

# On the accuracy of GOME and SCIAMACHY total ozone measurements in polar regions

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## INTRODUCTION

Total ozone retrieval algorithms operationally applied to GOME and SCIAMACHY have been based on the Differential Optical Absorption Spectroscopy (DOAS) technique already for several years. Validation exercises have shown that DOAS reaches retrieval results within the targeted 1% level in the low- and mid-latitude regions. However, in polar regions, correlative studies involving reference ground-based and complementary satellite data sets (e.g. from the NASA TOMS instrument) reveal larger discrepancies that point out to persisting accuracy issues, both from space and ground-based measurements.

Within the ESA-funded GODFIT project, the BIRA-IASB/RT-Solutions consortium has developed an advanced retrieval algorithm based on a direct fitting approach where backscattered spectral radiances simulated using the radiative transfer model LIDORT v2.5+ are fitted to measured radiances in a physically consistent way. This algorithm is used to investigate total ozone retrieval issues in polar regions. Sensitivity tests show the influence on retrieved total ozone columns of key input parameters such as cloud parameters (FRESCO or OCRA-ROCIINN), O<sub>3</sub> climatology (TOMS v8 or DOC), surface albedo, and temperature profile data bases. The two SAUNA campaigns in Sodankylä (67° N, 26° E) provide good opportunities to realize these sensitivity tests. Overall this leads to a better understanding of persistent discrepancies between satellite and ground-based measurements. Based on these results, one expects a consolidation of the retrieved GOME and SCIAMACHY O<sub>3</sub> columns in polar regions, even at high solar zenith angle.

## THE GODFIT ALGORITHM

- Direct fitting of the simulated radiances with LIDORT v2.5+ to the measured ones.
- One-single step fit: neither slant columns nor air mass factors as in DOAS.
- Simulated radiances and weighting functions calculated « on-the-fly »; no Look-Up-Tables.
- Effective temperature fixed at a value depending on the temperature profile used as input.
- Important to use one O<sub>3</sub> cross-section data set for both instruments to avoid inconsistencies due to different temperature dependencies. The Daumont et al. data, used in this work, lead to high quality fits.

• Fitting window: 325 nm - 335 nm

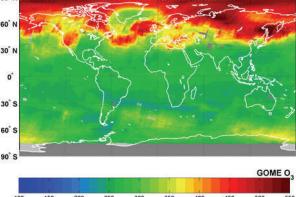


Fig. 1: Total ozone columns issued from the GOME measurements between the 1st and 3rd April 1999 using the GODFIT algorithm.

## TEMPERATURE PROFILE

- 2 possibilities:

1. The TOMS v8 climatology provides one profile for each month and 10° latitude band. The temperatures are given in 13 pressure layers (from 1013 to 0.03 mbar). A latitude and time interpolation is realized in GODFIT.
  2. The ECMWF provides temperature profiles every 6 hours on a 1° × 1° horizontal grid. Despite their better vertical resolution (37 levels), the temperatures are interpolated on the TOMS pressure grid.
- Fig. 2 illustrates that a temperature profile change leads to total O<sub>3</sub> relative differences linearly related to the effective temperature absolute differences via the temperature dependence of the O<sub>3</sub> differential cross-sections.
- Fig. 3 shows that using ECMWF temperature profiles instead of the TOMS v8 ones lead to O<sub>3</sub> differences generally ranging between -1% and -2% though they can be much larger in some conditions.
- Fig. 4 shows these important differences during the second SAUNA campaign (February-March 2007). Their magnitude also vary quickly in time.

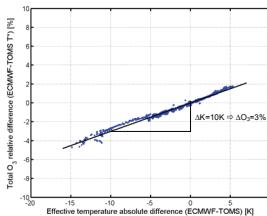


Fig. 2: Influence of the effective temperature on the retrieved O<sub>3</sub> columns for the GOME #23802 orbit.

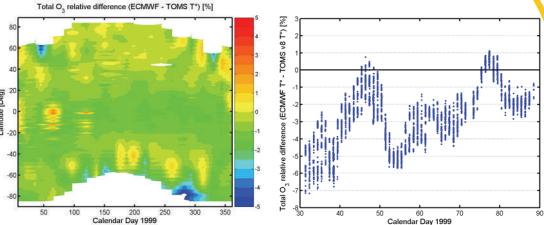


Fig. 3: Total O<sub>3</sub> relative differences using the ECMWF temperature profiles or the TOMS v8 ones for 24 GOME orbits in 1999.

Fig. 4: Total O<sub>3</sub> relative differences using the ECMWF temperature profiles or the TOMS v8 ones for SCIAMACHY retrievals around Sodankylä during second SAUNA campaign.

