Application of the GEOFIT analysis to real MIPAS data: from a scientific to an operational code

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INTRODUCTION

Recently an innovative forward and retrieval model for the analysis of satellite limb-scanning measurements, which does not make use of the horizontal homogeneity assumption, was developed [1]. In the new system the radiative transfer is made through a two-dimensional inhomogeneous atmospheric field. The retrieval algorithm is based on the simultaneous analysis of limb-scanning measurements of a whole orbit. This approach fully accounts for the horizontal variability of the atmosphere. At the same time it allows to gather information on the target atmospheric parameters from several contiguous limb-scanning sequences hence improving the trade-off between accuracy and horizontal resolution. The system, named GEOFIT, was successfully tested using MIPAS (Michelson Interferometer for Passive Atmospheric Sounding) simulated observations.

Initially the GEOFIT was designed only as a tool suitable for feasibility studies and therefore contained several simplifications not adequate for the analysis of real data. Now, since the successful launch of the ENVISAT satellite on March 1st, 2002, MIPAS is measuring high-quality middle-infrared limb-emission spectra of the atmosphere. In order to test the newly developed retrieval system on these measured data, the GEOFIT was adapted for real data analysis and is now providing the first results highlighting the importance of modelling the horizontal variability of the atmosphere especially in presence of discontinuities such as observed in proximity of the polar vortex.

THE RETRIEVAL MODEL

The GEOFIT retrieval system is based on the non-linear least squares fit carried-out with the Gauss-Newton method. No regularization or a-priori information on distribution of target molecules is used. The vector of the observations to be fitted includes a set of narrow (< 3 cm^{-1}) spectral intervals sampled at various depths in the atmosphere (limb scanning angles) along the full satellite orbit. The spectral intervals used for the retrieval are selected according to an optimised procedure [2] aiming at the minimisation of the total retrieval error compatibly with the available computing resources. The retrieval state vector includes the atmospheric distribution of the target gas sampled at a set of grid points defined by the user through their altitude and latitude. The retrieval grid used for the tests presented here consists of a set of vertical profiles located at the average latitudes of the tangent points of the individual limb-scans. Each individual profile is sampled at the nominal altitudes of the tangent points of the scan.

THE FORWARD MODEL

The forward model included in the retrieval algorithm is based on the forward model developed by our team for MIPAS near real-time data analysis [3] and validated against several accurate radiative transfer models available in Europe [4]. As additional feature the system implements the capability of modelling the horizontal variability of the atmosphere sounded by the line of sight of the instrument. This feature is obtained by operating a discretization of the atmosphere in both the horizontal and the vertical domain, as shown in Fig. 1. Each element of the discretized atmosphere (clove) is considered as having constant physical properties defined by Curtis - Godson pressure, temperature and gas slant columns. The radiance that reaches the instrument is obtained as the superposition of the emission of the individual cloves that is partially absorbed by the atmosphere between the considered clove and the instrument.

The measured radiance is finally obtained by convolving the high resolution atmospheric emission by the instrumental response in both the frequency (Instrument Line Shape) and the limb-viewing angle (Field of View) domains.

