Interactive discussion on AMTD-2017-286 "Minimizing aerosol effects on the OMI tropospheric NO_2 retrieval – An improved use of the 477 nm O_2-O_2 band and an estimation of the aerosol correction uncertainty"

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We would like to thank very much Referee #2 for his / her valuable comments. They give us the opportunity to solidify our messages and manuscript. Below we address them one by one (Referee #2 comments in blue, author and co-authors in black).

The paper introduces and compares two separate algorithms for correcting the aerosol effect in NO_2 retrievals through the computation of air mass factor. The implicit method uses an improved version of OMI cloud algorithm (OMCLDO2) where aerosols are treated as opaque Lambertian reflectors similar to clouds. The explicit method is based on a neural network technique aiming to reproduce aerosol scattering effects via more realistic aerosol model. The study analyses OMI NO_2 retrievals for cloud-free scenes over East China and South America. Both methods introduced in the manuscript tend to reduce the biases in retrieved NO_2, compared to the standard OMI DOMINO NO_2 retrieval.
The manuscript covers an important research topic and results obtained in this study are relevant for the current and new satellite missions providing NO_2 retrievals. The results in this study also highlight the importance of aerosol corrections in such retrievals, and the results are applicable for other trace gases too. The topic is well suited for AMT. I would recommend the publication of this manuscript after revision.

General comments:
1) The research itself is overall very interesting, but at places the language is not very "reader friendly" and there is room for improvement. In addition, there are typos and order of the words (e.g. p. 12, lines 26-27) that should be corrected. Some of the paragraphs, especially those with only two sentences, need revision and should be merged to other paragraphs.
We reviewed thoroughly our manuscript and tried to improve where necessary our writing, and clarified some sentences that could have been ambiguous. We also verified typos and made corrections where necessary. We also tried to remove the paragraphs with too little sentences.

2) Somewhat more detailed description of the aerosol conditions, in which the algorithms were tested, would be desirable. For example, what is the justification of using the selected SSA values? Can we assume that in East China and South America those SSA values are typical? Were there any cases where dust particles were dominating, how well the correction schemes perform in such situations?
We have evaluated the performance of our ALH retrieval, over East China, South America, and Russia areas with scenes including urban, industrial, and biomass burning pollution events and for different seasons (Chimot *et al.*, 2017, 2018). These scenes are mostly dominated by fine spherical particles, weakly absorbing (*e.g.* sulfate, and nitrate) or strongly absorbing (*e.g.* smoke). Dust particles may sometimes be mixed. We overall showed the good performance of the retrievals.

The rational of the SSA values relies on the fact that, at the time of the development, these algorithms were designed in an exploratory phase. The main motivation of the exploratory development of an aerosol layer height (ALH) retrieval algorithm, using the OMI 477 nm O_2-O_2 absorption band, has been the aerosol correction in the visible spectral range in view of tropospheric NO_2 retrieval. In Chimot *et al.* (2016), we quantitatively demonstrated that, for such a purpose, AOD and ALH are the key parameters needed. Other aerosol parameters, that are more related to their optical properties, shape, and size are of a second importance. This is supported by a number of studied such as (Boersma *et al.*, 2004; Leitao *et al.*, 2010; Castellanos *et al.*, 2015; Chimot *et al.*, 2016). The main reasons are because to correct of aerosol effects, we overall need the length of the average light path in presence of scattering and absorbing particles. This mainly is primarily driven by AOD and ALH (in addition to the shape of the NO2 vertical profile), much less by the detailed properties of particles. You can see more of our discussion in our previous publications (Chimot *et al.*, 2016, 2017).

Furthermore, retrieving ALH from passive hyperspectral sensor ideally requires aerosol type information (and vertical profile shape) for every single measured scene / pixel. However, such an accurate information is not available at such a scale. Therefore, we do need to make assumptions. One of the most common approaches is to assume one aerosol type model which should be representative, in average, of the most common aerosol types and mixtures encountered by the space-borne measurements.
Since, we cannot design NN training dataset for infinite SSA values, we decided to consider the typical values that encountered in regions with heavy NO_2 pollutions: *i.e.* east China and South America. These regions are mostly dominated by spherical particles (weakly absorbing urban continental such as nitrate and sulfate, and strongly absorbing smoke), and sometimes mixed with some dust spheroid particles (in particular in Spring). Typical SSA values are shown by Lin *et al.* (2014, 2015) who considered aerosol parameters from the GEOS-Chem model to correct of aerosol effects in tropospheric NO_2 retrievals. These studies show average values of 0.95-0.96 over China during summer time, and more around 0.9 in winter time.

Lin, J.-T., Martin, R. V., Boersma, K. F., Sneep, M., Stammes, P., Spurr, R., Wang, P., Van Roozendael, M., Clémer, K., and Irie, H.: Retrieving tropospheric nitrogen dioxide from the Ozone Monitoring Instrument: effects of aerosols, surface reflectance anisotropy, and vertical profile of nitrogen dioxide, Atmospheric Chemistry and Physics, 14, 1441–1461, doi:10.5194/acp-14-1441-2014, 2014.

