Absolute Calibration of SAOZ Measurements of Ozone by Comparison With Dobson And Brewer Instruments

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INTRODUCTION

Since 1990, total ozone has been routinely measured by an increasing number of SAOZ UV-visible spectrometers located at different latitudes from the Arctic to the Antarctic. O_3 vertical column amounts are obtained by differential absorption spectroscopy in the visible region using zenith-scattered sunlight at twilight. The application of this technique to O_3 measurements in the visible is rather recent and its precision and accuracy are still to be assessed. This poster reports on comparisons between SAOZ column O_3 measurements carried out from 1990 to 1994 at several mid- and high latitude sites and data from co-located or nearly co-located stations from the well-established Dobson and/or Brewer networks. The possible origins of the observed discrepancies are investigated and quantitified.

INSTRUMENTS

The SAOZ O_3 measurements are based on the differential absorption method in the visible range. Observations of the sunlight scattered at zenith are made at twilight twice a day (morning and evening). The small O_3 absorption coefficients in the visible region (Chappuis bands) as compared to the UV are compensated by the increase of the light path at large SZA. Line-of-sight column amounts are converted to vertical ones using airmass factors (AMFs) obtained from radiative transfer calculations assuming given vertical distributions of atmospheric absorbers and scatterers.

The Dobson is the standard instrument used to measure total ozone from Earth's surface. The technique utilises the differential absorption in the UV region where O_3 absorbs strongly (Huggins bands). The basic measurement relies on the ratio of the sunlight intensities at two standard wavelengths. The most widely used combination, recommended as the International standard, is the couple of pairs of wavelengths known as the AD pair (305.5-325.4/317.6-339.8 nm).

Like the Dobson, the Brewer spectrophotometer uses the differential absorption in the UV region. Here the determination of the O_3 column amount is obtained from a combination of five wavelengths in the region between 306 and 320 nm. The accuracy of this instrument is believed to be similar to the Dobson one.

TOTAL OZONE DATA SETS

Dobson and co-located or nearly co-located SAOZ total ozone measurements were compared at five sites in the Northern Hemisphere between 79°N and 44°N and at Faraday, Antarctica (65°S). In addition, comparisons with Brewer measurements were performed at Sodankyla, Finland (67°N) and in the Alps (Jungfraujoch/Arosa, 46°N). The locations of the stations and the associated instruments are

Table 1. List of the stations and instruments

Station	SAOZ	Dobson	Brewer	Lat	Long
Ny-Alesund	•			79°N	12°E
Longyearbjen		•(a)		78°N	15°E
Sodankyla	•		•	67°N	27°E
Oslo	•	•(b)		60°N	10°E
Aberystwyth	•			51°N	4°W
Camborne		•(c)		50°N	5°W
Jungfraujoch	•			47°N	8°E
Arosa		•(d)	•	46°N	9°E
Obs. Haute Provence	•	•(e)		44°N	5°E
Faraday	•	•(f)		65°S	64°W

(a) C pairs of wavelengths, 100% of zenith-sky (Z.S.) measurements.
(b) AD pairs, 87% of direct-sun (D.S.) measurements.
(c) AD pairs, 56% of Z.S. data
(d) AD pairs, 100% of D.S. data
(e) AD pairs, 100% of D.S. data
(f) AD or C pairs, 91% of Z.S. data

gathered in Table 1. Except for Camborne, mid-latitude Dobson data are exclusively direct-sun measurements using the AD pairs of wavelengths which are believed to give the most accurate results.

