Investigation of the spatial and temporal variation of tropospheric ozone using SCIAMACHY limb-nadir matching observations

EGU 2011
AS 3.14
XY150

Ebojie Felix, Christian von Savigny, Annette Ladstätter-Weißenmayer, Stefan Bötel, Heinrich Bovensmann, John P. Burrows
Institute of Environmental Physics(IUP), University of Bremen, Germany
Contact :felix@iup.physik.uni-bremen.de

Universität Bremen

SCIAMACHY

1) Introduction

Tropospheric ozone concentration varies both spatially and temporarily. It varies from non-detectable near the sources of production to several hundreds parts per billion (ppb) of air in areas downwind of the source of production. It also varies temporally in phase with human activity patterns, increasing during the day when formation rates exceed destruction rates, and decreases at night when formation processes are inactive. This diurnal variation in ozone depends on location, with the peaks being very high for relatively brief periods of time in urban areas, and being low with relatively little diurnal variation in remote regions. It also varies seasonally, being highest during summer and early spring months and lower during winter months. Tropospheric ozone concentration also varies annually due to some meteorological conditions such as El Niño, La Niña and other variations in global pressure systems that promote more or less dispersion of emission than normal. In this presentation, we investigate the spatial and temporal variation of tropospheric ozone using the SCanning Imaging Absorption spectroMeter for Atmospheric CartograpHY (SCIAMACHY) limb-nadir matching observation techniques. This technique involves the retrieval of stratospheric ozone column from the UV-B spectral range of the limb scattering measurements of SCIAMACHY, and the total ozone column also from the same instrument in the nadir viewing geometry. The stratospheric column was derived by integrating the stratospheric ozone concentration upward from the tropopause height. The tropopause height was determined using the daily temperatures of standard analyses from the European Centre for Medium-Range Weather Forecasts (ECMWF) in 1.5º x 1.5º x 91 levels, by an algorithm which was based on both the thermal definition of tropopause using the WMO lapse-rate criterion as well as the potential vorticity definitions of the tropopause. The total column was retrieved using the Weighting Function DOAS algorithm (WFDOAS) at the spectral window of 325 – 335.6 nm. The tropospheric ozone column was then derived by subtracting the stratospheric ozone column from the total ozone column.

2) SCIAMACHY limb-nadir matching observation

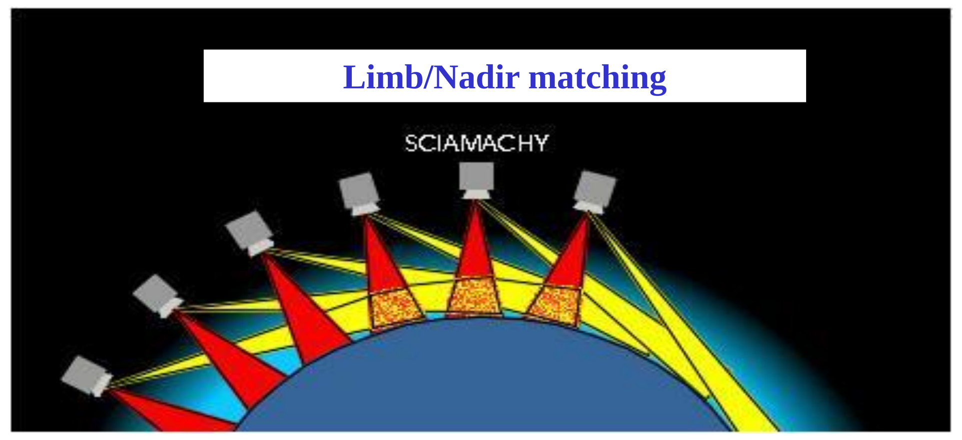


Figure 1: Illustration of the limb-nadir matching geometry

Features:

