Retrieval of stratospheric and tropospheric ozone from SCIAMACHY limb and nadir observations

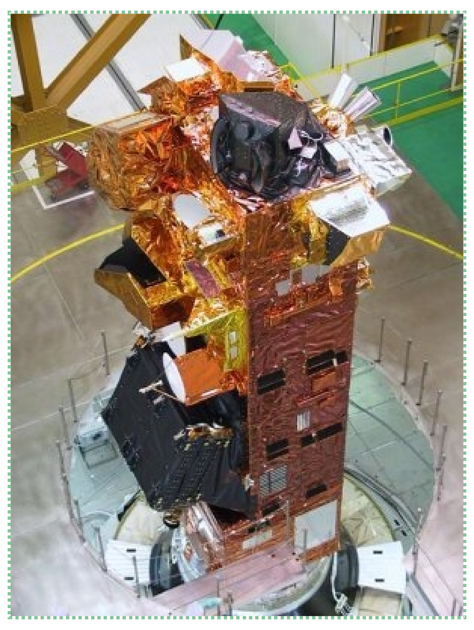
A. M. Schmoltner (1,2), B. Sierk (2), A. Ladstätter-Weißenmayer (2), C. von Savigny (2), A. Richter (2), A. Rozanov (2), V. Rozanov (2), J. W. Kaiser (3), and J. P. Burrows (2)

(1) Division of Atmospheric Sciences, National Science Foundation, 4201 Wilson Blvd. Ste. 775, Arlington, VA 22230, USA, (2) Institute of Environmental Physics, University of Bremen, P.O. Box 330440, D-28334, Bremen, Germany, (E-mail: aschmolt@iup.physik.uni-bremen.de), (3) Remote Sensing Laboratories, University of Zurich, Winterthurerstrasse 190, 8057 Zurich, Switzerland

Introduction

Tropospheric ozone is of great importance to society due to its potential hazards to human health, agriculture, and as a greenhouse gas. The ability to determine tropospheric ozone globally and continuously from space is therefore of major interest. Fishman [Fishman and Larsen, 1987] pioneered the concept of determining tropospheric ozone from the difference between total and stratospheric ozone, using TOMS (Total Ozone Mapping Spectrometer) total ozone and SAGE (Stratospheric Aerosol and Gas Experiment) stratospheric profile measurements. The main challenge of this approach is the fact that most of the atmospheric ozone is located in the stratosphere. In this poster, we present the application of limb- nadir matching to SCIAMACHY data.

SCIAMACHY Instrument



The SCIAMACHY instrument [Bovensmann et al., 1999] is a spectrometer designed to measure sunlight, transmitted, reflected and scattered by the earth atmosphere or surface in the ultraviolet, visible and near infrared wavelength region at moderate spectral resolution. In nadir mode, the atmospheric volume directly under the instrument is observed. Each scan covers an area on the ground of up to 960 km across track with a maximum resolution of 26 km x 15 km. In limb mode, the instrument looks at the edge of the atmosphere. Scans at different tangent altitudes over a range of up to 960 km in horizontal direction are performed with a geometrical vertical resolution of approximately 2.6 km. One of the most important features of SCIAMACHY is the possibility to observe the same atmospheric volume first in limb and then after about seven minutes in nadir geometry. Global coverage at the equator is achieved within six days.

Data Analysis

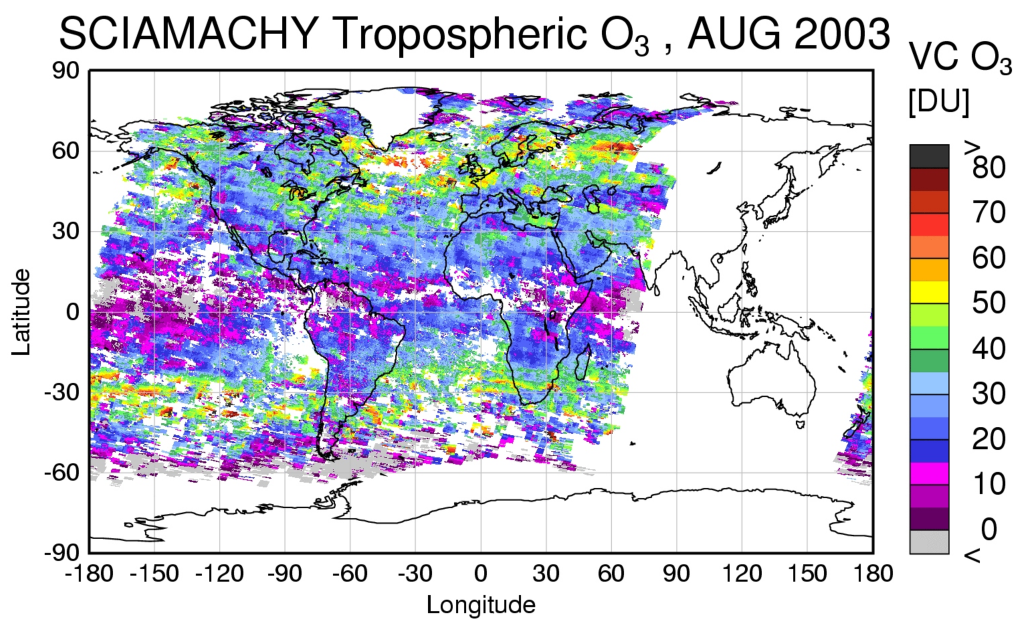
The limb retrieval method for ozone profiles was described by von Savigny et al. [2003]. Profiles are obtained by iterative optimal estimation driving a spherical radiative transfer model. Integrating the concentration profiles from the tropopause upwards yields stratospheric vertical column densities. The tropopause height is calculated from ECMWF (European Centre for Medium Range Weather Forecast) data.