RESULTS AND DISCUSSION

Fig. 1 shows the time series of the ratios between available SAOZ and/or Brewer total ozone data at the different measurement sites. Results obtained between October 1991 and December 1992 were eliminated because SAOZ measurements were significantly perturbed by increased amounts of stratospheric aerosol due to the eruption of the Mt Pinatubo in June 1991. For each station, the mean of the SAOZ/Dobson or SAOZ/Brewer ratio and the standard deviations at ± 1σ are represented by dashed lines. The values of these statistical parameters are gathered in Table 2. Also given in this table are the distances between the SAOZ and Dobson (or Brewer) sites. The comparison reveals significant differences between mid-latitude sites (shaded part of Table 2) and high latitude ones. At mid-latitude, SAOZ and Dobson measurements agree within 1% in average, with a scatter of about 5% (4% at OHP where SAOZ and Dobson instruments are co-located). The agreement is less good at high latitudes where in average the SAOZ appears to measure 3% less O_3 than the other instruments.

Table 2. Statistical parameters derived from SAOZ/Dobson and SAOZ/Brewer ratios shown in Fig. 1. Results at mid-latitude stations are displayed in the shaded area.

	Results at individual stations					All stations together		
Stations	Dist (km)	Points	Mean	Std dev	Corr	Points	Mean	Std dev
Ny-Alesund Longyearbjen (Dobson)	112	47	0.99	0.11	0.94	789	0.97	0.07
Sodankyla (Brewer)	0	392	0.97	0.07	0.93			
Oslo (Dobson)	0	25	0.96	0.05	0.69			
Aberystwyth Camborne (Dobson)	283	182	1.02	0.05	0.86	1621	1.01	0.05
Jungfraujoch Arosa (Dobson)	131	644	1.01	0.05	0.92			
Jungfraujoch Arosa (Brewer)	131	657	1.01	0.05	0.92			
OHP (Dobson)	0	138	1.01	0.04	0.89			
Faraday (Dobson)	0	325	0.94	0.07	0.90			

