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UV-OBSERVATIONS WITH A BREWER SPECTROPHOTOMETER AT HOHENPEISSENBERG

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ABSTRACT

Regular spectral UV-B measurements with a Brewer Spectrophotometer have been performed at Hohenpeissenberg since 1990. Intercomparison of the Brewer instrument with other UV-B monitoring devices have shown agreement to within ± 10%.

Comparisons of UV-B spectra measured on fair weather days reveal the well known increasing influence of ozone on UV-B irradiance with decreasing wavelengths. The integral amplification factor for the erythemal irradiance reaches values up to 2.8, which can be diminished by increasing turbidity. The influence of cirrus cloud on the UV-B is also shown.

1. INTRODUCTION

Although only 8% of the solar output is in the ultraviolet, it is a very meaningful part of the solar irradiance. UV-photons possess a high energy capable of damaging materials and living cells, e.g. causing erythema and photoceratitis. There are also positive effects such as the killing of germs, and the synthesizing of vitamin D.

The UV spectrum is usually divided into three regions: UV-C (200 - 290 nm), UV-B (290 - 320 nm) and UV-A (320 - 400 nm). While UV-C is totally absorbed by ozone in the upper atmosphere and UV-A reaches the surface of the earth nearly unaffected, the irradiance of UV-B is filtered proportionally by the column density of ozone.

Brewer spectrophotometer 10 was installed at Hohenpeissenberg for total ozone observations in 1983. (Total ozone observation have been made at Hohenpeissenberg with Dobson spectrophotometer 104 since 1967). In addition to making total ozone observations, the Brewer instrument is able to scan the UV spectrum from 290 to 320 nm with a stepwidth of 0.5 nm and a half width of the slit function of 0.6 nm. Initially UV-B measurements were not made with the instrument, but during 1985 to 1989 such observations were made sporadically. Since 1990 they have been performed in a regular schedule each half an hour.

Each UV-B measurement lasts approximately seven minutes and consists of two scans. The first scan starts at 290nm and proceeds to 320 nm in 0.5 nm steps, the second scan measures backward from 320 to 290 nm. Results of the two scans are averaged in order to minimize short-term fluctuations of the UV-B during a single scan due to clouds or short-term ozone variations.

2. CALIBRATION

Because the Brewer instrument does not measure the UV-B directly in absolute values but in corresponding photon counts, it must be calibrated. Figure 1 shows calibrations, that have been performed on Brewer instrument 10 during 1987 - 1992. The triangles indicate calibrations with the mercury lamps No. 26 and No. 53. Those emit discrete spectra. The calibration functions are linear interpolations between the calibration wavelengths, and linear extrapolations beyond. The X and Y indicate calibrations with quartz halogen lamps. Those emit continuous spectra. The functions obtained from these calibrations are also linear interpolations.

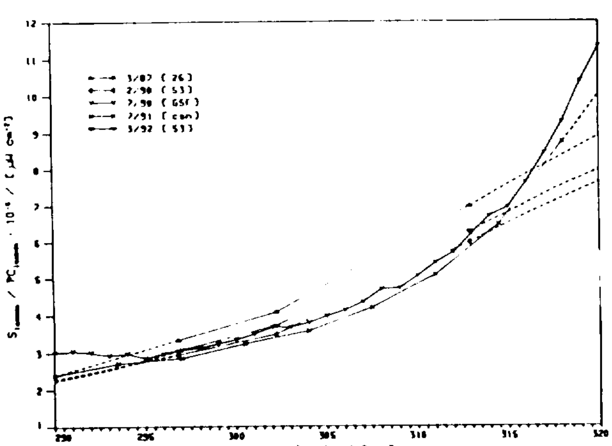

Fig. 1: Calibration functions; S_{lambda} denotes the irradiance, PC_{lambda} the measured photon counts at wavelength lambda.

Two results are obvious:

1. In spite of the different lamps, which were used, the stability of the calibration functions is fairly high. In particular, differences in the last calibrations are mostly less than 15%, considering that the calibrations of well calibrated lamps can differ up to 10%.