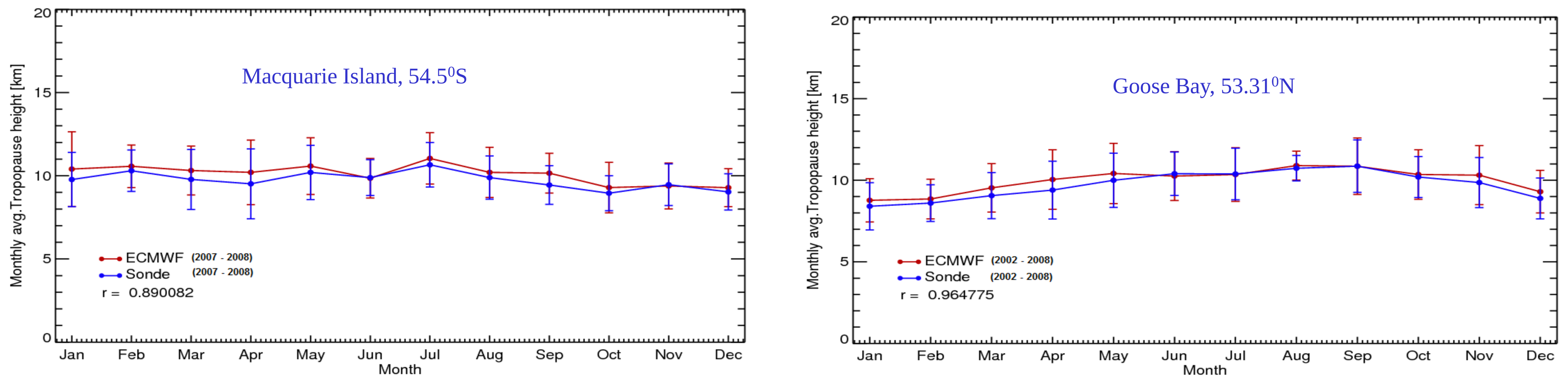
- Probe air masses first at limb geometry and 7 minutes later in nadir geometry
- Better spatial resolution (up to 30 x 30 km^2)
- Less spectral undersampling
- Reduced polarisation dependency
- Improved diffuser for solar irradiance measurements
- Coverage: 6 days at the equator

3) Methodology

- SCIAMACHY Level 0 and 1 limb scattering data were used to derive stratospheric O_3 density profiles (10 – 70 km) using wavelength triplet in Chappius-bands and Wavelet singlets in Hartley bands coupled to a radiative transfer model(SCIATRAN); accuracy 10-15% (Method same as in Savigny et al.,2003, Sonkaew et al., 2009)
- SCIAMACHY Level 1 version 6 nadir data were used to derive total column O_3 using Weighting function DOAS technique at a fitting window of 325 - 336.6, coupled to a radiative transfer model (SCIATRAN); (Method same as in Coldewey-Egbers et al., 2005, Weber et al., 2005)
- ECMWF Reanalysis (ERA) data were used to derive the tropopause height using both thermal and dynamical criteria. This was validated with the tropopause height derived from radiosonde (Method same as in Hoinka K. P., 1998)
- The stratospheric column was derived by integrating the stratospheric O_3 density profiles from the height of the tropopause to about 80 km. This was later screened of clouds contamination
- The nadir pixels that were screened of cloud contamination that fall into the limb box was averaged for a particular orbit at a particular time
- The tropospheric ozone column (TOC) was derived by subtracting the Stratospheric Column (SC) from the Total Column(TC).
- TOC = TC - SC

4a) Comparison of ECMWF and Sonde tropopause heights

For the eight years of the SCIAMACHY data used in our analysis, all available radiosonde data (from 2002 – 2008) were evaluated in order to validate the tropopause height derived from the ERA data. To compare the different datasets, the ERA tropopause fields are first interpolated linearly to the locations of the radiosonde stations. Then the data are averaged over months and certain geographical areas (see figure 2).



