GOME OZONE TOTAL AMOUNTS VALIDATION BY GROUND-BASED OBSERVATIONS PERFORMED AT THE NDSC/ALPINE STATIONS

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Abstract
The first results of the GOME geophysical validation campaign obtained by means of ground-based observations performed at the NDSC/Alpine and secondary stations are summarised. For validation purpose, the accuracy of the ground-based instruments is analysed and quantified. A special care is given to the retrieval of total ozone with the ground-based DOAS/SAOZ instrument. A methodology of comparison is defined, emphasising the optimisation of the co-location of the air masses probed by the satellite and the ground-based instruments. The 45 days of GOME data processed during the commissioning phase are compared to the total ozone measurements provided by two Brewer, four Dobson and one SAOZ instruments. The relative differences between the GOME and the correlative ground-based total ozone are analysed with respect to the solar zenith angle. In average, the GOME ozone total amounts underestimate the ground-based measurements, between 2 and 8%. Using ground-based data, a test case study is carried out on the fitting window which could be used for ozone retrieval in the visible, demonstrating the importance of O_4 interferences when defining the window spectral range.

1. INTRODUCTION

The Global Ozone Monitoring Experiment (GOME) on board the Earth Remote Sensing (ERS-2) satellite was launched by ESA on 21 April 1995 onto an heliosynchronous polar orbit. Its main scientific objective is the study of trace constituents in the lower and the middle atmosphere. GOME is a combination of four grating spectrometers observing the solar radiation scattered from the atmosphere or from the Earth's surface, covering the spectral range 240-790 nm. The instrument is operated in the nadir-viewing geometry and the current 960 km swath width is divided into three 80x40 km pixels. Atmospheric constituents are detected by means of the Differential Optical Absorption Spectroscopy technique (DOAS). In particular, the GOME ozone total amounts retrieved during the commissioning phase were obtained by using the DOAS method in the Huggins bands.

This work reports the first results of the geophysical validation campaign of the GOME ozone total amount measurements, obtained by means of ground-based observations performed at the NDSC (Network for the Detection of Stratospheric Changes) Alpine and complementary stations. Preliminary results of the validation of nitrogen dioxide total amounts are reported in the paper related to the SAOZ Network (Lambert et al., 1996). The following results are based upon only the limited set of 45 days of GOME ozone data processed during the commissioning phase (22 July - 13 December 1995), without fully adequate corrections for multiple scattering and Earth's sphericity in the air mass factors. Hence the conclusions given here are still preliminary and have to be confirmed by the validation of expanded time series of data.

2. GROUND-BASED INSTRUMENTS

The NDSC/Alpine Stations

The NDSC is a set of high-quality remote sensing research stations for observing and understanding the physical and chemical state of the stratosphere. The mid-latitude reference NDSC site in the northern hemisphere consists of the *International Scientific Station at the Jungfraujoch* (ISSJ, Switzerland), the *Observatoire de Haute Provence* (OHP, France) and the *Observatoire de Bordeaux - Plateau de Bure* (France). These stations combine measurements of total vertical columns of ozone and of other key constituents such as NO_y, ClO_y or CH_4, and vertical profiles of ozone, aerosols and ClO. In addition, complementary measurements are performed at two secondary stations, namely Arosa in Switzerland and Hohenpeißenberg in Germany. The validation results reported here are focused on the GOME ozone total amounts and rely on the observations performed with the Dobson, Brewer and SAOZ instruments listed in Table 2-1. Additional informations on the vertical profiles of ozone density were given by Brewer-Mast ozone sondes launched at Payerne (Switzerland).

Table 2-1 Correlative measurements at the NDSC/Alpine stations

Stations	Instruments
Arosa (46°N, 9°E)	Brewer, Dobson
Bordeaux (46°N, 1°W)	Dobson
Hohenpeißenberg (48°N, 11°E)	Brewer, Dobson
Jungfraujoch (47°N, 8°E)	SAOZ
O.H.P. (44°N, 5°E)	Dobson
Payerne (46°N, 7°E)	Ozone Soundings

Ground-based Instruments

Since 1958, *Dobson* spectrophotometers have been deployed in a world-wide network and measure the ozone total vertical amount from the ground. The Dobson instrument is a double-monochromator based upon the differential absorption method in the UV range where ozone exhibits strong absorption features (Huggins bands). The measurement principle relies on

the ratio of the direct sunlight intensities at two standard wavelengths. The most widely used combination, recommended as the international standard, is the couple of pairs of wavelengths referred to as the AD pair (305.5-325.4; 317.6-339.8 nm).

The *Brewer* grating spectrophotometer is similar in its principle to the Dobson, but it has an improved design. The determination of the ozone total amount is obtained from a combination of five wavelengths in the region between 306 and 320 nm.

The *SAOZ* instrument (Système d'Analyse par Observation Zénithale) is a UV-visible grating spectrometer looking at the sunlight scattered at the zenith during the twilights (Pommereau and Goutail, 1988). Narrow absorption features due to ozone, NO_2, O_4, H_2O, OClO and BrO are detected by means of the DOAS technique, based on the fit of the calculated differential optical thickness with the observed one. In particular, ozone slant amounts are derived from the absorption in the Chappuis bands, between 470 and 540 nm. They are converted into total vertical columns by using a standard air mass factor (AMF), which is calculated by a validated radiative transfer model (Sarkissian et al., 1995), assuming given vertical distributions of the atmospheric constituents controlling the penetration of the solar radiation in the atmosphere.

