THE UV CLIMATOLOGY IN BELGIUM DETERMINED FROM GROUND BASED UV MONITORING.

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1. INTRODUCTION

The penetration of solar UV radiation through the atmosphere depends on the solar zenithal angle (SZA), the ozone overhead column and other atmospheric absorbers and scatters such as clouds and aerosols. In particular, clouds are responsible for a great deal of the observed irradiance variability. The interpretation of observed UV-B time series, and e.g. the detection of possible trends due to human activity, requires the correct understanding of the effects of these different 'factors of influence' and a detailed study of their evolution with time.

The instrumentation is described in the next section. Total ozone is measured at Uccle by the Royal Meteorological Institute (KMI/IRM) using a Dobson and a Brewer spectroradiometer, [*De Muer and De Backer*, 1992]. Ozone, temperature and relative humidity profiles are obtained by balloon soundings, also provided by KMI/IRM. The cloud fraction and type as well as the ground meteorological parameters (pressure, temperature, horizontal visibility, …) are monitored routinely by KMI/IRM. Since 2000, clouds are directly monitored at the station site by two different instruments: the Total Sky Imager (TSI, from YES) providing clouds cover fraction by analysis of visible CCD camera pictures, and the Nephelo 1 (Groupe Leader-Fr /IASB-BIRA – Be) measuring temperature of 181 points of the sky dome (IR – 8-14 µm) providing cloud cover fraction and ceiling altitude.

UV measurements in Uccle (Brussels) Belgium are available since April 1989 by combining the IASB measurements and data from KMI/IRM. The major results are presented and discussed in terms of correlation between the UV-B irradiance and the main atmospheric parameters like Ozone, SO_2, Clouds cover, Aerosols, … . Some preliminary results on potential trends are also presented and discussed.

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2. EXPERIMENTAL

2.1 Ground based monitoring station

The IASB/BIRA automated station is located at Uccle, a residential area in the Brussels suburbs (lat.: 50°47'54''N, long: 4°21'29''E, Alt.: 105m asl). It is operational since mid-march 1993 [*Gillotay*, 1996]. The core instruments of the main station are two double monochromator (modified HD10, Jobin-Yvon). It includes also three filter radiometers (SPUV-10, UVMFR-7 from Yankee Environmental System, (YES), GUV 511C from Biospherical Instruments) and four pyranometers (YES), two in the UV-B range (UVB-1), one in the UV-A (UVA-1) and the last covering the wavelength range from the UV-A up to the near IR (TSP-700).

One spectroradiometer (HD10 modified), with its optical axis pointing the zenith direction, is fitted with a Lambertian Teflon diffuser (2 π sr field of view) measures the total solar irradiance (diffuse + direct), with a nearly perfect cosine response. The other is mounted on a sun tracker (INTRA, Brusag) and measures the direct solar spectrum with a field of view of 4 sun diameter (2°). One scan, in perfect simultaneity is performed with each spectro-radiometer every 15 minutes for SZA smaller than 100°.

The 10-channels filter radiometer (SPUV-10, YES) measures the direct solar irradiance from 300 nm to 1040 nm. It is mounted on a sun tracking system. This radiometer is designed to provide direct solar irradiance measurements from which the ozone total column and the atmospheric turbidity (the optical depth of aerosols in clear sky conditions) can be deduced.

GUV 511C and UVMFR-7 are respectively 5 and 7 channels 2 π sr filter radiometers. The UVMFR-7 equipped with a shadowing band is designed to perform direct and diffuse quasi-simultaneous measurements of the solar irradiance, from which complementary information on ozone and aerosols can be deduced.

The pyranometers cover the full range of the solar spectra scanned by the monochromators. It permits a direct measurement of integrated doses with a much higher time sampling (1 mean integrated measurement every minute). One of the

UV-B meters is shadowed in order to measure the diffuse component of the solar irradiance.

Finally, KMI/IRM perform UV-B measurements with a Brewer (Mk II) single monochromator from 280 to 325 nm, initially at noon (from April 1989 to December 1990) and more recently on an hourly base (January 1991 – today). A schematic view of the IASB station is shown in figure 1.