4b) Comparison of ECMWF and Sonde tropopause heights

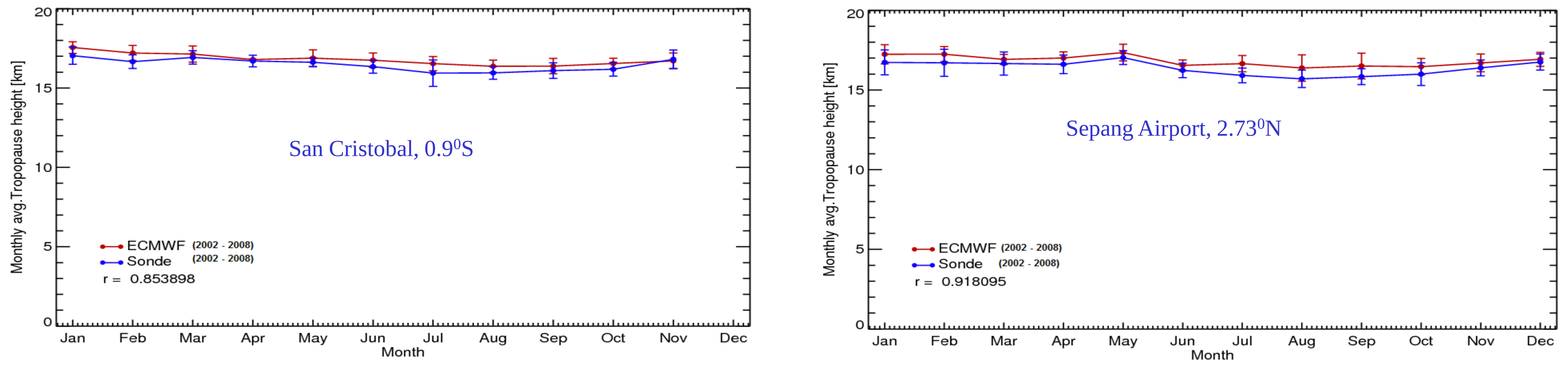


Figure 2: Comparison of tropopause heights derived from Sonde and ECMWF.

In the top panels, toward the poles, both instruments have good agreement with correlation coefficient of 0.89 and 0.9 respectively. In the down panel, ECMWF tropopause height is about 500m higher and also have good correlation.

5) The tropospheric O_3 column along the limb-nadir orbital tracks for a day

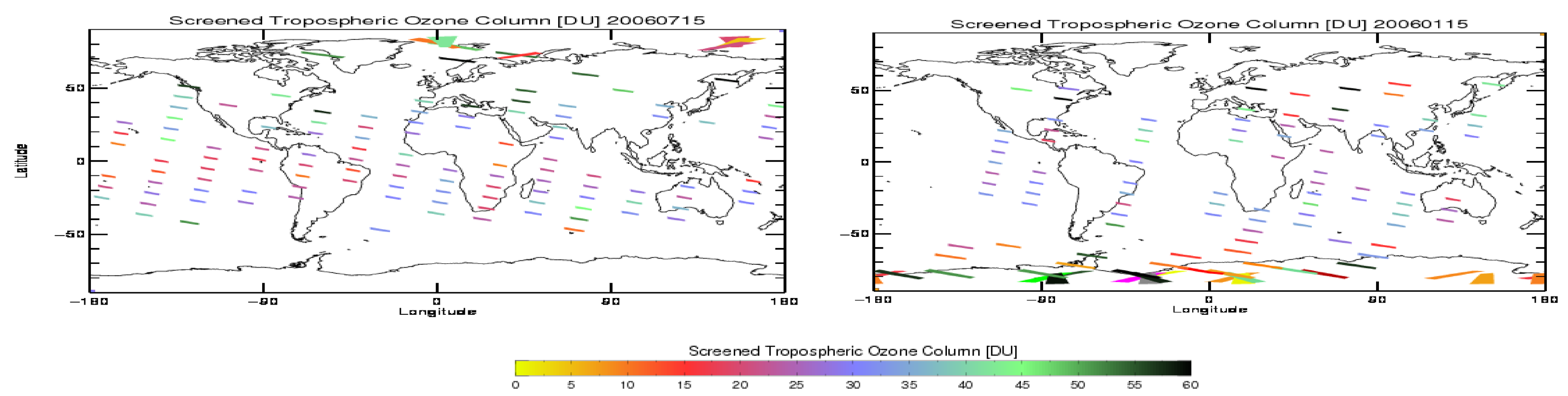


Figure 3: Orbital view of tropospheric ozone column.

The long integration times around the polar region close to the terminator, allow for the compensation for lower light intensities. This results in larger ground pixels in these regions.