3. ACCURACY OF THE GROUND-BASED DATA

The accuracy and precision budgets of the Dobson, Brewer and SAOZ measurements are analysed with respect to various critical parameters.

Absorption Cross-sections

The measurement with the Dobson and Brewer spectrophotometers is based on the absorption of ozone in the Huggins bands. The ozone absorption cross-sections in these bands are known to be temperature dependent. Using the temperature corrections of the Dobson ozone absorption coefficients determined by Komhyr et al. (1993) and the stratospheric temperature at 50 hPa above the sites, the temperature effect was found to account for a 2% systematic difference between the SAOZ and the Dobson measurements at mid-latitude (Van Roozendael et al., 1995). This systematic bias is introduced by the difference between the mean 50 hPa temperature and the reference temperature selected for the Dobson ozone absorption coefficients (226.85 K).

The SAOZ measurement is based upon the ozone absorption in the Chappuis bands. In this spectral range, the absorption cross-sections are almost temperature independent. The uncertainty associated to the spectral analysis comes from the fit between the observed and the calculated optical thicknesses, and from the laboratory cross-sections used in the fitting procedure. The fit generates a pseudo-random noise lower than 1% while the uncertainty on the absorption cross-sections introduces a systematic error of about 3% in the Chappuis bands.

SAOZ Air Mass Factor

The SAOZ AMF used to convert the observed slant total amount into vertical total amount depends on the scattering geometry and is sensitive to fluctuations in pressure, temperature and ozone vertical distributions. To estimate the contribution of the fluctuations of the scattering geometry to the accuracy of the SAOZ total ozone, the data obtained at the ISSJ with the standard SAOZ AMF were compared to those retrieved with an AMF calculated with ozone vertical profiles measured at Payerne by means of Brewer-Mast ozone sondes. Figure 3-1 depicts the relative differences between the SAOZ data obtained with the standard SAOZ AMF and those retrieved with the AMF calculated with measured ozone profiles. It also illustrates the effect of the residual ozone amount in the SAOZ reference spectrum (see below). The time-serie shows that the daily fluctuations might account for ± 1% of scatter in the SAOZ total ozone. The seasonal variation of the vertical distributions introduces in the SAOZ data a seasonal systematic bias of about 3% from July to November 1995.

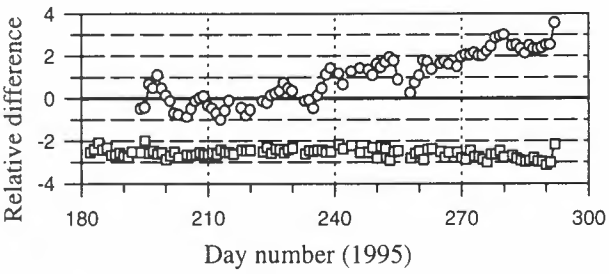

Figure 3-1 Relative differences (in per cent) between the SAOZ total ozone obtained with the standard and with the corrected SAOZ AMF calculated with measured ozone profiles (open circles), and relative differences between SAOZ total ozone obtained with two different reference spectra (open squares).

The SAOZ data obtained with the two methods were compared to the total ozone measured with the Dobson located at Arosa. Only the morning values of the SAOZ data were used for this intercomparison, to optimise the spatial coverage of the two measurements. The differences between the morning values of the SAOZ total ozone obtained with different AMF and/or reference spectra and the Dobson data from Arosa are displayed in Figure 3-2. This figure shows that the SAOZ total ozone retrieved with a corrected AMF (open circles) is closer to the Dobson measurements than the SAOZ data obtained with the standard AMF (shaded squares). The use of the corrected AMF cuts down the mean difference between the SAOZ and the Dobson total ozone from 1.6±2.8% down to 0.6±2.1%. The SAOZ AMF is also sensitive to the altitude of the site. For the Jungfraujoch station (3580 m a.s.l.) the standard AMF at sea level underestimates by 5% the AMF calculated for the altitude of the station.

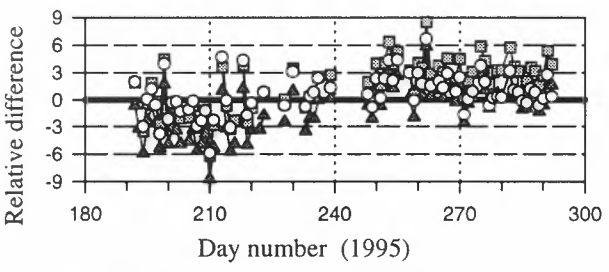

Figure 3-2 Relative differences (in per cent) between the SAOZ and the Dobson total ozone. SAOZ data are obtained with: (1) standard AMF and high SZA reference spectrum (dark triangles); (2) standard AMF and low SZA reference spectrum (dark squares); (3) corrected AMF and low SZA reference spectrum (open circles).