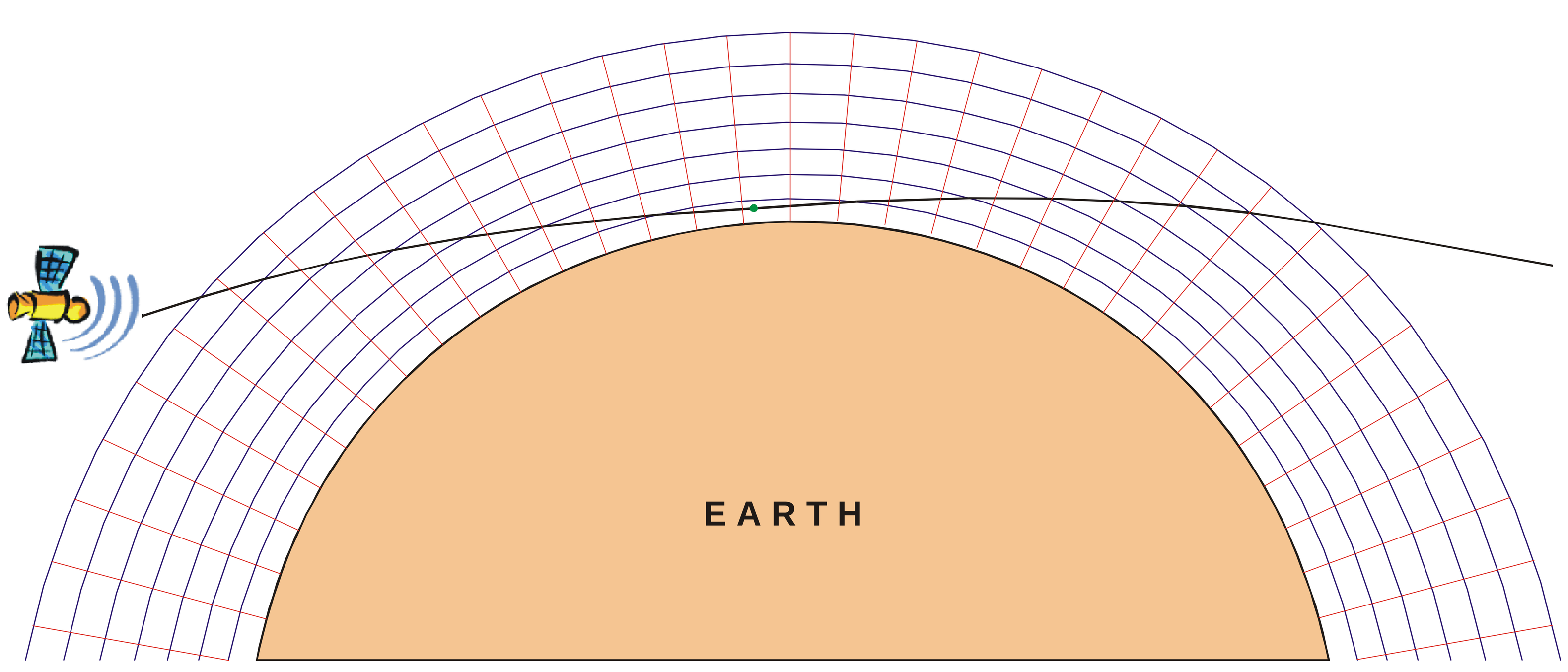

Fig. 1: Discretization of the atmosphere operated by the forward model. The line of sight bends toward the earth due to the refraction.

ADAPTATION OF THE SYSTEM TO HANDLE REAL MIPAS DATA

The GEOFIT retrieval system was initially developed by our team [1] to demonstrate the feasibility of a two-dimensional retrieval approach with the main advantage of overcoming the horizontal homogeneity assumption. For this reason the initial version of the GEOFIT adopted several simplifications in the earth and atmospheric models. While not affecting the results of feasibility studies, these simplifications are not adequate for the analysis of real measurements. In particular, compared to the initial GEOFIT version, the following new features were implemented in the modified retrieval algorithm:

- elliptical earth shape
- treatment of corrupted / cloudy measurements
- interface with ESA's Level 1 and Level 2 near real-time MIPAS products

These new features allowed the comparison between profiles retrieved in the horizontal homogeneity assumption (ESA's Level 2 processor, named ORM) and considering the horizontal variability of the atmosphere (GEOFIT).

IMPACT OF THE HORIZONTAL HOMOGENEITY ASSUMPTION

The impact of the horizontal homogeneity assumption was evaluated by comparing atmospheric distributions retrieved with the one-dimensional and the two-dimensional retrieval algorithms in case of both simulated and real MIPAS measurements. The results of tests based on synthetic observations are reported in [1], we report here the preliminary results obtained from the tests based on real MIPAS measurements.

In Fig. 2 we show the ozone volume mixing ratio (VMR) distribution obtained by operating the GEOFIT algorithm on MIPAS data acquired during orbit 2081 (July 24th, 2002). The horizontal axis is an orbital angular coordinate linked to the latitude of the measurements: 0° = north pole, 90° = equator descending node, 180° = south pole, 270° = equator ascending node.

Fig. 3 reports the percentage estimated standard deviation (ESD) of the retrieved ozone distribution scaled by the square root of the reduced chi-square of the fit (this quantity is expected to represent a rough estimate of the total retrieval error).

Fig. 4 shows the absolute differences between ozone VMR obtained from the one-dimensional retrieval system (ORM) implemented in ESA's ground processor and the GEOFIT algorithm.