2. Because no spectral lines exist for mercury between about 313 - 320 nm, mercury lamps are not able to describe the strong decrease of sensitivity of the Brewer instrument at these wavelengths, caused by a $NiSO_4$ stray light filter.

As a consequence it is planned to improve the mercury lamp calibrations with a universal calibration function obtained from quartz-halogen lamps. The first step was to create this universal function, which is displayed in fig.2. The analytical expression is:

$$y = a * x^b * e^{c*x} + d$$

where $x = \lambda - 286.5$ nm and λ is the wavelength given in nm. a, b, c, and d are constants, which are found to be 0.676635, - 0.562101, 0.13403, and 2.142 respectively.

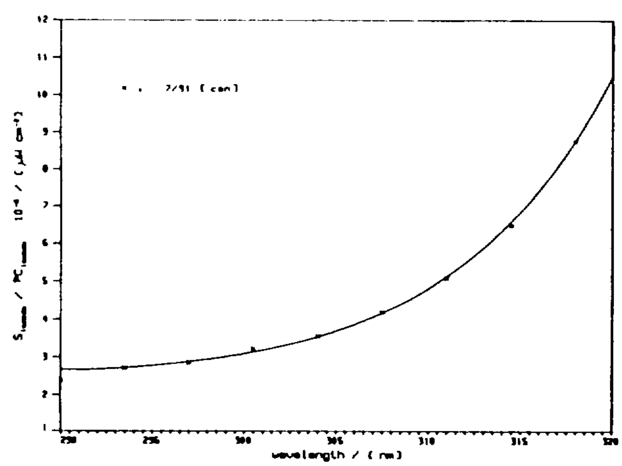

Fig. 2: *Universal calibration function (based on Canada lamp). S_{lambda} denotes the irradiance, PC_{lambda} the measured photon counts at wavelength lambda.*

This empirical function is obtained from the calibration values measured with the Canadian lamp. The mean difference between the empirical function and the calibration values, except that at 290 nm, is 0.12%. The deviation of 12.5% at 290 nm is assumed to be a maverick beeing neglectible because of the low solar irradiance and the stray light problems of the Brewer in this wavelength region. The second step is to find out how the empirical function has to be shifted. This problem is not yet solved.

Measurements presented here are preliminarily calculated with the GSF-lamp calibration (GSF = Gesellschaft für Strahlen- und Umweltforschung). This calibration was performed during an intercomparison of different types of UV-spectrometers. The intercomparison took place at the GSF near Munich on the 13[th] of July, 1990 (SECKMEYER et al. 1991). In the future we plan to improve the mercury lamp calibrations with a universal calibration function derived from the quartz-halogen lamp reprocess the data, and compare preliminary and final results.

Apart for the need of radiation calibrations, dead time and cosine corrections are necessary. As has been shown by JOSEFSSON (1986), the dead time correction is identical to that applied to total ozone calculations in the original Brewer program delivered by its manufacturer. Assuming Poisson statistics this correction compensates the dead time of the photon counting system. The cosine correction corrects the deviation from the ideal cosine response. For more detail see KÖHLER et al. (1988). Both corrections are applied to the evaluation of the UV-B spectrum.

Figure 3 shows comparison data obtained with Brewer instrument 10 and a Bentham instrument (BLUMTHALER, 1991). Both measurements were performed simultaneously at the GSF intercomparisons. The agreement in results obtained is very good over a wide wavelength range. The differences are mostly less than 10%. Only at short wavelengths (< 295 nm) does the Brewer instrument yield significantly higher values due to higher stray light.

