GOMOS/ENVISAT ozone error budget and ozone variability in the tropical middle atmosphere

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Abstract. The accuracy of GOMOS ozone measurements has been estimated from the dispersion of a series of profiles acquired around the globe at a fixed tropical latitude, where the atmospheric variability is expected to be minimum. A refined version of this method (the double difference method) allowed us to derive also the atmospheric variability. The best accuracy is obtained at 20-30 km (1 to 2%) and at 60 km (1%). The accuracy is degraded by the effect of atmospheric turbulence on star spectra at 35-45 km (around 4%). The atmospheric variability around a latitude circle ranges between 2 and 5 % at altitudes from 20 to 65 km and is as high as 20-25% in the upper mesosphere (70-90 km).

Introduction

The main objective of GOMOS/ENVISAT instrument is to built a global climatology of ozone in the middle atmosphere (15 to 100 km) with a very high accuracy. This climatology will be used to study the atmospheric natural variability, to test the validity of chemistry-transport models and as a reference for future trend studies. GOMOS night time measurements are especially well adapted for this task due to their self-calibrating nature and the perfect knowledge of their altitude, a particularity of the star occultation technique. A realistic estimation of the accuracy of GOMOS ozone profiles is crucial to assess the quality of the climatology. The accuracy, deduced from the error budget of instrument noise, may be strongly underestimated in the stratosphere due to the perturbation of star spectra by atmospheric turbulence (star scintillations). We propose here a method to estimate the error budget. It is based on the computation of the dispersion around their mean value of a series of slant path column ozone profiles in a small latitude band in the tropical region, where the ozone longitudinal dependence is assumed to be weak. A refined version of this method (the double difference method) allowed us to separate at least partially the contribution of measurement error and atmospheric variability in the observed dispersion.

Method

GOMOS is based on the principle of stellar occultation [Bertaux et al., 1988]. When a star sets behind the atmosphere, its light is absorbed by atmospheric constituents. Each constituent can be identified by its absorption spectrum. The atmospheric transmission spectrum is equal to the ratio between the star spectrum absorbed by the atmosphere and the reference star spectrum measured outside the atmosphere. The spectral range of the UV-visible spectrometer, from 250 to 680 nm, allows to determine of O3, NO2, NO3, aerosols and atmospheric density from Rayleigh extinction. Star spectra are affected by scintillations due to small-scale perturbations in atmospheric density induced by turbulence. Due to this effect, the accuracy of GOMOS ozone profiles, deduced from the error budget of instrument noise, may be strongly underestimated in the stratosphere. In order to have a realistic estimation of the true error bars, we propose a method to estimate the error budget, based on the computation of the dispersion around their mean value of a series of slant path column ozone profiles in a small latitude band in the tropical region, where the ozone longitudinal dependence is assumed to be weak. The variance of the dispersion is the sum of the measurement error variance and the atmospheric variance. In order to separate these 2 terms a method based on the double differentiation of the vetrical profiles has been developped. For each altitude z_i, the double difference is defined as :

$$DDO3(z_i)=O3(z_i)-[O3(z_{i+1}+1)+O3(z_{i-1})]/2$$

If we consider that the measurement error is not correlated between 2 successive spectra, its contribution to the variance of the double difference dispersion is equal to its contribution to the variance of the profile dispersion (the variance of the double difference has to be multiplied by 2/3 for normalisation). On the contrary, the contribution of the atmospheric variability to the variance is reduced by the double differentiation if this variability contains large vertical scale components. The dispersion of the double difference can be considered as an upper limit of the measurement error because it may still contain some contribution from the atmospheric varaibility.

Results

Five series of about 100 occultations of a magnitude 1.7 star (star ID 29, β Carinae), acquired between December 2002 and February 2003 in the North Tropics, have been analysed. During this period, the latitude of the profiles varies between 0° and 15°N). In each series, the latitude varies by less than 2°. For the last series (thick line on the figures) occultations were almost vertical on the atmospheric limb and the effect of scintillations was reduced. The total dispersion represented on Figure 1 is the sum of the atmospheric variability and the measurement noise (instrumental + induced by turbulence). It is comprised between 2 and 7 % between 18 and 65 km,, with a reduced value between 30 and 50 km for vertical occultations. A very high variability is observed in the upper mesosphere above 70 km.

