Improving satellite retrievals of large tropospheric NO_2 columns

EGU2014-11669
AS3.13
Z128

A. Richter, A. Hilboll, and J. P. Burrows
Email: Andreas.Richter@iup.physik.uni-bremen.de
Institute of Environmental Physics/Remote Sensing, University of Bremen, FB 1, P.O. Box 330440, D-28334 Bremen, Germany

Introduction

- NO_2 is one of the most important satellite data products
- analysis is performed using the Differential Optical Absorption Spectroscopy method (DOAS)
- in most situations, NO_2 is a weak absorber and the approximations made in DOAS are valid
- under very polluted conditions, NO_2 absorption can become significant (> 5%)
- here, we evaluate some effects present at very large NO_2 columns with respect to their impact on NO_2 fitting quality and the possible use as information source

Column dependent air mass factor

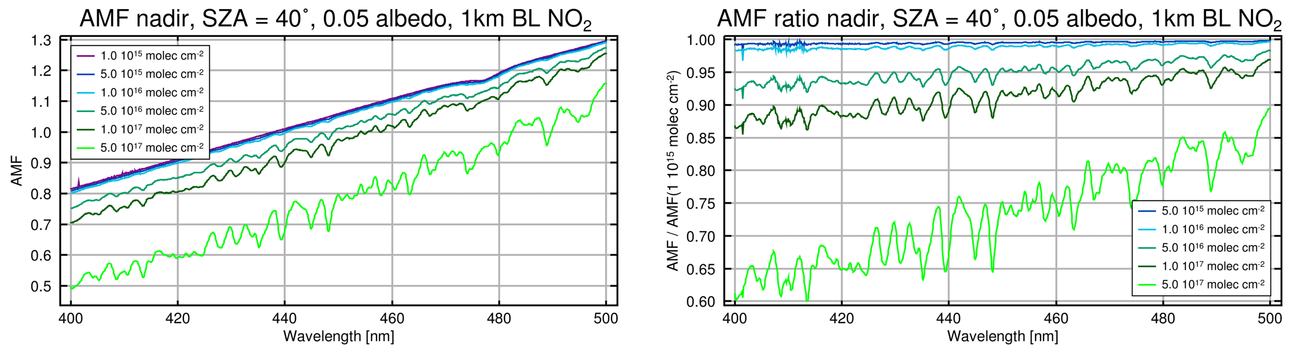

Figure 1: Wavelength dependent NO_2 air mass factors computed for different NO_2 vertical columns in a 1 km thick layer at the surface. **Left:** absolute values, **Right:** Change relative to the AMF having the smallest NO_2 a priori

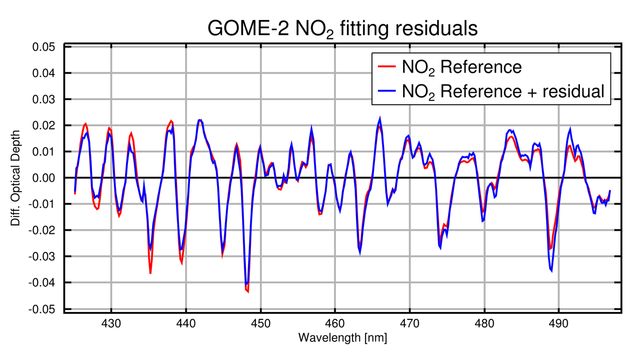

Figure 2: Example of a GOME-2 NO_2 fit result over China for a very large NO_2 slant column. The mismatch in the wavelength dependence of the NO_2 differential absorption amplitude resulting from the change in AMF over the fitting window is evident

- for an optically thin atmosphere, the air mass factor does not depend on the column amount of the absorber of interest
- in addition, the air mass factor does only smoothly vary with wavelength (wavelength dependence of scattering and surface reflectance)
- in the presence of large amounts of NO_2, the AMF decreases with increasing NO_2 column which will result in wrong vertical columns if not accounted for
- in addition, spectral structures of NO_2 appear in the AMF, further interfering with the NO_2 retrieval
- this needs to be corrected in the AMF application (not further discussed here)