Residual Ozone in the SAOZ Reference Spectrum

The observed optical thickness consists in the logarithm of the ratio between the observed and a reference spectrum. The uncertainty on the residual ozone amount contained in the reference spectrum introduces a constant offset in the retrieved total ozone. This offset depends on the method used to estimate the residual ozone (Vaughan et al., 1996). Figure 3-1 (open squares)

depicts the relative differences between the SAOZ data obtained with a reference spectrum recorded at high solar zenith angle (SZA), and those retrieved with a reference spectrum recorded at lower SZA. When the residual ozone amount is estimated with the classical methods using a reference spectrum recorded in the zenith viewing mode, the uncertainty on this residual ozone leads to a systematic offset in the total ozone of about 3% (Figure 3-1, open squares). This uncertainty can be attributed to the error on the SAOZ AMF at low SZA, error that can be significantly reduced by using a reference spectrum recorded in the direct Sun viewing mode, since the error on a direct Sun AMF is negligible at low SZA.

Tropospheric Perturbations of the SAOZ Data

At twilight, the tropospheric part of the effective optical path of the sunlight reaching the SAOZ is one order of magnitude smaller than the stratospheric part. In addition, the tropospheric amount of ozone is usually lower than 10% of the total column. Hence, the tropospheric contribution to the total absorption seen at twilight by the instrument is lower than 4%. However, the tropospheric contribution could occasionally increase due to the overpass of polluted air masses with high tropospheric ozone concentrations. Moreover, fog and snow showers could increase the tropospheric contribution of the observed total amount by enhancing the tropospheric multiple scattering and consequently the light path. Multiple scattering, normally negligible, is not taken into account in the SAOZ AMF calculation. In addition, absorptions by O_4 and H_2O are enhanced by tropospheric multiple scattering as well. Since O_4 and H_2O interfere with ozone, the retrieved ozone amounts can be biased (Van Roozendael et al., 1994). The statistical analysis of the differences between total ozone measured by the SAOZ at the ISSJ and the Dobson at Arosa shows that the scatter of this differences correlates with the observed O_4 slant amount, that is with the occurrence of multiple scattering events. On long time series, this random error should not exceed 1%.

Quality Control of the Ground-based Data

Most of the instruments operated at the NDSC/Alpine stations recently participated to intercomparison campaigns in order to control their quality, to assess their accuracy and to examine their consistency with other types of instruments. Comparisons between Dobson and Brewer data over long periods indicate that these instruments might suffer from long term drift associated to calibration changes and need to be corrected for. The day-to-day fluctuations in the differences between the Dobson and Brewer total ozone are usually small (± 1.5% in average). Calibration changes should not exist for SAOZ instruments since they are self-calibrated in wavelength with the solar Fraunhofer lines. The four Dobson used in the GOME validation exercise participated to the WMO Dobson Intercalibration Campaign held at Arosa in July-August 1995. The Brewer #40 (Arosa) and the SAOZ #13 (OHP) were operated at the same site for intercomparison purposes. The mean agreement between the various Dobson, the Brewer #40 and the SAOZ #13, was found to be better than 1.6% RMS. Another intercomparison campaign was held in September 1994 at Camborne (UK) for UV-visible DOAS zenith-sky spectrometers. The agreement between four SAOZ and two other DOAS spectrometers was within 3% for total ozone, as well as for the co-located Dobson measurements and ECC ozone soundings (Vaughan et al., 1996). During the GOME validation campaign, the co-location of the Brewer and Dobson spectrophotometers at Arosa and Hohenpeißenberg gave a permanent quality control. The consistency with measurements performed at the other sites has also been studied (e.g., Figure 3-2).

In summary, the following improvements have been implemented in the retrieval of the SAOZ data at the ISSJ, especially in the frame of the GOME validation exercise: (i) the calculation of a daily AMF by means of ozone profiles measured at Payerne; (ii) the most accurate method for the ozone residual amount estimation in the reference spectrum by using a direct Sun spectrum as reference; (iii) the rejection of erroneous data by using the slant amounts of O_4 and H_2O measured by the SAOZ at the ISSJ to detect tropospheric multiple scattering events. The error budgets for the direct Sun (Dobson and Brewer) and the zenith-sky (SAOZ) ground-based instruments are summarised in Table 3-1.

Table 3-1 Accuracy (in per cent) of the direct Sun (Dobson and Brewer) and zenith-sky (SAOZ) ozone measurements at the NDSC/Alpine stations

Error source	Dobson, Brewer	SAOZ
Cross-sections	± 2	< 3
Measurement	± 1.5	± 1
Multiple scattering		± 1
AMF		± 1
Residual O_3		< 1
Total Error (RMS)	**2.5**	**3.5**

4. METHODOLOGY OF COMPARISON

This section describes the methodology defined for comparing the GOME and the ground-based total ozone. Some potential sources of discrepancies between the different instruments, due to their own observing mode, are highlighted.

The total ozone observed at the Alpine stations from July to December 1995 ranged only from 240 up to 360 DU. Therefore, all the conclusions given here are valid only for the observed range of total ozone.

Geometry of the Ground-based Observations

Direct Sun measurements with the Dobson and the Brewer spectrophotometers are performed at SZA lower than 75°. When the cloud cover prevents from making direct Sun observations, the two instruments can be operated in the zenith-sky mode. In this case, the observed slant amount is converted into a vertical column by using empirical tables of correlation between the two observation modes. Nevertheless, data obtained within the direct Sun geometry are known to be more accurate by a few per cent than those obtained with the zenith-sky method (e.g., De Backer and De Muer, 1991). Therefore, only direct Sun data will be considered here. For the SAOZ, the most accurate measurements are obtained at twilight for SZA between 86° and 91°.

