SCIAMACHY SOLAR OCCULTATION: OZONE AND NO_2 PROFILES

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Abstract

Beyond SCIAMACHY's capability to perform global nadir and limb measurements of Earth's atmosphere in the ultraviolett, visible and near-infrared spectral range, solar occultation measurement are performed during sunrise at higher northern latitudes. Using an optimal estimation approach with the radiative transfer code SCIATRAN as forward model, these measurements are used to derive ozone and NO2 profiles. The sun as well known target in space is used to derive the exact tangent heights for the solar occultation measurements. Here we present a dataset for the time period 2002 to 2004, showing validation results with independent measurements from the HALOE instruments.

1. INTRODUCTION

SCIAMACHY solar occultation measurements are performed during sun rise occuring once per orbit in the northern hemisphere with tangent points between 48° N and 68° N . Usually, the sun disk is scanned permanently, while spectral measurements are performed every 62.5 msec. Only directly transmitted light contributes significantly in occultation geometry. Transmissions are calculated dividing atmospheric measurements by an appropriate measurement from above the atmosphere. SCIAMACHY also performs lunar occultation with measurements in the Southern hemisphere (Amekudzi, 2005).

The differential structure of transmission spectra are fitted using the optimal estimation method. With measurement information from several tangent heights, height resolved vertical profiles of atmospheric trace gases can be retrieved (Meyer, 2005). For this work, the up-to-date radiative transfer code SCIATRAN (Rozanov, 2005) was adapted for solar occultation and used as forward model.

At the time of writing of this paper, our download of the actual reprocessed SCIAMACHY Level 1 data (Version SCIA/5.04) was not completed, therefore only an incomplete dataset up to March 2004 is used. For the tangent height correction, data up to April 2005 are processed.

2. TANGENT HEIGHT CORRECTION

The pointing of the SCIAMACHY instrument is not precise due to uncertainties in the attitude of the Envisat platform. Uncertainties in the viewing direction are a prominent error source in the retrieval of trace gas profiles from SCIAMACHY limb and occultation measurements. In the case of solar occultation, the sun as well known target in space can be used to derive a very precise knowledge of the viewing direction.

Fig. 1 illustrate the scanning sequence of the usual occultation measurements. In the first part, SCIAMACHY scans the estimated sunrise region above the horizon. When the geometric centre of the sun reaches a tangent height of 17.2 km, the FOV starts to move up with a precalculated elevation rate up to an altitude of about 300 km. During the whole sequence, the sun is scanned up and down over the full solar disk. We use the scanning sequence above the atmosphere to determine the exact position of the top and bottom edge of the sun, from which easily the center of the solar disk can be derived.

Fig. 2 illustrates the measured intensity over one upscan and downscan, respectivly. The intensity is taken from the polarisation measurement device 5 (PMD), because the PMDs have a higer sampling rate than the science channels. Through the measured intensity a 4th order polynomial is fitted. Special care has to be taken to use only measurements not overlapping with the previous or next scan sequence. The zeros of the fitted polynomial than gives the upper and lower boundary of the solar disk with a precision about 10 times smaller than the height of field of view (FOV).

Using the Envisat Orbit propagator software CFI (ESA, 2006) and the actual orbit parameters delivered with each SCIAMACHY product, the precise tangent altitude for the line satellite – atmosphere – center of the solar disk can be calculated

