Inhomogeneous scene effects in OMI NO_2 observations

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1 Introduction

- satellite derived tropospheric NO_2 columns are an important source of information on NOx pollution
- retrieval of tropospheric NO_2 is performed in the visible part of the spectrum and reflectivity of scenes varies strongly in the presence of clouds or close to ice or snow covered surfaces
- it is well known that inhomogeneous illumination of the entrance slit of a spectrometer can lead to both wavelength shifts and distorted instrument line shape function compared to what is obtained for homogeneous illumination
- it is therefore expected that larger uncertainties are found for measurements over scenes with strong variability in reflectivity
- the effect will be more pronounced for imaging spectrometers such as OMI or S5P where the ratio between field of view (FOV) and instantaneous FOV is close to one compared to scanning instruments such as GOME or SCIAMACHY where this ratio is larger and inhomogeneities tend to be averaged out

2 OMI Observations

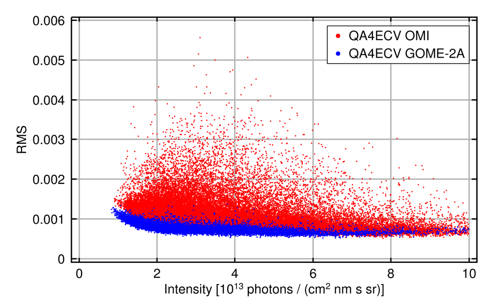

Figure 1: Comparison of NO_2 fitting residuals from OMI and GOME-2A covering a similar area. Both data sets were analysed using the QA4ECV settings

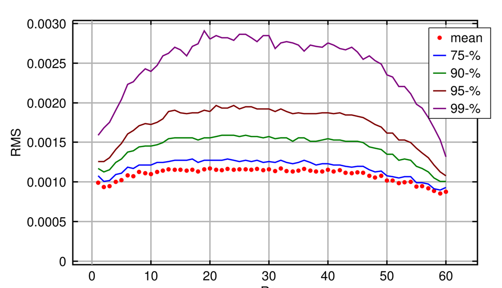

Figure 2: Dependence of OMI NO_2 fitting residuals on position in the swath. Lines are percentile values, showing the much increased scatter in the central part of the swath.

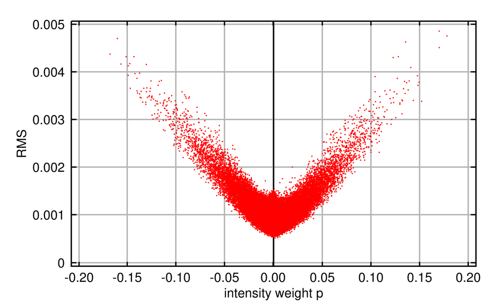

Figure 3: Dependence of OMI NO_2 fitting residuals on intensity weight within the ground pixel. Intensity weights are computed from small pixel measurements which have higher spatial resolution along track.

Comparison of fit residuals to GOME2A

- OMI fitting residuals are expected to be slightly larger than those from GOME2 because of the smaller pixel size
- there are however many fits which are much poorer than expected
- they also do not clearly show the expected dependency on scene intensity

Row Dependency

- fitting residuals are systematically larger in the centre of the swath where pixels are smaller and smaller at the edges where pixels are larger and more averaging happens

Dependence on scene inhomogeneity

- when plotting the fitting residual as function of the intensity centroid within the scene as computed from the small pixel observations which have better spatial resolution along track, a strong and nearly linear dependency is found

=> the large fitting residuals are the result of scene inhomogeneity

Acknowledgements

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- GOME2 lv1 data were provided by EUMETSAT
- OMI NO_2 v003 data was provided by NASA

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3 Empirical Correction

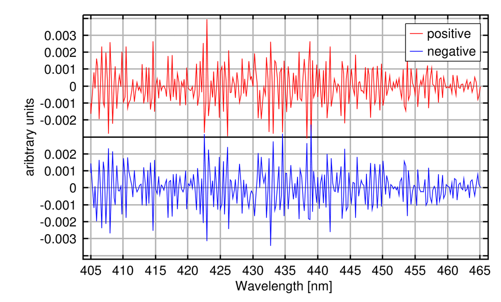

Figure 4: Empirical cross-sections determined from mean residuals of fits having large positive (top) or negative (bottom) intensity weights

