N95-11132

OZONE PROFILE RETRIEVALS FROM THE ESA GOME INSTRUMENT

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ABSTRACT

The potential of the ESA Global Ozone Monitoring Experiment (GOME) to produce ozone profile information, has been examined by carrying out two sample retrievals using simulated GOME data. The first retrieval examines the potential of the GOME instrument to produce stratospheric ozone profiles using the traditional *back-scatter ultraviolet* technique, while the second examines the possibility of obtaining tropospheric profile information, and improving the quality of the stratospheric profile retrievals, by exploiting the temperature dependence of the ozone Huggins bands.

1. INTRODUCTION

The GOME instrument is a nadir-viewing grating spectrometer under development by the European Space Agency for launch on the second European Research Satellite (ERS-2) in late 1994.

It will measure solar radiation back-scattered from the earth's atmosphere in the spectral region 240–790 nm, at moderate resolution (0.2–0.4 nm) throughout this range. The primary measurement technique to be exploited by the GOME is known as Differential Optical Absorption Spectroscopy (DOAS). Using this technique, the column abundance of a trace gas is derived from a back-scattered ultraviolet/visible spectrum by ratioing it to a solar spectrum, high pass filtering, cross-correlating with a laboratory measured spectrum to obtain the slant column density, and converting from slant to vertical columns by use of air-mass factors (Platt & Perner, 1985; Platt *et al.*, 1980a, 1980b, 1981; Hübler *et al.*, 1984).

In this capacity the GOME is expected to produce column abundances of a number of trace gases (e.g. O_3, NO, NO_2, BrO, H_2O, O_2 and O_4). In addition, the GOME will produce ozone profiles using the back-scatter ultraviolet method which has been successfully exploited by NASA's Solar Backscatter UltraViolet (SBUV) instruments (Heath *et al.*, 1975). This technique requires an absolute radiometric calibration. For this purpose, the GOME will have the capability to observe the sun via a diffuser plate, and the moon directly.

As the GOME will have a much broader spectral coverage and higher spectral resolution than the SBUV instruments, which obtain useful measurements at only eleven wavelengths between 273 and 340 nm, improved vertical profile information should be obtained. Of particular interest is the possibility of retrieving tropospheric ozone profiles. In order to obtain ozone profile information in the troposphere from the GOME measurements, it is necessary to take advantage of the temperature dependence of the ozone absorption features from 300–340 nm, known as the Huggins bands (fig. 1). Since the variation in absorption cross-section with temperature is small (around a few percent per 10K; Paur & Bass, 1985; Yoshino, 1988), it is necessary to obtain measurements with a high signal

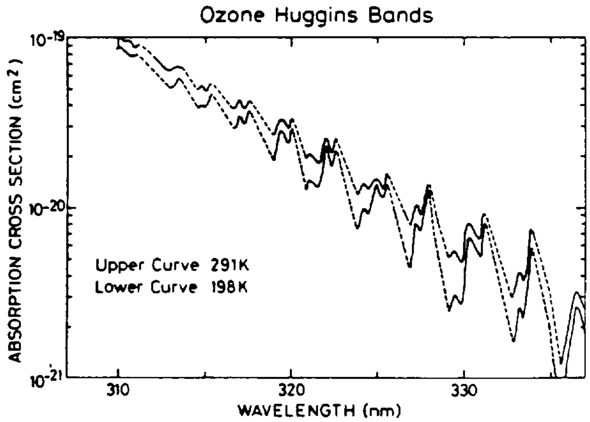

Figure 1. The ozone absorption bands known as the Huggins bands (Nicolet, 1980).

to noise ratio to allow the height information to be extracted. It is expected that the GOME will be able to provide measurements with sufficiently high signal to noise ratios (~1000) in this spectral region to allow tropospheric profile information to be obtained. The remainder of this paper is devoted to a discussion of ozone profile retrievals carried out using simulated GOME data.

2. METHOD

Two sample ozone profile retrievals have been carried out using simulated GOME data at a spectral resolution of 0.2 nm; the first using measurements from the 255–300 nm region only, and the second using measurements from the 255–340 nm region including the temperature dependent Huggins bands.