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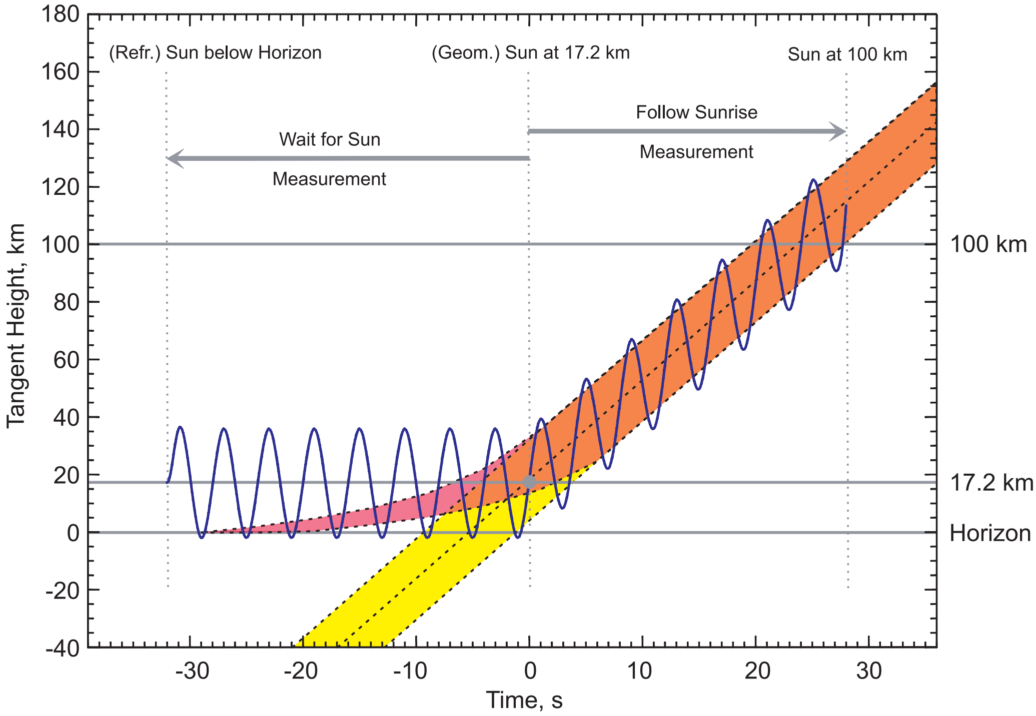

Figure 1. Schematic view of an solar occultation measurement sequence. Tangent height in km is plotted vs. time in seconds. The blue line represents the movement of SCIAMACHY's FOV, the shaded areas illustrate the refracted and the imaginary true Sun, respectively.

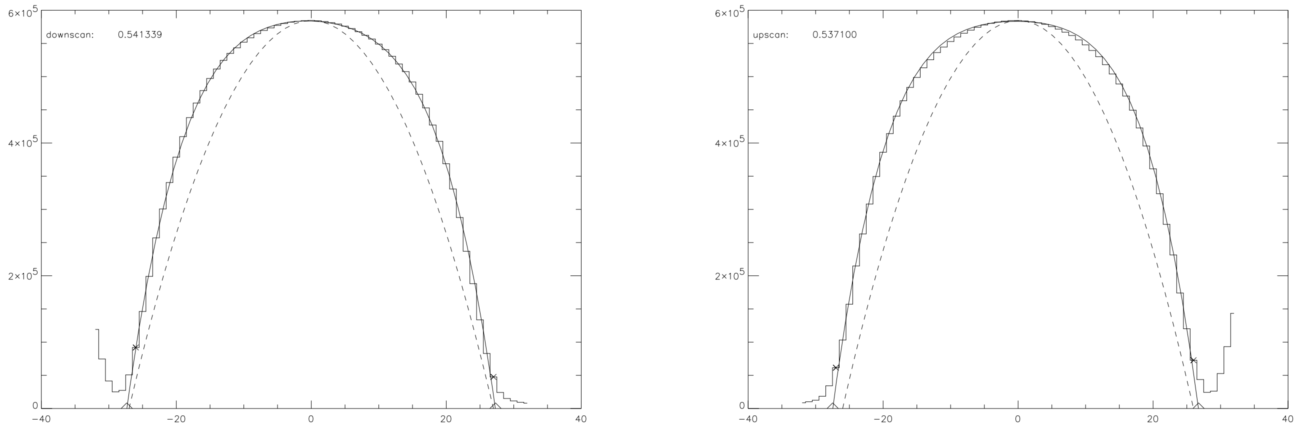

Figure 2. Bar plots of the measured solar intensity of one downscan and one upscan above the atmosphere. The dashed line is the starting polynomial, the continous line the fitted polynomial. Crosses denote the first and last measurement considered to match the actual solar disk. Zeros of the fitted polynomial are the top and bottom measured border of the solar disk.

for each position in orbit. The difference between this true tangent height and the one derived by the above scheme (using the tangent heights given in the product, which are calculated from the mirror positions and the (uncertain) satellite attenuation) gives a precise tangent height correction.

