Measurements of lunar and solar ultraviolet spectra at high latitudes

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Abstract

Quantitative spectral, solar UV measurements are introduced together with lunar spectral measurements in arbitrary units. Meteorological factors have a more pronounced effect on the UV irradiance than the ozone layer, and the ozone layer has an increasing attenuation effect towards higher latitudes. Coordinated biological and spectral lunar observations are outlined.

Introduction

The UV portion of the solar irradiance is influenced by the ozone layer, and it is the solar irradiance which has a direct impact on the biosphere. However, the general attention is focused on the ozone layer, whereas measurements of the solar irradiances have a low priority. It is clearly demonstrated that clouds and meteorological conditions have a stronger impact on solar UVB and UVA irradiances than variations of stratospheric ozone amount (Henriksen et al., 1992). Canadian UVB measurements in completely cloudless weather indicate that the UVB irradiance is independent of ozone amount for solar zenith angles greater than 60 degrees (Kerr and Wardle, 1993), demonstrating that other attenuating factors as Mie and Rayleigh scattering must be more important at high latitudes. It can also be added that the attenuating effect per Dobson unit of stratospheric ozone is higher at high latitudes because of the oblique incidence of solar radiation.

Instrumentation

The spectral solar irradiance between 290 and 600 nm has been measured with a Cerny-Turner single monochromator. This spectrometer is used only in the first order, because the spectral sensitivity for higher orders is much lower. The spectral irradiance becomes relatively negligible around 300 nm. Therefore the spectral range above 600 nm is excluded to avoid superposed irradiance from the second order.

The measurements are calibrated in absolute units, giving the number of photons hitting a horizontal surface per m^2, second, and nm. The horizontal surface consists of a ground quartz diffuser with a nearly cosine response or transmittance. Thus the global (direct and diffuse) solar irradiance is measured.

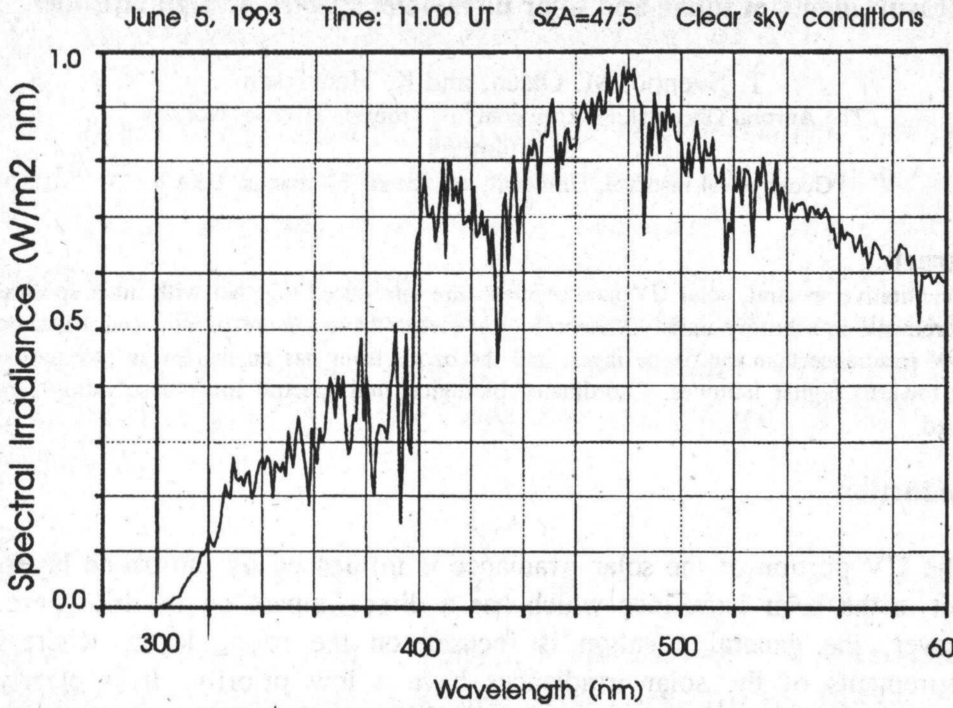
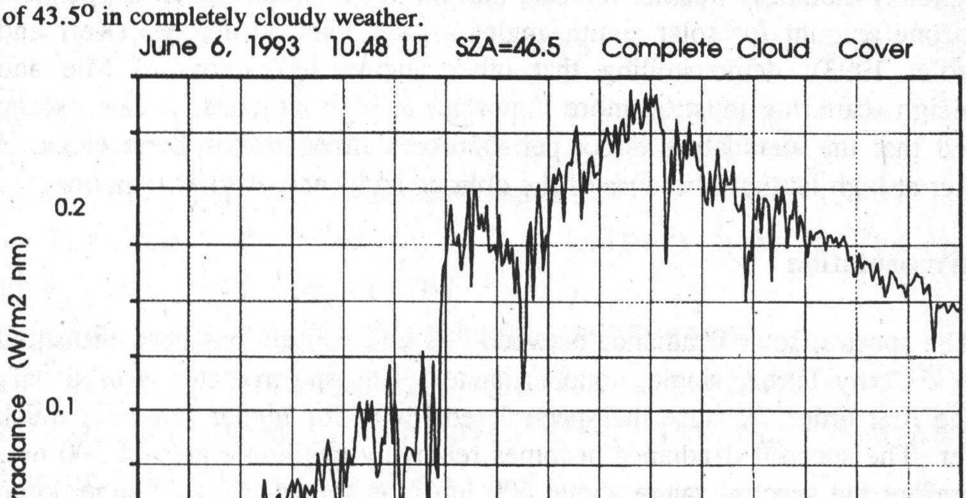


