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COMPARISON BETWEEN BREWER SPECTROMETER, M 124 FILTER OZONOMETER AND DOBSON SPECTROPHOTOMETER

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ABSTRACT

Concurrent measurements were taken using the *Brewer spectrometer # 30*, the *Filter Ozonometer M 124 # 200* and the *Dobson spectrophotometer # 71* from September 1987 to December 1988 at Potsdam. The performance of the instrument types and the comparability of ozone data was checked under the conditions of a field measuring station. Total ozone values derived from Dobson AD direct sun measurements were considered as standard. The Dobson instrument had been calibrated at intercomparisons with the World Standard Dobson instrument # 83 (Boulder) and with the Regional Standard instrument # 64 (Potsdam), while the Brewer instrument was calibrated several times with the Travelling Standard Brewer # 17 (Canada).
The differences between individual *Brewer DS* (direct sun) ozone data and *Dobson ADDS* are within ± 3 % with half of all differences within ± 1 %. Less than 0.7 % of the systematic difference can be due to atmospheric SO_2. Due to inadequate regression coefficients *Brewer ZB* (zenith blue) ozone measurements are by (3...4) % higher than *Dobson ADDS* ozone values.
M124 DS ozone data are systematically by (1...2) % higher than *Dobson ADDS* ozone with 50 % of the differences within ± 4 %, but with extreme differences up to ± (20...25) %. *M124 ZB* ozone values are by (3...5) % higher than *Dobson ADDS* with all the differences within ± 10 %, i.e. the scatter of differences is smaller for ZB than for M 124 DS measurements,
Results for differences in the daily mean ozone values are also addressed. The differences include the uncertainties in the ozone values derived from *both* types of measurements. They provide an indication of the uncertainty in ozone data and the comparability of ozone values derived from different types of instruments.

1. INTRODUCTION

Dobson spectrophotometers, Brewer spectrometers and Filter Ozonometers are the backbone of the ground-based part of the Global Ozone Observing Network that provides ozone data to the Global Environmental Monitoring System. Comparisons between different types of instruments can provide information on the uncertainties of the respective instrument type and the comparabilty of ozone values from different sources. Therefore, concurrent observations with the three types of instruments at the field station Potsdam were analysed for their differences in the derived ozone values.
Two Dobson instruments have been in use at the Meteorological Observatory Potsdam since more than 30 years. A Brewer spectrometer was delivered in 1987, and a M124 filter ozonometer was available at Potsdam on loan from the Geophysical Observatory in Petersburg from 1987 to 1988. The measurements taken with the three instruments from September 1987 to December 1988 were compared so as to study systematic and random differences in the derived individual ozone values as well as in the daily mean values. Differences in zenith cloudy (ZC) measurements were also studied. Due to the meteorological conditions ZC is the most frequent type of observations in winter at Potsdam and other sites in mid-latitudes.

2. CALIBRATIONS AND MEASUREMENTS

Dobson instrument # 71 used for routine ozone observations was considered as standard. Its calibration level has been checked by monthly standard lamp tests and by comparison with the Regional Standard Dobson Spectrophotometer # 64. Dobson instrument # 64 was calibrated with the World Primary Standard Dobson Spectrophotometer # 83 (Boulder) at Arosa in 1986 (difference in ADDS after the intercomparison 0.0 %) and with the World Secondary Standard # 65 (Boulder) at Arosa in 1990 (difference in ADDS before final calibration 0.21 %). The last figure includes an upward correction of the World Standard by 0.36 % (Komhyr et al. 1989, Komhyr 1990). Ozone observations and data processing have been made according to standard procedures given by Komhyr (1980).
Brewer instrument # 30, which was installed at Potsdam in 1987, was intercompared with the Canadian Travelling Brewer # 17 in April 1988, and in May 1989. The differences in DS measurements were found by K. Lamb to be less than 1 %.
The *M 124 Filter Ozonometer # 200* was available on loan from the Main Geophysical Observatory (MGO) Petersburg. It had been calibrated at the MGO before shipping to Potsdam. Nomograms for data processing and instructions for use were kindly provided by A. M.

