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Atmospheric Chemistry and Physics Discussions

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Interactive Comment

# *Interactive comment on* "Near-real time retrieval of tropospheric $NO_2$ from OMI" *by* K. F. Boersma et al.

**K. F. Boersma et al.**

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Response to Anonymous Referee 3

"The paper by Boersma et al. describes a new retrieval system set-up to provide tropospheric NO2 columns from OMI measurements in near-real time. It briefly describes the instrument and data flow, discusses some aspects of the algorithm used in comparison with a similar system used for GOME and SCIAMACHY data and the standard off-line OMI NO2 product. Some aspects of the error budget are discussed including precision and cloud treatment and a comparison to SCIAMACHY data is shown. The paper is well organised and clearly written although repetitive in some places. The topic is rather technical for ACP as it is mainly a description of an improved retrieval system with error discussion and only very brief examples of atmospheric applications. As the product (tropospheric NO2 columns from OMI) is of large interest to many sci-





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entists working in the field of tropospheric chemistry, I recommend publication after careful consideration of the points listed below."

We thank the reviewer for his careful reading. We have tried to remove repetition as much as possible.

"Major comments: * As stated above, the paper is rather technical for this journal and I recommend removing or drastically shortening section 2.2."

As fast data transport is essential to a near-real time algorithm, and is subject to less stringent quality requirements than standard production data, it is important to describe the key aspects. We therefore did not remove section 2.2. As we share the reviewer's concern about the technical nature of this part we have shortened section 2.2.

"* The authors try to clarify the relation of this retrieval system to the other systems used at KNMI and for the standard off-line processor. However, it is often not clear to me, which parts are identical and which are new. For example, the description in section 5.1 - does it apply to this product only or is it the same in GOME and SCIAMACHY data on the TEMIS web page?"

Section 3.2 explains similarities and differences between the NRT-system and off-line systems in use at KNMI. The use of data-assimilation to estimate the stratospheric column is common to GOME, SCIAMACHY, and OMI retrievals, but the difference is in the off-line assimilation used for GOME and SCIAMACHY retrievals, versus the operational assimilation and modeling used for the OMI NRT retrievals.

"* The one comparison that most readers will like to see, namely to the standard OMI off-line processor is not really given. Here, a table would be useful to show all the differences (fit, stratospheric correction, AMF calculation, cloud treatment etc.)."

Good point - we have now inserted a table in section 3.1.

"* The comparison with SCIAMACHY data is rather qualitative. I'd strongly recommend adding scatter plots, if possible coloured or separated by region. Also, it would be



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interesting to show the difference in tropospheric column the TM4 model predicts for the two observation times to support the author's claim that the observed 30% differences can be explained by the different overpass time. I understand that this will be the topic of a follow-on paper, but I don't think that such a significant difference can be ignored when presenting a new data product."

We agree that the comparison with SCIAMACHY is merely qualitative, but we argue that this is for a good reason. In the meantime, we have looked into the comparison with SCIAMACHY in a quantitative way, presented that work at the AGU 2006 Fall Meeting (http://www-as.harvard.edu/chemistry/trop/curresh.html#no2), and we are close to submitting a manuscript (Intercomparison of SCIAMACHY and OMI tropospheric $NO_2$ columns: observing the diurnal evolution of chemistry and emissions from space, Boersma et al., 2007) on this. If, as the reviewer recommends, we were to extend the OMI NRT retrieval paper with manuscript in preparation, the OMI NRT paper would address too many topics as well as run too long.

"* In the slant column fitting, no mention is made of H2O and O4 which both have significant absorption in the fitting region used. If these two species are in fact not included in the analysis, the author's must provide evidence that this does not introduce systematic errors in their NO2 columns, for example by comparing the results for one day of OMI data with and without accounting for these two absorbers."

Bucsela et al. (2006) and Boersma et al. (2002) found that within the 405–465 nm window used for OMI, it is not necessary to include the effects of absorption by H2O or O2-O2. Including these species did not affect the fitted NO2 slant columns. The reviewer likely refers to NO2 fitting results for GOME and SCIAMACHY, where H2O and O2-O2 are traditionally taken into account, but these spectral fits used much smaller spectral windows (425-450 nm).

"Minor comments: * Pixel size: I'm confused by the OMI pixel sizes given in the paper as they don't agree with the description in the OMI web page



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(http://www.knmi.nl/omi/research/instrument/characteristics.html): The small size given is only for the nadir point which should be noted in the text, and also at the edges of the scan, the pixels seem to be larger than 120 km, not 60 km as stated."

This has been corrected.

"* Pixel size SCIAMACHY: This actually is 30 x 30 km2 in some seasons over some areas, e.g. over Europe now."

We have chosen to stick to nominal pixel sizes for both SCIAMACHY and OMI. Note that with OMI a spatial zoom-in is possible, reducing the pixel size to 13 x 12 km2.

"* Page 12313: "The AMF is computed as described in Sect. 3.1 " - actually, I don't think the computation of the AMF is described in this section or anywhere else in the paper."

