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A Comparison of the New Filter Ozonometer MICROTOPS II with Dobson and Brewer Spectrometers at Hohenpeissenberg

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Abstract. The recently developed filter ozonometer MICROTOPS II No. 3128 (MTops 3128) was purchased in October 1996. Almost two years of intensive comparative measurements with the regular spectrometers Dobson No. 104 (D104) and Brewer No. 10 (BR10) and intercomparison with the standard Dobsons No. 065 (D065) and 064 (D064) on selected days confirmed that the handy MTops 3128 is able to yield good total ozone measurements. The differences between the various instruments are mostly less than ± 2%, increasing at air masses higher than 3.5 or at hazy sky conditions. Both instrumental types contribute to this increase with opposite effects. The handling during observation and data processing turned out to be easy with only few minor shortcomings. Replacement of the quartz cover didn't change the original MTops calibration significantly. Adverse effects of the filter aging or a calibration drift could not be detected over this 21-months period.

Introduction

The Global Ozone Observing System (GO_3OS) of the Global Atmosphere Watch (GAW) programme of the World Meteorological Organization (WMO) employs various total ozone measuring instruments, among them the Dobson Spectrometer, originally developed in the 1920s (*Dobson*, 1931), the modern, automated Brewer Spectrometer, available since the early eighties (*Brewer*, 1973) and the Russian M 83/M 124 Filter Instruments (*Gushchin*, 1963, *Gushchin and Sokolenko*, 1984). The spectrometers have shown their reliability and accuracy in several long term investigations and intercomparisons during the last 15 years (*Kerr et al.*, 1988, *Basher*, 1994, *Evans et al.*, 1998). Research results, yielded at the Meteorological Observatory Hohenpeissenberg (MOHp) from its long term operation of D104 (since 1967) and BR10 (since 1983), provide a considerable contribution to the international knowledge about accuray, precision, stability and conformity of both spectrometer types (*Köhler et al*, 1985, *Köhler and Attmannspacher*, 1986, *Köhler et al.*, 1988, *Köhler*, 1995).

Disadvantages of the spectrometer are their high price, high costs for operation and maintenance and large size and weight, which is adverse for field campaigns. Well trained staff is absolutely necessary to achieve good results and to keep the instruments well calibrated over a long time of operation. These reasons have prevented a more extensive use of the spectrometer in the GO_3OS network, especially in developing countries, which cannot afford the high instrumental and personal expenses needed for the successful operation of a Dobson or Brewer instrument.

The recent development of a small, inexpensive filter ozonometer such as the MICROTOPS by Solar Light Co. (*Morys et al.*, 1996) offers the opportunity to improve the spatial distribution of total ozone observing stations and to close the gaps in the GO_3OS. The MOHp purchased the MTops No. 3128 in October 1996 to keep its ozone observing programme as complete and modern as possible with "old" recognized and new types of ozonometers.

Detailed and intense tests and comparisons are necessary, to find out, whether this new MICROTOPS II instrument can meet all requirements under regular field conditions. Until now only few publications, partly about the predecessor TOPS-instrument, are available (*Flynn et al.*, 1996, *Labow et al.*, 1996). This paper presents the results of a 21-months lasting comparison (October 1996 until June 1998) of quasi-simultaneous measurements for MTops 3128 and the regular MOHp instruments D064, D104 and BR10. The results of a Dobson intercomparison with the world standard D065 in Greece in July/August 1997, in which the MTops No. 3128 participated, are shown.

Instruments and Data

Detailed descriptions of the instruments and their measurement algorithms can be found in *Komhyr*, 1980, *Wardle et al.*, 1963, *Brewer*, 1973, and *Morys et al.*, 1996. The employed instruments and the specifications of the observation types and the used wavelengths are summarized in the following table 1.

Total ozone observations are carried out on each day with sun for at least 4 minutes (observational time) with the BR10 and for at least 10 s with the MTops (less skilled personnel on weekend and holidays), on each workday with sun for at least 3 minutes with the D104. Observations with the D064 are made occasionally in order to check the calibration of D104. MTops data are marked by a flag, which indicates the conditions during the observations. The code number 1 (very hazy or thick Cs-clouds) to 4 (totally free sun, clear) was chosen following the Dobson observation procedure.

The MTops data since October 1996 are compared with all total ozone values of the spectrometers D104 and BR10, measured within 20 minutes of the corresponding MTops observations. The BR10-observations are, however, normalized to the D104 total ozone. This method provides a larger, but nevertheless uniform data base and will be described in separate paper, which will be submitted for publica-

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Table 1. Description of the employed instruments and used observation types

Instrumental type	Observation specifications
Dobson:	
D064 (MOHP) D104 (MOHp) D065 (Boulder)	Direct Sun (DS) at 2 wavelengths pairs A-D (305.5, 325.4; 317.6, 339.8 nm)
Brewer:	
BR10 (MOHp)	DS at 5 wavelengths (306.3 for SO_2, 310.1, 313.5, 316.8, 320.1 nm for O_3)
MICROTOPS II:	
MTops 3128	DS-observations at 3 wavelengths (300, 305.5, 312.5 nm ±0.4nm FWHM)

tion in GRL by *Köhler* in 1999. In the following these combined **T**otal **Oz**one data are called TOZ.

