Tropospheric trace gas amounts from combined limb/nadir analysis of SCIAMACHY data

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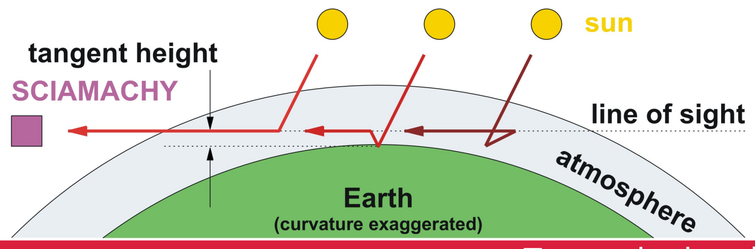
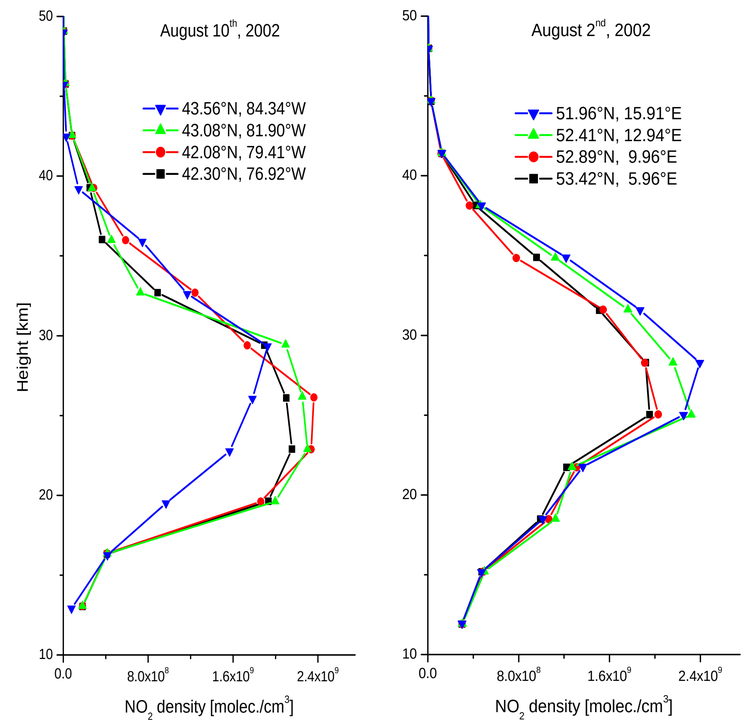
Introduction

The Scanning Imaging Absorption Spectrometer for Atmospheric Chartography (SCIAMACHY) is one of the remote sensing instruments aboard ESA's new Environmental Satellite (ENVISAT). The grating spectrometer measures radiance spectra of backscattered solar radiation, from which concentrations of various trace gases can be retrieved. It covers the spectral region from 220 to 2400 nm with a resolution of 0.25 nm in the UV, 0.4 nm in the visible and less in the NIR. A unique feature of SCIAMACHY is the capability of sensing the atmosphere in different observation geometries. In nadir measurement mode total column amounts of trace gases are derived with high spatial resolution. The size of the nadir ground-pixels depends on wavelength range and solar elevation and can be as small as 60 x 30 km^2. Nadir observation states are continuously alternated with the limb viewing mode, which enables the retrieval of vertical profiles of trace gas concentrations in the stratosphere. The combined analysis of spectra acquired in limb and nadir measurement mode allows the separation of tropospheric and stratospheric absorption components, offering the possibility to determine global distributions of tropospheric trace gases such as O_3 and NO_2. Such data sets are highly valuable for large scale pollution studies (e.g. on ozone smog). We present case studies demonstrating the capability of tropospheric column retrieval from SCIAMACHY data and pointing to future developments of optimized algorithms.