## O<sub>3</sub> PROFILE CLIMATOLOGY

- 2 total O<sub>3</sub>-climatologies were tested:
  1. The TOMS v8 climatology provides profiles for each month and 10° latitude band. They are constituted of partial columns given in 11 pressure layers.
  2. The DOC climatology provides VMR<sub>O3</sub> and p<sub>O3</sub> for 61 altitude levels (from 0 to 60 km). They are binned in 30° latitude bands and also in six-month seasons (winter/spring and summer/fall), except for the tropics. In this work, the DOC profiles were integrated in order to have partial columns in the TOMS v8 layers.
- The relative differences between O<sub>3</sub> columns using TOMS v8 or DOC profiles are strongly dependent on the latitude band, especially in the ±30°±40° band (Fig. 5). However, the differences are not constant in a latitude band (Fig. 6) as the climatologies are total O<sub>3</sub>-classified and above all the retrieved columns are differently affected by the cloud coverage depending on the O<sub>3</sub> profile shape.
- The influence of the O<sub>3</sub> profile on the retrieved column is the largest at low solar elevation (high solar zenith angles) as illustrated in Figs. 7 and 8.

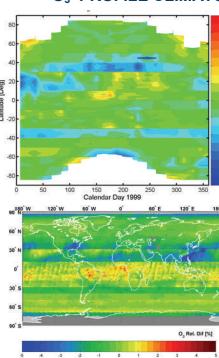


Fig. 5: Latitude dependence of the O<sub>3</sub> relative differences (DOC - TOMS v8) for 24 GOME orbits in 1999.

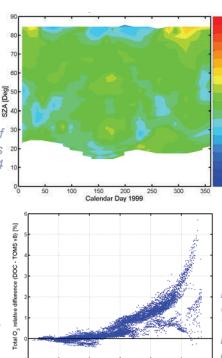


Fig. 6: O<sub>3</sub> relative differences (DOC - TOMS v8) for the GOME orbits of the 1-2-3 April 1999.



Fig. 7: SZA-dependence of the O<sub>3</sub> relative differences (DOC - TOMS v8) for 24 GOME orbits in 1999.

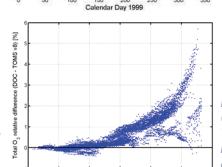


Fig. 8: SZA-dependence of the O<sub>3</sub> relative differences (DOC - TOMS v8) for SCIAMACHY retrievals around Sodankylä during second SAUNA campaign.

## CLOUD ALGORITHM

- For the GOME instrument, the cloud parameters coming from two algorithms can be used:
  1. The OCRA/ROCIINN algorithm provides the cloud fraction (CF), cloud top albedo (CTA) and cloud top pressure (CTP). There is an ice mode for high surface albedo pixels in which CF is set to 1.
  2. The FRESCO algorithm gives the CF and CTP while the CTA is set to 0.8. There is also an ice mode for high surface albedo pixels in which CF is set to 1 and CTP and CTA are provided.
- The cloud parameters issued from both algorithms are compared in Fig. 9. The cloud radiances (CTA × CF) are in good agreement for normal pixels while, for ice mode pixels, they are generally larger for FRESCO than for OCRA/ROCIINN. The CTP from both algorithms are also relatively well correlated though the dispersion is more important and the FRESCO values are slightly larger.
- Fig. 9 shows also that the O<sub>3</sub> relative differences using these two algorithms come mainly from the CTP differences for normal pixels while they are also due to the CTA differences for ice mode pixels.
- Fig. 10 illustrates that the cloud parameter differences lead to O<sub>3</sub> relative differences generally lower than 2%. However, they can reach 4% for the ice mode pixels.

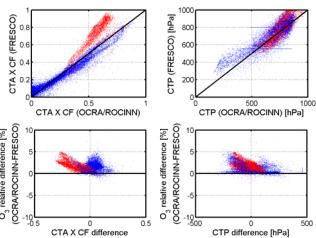


Fig. 9: Upper panel: Comparison of cloud parameters (CTA × CF, CTP) for normal mode (in blue) and ice mode (in red) for 24 GOME orbits. Lower panels: influence of the parameter differences on the total O<sub>3</sub> columns.

Fig. 10: O<sub>3</sub> relative differences (OCRA/ROCIINN - FRESCO) for the GOME orbits of the 1-2-3 April 1999.

## SURFACE ALBEDO

- Fig. 11 illustrates the air mass factor errors due to surface albedo uncertainties for different SZA. They increase linearly with albedo errors and are not very dependent on the SZA.

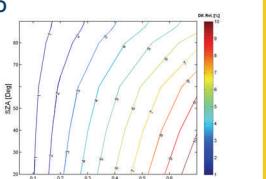


Fig. 11: AMF relative errors due to uncertainties on the surface albedo for different SZA.

## CONCLUSIONS

- It is advised to use the more realistic ECMWF temperature profiles instead of profiles provided by climatologies as it may lead to important differences.
- The sensitivity of the retrieved column to the O<sub>3</sub> profile is the largest at high SZA and the choice of an adequate O<sub>3</sub> profile is then crucial for the polar regions. The differences between O<sub>3</sub> columns issued from the TOMS v8 or DOC climatology depend also on the latitude band and are quite important in the ±30°±40° band.
- The OCRA/ROCIINN cloud algorithm leads to slightly higher O<sub>3</sub> columns than the FRESCO one. These differences are far more marked for the high albedo surface pixels, in a large majority in the polar regions.
- The uncertainties on the surface albedo may be quite important in polar regions where the surface albedo change strongly and quickly during season change giving rise to possible important errors on the total O<sub>3</sub> columns.
- During the validation phase of GODFIT, we will focus especially on the polar regions in order to determine the best key input parameters to use for O<sub>3</sub> retrievals with GODFIT.