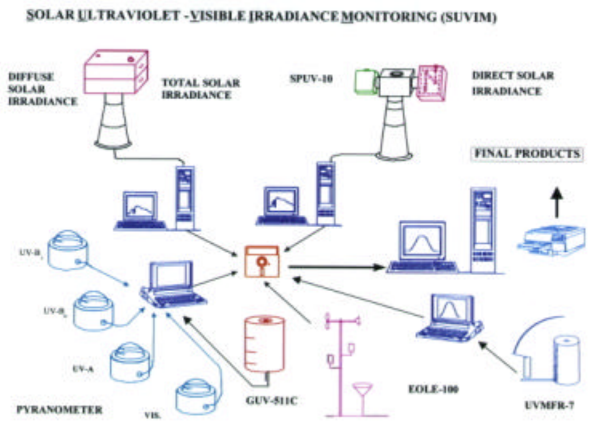

Figure 1. *Schematic view of the IASB UV station*

2.2 Calibration and quality control of the data

Periodical absolute calibration is performed in a dark room using five different NIST-FEL 1000 W standard lamps. Furthermore, stability is periodically checked by means of a **T**ransportable **L**amp **S**ystem (TLS) developed specifically in our laboratory. It consists of five 200 W quartz-halogen lamps and a Mercury low-pressure source, mounted on a carrousel inside a movable container. In the field, the different lamps are successively placed and automatically aligned with the entrance optics of the instruments. With both 'standards' the uncertainties can be estimated to be less than ±5% over all the wavelength range. This estimation was confirmed during the previous European Inter-comparison Campaign [*Gardiner et al.*, 1993]. Moreover, the coherency of the data set is verified by comparing the filter radiometer and broadband measurements with the corresponding convoluted spectral measurements.

2.3. Time series of measurements

Erythemal doses at noon in Uccle are evaluated from both sets of spectral UV-Visible measurements, by weighting each spectrum by the CIE action spectrum. [McKinlay and Diffey, 1987]. The KMI/IRM data set is corrected to take into account the lack of spectral measurements between 325 and 400 nm. The comparison of the two data sets gives a good agreement (within 5%) for most of the cases over the overlap period (1993-2001). Nevertheless, in some occasions, the discrepancy can reach 20-25%. This is probably due to 1) the unperfected synchronism between the measurements and 2) the correction of the Brewer measurements which does not take into account the modification of the cloud cover during one scan duration.

Figure 2 illustrates the available time series and shows their seasonal variation. The peak values are achieved in June, corresponding to the smallest SZA of the year and relatively low ozone columns. The scatter within the seasonal fluctuation can be ascribed to changes in cloud coverage.

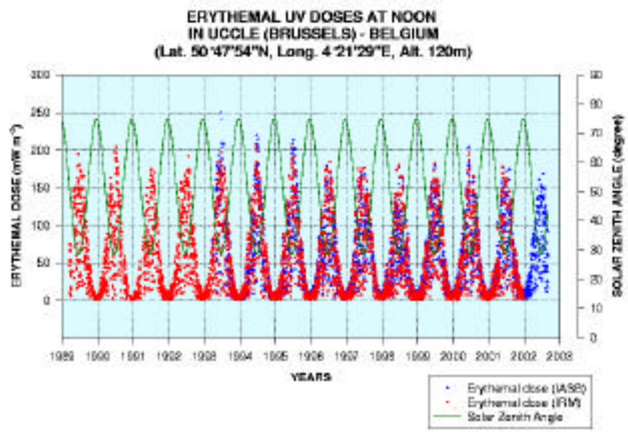

Figure 2. *Time series of the erythemal doses at Uccle.*

3. FACTORS OF INFLUENCE

The two most important factors limiting the penetration and explaining the day-to-day variations of the UV-B radiation to the Earth's surface are the ozone and the cloud coverage. These two 'factors of influence' will be detailed in the next sections. Other factors like aerosols, which are relatively constant in Brussels, will be neglected in this paper.

3.1 Ozone.

Figure 3 illustrates the anti-correlation between ozone total column and UV-B integrated irradiance corrected for the effect of cloud cover. The applied correction relatively simple: it consists in the ratio UV-B/UV-A that takes into account, as a first approximation, the effect of clouds as a neutral filter, combined with a corrective factor to describe the non-neutral effect of clouds in the shorter wavelengths of the spectrum.

A discrete ordinates radiative model [*Stamnes et al.*, 1988] has been used to simulate the experimental data and to verify the anti-correlation function between ozone and UV-B.

The extraterrestrial flux is a combination of the SUSIM spectrum below 350 nm [Van *Hoosier et al.*, 1984] and the Neckel and Labs spectrum [Neckel *and Labs*, 1984] up to 600 nm. The wavelength dependence of the aerosol optical properties follows the parameterisation of WCP [*WCP*, 1986] for typical continental mixtures. This choice is motivated by air pollution lower in Uccle than in typical urban centres. The weak dependence of cloud extinction and asymmetry factor is parameterised following the procedure developed by Slingo (1989).

