How large is the influence of tropospheric signals on SCIAMACHY limb measurements?

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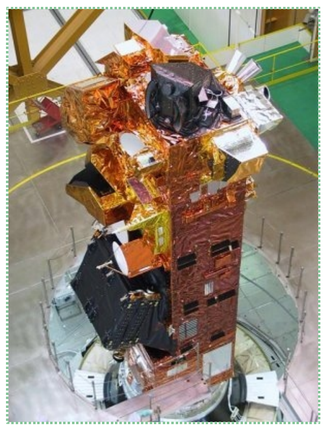
Introduction

NO_2 is a key trace gas in the atmosphere. In the stratosphere, it is involved in catalytic ozone destruction, both directly in the NO_x cycle and indirectly by forming reservoir species with the halogen oxides. In the troposphere, NO_2 together with VOCs leads to the formation of ozone and, if present in large concentration, photochemical smog. It also contributes to acidification and aerosol formation.

For a better understanding of the role of NO_2 in the atmosphere, vertically resolved measurements are needed. SCIAMACHY on ENVISAT can provide such measurements from the limb observation mode that enables retrieval of NO_2 profiles in the stratosphere. Tropospheric NO_2 columns can also be determined, e.g., by combining nadir and limb measurements of the instrument.

Here, we investigate how large the impact of tropospheric NO_2 is on the limb measurements. This is relevant for a number of issues including the accuracy of limb profiles in the lower stratosphere, the potential to use limb measurements in the upper troposphere to study the emissions of lighting and aircraft and the accuracy of tropospheric NO_2 from limb nadir matching.

SCIAMACHY Instrument

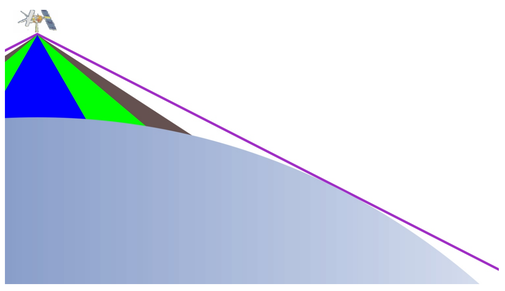


The SCIAMACHY instrument is a 8 channel grating spectrometer measuring in nadir, limb, and occultation (both solar and lunar) geometries. SCIAMACHY covers the spectral region from 220 to 2400 nm with a spectral resolution of 0.25 nm in the UV, 0.4 nm in the visible and less in the NIR. The size of the nadir ground-pixels depends on wavelength range and solar elevation and can be as small as 30 x 30 km^2. The instrument was launched on ENVISAT in a sun-synchronuous orbit on March 1st, 2002 and is in nominal operation since August 2002.

Using the *Differential Optical Absorption Spectroscopy* (DOAS) technique, a number of atmospheric trace gases can be retrieved from the spectra, including O_3, NO_2, BrO, OClO, SO_2, HCHO, and H_2O. In the absence of clouds, a large part of the photons observed by SCIAMACHY in the nadir have penetrated down to the troposphere, and global maps of tropospheric concentration fields can be derived from the measurements.

Compared to GOME, the SCIAMACHY instrument has improved spatial resolution and the ability to measure stratospheric profiles. At the same time, nadir coverage is reduced by a factor of two as result of the time sharing between nadir and profile measurements.

Observation Geometry



SCIAMACHY swath (30°)
GOME-2 swath (50°)
OMI swath (57°)
lowest limb direction (63°)