Profile retrieval in limb mode

The viewing geometry in limb measurement mode is depicted in the sketch below. SCIAMACHY measures radiance spectra of sunlight that is scattered into the line of sight (LOS) across the atmosphere. During a limb scan the atmosphere is probed vertically by changing the tangent height in discrete steps from 100 km to 0 km. The trace gas concentration is inferred from the measured spectra by fitting forward modelled radiances to the observations using an iterative optimal estimation (OE) technique. The theoretical radiances are computed by the radiative transfer model SCIATRAN [1], which involves all relevant physical processes including multiple scattering. A simultaneous scan in azimuth direction allows the retrieval of up to four vertical trace gas profiles for each limb scan. The plots on the right hand side show retrieved vertical NO_2 profiles observed over the Great Lakes region, North America on August 10th, 2002, and central Europe on August 2nd. The geolocations of the profiles, which are used to separate the tropospheric component of NO_2 in the subsequent Figures, are indicated in the plots.



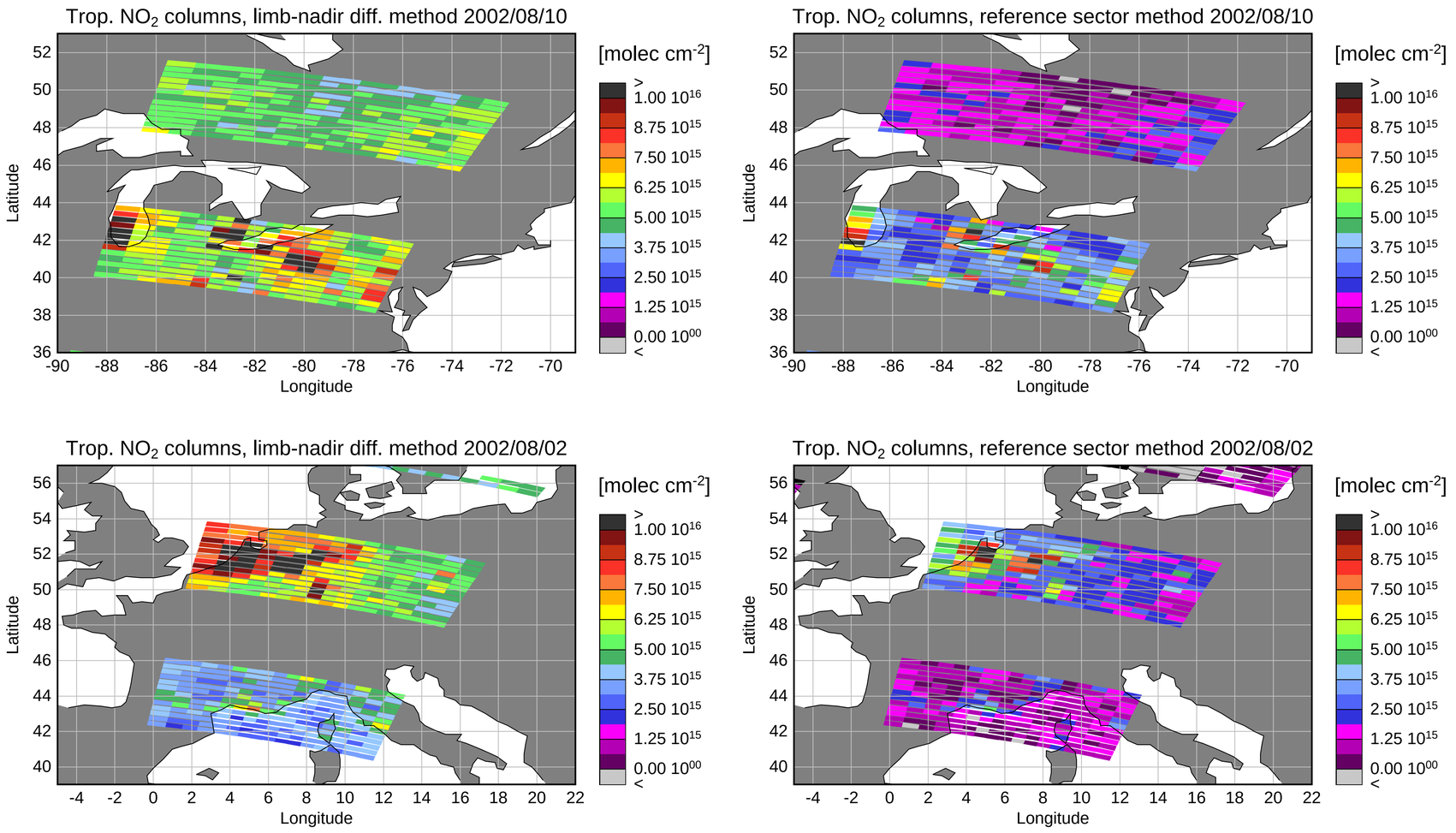


DOAS retrieval and difference method

In nadir measurement mode, SCIAMACHY detects upwelling solar radiation reflected from the Earth's surface. Using the Differential Optical Absorption Spectroscopy (DOAS) technique, column amounts of a various 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 nadir have penetrated down to the troposphere. The DOAS analysis thus yields total slant columns of the retrieved molecular species. We tested a first approach to tropospheric column retrieval by calculating slant stratospheric columns from limb profiles using air-mass factors computed by the SCIATRAN model. The results are subtracted from the total nadir column obtained in the DOAS analysis. The difference is interpreted as the tropospheric contribution which is mapped into vertical column applying simple assumptions on the absorber profile in the troposphere.

Two examples for limb-nadir combined NO_2 retrieval are shown in the Figures on the right hand side. The two upper plots show tropospheric columns detected on August 10th, 2002 over the Great Lakes in North America, the two lower above central Europe on August 2nd. The plots in the left column represent the results obtained from the limb-nadir difference method. Those in the right column show the NO_2 amounts estimated using the so-called reference sector method [2]. This technique approximates the tropospheric contribution by forming the difference of the total columns of a polluted region with respect to a reference sector at equal latitude which is assumed