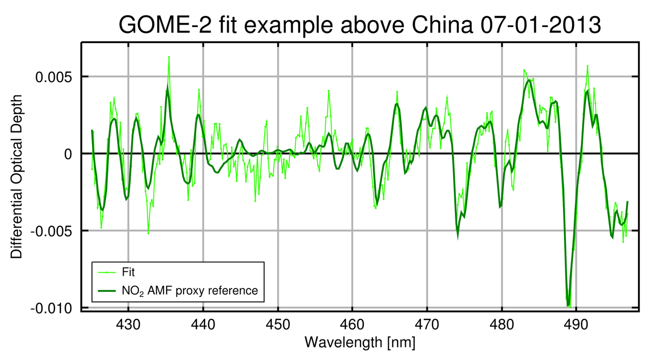

Figure 3: Example of a GOME-2 fit result for the AMF proxy created by linearly scaling the NO_2 cross-section and then orthogonalising it to the original cross-section . The same ground pixel as shown in Fig. 2 is used.

- at strong NO_2 absorption, the wavelength dependence of the AMF (which is always present) will lead to poor fits (see Fig. 2)
- the effect can be compensated by using an additional NO_2 cross-section, scaled linearly in wavelength and orthogonalised to the original NO_2 cross-section
- this AMF proxy can be retrieved from GOME-2 data over polluted regions (see Fig. 3)

Acknowledgements

- Funding by the University of Bremen and DLR (project 50 EE 1247) is gratefully acknowledged
- GOME-2 lv1 data were provided by EUMETSAT

Temperature dependent cross-section

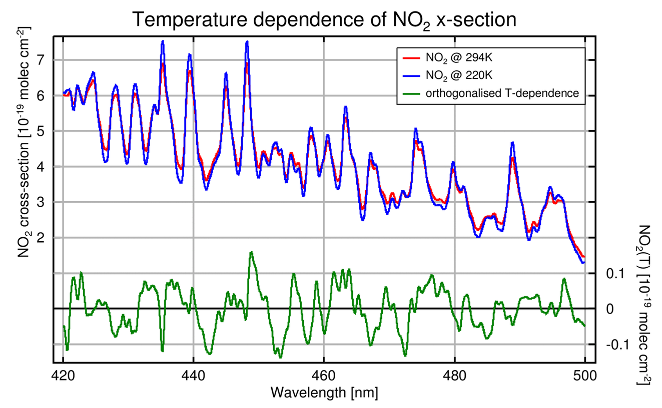

Figure 4: Temperature dependence of the NO_2 cross-section at spectral resolution of GOME-2. The green curve is the orthogonalised differential temperature dependence which can be included in the fit as additional absorber.

- NO_2 absorption cross-section depends on temperature
- effect is relatively large (up to 30%) but mainly a linear scaling
- current retrievals use a low temperature cross-section and correct for the temperature effect a posteriori in the AMF application
- at very large NO_2 columns, the difference in cross-sections can lead to poorer fits
- at least in principle, it can provide information for the separation of BL and stratospheric NO_2

I_0 correction

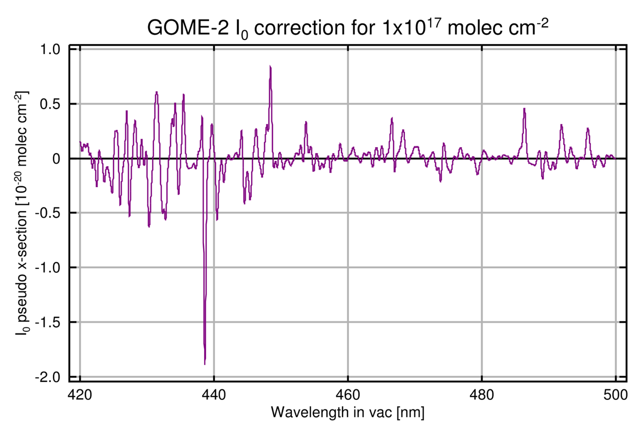

Figure 5: I_0 correction for NO_2 at a slant column of $1x10^{17}$ molec cm^{-2} and for GOME-2 spectral resolution. The correction has been calculated by simulating the effect of exchanging convolution and absorption

