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Atmospheric Measurement Techniques Discussions

Interactive comment on "Improved aerosol correction for OMI tropospheric NO_2 retrieval over East Asia: constraint from CALIOP aerosol vertical profile" *by* Mengyao Liu et al.

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The paper "Improved aerosol correction for OMI tropospheric NO2 retrieval over East Asia: constraint from CALIOP aerosol vertical profile" by Liu et al. describes an improved OMI tropospheric NO2 retrieval for East China using CALIOP aerosol vertical profile information. This study updates the POMINO retrieval algorithm described in Lin et al., 2014 and 2015. Comparisons have been made between the NO2 satellite data and ground-based MAX-DOAS measurements at three sites in East-China.

The topic of the manuscript is within the scope of AMT and it is of interest to the scientific community. It can be recommended for publication, if the authors make an

effort to address the comments listed below, and improve the manuscript accordingly.

Specific comments:

Section 2.2

P9-10 The improved POMINO NO2 algorithm for China builds on the Dutch OMI NO2 v2 algorithm from 2011. The DOMINO v2 algorithm is now about 7 years old, and the authors shortly discuss some recent improvements in the satellite retrieval (e.g. improvements in the slant column retrieval). Please include the recently released "Dutch/European" OMI NO2 product provided in the framework of the QA4ECV project (v1.1) in this discussion as well (e.g. including the latest developments in the STS and the trop. AMF algorithms).

Thank you for this valuable suggestion. We have now included an evaluation of QA4ECV in the revised manuscript. Figure 9, Table 2 and Table 3 have been updated accordingly. QA4ECV is still bias low in highly polluted cases, although its R2 with respect to MAX-DOAS is better than DOMINO v2. This additional comparison further strengthens the importance of aerosol correction in NO2 retrieval over East Asia. POMINO v1.1 is closer to MAX-DOAS than QA4ECV is, especially in hazy days, highlighting the capability of POMINO v1.1.

P11 The authors mention that the climatological adjustments in the aerosol information is based on the assumption that systematic model limitations are month-dependent and persist over the years and days. On the other hand, the daily variations in the aerosol extinction profile are coming from the model only (Eq. 3). How good are the daily variations in the aerosol parameters modeled by GEOS-Chem?

The extent to which model aerosol information can be corrected depends on the availability of aerosol observations. MODIS and especially CALIOP suffer from low coverage on the day-to-day scale, preventing their direct use in satellite NO2 retrieval product and in daily correction of model aerosols.

Previous studies have shown that GEOS-Chem is able to simulate day-to-day variation of AOD from AERONET (Li et al., 2013, 2015) and satellite (Johnson et al., 2012), surface PM2.5 (Liu et al., 2018), and aerosol vertical profile (Ford and Heald, 2012).

P11 From Eq. (2) and (3), I would expect a "jump" in the aerosol extinction profile from the last day of the month to the first day of the next month (because of the change in R). Is this 'jump' also noticeable in the trop. AMF and VCD?

Here we test this "jump" issue over Northern East China. For every first day in each month of year 2012, we use the monthly correction from the last month (ie. For 1st, Feb, we will use the ratio of January to adjust aerosol extinction profile of GEOS-Chem on this day). Figure R1 shows the test results. In particular, the difference in NO2 VCD between this sensitivity test and our actual retrieval is below 3.8% for most cases. Besides, the distribution of VCD difference seems to be random. Thus the "jump" issue does not influence our results systematically.

We have added in the revised Sect. 2.2 that "Although this monthly adjustment means discontinuity on the day-to-day basis (e.g., from the last day of a month to the first day of the next month), such discontinuity does not affect the NO2 retrieval significantly, based on our sensitivity test."

P12 How large is the effect of neglecting polarization in the RTM (LIDORT) on the trop. AMF calculation?

The impact of polarization is small, affecting stratospheric retrievals by 0.1% and reducing tropospheric AMF by < 0.5% (Boersma et al., 2011). According on Lorente et al., (2017), top-of-atmosphere reflectance simulated by four RTMs (DAK with polarization, McArtim, SCIATRAN and VLIDORT with polarization) agree within 1.5%.

