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REVISION OF THE DOBSON TOTAL OZONE SERIES AT HOHENPEISSENBERG

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Abstract

Total ozone measurements with the Dobson No. 104 (D 104) have been performed at the Meteorological Observatory Hohenpeissenberg since 1967.

A critical review of this time series and the comparison with other instruments like TOMS or Brewer spectrophotometer revealed some intervals with uncertainties. Especially in the early eighties a monthly mean bias of about -3% to TOMS-data with annual variations depending on the mean sun-height exists. An extreme amplitude of 5.6% occurs in 1980 with -0.76% (February) and -6.36% (July).

Two different methods were applied to reprocess the Dobson data set. A comparison of the differently recalculated data showed, that the application of N-corrections by means of the standard-lamp tests starting from the reference values of the Arosa Intercomparison 1986 yields better results than the N-corrections based on a Langley-plot of the Arosa Intercomparison 1978. The extreme amplitude of the year 1980 is now reduced to 3.02%.

There is still a slight drift in the monthly and yearly mean differences between TOMS and revised Dobson data. It cannot be excluded, that the satellite data may be responsible for the trend.

1. Introduction

During the last years great efforts have been done to enhance the quality of the Dobson total ozone network. Three Dobson intercomparisons took place in Arosa (Switzerland) in 1978, 1986 and 1990, in which the Observatory Hohenpeissenberg participated with its D 104. Especially the last two comparisons revealed, that it is possible to maintain the Dobson network in Europe in a good state (**Komhyr et al., 1989; Komhyr et al., 1990/1991**). On the other hand problems are reported on the '78-comparison in Arosa (**Grasnick et al., 1991**). These uncertainties are responsible for the D 104 - TOMS differences in the late seventies and early eighties.

Investigations by **Fleig et al.** (1983) and **Bhartia et al.** (1985) indicated, that there was obviously a negative bias of some percent with a remarkable annual amplitude. Figure 1 shows these differences between the original D 104 data and the latest TOMS Version 6. A comparison with the Brewer No. 10 (**Köhler, Attmannspacher, 1986**), which was installed at Hohenpeissenberg in 1983, and a calibration check with traveling standard lamps (**Grass, Komhyr, 1985**) confirmed this calibration problem of D 104.

A first attempt to improve at least the actual data was made in 1985. By means of the well calibrated BR 10 the D 104 was recalibrated. Instead of the normal calibration (determining the extraterrestrial constants ETC of the Dobson) a new method using effective absorption coefficients EAC was applied (**Kerr et al., 1985**). The success of this first Dobson "improvement" is described in **Köhler** (1986) and can also be seen in Figure 1. The D 104 - TOMS differences are clearly reduced since March 1985.

After the successful intercomparison in Arosa 1986, it was decided to check and recalibrate the D 104 total ozone series. In the following the different attempts and methods are described.

2. Methods for data reprocessing

One main condition for the re-evaluation of a total ozone data set of a Dobson instrument is a complete documentation of all tests (at least standard- and mercury-lamp tests) and the computer availability of all raw data (R - or at least N - values). Furthermore it is necessary to have all former and actual R - N tables at one's disposal. An advantage would be to possess the records of all intercomparisons inclusively the wedge calibration data.

At Hohenpeissenberg all conditions except the raw data availability were existing. The time consuming transfer of the raw data from tables to a PC is at present done for the period 1/1978 - 12/1991 and it is planned to complete this task for the entire time series of Dobson total ozone observations. Unfortunately in the first period 1967 - 1977 only single total ozone values but no R- or N-values are available in tables. This data will be sufficient, if only an ETC-correction is necessary, which seems to be the case with Hohenpeissenberg Dobson during the concerning period.

The first attempt to re-evaluate the D 104 series was done by Bojkov and Hartmannsgruber (**Bojkov, 1987/88**). They used the TOMS observations as reference and determined monthly mean correction factors in order to adjust the Dobson to the TOMS. With this empirical correction method it is not possible to recalculate each single measurement but only the daily average, because the μ-depending ($\mu \approx 1/\cos(\text{solar zenith angle})$) bias during the diurnal course cannot be corrected. Preliminary results were published in **Bojkov et al., 1988** and **Bojkov et al., 1990**.

