SCIAMACHY ON ENVISAT: TRACE GAS VERTICAL COLUMN RETRIEVAL USING CHANNEL 8 NADIR MEASUREMENTS: FIRST PRELIMINARY RESULTS

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ABSTRACT

First preliminary results are presented concerning the retrieval of vertical column densities (VC) of important atmospheric trace gases from SCIAMACHY data compiled for initial verification of the operational Level 1 and 2 data products. Although the Level 1 spectra are not yet fully calibrated, the spectral absorption features of the major near–infrared (NIR) absorbers CH_4 and H_2O (and channel 7 CO_2) have clearly been identified. The quality of the Level 1 spectra and Level 1 to 2 algorithms, however, need to be further improved to enable an accurate quantitative retrieval. At present the accuracy does not seem to be good enough to clearly identify the minor NIR absorbers CO and N_2O. This study focusses on CH_4 VC retrieval using channel 8 nadir measurements ($\sim$2.3 μm). One of the major scientific objectives of the SCIAMACHY methane total column measurements is to derive information on methane surface sources and sinks. For such an application very precise measurements close to the signal–to–noise performance of SCIAMACHY are required.

1 INTRODUCTION

Vertical columns of CH_4, CO, N_2O, and H_2O have been retrieved from the SCIAMACHY channel 8 nadir measurements using different algorithms (and processors), e.g., WFM–DOAS and BIAS.

WFM–DOAS (Weighting Function Modified Differential Optical Absorption Spectroscopy) is an algorithm developed at the University of Bremen [1]. BIAS (Basic Infrared Absorption Spectroscopy) refers to the operational (NRT and off–line) algorithm implemented for Level 1c to 2 processing [2] of the SCIAMACHY Level 1c NIR nadir measurements.

This study uses initial verification data (Level 1c and 2) compiled and made available to the SCIAMACHY processors verification team by ESA/ESTEC. One objective of the work presented here is to compare the operational BIAS VC data products with columns derived with an independent algorithm. Based on the outcome of the analysis of the operational data, the quality of the SCIAMACHY data products is expected to be improved using an iterative approach. The Level 1c data products [3] used in this study are not yet fully calibrated (e.g., wavelength calibration based on on–ground measurements, no polarisation correction). Therefore, all results presented in this study are highly preliminary. This study focusses on verification orbit 2338 (11-Aug-2002) covering parts of central Europe and western Africa.

2 WFM–DOAS RETRIEVAL

WFM–DOAS is based on fitting a linearized radiative transfer model plus a low–order polynomial to the logarithm of the ratio of a measured nadir radiance and solar irradiance spectrum. The reference spectra are the logarithm of the sun–normalized radiance and its derivatives computed with a radiative transfer model [4]. The main fit parameters are the desired trace gas vertical columns. A detailed description of WFM–DOAS is given in [1].

The SCIAMACHY NIR detectors (channels 6–8) are characterized by a relatively strong detector pixel to pixel variability, e.g., with respect to dark current and quantum efficiency. Some pixels have been flagged “bad” or even “dead” during on–ground characterization and calibration. For this study the dead detector pixels (as listed in the so called dead/bad pixel mask file) have not been used for the retrieval results shown here. Even some more pixels have been masked out as they exhibited unexpected spikes in the radiance, irradiance or in the fit residuum.

2.1 Fitting window 2360.0-2368.7 nm

This spectral region has been investigated because it covers important CO lines. A typical WFM–DOAS fit result for a ground scene with relatively high surface albedo is shown in Fig.1. It has to be pointed out that the quality of the fit gets worse for ground pixels with low albedo, e.g., over water. The fit residuals are similar for ground pixels with similar surface albedo, i.e., they are not dominated by noise but by systematic (rather stable) spectral features probably resulting from imperfect calibration. Imperfect dark signal correction might explain this. For most conditions the dark signal is higher than the signal induced by atmospheric radiation (especially over water