6) Comparison of SCIAMACHY and Sonde tropospheric ozone columns

- Good agreement in the collocated tropospheric ozone column derived from Sonde and SCIAMACHY limb-nadir matching observations.
- Collocation criteria used: ± 10° in longitude, ± 5° in latitude
- Negative tropospheric ozone column due to either nadir total column being too small or stratospheric column being too large.
- Limb and nadir pixels that are completely cloud free were considered.

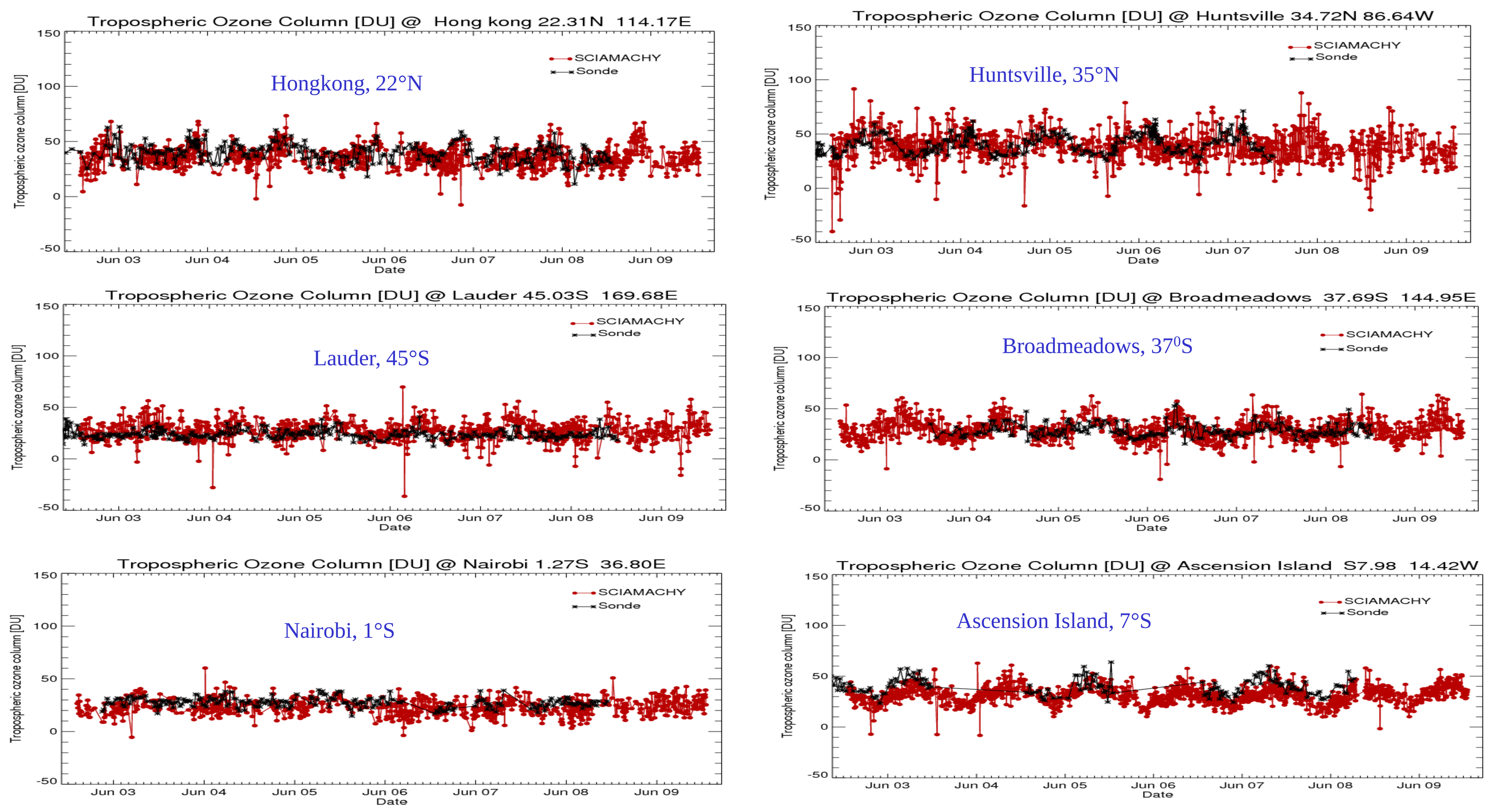


Figure 4: Tropospheric ozone at some stations in the northern and southern hemispheres