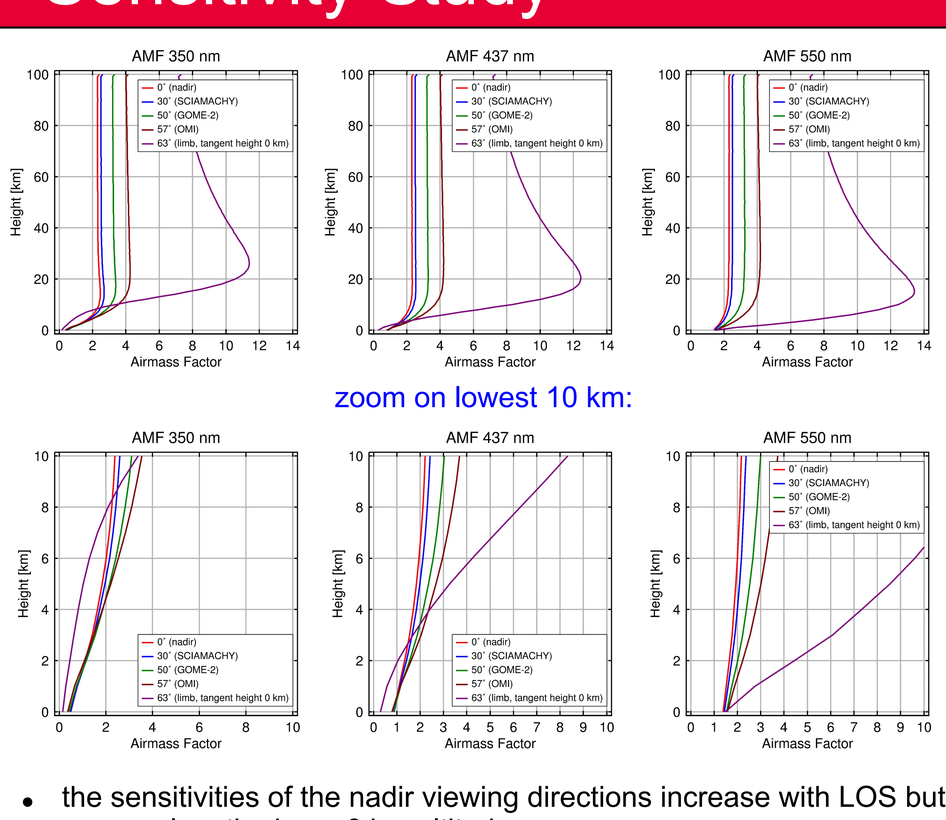
Geometry:

- larger swath improves coverage
- larger viewing angle increases geometrical light path in the stratosphere
- lowest limb viewing direction reaches surface
- higher limb directions also contain some signal from the surface through reflected and multiple scattered light

Wavelength dependence:

- the vertical sensitivity depends on wavelength for two reasons: changes in surface albedo (not treated here) and increasing Rayleigh scattering in the UV.
- more scattering reduces the penetration depth and therefore the sensitivity to the surface

Sensitivity Study



Settings:

- SCIATRAN 2.0
- full multiple scattering
- full sphericity
- no aerosols
- surface albedo 5%
- 40° SZA
- 780 km satellite altitude
- wavelength see figure title

- The angles selected are indicative of the maximum scan angle used with the respective instruments
- The limb direction shown is just touching the surface at the tangent point.

- the sensitivities of the nadir viewing directions increase with LOS but depend only slightly on wavelength above 6 km altitude
- the limb direction has much higher stratospheric sensitivity
- below 6 km, the LOS dependence decreases, in particular in the UV
- below 6 km, the sensitivity decreases systematically to the UV for the nadir directions
- this effect is even more pronounced for the limb direction
- only at 550 nm, the limb direction should be sensitive to pollution NO_2 in the boundary layer

