# VALIDATION OF OZONE PROFILES RETRIEVED FROM SCIAMACHY LUNAR OCCULTATION MEASUREMENTS

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**Abstract**

Stratospheric number density profiles of ozone have been retrieved from lunar transmission spectra measured by Scanning Imaging Absorption Spectrometer for Atmospheric Chartography (SCIAMACHY), over the high Southern latitude ($50^o$ S–$90^o$ S). The ozone profiles were retrieved from level-1 (calibrated) data using the spectral window of 520–580nm. In order to assess the accuracy of the retrieved profiles, a comparison of the retrieved ozone profiles with ozone profiles inferred from POAM III, SAGE II and HALOE were carried out. The validation results show that the quality of SCIAMACHY ozone is within the accuracy better than 15% in the altitude range of 20–40 km.

## 1. INTRODUCTION

The Scanning Imaging spectrometer for Atmospheric Chartography (SCIAMACHY), which was developed to contribute to ozone chemistry, air pollution, and climate monitoring issues flies on Board the European Environmental Satellite (ENVIISAT) since March 2002. SCIAMACHY is a uv-visible and short wave infrared, moderate spectral resolution spectrometer with eight channels covering the spectral range of 240–2380 nm. The instrument observes the Earth atmosphere in Nadir, limb and occultation geometries (*Bovensmann et al.*, 1999). Occultation measurements are performed by SCIAMACHY instrument in both hemispheres of the Earth's atmosphere. Solar occultation measurements are performed in the Northern hemisphere between $50^o$–$70^o$ during sunrise. These measurements are carried out by SCIAMACHY instrument using the Sun scanning mode (*Meyer et al.*, 2005).

Lunar occultation measurements are performed by SCIAMACHY instrument in the Southern hemisphere between $30^o$–$90^o$ during local nighttime. The lunar occultation measurements are performed in Moon pointing mode, these measurements begin when the phase of the Moon is 0.6-0.7 and end shortly after full moon. The SCIAMACHY lunar occultation measurements are thus performed 6–8 days per month and 4–8 months in the year. These measurements usually start from 17.2 km altitude to 100 km in a vertical resolution of 3 km. Above 100 km, lunar measurements are performed for instrument calibration purposes. The integration time for the lunar occultation measurements is 1.0 s and the horizontal resolution is $30\times400\,\mathrm{km}^2$. Detailed information on SCIAMACHY lunar occultation measurements are provided in (*Amekudzi et al.*, 2005b; *Amekudzi*, 2005).

The first SCIAMACHY lunar occultation retrieval and preliminary validation results of ozone and nitrogen dioxide have been reported in *Amekudzi et al.* (2005a). In order to assess accuracy of the retrieved ozone profiles from the SCIAMACHY lunar occultation level-1 data product, the retrieved ozone profiles were validated by comparison with retrieved ozone profiles from other satellite instruments. These instruments are the third Polar Ozone and Aerosol Measurement (POAM III), the second Stratospheric Aerosol and Gas Experiment (SAGE II) and the Halogen Occultation Experiments (HALOE). There are only few SCIAMACHY lunar occultation measurements, therefore the best criteria employed for the validation are large collocation radius in the range of 200–1000 km.

The study presented in this paper focuses on ozone validation results. In the second section a brief information on the lunar occultation retrieval method is presented. The validation results are reported in section 3 and the final section presents the conclusions of the study.

## 2. VERSION 2.2 SCIAMACHY LUNAR OCCULTATION OZONE PROFILES

The SCIAMACHY lunar occultation profiles are so far only retrieved in IUP/IFE, University of Bremen. The first version (i.e version 2.1) reported in *Amekudzi et al.* (2005a) and *Amekudzi* (2005) uses the GOMETRAN occultation version radiative transfer model for computing the atmospheric radiance and its Jacobian. The