In section 3.1 describes that AMFs are computed with the DAK radiative transfer model and that the best estimates of forward model paramaters are used in the computation. We have added that the actual computation is described in Boersma et al. (2004).

"* Section 4.1, across track variability: Wile this correction will probably work well in reducing the apparent stripes it does assume that the average value of the NO2 slant column is correct. Experience with the GOME diffuser plate problem however shows, that even when making the data set consistent, there remains an uncertainty in the absolute value which should be added to the error budget."

Any bias introduced by the correction procedure in the total slant column propagates into the estimate of the stratospheric column. Upon subtraction this bias will largely cancel, as is the case in GOME tropospheric NO2 retrievals, and therefore we do not include this in the error budget calculations.

"* Section 4.2., slant column precision: it is not clear to me, how much data was used for this analysis. If several OMI orbits were used, there must have been some overlap in mid- and high latitudes and such pixels must necessarily have different AMFs. Please



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clarify."

As stated in section 4.2, we used 2893 pixels to compute the slant column precision as shown in Figure 5b. This corresponds to 70 pixels per 2 x 2 degree box shown in Figure 5a. Furthermore we used the requirement that AMF variability is to be $<$0.1%, hence the absence of boxes for higher latitudes in Fig. 5a.

"* Section 4.2., slant column precision: Why would one expect not to see a latitudinal dependence? Please indicate the SZA range covered by the measurements. In GOME and SCIAMACHY data, a clear dependence of noise on the SZA can be observed as expected from the variation in intensity."

The fitting error is determined by random noise in the OMI reflectance measurements and by the apparent strength of the NO2 signal along the average light path from the Sun through the atmosphere to the satellite. Both depend on viewing angles and atmospheric conditions (e.g. clouds). In section 4.2, we averaged over a great number of conditions (n=2893), and this likely smears out the change of fitting error as a function of latitude, if any. Additionally, Mark Wenig (Ph.D.-thesis, University of Heidelberg) found a comparable weak dependence of fitting error as a function of latitude for GOME NO2 retrievals.

"* Section 5.1: The details of how the model is forced to the measurements (which weights are used?) and how the weighting for polluted scenes is down are not clear to me. Please clarify or add a reference to a publication which gives more detail."

We have added the following. The forcing depends on weights (from observation representativeness and model errors) attributed to model and observation columns. The observation error is set to A times the modelled tropospheric slant column plus B times the modelled (assimilated) stratospheric slant column. A and B are relative errors, and are chosen as A=4 and B=0.25. This implies that the observation error rapidly increases for modelled tropospheric vertical columns larger than or of the order of 0.5 $\times$ $10^{15}$ molec.cm$^{-2}$. As a consequence, moderately and highly polluted regions obtain



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a small weight in the assimilation. The ratio A/B roughly reflects the high uncertainties in the tropospheric retrieval as compared to the stratosphere.

"* Comparison with SCIAMACHY data: As said above, I think more figures are needed. Also, I think Fig. 9 should show data from August 2006 for consistency and include the corresponding SCIAMACHY plots at the same resolution for comparison."

As explained above, we choose to submit a separate manuscript on the SCIAMACHY-OMI comparison soon. This manuscript (and the on-line presentation mentioned above) shows detailed comparisons for the regions indicated above. The purpose of Fig. 9 is to stress the OMI capability.

"* I might have missed that point, but somehow I didn't understand how you deal with the difference in local time across a OMI swath in the assimilation system and when subtracting the stratospheric column Could you please give a bit more details?"

Good point. We have now added the following. We take model fields that are closest in time to the mean OMI orbit time (model information is stored in UT with 30 minutes increments, 48 fields per day). This limits differences between observation and model times in the assimilation to at most 55 minutes (plusminus 25 from actual vs. mean orbit time, plusminus 30 from model vs. mean orbit time). Taking model fields closest in time is relevant only at high latitudes where local time differences across an OMI swath are considerable and could lead to large assimilation errors if the model was just sampled at 13:30 local time. Rejecting retrievals with solar zenith angles $>$80 degrees, we avoid regions with day-night transitions.

"* One important difference between SCIAMACHY and OMI is the swath width which can be quite important for the tropospheric airmass factor in particular in the presence of aerosols. Can you please explain how this is treated in the retrieval?"

We have added to section 5.2.3 that we do not explicitly correct for aerosols as these influence cloud retrievals. Modified cloud parameters indirectly account for the effect



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of aerosols on the retrieval (Boersma et al., 2004).

"* section 3.1: * Typographic corrections:

* page 12305: current the level 1 => current level 1"

Corrected.

"* page 12307 and OClO => and OClO columns"

Corrected.

"page 12312 as soon meteo => as soon as meteo"

Corrected.

"* reference van Noije has been published in ACP"

This has been updated.

"* reference van der A now published"

This has been updated.

"Table 2: I'm missing either * and ** in the caption"

We do see both the * and ** (in the table line on the standard product).

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Interactive comment on Atmos. Chem. Phys. Discuss., 6, 12301, 2006.