The GODFIT algorithm: a direct fitting approach to improve the accuracy of the total ozone measurements

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INTRODUCTION

The global monitoring of the long-term trend of the ozone concentrations in our atmosphere is a key task to watch the expected recovery of the ozone layer, but also to improve our understanding of the interactions between the global warming and the ozone production/destruction processes. The combined total ozone measurements from GOME, SCIAMACHY and GOME-2 constitute a data set covering more than 12 years and is expected to be continued at least until 2020 (cf. talk of Loyola et al. in session 10).

Since the onset of the ERS-2 GOME observations in 1995, total ozone has been operationally retrieved using algorithms based on the Differential Optical Absorption Spectroscopy (DOAS) technique. Despite the continued improvements and the high accuracy achieved over the years, culminating with the latest version of the GOME processors GDP 4.2 (also used for SCIAMACHY and GOME-2), correlative studies reveal unresolved discrepancies with ground-based reference observations as well as with complementary satellite data set, particularly for large solar zenith angles.

The BIRA-IASB/RT-Solutions consortium has developed a direct fitting retrieval algorithm (GODFIT) in which simulated backscattered spectral radiances from the radiative transfer model LIDORT v3.3 are fitted to measured radiances in a physically consistent way. Here, we compare the GOME total O_3 columns retrieved with GODFIT to the OMI columns retrieved with the TOMS algorithm. It is also shown that using GODFIT leads to a further decrease of the seasonalities in the ground-based – satellite differences and to an improvement of the accuracy of the measurements at high latitudes. GODFIT is currently being implemented into the operational UPAS processor which will end up with the new GDP 5.0 total ozone data product to be issued in spring 2009. In this frame, we also focus on the computational performance of the algorithm.

THE GODFIT ALGORITHM

- **Direct fitting** of the simulated radiances with LIDORT v3.3 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.
- **Temperature profiles** provided by **ECMWF** every 6 hours on a 1°×1° horizontal grid.
- The O_3 profiles are provided by the **TOMS v8** climatology for each month and 10° latitude band.
- For GOME, the **cloud parameters** (cloud fraction, cloud top height and cloud top albedo) used for the cloud correction come from:
  - Either the **OCRA/ROCINN** algorithm, which is integrated in GODFIT itself,
  - or the **FRESCO+** algorithm which provides auxiliary input to GODFIT.
- Parameterized **molecular Ring correction**.
- Surface albedo/aerosols better handled, due to **internal closure** mode.
- **O_3 cross-section** data set: The **Daumont et al. data** lead to **high quality fits**.
- Fitting window: 325.0 nm - 335.0 nm.

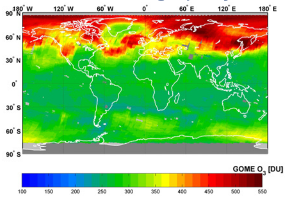

Fig. 1: Total ozone columns issued from the GOME measurements between the 1st and 3rd April 1999 using the GODFIT algorithm.

COMPARISONS WITH OMI (TOMS)

In this section, the GOME total O_3 columns derived using GODFIT are compared to the OMI columns retrieved with the TOMS algorithm (*http://toms.gsfc.nasa.gov*). The data considered for these comparisons lie between August 2004 and January 2007. The overpass criteria was that respective measurements are within 250 km and 5 hours from each other.

- Figure 2 shows the mean relative differences between the GODFIT O_3 columns and the OMI columns as a function of the latitude and the month of the year. The overall agreement is very satisfactory as the differences generally range between –1% and 0%. The differences are slightly larger in winter for both hemispheres.

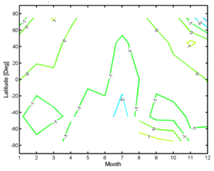

Fig. 2: Latitude and intra-annual dependencies of the mean relative differences between the GODFIT and the OMI columns.

- Figure 3 shows the solar zenith angle dependencies of the mean GODFIT-OMI relative differences for both hemispheres. In Northern Hemisphere, the differences, slightly negative for low SZA, become close to zero and then slightly positive when SZA increases. For SZA larger than 80°, the differences are negative and a bit larger. In Southern Hemisphere, the slightly negative differences are fairly not dependent on SZA.

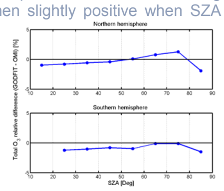

Fig. 3: SZA dependence of the mean relative differences between the GODFIT and the OMI columns for both hemispheres.

- As illustrated in Fig. 4, no significant total O_3 column dependence in the GODFIT-OMI differences is visible, whatever the hemisphere.

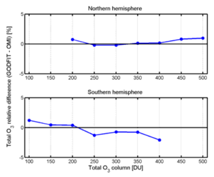

Fig. 4: Total O_3 column dependence of the mean relative differences between the GODFIT and the OMI columns for both hemispheres.