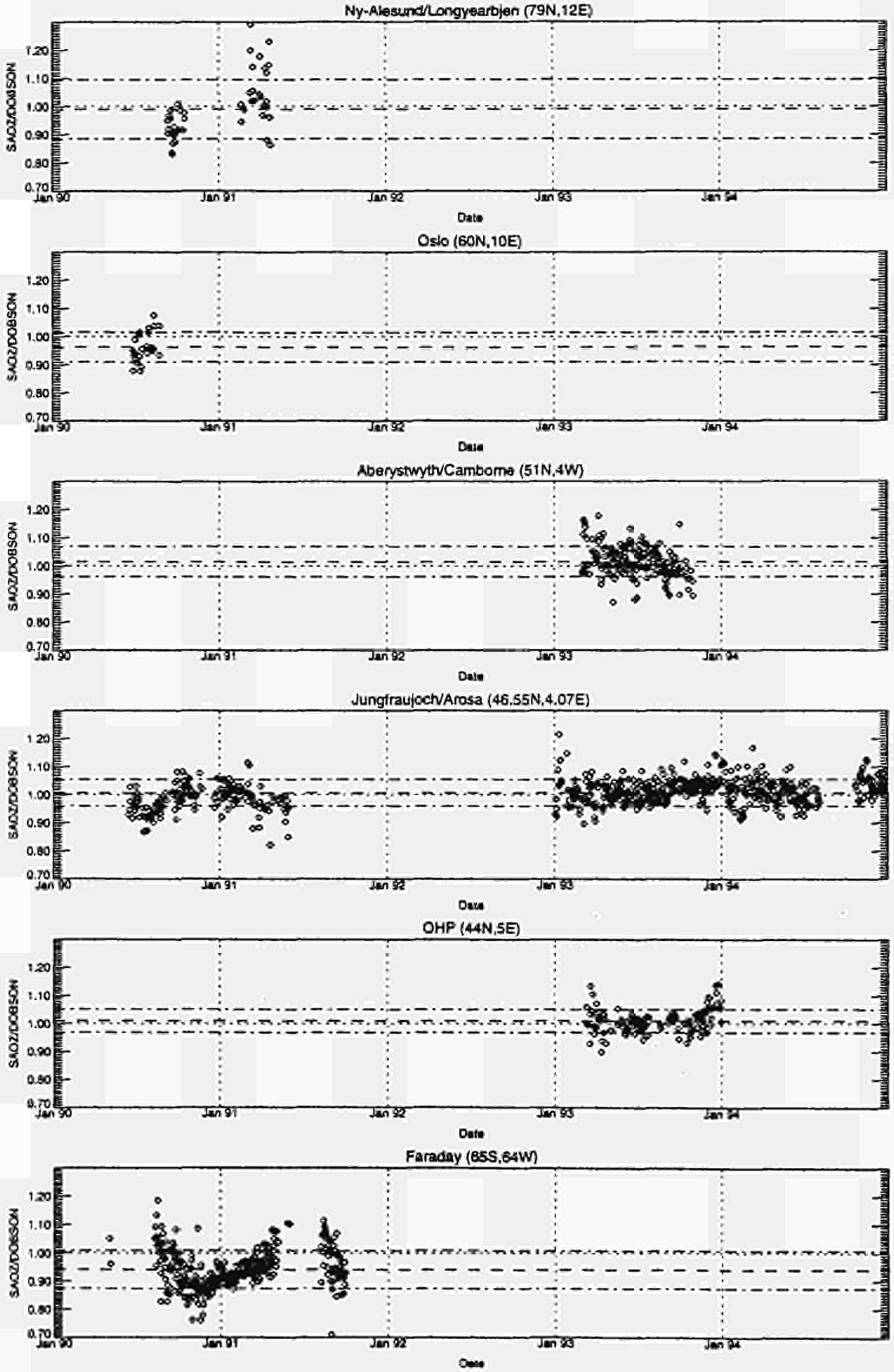

Fig. 1. Ratios of total ozone column measured by SAOZ to that of the Dobson or Brewer at seven different stations from 1990 to the end of 1994. Mean values and standard deviations (± 1 σ) are represented by dashed lines. Data between July 1991 and January 1992 have been eliminated in order to exclude artefacts in the comparison due to the presence of Pinatubo aerosols, which significantly alter the SAOZ air-mass factors.

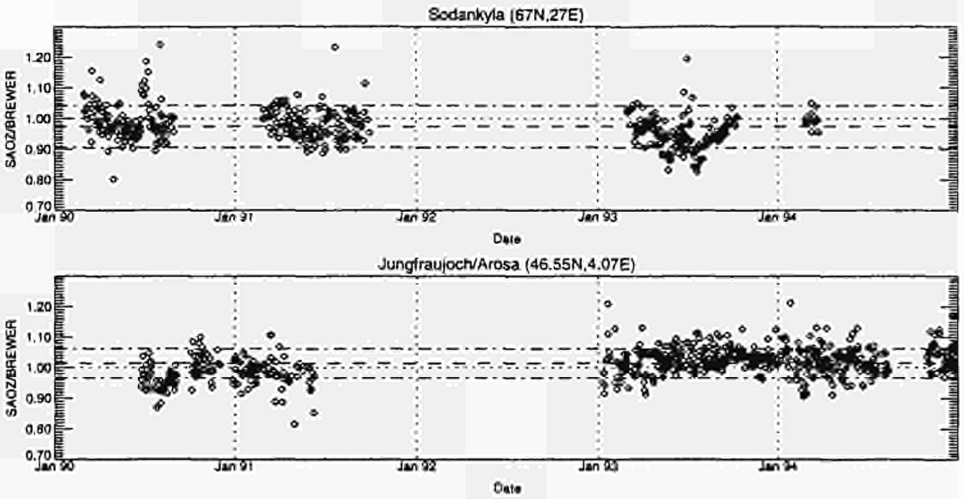

Fig. 1 (continued)

In this case, the mean scatter is of about 7%. All SAOZ/Dobson or SAOZ/Brewer ratios (S/D or S/B) display systematic seasonal variations characterised by a winter maximum and a summer minimum. The amplitude of this seasonality is significantly larger at high latitude.

