THE INFLUENCE OF DIFFERENT TYPES OF CLOUD LAYERS ON THE UV CLIMATOLOGY IN UCCLE, BELGIUM

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ABSTRACT

The influence of ozone, and clouds on the UV climatology at Uccle (Belgium) has been studied experimentally and theoretically, since mid-1993. The correlation between the solar UV-B irradiances measured at the Earth's surface and independent observations of the cloud characteristics have been quantified for several cloud conditions. A radiative transfer model has been used to simulate these observations for clear and cloudy sky conditions, in the presence of well-defined types of cloud formations. The model results agree well with the clear sky observations for a wide range of total ozone columns. The observed spectral dependence of the irradiance attenuation due to clouds is qualitatively reproduced and explained by the model simulations.

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 scatterers 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 and simulation of the clouds effects. This, in turn, requires the examination of intensive observation data-sets by detailed radiative transfer models using co-located meteorological and ozone measurements. Such a contribution is presented here.

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 types as well as the ground meteorological parameters (pressure, temperature, horizontal visibility,...) are monitored routinely by KMI/IRM.

2. EXPERIMENTAL

1.1 Ground based monitoring station

The fixed automated station is located at Uccle, a residential area in the Brussels suburbs (50°47'54''N, 4°21'29''E, Alt. Asl : 105m). It is operational since mid-march 1993 [*Gillotay*, 1996]. The core instruments of the main station consist in two double monochromators (modified HD10, Jobin-Yvon). It includes also four pyranometers (Yankee experimental Instruments, 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-1).

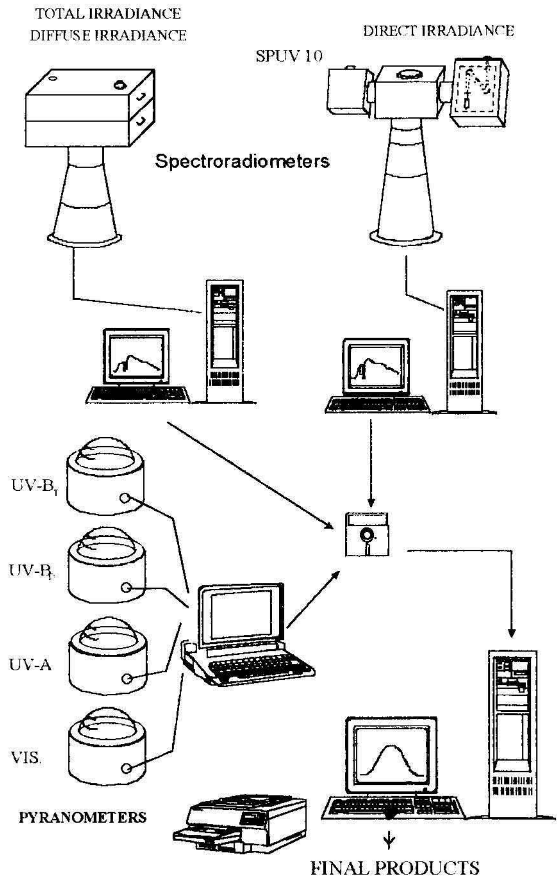

Figure 1. Schematic representation of the Uccle fixed station.

Both spectro-radiometers have their optical axis pointing the zenith direction. The first HD10 (inst. # 1) which is fitted with a Lambertian Teflon diffuser with a 2πsr field of view, measures the total solar irradiance (diffuse + direct) whereas the second spectro-

radiometer (inst. # 2) with a solid angle of 10° as field of view, measures a fraction of the diffuse irradiance at the zenith, and is mainly used for the characterisation of the cloud layer optical homogeneity. One scan is performed every 15 minutes for SZA smaller than 100°.
The pyranometers cover the full range of the solar spectra scanned by the monochromators, 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.

An additional instrument, a 10-channels filter radiometer (SPUV-10, YES) is presently under validation. The specific spectral response of the ten channels of this instrument covers a wavelength range from 300 nm to 1040 nm. The SPUV-10 is mounted on a sun tracking system (INTRA, Brusag). This radiometer is designed to provide direct solar irradiance measurements from which the ozone total column and the atmospheric tubidity (the optical depth of aerosols in clear sky conditions) can be deduced.

- **SPECTRORADIOMETERS**

INSTRUMENT	# 1	# 2	# 3
COMPANY	Jobin-Yvon		Optronic Lab.
TYPE	Modified HD10		OL754-O
FOCAL LENGTH (mm)		100	
GRATINGS		Holographic Concave	
lines/mm		1200	
FWHM at 300 nm (nm)	0.488	0.492	0.5
USUAL STEP (nm)		0.5	
USUAL RANGE (nm)			
from	211	206	280
to	683	684	500
SCAN DURATION (s)	400		800
FIELD OF VIEW	2πsr	±5°	2πsr
DIFFUSER	Teflon	Quartz	Int. sphere
DETECTOR		PMT	
type	Hamamatsu R292		S-20

- **YES PYRANOMETERS**

	UV-B METER	UV-A METER	TOTAL
	UVB-1	UVA-1	TSP-1
RANGE (nm)			
from	280	300	300
to	330	380	3000
maximum	294	330	

Moreover irradiance measurements from a mobile station consisting in a double spectro-radiometer (OL754-O, Optronic Lab.) (inst. # 3) and a 4-channels filter radiometer [305, 320, 340 and 380 nm + par channel], (GUV-511C, Biospherical Instruments), are also available when this station is home based..

