

# High-precision total ozone measurements from space using a direct-fitting retrieval approach

Christophe Lerot, Jeroen van Gent, Michel Van Roozendael, Jean-Christopher Lambert, José Granville

## Introduction

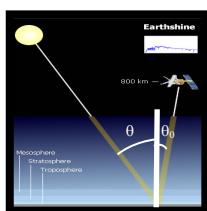
The global monitoring of the long-term trend of ozone concentrations and its day-to-day variability is a key environmental task in the study of our changing atmosphere. Indeed, a gradual recovery of the ozone layer is expected in the next decades as a consequence of the application of the Montreal protocol and its amendments. Currently, the question related to the timing of full recovery is still open. Moreover, such observations help to improve our understanding of the interactions between global warming and ozone production/destruction processes.

The different ultraviolet/visible spectrometers GOME, SCIAMACHY and GOME-2, respectively on board of the European satellite platforms ERS-2, ENVISAT and METOP-1, constitute a combined ozone column data set covering more than 13 years, expected to be continued at least until 2020.

The Belgian Institute for Space Aeronomy has developed an advanced total ozone retrieval algorithm (GODFIT) by fitting simulated backscattered spectral radiances from a radiative transfer model to measured radiances in a physically consistent way. The accuracy of the measurements realized with GODFIT is shown to be improved with respect to previous retrieval methods, especially in polar regions. The state-of-the-art algorithms developed at BIRA-IASB are operationally applied at the German Aerospace Center on behalf of the European Space Agency (ESA).

### From slant columns to total columns...

- Ozone slant columns are generally retrieved in the spectral window [325 nm - 335 nm].
- Slant column  $N$ : number of  $O_3$  molecules along the mean photon path through the atmosphere.
- The needed measurement is the total column  $V$ : number of  $O_3$  molecules between the satellite and the ground in the nadir direction.
- The conversion is realized via the calculation of an air mass factor  $AMF = N/V$ .
- Geometrical approximation:



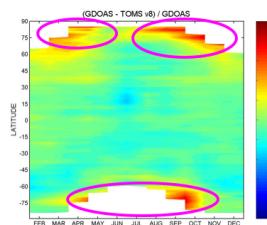
$$AMF = \frac{1}{\cos \theta} + \frac{1}{\cos \theta_0}$$

→ Rough approximation; leads to large errors.

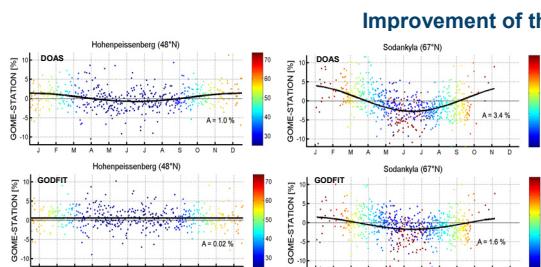
- The AMF is **more accurate** when calculated using **radiative transfer models** (LIDORT v3.3). These models simulate the real path of the radiation (at one wavelength) through a given state of the atmosphere.

## Limitations of DOAS

- The DOAS method is **only applicable** if the effective photon path-length through the absorbing layer of interest doesn't vary too much with the wavelength (**optically thin atmosphere**).
- The air mass factor is calculated at only 1 wavelength in the fitting interval.
- Ozone is a **strong absorber** in the UV and has large concentrations in the atmosphere
- The DOAS approximation may be not valid for  $O_3$  retrievals, especially for high total ozone columns and/or low solar elevation (or high solar zenith angle) conditions. This makes the  $O_3$  retrievals in Polar Regions less accurate.

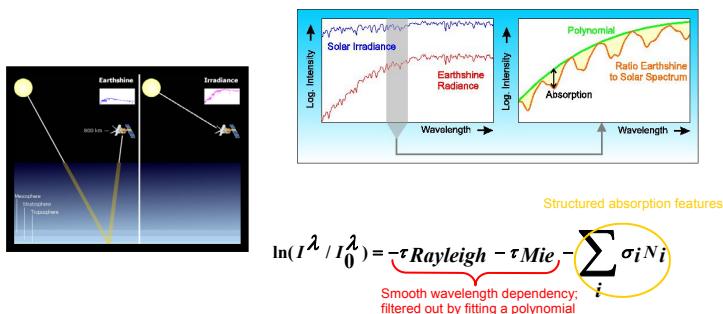


Subsisting discrepancies in low solar elevation conditions between the total  $O_3$  columns retrieved from GOME measurements using DOAS compared to other satellite data set (left plot) or to ground-based measurements (right plot).