7a) Meridional variation of tropospheric O_3 column

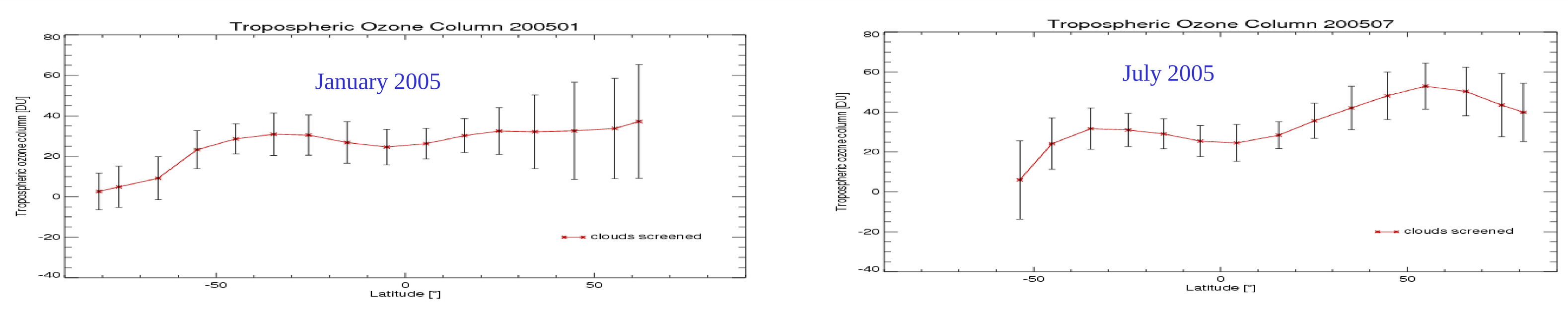


Figure 5: Meridional variation of tropospheric O_3 column for the northern winter and summer months.

7b) Meridional variation of tropospheric O_3 column

- Observable maximum at mid-latitudes is reproduced
- Tropical minimum is present, higher towards the northern hemisphere than towards the southern hemisphere
- Tropospheric ozone amount higher at the southern tropics than the northern tropics due to biomass burning

