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CHECKING OZONE AMOUNTS BY MEASUREMENTS OF UV-IRRADIANCES

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Abstract:

Absolute measurements of UV-irradiances in Germany and New Zealand are used to determine the total amounts of ozone. UV-irradiances measured and calculated for clear skies and for solar zenith angles less than 60^0 generally show a good accordance. The UVB-irradiances, however, show that the actual Dobson values are about 5 % higher in Germany and about 3% higher in New Zealand compared to those obtained by our method. Possible reasons for these deviations are discussed.

1. Introduction

The evaluation of the total column of atmospheric ozone in Dobson Units (DU) is done by satellite measurements (for example TOMS) or by ground based spectrometers (for example Dobson or Brewer spectrometers) using the wavelength-dependent absorption of the direct sunbeam. In both cases the influences of aerosols put some uncertainty on the ozone values. For the determination of total ozone with the Dobson spectrometer different wavelength pairs are used to minimize the influence of the aerosols (Basher, 1982). For the determination of the ozone values by satellite measurements a radiative transfer model is used to correct the influences of aerosols. The information about the influence of the space- and time-dependent amounts of aerosols usually is insufficient, and it is helpful to look for independent methods of determining the amounts of ozone.

2. Measurements of UV-irradiances

Usually the ozone values are used to calculate UV-irradiances by means of radiative transfer models (Madronich et. al 1991). The opposite procedure is possible as well: Determination of ozone values by measuring UV-irradiances. If everything was consistent, these calculated ozone values should agree with ozone values determined by the methods described above.

Absolute measurements of UV-irradiances were made at Neuherberg, Germany (48.2^0 N, 11.5^0 E, altitude 500 m (Seckmeyer, 1989)), at Garmisch-Partenkirchen, Germany (47.5^0 N, 11.1^0 E, altitude 700 m), the Wank Mountain (47.5^0 N, 11.1^{0}E, altitude 1800 m) and in Lauder, New Zealand (45.04^0 S, 169.68^0 E, altitude 300 m) (Seckmeyer, McKenzie, 1992).
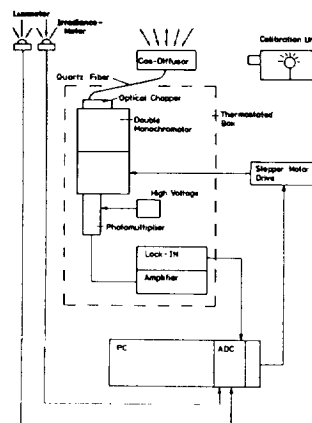

Fig.1: Schematic arrangement of the measurement system for irradiances

As shown in Fig. 1, the optical system (commercially available from Bentham, UK) consists of a cosine diffusor, an optional quartz fiber for weatherproof operation of the instrument, an optical chopper, a double monochromator (to minimize stray light) with 2400 lines/mm gratings for high resolution and transmission, a stepper motor drive, a photomultiplier, and a programmable current-

and a lock-in-amplifier. This spectrora-
diometer is supplemented by an irradi-
ance meter with a "Kipp&Zonen
Solarimeter", and an illuminance meter.
Data are transformed by an analog-digi-
tal-converter, and are analyzed by a
personal computer. Due to its sensitivi-
ty the whole system is positioned in a
thermostated container. The system is
calibrated for spectral irradiance by
means of quartz-halogen lamps. This ca-
libration was checked by the use of ca-
librated deuterium lamps. Both lamp
types were calibrated at National Physi-
cal Laboratories, UK (NPL). The calibra-
tion lamps are kept in a housing
specially designed to allow calibrations
at the measuring site.