Temporal Coincidence of the Probed Air Masses

For validation purpose, the air masses probed by GOME and by the correlative ground-based instruments should be as similar as possible. Since the Dobson and the Brewer are usually operated several times a day, it is sometimes possible to obtain correlative total ozone for ERS-2 overpasses within a time window of two hours. Correlative data within a larger time window are also taken into account if the temporal variability in the ozone field is lower than the measurement accuracy. This can be checked by looking at the variability of the ozone data obtained during the day. The TOVS (TIROS Operational Vertical Sounder) ozone maps delivered by the KNMI (Royal Dutch Meteorological Institute) can also give some informations on the homogeneity of the

ozone field in the line-of-sight of the instruments. The zenith-sky measurements (SAOZ) are always performed during twilight while ERS-2 overpasses the mid-latitude sites around noon. Therefore, a significant difference in time exists between the air masses probed by GOME and by the SAOZ, varying from 5 hours in winter up to 8 hours in summer for the Alpine stations.

Geometrical Coincidence of the Probed Air Masses

The differences in the geometry of observation between the nadir, the direct Sun and the zenith-sky viewing instruments can also introduce some scatter in the comparison. From a crude calculation of the ozone gradients using the TOMS (Total Ozone Mapping System) total ozone maps, within a spatial extent of several hundred kilometres, the spatial gradients of the ozone field might contribute by ± 2.5% to the scatter (Van Roozendael et al., 1995). For the GOME validation, the viewing geometry of the ground-based instrumentation has been taken into account.

Optimisation of the Co-location of the Measurements

The absorption light path related to the viewing geometry has been investigated for the ground-based ozone monitoring instruments in order to estimate the geolocation of the air masses effectively probed. For the direct Sun viewing instruments, the estimation is straightforward. For the zenith-sky measurements (DOAS/SAOZ), the estimation needs a radiative transfer model assuming given vertical distributions of the atmospheric constituents controlling the penetration of the solar radiation in the atmosphere. The GOME pixels are selected when presenting an intersection with the absorption light path of the correlative ground-based measurement.

The Brewer and Dobson spectrophotometers operated in the direct Sun mode sample air masses up to 200 km from the station, depending on the SZA, and hence on the season. The effective geolocation of the air mass probed by the SAOZ at twilight extends up to several hundred kilometres from the ground-based site within an azimuth range varying with the season. The horizontal projection of the air mass sampled by the SAOZ extends from 100 up to 350 km at 87° SZA and from 150 up to 550 km at 91° SZA.

The same radiative transfer model used for the ground-based instruments has been applied to the nadir viewing geometry. The effective geolocation of the GOME measurement is calculated to extend from the ground pixel up to 30 km in summer and up to 100 km in winter. This is not taken into account in this first validation exercise, mainly because of the 30 km difference between the pixel geolocation given in the GOME data files and by the ESA orbit propagator.

5. RESULTS OF TOTAL OZONE VALIDATION

Since the work reported here is based upon only the 45 days of GOME ozone data processed during the commissioning phase, the conclusions are still preliminary and have to be confirmed by a validation based on expanded time series of data and an upgraded version of the processing algorithm. The SZA of the GOME measurement never reaches 75° for latitudes lower than 52°. Therefore the lack of AMF corrections for multiple scattering and Earth's spherical geometry for SZA larger than 75° does not preclude the GOME data validation at mid-latitude. Moreover, the proximity of the NDSC/Alpine stations prevents from any disturbance introduced by the use in the GOME AMF calculation of latitude-band climatologies without interpolation. The ozone total amounts measured by GOME and the ground-based instruments generally exhibit a similar behaviour.

Validation by the Brewer spectrophotometer

The relative difference between the GOME and the correlative Brewer total ozone at Arosa (solid circles) and at Hohenpeißenberg (open squares) is depicted in Figure 5-1. For both stations, the GOME total ozone underestimates in average those measured by the Brewer: -2.5±2.4% at Arosa and -3.8±2.3% at Hohenpeißenberg. This underestimation might depend on the SZA of the GOME measurement. This assumption has to be confirmed by a validation study with expanded time series of measurements. The difference in total ozone does not seem to depend on the latitude of the centre of the GOME pixel, as shown in Figure 5-2. In Figure 5-3, the correlation plot between the total ozone measured by GOME and the Brewer indicates that the sensitivity of GOME to ozone might be lower than the Brewer one for ozone total amounts ranging from 240 to 360 DU. At Arosa, this difference is currently 16% (r^2=0.82) and at Hohenpeißenberg only 5% (r^2=0.91).

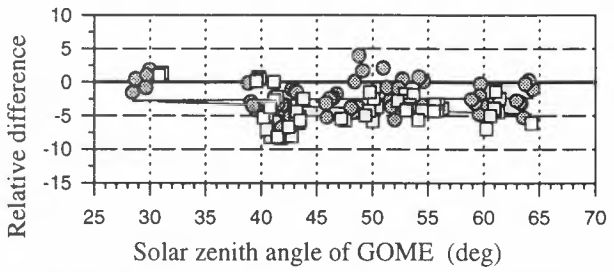

Figure 5-1 Relative difference (in per cent) between the GOME and the Brewer total ozone at Arosa (dashed circles) and at Hohenpeißenberg (open squares), as a function of the solar zenith angle of the GOME measurement.