Fig. 1. Measurements of global spectral irradiance from the sun obtained at Tromso with solar elevation angle of 42.5^{0} with clear sky.

Fig. 2. Global spectral measurements of solar irradiance at Tromso with solar elevation angle of 43.5^{0} in completely cloudy weather.



Measurements

In Tromso global spectral measurements of the solar irradiance are running continuously for extended periods. In Fig. 1 a single scan is shown. Its recording time is 1 minute and resolution close to 2 nm. Another scan is shown in Fig. 2 in completely cloudy weather and the irradiances are lowered by a factor close to five. Both measurements are carried out with a solar zenith angle (SZA) close to 47°, and the ozone column density was 360 DU on the clear day and 350 DU on the cloudy day. Therefore it is obvious that the difference in irradiance must be essentially due to meteorological conditions.

The moon light may have influence on the biosphere in the Arctic during the polar night, and therefore we intend to measure the irradiance of the moon in absolute units. The spectrum of direct lunar irradiance resembles closely spectra direct solar irradiance. However, direct lunar irradiance is about 10^6 less intense than direct solar irradiance.

Comparison of deduced ozone values

During July 1992 continuous spectrometric measurements of the global irradiance were carried out in Svalbard at 78°N, and the amount of ozone was deduced using an algorithm developed by Stamnes et al. (1991). As a correction for this method the atmospheric column density was measured with Dobson spectrophotometer no. 8. Because of the midnight sun the measurements could be made throughout 24 hours per day. Comparisons of the results are given in Figs. 3 and 4. During this measuring period the solar elevation during the day decreased from 33° to 30° and during the night from 5° to 2°.

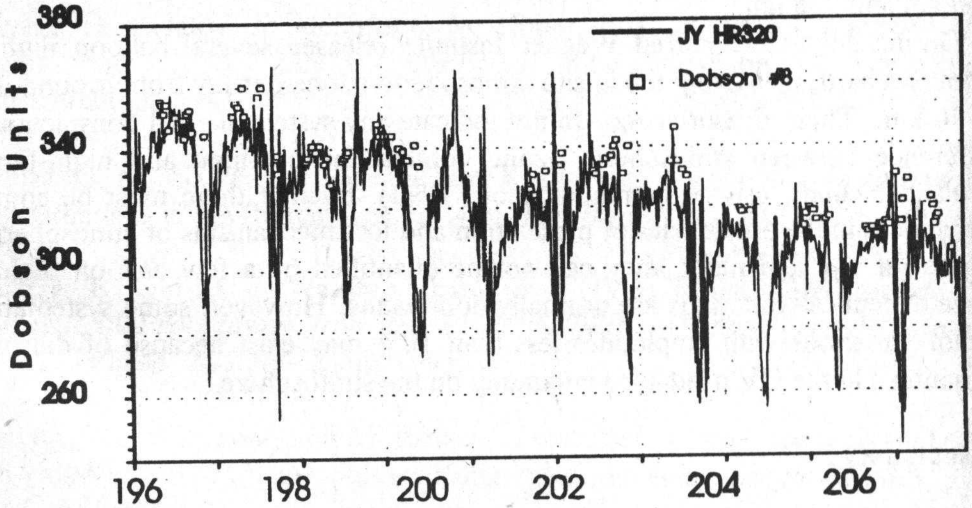


Fig. 3. Ozone column densities obtained from spectrometric measurements and Dobson instrument. A fairly good agreement appears except with low solar elevation. Day number 196 is July 15 and day number 206 is July 25.

In Fig. 3 there is a relatively good agreement between ozone values from the Dobson instrument and the spectrometer throughout most of the day. However, during the night with the lowest solar elevation the spectrometric deduction gives conspicuous low ozone values. In this case the deduction was using the measured intensity ratio between spectral intervals centered at 340 nm and 305 nm, and the width of the intervals were 2 nm.