Stratospheric slant column densities (SCD) are derived from the vertical column densities (VCD) by applying appropriate air mass factors (AMFs) according to SCD = VCD x AMF. These AMFs are calculated using a radiative transfer model, taking into account the actual stratospheric ozone profiles as determined by the SCIAMACHY limb measurements.

Total ozone slant column densities are retrieved in the UV region (325.5-335.5 nm) using the Differential Optical Absorption (DOAS) method [Platt und Perner, 1983]. From the difference between the total and the stratospheric slant columns, tropospheric slant columns are obtained. The conversion to tropospheric vertical columns, the desired result of this analysis, requires the determination of tropospheric AMFs. These are dependent on a variety of factors, especially the vertical distribution of ozone in the troposphere, the surface albedo, and the nature and vertical distribution of tropospheric aerosols. So far, full consideration of all these factors and the calculation of AMFs for each ground pixel has not been feasible except for special cases.

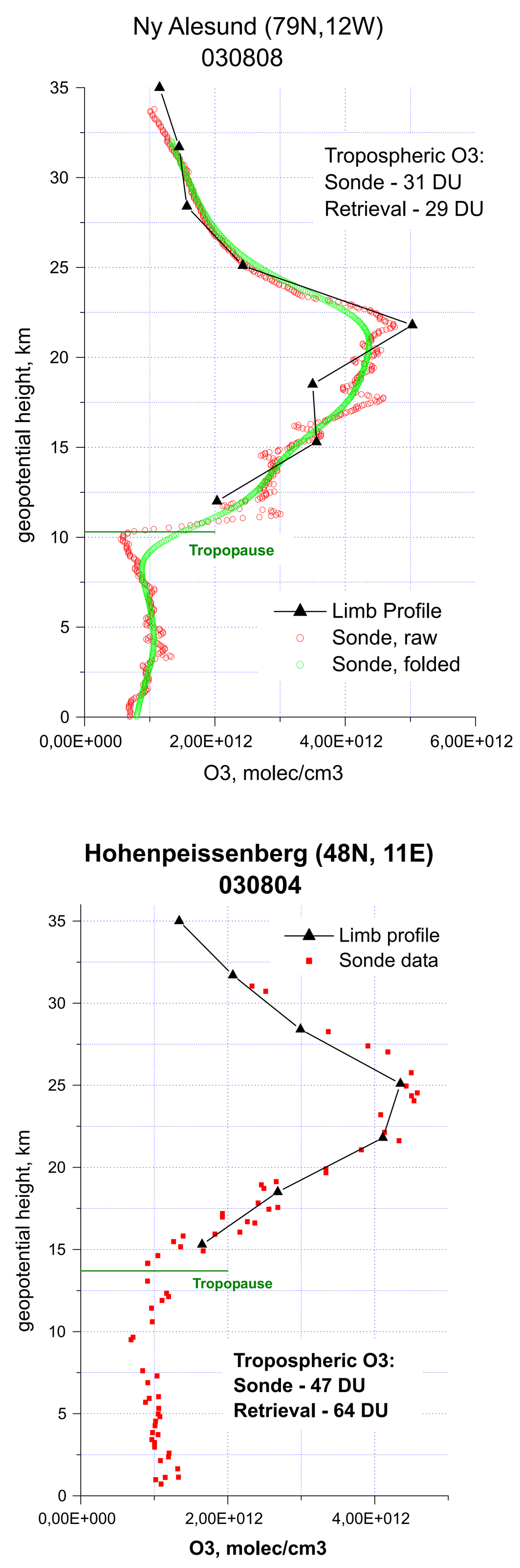
Global Trop. O_3 - Preliminary Results

This figure shows preliminary results for tropospheric ozone (in Dobson Units, DU) averaged over the period August 1-25, 2003, based on a purely geometrical AMF (1 + sec (SZA), SZA being the solar zenith angle) for the troposphere. This most likely leads to an underestimation of tropospheric ozone values especially for mid- and high latitudes. Data for cloudy ground pixels were filtered out.



The main sources of error in the DOAS slant column determination are uncertainties in the ozone differential absorption cross sections, estimated to be on the order of 2-3% or 5-10 DU. The errors in the stratospheric profile retrieval are estimated to be about +/- 5% under optimum conditions [von Savigny et al., 2003], or 10-16 DU. Errors in the calculation of tropospheric AMFs could be as high as 50%. Other error sources include uncertainties in the determination of the stratospheric AMFs, uncertainties in the tropopause height determination, and stratospheric variability within a limb state. Future attempts to improve the retrievals will address all these factors.

Comparison With Ozone Sondes



This figure shows two examples of comparisons of an ozone profile derived from SCIAMACHY limb measurements with ozone sonde data. The upper panel shows an overflight of Ny Ålesund (78.93°N, 11.88°W) on August 8, 2003 [König-Langlo, pers. Comm.], the lower panel an overflight of Hohenpeissenberg (47.80°N, 11.02°W). As can be seen, in both cases there is excellent agreement between the satellite and the sonde-derived profiles in their region of overlap, considering the very different vertical resolution of the two measurements. This good agreement between the SCIAMACHY limb retrievals and sonde profiles in the stratosphere was also found for ozone sondes from a variety of other locations.