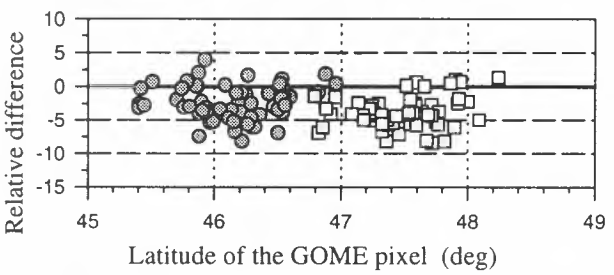

Figure 5-2 Relative difference (in per cent) between the GOME and the Brewer total ozone at Arosa (dashed circles) and at Hohenpeißenberg (open squares), as a function of the latitude of the GOME pixel.

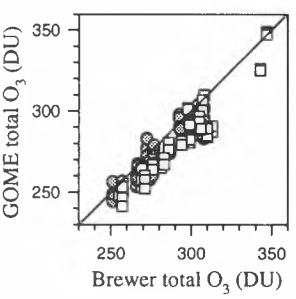

Figure 5-3 Correlation plot between the total ozone measured by GOME and by the Brewer at Arosa (dashed circles) and at Hohenpeißenberg (open squares), in Dobson units.

Validation by the Dobson spectrophotometer

Figure 5-4 and Figure 5-5 display the relative differences (in per cent) between the ozone total amounts measured by GOME and the different Dobson instruments of the Alpine stations, respectively versus the GOME SZA and the latitude of the GOME pixel. Similarly to Figure 5-1, Figure 5-4 shows that in average the GOME total ozone underestimates the Dobson measurements, whatever the location of the instrument:

-5.6±3.1% at Arosa, -5.3±3.4% at Bordeaux, -5.1±3.9% at Hohenpeißenberg and -2.7±4% at the OHP. The number of comparison points is too scarce to reveal any SZA dependence in the differences which, in addition, do not depend significantly on the latitude of the GOME pixel.

Validation by the SAOZ spectrometer

The relative difference between the total ozone measured by GOME and by the SAOZ instrument at the ISSJ station is displayed in Figure 5-6. The mean difference is -4±3%. This result confirms the lower total ozone observed by GOME by comparison with the ground-based measurements. In average, the difference displays a significant SZA dependence: -2±4% at SZA lower than 45°, -4±4% between 45° and 60° SZA, and -8±3% between 60° and 75° SZA. The SAOZ total ozone is corrected for the seasonal variation of its AMF, and should be consequently independent on the GOME SZA. The discrepancy between the GOME and the SAOZ total ozone does not depend significantly on the latitude of the centre of the GOME pixel, as shown in Figure 5-7. The SZA dependence of the discrepancy prevents from seeing any difference in the ozone sensitivity between GOME and SAOZ observations. A method to solve this problem has been applied in the results of the GOME validation with the SAOZ network (Lambert et al., 1996), but the number of observations available in this study is too scarce to proceed for a single station.

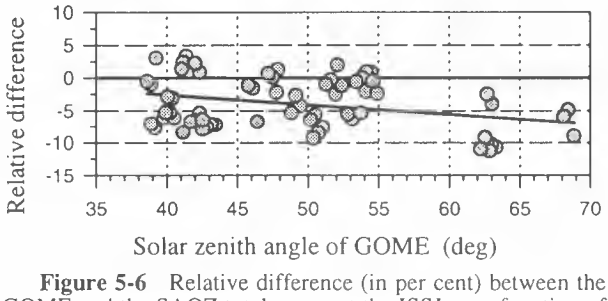

Figure 5-6 Relative difference (in per cent) between the GOME and the SAOZ total ozone at the ISSJ, as a function of the SZA of the GOME measurement.

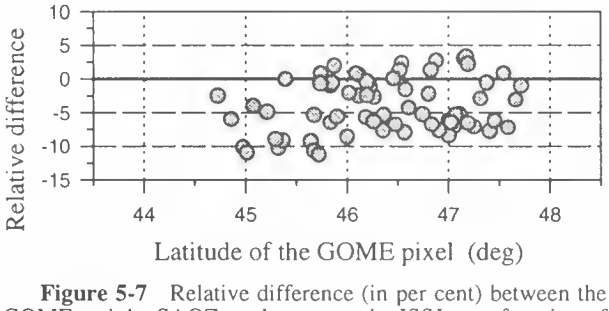

Figure 5-7 Relative difference (in per cent) between the GOME and the SAOZ total ozone at the ISSJ, as a function of the latitude of the GOME pixel.

6. TOTAL OZONE DETERMINATION FROM VISIBLE SPECTRA: A TEST CASE STUDY ON THE FITTING WINDOWS USING GROUND-BASED DATA

The GOME ozone vertical column amounts retrieved during the commissioning phase were obtained by application of the DOAS method in the UV region (Huggins bands of ozone). It is anticipated that GOME would be able to retrieve ozone total amounts from the visible range (Chappuis bands) as well. The choice of the most relevant visible windows is still a matter of discussion. Except for the differences in observation geometry, the retrieval of total ozone in the visible region is rather similar for GOME and the DOAS ground-based instruments. Hence an additional interest of the ground-based instruments in the context of the GOME validation is the potential for test case studies using ground-based data analysed in different fitting windows. In this work, two different windows were selected for processing the SAOZ data recorded at the ISSJ during the commissioning phase: (1) the usual DOAS/SAOZ window for ozone (470-540 nm) and, (2) an ozone window recently suggested for GOME (510-550 nm). Figure 6-1a shows the percentage relative differences in total ozone obtained when comparing the time series determined in both windows.