Shalamjanski from the MGO. Concurrent measurements were taken from September 1987 to December 1988. Differences between ozone values from the Brewer or M 124 instrument and the Dobson instrument were considered. The ozone observations with two instruments were not taken at exactly the same time, but were grouped in ranges of μ values corresponding to classes of solar zenith angles. Percentiles have also been used in the analysis, because they do not depend on the statistical distribution of the sample. Due to the measurement errors of the standard instrument the differences are higher than the uncertainty of the instrument under consideration. This is illustrated by the following equation showing the uncertainty of an instrument σ that is determined by the mean square difference σ_d between the instrument and the standard, and the uncertainty of the standard instrument σ_S

$$\sigma = \sqrt{\sigma_d^2 - \sigma_S^2 - d^2}$$

whith d beeing the systematic difference between both instruments (Feister et al. 1985). It should be kept in mind that the uncertainty of individual Dobson ozone measurements σ_S is (1...3) % for ADDS observations (Basher 1982).

C	Reference
1.06	Evans et al. (1980)
1.06	Kerr et al. (1980)
1.53	Komhyr and Evans (1980)
1.00	Köhler and Attmannspacher (1986)
1.41	De Backer & De Muer (1991)
0.91 ... 0.99	this study

Table 1 Constants C to be multiplied by the column SO_2 [D] amount derived from Brewer DS measurements. The result must be added to Brewer ozone measurements to make them comparable to Dobson ozone measurements.

3. Differences between Brewer and Dobson Spectrophotometer

The Brewer spectrometer is a grating spectrometer measuring solar beam radiation at five wavelengths, which are different to Dobson wavelengths, with a bandpass of 0.6 nm (Kerr et al. 1985). Possible interferences of atmospheric SO_2 on the Dobson ozone measurements have not been eliminated,so as to maintain the common observational scheme.The average SO_2 column amount derived from Brewer measurements in 1987/88 is 2.5 D. If all the differences between Dobson and Brewer ozone from DS observations are correlated with the SO_2 values obtained from Brewer DS measurements, we find regression constants between C = 0.91 (5/87 through 12/91) and C = 0.99 (5/87 through 6/92). C multiplied by the Brewer DS column SO_2 amount is to be added to the Brewer ozone values to make them comparable with the ozone from Dobson spectrophotometer observations (Fig. 1). The C values derived from our measurements are slightly lower than the values found for other stations or from theoretical considerations (Table 1).

Due to SO_2 the average difference between Dobson and Brewer DS ozone should have been 2.3 ... 2.5 D in 1987/88, i.e. less than 1 %. It should be noted that the Brewer SO_2 values have decreased by 0.4 D per year since 1987. This decrease is non-significant, if simple linear regression is applied. However, the decrease seems to be reasonable as a likely result of the reductions in SO_2 emissions in many European countries over that period.

Fig. 2 shows the differences between *Brewer DS* and *Dobson ADDS*. They are within about $\pm$ 3 % with 50 % of the differences within $\pm$ 1 %. There is practically no systematic deviation between both types of data (d=0), and almost no dependence of the differences on μ can be seen. Fig. 3 shows the differences between *Brewer ZS* (zenith sky) and *Dobson ADDS* measurements. A distinction between zenith blue and zenith cloudy in the Brewer data cannot be made, but it can be assumed that the majority of the data in the respective comparison are zenith blue measurements, because Dobson ozone is from direct sun observations. A systematic deviation of + 4 % with low μ and + 3 % with high μ can be seen that should be due to inadequate regression coefficients in the original Brewer operating software. There is a need to re-determine the regression coefficients from a set of regular measurements at the station. The availability of software for that purpose would be a helpful tool. The scatter of differences around the median is about $\pm$ 2 %. Zenith Brewer data (mostly cloudy sky) differ from Dobson ADZC (zenith cloudy) ozone measurements by $\pm$ (3...6) % (half of the differences) with individual differences up to (-5...+15) %.