Figure 1 shows, why the BR10-normalization to D104-standard is prefered: The annual cycle of the monthly means of the relative difference D104/BR10, which is common for all instruments and not a specific MOHp-feature (*Staehelin et al.* 1998, *Vanicek*, 1998), is mainly due to different straylight sensitivity of the instruments, resulting in sun-height depending differences. A minor reason are the nominal ozone absorption coefficients of Brewer and Dobson, which have different dependences on the effective temperature in the ozone layer (*Kerr et al.*, 1988). As the Dobson is still the standard in GO_3OS, the BR10 measurements are corrected to match with this standard total ozone. Although the comparison of MTops with the spectrometers covers only 21 months, the pattern of the corresponding differences shows, that the MTops 3128 was calibrated against the Dobson standard: No annual variation is noticeable in the D104 - MTops 3128 difference (triangles), whereas the BR10 - MTops 3128 difference (rhombs) is very similar to the BR10 - D104 curve (squares).

To confirm that the general feature of all quasi-simultaneous observations is valid for single measurements

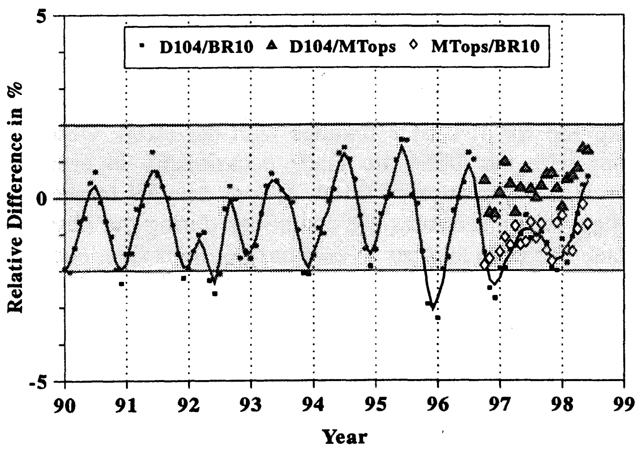

Figure 1. Monthly means of the relative differences between D104 and BR10 (squares, solid curve is 3-months-smoothed), D104 and MTops (triangles) resp. MTops and BR10 (white rhombs). ± 2 difference is marked by the grey area.

on single days too, days with a large number of observations are chosen as representative for spring time (March 31, 1998 at Hohenpeissenberg) and summer season (August 1, 1997 at Kalavryta, Greece). Moreover, the MTops was compared with the world standard instrument D065 at Kalavryta during an international Dobson intercomparison.

Results

3406 single MTops 3128 observations were compared with the TOZ data. This complete set was split into several subgroups with different ranges of sun elevation and total ozone values. The different sun elevations are characterized by the relative optical pathlength μ of the sunlight through the ozone layer; the limits of subgroups were defined as $\mu < 2$, $2 < \mu < 3$ and $\mu > 3$. Total ozone ranges were chosen as TOZ < 300 D.U., 300 to 350 D.U., 350 to 400 D.U. and > 400 D.U..

Figure 2 shows the entire data set (a) and the observations classed by the above mentioned μ-ranges (b - d). It is obvious from all panels of figure 2, that the majority of MTops values lies within the yellow marked range of ± 3% difference to TOZ. Only 132 (≙ 3.9%) values exceed this limit. Even if the marked range is reduced to ± 2%, not more than 11% of the MTops values fall outside of this limit. This means, that approx. 90% of the MTops observations can be marked as excellent. Most of the poorer measurements were made under conditions worse than code number 3 (s. previous chapter) or at weekend, when less skilled personnel carried out the MTops-measurements, whereas the TOZ-measurements only consist of the reliable automated BR10-observations. 27% of all observations outside of the ± 2%-limit are weekend observations, whereas only 15% of the entire data set are measured on weekends.

