Authors' Response to Reviewer #1

The paper by Castellanos et al. presents an important study of how the NO2 retrieval is affected by the implicit aerosol treatment in current satellite products, with a focus on biomass burning aerosols. The study has important implications for using satellite NO2 products. The paper is well within the scope of AMT. I have a few suggestions below.

The study is focused on cloud-free conditions. While there are good reasons to do so, as indicated by the authors, the choice largely limits the amount of usable pixels and affects its applications (for example, only 13000 or so of pixels can be used here, over a large domain in 3 seasons).

> The cloud free limitation does not largely limit the number of usable pixels to ~13,000 in this study (which is a significantly larger dataset than so far has been analyzed in this context in the literature). The primary limitation is that we restrict our analysis to OMI pixels that have a simultaneous active fire retrieved by MODIS. The secondary limitation is the presence of a coincident CALIOP observation, which has limited spatial coverage. Because the dry season in South America is largely cloud free, simply imposing cloud-free conditions would result in a considerable dataset.

Moreover, the effect of explicit versus implicit aerosol treatments on NO2 retrievals may be offset or enhanced, if there is a certain amount of clouds present at certain heights. Some discussions on these aspects would be appropriate.

> Change made.
>
> Page 22, Line 9: "In the presence of actual clouds, the effect of aerosols on the tropospheric AMF may be offset or enhanced depending on the amount and height of the clouds (Lin et al., 2014). As aerosol optical depth from OMI is not observable in the presence of clouds, further work is needed to exploit data from high spatial resolution aerosol sensors that can resolve scene heterogeneity, as well as global atmospheric simulations of aerosols."

Also, the title of the paper should better reflect the cloud-free conditions being studied.

> As stated above, the main limitations in the study concern the presence of biomass burning aerosol. As biomass burning occurs during clear sky conditions, including 'cloud-free' in the title would be redundant. That we only consider cloud-free scenes is clearly stated in the abstract.

Implicit aerosol treatment is used also by other products (other instruments, other algorithms, and other species). It would be appropriate to point this out in the introduction.

Change made.

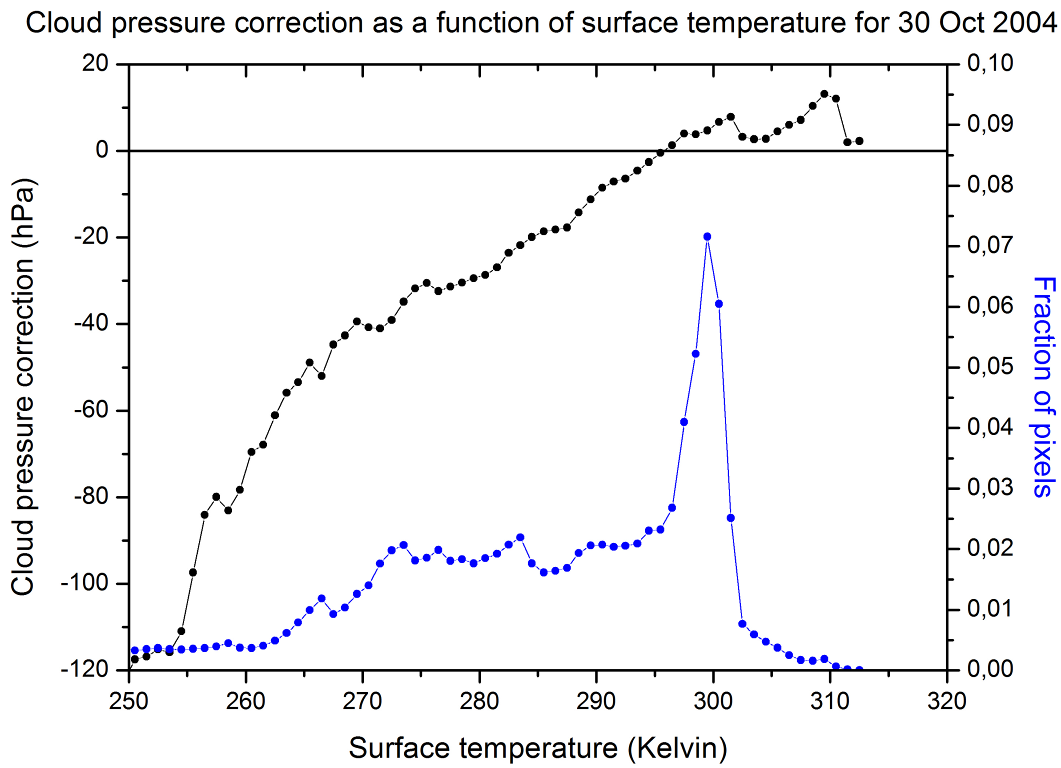
Page 3, Line 9: “as well as DOAS-based retrievals for other instruments and species such as formaldehyde (De Smedt et al., 2012) and ozone (Van Roozendael et al., 2006)”