Figure 2 represents the dispersion of the double difference of the profiles. It van be considered to an upper limit of the random measurement error. Between 20 and 30 km it is comprised between 1 and 2%. In the altitude range more affected by turbulence (30-45 km) it varies from 1.5% for vertical occultations to 4% for oblique ones. The enhancement of the dispersion is attributed to the effect of turbulence, maximum in this altitude range. Between 50 and 65 km the dispersion is very low, from 1 to 1.5%. In the upper mesosphere (70-90 km) it is around 5% but it may include a residual contribution some of the very high atmospheric variability at this altitude.

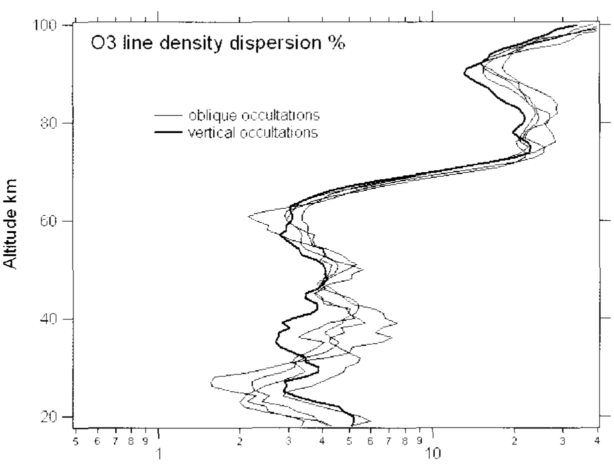

Figure 1. O3 line density dispersion in the Tropics

An estimation of the atmospheric variability is given by the square root of the difference between the variance of the profile dispersion and the variance of the double difference dispersion. This estimation can be considered as a lower limit because the substracted double difference variance may contain some atmospheric contribution. It is minimum around 25 km (1.5 to 2.5%), varies between 3 and 5% in the altitude range 30-50 km, has a second minimum at 60 km (2 to 3%) and is very high between 70 and 90 km (15 to 25%) in the upper mesosphere (70-90 km).

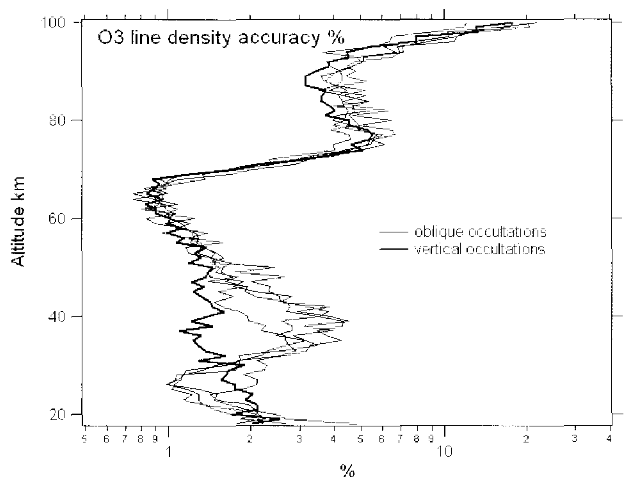

Figure 2. Upper limit of O3 line density accuracy (see text)

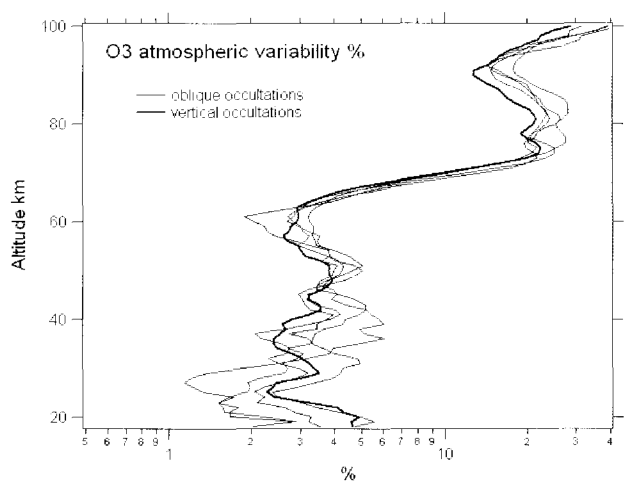

Figure 3. Estimation of O3 atmospheric variability in the Tropics (see text)

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References

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