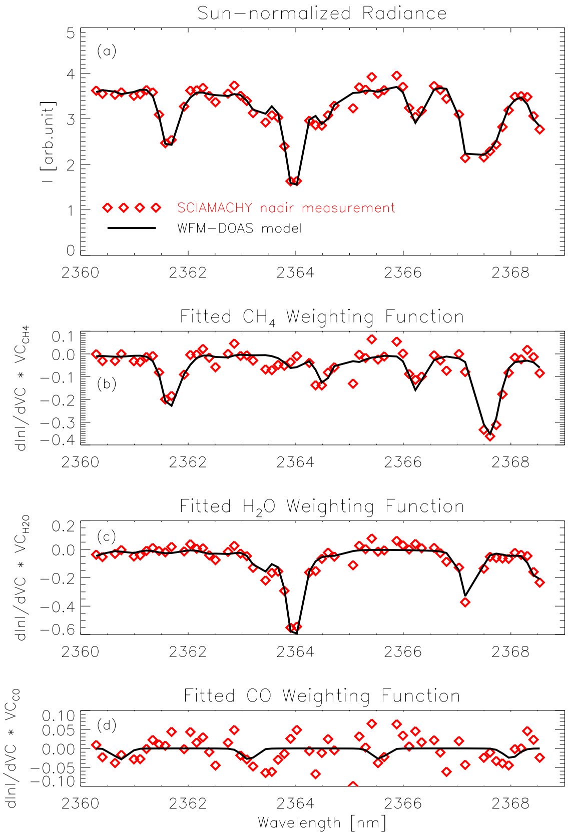

Figure 1: Typical result of a WFM–DOAS fit as applied to a SCIAMACHY nadir measurement over the Sahara. The spectral absorption features of CH_4 and H_2O are clearly visible. The fit residual as shown here is, however, larger than the expected CO absorption signal of about 2-3% (see bottom panel). Note that the residuum is not determined by instrument noise. For other Sahara ground pixels the residuum is nearly identical.

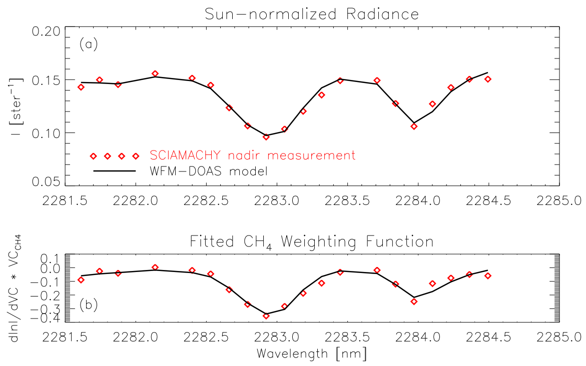

Figure 2: Typical result of a WFM–DOAS fit as applied to a SCIAMACHY nadir measurement over the Sahara. The retrieved methane column is 2.5 10^{19}molec./cm^2 ± 7%.

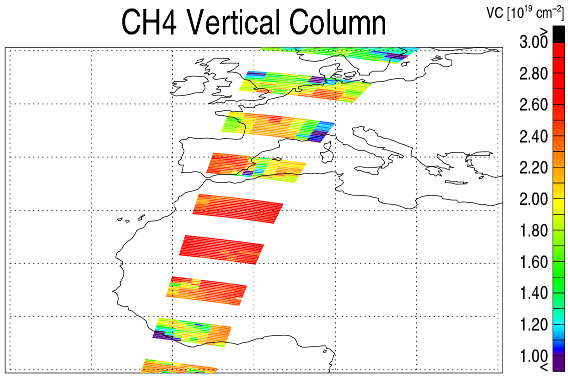

Figure 3: Methane vertical columns retrieved with WFM–DOAS. The column over the cloud free Sahara region is underestimated by approx. 25%. Note that central Europe and the region approx. 0°-15°N latitude (approx. the last quarter of the part of the orbit shown here) are partially covered by clouds and that no cloud correction or filtering has been applied.