1.2 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 Transportable Lamp System (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% on all the wavelength range. This estimation was confirmed during the previous European Inter-comparison Campaign. [*Gardiner et al.*, 1993].

1.3. Time series of measurements

From the spectral UV-vis. measurements, the erythemal cumulated doses in Uccle are evaluated on a daily basis.
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.

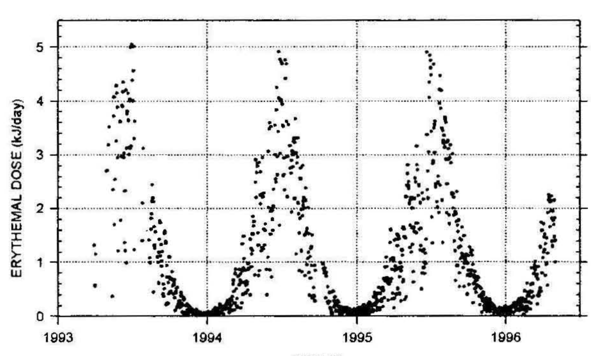

Figure 2. Time series of the erythemal doses at Uccle.

2. MODELING

2.1 Description of the model

A discrete ordinates radiative model [*Stamnes et al.*, 1988] is used to simulate the experimental data.
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.

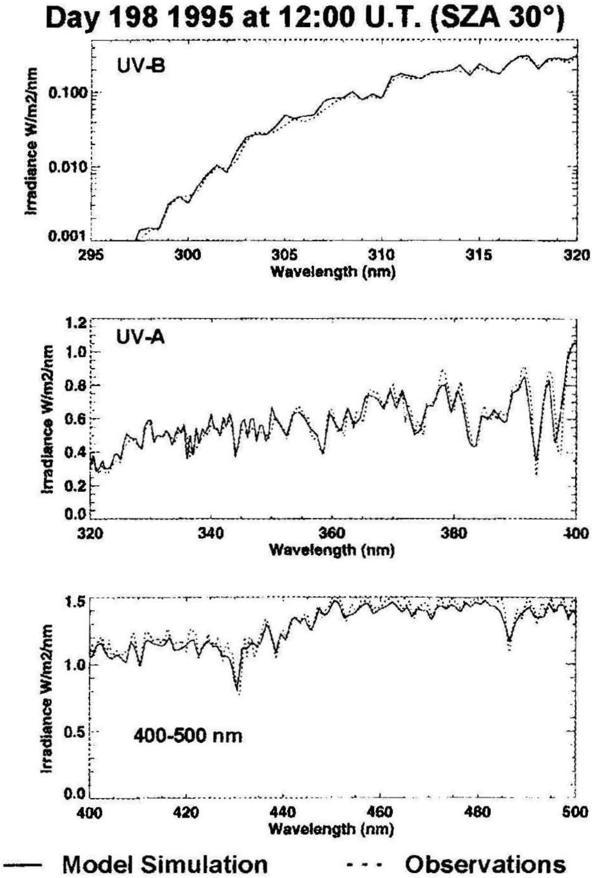

Figure 3. Comparison between experimental and modelled results for clear sky condition (Day 95-198).

The wavelength dependence of the aerosol optical properties follows the parametrisation of WCP [*WCP*, 1986] for typical continental mixtures. This choice is motivated by an air pollution lower in Uccle than in typical urban centres. The weak dependence of cloud extinction and asymmetry factor is parametrized following [*Slingo*, 1989].

A good agreement (better then 5%) between experimental data and the simulation has been established for SZA between 30° and 60° in clear sky condition. An example is shown on figure 3. The discrepancies between modelled and experimental data increase generally with the SZA and can exceed 10% at high SZA in the visible range.

3. PRELIMINARY RESULTS

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 on figure 4, and compared to a modelled transmission ratio. An 1-km low cloud with an optical depth equal to 50 has been assumed.

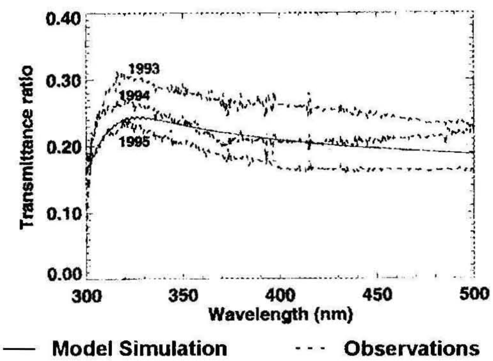

Figure 4. Ratio of cloudy (8 Octas) to clear sky irradiances.

