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A COMPARISON BETWEEN GLOBAL ***RADIATION*** AND ERYTHEMAL EFFECTIVE DOSE IN THE PRETORIA AREA

There is now little doubt regarding the depletion of the stratospheric ozone layer, the resulting increase in ***ultraviolet radiation*** at the Earth's surface, and a consequent increase in the risk of skin damage. To inform the public of this hazard, the School of Pharmacy at Medunsa and the Weather Bureau have arranged to provide daily erythemal indexes measured at Cape Town, Durban and Pretoria, for inclusion in the weather reports presented in the 8 p.m. news bulletin on TV1. With the aims of a future extension of the coverage and perhaps of estimating values for the following day, comparisons have been made between hourly UV-biometer readings at Medunsa and simultaneous readings of global ***radiation*** in Pretoria. Under cloudless conditions, the ratio of erythemal index to global ***radiation*** depends primarily on the optical airmass. Cloud tends to increase the ratio.

It is widely accepted that there has been a continuing depletion of stratospheric ozone in recent years, although there is still argument as to the causes of the effect and its future continuance. [1-7] It is also accepted that an increase in ***ultraviolet radiation*** at the Earth's surface, resulting from the decrease in stratospheric ozone, will result in an increase in erythemal stress on exposed skin in addition to other adverse biological effects. We feel that the public should be given a realistic assessment of the hazards of excessive exposure to UV-B ***radiation***, that is, ***radiation*** in the

spectral range from about 280 to 320 nanometres.

Accordingly, the School of Pharmacy at the Medical University of Southern Africa (Medunsa) arranged sponsorship for the purchase of four UV-biometers. These have been installed at various places in South Africa. The sensors are UV-B detectors of the Robertson-Berger type.[8] ***Radiation*** enters the detector through a quartz dome, under which a UV filter allows only the UV component to pass, blocking ***radiation*** of longer wavelengths. The transmitted UV ***radiation*** causes a phosphor layer to emit green light proportional to its intensity. A second filter passes only the emitted light to a photodiode, whose output is thus proportional to the UV intensity. The output is convened to frequency for transmission to the biometer recorder. The detector's internal temperature is stabilized by means of a temperature sensor and a Peltier element, controlled by the recorder. In the present application the instrument is calibrated according to the erythema action spectrum of McKinlay and Diffey. It therefore measures the erythemal effective dose (EED) resulting from a given time of exposure to the UV-B ***radiation***, rather than UV ***radiation*** per se. Three instruments have been installed in the Weather Bureau's offices in Pretoria, at Cape Town Airport and Durban Airport. The total EED at each station for the current day is transmitted to the Forecast Office, for inclusion in the weather report presented in the 8 p.m. news bulletin on TV1.

The Weather Bureau operates an extensive network of automatic weather stations capable of measuring solar ***radiation***, and already possesses a large database of global solar ***radiation***; that is, ***radiation*** in the spectral band from about 300 to 2800 nanometres, falling on a horizontal surface. This includes only part of the UV-B band, together with a much greater amount of ***radiation*** lying outside the band. It has been shown, however, that a fairly close relationship nevertheless exists between global and UV-B amounts.[9,10] Such a relationship could be used to supplement the EED values from the biometer stations, by using it to estimate values from global radiation measurements at the automatic weather stations. The relationship might also be used to develop an EED climatology from the existing global ***radiation*** database, and may help towards developing a method of estimating the following day's EED values from current readings.

The three biometers in the Weather Bureau's network were installed in December 1993, and have not yet produced enough data to warrant analysis. However, one or two instruments have been in experimental operation at Medunsa since February 1993, and have produced a substantial amount of useful data.

Accordingly, a comparison has been made between hourly EED readings made by a biometer at Medunsa and global ***radiation*** readings made simultaneously by a Kipp pyranometer in Pretoria, during the months of February to October 1993.

Both instruments measure the ***radiation*** falling on a horizontal surface, and are thus equally affected by the cosine response to ***radiation*** which falls on them obliquely, in accordance with Lambert's law. This greatly simplifies the comparison of their data. The measurements presented in this paper are expressed in MJ $m^{-2}h^{-1}$ for global ***radiation***, and in units of 210 J $m^{-2}h^{-1}$, the so-called minimum erythema hourly dose, for EED.