The relative difference for the entire data set is - 0.3% in the average with a ± 1σ standard deviation of 1.48%. High sun (small μ) is correlated with some lower MTops-total ozone. The linear regression fits (straight lines) yield

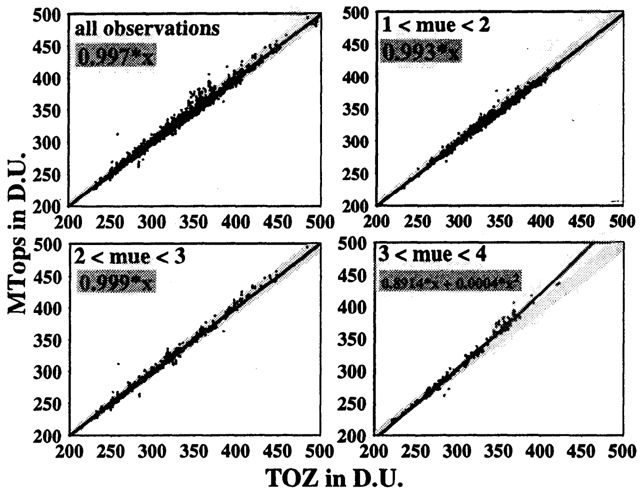

Figure 2a-d. Comparison between MTops and Dobson/Dobson-normalized Brewer total ozone in different sun elevation ranges. Top left : all observations; top right: $1 < \mu < 2$; bottom left: $2 < \mu < 3$; bottom right: $\mu > 3$. ± 3% difference is marked by the grey area, the linear regression fit by the solid line.

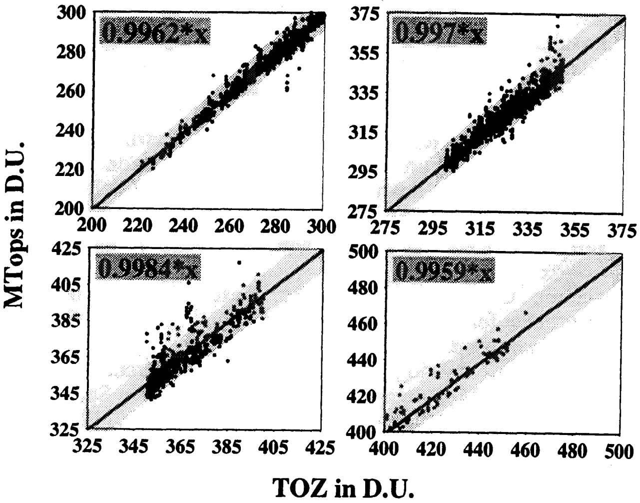

Figure 3a-d. Comparison between MTops and Dobson/Dobson-normalized Brewer total ozon in different total ozone ranges. Top left: TOZ < 300 D.U.; top right: 300 - 350 D.U.; bottom left: 350 - 400 D.U.; bottom right: TOZ > 400 D.U.. ± 3% difference is marked by the grey area, the linear regression fit by the solid line.

slopes between 0.999 (2 < μ < 3) and 0.993 (1 < μ < 2). The slope 0.997 for the entire data corresponds with the mean relative difference of - 0.3%. An opposite behaviour can be seen at very low sun with μ-values > 3 (solar zenith angles > 71°). Here the MTops provides higher ozone values than the spectrometers. This increase depends on the thickness of the ozone layer, because a simple linear regression does not fit the data points very well (Figure 2d). The mean relative difference over the entire range amounts to + 1.1%. Only 10.5% of all measurements, mainly during the winter season, belong to this "low sun range".

Figure 3a-d shows the comparison for various total ozone ranges. The features should not differ very much from the comparison in the various μ-ranges. The only distinction is: Too high and too low MTops values can be found equally distributed in all sets of data. The relative deviations vary between - 0.2 up to - 0.4% corresponding to slopes of the linear regression fits of 0.998 and 0.996. The groups of too high MTops values in the top right and bottom left panels belong at 85 % to the observation group at very low sun (μ > 3). The five too low MTops values in the top left panel were observed during poor atmospheric conditions (thick cirrus with hardly discernible sun disk).

Figure 4a-b shows single days with a wide μ-range from 1.4 to 4.2 (August 1, 1997 in Kalavryta, Greece, top panel) and 1.4 to 3.4 (March 31, 1998 at MOHp, bottom panel). As before the MTops agrees within ± 2% with all Dobson spectrometers over a wide μ-range. The results, especially during the Dobson Intercomparison in Greece in 1997 are impressingly good in the average. The MTops total ozone is approx. -0.60 ± 0.64% lower than the standard D065 at μ-values below 3.5. This difference is getting positive and very large in the μ-range 3.5 - 4.5.

Reasons for this are the well-known decrease of Dobson total ozone due to increasing straylight effects at low sun and an increase of MTops total ozone. *Morys et al.* (1996) explains this behaviour by a straylight leakage in the two ozone values, derived from the wavelength combinations 300/305.5 and 305.5/312.5, which might be overrated in the corresponding correction term in the ozone calculation by the combined 3-wavelengths algorithm. One additional problem is, that only a very small amount of radiation reaches the earth's surface at the shortest MTops-wavelength of 300 nm, especially at low sun, high turbidity and thick ozone layer. Thus the next MICROTOPS-generation will have slightly changed wavelengths (305.5, 312.5 and 320 nm) to overcome this problem.