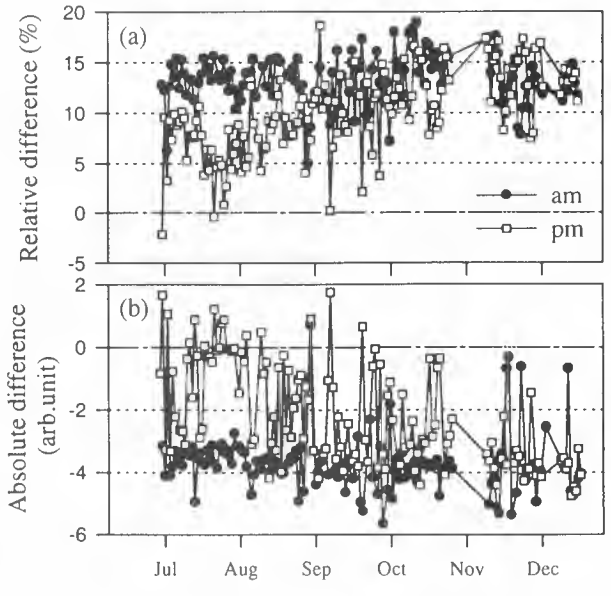

Figure 6-1 Comparison of O_3 and O_4 retrievals using two different spectral windows (see text): (a) relative difference in total ozone, and (b) absolute difference in O_4 slant amounts.

The results show large differences in the retrieved ozone values (between 0 and 20%) which are anticorrelated with differences in the O_4 amounts (Figure 6-1b). The origin of the problem appears clearly when looking at the differential structures (Figure 6-2) for both species in the two windows.

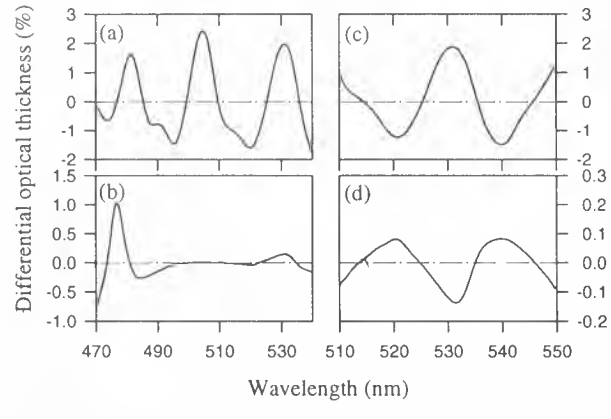

Figure 6-2 Differential optical thicknesses (in per cent) of O_3 (a,c) and O_4 (b,d) derived from least-squares analysis of SAOZ data (25.07.95, 88° SZA, PM) in two different spectral windows (see text).

For the 510-550 nm window (Figure 6-2c,d), the correlation coefficient between ozone and O_4 is larger

than 0.9. Additional tests using a slightly enlarged window (510-565 nm) give similar results. Consequently, the 510-550 nm window appears to be not suitable to fit ozone in the visible, at least for ground-based measurements. This conclusion might be extended to GOME observations as well, although the contribution of O_4 to the optical thickness in the GOME geometry (nadir) is expected to be smaller.

7. CONCLUSIONS

Within the scope of the validation of the GOME ozone total amounts, the accuracy and the precision of the ground-based measurements have been discussed and quantified for the Dobson and Brewer spectrophotometers and for the SAOZ instrument. The seasonal variation of the SAOZ AMF, the estimation of the residual ozone amount in the reference spectrum and the tropospheric multiple scattering have been taken into account in the retrieval of total ozone with the SAOZ spectrometer. A methodology of comparison has been developed, emphasising the problem of the coincidence of the air masses probed by the satellite and the ground-based measurements. In particular, a selection criterion of the GOME pixel, based on the modelisation of the instrument line-of-sight, has been defined. The comparison of the 45 days of GOME data processed during the commissioning phase with the ground-based total ozone has shown that GOME ozone data are in average lower than the ground-based measurements. The mean discrepancies with the Dobson and the Brewer total ozone are given in Table 7-1. The comparison also pointed out the SZA dependence of the differences between the GOME and the SAOZ data, which is summarised in Table 7-2. The number of observations with the Brewer and the Dobson to be compared with GOME is too small to see any significant SZA dependence. According to the correlation plot between the GOME and the Brewer observations, the total ozone sensitivity of GOME between 240 and 360 DU might be lower than the Brewer one, by 16% at Arosa and by 5% at Hohenpeißenberg.

Table 7-1 Relative difference (in per cent) between the GOME and the Dobson and Brewer total ozone at the NDSC/Alpine and secundary stations.