The tropospheric ozone column was calculated from the satellite retrieval using AMFs that incorporated the exact satellite viewing geometry as well as the shape of the tropospheric vertical distribution of ozone obtained from the respective coincident ozone sonde. The aerosol loading was assumed to be determined by background conditions. Close agreement was obtained between the two methods of determining tropospheric ozone for Ny Ålesund: integration of the sonde profile through the troposphere yields a value of 31 DU, whereas the limb-nadir matching retrieval yields 29 DU. On the other hand, there is a larger difference between the two values for Hohenpeissenberg, where the sonde value is 47 DU, but the retrieval yields 64 DU.

Conclusions

- The retrieval of tropospheric ozone from SCIAMACHY limb and nadir measurements yields generally reasonable results, given estimated errors of the procedure.
- The comparison with ozone sondes shows that with full consideration of viewing geometry and ozone profiles shapes, good agreement can be achieved.

Acknowledgements

- SCIAMACHY raw radiances and irradiances have been provided by ESA/ ESRIN
- Parts of this project were funded by the University of Bremen
- We thank ECMWF for providing meteorological data
- We thank Dr. G. König-Langlo, Alfred Wegener Institute for Polar and Marine Research, Bremerhaven, and the Meteorological Observatory Hohenpeissenberg for sharing unpublished ozone sonde data for this work. Hohenpeissenberg data were provided through the NILU database for Envisat Validation.
- A. Schmoltner thanks the National Science Foundation, USA, for the support of her work

Selected References

H. Bovensmann, J. P. Burrows, M. Buchwitz, J. Frerick, S. Noël, V. V. Rozanov, K. V. Chance, and A. H. P. Goede, SCIAMACHY - Mission objectives and measurement modes, *J. Atmos. Sci.*, 56, (2), 127-150, 1999

Fishman, J., and J.C. Larsen, Distribution of total ozone and stratospheric ozone in the tropics: Implications for the distribution of tropospheric ozone, *J. Geophys. Res., 92*,6672-6634, 1987

König-Langlo, G., personal communication

Platt, U., and D. Perner, *Measurements of atmospheric trace gases by long path differential UV/visible absorption spectroscopy*, Optical and Laser Remote Sensing, edited by D.A. Killinger, and A. Mooradien, pp. 95-105, Springer Verlag, New York, 1983

von Savigny, C.., et al., Stratospheric ozone profiles retreived from limb scattered sunlight radiance spectra measured by the OSIRIS instrument on the Odin satellite, *Geophys. Res. Lett., 30,* 1755, doi:10.1029/2002GL016401, 2003

Universität Bremen

www.iup.physik.uni-bremen.de