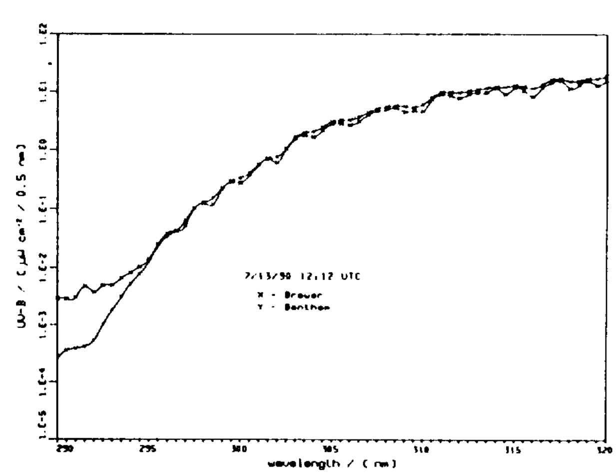

Fig. 3: *Comparison between Brewer 10 and Bentham.*

A possible way of correcting for stray light at shortest wavelengths is to average the photon counts below 292 nm and to subtract the mean value from all spectral raw data. This method was applied to the results presented in follwing section.

3. RESULTS

Figure 4 shows the influence of ozone variations on the UV-B irradiance. During the night from the 15[th] to the 16[th] of April, 1991, the daily mean of total ozone decreased by 11% from 392 D.U. to 348 D.U., while the diurnal course of total ozone for both days revealed no extraordinary variation. The spectral UV-B changes in the figure are expressed as percentage.

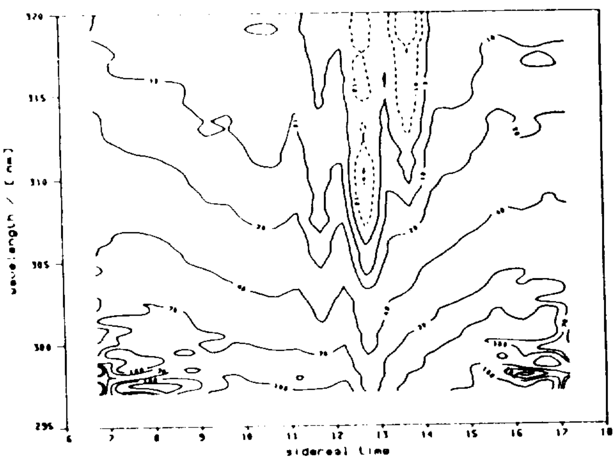

Fig. 4: *Diurnal course of spectral UV-B changes expressed as percentage caused by an ozone decrease of 11% from the 15th to the 16th of April, 1991.*

Note in figure 4 that the percent increase of UV-B irradiance increases with decreasing wavelengths. Because absolute UV-B irradiance values at short wavelength are very low and strongly influenced by stray light which cannot be entirely eliminated by the simple correction method described at the end of the section above, these values become very noisy with decreasing solar height.

Note, also from figure 4 that the percent increase of the UV-B irradiance weakens at a fixed wavelength as solar height increases. But the most striking feature is the negative UV-B irradiance deviations near noon in the wavelength region 320 - 305 nm. These are manifested in the strong undulations of the isopleths, which indicate short term variations of the UV-B. These variations were not caused by ozone fluctuations but are due to cirrus clouds which covered the sky with two octa during noon on the 16th of April. Cirrus clouds can cause a decrease or an increase in UV-B irradiance, depending on where they are located relative to the sun. It appears that longer wavelengths are more affected than shorter ones. It is of interest, therefore, to examine how erythemal irradiance was influenced during these two days.

For that purpose the spectral values measured by the Brewer instrument were weighted by an action function and then integrated. The action function used describes the relative spectral response of the MOH3-filter instrument installed at Hohenpeissenberg in 1985 (DEHNE, 1986). The instrument was developed at the Meteorological Observatory Hamburg for direct, integral UV_{er}-measurements.

Figure 5 shows the diurnal courses of the erythemal UV, measured by both instruments. The half-hourly values of the Brewer instrument are connected by a cubic spline. The MOH3 measures the integral erythemal irradiance continuously over the entire UV region with a special UV-filter. Its hourly sums are also connected by a cubic spline.