The measurements were simulated using LOWTRAN7, a multiple scattering radiative transfer code (Kneizys *et al.*, 1988). Representative GOME instrument noise was then added. The simulated back-scattered spectrum was subsequently divided by the solar source spectrum in order to remove the effect of the large variation in incident intensity. The solar spectrum was also calculated using LOWTRAN7.

To date, no attempt has been made to examine the effect of errors in wavelength registration between the measured back-scattered and solar spectrum. Neither has the effect of uncertainties in radiometric calibration been examined. Total ozone, assumed to be known to within ±1%, was also included as an additional measurement.

In both cases the retrieval method used was optimal estimation (Rodgers, 1976, 1990) and the forward model used in the retrieval process was once again LOWTRAN7 (Kneizys, *op. cit.*). The *a priori* information was assumed to be known to within ±30% (in volume mixing ratio) of the "true" profile used to simulate the measurements.

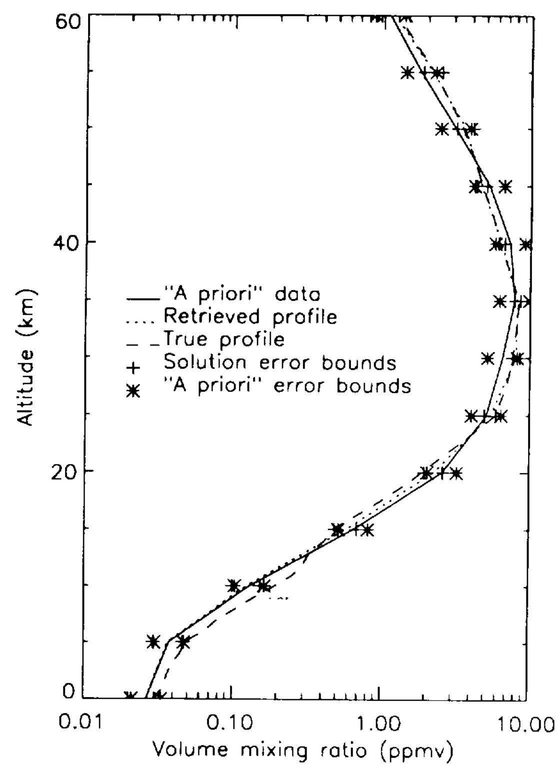

Figure 2. Ozone profile retrieval using simulated GOME data from 255–300 nm.

Both simulations were carried out under the following conditions: nadir viewing; no clouds; no aerosol; over-head sun; a surface albedo of 0.3; temperature profile known exactly and spectroscopic data known exactly. The background atmosphere used was the US Standard Atmosphere (NOAA, 1976). The results obtained under these conditions are discussed in the following section.

3. RESULTS AND DISCUSSION

As shown in fig. 2, the retrieval carried out using only measurements in the 255–300 nm region, reproduces the *true* atmospheric profile well over the altitude range 20–60 km. In this case, height information is obtained by exploiting the wavelength dependence of effective scattering altitude for radiation at wavelengths shorter than 300 nm. As noted, this technique has been successfully applied to the SBUV instrument data sets (Heath *et al.*, *op. cit.*). Since the Huggins bands have been excluded, and all radiation at wavelengths shorter than 300 nm is scattered above the tropopause (Brasseur & Solomon, 1986, fig. 4.3) no tropospheric profile information has been obtained. Con-

