A multi-wavelength retrieval of tropospheric NO_2 from GOME-2

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

Introduction

- Retrievals of tropospheric NO_2 from nadir satellite observations are based on application of the Differential Optical Absorption Spectroscopy method on UV/visible spectra
- The approach separates the spectral retrieval and radiative transfer calculations which are tabulated into air mass factors (AMF)
- The basic assumption is that the AMF does not depend significantly on wavelength and that a single AMF is thus appropriate for the conversion of the fitted slant columns (SC) to the final vertical columns (VC)
- As a result of strong Rayleigh scattering, this assumption is not really fulfilled for the retrieval of NO_2 in a layer close to the surface (see Fig. 1)
- The wavelength dependence of the AMF results in
  - poorer fits if not corrected
  - a possible source of information on the vertical NO_2 distribution

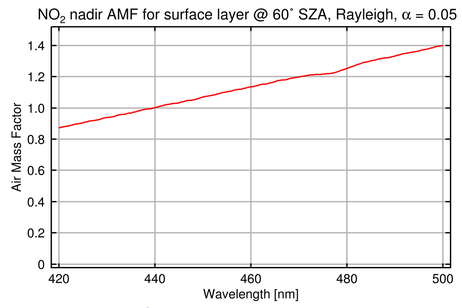

Fig. 1: Nadir ÂMF for a 1 km surface layer of NO_2 at 60° SZA and an albedo of 0.05

Problem and Method

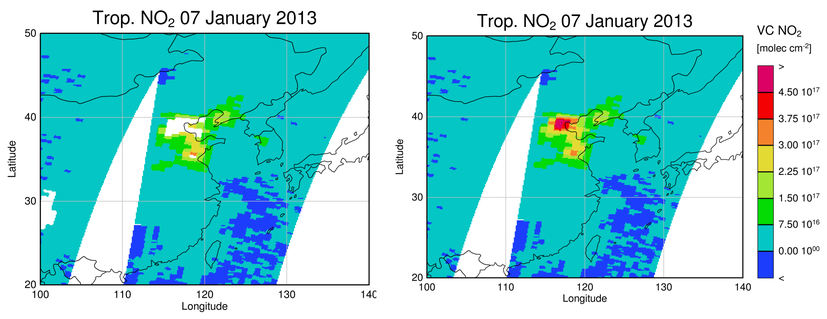

Fig. 2: Example of GOME-2 tropospheric NO_2 columns over China during the heavy pollution episode on January 7, 2013. The largest NO_2 values are removed by the fit quality criterion (left)in the standard retrieval. Right: all data is shown

- in regions of very large tropospheric NO_2, the fit quality is compromised
- this leads to a low bias in data applying fit quality criteria
- the residuals indicate that the problem is linked to the wavelength dependence of the AMF (Fig. 3)

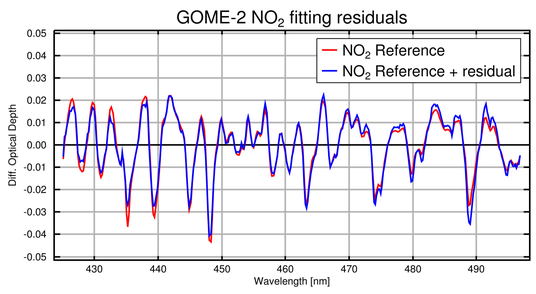

Fig. 3: Example of an NO_2 fit under very large pollution

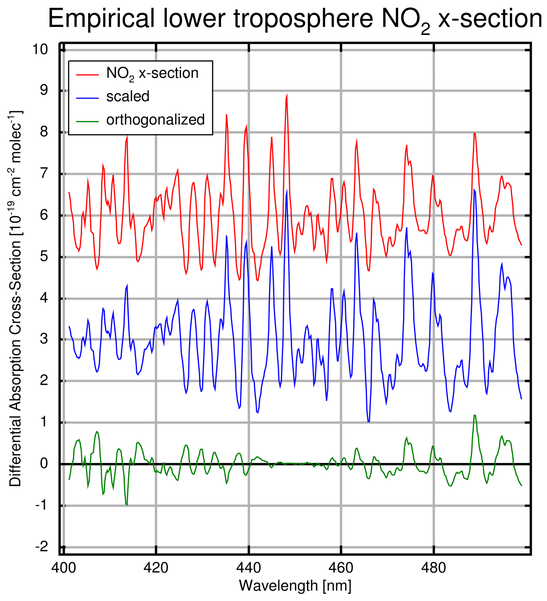

Fig. 4: illustration of the creation of the NO_2 AMF proxy by taking the NO_2 cross-section (red), scaling it with wavelength (blue) and orthogonalising it to the original (green)

Idea:

- approximate the wavelength dependence of the NO_2 AMF for BL pollution by linearly scaling the NO_2 cross-section
- orthogonalise the scaled cross-section to the original cross-section in order to not change the NO_2 columns retrieved (Fig. 4)
- include the NO_2 AMF proxy in the fit as additional cross-section

Results:

- for very polluted scenarios, the spectral signature of the AMF proxy is well retrieved (Fig. 5)
- the fitting residual in these pixels is reduced to the level of other fits
- the impact on computational time is small (just one more cross-section in the fit)

