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MEASUREMENTS OF ERYTHEMAL ULTRAVIOLET DOSAGE AT PENANG

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INTRODUCTION

AS a result of the recent concern about the ozone layer depletion (Cutchis, 1974; Bauer, 1978; Ilyas, 1979), considerable attention has been directed towards the investigations of the natural erythemal ultraviolet dosage — responsible for sunburn and skin cancer (Green *et al.*, 1976; Cutchis, 1978) — reaching the terrestrial surface. However, much of these investigations have been of theoretical nature involving estimation of the erythemal dosage distribution with latitude and season (Mo and Green, 1974; Johnson *et al.*, 1976; Mattingly, 1976) as well as the relative effect of any ozone decrease on this dosage (Cutchis, 1974; Mo and Green, 1974; Mattingly, 1976); estimates of the former type are primarily for the clear weather conditions although some progress has been made towards including the effect of average weather conditions (Mo and Green, 1974; Johnson *et al.*, 1976). The experimental data is still restricted to a relatively few stations primarily at the mid latitudes, Australia, Western Europe, North America (Robertson, 1972; Urbach *et al.*, 1974). In view of an almost complete lack of such data originating in the equatorial region and its importance, one of the erythemal UV instrument units from the Australian (CSIRO) network was installed at USM (Universiti Sains Malaysia) Campus, Penang, some months ago. The instrument has an spectral response close to the erythemal damage spectrum of the skin (Fig. 1). The unit prints out half-hourly integrated erythemal dosages. Results from a preliminary analysis of the data are the subject of this note.

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RESULTS AND DISCUSSION

(a) Annual Dosage

Over the observational period (September 78 — Jan 79), the daily dosages were obtained by adding the measured half hourly dosages. The daily dosages were then added to obtain an average daily dosage of 4.06×10^3 counts or an annual dosage of 1.48×10^6 counts. Using the absolute energy calibration of the unit, these correspond to a daily dosage of 4.10×10^3 Jm^{-2} and an annual dosage of 1.50×10^6 Jm^{-2}. A better idea of the annual dosage could be had by comparing it with similar dosage for other places. Green *et al.* (1976) have reported measured dosages for several U.S. stations. The instrument used had an spectral response almost identical to the present unit (Barton and Robertson, 1975) but the units differ in their absolute sensitivities. However, this constant can be easily obtained by comparing the average daily dosage at Penang, using the data for cloudless days with similar reported daily dosage estimate at 5^oN latitude and cloudless conditions for the U.S. instrument (Green *et al.*, 1976). The comparision indicated that the U.S. unit was 9.98 times more sensitive; the dosage data for Penang, as measured by the present unit, should be multiplied by this factor for comparision with the similar data at the U.S. stations. The so adjusted annual dosage of 14.76 MJm^{-2} for Penang may be directly compared with the reported annual dosages (in brackets) for Minneapolis (6.5), Philadelphia (6.8), Oakland (9.3), Tallahassee (10.2), Albuquerque (11.7), El Paso (13.7) and Mauna Loa (17.0). The comparision clearly shows that Penang indeed receives a very high dosage; the dosage at Mauana Loa is higher than the dosage at Penang primarily because of the former's elevation of about 4000 feet (UV-B is known to increase with elevation at the rate of about 10 - 20% per km - see Ilyas (1979) for a recent summary). The above dosages (D) may be easily converted into erythemal dosages (D_E) corresponding to the normalized damage spectrum of the skin (Fig. 1) using the empirical relationship developed by Green *et al:* $D = 13.0\ D_E^{0.82}$.

(b) Diurnal and Day to Day Variability

At any given time, the incoming solar ultraviolet radiation reaching the surface depends, primarily, upon the Solar elevation and the absorbing ozone (and aerosol) column above the surface. Over a short period of a day, the surface ultraviolet dosage varies with time due to the fast changing elevation of the sun. The dosage is additionally affected by the prevailing unclear weather conditions, especially the rainy weather (unlike the visible wavelengths, significant ultraviolet dosages may be received at the surface even with an overcast sky). Large fluctuations in the ozone column, thereby affecting UV-B dosage, over short periods of hours are generally infrequent. Diurnal variability of ½ hourly measured erythemal dosages for some of the most clear days is shown in Fig. 2. The curve for Spetember has been included to show the immediate effect of weather in the form of sharp dips (on the basis of this effect, it has been suggested to use UV-B monitoring for inferring clouds conditions). Information on the diurnal variability of UV-B may be (and should be) utilized to plan the outdoor activities outside the high intensity periods so that, damaging and harmfully high UV dosages even over short exposure intervals, may be avoided.