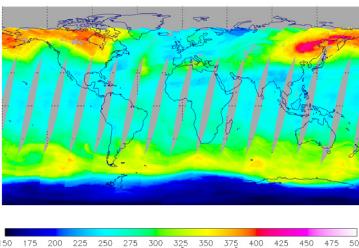
**Acknowledgements** - The GODFIT algorithm development was supported by the European Space Agency through the GODFIT and GDP 5 projects. The SCIAMACHY operational  $O_3$  product is monitored by the SCIAMACHY Quality Working Group funded by ESA. The DOAS  $O_3$  retrieval algorithm was adapted to the GOME-2 instrument in the framework of the EUMETSAT-funded project GOME-2 TOOLS.

## Differential Optical Absorption Spectroscopy (DOAS)

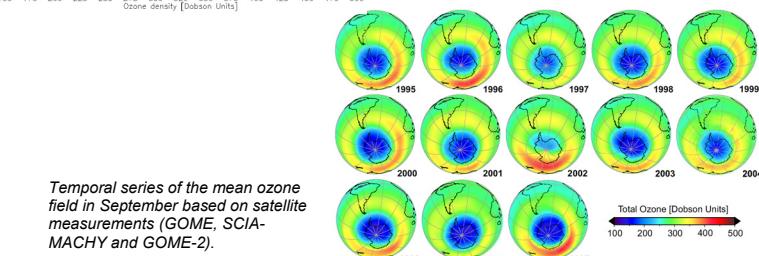


where  $\sigma_i$  = reference differential cross-section of species  $i$ .  
 $N_i$  = slant column of species  $i$ ; adjusted in the fit DOAS.

## Applications

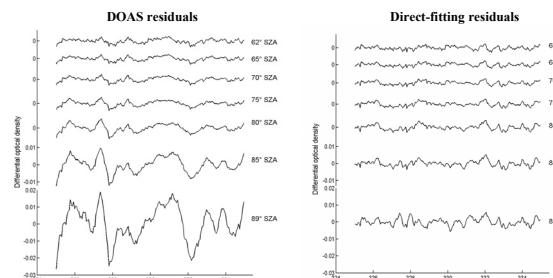


State of the ozone field on 16th November 2008. The total  $O_3$  columns are retrieved from GOME-2 measurements using the DOAS technique.

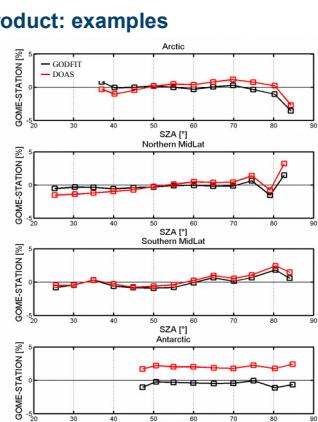


## GODFIT: a high precision direct-fitting retrieval approach

- Direct fitting** of the simulated radiances at every wavelength of the fitting window with the radiative transfer model (LIDORT v3.3) to the measured ones using a least-squares procedure.
- One-single step fit**: neither slant columns nor air mass factors as in DOAS. The total  $O_3$  column is one of the quantities derived from the fit.
- Technique much more **physical**.
- Results more accurate**, especially at high solar zenith angles (low solar elevation)..
- Shortcoming: retrievals more time-consuming.



Improvement of the fit quality at high solar zenith angles using a direct-fitting approach compared to the DOAS technique.



Solar zenith angle dependency of the differences between satellite (GOME) and ground-based measurements in various latitude bands. The differences are plotted for the GOME columns derived using DOAS or the direct-fitting approach.

