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Interactive comment

Interactive comment on "Improving algorithms and uncertainty estimates for satellite NO_2 retrievals: Results from the Quality Assurance for Essential Climate Variables (QA4ECV) project" *by* K. Folkert Boersma et al.

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We thank the reviewer for the positive and useful comments, and for their careful reading of the paper. We have addressed the questions as follows, with our response in blue.

Reviewer Comment 2

The paper "Improving algorithms and uncertainty estimates for satellite NO2 retrievals: Results from the Quality Assurance for Essential Climate Variables (QA4ECV) project"

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Discussion paper

by Boersma et al. describes the improvement of NO2 retrieval algorithms for GOME, SCIAMACHY, OMI and GOME-2, and the production of a multi-decadal record of global NO2 columns. This manuscript provides an overview of the NO2 retrieval results from the QA4ECV project, which have been partially reported in earlier papers. Furthermore, first comparisons have been made between the OMI tropospheric NO2 data and ground-based MAX-DOAS measurements at one site in 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.

Thank you for this comment.

Section 3

Table 2 The spatial resolution of GOME-2A was changed to 40x40 km^2 on 15 July 2013.

We have now included this in Table 2.

P18 The diffuser plate also causes spectral structures in the GOME-2 solar irradiances, but the effect is much smaller than for GOME/ERS-2.

We have now added this sentence to Section 3.

Section 5.1

The manuscript discusses a consistent NO2 retrieval for GOME, SCIAMACHY, OMI and GOME-2, and Table 4 lists the specific DOAS settings for the 4 satellite instruments. However, in the text only the analyses of the fitting results for OMI are discussed in detail. Considering the specific instrument characteristics affecting the DOAS retrieval (as described in Sect. 3), a short discussion on the NO2 fitting results for the other instruments should be included, and the consistency between the results of the 4 instruments discussed.

Good point. Although the focus within QA4ECV was initially on OMI, we also evaluated the consistency in the NO2 SCDs from the other instruments. We have now added a discussion of our tests on the consistency of the NO2 fitting results from GOME-2, SCIAMACHY, and GOME.

P23-24 The differences in the NO2 slant column shown in Fig. 4 are significant. As described in the text, the differences are mainly a result of the intensity vs optical density fit and the intensity offset (while the stratospheric AMF effect is very small). These two key DOAS subjects should be discussed in more detail in this section. In particular, I suggest adding a discussion/recommendation about the intensity vs optical density fit method.

We discuss in more detail now the use of the optical density fits and intensity offset used in the QA4ECV fitting process. For a detailed discussion of the tests done, we refer to QA4ECV D4.2, and a work in preparation on these test by the University of Bremen.

Fig 5b The illustrated scenario (SZA=VZA=0) is not really a typical OMI viewing geometry. Please use a realistic mid-latitude OMI measurement scenario.

We have done this, and now show the scenario for SZA = VZA = 30°.

Section 5.2 P27 Here it is mentioned that NO2 SCDs are assimilated in TM4, while at the end of Sect. 5.3 TM5 is mentioned.

In the testing phase, we used the DOMINO v2 code, where assimilation is done in TM4 [Boersma et al., 2011; Dirksen et al., 2011]. In the retrieval development phase, we updated the model framework to TM5. The text now reflects this.

P28 Please provide examples of "particular applications" of the two different STS approaches.

The purpose of either STS approach is to correct for the stratospheric contribution to the observed SCD, in order to retrieve a high-quality tropospheric product. Both corrections perform similarly over regions with strong anthropogenic NO2 pollution.

Data assimilation can be applied for global retrievals. The strength of data assimilation is that it provides a correction that is based on broad and consistent knowledge on the state of the atmosphere (NO2 and temperature profile, stratospheric dynamics). Especially in situations with strong stratospheric NO2 gradients, such as near the polar vortex, assimilation is the preferred approach. It has been shown that the data assimilation captures the strong spatial gradients occurring near the vortex [Dirksen et al., 2011], whereas the STREAM method by design results in zonally smooth structures in those regions.

STREAM can be applied especially for studies into small sources, such as emissions from soil, ships, and small, isolated anthropogenic sources. The strength of STREAM is that it does not rely on chemistry transport models. Data assimilation is potentially somewhat vulnerable to misinterpret tropospheric contributions as stratospheric NO2. This qualifies STREAM as a useful alternative for data assimilation for studies in areas away from strong stratospheric gradients (where the zonally smooth structure of the stratospheric field is of little consequence). The text has been updated accordingly.

Section 6.2 Tabel 5 Are the “Symbols” for the three “Contribution to the uncertainty of . . .” entries correct?

They are indeed correct, but could be clarified a bit more. The first term, between brackets, indicates the AMF uncertainty caused by uncertainty in the forward model parameters. These terms are the same as Eq. (12) in Boersma et al. [2004]. Since we’re interested here in the contribution of these uncertainties to the NO2 column, we ratio the AMF uncertainty by the AMF itself, and multiply with the actual tropospheric NO2 column. We now include a clarification in a footnote to Table 5.

Section 7 As also mentioned in the text, the ground-based validation discussed in the paper is for one site only and has a very limited time range. Although it is understandable that in this manuscript only a first validation is presented and a dedicated validation paper is in preparation, it is problematic to draw conclusions about OMI retrieval uncertainties based on regression/differences analysis of such a small data sample. If the validation and uncertainty analysis are illustrated for one site then a longer data period should be used to increase the number of measurements and to be able to account for seasonal variations. Why has the site Tai'an been selected if only campaign data for a short period is available? (also considering the fact that the authors have access to longer MAX DOAS data records for several other sites).

A more comprehensive validation work, with focus on other sites and over longer periods, is in preparation by our Belgian colleagues (as was mentioned in the manuscript). We chose to do a first evaluation of the OMI QA4ECV NO2 product and their uncertainties with the Tai'an data available to us, because these data have been used before to validate the DOMINO v2 product with good agreement [Irie et al., 2012]. This anchors our evaluation of the new QA4ECV product to previous, well-established efforts. Moreover, the scope in section 7 is not just on validation but as much on bringing forward ideas on evaluating satellite data, such as correcting for spatial gradients, and using the deviations to check on the reported uncertainties.

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