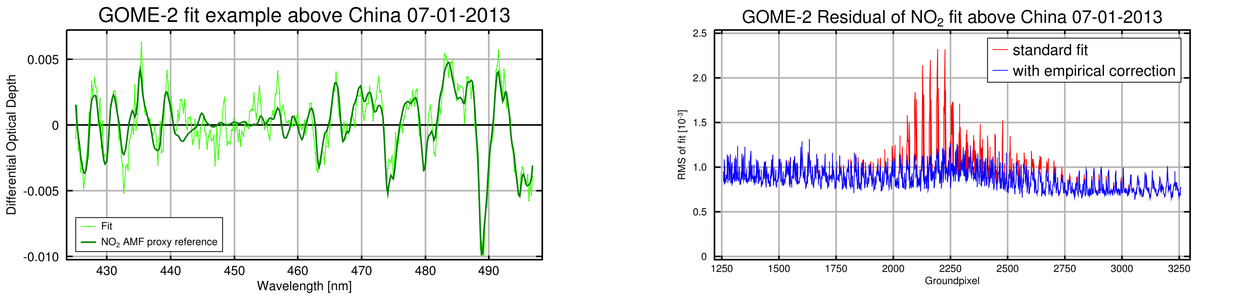

Fig. 5: Example of a spectral retrieval of the NO_2 AMF proxy (left) and demonstration of the improvement in the chisquare of the retrieval over China when including the additional cross-section (right)

Sensitivity Study

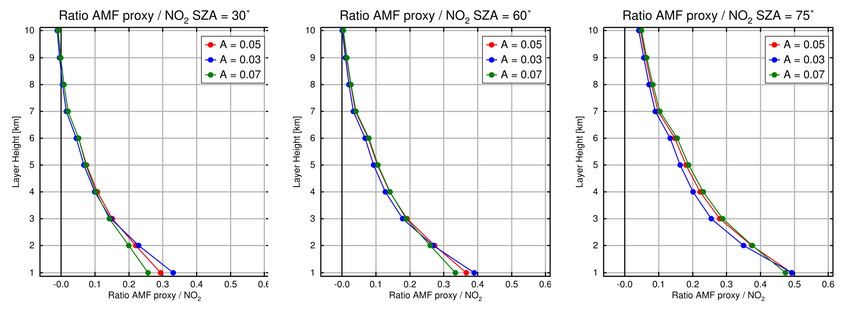

Fig. 6: Altitude dependence of (AMF proxy) / NO_2 ratio in retrievals on synthetic spectra for SZA = 30°, 60°, and 75° and three typical surface albedos of 3%, 5%, and 7%.

Synthetic spectra were created for
- Rayleigh atmosphere, no Raman scattering
- albedo constant with wavelength
- no noise
- NO_2 confined to 1 km layer at different altitudes
- DOAS retrieval for NO_2 and NO_2 AMF proxy

The (AMF proxy) / NO_2 ratios show
- high values close to surface, low values at higher altitudes
- little variation for albedos between 3% and 7%
- systematic dependence on SZA

At large surface albedo, the fitting coefficient for the AMF proxy decreases and even gets negative (Fig. 7). This is a result of multiple scattering over bright surfaces which leads to an decrease of AMF with wavelength, inverting the effect.

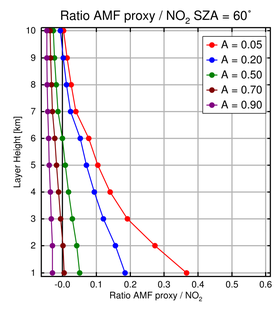

Fig. 7: Albedo dependence of the (AMF proxy) / NO_2 ratio at 60° SZA

Application to GOME-2 Data

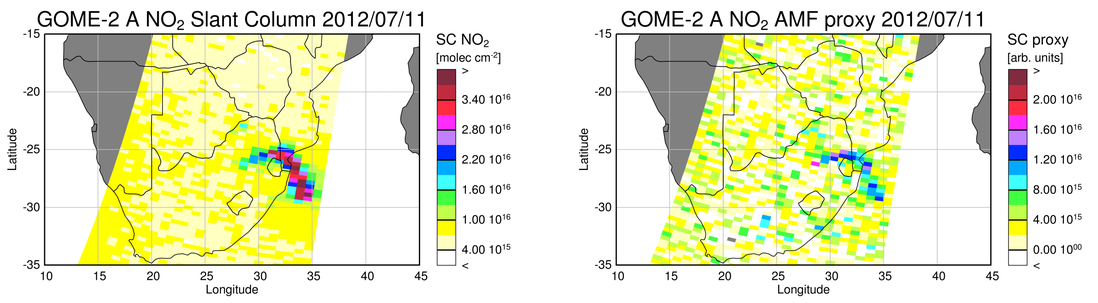

Fig. 8: NO_2 slant columns (left) and AMF proxy fitting coefficient (right) for a large NO_2 plume

Application 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
- 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

- for satellite nadir retrievals of tropospheric NO_2, the AMF is varying in a nearly linear fashion over the spectral range used for fitting
- at very large tropospheric NO_2 columns, this can deteriorate fitting residuals if not taken into account
- a simple AMF proxy is proposed for inclusion in the retrieval
- with this AMF proxy included, the fitting quality is good also at very large pollution
- a sensitivity study on synthetic data indicates the potential to use the ratio of the fitting coefficients of the AMF proxy and the NO_2 column to identify situations where the NO_2 is located mainly in the boundary layer
- the dependence on surface albedo is small for typical values making this retrieval relatively insensitive to a priori assumptions
- a first application on GOME-2 data shows some interesting potential

Acknowledgements

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