate the ALH, in their work, they determined the CALIOP ALH as extinction coefficient weighed height).

Line 326-27. Not the same as O2-O2. It was stated above that AOD < 0.5 are discarded

Author's response:

The 'same' here indicates that "to avoid NN extrapolation due to scenes not included in the training process", not exactly the same threshold values are applied to TROPOMI variables. The neural network for OMI O2-O2 ALH and TROPOMI ALH has different training data and input feature spaces.

Change of the manuscript:

Similar to the pre-processing of the OMI O_2-O_2 ALH, to avoid NN extrapolation due to scenes not included in the training process. Samples are kept only if they satisfy the following criteria: AOD between 0.05 and 5, SZA between 8.2° and 70°, ALP between 75 and 1000 hPa, surface pressure between 520 and 1048.5 hPa and surface albedo smaller than 0.7.

Line 344. Please provide a peer-reviewed reference.

Author's response:

It is an ATBD of GOME-2 absorption aerosol layer height (AAH) product that will be released soon. The AAH is based on the findings in Wang et al. (2012) as we mentioned in the paper.

Line 349. Provide a validation reference like a comparison to CALIOP.

Author's response:

In the GOME-2 AAH ATBD (Tilstra et al., 2019), the GOME-2 AAH is validated by CALIOP profiles and MISR plume height with individual cases, including fire events, dust storms and volcano eruptions. Due to the co-located CALIOP and MISR data is not widely available, the comparison is not straightforward but only analytic. The qualitative validation shows that the GOME-2 and CALIOP is generally in good agreement in indicating the vertical distribution of absorbing aerosol layers. The comparison with MISR is less encouraging. Besides, evaluating the quality these of ALH products, how they are compared with CALIOP measurements, etc., are not the major purposes of this work. Our aim is just to find an ALH data set that UVAI has a reasonable dependence on.

Instead, we have added a section that compares of each ALH products with reference of CALIOP monthly profiles in Appendix D. We still use the CALIOP level 3 aerosol profile climatology to validate each satellite ALH data. Because the number of pixel-by-pixel satellite (OMI O2-O2, TROPOMI ALH and GOME-2) to CALIOP data is not statistically enough. Instead we validate the ALH data using zonal seasonal average profile as we did for ALHs derived for MERRA-2 in Appendix B.

Change of the manuscript:

Appendix D: validating satellite ALH with CALIOP measurements

We validate satellite ALH products used in this paper with CALIOP measurements. Fig. D1 presents the zonal average of each ALH product (blue and green lines) against corresponding CALIOP climatology (contour). For better understanding the physical mean of each ALH products, we also calculate the ALH from CALIOP extinction profiles using ALH definitions introduced in Section 2.

The ALH reported in OMAERUV (first column) generally presents lower values except for that at high latitudes and the mid latitude in the Southern Hemisphere. This is consistent with Fig .5a, where OMAERUV ALH over remote ocean is significantly higher than source regions. The potential reasons, as we explained in Section 3.1, are aerosol type misclassifications, the unrealistic ALH assumptions when no climatology data available, and high sensitivity to outliers due to less observations, etc. Between 10-30°N where the dominant aerosols come from the world dust belt according to Fig.5c, the OMAERUV ALH matches well with the 'effective' heights (H_{aer}^{β}, H_{aer}^{τ} and H_{aer}^{63}) derived from CALIOP climatology, which may own to the proper ALH determination for dust aerosols (Torres et al., 2013). However, the ALH is almost close to the surface at biomass burning regions in tropics (0-30°S). The reason could be that the ALH for smoke aerosols is determined to be less than 3 km if no climatology data is available (Torres et al., 2013).

The comparison between OMI O2-O2 ALH and CALIOP (second column) only covers 3 seasons as CALIOP data is only available from June 2006. The ALH retrieved by SSA = 0.90 (blue line) is slightly lower than that retrieved by SSA = 0.95 (green line), which agrees with conclusions in Chimot et al. (2017). The OMI O2-O2 ALHs are close to the top boundary of the aerosol layer (H_{aer}^{t}) within 0-30°S. Combined with data distribution provided in Fig.5d-f,

the ALH well presents the smoke plumes over tropics and subtropics. It also captures the dust outbreaks during JJA. During DJF and SON, the ALHs are retrieved mainly for urban aerosol in East Asia, where aerosol extinction is strongest near surface. The magnitude of OMI O2-O2 ALH is between the effective height and the top boundary height. However, in high latitude in the Southern Hemisphere, the ALH is remarkedly high. The reason is that the high sensitivity to the retrieval outliers due to the lack of retrievals (Fig.5d, 5g).