Fig. 3 shows the calculated tangent height offsets for the available data. Until end of 2003, a seasonal variation from -0.5 to -2.5 km can be observed. After the on-board software update end of 2003 a constant offset of about -2 km is observed. These results are in line with previous examninations of the tangent height problem, see von Savigny (2005). Some on-board anomalies leading to reduced pointing stability can be clearly identified in the plot, see text at Fig. 3.

All retrievals presented here use the corrected tangent heights.

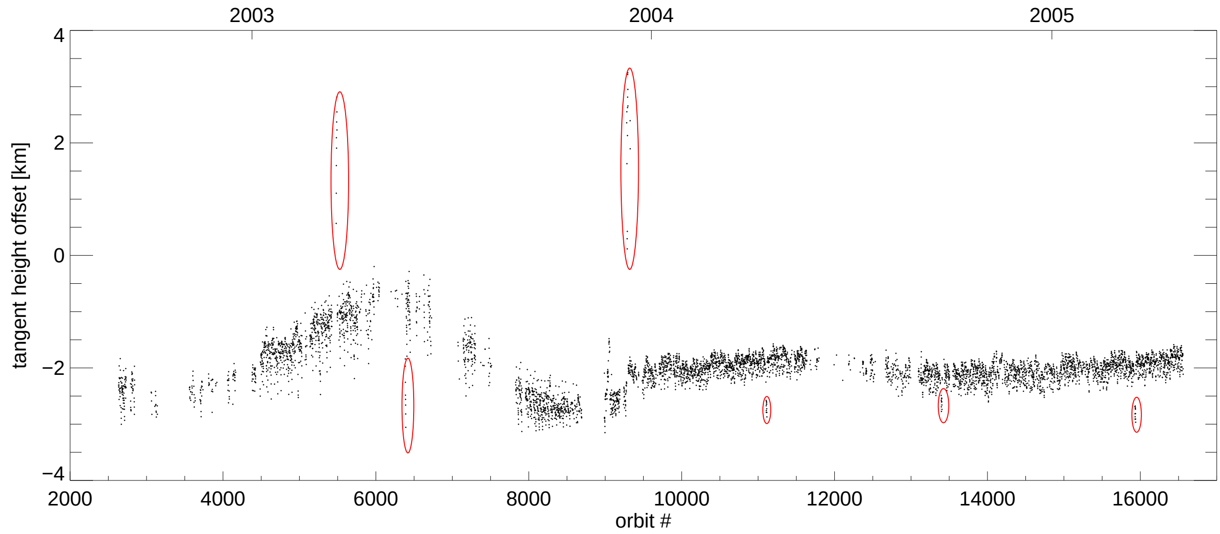

Figure 3. Tangent height offsets calculated from solar occultation measurements, for all measurements available at the time of writing. With begin of 2004, the pointing has been improved by an upgrade of the on-board software. The red circles denote some enhanced pointing instability caused by Envisat anomalies. From left to right: March 19th, 2003: Payload switch off the previous four days caused by tests related to the Artemis relay satellite. May 19th, 2003: first measurements after an orbit control manouvre. December 9th-10th, 2003: Tests for the new on-board software regarded to pointing stability. April 14th, 2004, September 21st, 2004, March 17th, 2005: first measurements after an orbit control manouvre.