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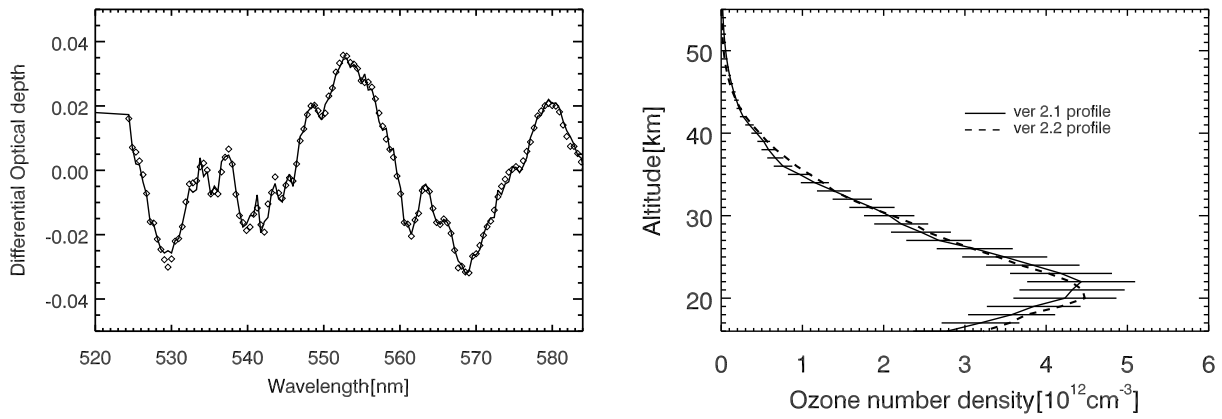


*Figure 1. Left: The spectral fit of ozone at 24 km tangent height . The diamond points represents the modeled differential optical depth and the solid line is the measured differential optical depth. Right: The retrieved ozone profiles for orbit 10100, measurement day of 04/04/2004 at 17:09 hours.*

current version, which we shall call version 2.2 SCIAMACHY lunar occultation ozone profiles use the SCIATRAN occultation version radiative transfer (*Rozanov et al.*, 2005). In addition version 2.1 products were derived from SCIAMACHY lunar occultation level-0 (un-calibrated) data whereas the version 2.2 ozone profiles we are reporting in this paper were inferred from lunar occultation level-1 data.

The complete retrieval algorithm for version 2.2 SCIAMACHY lunar occultation ozone profiles, however is similar to the retrieval scheme described in *Amekudzi* (2005). In the current retrieval scheme, the MPI ozone profile were used as an ozone a priori profile and ECMWF analysis temperature and pressure information were used. The retrieval was carried out using the spectral window of 520–580 nm within the Chappius absorption band of ozone at the spectral resolution of the SCIAMACHY instrument. In order to remove broad band features from the measured spectra a polynomial of third order was subtracted. Smoothing constraint parameters (Twomey-Tikhonov regularization) was applied to smooth the retrieved ozone profiles. Within the selected spectral window the appropriate signal-to-noise ratio for SCIAMACHY lunar occultation measurements is 1000–2000, hence a signal-to-noise ratio of 1500 was used.

The left panel of Figure 1 shows the spectral fits of ozone at 24 km tangent height for February 4, 2004, corresponding to ENVISAT orbit 10100 and covering a spectral band of 520 nm–580 nm. The diamond point represents the modeled differential optical depth and the solid lines the measured differential optical depth. The spectral fits are good as strong ozone absorption features are mainly seen. The corresponding retrieved profile for orbit 10100 is shown at the right panel of Figure 1. The solid line is the retrieval result from version 2.1 and the dash line is the result from version 2.2. The error bar is the maximum retrieval error of 15 %. There is a good agreement between the two results for all retrieval altitudes.

## 3. VALIDATION RESULTS

In this section, the results of the validation carried out for version 2.2 SCIAMACHY lunar occultation ozone profiles are presented.

### 3.1 SCIAMACHY-POAM III validation

Here, the results of the validation carried out for POAM III retrieved ozone vertical profiles and version 2.2 SCIAMACHY lunar occultation ozone profiles are presented. The criteria employed in this study to select coincident measurements are that measurements were taken on the same day with collocation radius in the range of 300–900 km. Example of this study is shown in Figure 2 (left). The result of the relative mean and the standard deviations are also shown in Figure 2 (right). In general there is a good agreement between POAM and SCIAMACHY ozone profiles with a slight negative relative mean deviations in most of the relevant altitudes in the range of 3–17 %. The standard deviations in the altitude range of 18–45 km are between 10–20 %.