The next step was the re-evaluation of the Arosa Intercomparison in 1978. **Grasnick et al.** (1991) described its results only as preliminary. Although both used standard Dobsons (No. 71 from the former GDR, No. 41 from U.K.) had participated in the Boulder Intercomparison 1977 they had a remarkable difference in the D-wavelength. The negative result for D 104 can be seen in Figure 1. Large differences to the TOMS up to -6.36% in July 1980 and an additional, large annual variation (5.6% in 1980) depending on the mean μ-range of the corresponding months confirm the miscalibration of the D 104. An additional trend of +0.55% p.a. is superimposed.

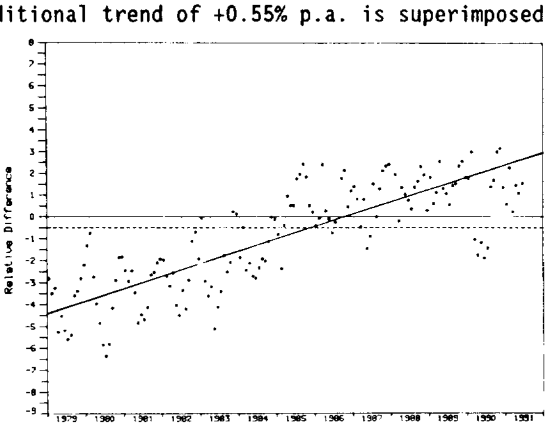

Fig. 1: Comparison Dobson 104 (orig. data) - TOMS (Vers. 6). Ordinate: Relative monthly mean differences (D104 - TOMS)/TOMS in %.

As no correction method using any standard instrument was possible, the only independent calibration method, the so-called Langley-plot was applied to determine better ETC's for D 104. The Na-, Nd and Nad-values (N-values for A, D and AD wavelength pairs) of the observations on August 24, 1978, were plotted versus the corresponding μ-values. The intercept of the linear regression curve as the best fit yields the correction values, which should be applied to the N-tables.

Thus the original Nad-correction of +9 was changed to 27.4. Figure 2 represents the effect of the modified ETC-values to the observations of August 24. The original total ozone (squares), with its obvious μ-depending trend is shifted to higher values (crosses) and the trend is significantly reduced. The daily mean changed from 302.5 D.U. (±2.7 D.U. standard deviation) to 310.4 D.U. (±1.3 D.U.).

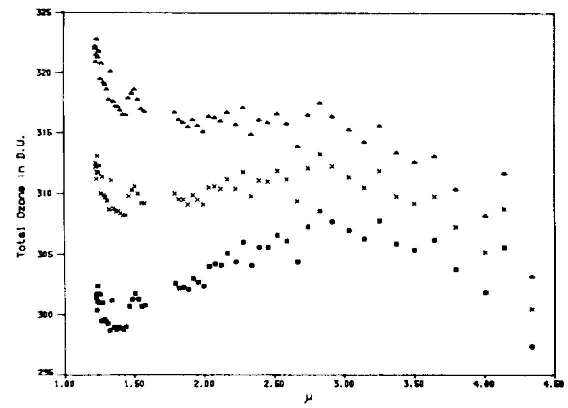

Fig. 2: Total ozone measurements of Dobson 104 in Arosa on August 24, 1978.
□ : original data
x : recalc. data Vers.1 (Arosa '78 forward)
Δ : recalc. data Vers.2 (Arosa '86 backward)

A further method is the use of a successful intercomparison (in this case Arosa 1986) and the standard-lamp record. As a first step the initial ETC's of the D 104 were determined during this campaign by means of a comparison with the world standard Dobson. A set of reference standard-lamp values were measured at the same time. A new calibration of the optical wedge confirmed, that the original wedge calibration was still valid. Thus it was possible to use the historical standard-lamp tests for calculating ETC-corrections backward till 1978, which bases on the reference values of 1986.

This method follows the recommendations of the first International Dobson Instrument Data Workshop held in September 1991 in Lanham, Maryland, near Washington (**Komhyr and Grass, 1991**). It has already been applied by some Dobson scientists and the first results were presented at that workshop.