A variability in daily dosage from one day to another results primarily because of differing weather and sky conditions. The effect is particularly important for the equatorial climate of Malaysia and may be clearly seen in the daily dosage data for the earlier wetter months of September and October in Fig. 3. Over longer time periods (months), the daily insolation (hence erythemal dosage) is affected significantly by the seasonal effects of changing position of the sun (declination) and the variability of the ozone column (the two effects are almost opposed to each other at Penang). The daily dosages averaged over a month (Fig. 3) can be seen to vary rather smoothly (and slowly) and indicate an increase in the average daily dosage towards December when the sun is farthest. The effect, in addition to the clear sky conditions, is mainly

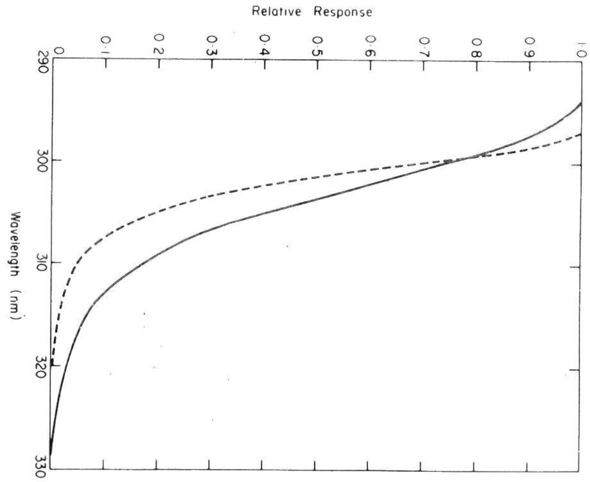

Fig. 1. Spectral response of the detector [solid line] and the erythemal response of human skin.

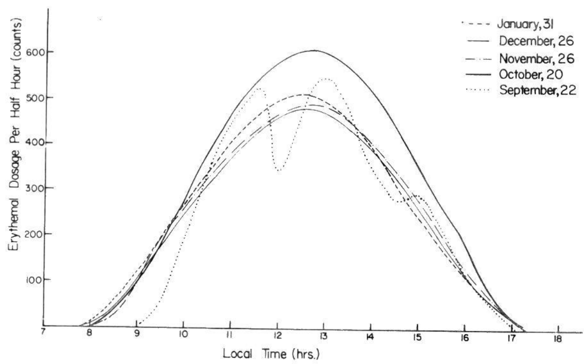

Fig. 2. Diurnal variation of the measured ½ hourly [preceeding the time indicated] erythemal dosage for some of the most clear days during the observation period [Sept. 78-Jan. 79]. The curve for Spetember is included to illustrate the effect of sky [and weather] conditions on the dosage data.

because of the decreased overhead ozone column thus allowing a larger fraction of UV to reach the surface.

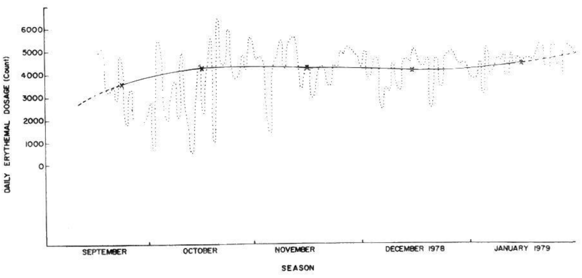

Fig. 3. Seasonal variation of the daily erythemal dosage as measured by the instrument [dotted curve] and the daily dosage averaged over month [solid curve].

CONCLUDING REMARKS

The present results represent first such observational data not only in this region but perhaps over the entire northern equatorial/subtropical latitudes. These data clearly show the erythemal dosages to be relatively higher at Penang (and other equatorial stations) compared to the high latitude stations despite the former experiencing extended periods of cloudy and rainy weather. Further data acquisition would be helpful in developing long term averages but this would very much depend upon the instruments availability, (nevertheless, another UV photometer unit has been acquired by the School of Physics to continue long term monitoring using some intercalibration with the present unit). Of specific interest would be the investigations of the elevation dependence of the erythemal dosage by operating the instrument at some highland stations. The erythemal dosage data together with the ozone data (from another project) should also provide some information on relative UV-B increase as a result of any ozone layer depletions due to activities like SSTs, aerosol spray usage etc. At the same time, erythemal dosage data should be useful to a local dermatologist to correlate the skin cancer and other UV radiational skin damage cases in the local populations as has been done elsewhere (Green *et al.*, 1976; Cutchis, 1978).

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