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Atmospheric Measurement Techniques Discussions

Interactive comment on "Validation of tropospheric NO_2 column measurements of GOME-2A and OMI using MAX-DOAS and direct sun network observations" *by* Gaia Pinardi et al.

Anonymous Referee #2

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Pinardi et al present inter comparison of tropospheric NO_2 columns between satellite (OMI and GOME-2A) and the ground-based (direct sun and MAX-DOAS) measurements at 39 locations over a period of 2007-2018. The authors take 3 different approaches for selecting the satellite data and intercomparison: 1) all pixels within 50 km of the ground-based site; 2) only pixels smaller than 40 km and encompassing the ground-based site; 3) account for horizontal spatial heterogeneity using dilution correction derived from OMI (2005) resampled data on 0.025° x 0.025° with and without ground-based data filtering over 75th percentile. The authors presented a good literature review of the prior validation work considering spatial heterogeneity in tropospheric NO_2 field. They discussed in detail uncertainties in the satellite and ground-based

tropospheric NO_2 column retrievals. The authors concluded that satellites underestimated NO_2 tropospheric columns at most locations with the largest effect over the urban locations. The comparison improved if pixel size was limited and encompassed the site location. The best agreements (expressed as slopes and correlation coefficients of the linear regression analysis) were achieved from data filtering of the largest columns and applying dilution correction.

The paper is well written, addresses a very important question of satellite NO_2 tropospheric column quality and is within the scope of AMT.

Major comments:

I recommend the authors consider some reorganization of the paper. Based on the previous studies and the knowledge of the local sources it seems that the "base" case for the validation should be the smallest pixels encompassing the site locations and with the consideration of the measurement direction and horizontal extent within the pixels. After this comparison is done the authors can address the question of differences in pixel size and significantly reduced statistics by expending to include satellite data within 50 km of the site, demonstrating that this approach (as expected) does not improve the comparison even with the larger sample size. Then the authors can introduce the dilution correction method, which potentially increases the sample size and accounts for the heterogeneity. While this is a very promising technique especially if this can be applied to sub pixel heterogeneity, it is premature to call the dilution correction results "validation" due to correctly listed limitations. There are some filter selections and classifications that need better explanation, since a somewhat different selection criterion can potentially lead to a different conclusion.

Minor comments:

P2, l34: Pandora provides operationally only total columns of NO_2 and O_3 from the direct sun measurements

P3, l20: “direct sun measurements also match better the horizontal resolution of satellite observations”. DS during the summer months or near tropics at 13:30 local time will not provide a representative horizontal resolution;

P14, l29: I would recommend: “Equipped with a 2-axis positioner, direct sun-capable DOAS instruments measure non-scattered photons. Such measurements are equally sensitive to both tropospheric and stratospheric absorptions (Figure 1b). They have a very small uncertainty in AMF, and can provide accurate total column measurements with a minimum of a-priori assumptions.”

P14, l35: I would recommend: Direct sun observations are routinely available from the Pandora spectrometer instruments. A standardized Pandora network has been set-up by NASA (Herman et al., 2009, Tzortziou et al., 2014, Pandora project, https://pandora.gsfc.nasa.gov/) and expanded by ESA and LuftBlick to form the PGN (Pandonia Global Network, https://www.pandonia-globalnetwork.org/).

P15, l27: how was the cloud radiance fraction selected?

P16, l9: Do you mean to say: “On this basis, in addition to the daily comparisons at each station, corresponding monthly averages were also compared.” If not, please elaborate why do you think daily data are accurate enough considering spatial and temporal variability and averaging?

P18, l4: I would recommend rephrasing: Due to different deployment strategies, the direct sun measuring instruments (especially Pandoras) were located closer. . .

P18, l6: I would recommend rephrasing: The MAX-DOAS ensemble of stations measured NO_2 total columns in the 2 to 20 x 10^{15} molecule/cm^2 range. . .

P18, l7-8: I am not sure how relevant this statement is to the satellite validation since accuracy of both satellite and MAX-DOAS retrievals are impacted by the clouds. A part of the observed variability in MAX-DOAS measurements is the retrieval error since most MAX-DOAS inversion algorithms assume cloud-free conditions.

P19, l7-8. Part of the bias can also be difference in NO_2 molecular absorption cross section temperature used in DOAS analysis. MAX-DOAS is typically analyzed using 298K while direct sun (at least Pandora data) at the profile effective temperature of 254K. Spinei et al., 2014 (https://amt.copernicus.org/articles/7/4299/2014/amt-7-4299-2014.pdf) showed that at polluted sites during hot summer months this could result in 5-10% underestimation in NO_2 total column derived from the direct sun data compared to the true effective temperature.

P20, l19: what definition was used for urban and suburban? Is there some specific distance and “source” size used?

P20, l19: It appears that the “goodness” of the linear correlation, as shown in Fig 5, is almost entirely driven by the highly polluted sites for GOME-2A with MAX-DOAS comparison. If for some reason Yokosuka and Beijing data were removed the conclusion about the correlation “goodness” will be very different. In my opinion, the authors did not convenience the readers that using the urban-suburban classification vs. “source strength combined with the source size” help understand actual correlation between the satellite and ground-based measurements.

P27, l22: While the slope improves, the scatter actually gets worse. Adding fit RMS might be more representative of the actual fit quality.

P28, l4-5: Pandora is a spectroscopic instrument with a 2-axis positioner, diffusers and neutral density filters to allow for a wide dynamic range measurements (direct sun, moon, and multi-axis). I would recommend changing: This is likely related to the fact that, as already mentioned, direct sun measurements (specifically Pandoras) tend to be located. . .Another potential reason is also higher uncertainty in determination of the “true” amount in the reference spectrum and much more “localized” measurements (e.g. at high sun)

P30, l13: Why 9th and 91th percentiles were chosen?

Fig. 11: please add the color-coding.

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