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


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1) Introduction

Tropospheric ozone concentration varies both spatially and temporally. It varies from non-detectable near the sources of production to several hundreds parts per billion (ppb) at 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 denoted at using data these daily temporal analyses of standard analyses from the European Centre for Medium Range Weather Forecasts (ECMWF) as 1.5 × 15° x 15° grid, 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 definition of the tropopause. The total column was retrieved using the Weighting Function DOAS algorithm (WFDOS) at the spectral window of 325 – 335.5 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

![Image](image1.png)

Figure 1: Illustration of the limb-nadir matching geometry

3) Methodology

- **SCIAMACHY Level 1 and 2 limb scattering data were used to derive stratospheric O₃ density profiles (10 – 70 km) using the strength technique in Chapman bands and Voigt single in Hartley bands coupled to a radiative transfer model (SCIATRAN).**
- **SCIAMACHY Level 1 version 6 nadir data were used to derive total column O₃ using weighting function DOAS technique at a fitting window of 325 – 338.5 nm coupled to a radiative transfer model (SCIATRAN).** (Method same as in Coldewey-Egbers et al., 2005, Weber et al., 2005)
- **ECMWF Reanalyses (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, P. J., 1998).

The stratospheric column was derived by integrating the stratospheric O₃ density profiles from the height of the tropopause to about 80 km. This was later smoothed by smoothing techniques.

The nadir pixels that were screened of cloudy contamination that fall into the limb box were averaged for a particular altitude 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

4) 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 – 2009) 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 geographic areas (figure 2).

![Image](image2.png)

Figure 2: Comparison of ECMWF and Sonde tropopause heights

5) The tropospheric O₃ column along the limb-nadir orbital tracks for a day

![Image](image3.png)

Figure 3: Tropospheric ozone column along the limb nadir across the climatological median of the tropical boreal summer season

6) Comparison of SCIAMACHY and Sonde tropospheric ozone columns

- **Cloud 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 nadir pixels that are completely cloud free were considered.**

7) Meridional variation of tropospheric O₃ column

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

8) Global tropospheric O₃ column

![Image](image4.png)

Figure 6: Global distribution of tropospheric ozone from 2001 – 2009

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

- **Known maximum during summer in high latitude is reproduced.**
- **Known maximum during summer in mid-latitude is reproduced.**
- **Enhanced low at tropospheric ozone amount found in the tropical 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-sounding 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 during northern spring.**
- **Comparison of tropospheric ozone column with sondes show overall good agreement (incl. seasonal cycle).**
- **Observed daily and seasonal variation in tropospheric ozone column derived from both sondes and SCIAMACHY.**
- **Clouds have large impact on tropospheric ozone column, contaminated pixels show bias in tropospheric column amount retrieval.**

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Selected References


