

Review:

Pinardi et al., Validation of tropospheric NO₂ column measurements of GOME-2A and OMI using MAX-DOAS and direct sun network observations

Summary

Validation of satellite NO₂ measurements via aircraft or ground-station instruments is hampered by disparities in the spatial resolutions of the different measurement types. Strong localized pollution sources can be effectively sampled at a ground station but are diluted by smearing within the satellite footprint. The authors demonstrate a method to correct for this dilution, using long-term high-resolution NO₂ datasets to give an estimate of the spatial variability within a satellite ground pixel. Related approaches, using proxies for NO₂ spatial distributions have been employed in the past for limited instruments over limited regions. However, this study is valuable, because it provides a more robust test of the correction algorithm with a large number of sites and combination of ground-based MAX-DOAS and direct-sun instruments. Results show significantly improved correlations with reduced bias between satellite (OMI and GOME-2A) and the validation data. As such, it makes an important contribution and can/should be employed in future validation studies.

The paper is well-written, organized and referenced. In addition to presenting the dilution correction, it stands by itself as a good validation study. I have only a few comments and minor corrections. If addressed, I recommend acceptance in AMT.

General comments

(1) The dilution factor is computed in a 50 km-radius circle centered on the measurement site. This approach is convenient, but the satellite FOVs are not circular and vary widely in size. It seems that systematic errors could be large and could be mitigated using the pixel-corner coordinates in the OMI and GOME-2A level-2 files. In the conclusions, the authors acknowledge this, but more discussion should be given earlier in the text. A comparison with a dilution correction based on physical pixel dimensions for perhaps one challenging case would be useful to show whether errors in the fixed-circle assumption are significant.

(2) An error in the estimated stratospheric component of the satellite NO₂ is suggested as a reason for the non-zero y-intercepts in the scatter plots of Figure 9. Highly structured stratospheres – e.g. in the NASA OMI Standard Product or from assimilation (as in DOMINO) – may be locally more realistic on a given day than smoother stratospheres (e.g. from STREAM)

but may also be prone to mean systematic biases that alias some tropospheric NO₂ into the stratosphere and vice versa. This is discussed in the STREAM and NASA v2 algorithm papers and elsewhere. Small stratospheric errors can be amplified by the AMFs.

a) An investigation of how stratospheric aliasing may affect validation is beyond the scope of this study, as stated. But a brief comment could be included, since the OMI and GOME-2A data used here are based on assimilated stratospheres. Future examination based on STREAM would be interesting.

b) Equation (2) states that satellite-derived stratospheric NO₂ is subtracted from the direct-sun measurements. If the same stratosphere has been subtracted from the satellite total columns, shouldn't any stratospheric errors at least partially cancel, leading to a ~0 intercept? Are there other factors that could cause the non-zero intercepts?

c) Minor point: For the DS data, the slopes in Figure 9 show best agreement with GOME-2A for filtered, dilution-corrected data. Table 5 suggests no filtering gives better overall agreement. Is this again an effect related to the y-intercepts?

Specific and minor comments

(1) Page 2, lines 19-20: "...Since the mid-1990s, NO₂ has been measured from space..."

(2) Page 2, line 23: "...afternoon have also been made by the OMI..."

(3) Page 4, line 26: "...from slant (SCD) to vertical (VCD) column densities."

(4) Page 4, line 37: "...2018). SCD structural uncertainties..."

(5) Page 6, line 6: "...Satellite-to-satellite comparisons...have been performed..."

(6) Page 6, line 21: "...crossing the Equator around 13:45 LT (in ascending node)."

(7) Page 6, line 29: "...the GOME-2A product..."

(8) Page 7, line 14: "...). For 18 cloud-free..."

(9) Page 8, Table 1: The table would be easier to read if the two satellite instrument columns were better delineated (e.g. a vertical divider). GDP4.8 and Q4ECV v1.1 should be grouped with GOME-2A and clearly marked as the first and second column headings applied to the entire table below the instrument information box. Similarly, DOMINOv2.0 and QA4ECV v1.1, grouped with OMI, should be clearly marked as the third and fourth column headings throughout.

(10) Page 14, line 33: Define DS since it is used later. "Direct-sun (DS) observations are routinely..." Technically "direct-sun" should be hyphenated throughout, but this may be at the discretion of AMT.

(11) Page 15, line 14: "Those account for..."

- (12) Page 15, line 17: "...estimated using satellite data (SAT) (alone or within assimilation...)"
- (13) Page 15, line 36: "...and only OMI pixels centered..."
- (14) Page 16, line 4: "Ground-based (GB) MAX-DOAS data were interpolated..."
- (15) Page 17, line 18: "...compared to early afternoon (13:30 hrs)..." Are LTs in this paragraph mean values for the stations (given 13:45 equator crossing)?
- (16) Page 19, lines 6 and 24: "...and GOME-2A overpass...", "...and GOME-2A overpasses..."
- (17) Page 20, lines 3 and 24: "...their median difference at OMI and GOME-2A overpass are 5.7 and ...", "...than for GOME-2A..."
- (18) Page 25, line 15: "...the outer extent of any 40 x 40 km² GOME-2A pixels whose centers are within the 50 km radius."
- (19) Page 27, lines 3, 4: "...GOME-2A..."
- (20) Page 27, line 18: "...scatter plots of GOME-2A and ground-based data..."
- (21) Page 30, line 11: "...and GOME-2A GDP..."
- (22) Page 31, lines 3-4: "...but should have relatively little systematic effect on regression slopes."
- (23) Page 31, line 8: "...morning GOME-2A overpass..."
- (24) Page 32, Figure 11: Please define seasonal colors in the caption, or preferably as a legend on the figures.
- (25) Page 32, line 2: "...GOME-2A..."
- (26) Page 33, line 19: "...they found a complex spatial distribution..."
- (27) Page 35, line 4: "The number of comparison points for each case is shown in the corresponding color."
- (28) Page 38, line 9, Figure 16 caption: Please explicitly define the colors.