The comparison between SAOZ and Dobson or Brewer measurements can be affected due to several reasons. In the following we distinguish between factors contributing to the scatter of the S/D(B) ratios and factors contributing to the seasonality of these ratios.

1. SCATTER

Measurement noise: this contribution is small for all instruments. Extensive comparisons between Dobson and Brewer instruments (e.g. De Backer and De Muer, 1991) show that these instruments might suffer from long term drift, but the day-to-day fluctuations in the Dobson/Brewer ratios are usually small (± 1.5% in average). In the case of the SAOZ instrument the measurement noise is less than 1%, as estimated from the spectral analysis procedure.

SAOZ AMFs: the sensitivity of the scattering geometry to the daily fluctuations in pressure, temperature and O_3 vertical distributions can contribute to the scatter in the S/D and S/B ratios because SAOZ O_3 data are retrieved using constant air mass factors (AMFs) throughout the year. Recent studies in the frame of EC projects SCUVS and SESAME have shown that this effect could contribute a ±2% noise in the SAOZ O_3 data (Sarkissian et al., 1995; Kaastad et al., 1995).

O_3 field inhomogeneities: due to the difference in the geometry of observation at twilight (SAOZ) and noon (Dobson and Brewer), the instruments sample airmasses separated by a few hundreds of kilometers. From a crude calculation of the O_3 gradients within this spatial extent obtained using total O_3 maps measured by TOMS, we can estimate that O_3 spatial gradients contribute a maximum of ±2.5% to the noise in the S/D and S/B ratios (in average and for co-located instruments). This contribution will naturally increase when comparing instruments not exactly collocated.

Tropospheric multiple scattering: using the zenith-scattered sunlight as a source, SAOZ observations are performed whatever the cloud cover. In case of thick clouds, snow showers or rain falls the tropospheric light path can be significantly increased which leads to large enhancements of the absorption by tropospheric constituents like O_4 and H_2O. Some authors have recently indicated that such tropospheric light path enhancements (TLPE) can occasionally bias significantly total ozone measurements due to the presence of some O_3 in the troposphere (Van Roozendael et al., 1994; Erle et al., 1995; Wagner et al., 1995). It is expected however that the size and frequency of this effect will be largely modulated depending on the cloud climatology at different sites. More work is needed to quantify this contribution.

2. SEASONALITY

Temperature sensitivity of the O_3 absorption coefficients: Unlike the SAOZ which uses the visible part of the O_3 absorption spectrum known to be almost temperature independant, the Dobson and Brewer instruments can be affected by the temperature sensitivity of the O_3 absorption cross-sections in the Huggind bands. Recently the temperature coefficients of the Dobson ozone absorption coefficients were accurately determined by Komhyr et al. (1993). Using these coefficients and measured stratospheric temperatures above the sites, the temperature contribution to the S/D and S/B ratios can therefore be estimated from the relation:

$D_{corrected} / D = 1 / (1 + a (T-T_0))$, where D is the measured Dobson value, $D_{corrected}$ the corrected value, T the 50 hPa temperature, T_0=-46.3°C and a=0.13%/°C.

Actual calculation of the effect show that it account for a 2% systematic difference between SAOZ and Dobson instruments at mid-latitude due to the difference between T_0 and the mean 50 hPa temperature. At high latitude (Faraday and Sodankyla), the seasonal change of the 50 hPa temperature is much larger and leads to a 5% contribution to the S/D seasonality (peak to peak amplitude).