Lin, J.-T., Liu, M.-Y., Xin, J.-Y., Boersma, K. F., Spurr, R., Martin, R., and Zhang, Q.: Influence of aerosols and surface reflectance on satellite NO2 retrieval: seasonal and spatial characteristics and implications for NO_x emission constraints, Atmospheric Chemistry and Physics, 15, 11 217–11 241, doi:10.5194/acp- 15-11217-2015, 2015.

3) In the manuscript it is stated that the aerosol optical properties (g, SSA) are of secondary importance compared to the AOD that is used in the training data. How accurate AODs used in the training data are, *e.g.* as compared to AERONET?
It is important to emphasize that the context, in which we discuss the fact that AOD has a higher importance than more detailed aerosol properties (*e.g.* g or SSA), is related to the aerosol correction when computing the tropospheric NO_2 air mass factor (AMF). This is not in the context of retrieving an accurate aerosol layer height (ALH) from the O_2-O_2 absorption band at 477 nm.
The sensitivity of the tropospheric NO_2 AMF was carefully analyzed in our previous study (Chimot et al., 2016). Our findings are supported by many other studies such as (*e.g.* Boersma *et al.*, 2004; Leitao *et al.*, 2010; Castellanos *et al.*, 2015). We quantitively demonstrated that the most critical parameters are AOD and ALH for computing an accurate tropospheric NO_2 AMF. In case of heavy aerosol pollution, AOD and ALH impact the AMF up to 60%-80% depending on the conditions. Parameters related to aerosol types also impact the AMF computation, but clearly as a second order of magnitude (in the range of 10%). Therefore, it is concluded that a correct estimation of tropospheric NO_2 AMF requires first AOD and ALH parameters. Assumptions about particle properties are much less critical.

The training dataset is based on a large simulated dataset (~400 000 simulations) from a physical and well validated radiative transfer model (RTM): *cf.* DISAMAR from KNMI. The range of scenario included in this training dataset is as representative as possible and includes several AOD(550 nm) values from 0 (no aerosol pollution) to 2 (very optically thick aerosol layers). These are the AOD values specified as input of the RTM for the training. When applying the trained NN to the OMI dataset, prior AOD value come from the reference MODIS aerosol datasets. They are known to be well validated in the atmospheric community. We also considered, in a second time, the AOD values retrieved from the OMI visible measurements. We discussed in our manuscript (*cf.* Sect. 5) the impact of their lower qualities on the AMF computation.

Detailed comments:
Table 1. The caption should be rewritten in more clear way. While reading the text and especially figures, I needed to go back to the Table 1 to remain myself what were the main differences between

different scenarios. The authors could think if it would be possible to shortly indicate in the figure captions what is likely the main reason for the differences; e.g. improved LER etc.
Thanks for your suggestion. We took it into account by adding, where necessary, key sentences highlighting the main reasons of the improvements of differences.

Figure 1: grid lines would help to interpret the image, now it is hard to say when the difference is close to zero, positive or negative.
We avoided to use too many grid lines as they can overload the figures. Instead, we added scales on both right and left axes to help the reader to make the connection the numbers.

Figure 2: Is the correct interpretation that the new implicit aerosol correction will improve the retrievals especially in cases of elevated aerosol layers? Why in the OMCLDO2- new the NO_2 bias seems to peak at about AOD= 0.6 (w=0.95) at low ALH heights?
As explained in our manuscript, the cases of aerosols located very close to the surface remain overall very challenging. The main reason is likely due to the difficulty to disentangle scattering signals coming from aerosol layers and from the surface. As a consequence, given the fact that tropospheric NO_2 bulk essentially remains close to the surface, every ALH bias, even if minor, affects in a non-significant way the computed tropospheric NO_2 AMF. Since our ALH retrieval generally becomes more accurate for high AOT >0.5-0.6, the tropospheric NO_2 AMF bias tends to reduce in these cases.

Figure 3: The vertical scale of the image could be smaller, also grid lines would be helpful.
The vertical scale is scaled to the case where the standard deviation of the relative difference in NO_2 tropospheric columns is larger: *i.e.* China winter in Figure 3 d). It is remained constant and the same everywhere so then each panel can be directly compared. The reader can then see that overall the standard deviation is lower than 20%, except in the panel d). We are afraid that adding grids here would too much load all the figures.

Figure 5 b): Extra symbols in the label that should not be there?
Correct. We removed the symbols that are related to the orientation display of the label. Thanks!

Figure 7: The scale could be smaller to see more clearly the differences between the lines.
The scales are kept the same as in Figs. 2 and 12, where biases on NO_2 tropospheric columns due to other assumptions. We think they should be kept consistent between all of them, so then the reader can verify our analyses and properly make their own comparisons and deductions.

Figure 8: Please add grid lines
Note that lines to each value on the y axe are present on both sides of each panel / figure. So, this helps to directly relate each curve to the numbers. We have though enlarged their thickness for visibility purpose.

Figure 9. In my version subfigures d-f are missing. The caption could be rewritten.
Corrected.

Figure 11, you could add to the caption what is the SSA.
This is added.