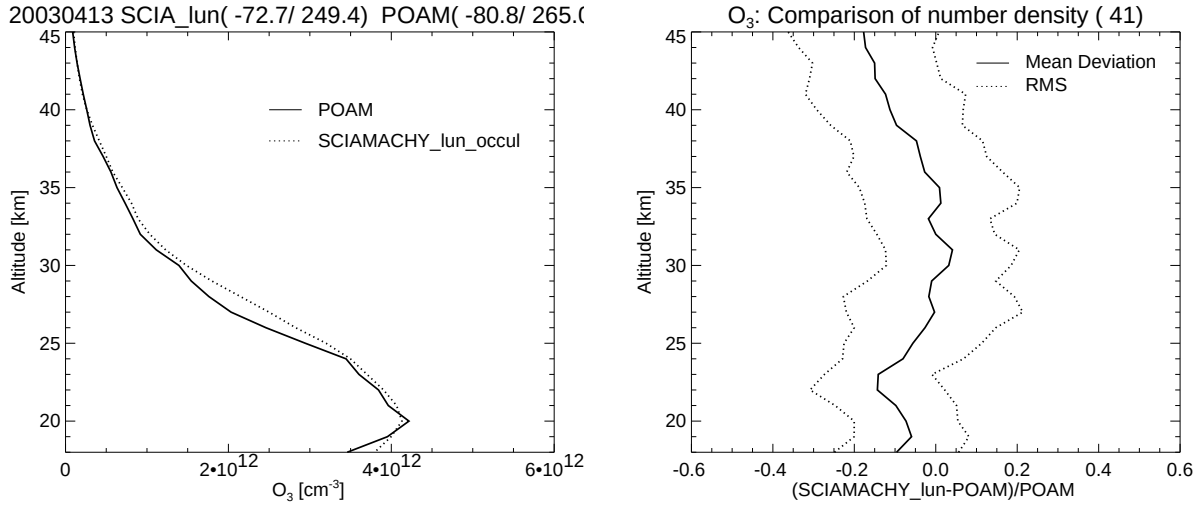


*Figure 2. Left: example of ozone profiles from coincident SCIAMACHY and POAM III retrievals for 13/04/2003. The dotted line is the SCIAMACHY result and the solid line POAM III result. Right: the mean relative deviation (solid line) and the standard deviation (dotted line) of the comparisons of 41 collocated SCIAMACHY ozone profiles with POAM III.*

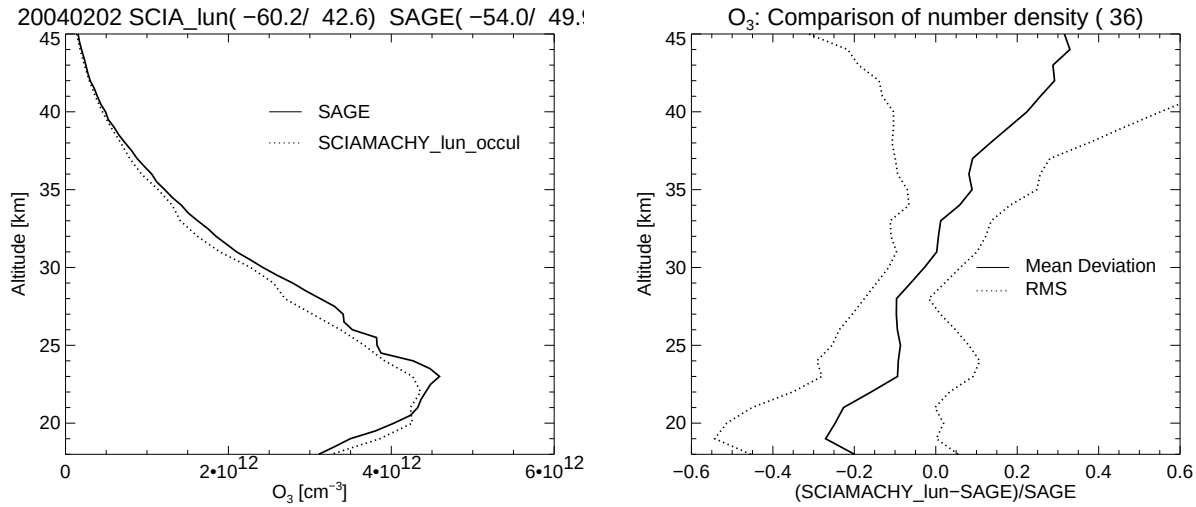


*Figure 3. Left: example of ozone density profiles from coincident SCIAMACHY and SAGE II retrievals for 02/02/2004. Right: The mean relative deviation (solid line) and the standard deviation (dotted line) of the comparison of 36 collocated SCIAMACHY ozone profiles with SAGE II.*