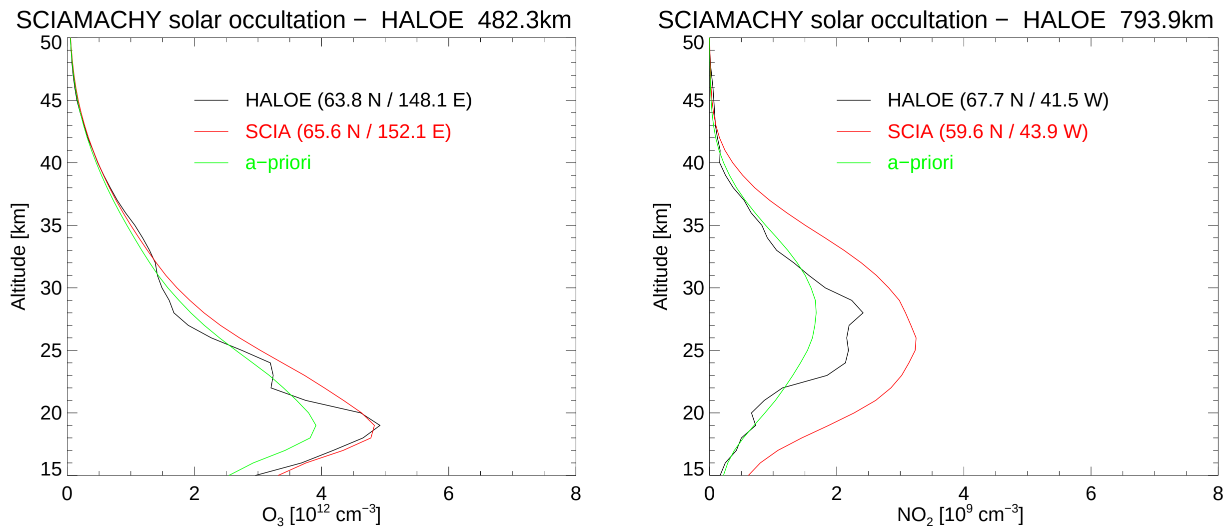

Figure 4. Ozone and NO_2 profiles retrieved from SCIAMACHY solar occultation compared to colocated HALOE measurements. ***Left:*** *Ozone profile measured in Orbit 8234 (04-OCT-2003).* ***Right:*** *NO_2 profile measured in Orbit 7892 (03-SEP-2003). Please recognize, that there are 9° difference in latitude (950 km) due to lack of a nearer colocations with HALOE sunrise measurements.*

3. PROFILE RETRIEVAL

Profiles of NO_2 and Ozone are derived from solar occultation measurements in the spectral windows 425 – 453 nm and 525 – 590 nm in a simultaneous fit. Used are 11 measurement with tangent height from 14 – 45 km and a fixed solar reference measurement well above the atmosphere. Fig. 4 shows an example for each species compared to nearby profiles derived from measurements of the Halogen Occultation Experiment (HALOE, version 19).

NO_2 is highly variable trace gas in the atmosphere with a strong diurnal cycle. Therefore, a direct comparison is only possible if both measurement are taken at the same local time, otherwise a photochemical model is necessary to take into