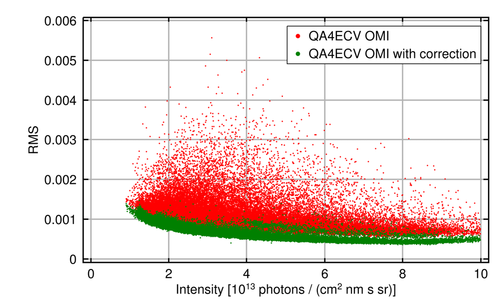

Figure 5: Comparison of NO_2 fitting residuals from with (green) and without the correction

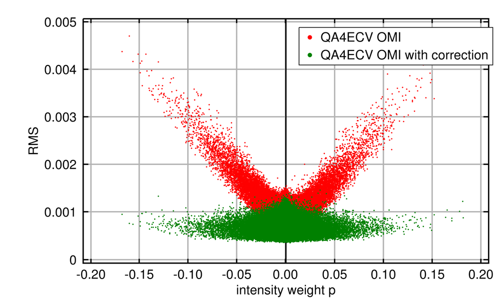

Figure 6: Dependence of OMI NO_2 fitting residuals on intensity weight within the ground pixel for the fit with (green) and without (red) correction

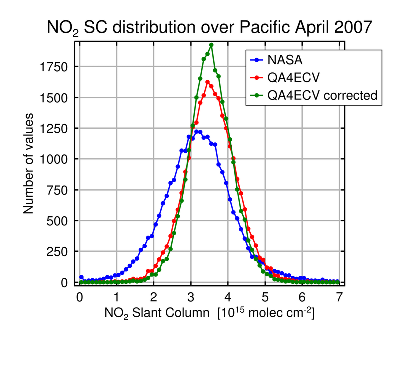

Figure 7: Comparison of the scatter of viewing angle normalised NO_2 slant columns. The blue curve is the NASA product v003.

Correction approach

- one orbit over the clean Pacific is used
- the mean fitting residual (per row) is determined
- NO_2 slant columns are smoothed using along-track box-car averaging over 21 points and are prescribed in a second fit which also includes the mean residual
- residuals from this fit are averaged into two pseudo cross-sections using pixels with large positive and large negative intensity weight
- these three pseudo cross-sections are added in the new NO_2 evaluation called „with correction"

Effect on residuals

- in the fit with the additional cross-sections, most outliers in the fitting residuals are removed and overall residuals are reduced
- there is nearly no dependency remaining on intensity weight

Effect on scatter of NO_2 columns

- when comparing the NO_2 columns over the tropical clean Pacific, the fit including the correction terms results in less scatter and thus has reduced uncertainty

Effect on NO_2 columns

- while NO_2 column changes are small between the fit with and without correction, systematic changes can be observed over regions with persistent intensity gradients (orographic clouds, ice edges, snow)
- in these regions, artefacts are apparent in both the standard QA4ECV NO_2 product and the NASA operational product
- these artefacts are not present in the fits using the correction terms
- the magnitude of the improvements is small but in the order of magnitude of weak anthropogenic pollution signals such as from ships