The Nad-correction for August 1978 after this method was +44, which causes another increase of the total ozone on August 24 (s. Figure 2) up to 317.6 D.U. (±2.2). Now there is nearly no trend in the μ-range 1.5 - 3.0. The strong increase at small μ (high sun) in all three data sets may be natural, which means a real ozone increase, for example due to an airmass change. The general decrease at μ > 3.0 is characteristic for almost each Dobson due to stray light problems etc.

3 Results of the different methods

The following discussion of the results will clarify, which correction method yields the best or most reasonable total ozone series. It should be mentioned, that in all drawings the dashed line represents the reference zero line taking into account the difference between the altitude of the Hohenpeissenberg (1000 m a.s.l.) and the mean altitude for the corresponding TOMS area (500 m a.s.l.). Nevertheless all previous and following values are related to the normal zero line.

Figure 3 and 4 show the comparisons of both correction methods (Arosa 78 used for recalculating forward = Version 1, Arosa 86 used for recalculating backward = Version 2) with the TOMS Version 6.

It is obvious, that both methods remarkably improve the data set. Version 1 reduces both the mean bias to TOMS and the annual amplitudes of the differences. In 1980 the extreme amplitude of 5.6% is diminished to 4.15%, generally the monthly mean bias amounts about -1% instead of -3% in the original data. Figure 3 also reveals, that this correction is not sufficient enough. There is still a trend in the monthly mean differences of about +0.33% p.a. with significantly lower values in 1979 - 1983 than in 1984 - 1991.

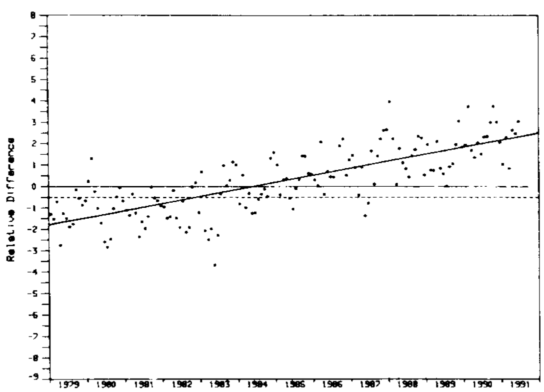

Fig. 3: Comparison Dobson 104 (recalc. data Vers.1) - TOMS (Vers. 6). Ordinate: Relative monthly mean differenced (D104-TOMS)/TOMS in %.

Correction method Version 2 yields a further improvement. The largest amplitude of 5.6% in 1980 is once more reduced to 3.02% with extremes of -0.08% in July and +2.94% in February. Positive trends in the original and recalculated (Version 1) data sets (difference Dobson - TOMS) are replaced by a small decrease between 1979 - 1984 (-0.23% p.a.) and an increase between 1985 - 1990 in the same order of Version 1 with +0.35%.

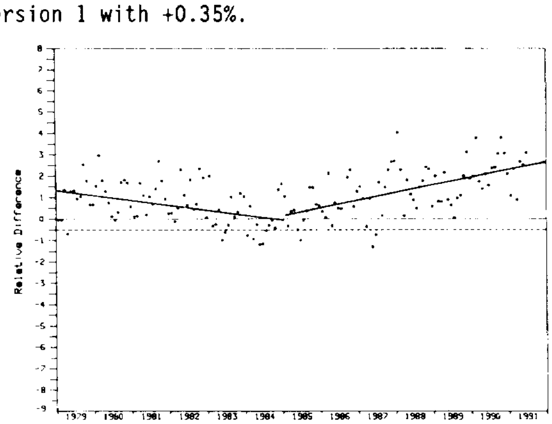

Fig. 4: Comparison Dobson 104 (recalc. data Vers.2) - TOMS (Vers. 6). Ordinate: Relative monthly mean difference (D104-TOMS)/TOMS in %.