The last two column shows the comparison between TROPOMI ALH and GOME-2 AAH with CALIOP profiles. Although the TROPOMI ALH and GOME-2 AAH are collected during the similar period, the latter has larger variations due to the wider spatial coverage over both continents and oceans (Fig.5l, 5o). Similar to the OMAERUV ALH, the magnitude of both TROPOMI ALH and GOME-2 AAH match well with the 'effective' heights (H_{aer}^{β}, H_{aer}^{τ} and H_{aer}^{63}) derived from the CALIOP profiles at latitudes between 10 and 30°N. At these locations, both ALH products are mainly retrieved for dust outflows over ocean. Disagreements between these two satellite ALH products and CLAIOP profiles appear at mid to high latitudes regions. At these regions, the satellite ALHs are only available for individual cases (with UVAI larger than certain values) that are not visible in CALIOP profiles due to averaging effects. For example, the high values of TROPOMI ALH present the smoke plumes due to fire events at the South America in DJF, Australia in DJF and MAM and South Africa in SON, and the high values of GOME-2 AAH present the smoke plumes due to fire seasons in the North America from MAM to SON and Asia in MAM and JJA. The Australia fire presented in TROPOMI ALH but invisible in GOME-2 AAH is also due to the averaging effect, since the latter has wider coverage over ocean (AAH over remote ocean is generally lower compared with smoke plumes).

In summary, the OMAERUV ALH, TROPOMI ALH and GOME-2 AAH indicate the 'effective' height (the altitude where aerosol extinction is strongest) for dust dominant aerosols layers. Large discrepancy between these satellite ALHs and CALIOP profiles are found at mid and high latitudes. For OMAERUV ALH, the disagreement mainly due to the unreasonable ALH determination, while for the other two products, the mismatches also result from the difference in spatial coverages due to the retrieval algorithm limitation and averaging effects of CALIOP profiles. On the other hand, the OMI O2-O2 ALH varies along with CALIOP profiles and captures the aerosol layer top boundary height for smoke aerosols, although it is sensitive to outliers in high latitude regions.

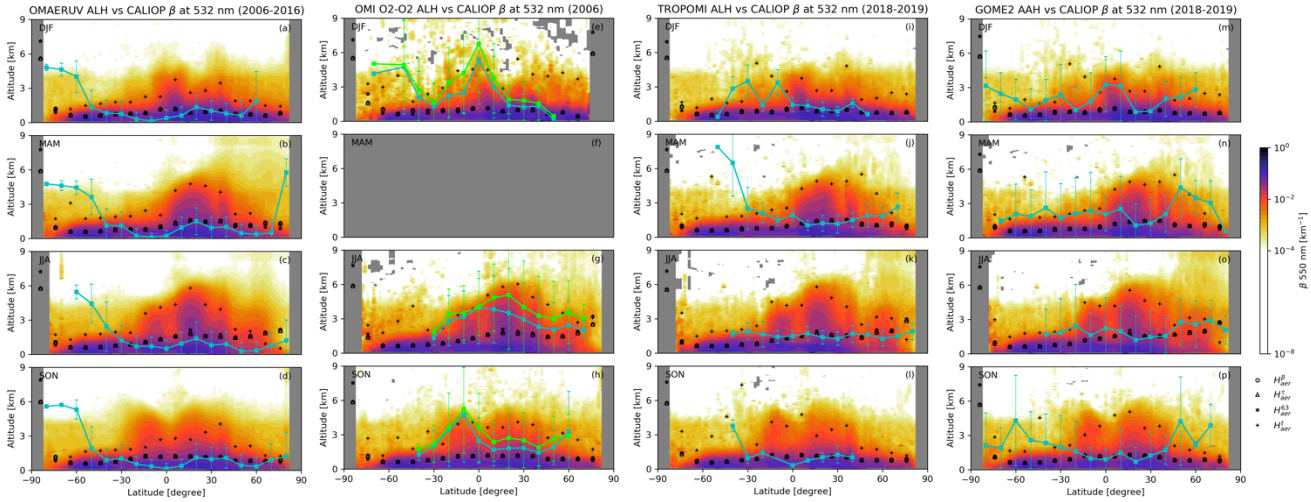


Figure. D1 The zonal average and the standard deviation of the satellite ALHs (blue lines) against the zonal average of the CALIOP extinction coefficients (contours) during the corresponding periods. Rows represent different seasons and columns represent different ALH products. For OMI O2-O2 ALH (second column), the ALHs retrieved SSA = 0.90 and 0.95 are indicated by blue and green line, respectively. The ALHs calculated for CALIOP profiles using different ALH definitions introduced in Section 2 are also indicated by different markers.

Line 351. This is another non-accessible data set.

Author's response:

The GOME-2 absorption aerosol layer height (AAH) product is not publicly accessible, but will be accessible soon in future. If interested in AAH, one can contact with Tilstra. We have mentioned this in section Data availability.