- in the DOAS method, measurements are usually performed at intermediate spectral resolution (0.1 - 1 nm) which do not fully resolve the structures of the solar spectrum
- absorption in the atmosphere is approximated by using convolved cross-sections and the measured (convolved) intensities instead of treating absorption at high spectral resolution and convolving the results
- for strong and structured absorptions, this can lead to systematic residuals (I_0) effect

Application to GOME-2 data

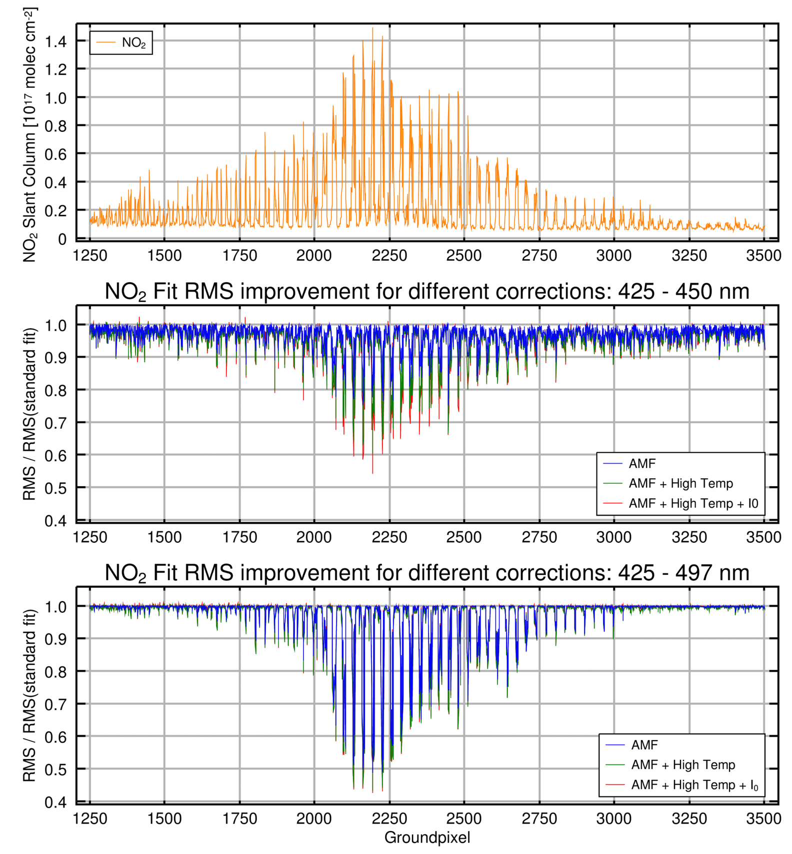

Figure 6: Small section of one GOME-2A orbit over China on January 7, 2013. **Top**: NO_2 slant columns, **Middle:** relative change in fit residual when successively applying correction for wavelength dependence of AMF, temperature and I_0 effect in the 425 - 450 nm window. **Bottom:** As middle but for 425 - 497 nm

- NO_2 slant columns over China can become as large as $1x10^{17}$ molec cm^{-2}
- three corrections have been tested on GOME-2 data
  - an NO_2 AMF proxy
  - an NO_2 temperature correction
  - an I_0 correction assuming an SC of $1x10^{17}$ molec cm^{-2}

425 - 450 nm window:
- clear improvement of fitting RMS when including corrections
- AMF and T-effects of similar size, I_0 less important

425 - 497 nm window:
- even larger improvement
- AMF effect dominates
- I0 effect not important (less NO_2 structures and smaller absorption)