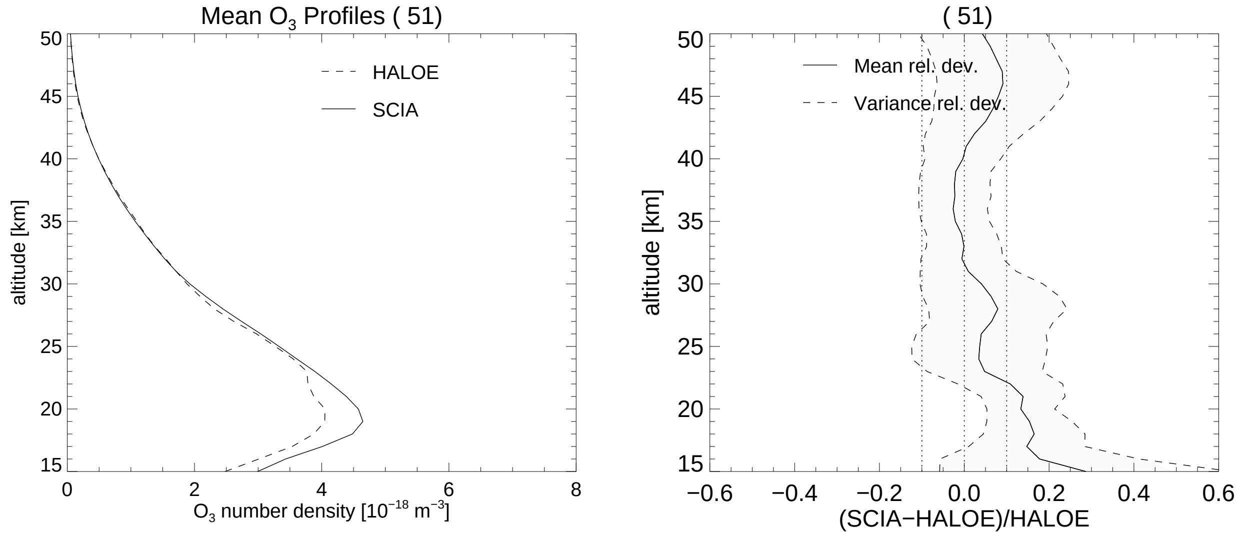

Figure 5. ***Left:*** *Mean profiles of 51 co–located HALOE and SCIAMACHY measurements.* ***Right:*** *Mean relative deviation and the standard error of the mean relative deviation between 51 co–located HALOE and SCIAMACHY measurements. The co-locations are found within the available measurements up to March 2004.*

account the diurnal cycle (Bracher et al., 2005). In case of HALOE which is also a solar occultation instrument, only the sunrise measurements of HALOE fulfil the criteria for direct comparison as SCIAMACHY only measures at sunrise. Unfortunately, the orbits of both instruments are quite different, and there are only a set of matches in the available date for the period Sep. 1st to Sep. 4th 2003 with distances around 900 km. The HALOE measurement are around 68° N , whereas SCIAMACHY tangent point are around 59° N . All NO_2 comparison are similar to the one shown in Fig. 4, showing about 70 % higher NO_2 values from SCIAMACHY. Further investigation are necessary to distinguish, which part of the difference is caused by the distance between the measurements and what might be a problem in the current NO_2 retrieval scheme.

In Fig. 4, the SCIAMACHY ozone profile fits quite well to the HALOE profile. As ozone has no diurnal cycle in the stratosphere, also HALOE sunset measurement can be used. Within a maximum distance of the tangent points of 500 km, 51 co–locations are found and used for a statistical analyses, plotted in Fig. 5. Above 22 km, both instruments fit very well within -2 to 10 % mean difference. Above 16 km, the instruments agree within 16%. SCIAMACHY gives the higher values. Below 16 km the difference increase, but the uncertainties of both instruments are enlarged at the lowest altitudes.

4. CONCLUSIONS

By using the sun as well–known target in space, the pointing problems of the platform can be circumvented, which is otherwise a prominent source of error for SCIAMACHY occultation and limb retrievals. Ozone profiles agree well to co-located measurements of the HALOE instrument. Nevertheless, the algorithm has to be further tuned. The parameters for the newly invented retrieval scheme based on the actual version of SCIATRAN have to be optimized. The choice of the reference measurement has to be improved, because the sun is not a homogenous light source (sun spots and limb darkening are the keywords here) and in vertical direction the entry–slit of SCIAMACHY covers only a small part of the solar disk. At lower altitudes the refraction within Earth's atmosphere leads to a flattening of the visible solar disk. The algorithm detecting the edges of the sun used here for tangent height correction only will be used also for an optimised selection of the solar reference measurement. With these improvements we expect further improved ozone and NO_2 profiles for all solar occultation measurement of the entire mission of SCIAMACHY, giving improved insight to the constituents and dynamics of the atmosphere in Northern latitudes.

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