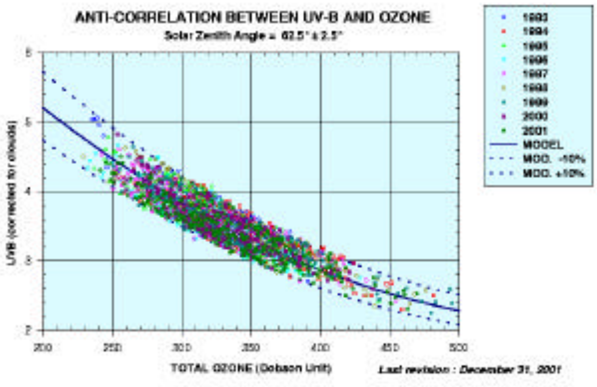

Figure 3. *Anti-correlation between ozone and UV-B*

A good agreement (better than 5%) between experimental data and the simulation has been established for SZA between 30° and 70° in clear sky condition. The discrepancies between modelled and experimental data increase generally with the SZA and might exceed 10% at high SZA in the visible range. Figure 3 shows clearly that (i) the anti-correlation factor observed experimentally is well reproduced by modelling and (ii) practically all the experimental conditions are included within a ± 10% limit vs the predicted values. This 10 % variation can easily be explained by considering the error in the ozone measurements (5%) and the unsophisticated correction of the cloud layer effects.

3.2 Clouds

In order to investigate the role of clouds as a function of wavelength, average spectra for well-defined conditions (complete overcast, similar zenith angles) have been derived from the observations, and compared with a corresponding clear sky spectrum. The average cloud transmission ratios for SZA=30 ° are displayed in figure 4, and compared to a modelled transmission ratio. A 1-km low cloud with an optical depth equal to 50 has been assumed. Despite the large variability of the cloud impact, a consistent picture is found. The attenuation is lowest in the UV-A, and highest in the ozone absorption bands (UV-B) because of the increased multiple scattering and tropospheric ozone absorption caused by cloud.The attenuation increases into a lesser extent in the visible range, reflecting the lesser importance of Rayleigh diffusion at higher wavelengths.

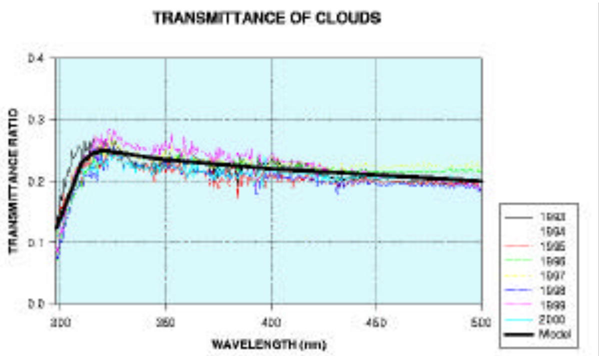

Figure 4. *Ratio of fully cloudy (8 Octas) to clear sky irradiance.*

Finally, the average attenuation of sunlight by different type of clouds can be also directly estimate from the pyranometers data. As expected, the attenuation by cirrus clouds (high altitude) is found to be very small. In contrast, low clouds (mainly stratocumulus) reduce solar irradiance by about a factor 5 on average. A more detailed study on this topics can be find in [Gillotay et al, 2002] This attenuation is found to increase monotonously with the solar zenith angle in the UV-A and UV-B ranges, but not for the total integrated irradiances (300-3000 nm). These last results have to be examined in the more detailed future modelling studies.

4. TRENDS

The bring to light of potential trends of UV-B radiation at the Earth's surface due to human activity is of high interest for the public health medical community as well as for all the scientists interested in the effects of UV-B on biology and material sciences.

The aim of this section is just to illustrate what can be deduced from a 14-years period of UV-B monitoring. Figure 5 illustrates the high variability of UV-B effective doses on a monthly base mainly due to the variability of meteorological conditions. Figure 6 and 7 give a first idea of the potential trends of UV-B and ozone in Brussels. UV-B trends show an increase of 0.55% per year that looks coherent with the ozone trends of 0.25%.