4. Differences between M 124 Filter Ozonometer and Dobson Spectrophotometer

The M 124 Filter Ozonometer is based in its configuration on the older version M 83 (Guščin 1963, 1979) with somewhat different view angles and changed electronics (Gushchin et al. 1985). As glass filters are used with broad band transmission characteristics for the selection of wavelength bands, their peak transmission shifts depending on the solar zenith angle and the amount of ozone. Empirical nomograms have to be used to determine total ozone from direct sun or zenith sky measurements.

Fig.4 shows the differences between *M 124 DS* and *Dobson ADDS* measurements. In addition to the large scatter of differences, which has been known also for the M 83 instrument (Bojkov 1968, Guščin 1979), there is a small systematic deviation of + (1...2) % for high μ and no bias for low μ. One half of all differences are within (-4...+6) %, and all differences are within about $\pm$ (15...20) %. Smaller values occur for the differences between *M 124 ZB* and *Dobson ADDS* measurements with 50 % of all differences within (0...8) % (Fig. 5). Both the DS and ZB observations with the M 124 show a slight μ dependence. The bias in the M 124 zenith observations of 4 % is assumed to be due to inappropriate M 124 zenith nomograms that should be corrected by concurrent measurements to account for the typical atmospheric conditions at the site.

5. Daily averages of differences

Daily average ozone values are used to determine monthly, seasonal and annual averages that are used in analyses of ozone variations in time and space. All the daily averages of *differences* between *Brewer DS* and *Dobson ADDS* are within $\pm$ 2 %, with only a few exceptions. The *Brewer ZS* daily ozone data show the same bias of + 4 % as was shown for the individual differences. The *M 124 DS* daily mean values differ from *Dobson ADDS* up to $\pm$ 15 %, with 50 % of the differences within about $\pm$ 5 %. *M 124 ZB* ozone values seem to be a little more reliable than M 124 DS ozone data, but for the used instrument they are systematically higher than Dobson ADDS by 4 %.

6. Conclusion

The differences in ozone derived from measurements with the Dobson, Brewer and M 124 instruments at a field station were studied. There is a very good correspondence in the DS ozone data of Brewer #30 and Dobson # 71. A bias exists in the Brewer zenith measurements. It is to be eliminated by subsequent correction of the ozone data or by re-determining the regression coefficients. Having done that task, the zenith data of both instruments are comparable.

Individual measurements with the M 124 instrument # 200 cannot be considered as reliable and can, therefore, not be recommended for use in analyses of ozone data. The uncertainty of the measurements can be reduced by calculating daily averages, but still the uncertainty remains higher than for the corresponding Brewer measurements. Nevertheless, the uncertainty of daily averages of M 124 ozone values is smaller than the natural ozone variability from day to day, i.e. by using the daily averaged ozone values information on the actual ozone amount be gained. In that respect, the averaged ozone values of the M 124 instrument are valuable.

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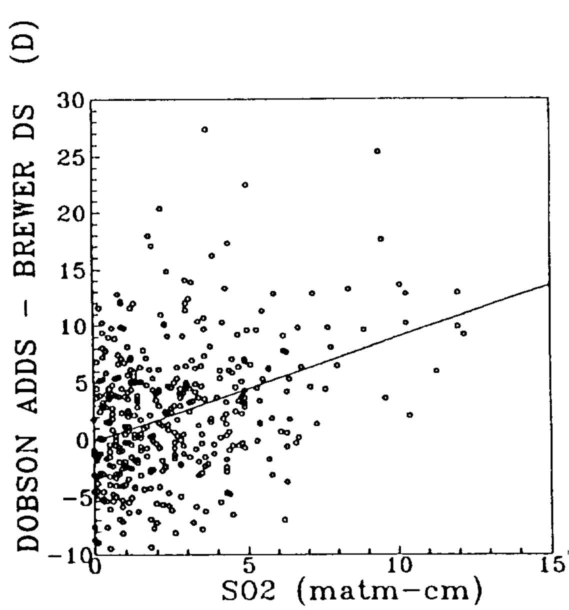