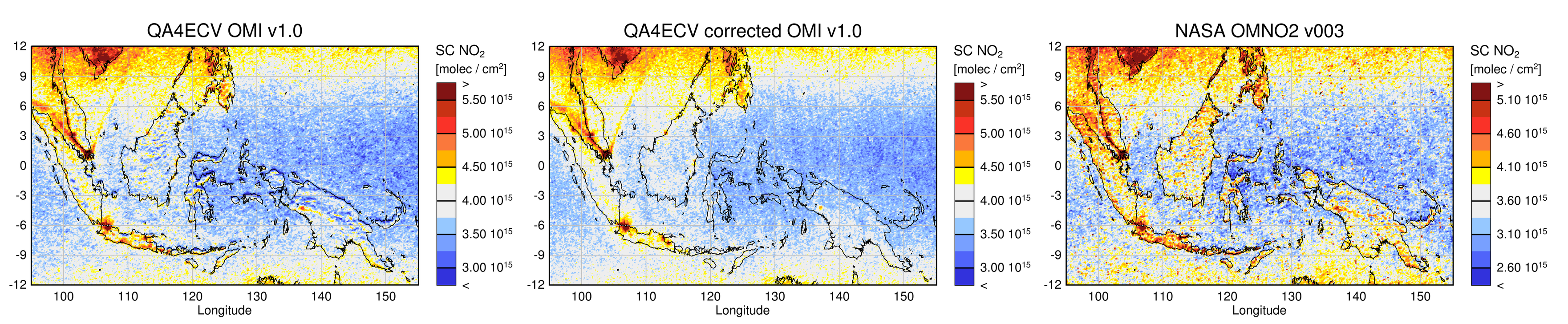

Figure 8: Effect of inhomogeneous scenes on viewing angle normalised OMI NO_2 slant columns. Left: Standard QA4ECV product, middle: QA4ECV product including the three correction terms, right: NASA v003 product. Data are monthly averages for April 2007 without cloud screening. Cloud related artefacts are clearly visible in the QA4ECV product and the much more noisy NASA data. In the product with correction, only anthropogenic signals such as from the Grasberg mine in New-Guinea remain.

4 Separation of effects

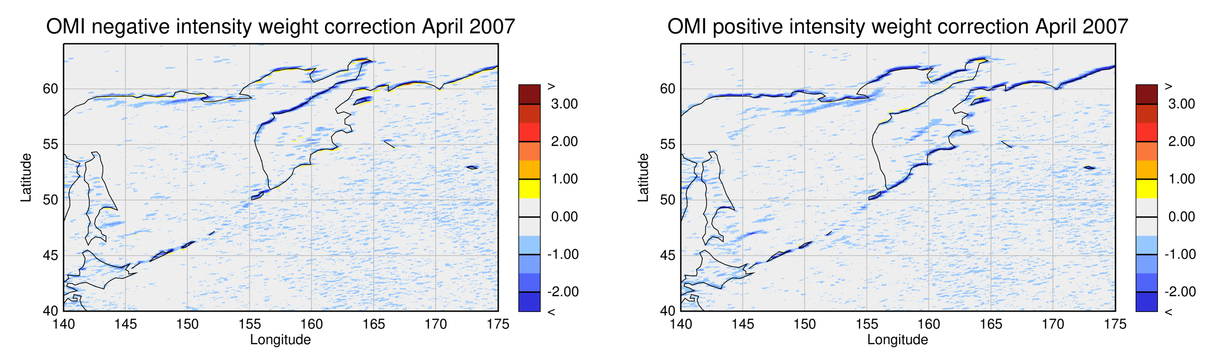

Figure 9: Fit factor for the two pseudo cross-sections shown in Fig. 4. The scene is dominated by the contrast between dark water and bright snow and ice on the continent. The two fit parameters differentiate between changes from dark to bright and from bright to dark. OMI flight direction is roughly from South to North.

Separation of positive and negative intensity weights

- two different cross-sections were created which look very similar (Figure 4)
- including only one of them leads to clearly poorer results than using both
- evaluating the fitting factors, it can be seen that one cross-section corrects changes in intensity from dark to bright and the other one changes from bright to dark.
- apparently, these two inhomogeneous illuminations create slightly different effects

5 Summary & Conclusions

- inhomogeneous illumination can affect the wavelength registration and instrument line function of spectrometers
- this leads to poor NO_2 spectral fits in OMI data over scenes having strongly inhomogeneous reflectance
- a simple empirical correction is proposed based on mean residuals of fits with strong scene inhomogeneity from clouds
- the correction leads to much reduced fitting residuals for inhomogeneous pixels
- in monthly means, some artefacts apparent in NO_2 maps over regions with persistent clouds or ice edges are removed, and overall scatter of the slant columns is reduced
- inhomogeneous scene effects are also present for other OMI trace gases and in data of the recent S5P instrument

Correction for inhomogeneous scene effects appears to be necessary in OMI and possibly also S5P data.

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