It is not easy to clarify whether this oscillation is caused either by TOMS or by D 104. In some papers (**Chesters and Neuendorffer, 1991; Herman et al., 1991; McPeters and Komhyr, 1991; Stolarski et al., 1991**) it is claimed, that the last TOMS Version 6 should be free of any artificial trend, caused by e.g. instrumental degradation, but especially the comparison with selected Dobson stations (**McPeters and Komhyr, 1991**) does not exclude such a trend. In **Herman et al.** (1991) one possible reason for a trend especially during winter is given: The difference between the shape of the standard and the actual profile. Indeed the shape of the mean ozone profile has been changing during the last years. The ozone soundings of Hohenpeissenberg with the Brewer/Mast sonde yield a downward trend in the stratosphere of about -0.5% p.a. and an upward trend in the troposphere of +2% p.a. (**Claude et al., 1992**). These trends are changing the proportions stratosphere:troposphere from 93:7 to 90:10.

A further confirmation of the assumption, that the D 104 does not cause the above mentioned trend is the comparison between D 104 and BR 10 (Figure 5). The Brewer has been very stable since Arosa 1986. The linear regression using only the annual means yields +0.16% p.a. in the period 1986 - 1991 with a correlation coefficient of 0.443. This trend is obviously not significant. The large annual oscillations with amplitudes of 2.5 to 3% are caused by the mean sun height of the compared daily means. The Dobson observations are mainly performed at higher sun than the Brewer measurements during summer. A comparison only of simultaneous observations will clearly reduce these amplitudes.

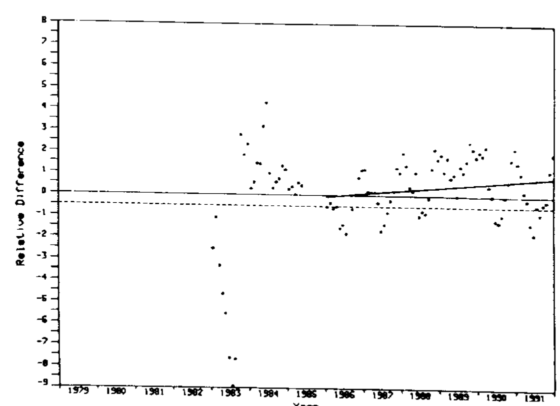

Fig. 5: Comparison Brewer 10 (orig. data) - Dobson 104 (recalc. data Vers. 2). Ordinate: Rel. monthly mean diff. (BR10-D104)/D104 in %.

Figure 6 represents the application of the new Bass and Paur absorption coefficients in the Dobson total ozone calculation (Vers. 3) instead of the Vigroux coefficients. The monthly averages are only shifted by about -2.6%, but the features are still the same.

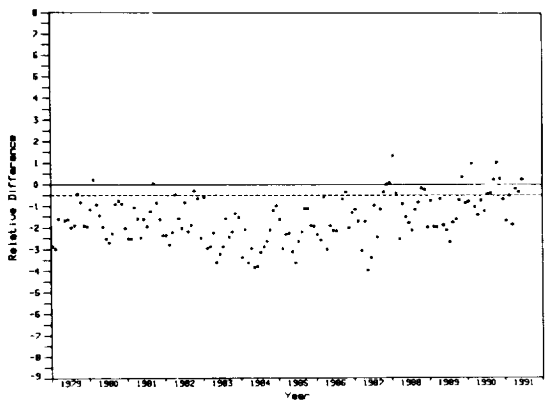

Fig. 6: Comparison Dobson 104 (recalc. data Vers.2 after Bass and Paur) - TOMS (Vers.6). Ordinate: Relative monthly mean differences (D104-TOMS)/TOMS in %.

4. Conclusion and outlook

The results of this investigation show that it will be possible to reprocess a Dobson total ozone series, if the records of raw data, tests and results of intercomparisons are available. Computer-availability of these data is a remarkable facilitation. The comparison with other instruments, especially satellite data, can be used to detect suspicious periods and to check, whether a re-evaluation is successful. They should not be used as a reference for the determination of corrections to the Dobson calibration. With this re-evaluation after method Version 2 the total ozone series of the Hohenpeissenberg D 104 is now homogeneous and reliable in the period 1978 - 1991.

It is planned to apply a similar correction to the data set of 1967 - 1977. Instead of the not available satellite or Brewer data the correlation between total ozone and 100 hPa-temperature will serve as test for the success of the re-evaluation. Additionally the Brewer/Mast-sonde correction factor from the Dobson total ozone, can be used as criterion for the homogeneity of the D 104 data set.

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