8) Global tropospheric O_3 column

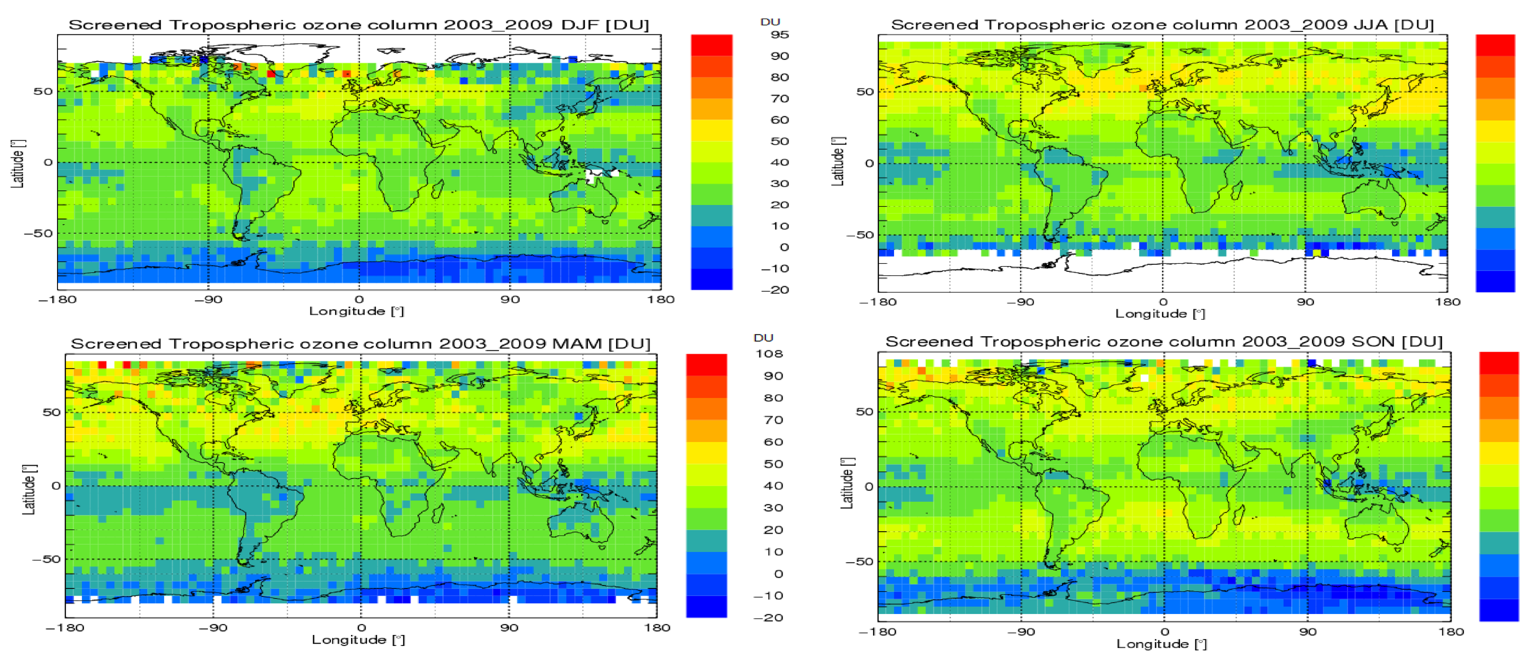


Figure 6: Global distribution of tropospheric ozone from 2003 – 2009.

From the top panel, left to right DJF, JJA. In the down panel from left to right MAM, SON.

- Known maximum during spring in high latitude is reproduced
- Known maximum during summer in mid- latitude is reproduced
- Enhanced low tropospheric ozone amount found at the tropical pacific during northern spring

9) Conclusions

- Limb-nadir matching technique is a unique method of tropospheric ozone retrieval
- Reduction of error due to zonal variability in tropospheric ozone column retrieval as compared to limb scattering technique
- Reduction in error of estimating the stratospheric column concentration as compared to only nadir observation technique
- Seven years observation of tropospheric ozone show many details of both its spatial and temporal variation
- Great decrease in tropospheric ozone column in the tropical pacific during northern spring
- Comparison of tropospheric ozone column with sondes show overall good agreement (incl. seasonal cycle)
- Observable daily and seasonal variation in tropospheric ozone column derived from both sonde and SCIAMACHY variation
- Clouds have large impact on tropospheric ozone column, contaminated pixels show bias in tropospheric column ozone retrieval

Acknowledgements

We are greatly indebted to the ESA for providing the SCIAMACHY level 0 and level 1 data used in this study. We are also thankful to the SCIAMACHY team of IUP whose effort has made the scientific analysis of the data possible. We thank the ECMWF for providing the reanalysis data. Parts of this work have been funded by the German Ministry of Education and Research BMBF, the German Aerospace Centre DLR and the University of Bremen.

Selected References

Bovensmann, H., 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.

Coldewey-Egbers M., M. Weber, L. N. Lamsal, R. de Beek, M. Buchwitz, J. P. Burrows,: total ozone retrieval from GOME UV spectral data using the weighting function DOAS approach, Atmos. Chem. Phys. 5, 1015-1025, 2005.

Hoinka, K. P. : Statistics of the global tropopause pressure, Mon. Wea. Rev., 126, 3303– 3325, 1998.

Savigny, C., et al.: Stratospheric Ozone Profiles retrieved from Limb Scattered Sunlight Radiance Spectra Measured by the OSIRIS Instrument on the Odin Satellite, *Geophys. Res. Lett*., 30, doi:10.1029/2002GL016401, 2003.

Sonkaew, T., Rozanov, V. V., von Savigny, C., Rozanov, A., Bovensmann, H., and Burrows, J. P.: Cloud sensitivity studies for stratospheric and lower mesospheric ozone profile retrievals from measurements of limb-scattered solar radiation, Atmos. Meas. Tech., 2, 653–678, doi:10.5194/amt-2-653-2009, 2009.

Weber M., L. N. Lamsal, M. Coldewey-Egbers, K. Bramstedt, J. P. Burrows: "Pole-to-pole validation of GOME WFDOAS total ozone with groundbased data", Atmos. Chem. Phys. 5, 1341-1355, 2005.