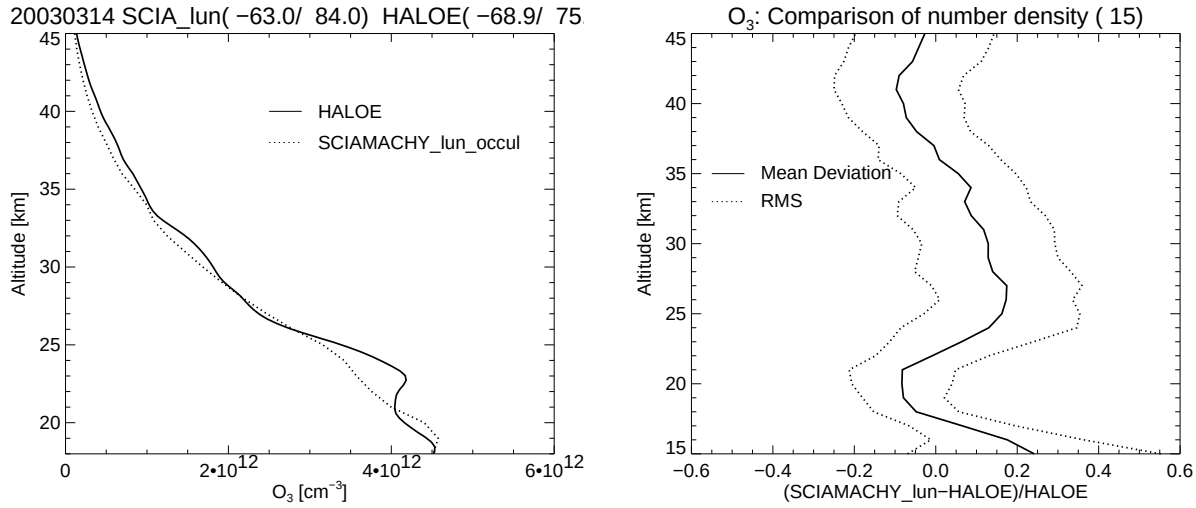


*Figure 4. SCIAMACHY-HALOE example ozone profiles comparison for 14/03/2003 (left). The dotted line is the result of the SCIAMACHY and the solid line HALOE ozone profile. Right: the mean relative deviation (solid line) and the standard deviations (dotted line) of the comparison of 15 collocated SCIAMACHY ozone profiles with HALOE.*

### 3.2 SCIAMACHY-SAGE II validation

The quality of SAGE II ozone number density profiles is 10 % in the altitude range of 15–50 km (*Cunnold et al.*, 1989). In this study, the validation results for version 2.2 SCIAMACHY lunar occultation ozone profiles with ozone profiles from the recently provided SAGE II data version 6.2, downloaded from http//:wwwsage2.larc.nasa.gov/data are presented. The criteria employed in this study are that coincidence measurements were taken from the same day, having a collocation radius in the range of 600–1000 km. The results of this study are shown in Figure 3. Left: the example of the comparison is presented and right: the statistical result. We found a good agreement between 30–45 km, however below 30 km SCIAMACHY results are sometimes lower than the results of SAGE II. The relative mean deviation is less than 15 % between 22–40 km and in the same altitude, the standard deviation is less than 20 %.

### 3.3 SCIAMACHY-HALOE validation

In this study the version 19 (v19) of HALOE ozone profiles downloaded from (http://haloedata.larc.nasa.gov) was used. The accuracy of HALOE ozone profiles according to *Brühl et al.* (1996) are 20–30 % in the altitude range of 15–30 km and 6–12 % in the altitude range of 30–60 km. The preliminary validation performed for version 2.1 SCIAMACHY lunar occultation ozone profiles with HALOE v19 ozone profiles, reported in *Amekudzi et al.* (2005a) have standard deviations within 10-30 % in the altitude range of 17–45 km.

The SCIAMACHY-HALOE validation we are reporting was based on 15 single collocated measurements, which was based on collocated radius in the range of 600–1000 km. Figure 4 (left) is an example of the SCIAMACHY-HALOE validation result and Figure 4 (right) the statistics of the results. In general we find good agreement with a slight positive bias in their mean profiles. The mean relative deviations and the standard deviations are -10 to +15 % and 5–20 % respectively in the altitude range of 20–45 km.

## 4. CONCLUSIONS

Ozone profiles retrieved from SCIAMACHY lunar occultation level-1 data have been compared with retrieved ozone results from POAM III, SAGE II, and HALOE instruments. We found that SCIAMACHY results are in good agreement with all the other instruments within the accuracy of 15 %. These results are in a better agreement than the ones reported in *Amekudzi et al.* (2005a) and *Amekudzi* (2005) because an improved level-1 data product was used for the retrieval. There are however, a systematic negative biases found in the lower altitudes (altitudes less than 25 km), which may be due to inaccurate pointing information in these altitudes. In addition, these biases may be due to poor collocation (different air masses). In the future a potential vorticity check will be performed.

## ACKNOWLEDGMENT

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