Line 358. Retrieval capability over deserts is important. Please include a comparison to CALIOP over the Saharan Desert.

Author's response:

As stated in the GOME-2 AAH ATBD (Tilstra et al., 2019), the co-located CALIOP and GOME-2 data is not widely available, and the two sensors have a large temporal gap (CALIOP overpass time is 13:30 while GOME-2 overpass time is 09:30). The directly quantitative comparison is challenging. Also, validation of each ALH product is not the purpose of this paper.

Instead, we have added a climatology comparison of each ALH products with reference of CALIOP monthly profiles. See previous response and changes in Appendix D.

Line 380. Again HG. This sensitivity analysis must be carried out with actual radiative transfer calculations using Mie Theory for spherical particles and the adequate approach for non-spherical particles.

Author's response:

We have to emphasize that the sensitivity study here is to present the UVAI dependence on ALH under different conditions of aerosol loading (AOD), aerosol absorption (SSA) and surface reflectance (As).

For your requirements, we have changed the HG aerosol models to Mie Theory. The aerosol models are taken from OMAERUV algorithm and the wavelength dependent surface reflectance is taken from OMI LER climatology. The HG indeed simplifies the aerosol properties, but the major conclusion of UVAI's dependence on ALH will not change.

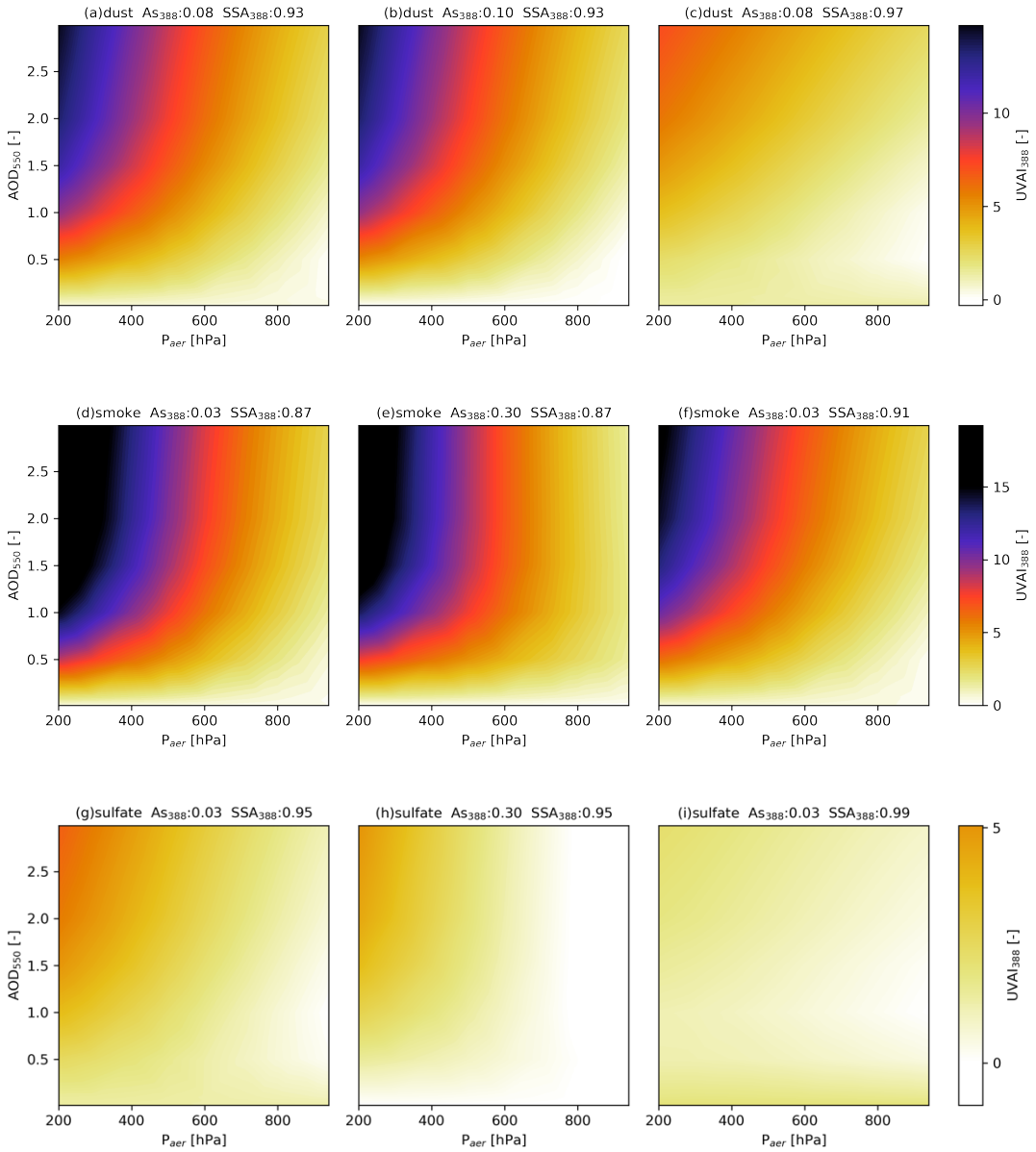
Change of the manuscript:

Changes in section 4.1:

In the forward radiative transfer simulations, the aerosols are characterized by the Mie Theory with aerosol models taken from OMAERUV algorithm (Jethva and Torres, 2011). The aerosol layer is parameterized as a box-shape profile with a constant depth of 50 hPa. The input AOD at 550 nm varies between 0.01 and 3 and the input ALH varies between 0.5 and 12 km. Other inputs and detailed settings for the radiative transfer simulations are provided in Appendix D. We design several scenarios by choosing either absorbing (lower SSA) or less-absorbing/scattering (higher SSA) aerosols over either a dark (lower surface albedo) or bright surface (higher surface albedo).

Fig.6 shows the results for dust (first row), smoke (second row) and sulfate (third row) aerosols from OMAERUV algorithm, respectively. UVAI increases with ALH due to more molecular radiation coming from below is absorbed by aerosols. The higher aerosol loadings, the stronger the UVAI dependence on ALH. However, the dependence becomes weaker over brighter surfaces, particularly under low aerosol loading (Fig.6b, e and h). On the other hand, little altitude dependence is found for less-absorbing (dust and smoke with higher SSA, Fig.6c and f) and scattering aerosols (Fig.6g-h). The above features of UVAI-ALH relationship can be used to validate the performances of MERRA-2 ALHs and satellite ALH products. As the influence of surface albedo is negligible compared with that of AOD, in the following analysis, we only focus on the UVAI dependence to ALH under different aerosol loadings.

Fig.6 also has been changed:



Changes in Appendix D:

The aerosols are described by the Mie Theory with dust (7 subtypes) and smoke (subtypes) aerosol models taken from OMAERUV algorithm (Jethva and Torres et al., 2011). The wavelength dependence of aerosol absorption in UV band, represented by the imaginary refractive index difference between 354 and 388 nm ($\Delta\kappa$), is assumed to be 20% . The AOD varies from 0.01 to 3. The aerosol layer is parameterized as a box-shape profile with a constant geometric depth of 50 hPa and a varying middle altitude from 0.5 to 12 km. The wavelength dependent surface albedo is specified by the OMI level 3 Lambertian equivalent reflectance (LER) monthly climatology calculated from 2005 to 2009 (Kleipool et al., 2008, 2010) (https://doi.org/10.5067/Aura/OMI/DATA3006, last access: 19 May 2020). Other inputs are listed in Table D1.

Line 383.How about in the UV? Spectrally invariant SSA in the UV s not realistic.

Author's response:

Please see the above response.

Line 389. The spectral dependence of surface albedo is important because it generates a 'spurious' aerosol signal. It may not be that important in single channel retrievals, but it is quite important for UVAI analyses. The high background UVAI (about 1.0) over arid regions is the result of surface albedo wavelength dependence in the near UV.

Author's response:

The surface reflectance is changed to be spectrally dependent by using the OMI LER climatology (Kleipool et al., 2008, 2010). Please see the above response.

Line 393. The current UVAI definition in OMAERUV is not consistent with Equation 5. The new definition accounts for water cloud effects and surface spectral dependence. For historical reasons, the traditional definition (Equation 5) is also reported in the OMAERUV product under a different variable name. Authors should make sure they are using the correct parameter.

Author's response:

From my view, the definition of the latest OMAERUV UVAI is still the same as Eq (5), but the way calculating the simulated radiance changed by considering the effect of clouds and surfaces. In this paper, we use the 'residue', i.e. the conventional definition in order to be in parallel with TROPOMI and GOME-2 UVAI. Corresponding change has been done.

Change of the manuscript:

where obs and cal indicate measured and simulated for atmosphere without aerosols, respectively. $R_{\lambda 1}^{cal}$ is used to be simulated at the surface albedo that satisfies $R_{\lambda 2}^{obs} = R_{\lambda 2}^{Ray}$, where Lambertian approximation is made and wavelength independent surface reflectance is assumed. In the latest OMAERUV product, the clouds and surface radiances are also taken into considerations by introducing a cloud fraction (Torres et al., 2018). In this paper, we use the conventional definition, i.e. 'residue' reported in the OMAERUV product, in order to be consistant with UVAI definition of TROPOMI and GOME-2.