SCIAMACHY Measurement Results

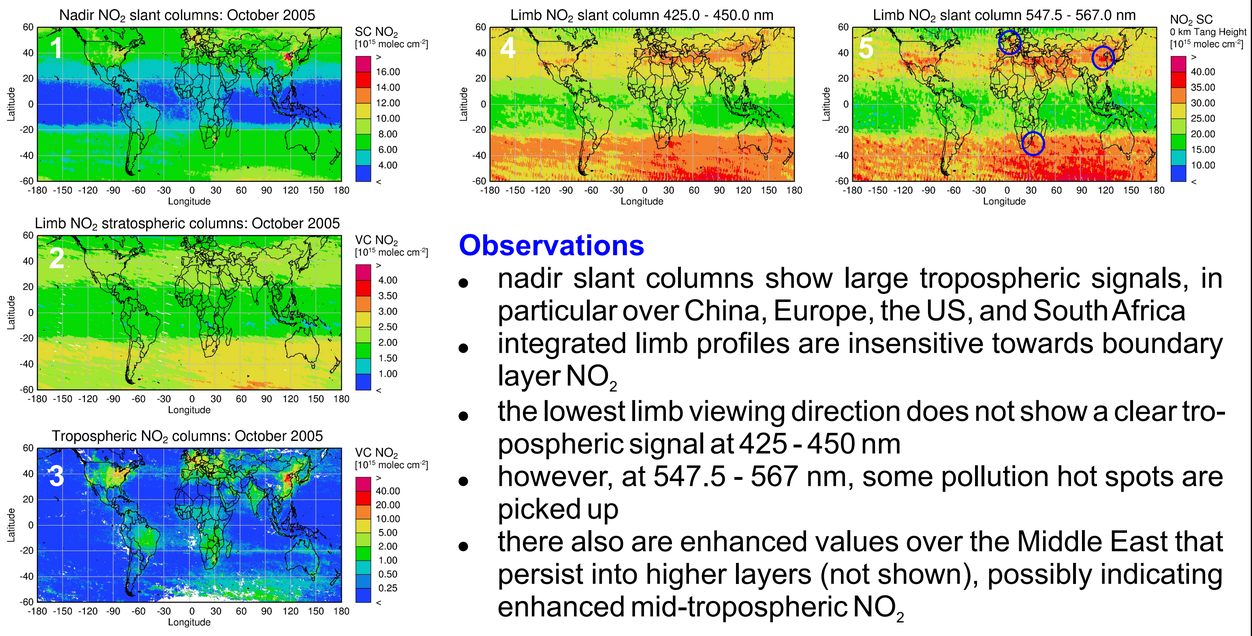


Figure: Different NO_2 columns for SCIAMACHY measurements from October 2005. 1) nadir slant columns, 2) integrated limb stratospheric profiles, 3) vertical tropospheric columns (with cloud screening), 4) slant column for surface viewing limb measurement at 425 - 450 nm, 5) slant column for surface viewing at 547.5 - 567 nm. pollution hot spots are marked with circles

Observations

- nadir slant columns show large tropospheric signals, in particular over China, Europe, the US, and South Africa
- integrated limb profiles are insensitive towards boundary layer NO_2
- the lowest limb viewing direction does not show a clear tropospheric signal at 425 - 450 nm
- however, at 547.5 - 567 nm, some pollution hot spots are picked up
- there also are enhanced values over the Middle East that persist into higher layers (not shown), possibly indicating enhanced mid-tropospheric NO_2

Analysis

- the results are in agreement with SCIATRAN model calculations (see box to the left)
- some sensitivity to boundary layer NO_2 could be demonstrated in the visible fit
- the results depend critically on clouds (not shown)

Conclusions

- the sensitivity of nadir measurements to boundary layer NO_2 depends systematically on wavelength with higher sensitivity at longer wavelengths
- below 6 km, the dependence on viewing angle is small, in particular in the UV
- even the lowest limb viewing direction (the tangent point just touching the surface) has much lower sensitivity to the boundary layer than to the stratosphere
- this is particularly true at UV wavelengths
- at 560 nm, the sensitivity to the boundary layer is comparable to that of nadir measurements, albeit on a large stratospheric background
- this could be confirmed in SCIAMACHY measurements

- the impact of boundary layer NO_2 on the standard limb retrieval can be neglected
- using retrievals at longer wavelengths, the sensitivity to tropospheric NO_2 can be much improved, making it a better choice for upper tropospheric retrievals
- detection of upper tropospheric NO_2 might then however be affected by some influence from the polluted boundary layer

- the effect of aerosols and clouds has been neglected here but can be substantial

Acknowledgements

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see also: www.iup.physik.uni-bremen.de/doas