to contain low amounts of NO_2. Differencing ground pixels of corresponding latitudes assures the equality of the stratospheric column, since the conditions of NO_2 photolysis are largely identical during satellite overpass. The sources of industrial pollution are visible in all four plots. However, the reference sector method yields significantly lower NO_2 columns than the limb-nadir combination. On the basis of our preliminary results we determined a consistent offset of approx. 3E15 molec/cm^2 between the two techniques. Although this difference can partly be associated to the contribution of the tropospheric background in the reference sector, the large offset suggests that the stratospheric columns obtained from the limb retrievals might be underestimated. It should be noted that due to unresolved calibration issues, both the nadir and limb retrievals from SCIAMACHY data are still preliminary.

Tropospheric columns of NO_2



Conclusions and Outlook

We tested a first approach to combining SCIAMACHY limb and nadir measurements for retrieving tropospheric NO_2. Differences of nadir total and limb stratospheric columns from preliminary retrievals yield plausible results, but seem to overestimate tropospheric concentrations. Comparisons with independent measurements of NO_2 and O_3 will be carried out to identify error sources and determine the potential accuracy of tropospheric trace gas retrieval from SCIAMACHY data. Also, alternative strategies for optimized limb-nadir combination will be investigated, including a tomographic approach utilizing a simultaneous retrieval of tropospheric and stratospheric trace gas concentrations. The combination of limb and nadir measurements offers a number of advantages over the reference sector method. Besides the independence from an unknown tropospheric background, it does not rely on the assumption of identical stratospheric profiles at equal latitudes. In particular, it should therefore be applicable for retrievals of tropospheric ozone at higher latitudes.

Acknowledgements

SCIAMACHY raw radiances and irradiances have been provided by ESA/ESRIN. Parts of this project have been funded by the University of Bremen, the BMBF/DLR through projects 50EE0023 and 50EE005 and the European Community under contracts EVK2-2001-00104 and EVk2-2001-00370. We would like to thank the Bremen SCIAMACHY team, in particular J. Skupin and K.-U. Eichmann for valuable support with software and explanations.

References

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[2] Richter, A. and J. P. Burrows, Retrieval of tropospheric NO_2 from GOME measurements, *Adv. Space Res.* 29 (11), 1673-1683, 2002

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