DASAMAR-standard follows DOMINO to take the cloud parameters from OMCLDO2. However, the temperature and pressure profiles assumed in OMCLDO2 differ from DASAMAR. How will this inconsistency affect the cloud parameters used and the subsequent comparison between CP and aerosol height and between DASAMAR-standard NO2 and DASAMAR-aerosol NO2? Please discuss.

Please see the discussion beginning on Page 2690 in the manuscript regarding the effect of the assumed temperature profile in the OMCLDO2 retrieval:

“Because the LUT was derived using a mid-latitude summer temperature profile in the DAK radiative transfer calculations, there is a systematic error in the retrieved cloud pressures when the actual temperature profile deviates significantly from the standard mid-latitude summer atmosphere. If the actual temperature is significantly lower than the mid-latitude summer profile, the O_2-O_2 effective cloud pressure overestimates the true cloud pressure, and vice versa. In Maasakkers (2013), the magnitude of this error was found to be ± 0-100 hPa, within the estimated accuracy of the effective cloud pressure retrieval as shown in a comparison to MODIS and CLOUDSAT observations (Sneep et al., 2008).”

The figure below from Maasakkers (2013) shows the change in O_2-O_2 effective cloud pressure as a function surface temperature for one OMI orbit. Note that the mid-latitude summer profile surface temperature used in OMCLDO2 is 294 K. The figure shows that if surface temperatures are within 30° C of the mid-latitude summer surface temperature, cloud pressure errors are less than ±50 hPa.



> We have added the following on Page 18 Line 18: "First, internal retrieval assumptions for the surface pressure and temperature profile may lead to biases in retrieved effective cloud pressures (Maasakkers, 2013; Lin et al., 2014), but the biases are typically less than 100 hPa."

The paper discusses the effects of (CP – ALP), AOD, SSA and other factors on the difference between DASAMAR-standard and DASAMAR-aerosol NO2. Are these factors independent?

> It's clear from our discussion and analysis (see Figure 12 & 14) and previous studies (Boersma et al. 2011), that the relevant aerosol and effective cloud parameters are not independent. That is the premise behind the implicit aerosol correction.

For example, whether, and if so how, does (CP – ALP) depend on AOD and SSA?

> Figures 14 a & b show how a decrease in SSA can decrease the retrieved effective cloud pressure, and thus increase the difference between the retrieved effective cloud pressure and the observed aerosol layer pressure (CP-ALP). Other retrieval parameters and assumptions and scene characteristics could also lead to the perceived difference in CP and ALP. For example, we show that CP-ALP appears to depend on the albedo

used in the O_2-O_2 retrieval. A deeper understanding of the O_2-O_2 effective cloud retrieval in the presence of aerosols requires still further research.

We've added the following to our discussion on Page 21 Line 18: "In general, further research is needed to better interpret the retrieved O_2-O_2 effective cloud parameters in the presence of aerosols."