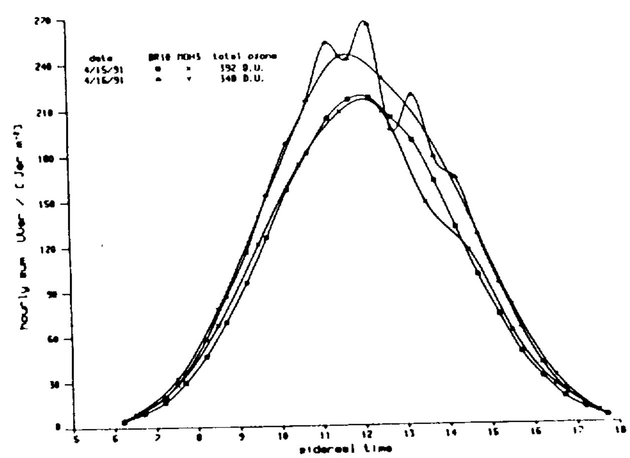

Fig. 5: *Diurnal course of erythemal irradiance measured by Brewer 10 and MOH3 instrument on the 15th and 16th of April, 1991. The subscript er indicates that UV-B irradiance is erythemally weighted.*

The agreement in results for these two different instruments is highly satisfactory for the 15th of April. On the 16th of April the discrepancy due to cirrus clouds becomes obvious. While the MOH 3 instrument shows a smooth diurnal course, the curve measured by the Brewer is strongly undulated. Cloud cover rapidly changed in the vicinity of the sun, around noon on April 16, so that the half hourly erythemal irradiance values measured by the Brewer fluctuate by nearly 30%.

In comparison with the day before, the maximum increase of the erythemal irradiance on April 16 amounts 24%. This value is surprisingly high (integral amplification factor of 2.2) taking into account, that turbidity, which was much higher on the 16th than on the 15th of April, weakens the UV-B irradiance (JOSEFSSON, 1986). The visibility, as a measure of the turbidity, decreased from 45 to 22 km.

Figure 6 shows, that the relative increase of the erythemal irradiance can be much higher due to decreasing total ozone, when the turbidity remains low. On the 26th as well as on the 29th of January, 1992, the visibility was between 100 and 110 km. In combination with low sun heights (see also fig. 4) the increase of erythemal UV amounted to 50%, whereas the total ozone decreased only by 18%. This indicates an integral amplification factor of 2.8, which is in agreement with model calculations (KÖPKE, 1992).

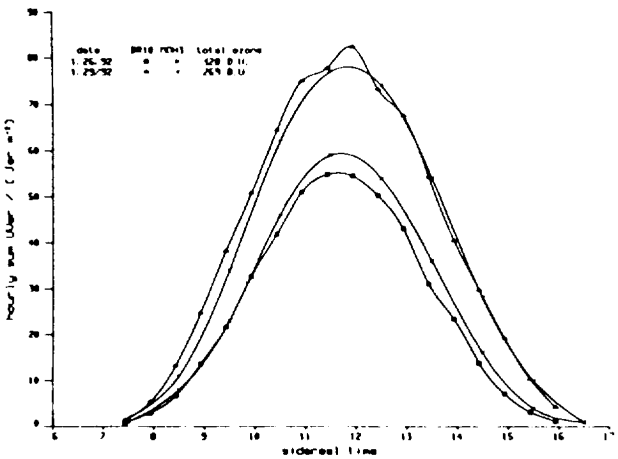

Fig. 6: Same as Fig. 5, but for the 26th and 29th of January, 1992.

For these two days the "normal" UV-B only increased by 22%. Similar results for monochromatic UV-B irradiance were obtained by ZEREFOS et al. (1985) for the wavelength range from 300 to 317 nm.

4. CONCLUSION

The amount of UV-B and erythemal irradiance depends naturally on solar height. But on fine days they are strongly influenced by the total ozone amount, cirrus clouds and turbidity. While the influence of a single cirrus cloud can cause an increase or a decrease in the irradiance, the decrease in turbidity or ozone always causes the irradiance to increase.

The impacts of clouds, turbidity, total ozone, and even the vertical ozone distribution (BRÜHL and CRUTZEN, 1989) is very complex. This impedes the forecast of a UV-B due to the stratospheric ozone decrease of about 0.5% per year, as actually measured at Hohenpeissenberg. But amplification factors larger than 1.0 (up to 2.8) suggest serious consequences to human life.

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