Fig. 1 Differences between Dobson and Brewer ozone observations (DS) against SO_2 amount derived from DS Brewer measurements at Potsdam (September 1987 to December 1991)

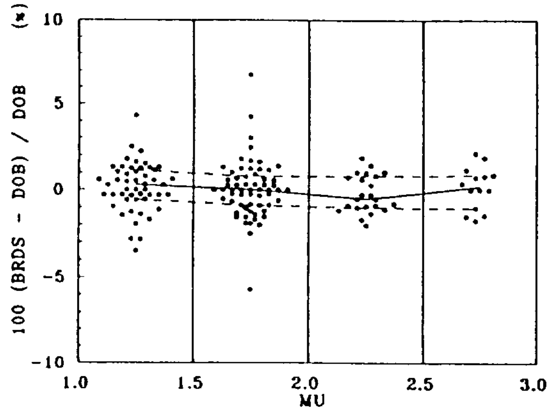

Fig. 2 Differences between Brewer (DS) and Dobson (ADDS) ozone
____ median (50 percentile)
— 25 and 75 percentile

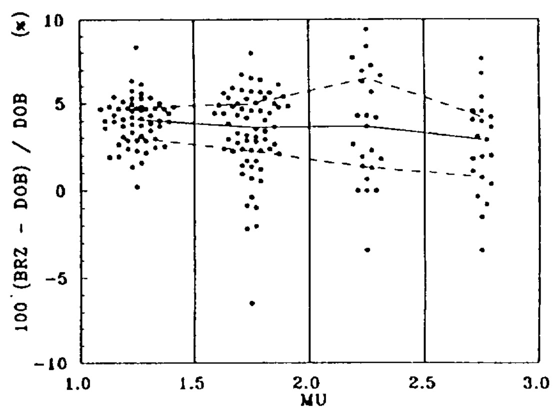

Fig. 4 Differences between M 124 ozonometer (DS) and Dobson (ADDS) ozone
____ median (50 percentile)
— 25 and 75 percentile

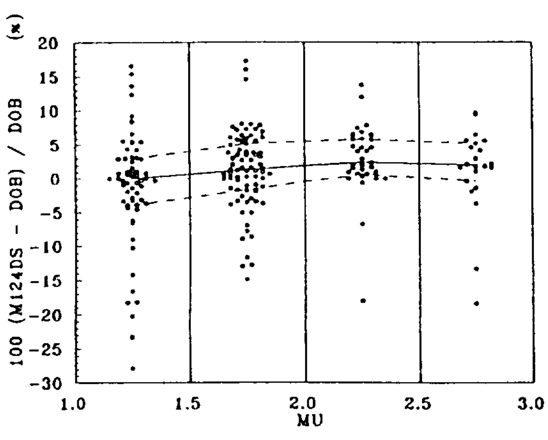

Fig. 3 Differences between Brewer (ZS) and Dobson (ADDS) ozone
____ median (50 percentile)
— 25 and 75 percentile

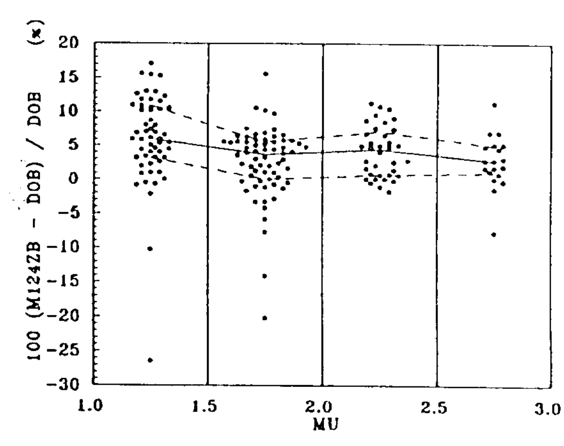

Fig. 5 Differences between M 124 ozonometer (ZB) and Dobson (ADDS) ozone
____ median (50 percentile)
— 25 and 75 percentile