Focusing on the independent factors would reduce the dimension of complexity and lead to easier understanding of aerosol effects.

We chose to show the correlations of the difference between DISAMAR-standard and DISAMAR-aerosol AMF calculations to each individual parameter because depending on the application, the readily available observable data could be limited to perhaps only one of the parameters. Thus it is useful to the reader to have available all the data correlations presented here.

Abstract line 10-15: the sentence is too complex. Please separate, and highlight that only cloud-free conditions are considered here.

Change made.

Abstract: "In this work, we explicitly account for the effects of biomass burning aerosols in the Ozone Monitoring Instrument (OMI) tropospheric NO_2 AMF calculation for cloud-free scenes. We do so by including collocated aerosol extinction vertical profile observations from the CALIOP instrument, and aerosol optical depth (AOD) and single scattering albedo (SSA) retrieved by the OMI near-UV aerosol algorithm (OMAERUV) in the DISAMAR radiative transfer model."

P2686, line 25. Aerosols can lead to higher or lower cloud pressures. See, for example, Figs. 5 and 6 of Lin et al. 2014.

Change made.

Page 4, Line 1: "Lin et al. (2014) showed that the presence of aerosols can lead to lower or higher cloud pressures depending on the aerosol height, cloud height, and aerosol optical properties."

P2700, line 20-22. The sentence is not clear.

Change made.

Page 15, Line 22: "An additional check was made by comparing the CALIOP measured cloud + aerosol optical depth (CAD scores less than –20 and greater than 20), to the AOD. The increase in optical depth was negligible (<0.1%)."

P2700, line 26. How about the conversion of SSA to other wavelengths?

Change made.

Page 15, Line 28: "In DISAMAR, the Ångström exponent calculated from the OMAERUV AOD at 388 and 500 nm gives the spectral dependence of the AOD, while the SSA was linearly interpolated to 439 nm from the retrieved SSA at 388 and 500 nm."

P2703, line 21-26. Please clarify that the uncertainty is for DISAMAR-standard.

Change made.

Page 18, Line 11: "The remaining difference between the DISAMAR-standard and DISAMAR-aerosol calculations stems from…."

P2705, line 11-15. The discussion on cloud pressure changes implies a cloudy case, otherwise it is meaningless to say cloud pressure increases/decreases.

Here we refer to *effective* cloud pressure. This analysis is clearly limited to clear sky cases where aerosols are retrieved as effective clouds, and thus have an effective cloud fraction and cloud pressure. The discussion the reviewer is referring to is in reference to Figure 4, where we show how a change in aerosol absorption can decrease the retrieved effective cloud pressure.

In addition, aerosols affect cloud fractions, and the resulting changes in cloud fraction in turn affect cloud pressure. Therefore, aerosols, no matter scattering or absorbing, can increase or decrease cloud pressure depending on aerosol heights, cloud heights and other factors (although in most time scattering aerosols increase CP and absorbing aerosols decrease CP). See, for example, Figs.5 and 6 of Lin et al. (2014).

We have now indicated to the reader on Page 4, Line 1 as well as Page 21, Line 8 how previous work has shown that aerosols can affect (actual) cloud retrievals and thus NO_2 tropospheric AMFs.

Page 4, Line 1: "Lin et al. (2014) showed that the presence of aerosols can lead to lower or higher cloud pressures depending on the aerosol height, cloud height, and aerosol optical properties."

Page 22, Line 9: "In the presence of actual clouds, the effect of aerosols on the tropospheric AMF may be offset or enhanced depending on the amount and height of the clouds (Lin et al., 2014).

P2708, line 7: computational constraint can be alleviated or solved by parallel code.

Change made.

Page 22, Line 15: “although in the future enhanced computational techniques as well as using more and faster processors may alleviate this problem, particularly for off-line regional retrievals.”