All three slits were set to 1 nm nominal
resolution (halfband width), the spectra
were scanned in 1 nm steps from 285 to
410 nm. In order to minimize wavelength
errors, we used a correction procedure
to align the spectra accurately to an
extraterrestrial solar reference spec-
trum. The extraterrestrial spectrum is
that of Arvesen (Arvesen, 1969) with
corrections described by Nicolet (Nico-
let, 1981) and wavelength intervals of
0.1 nm in the UV-range. The spectral
lines of a mercury lamp were measured
indepedently to check the correction. We
assume the remaining measuring uncer-
tainty in wavelength to be ± 0.1 nm.

3. Comparison of measured and calculated UV-irradiances

We used an adaptation of a simple para-
metric clear-sky radiative transfer
model, based on the "Green model"
(Green, 1983) (Rundel, 1986). The green
model is basically a single scatter
model with empirical adjustments in
agreement with the Dave sperical harmo-
nics model. The theoretical accuracy of
the Green model is limited to these em-
pirical adjustments in the optical pro-
perties of aerosols and relative to mul-
tiple scattering. Our adaptation in-
cludes the use of the above decribed
reference spectrum (Arvesen, 1969) (Ni-
colet, 1981), convoluted with the in-
strument slit function. Because of the
limited accuracy of the Green model we
compared our data with two other models,
known as the "Helionda" model (Tamm,
1991) and a model based on a computer
code of Nagajima (Nakajima, 1986), (For-
kel, 1991). The results discussed here
were basically the same.

To demonstrate typical results for mea-
sured and calculated UV-irradiance we
present the data measured at noon time
on a clear sky day in Neuherberg (13
July 1990) without quartz fiber. Parame-

ters for the model are: 26.335 solar
zenith angle, 965.8 hPa air pressure,
0.03 albedo, aerosol optical depth of
0.18 at 300 nm, ozone value 316.6 DU,
determined by a Brewer spectrometer. The
Dobson spectrometer (situated at Hohen-
peißenberg 60 km away) showed 311.1 DU.
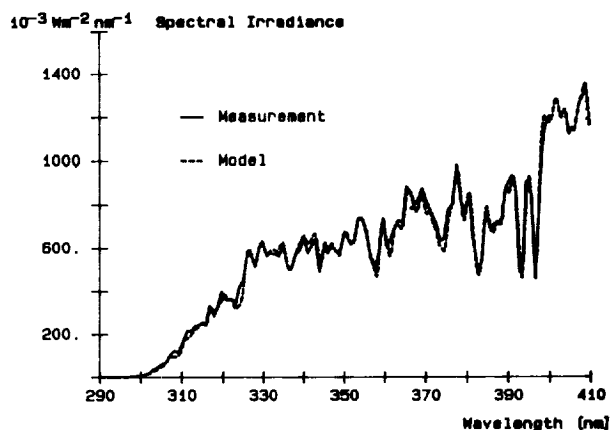The short wave limit was about 292 nm.

Fig. 2: Measured and calculated spectra
in Neuherberg for the noon time of a
clear summer day

We divided both curves of Fig. 2 to look
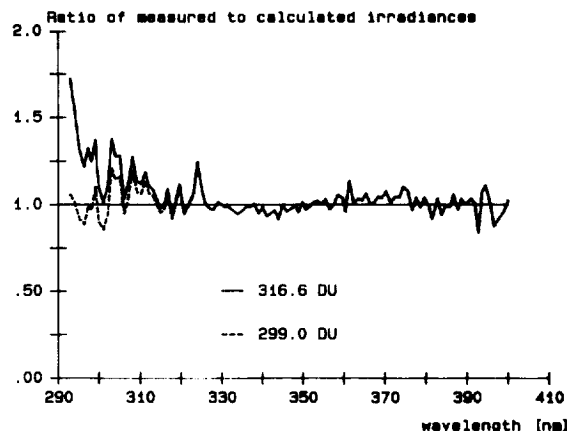for discrepancies. The result can be
seen in Fig. 3 (solid line).