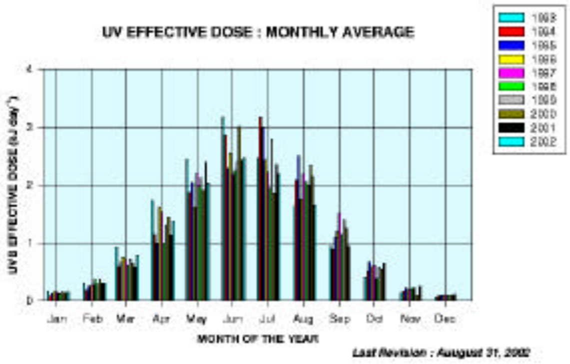

Figure 5. *UV-B effective monthly averaged doses in Uccle (Brussels) Belgium.*

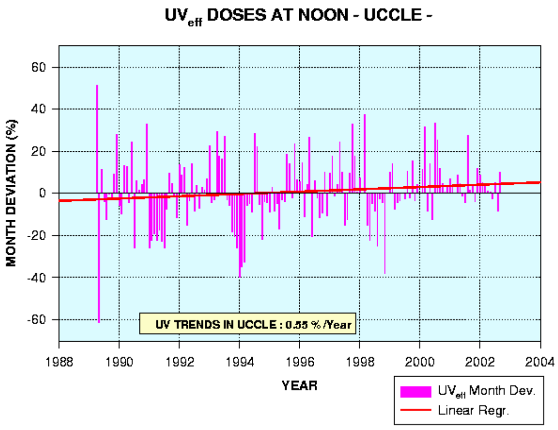

Figure 6. *UV-B trends in Brussels 1989-2002.*

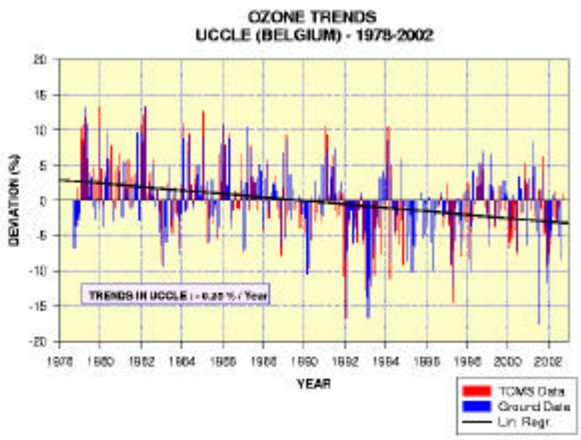

Figure 7. *Ozone trends in Brussels (1978-2002) by combining TOMS and KMI/IRM data.*

4. CONCLUSION

These results show the consistency of both our model and experimental data. They provide a first understanding of the UV-B climatology in Belgium that could be extrapolated to the 50°-latitude area.

An extended period of measurements is necessary to improve the preliminary trends given above. Nevertheless the increase of UV-B radiation seems to be real and needs to be explored in more details.

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REFERENCES

De Muer, D., and H. De Backer, 1992, Revision of 20 years of Dobson total ozone data at Uccle (Belgium): Fictitious Dobson total ozone trends induced by sulfur dioxide trends, *J. Geophys. Res.*, *97*, 5921-5937.

Gardiner B.G., Webb A.R., Bais A. F., Blumthaler M., Dirmhirn I., Forster P., Gillotay D., Henriksen K., Huber M., Kirsch P.J., Simon P.C., Svenoe T., Weihs P. and Zerefos C.S., 1993, European Intercomparison of ultraviolet spectro-radiometers, *Environ. Technol.*, *14*, 25-43.

Gillotay D., 1996, UV monitoring in Belgium: Past, present and future. in Measurements and Trends of Terrestrial UVB Radiation in Europe, (Ed. B. L. Diffey), pp. 41-53.

Gillotay D., T. Besnard and Y. Labaye, 2002, Impact of cloud spatial distribution on solar UV radiation transfer., in proceedings of 11th conference on Cloud Physics, Ogden, UT, USA, 3-7 June.

Neckel, H., and D. Labs, 1984, The Solar Radiation Between 3300 and 12500 A, *Solar Physics*, *90*, 205-258.

McKinlay, A.F; and B.L. Diffey 1987, A reference action spectrum for Ultraviolet induced erythema in human skin. CIE J. **6** p; 17-22

Stamnes, K., S. C. Tsay, W. J. Wiscombe, and K. Jayaweera, 1988, Numerically stable algorithm for discrete-ordinate-method radiative transfer in multiple scattering and emitting layered media, *Appl. Opt.*, *27*, 2502-2509.

Van Hoosier, M., J.D. Bartoe, G. Brueckner, and D. Prinz, 1988, Absolute solar spectral irradiance 120 nm - 400 nm (Results from the Solar Ultraviolet Spectral Irradiance Monitor - SUSIM-Experiment on board Spacelab 2), *Astro. Lett. and Communications*, *27*, 163-168.

World Climate Programme (WCP), 1986, A preliminary cloudless standard atmosphere for radiation computation, *WMO Report WMO/TD-No. 24*, World Meteorological Organisation.