Station	Dobson	Brewer
Arosa	-5.6±3.1	-2.5±2.4
Bordeaux	-5.3±3.4	-
Hohenpeißenberg	-5.1±3.9	-3.8±2.3
OHP	-2.7±4.0	-

Table 7-2 Relative difference (in per cent) between the GOME and the SAOZ total ozone at the ISSJ, as a function of the GOME SZA.

GOME SZA	Relative Difference
45°	-2±4
55°	-4±4
70°	-8±3

As, in addition to its retrieval in the UV range, GOME total ozone is intended to be derived from the visible, a test case study on the 510-550 nm and 510-565 nm fitting windows has been applied to the SAOZ data from the ISSJ, leading to the conclusion that interferences between ozone and O_4 can dramatically alter the retrieval of ozone total amounts in these windows, and that the 510-550 nm fitting window might be inadequate for GOME processing.

8. REFERENCES

De Backer, H., and D. De Muer, *Intercomparison of Total Ozone Data Measured with Dobson and Brewer Ozone Spectrophotometers at Uccle (Belgium) from January 1984 to March 1991, Including Zenith-sky Observations*, J. Geophys. Res., 96, 20711-20719, 1991

Komhyr, W.D., C.L. Mateer, and R.D. Hudson, *Effective Bass-Paur 1985 Ozone Absorption Coefficients for Use with Dobson Ozone Spectrophotometers*, J. Geophys. Res., 98, 20451-20465, 1993

Lambert, J.-C., M. Van Roozendael, P.C. Simon, M. De Mazière, F. Goutail, A. Sarkissian, J.-P. Pommereau, L. Denis, V. Dorhokov, P. Eriksen, E. Kyro, J. Leveau, H.K. Roscoe, G. Vaughan and C. Wahlstrom, *Validation of the ERS-2 GOME Products with the SAOZ Network*, Proceedings of the GOME Validation Campaign Final Results Workshop, Frascati, Italia, 24-26 January 1996, this volume

Pommereau, J.-P., and F. Goutail, *Ground-based Measurements by Visible Spectrometry during Arctic Winter and Spring 1988,* Geophys. Res. Lett., 15, 891, 1988

Sarkissian, A., H.K. Roscoe, D.J. Fish, M. Van Roozendael, M. Gil, H.B. Chen, P. Wang, J.-P. Pommereau and J. Lenoble, *Ozone and NO2 air-mass factors for zenith-sky spectrometers: Intercomparison of calculations with different radiative transfer models*, Geophys. Res. Lett., 22, 1113-1116, 1995

Van Roozendael, M., M. De Mazière and P.C. Simon, *Ground-based Visible Measurements at the Jungfraujoch Station since 1990*, J. Quant. Spectrosc. Radiat. Transfer, 52, 231-240, 1994

Van Roozendael, M., P. Peeters, P.C. Simon, H.K. Roscoe and A. Jones, L. Bartlett and G. Vaughan, F. Goutail, J.-P. Pommereau, E. Kyro, C. Wahlstrom, G. Braathen, *Absolute Calibration of SAOZ Measurements of by Comparison with Dobson and Brewer Instruments*, Proceedings of the Third Annual Symposium on Polar Stratospheric Ozone, Schliersee, Bavaria, 18-22 September 1995, in press

Vaughan, G., H.K. Roscoe, L.M. Bartlett, F. O'Connor, A. Sarkissian, M. Van Roozendael, J.-C. Lambert, P.C. Simon, K. Karlsen, B.A. Kaestad Hoiskar, D.J. Fish, R.L. Jones, R. Freshwater, J.-P. Pommereau, F. Goutail, S.B. Andersen, D.G. Drew, P.A. Hughes, D. Moore, J. Mellqvist, E. Hegels, T. Klupfel, F. Erle, K. Pfeilsticker, U. Platt, *An intercomparison of ground-based UV-Visible sensors of ozone and NO_2*, J. Geophys. Res., 1996, in press