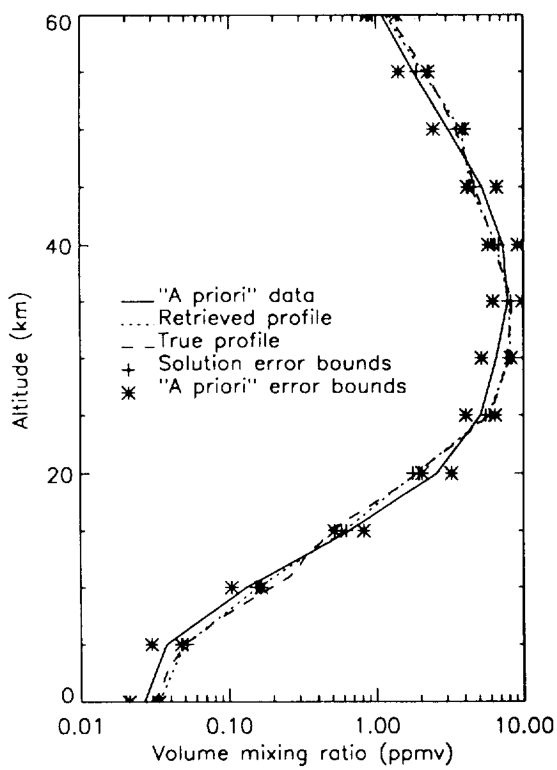

Figure 3. Ozone profile retrieval using simulated GOME data from 255–340 nm, including the temperature dependent Huggins bands.

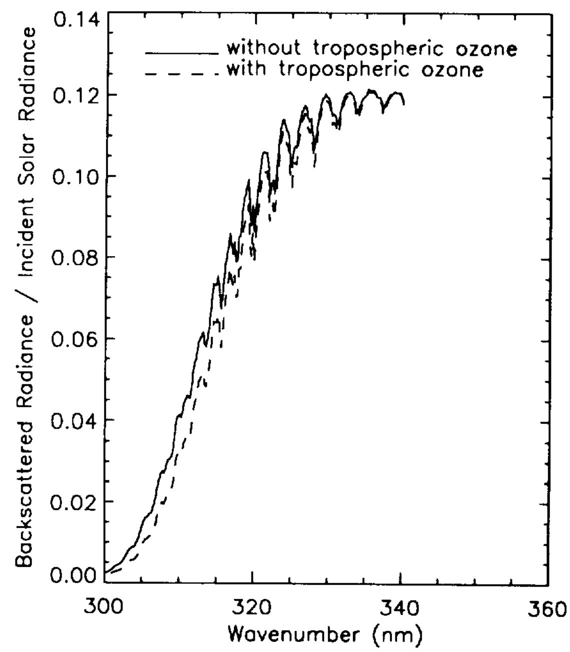

Figure 4. Ratio of the measured back-scattered spectrum to the incident solar spectrum, both with and without tropospheric ozone.

versely, when the Huggins bands are included in the retrieval both the stratospheric and tropospheric profiles are well determined (fig. 3). The relative contribution of tropospheric ozone to the total absorption in the Huggins bands may be seen in fig. 4. This shows the ratio of the measured backscattered spectrum to the incident solar spectrum, both with and without tropospheric ozone. It is possible to see that tropospheric ozone does make a notable contribution to the total absorption in the Huggins bands, thus providing sufficient information to discriminate between the stratospheric and tropospheric profiles. Inclusion of the Huggins bands also significantly improves the information content of the retrievals at stratospheric altitudes, up to 40 km. However, these simulations represent the best possible situation only. In practice, factors such as uncertainties in spectroscopic parameters, uncertainties in the temperature profile, poor *a priori* information, uncertainties in the radiometric calibration of the instrument etc. will all serve to degrade the quality of the profile information. The issue of partially or completely cloud contaminated ground pixels also requires detailed consideration. To facilitate the retrieval of ozone profiles it is necessary to determine the presence of clouds on a pixel or sub-pixel level. Once clouds have been detected, it is possible to retrieve ozone profiles above the cloud level by using only those wavelengths that are not affected by the presence of clouds i.e. only those that do not penetrate to the troposphere. Therefore in the presence of clouds it will only be possible to obtain stratospheric ozone profiles. No tropospheric profile information will be obtained.

4. CONCLUSION

The potential of the ESA GOME instrument, to produce both stratospheric and tropospheric profiles of ozone, has been demonstrated by carrying out two sample retrievals using simulated GOME data. The simulations have shown that it is possible to obtain good ozone profile information from the ground up to 60 km by taking advantage of the temperature dependence of the ozone Huggins bands. It must be recognized that these simulations represent the best possible situation only. In practice, there will be many other sources of error which will increase the uncertainties on the retrieved profiles. In addition, it has been shown that using the GOME data, it is possible to retrieve stratospheric ozone profiles using the traditional back-scatter ultraviolet technique exploited by NASA's SBUV instruments.

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