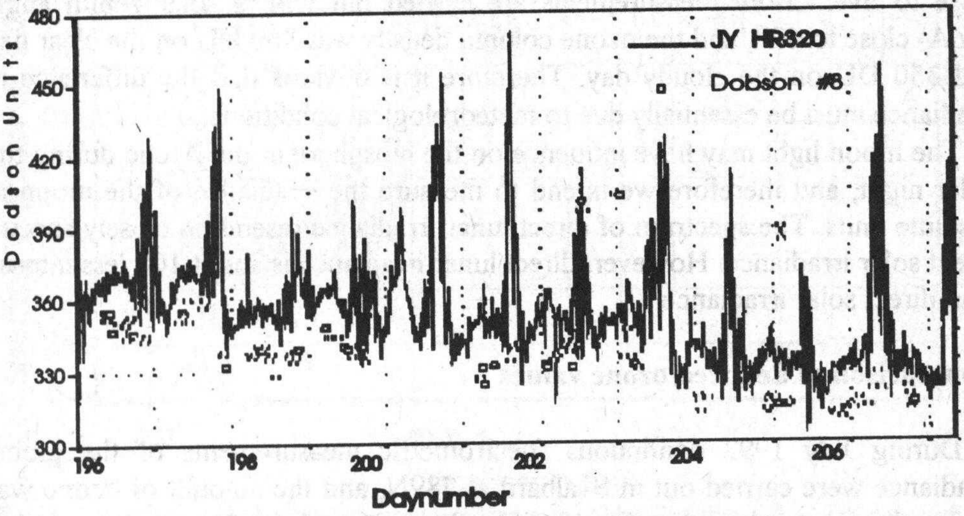


Fig. 4. Ozone column densities obtained from spectrometric meausrements and Dobson instrument. The agreement is less than in Fig. 3.

In Fig. 4 a similar comparison is shown, and the overall agreement is less. In this case the spectrally deduced ozone values show increase during night hours, and this deduction is based on the spectral ratio between intervals centered at 340 nm and 308 nm.

During July 1992 Alfred Wegner Institute released several balloon flights from Svalbard, measuring the in situ atmospheric ozone density from ground up to 30 km. Their measurements do not indicate any systematic and conspicuous difference between atmospheric ozone content for day-time and night-time (Roland Neuber, private communication, 1992). Even if there must be some differences in the efficiencies of production and loss mechanisms of atmospheric ozone for day and night, they can not be quantified by a few balloon flights since dynamical variations are normally dominating. However, some systematic minor variations with amplitudes less than 10% may exist because of diurnal variation s in the UV irradiance impinging on the stratosphere.

Discussions

At present spectral solar measurements are intermittently running in Svalbard and Tromso, and calibration and measuring routines are considered and studied in a European group (Gardiner et al., 1993). The purpose with the European study is to measure the spectral UV irradiance throughout the European region, and in this context the Tromso group is responsible for the northern part of the Scandinavian sector.

During the polar night no direct solar UV exists, only scattered light from the moon. From geometrical calculations its intensity is of the order of 10^6 less than direct solar irradiance, and a small significant portion of the moon spectrum consists of UVB. Can this UVB amount be sufficient to generate vitamin-D in the reindeers of Svalbard? These animals have so low content of vitamin-D around winter solstice that they are considered as critical cases and must have external supply before twilight gets bright in February. Using simultaneous moon spectra and vitamin-D tests of reindeers we anticipate to be able to find out if these animals are able to produce vitamin-D in their bodies by the weak UVB irradiance from the moon.

In addition to biological consequences of the solar irradiance, it contains information about the radiation source and interactions in front of the Earth surface. It is obvious that for determinations of trace constituents in the terrestrial atmosphere and albedo of the moon, spectral data are superior to broad band data.

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References

Gardiner, B. G., A. R. Webb, A. F. Bois, M. Blumthaler, I. Dirmhirn, P. Forster, D. Gillatoy, K. Henriksen, M. Huber, P. C. Simon, T. Svenoe, P. Weihs, and C. S. Zerefos, "European Intercomparison of Ultraviolet Spectroradiometers," *Environmental Technology*, 14, 25-43, 1993.

Henriksen, K., S. Claes, T. Svenoe, and K. Stamnes, "Spectral UV and Visible Measurements in the Barents Sea," *J. Atm. Terr. Phys.*, 54, 1119-1127, 1992.

Kerr, J. B. and D. J. Wardle, "Ozone and UV-B Monitoring Program in Canada," in *Proceedings from the EUROPT/SPIE Symposium High latitude Optics,* Tromso, 28 June - 2 July 1993.

Stamnes, K., J. Slusser, and M. Bowen, "Derivation of total ozone abundance and cloud effects from spectral irradiance measurements," *Applied Optics*, 30, 4418 4426, 1991.