The common feature of all instruments, that data quality is reduced at high sun (μ < 1.5), is revealed in an increased scattering of the total ozone values. The BR10-ozone values at the MOHp-comparison (Figure 4b) are original (not normalized) and therefore higher than the Dobson values.

In March 1998 the MTops was dropped and the frontal quartz cover was broken. Only small insignificant changes (< 1%) in the calibration levels occurred after repair (s. also figures 1 and 4a-b). Therefore, no changes have been applied to the original calibration factors until now. No statement can be made about the long term stability and aging of the filters on time scales longer than 21 months.

The following problems occurred affecting operation and data processing, but not the quality of the measured:

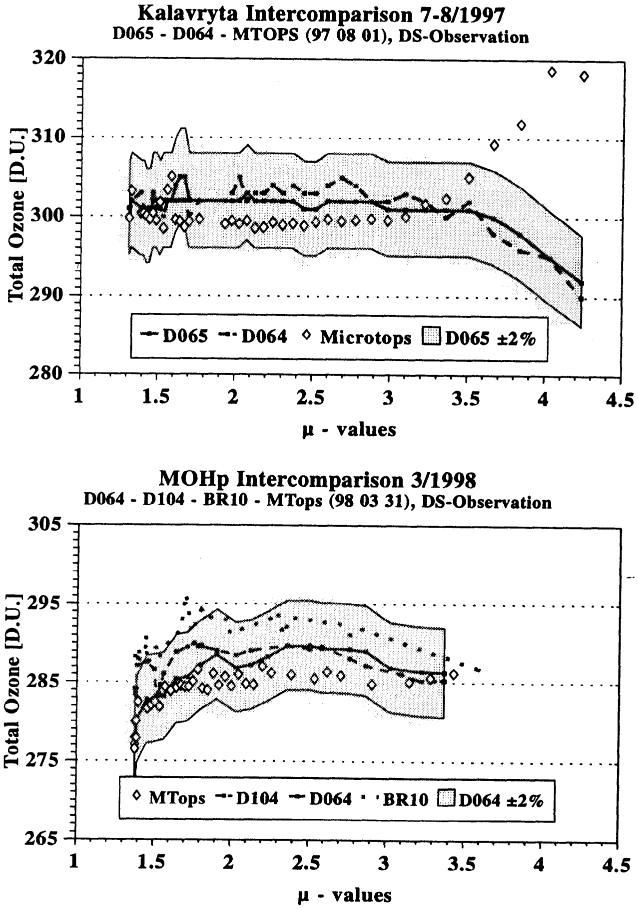

Figure 4a-b. μ-dependant comparisons of MTops with other spectrometers D064, D065, D104 and BR10 (not normalized) on single days: August 1, 1997 at Kalavryta (Greece) and March 31, 1998 at MOHp. ± 2% deviation from D065 and D064, respectively, is marked by the grey area.

- The data buffer is cleared automatically, if more then 800 data sets are measured. This means a complete data loss, if they are not read and processed before.
- Sensitivity to electrostatical discharges, especially during data reading: fatal consequences were loss of data and factory calibration values and even destruction of the serial PC-port.

Summary and Conclusion

The results of this 21-months intercomparison of the new MICROTOPS II filter ozonometer with the regular total ozone observations of Dobson and Brewer spectrometers confirm, that the MTops can measure total ozone with an accuracy comparable to the recognized spectrometers. The agreement between both types of instruments is better than ± 1% over a reasonable range of μ. Adverse observing conditions like clouds, haze or low sun cause deviations of more than ± 2% or even ± 3%. Also, there is evidence that many of the lower quality measurements were taken by inexperienced operators. This confirms, that the data quality of total ozone records strongly depends on the employment of skilled observers.

The small size and easy operation of the MTops is a great advantage over the spectrometers. The MTops can be recommended as a very useful instrument for field campaigns. It seems to be even useful as travelling instrument, e.g. to check (but not to correct!) the calibration level of Dobsons operational in the global network, provided that it is regularly calibrated against a standard Dobson. The short time needed for one observation (10 s) often allows at least one observation even on days with adverse weather conditions, where a normal Dobson or Brewer observation (several minutes) is difficult or even impossible.

Data processing with the MTops organizer software, dBase-files, and/or using EXCEL files and routines as done at MOHp is relatively easy. The data are stored in ASCII-Files and can be processed for instance with FORTRAN-programms afterwards, to obtain statistical evaluations or to compare with the data of the other instruments.

The observed shortcoming of measurements at low sun angles should be improved with the new MTops version using longer wavelengths. The use of a tripod is recommended for stable observations, as it reduces the scattering of observed total ozone values remarkably. An ESD protector is strongly recommended to overcome the above mention problem with electrostatical discharges.

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