Section 3.1

Fig.3 For some specific areas there seem to be large differences between the two CALIOP ALH datasets, e.g. for Shandong in summer. Is this only caused by the

differences in resolution/sampling/regridding, or are there other factors?

The large difference over Shandong is persistent across the seasons. It is mainly caused by resolution/sampling/regridding process. Our climatological dataset uses the same criteria as the NASA Level-3 product does, but we aim at compiling a climatology to adjust GEOS-Chem outputs in a temporally and spatially consistent manner.

Section 4

A difficult/confusing concept of the POMINO NO2 algorithm is that for the trop. AMF, (thin) clouds are treated as reflecting boundaries in the RTM calculations (using effective cloud parameters retrieved from the O2-O2 band), while Mie parameters are used in the RTM for the layers with aerosols. It is clear that the aerosols are included in the POMINO O2-O2 cloud retrieval, but the different treatment of scattering by clouds and aerosols in the trop. AMF calculation could be addressed in more detail.

As in all other cloud products used for NO2 retrieval, we treat clouds as "effective" Lambertian reflector with a fixed albedo (80%). Assuming Mie scattering for clouds implies an explicit treatment of vertical cloud structure, cloud droplet sizes, etc., which is actually a new direction we could explore for NO2 retrieval.

We have added a statement in the revised Sect. 2.2: "Note that the treatment of cloud scattering (as "effective" Lambertian reflector, as in other NO2 algorithms) is different from the treatment of aerosol scattering/absorption (vertically resolved based on the Mie scheme)."

Section 6

The evaluating of the improved OMI NO2 product with MAX-DOAS data is an important part of this study. However, the number of measurements/points in Fig. 10 seems low (e.g. compared to other satellite validation studies using the BIRA-IASB MAXDOAS data at these sites). Can the number of points be increased, e.g. by increasing the time period, relaxing the cloud screening, collocation criteria etc? Then the statistics can be improved and also time series could be added.

We would definitely prefer to have a larger set of MAX-DOAS NO2 data. Unfortunately, very few high-quality MAX-DOAS measurements are available over China. We have made efforts to get data from multiple sites to enhance the spatial representativeness. Our criteria to select MAX-DOAS data and OMI data mainly follow Wang et al., (2017b) and Lin et al., (2014b), who have already discussed the influence from various statistical methods. We have included a statement in the end of Sect. 6 that “Further research may use additional MAX-DOAS datasets to evaluate the satellite products more systematically.”

In addition to the comparisons in Fig. 10, the MAXDOAS retrieved NO2 profiles could also be exploited with the Averaging Kernel (AK) of the OMI NO2 columns. Comparisons of the satellite NO2 columns with these “smoothed” MAXDOAS NO2 columns could provide useful additional information (e.g. to isolate the impact of the satellite a priori NO2 profile).

We only have the vertical profiles at Xianghe, with lack of spatial representativeness. Our previous study (Lin et al., 2014b) shows that using the MAX-DOAS vertical profiles have a minor impact on the retrieved NO2.

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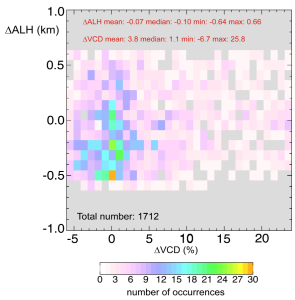

Figure R1. Percentage change in retrieved NO_2 VCD when using the CALIOP aerosol extinction profile in a formal month (POMINO_change) to adjust modeled profile on the first day of each month ([POMINO_change-POMINO v1.1]/[POMINO v1.1]), for each bin of ΔALH (bin size = 0.1 km) and ΔVCD (bin size = 1%) across pixels in 2012 over Northern East China. Here we only choose the pixels with WCLD < 0.5, surface albedo < 0.3 and SZA < 70°.

Fig. 1.