COMPUTATIONAL PERFORMANCE

- Main **shortcoming** of GODFIT: slow **performance** of the algorithm. Indeed, the radiative model is called for each wavelength of the fitting window instead of 2 times in the DOAS technique. For GOME O_3 retrievals, the processing time is 40 times larger using GODFIT.
- **Resampling** of measured spectra (with a coarser grid) ➔ **Reduction of processing time**.
  - Requires a **lowering of the resolution** (in order not to lose information content) by convoluting the spectra with a Gaussian function.
  - Impact on total O_3 columns?
- The relative differences between the O_3 columns retrieved from degraded GOME spectra and from original spectra are negligible for any SZA lower than 70° and for a Gaussian width up to 0.5 nm (Fig. 8.a).
- The maximum resampling step has to be adjusted depending on the resolution of the spectra so that the information content is sufficient to retrieve physical columns (Fig. 8.b).
- Resampling of GOME spectra (resolution= ~0.53 nm, sampling step=0.33 nm - Fig. 8.c)
  ➔ Processing time divided by **3**. Only applied for pixels with SZA < 70°.

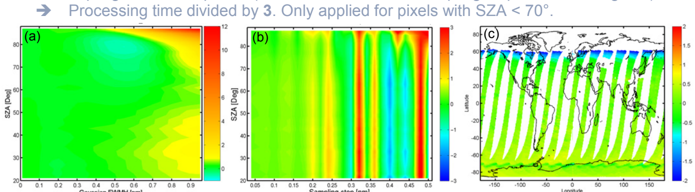

Fig. 8. O_3 column relative differences due to the degradation and/or the resampling of the measured spectra. (a) Impact of the resolution degradation as a function of the SZA and the degradation itself for one GOME orbit (#29396); (b) Impact of the resampling of GOME spectra (resolution = ~0.27 nm) as a function of the SZA and the sampling step for one GOME orbit (#29396); (c) Impact of the resampling with a step of 0.33 nm for all GOME spectra degraded at a resolution of ~0.53 nm on 3rd December 2003.

VALIDATION

In the frame of the second phase of the GODFIT project, the total O_3 columns retrieved from GOME-1 using the direct fitting approach were validated with data from 55 stations belonging to the NDACC and the WOUDC (Fig. 5). For this validation, four years of GOME data were selected in order to test GODFIT in extreme conditions (« warm » and « cold » years in 1999 and 2000, unpredictable vortex split of September 2002).

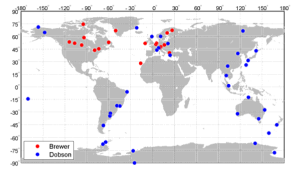

Fig. 5: Geolocation of the NDACC and WOUDC stations considered for the validation of the GOME total O_3 columns derived with GODFIT.

From this validation, it was concluded that:

- No obvious long-term trend in the satellite-GB differences.
- GODFIT reproduces well unpredictable interannual variations (e.g. "warm" and "cold" years) and unexpected events (e.g. vortex split of 2002).
- With respect to GDP v4.1:
  - At most of stations, GODFIT decreases the standard deviation of satellite-GB differences by 0.5-1.1%.
  - The residual cyclic signatures in the GOME/Brewer comparisons observed at Northern mid-latitudes with GDP 4.1 are strongly attenuated (Fig. 6).
  - The solar zenith angle dependence is slightly improved (Fig. 7).
  - The column dependence is small and comparable to GDP v4.1 (Fig. 7).
  - The GOME-GB agreement is considerably improved in Antarctica (Fig. 7).

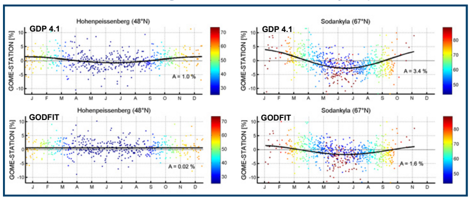

Fig. 6: Illustration of the reduction of the persistent seasonalities in the satellite-GB differences using GODFIT instead of GDP 4.1 for two Northern mid-latitude stations.

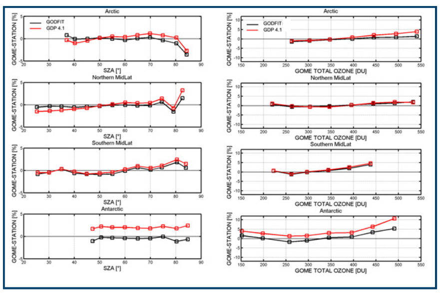

Fig. 7: Solar zenith angle and total column dependencies of the GOME-GB differences binned in various latitude bands. The differences are plotted for the GOME columns derived using GODFIT and GDP 4.1.

CONCLUSION

GODFIT is an algorithm developed by the BIRA-IASB/RT-Solutions consortium for total O_3 retrievals and is based on the direct-fitting technique instead of the classical DOAS technique. Applied to the GOME L1 spectra, it leads to total O_3 columns in very good agreement with the columns derived from OMI. Preliminary validation has also showed that this algorithm behaves still better than the GDP 4 algorithm, especially at large solar zenith angle and above Antarctica. Also, persistent seasonalities in the GDP 4 product are further reduced using GODFIT. Unfortunately, such an improvement is realized at the cost of the computational performance, slower than that of the DOAS technique. However, a factor 3 in the processing time can be saved by resampling the spectra. In the future, a substantial gain in processing performance will be realized using LIDORT v3.5, which permits parallel computing. Finally, the ongoing implementation of GODFIT into the UPAS operational system will lead to the 5th version of the GOME data processor.

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