Fig. 3: Ratio of measured irradiance in
Neuherberg to calculated spectral ir-
radiances for two different assumptions
of total ozone amounts

Figure 3 shows the good accordance
between measurement and calculation in
the UVA (above 320 nm). The measured
UVB-irradiances, however, are higher
than the calculated values. Assuming
that the total ozone is lower by 5.5 %
(299 DU), we come to the dashed line of
Fig. 3.

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4. Determination of ozone values

The following formula was used to determine the total ozone:

$$\sum_{\lambda_u}^{320nm} \frac{E_\lambda}{G_\lambda} \frac{E_\lambda^2}{\Delta E_\lambda^2} \frac{E_{0\lambda}}{E_\lambda} c - 1 = 0$$

where

E_λ is the measured spectral irradiance

ΔE_λ is the uncertainty of E

G_λ is the calculated spectral irradiance and is sensitive to variations in total ozone

$E_{0\lambda}$ is the extraterrestrial spectral irradiance

c is a normalization constant for the weighting function

$$\sum_{\lambda_u}^{320nm} \frac{E_\lambda^2}{\Delta E_\lambda^2} \frac{E_{0\lambda}}{E_\lambda} c = 1$$

λ_u is the short wave limit determined by the following condition:

$$2\Delta E_\lambda < E_\lambda$$

The results of this method are:

- The method is sensitive to clouds, only clear sky data show reasonable values

- The determined values of total ozone are generally lower than the Dobson values determined by the AD wavelength pairs. CD wavelength pairs are not used at Hohenpeissenberg.

- There is a systematic dependence on solar zenith angles greater 60^0 (decreasing values for increasing solar zenith angles).

- For solar zenith angles less than 60^0 our calculated total ozone amounts differ from the ozone values determined by the standard methods only by 1 to 6 %

- New Zealand data seem to differ less than German data by about 2 %.

5. Discussion

There is a number of possible explanations for the deviation between measurements and calculations:

a) The UV-measurement system did not work correctly

b) The model is not correct, or the input parameters in the model are not sufficient

c) The standard methods of determining ozone are overestimating the total amount of ozone

Possibility a) is unlikely, because other instruments measuring on 13th July 1990 showed the same behaviour as the system described above (Seckmeyer et al., 1992). The large increase of UV-irradiance compared to the model values is higher than the measuring uncertainty.

Possibility b) obviously is true for solar zenith angles greater than 60^0. For smaller solar zenith angle we got the same result with two other models (Tamm, 1991), (Nakajima, 1986) as with the Green model leading to the conclusion that we have not a special problem with our model.

Another possibility for the deviation is that the parameters needed for determining the UV-irradiances are not sufficiently known. One possible parameter is the decrease of ozone in the stratosphere and the increase of ozone in the troposphere. This assumption would lead to lower UV-irradiances (Brühl, 1989) compared to our ozone profile, but we measured higher values. The other possible parameter is the influence of aerosols. This influence is quite small in our model. But the as-

sumption of more absorption by aerosols would again lead to lower UV-irradiances (Madronich et. al 1991).

The revised Dobson values used at Hohenpeissenberg since 1992 generally show a better accordance with the values determined by our method, but the correction ranging to approximately 2.5 % (U.Köhler, personal communication, May 1992) cannot fully explain the 5 % difference.

Summing up: the uncertainties in the model calculations cannot fully explain the difference. Although we found big differences in the levels of UV-irradiances between New Zealand and Germany (Seckmeyer, McKenzie, 1992), the data analyzed so far is not sufficient to validate the significance of a difference between New Zealand and Germany with respect to an accordance between measurements and calculations. One explanation for such a difference would be that the higher aerosol content in southern Germany is responsible for a higher wavelength-dependent scattering of radiation out of the direct sunbeam and that the total ozone amounts measured in Germany must be corrected to lower values. As there are indications that the amount of aerosols has increased during the last decades over the northern hemisphere (Charlson, 1992), the actual negative ozone trends may be stronger than discussed for mid-latitudes of the northern hemisphere compared to the data presently used.

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