Notice that the differences between the results from different years are not significant, the number of spectra in the averages being too low. 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.

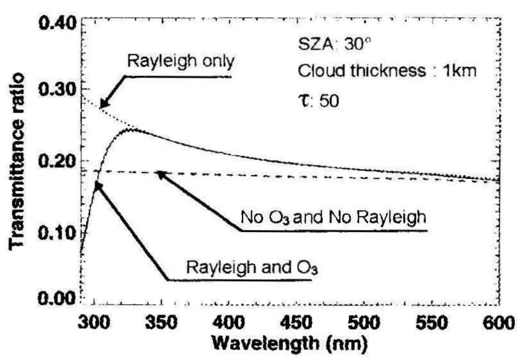

Figure 5. Simulated ratio of the mean clear sky spectrum vs. full cloud coverage.

The attenuation increases into a lesser extent in the visible range, reflecting the lesser importance of Rayleigh diffusion at higher wavelengths. These factors are illustrated in figure 5, where the cloud attenuation has been calculated with and without ozone and Rayleigh absorption.

Another way to study the impact of clouds is illustrated in figure 6, where a drastic change in the irradiance intensity is caused by a major cloudiness variation during the day. By this way spectra for similar conditions (same day, ozone,...) except for cloudiness are directly comparable. The abrupt change seen in figure 6 around 15 TU is caused by the appearance of complete overcast by low clouds at that time.

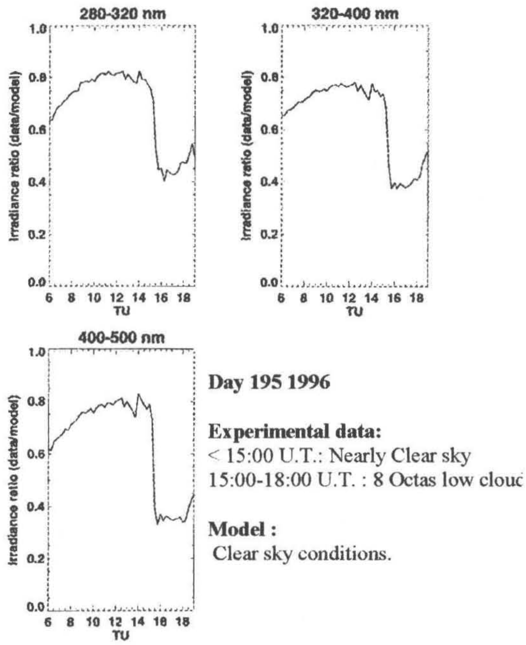

Figure 6. Ratio of measured to modelled irradiances.

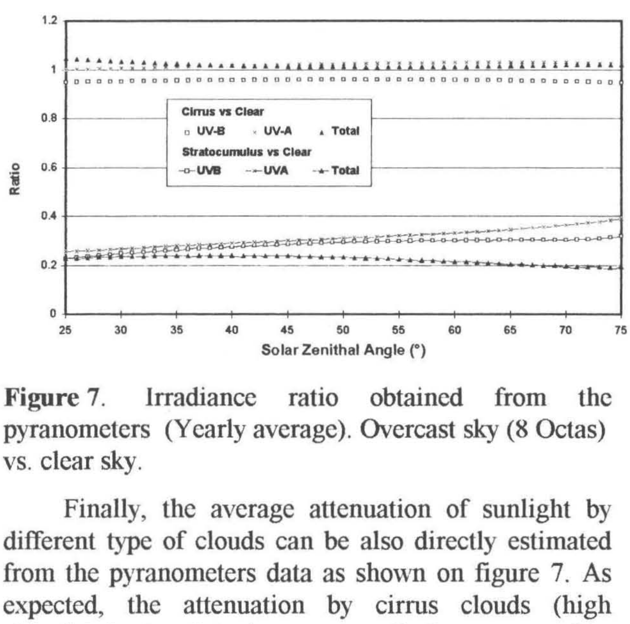

Figure 7. Irradiance ratio obtained from the pyranometers (Yearly average). Overcast sky (8 Octas) vs. clear sky.

Finally, the average attenuation of sunlight by different type of clouds can be also directly estimated from the pyranometers data as shown on figure 7. 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.

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 results will be examined in the future modelling studies.

4. CONCLUSIONS

These results show the consistency of both our model and experimental data. They provide tools to predict UV and visible irradiances for clear and full overcast sky. They already constitute a firm basis for a more systematic treatment of observations and particularly a better understanding of the cloud effect on UV irradiances.

Necessary improvements are necessary to model more specific cases such as scattered and multi-layer cloud coverage, and to increase accuracy for clear sky simulations, especially for large SZA.

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