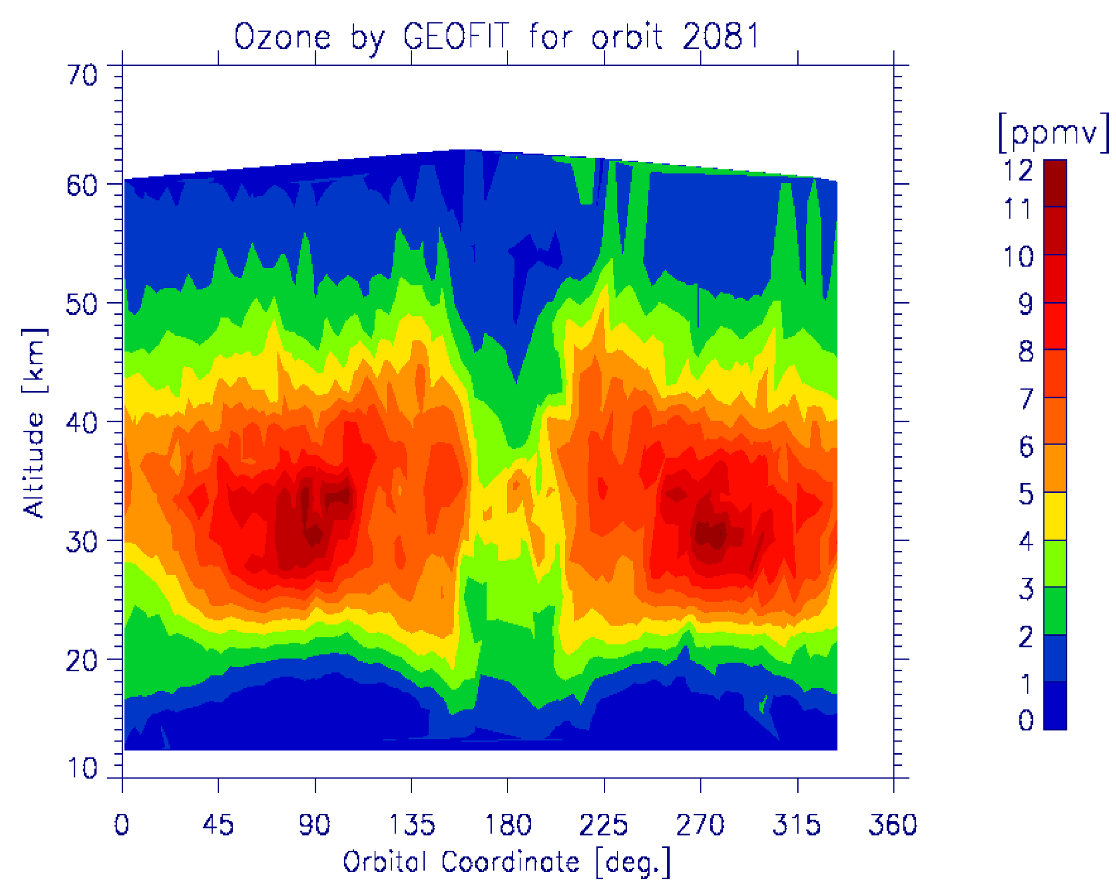

Fig.2: Ozone distribution retrieved by GEOFIT using MIPAS data relating to orbit 2081 on 24 July 2002.

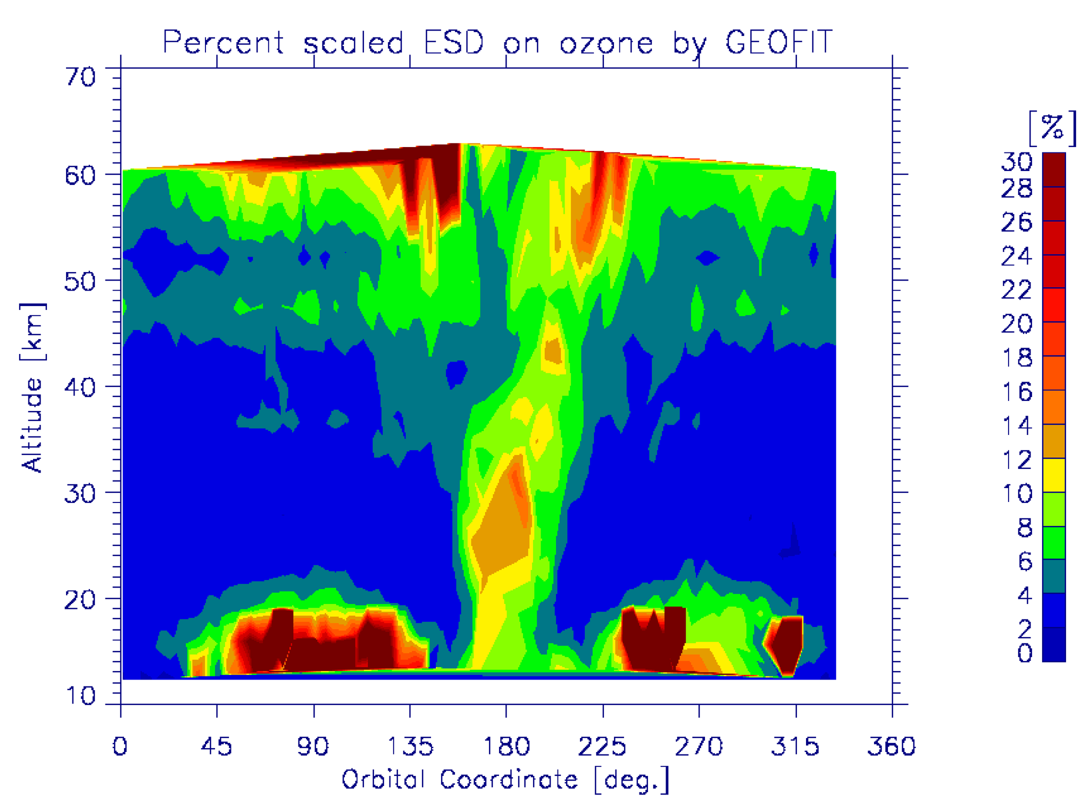

Fig.3: Scaled ESD for the ozone distribution retrieved by GEOFIT.