NO_2 layer height and AMF proxy

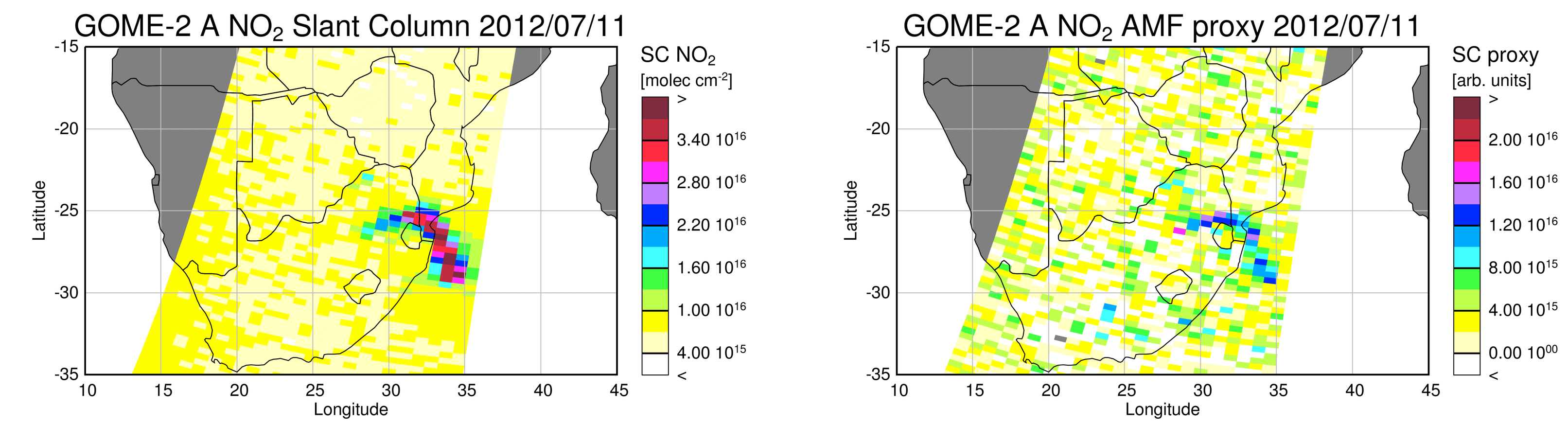

Fig. 8: NO_2 slant columns (left) and AMF proxy fitting coefficient (right) for a large NO_2 plume

Application of the AMF proxy to GOME-2 data shows
- clear signatures of the AMF proxy over all major pollution hot-spots (China, Europe, US, large cities) in monthly averages
- in daily values, the scatter is large outside of very polluted scenes
- for cloudy scenes, the AMF proxy is not found even if large NO_2 columns are present as expected from radiative transfer considerations
- there appears to be an interference over clear water bodies

A case study over South Africa (Fig. 8) shows that
- the AMF proxy tracks the NO_2 plume
- highest NO_2 SCs are found at the end of the plume (elevated NO_2)
- highest AMF proxy values are found close to emission point (NO_2 close to surface)

Conclusions

- in very polluted situations in China, satellite slant columns of NO_2 can get as large as $1x10^{17}$ molec cm^{-2}
- under these circumstances, the AMF is no longer independent of NO_2 column which has to be taken into account for the calculation of vertical columns
- because of the large (> 5%) NO_2 absorption, several effects can deteriorate the spectral fit:
  - the wavelength dependence of the AMF
  - the temperature dependence of the NO_2 cross-section
  - the I_0 effect
- All effects can be corrected, reducing NO_2 fitting RMS by up to a factor of 2
- the NO_2 AMF proxy has the potential to provide information on the vertical position of an NO_2 layer

Selected references

Hilboll, A., Richter, A., and Burrows, J. P.: Long-term changes of tropospheric NO2 over megacities derived from multiple satellite instruments, *Atmos. Chem. Phys.*, **13**, 4145-4169, doi:10.5194/acp-13-4145-2013, 2013

Richter, A., Begoin, M., Hilboll, A., and Burrows, J. P.: An improved NO2 retrieval for the GOME-2 satellite instrument, *Atmos. Meas. Tech.*, **4**, 1147-1159, doi:10.5194/amt-4-1147-2011, 2011

Schreier, S. F., Richter, A., Kaiser, J. W., and Burrows, J. P.: The empirical relationship between satellite-derived tropospheric NO2 and fire radiative power and possible implications for fire emission rates of NOx, *Atmos. Chem. Phys.*, **14**, 2447-2466, doi:10.5194/acp-14-2447-2014, 2014

Zien, A. W., Richter, A., Hilboll, A., Blechschmidt, A.-M., and Burrows, J. P.: Systematic analysis of tropospheric NO2 long-range transport events detected in GOME-2 satellite data, *Atmos. Chem. Phys. Discuss.*, **13**, 30945-31012, doi:10.5194/acpd-13-30945-2013, 2013

Universität Bremen

www.doas-bremen.de