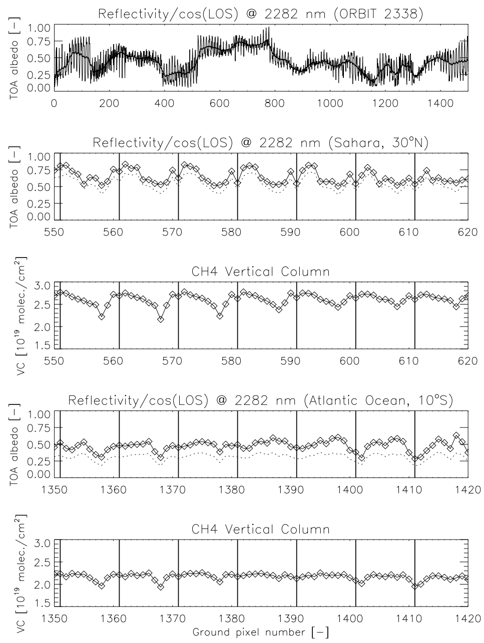

Figure 4: Top panel: Reflectivity (divided by the cosine of the line–of–sight zenith scan angle) at 2282 nm as a function of ground pixel number. As can be seen, the reflectivity shows a high frequency variability correlated with the (5 s) scanning sequence all along the orbit. The last four panels show parts of this data in more detail along with the retrieved methane column. The vertical lines mark the most eastward ground pixel indicating the beginning of a new (5 s) scan. The dashed lines show the sun–normalized radiance without any cosine divisions to demonstrate that the radiance shows the same scan angle dependence as the reflectivity. The same scan angle dependence is also visible in the raw data (not shown). The retrieved methane column correlates with the radiance.

and at the end of channel 8). A small error in dark signal correction can result in a relatively large radiance error. This error increases with decreasing surface albedo as the relative importance of the dark signal correction gets larger for decreasing atmospheric radiance levels. Another important finding is that the presently used spectral calibration (which is still based on on–ground measurements) needs to be adjusted by approx. -0.3 nm (3 pixels) in this spectral region.

2.2 Fitting window 2281.5-2284.8 nm

This is the spectral region also containing some (week) N_2O lines. The driver for the selection of this window is CH_4 (see Fig.2). Methane vertical columns derived along the orbit are shown in Fig.3. Fig.4 basically shows the same data as a function of ground pixel number along with the (normalized) radiance. As can be seen, the radiance as well as the methane columns show a large (unexpected) variability related to the nadir scanning sequence, probably resulting from imperfect calibration. Note that the absolute value of the reflectivity seems to be too high, probably due to too low values ($\sim$50%) of the solar irradiance (sun mean reference spectrum D1), and probably also due to imperfect calibration of the nadir radiances.

3 LEVEL 2 BIAS PRODUCTS

The BIAS derived trace gas vertical column densities of CH_4, CO, N_2O, and H_2O given in the initial Level 2 verification data product largely deviate from climatological values and cannot be considered scientifically useful at present. This is most probably due to the imperfect calibration of the Level 1 spectra.

4 CONCLUSIONS

Initial SCIAMACHY Level 1c and 2 data products compiled for verification purposes have been used and investigated in this study. Although the spectra are not yet fully calibrated, the spectral signatures of CH_4 and H_2O (and channel 7 CO_2) have clearly been identified. At present the fit residuals are, however, too large to clearly identify the weak NIR absorbers CO and N_2O. The fit residuals are currently dominated by systematic (rather stable) spectral features, not by instrument noise. This study suggests that the spectral and radiometric calibration of the channel 8 (and probably also channel 6 and 7) nadir and solar spectra needs to be significantly improved to enable the retrieval of accurate vertical column amounts of, e.g., CH_4 and CO. The initial Level 2 (BIAS) CH_4, H_2O, CO, and N_2O vertical column data products compiled for verification purposes strongly deviate from climatological values. They cannot be considered scientifically useful at present. This is probably due to the still incomplete calibration of the Level 1c spectra (imperfect spectral calibration, missing polarisation correction, etc.).

5 REFERENCES

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