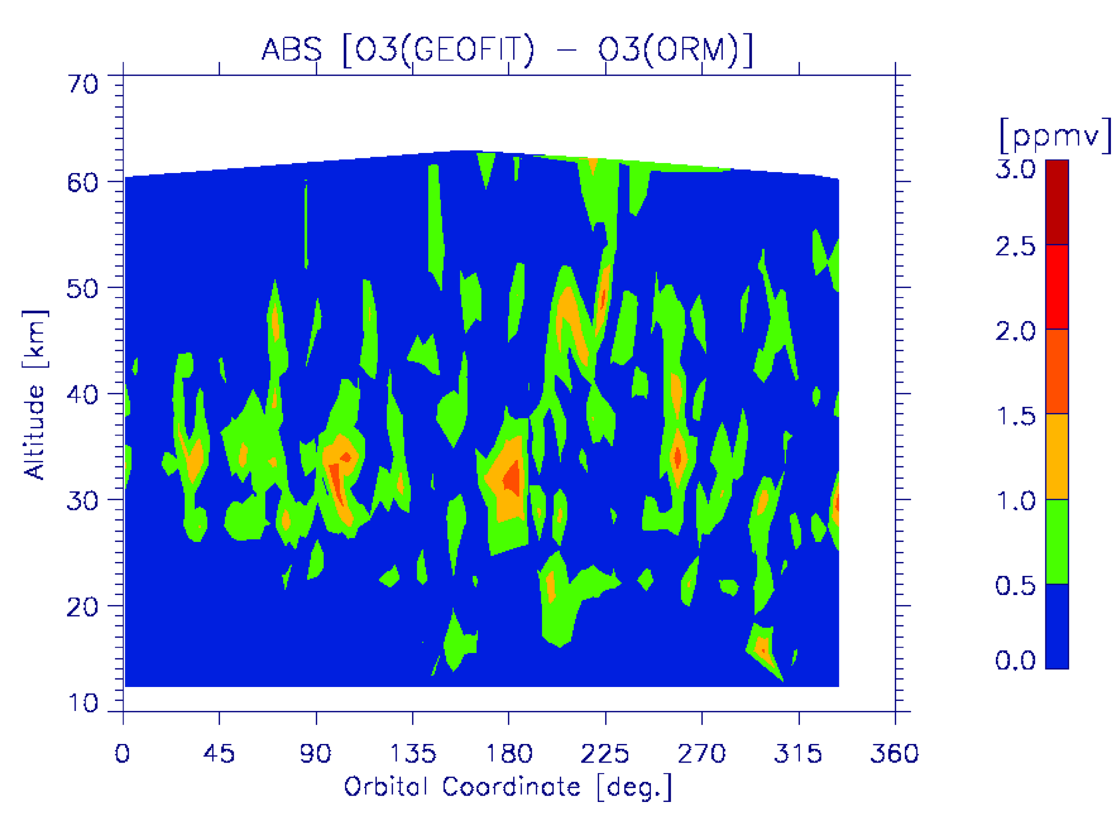

Fig.4: Absolute differences between the GEOFIT retrieved ozone VMR and the VMR retrieved by the 1D retrieval system (ORM). The same set of observations was used in both retrievals.

CONCLUSIONS

The observed differences between ozone VMR retrieved from MIPAS measurements with and without consideration of horizontal homogeneity assumption are significant, especially in case of important horizontal structures in the atmosphere (southern polar vortex and equator). These differences represent a systematic error affecting the VMR profiles retrieved under the horizontal homogeneity assumption. The above results, even if very preliminary, show that this systematic error may easily exceed the retrieval error due to measurement noise.

In the future the above tests will be repeated for a statistically significant set of MIPAS measurements and the impact of horizontal homogeneity assumption will be evaluated also for the MIPAS key parameters other than ozone. Furthermore the system will be adapted to carry-out simultaneous pressure and temperature retrievals.

So far the GEOFIT approach requires 1Gb RAM memory and 1-hour CPU time for retrieval of ozone distribution along a full MIPAS orbit on a COMPAQ ES45 server with 1GHz CPU clock.

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