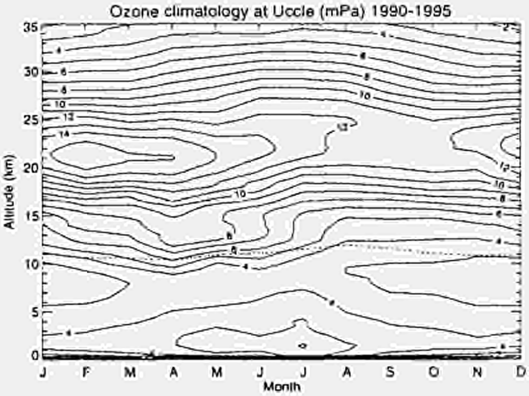

Fig. 2 Climatology of the O_3 vertical distribution derived from a time series of O_3 soundings recorded at Uccle, Belgium between 1990 and 1995 (De Backer, KMI, private communication). The approximate altitude of the tropopause is indicated by a dotted line.

SAOZ AMFs

Errors on the SAOZ AMFs can contribute to both scatter and seasonality of the S/D ratios, the latter mainly because of a sensitivity to the seasonal changes of the O_3 vertical distribution (Sarkissian et al., 1995b). In order to investigate quantitatively this effect for the mid-latitudes, AMFs have been calculated using the measured O_3 climatology shown in Fig. 2, climatology derived from a time series of O_3 soundings performed at Uccle (51°N, 4°E) from 1990 to 1995 (De Backer, private communication). Averaged AMFs (between 87 and 91°SZA) were calculated for each month between January and December using a home-made single scattering algorithm recently validated (Sarkissian et al., 1995a). To display the seasonality, these values were divided by the standard AMFs used by all SAOZ instruments considered in the present comparison. The results are shown in Fig. 3, together with 10-day running averages of the actual S/D ratios at the three mid-latitude stations (Jungfraujoch, OHP and Aberystwyth). The 5% seasonality in the calculated AMF/AMF_{std} curve appears to be consistent with observed S/D ratios. The larger amplitude of the seasonality in the S/D ratio at Sodankyla can be accounted by a combination of errors in the Dobson measurements

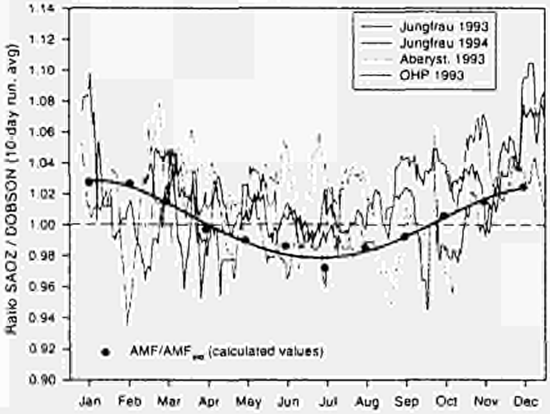

Fig. 3 10-day running averages of S/D ratios at three mid-latitude stations (thin lines). Shown together in black dots, calculated AMF/AMF_{std} ratios displaying the seasonality due to SAOZ AMFs.

(temperature and possibly airmass sensitivity) and in the SAOZ AMFs. The seasonal change of the S/D ratio is the largest at Faraday. According to Jones et al. (1995), most of the discrepency at this station is likely to be due to SAOZ AMFs although the problem has not been quantitatively elucidated yet.

CONCLUSION

SAOZ total ozone measurements have been compared to Dobson and/or Brewer data at seven different sites at mid- and high latitudes. The results show a better agreement for the mid-latitude stations. In average mid-latitude SAOZ measurements agree with other instruments data within 1% with a scatter of about 5%. This scatter can be explained by the different observational geometry of the instruments and by uncertainties in the SAOZ AMFs. There might be an additional contribution due to tropospheric multiple scattering in clouds that still need to be quantified. SAOZ/Dobson and SAOZ/Brewer ratios are characterised by seasonal variations with peak-to-peak amplitudes going from about 5% at mid-latitude to a maximum of 15% at Faraday, Antarctica. At mid-latitudes, the amplitude and phase of this seasonality is shown to be consistent with SAOZ AMFs uncertainties. For the high latitudes, the same conclusion is likely to apply although the temperature sensitivity of the Dobson and Brewer absorption coefficients needs to be taken into account.

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