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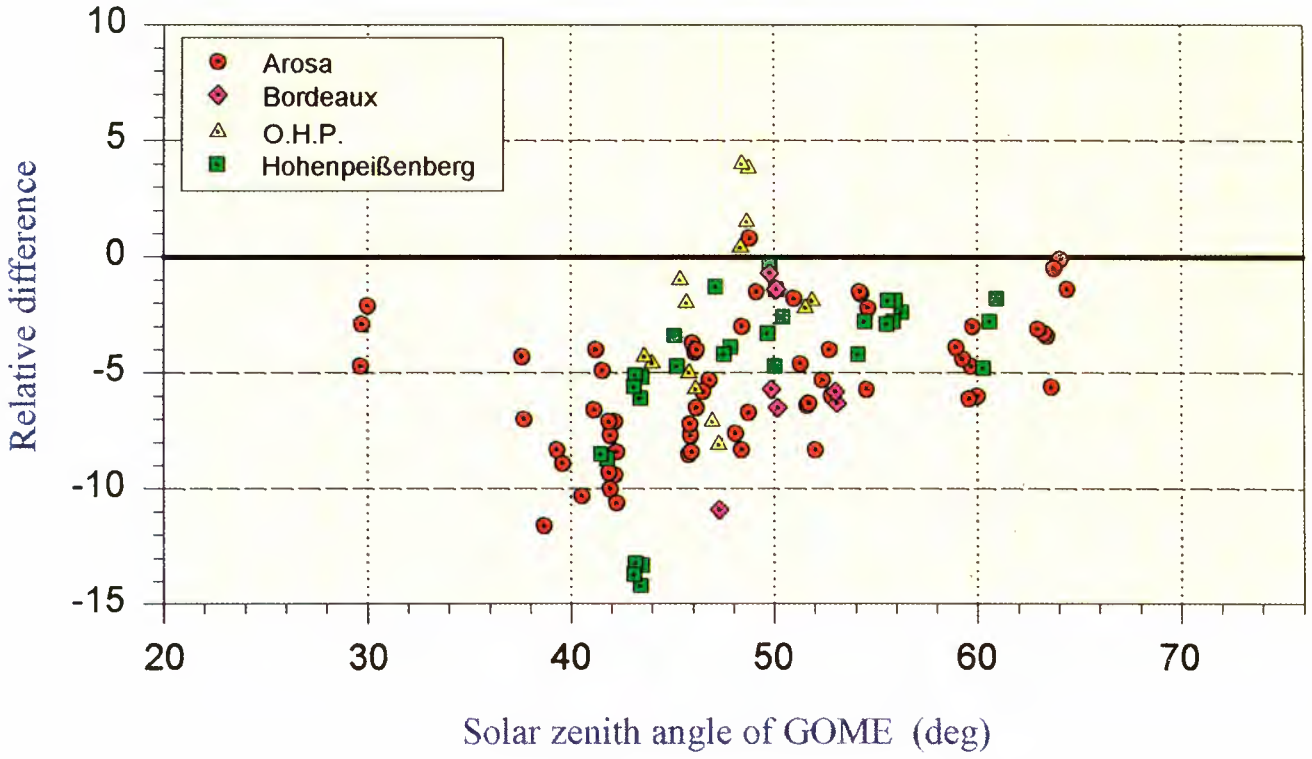

Figure 5-4 Relative difference (in per cent) between GOME and Dobson total ozone, as a function of the GOME solar zenith angle

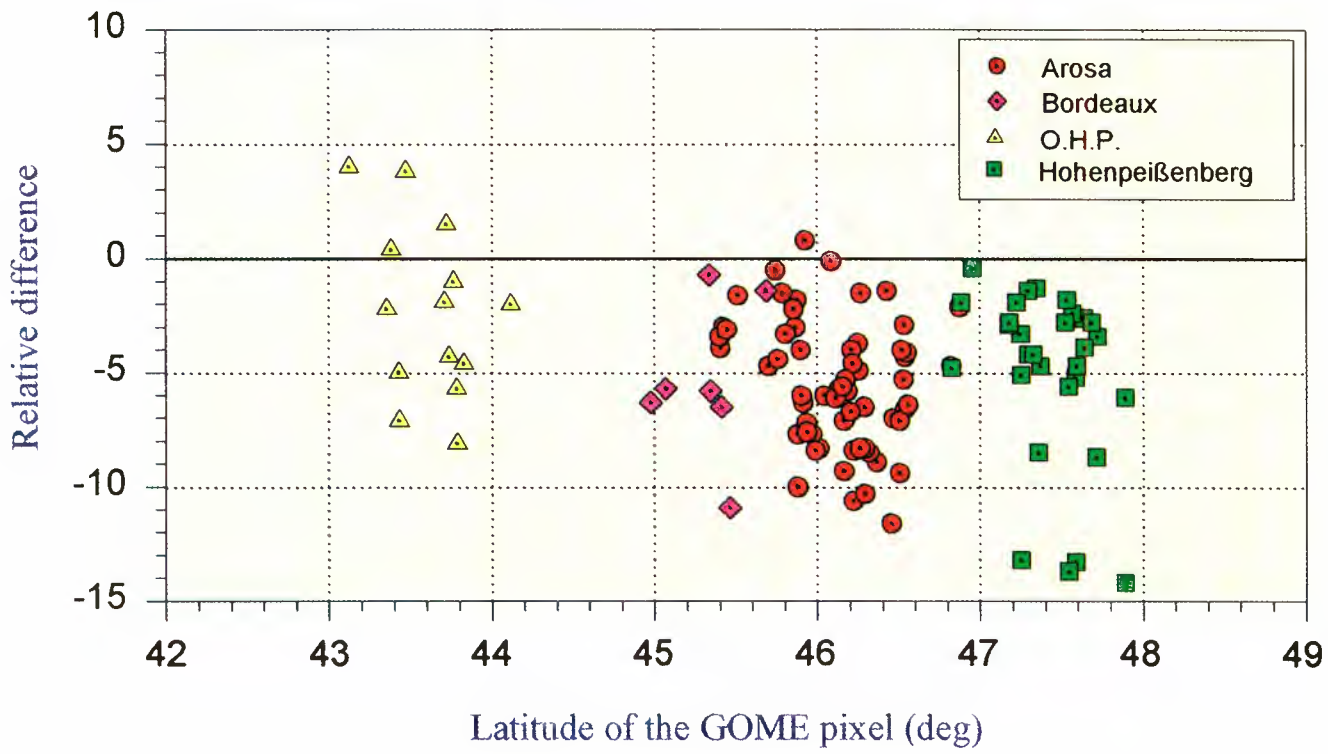

Figure 5-5 Relative difference (in per cent) between GOME and Dobson total ozone, as a function of the latitude of the centre of the GOME pixel