Figure 1 shows EED plotted against global ***radiation*** for all available pairs of hourly values. There is an obvious non-linear relationship between the two variables, together with a considerable apparently random component. It can be seen that the scatter is almost entirely towards higher EED values for any given global value. UV-B ***radiation*** is almost isotropically distributed over the sky dome compared with solar ***radiation*** at longer wavelengths, and is thus less affected by moderate amounts of cloud. This suggests that the scatter is due mainly to cloud

interference.

The suggestion is confirmed by Fig. 2, in which the EED values are again plotted against global ***radiation***, but with cloud-affected hours omitted. It is seen that the scattered values are almost completely eliminated. Some residual scatter must be expected; the two instruments are several kilometres apart, and there are probably still hourly data pairs where the ***radiation*** at one or other station was disturbed by local atmospheric conditions.

The cloud-free relationship between EED and global ***radiation*** can be closely fitted by a cubic equation, the coefficients of which are shown in Fig. 2. For obvious physical masons the curve has been constrained to pass through the coordinate origin, so the constant term in the equation is zero. The three other terms are all statistically significant. The correlation index between the two data sets is 0.75 and the standard error of estimate from the regression line is 0.15 EED unit.

Having the cosine responses of the two instruments equal, and having virtually eliminated the effects of cloud, the main cause of disparity between the two cloud-free data sets is the variation of the optical path length through the atmosphere at different solar elevations. The optical path length is usually expressed as a multiple of the optical path length vertically through one standard atmosphere; this ratio is termed the optical airmass. UV-B attenuation takes place almost entirely in the stratospheric ozone layer, whereas the attenuation of global ***radiation*** occurs more uniformly throughout the depth of the atmosphere. Due to the strong attenuation of UV-B by the ozone layer, the intensity of UV-B at the Earth's surface is very sensitive to changes in optical airmass caused by changes in solar elevation. This can be seen in Fig. 3, where the ratio of cloud-free EED to global ***radiation*** is plotted against optical airmass. The ratio is measured as the multiple of a dimensionless unit with a value of 0.00021.

The curve in Fig. 3 approximates a rectangular hyperbola. One can achieve a more nearly linear relationship by plotting the ratio of cloud-free EED to global ***radiation*** against the reciprocal of optical airmass. The result is shown in Fig. 4, which also shows a quadratic regression line fitted to the data. The constant term is probably not statistically significant; in other words, the regression line could be forced through zero with little loss in representativeness. The correlation index is 0.98 and the standard error of estimate is 0.05 EED-to-global unit.

In Fig. 5 the EED to global ratios for all available hours are plotted against the reciprocal of optical airmass. The quadratic relationship is still clearly apparent, as is the dispersion of the EED to global ratios caused by cloud.

Remembering our purpose in seeking a relationship between EED and global ***radiation***, we must consider the effect of this dispersion. Table 1 shows the frequency distribution of the deviation of the EED to global ***radiation*** ratios from the regression line of Fig. 4. One sees that about 87% of the measured values lie within 0.2 of the value predicted by the regression line. Less than 2% of the values lie below this error band, and 11% lie above it. If the regression line is used to predict EED values, it will seldom overestimate the value, and will occasionally tend to underestimate it. It would thus provide rather conservative estimates of EED and ***radiation*** hazard.

In practical terms, this source of uncertainty is at least equalled by others. For example, the manufacturers of the UV-biometer state that the calibration of any instrument relative to the McKinlay and Diffey action spectrum may be in error by as much as 5%, and disagreements greater than this have been found between two instruments exposed side by side. Moreover, the

McKinlay and Diffey action spectrum is only one of several published attempts to quantify the erythemal effect of UV-B ***radiation***, and these differ by a factor of two or more.[11] Finally, the value adopted for the minimum erythema hourly dose also varies significantly from one authority to another.

Relative to these uncertainties, the uncertainty in estimating EED from global ***radiation*** seems to be acceptable. It therefore seems that one of our aims, namely to supplement data from the UV-biometer stations by means of EED values derived from the global ***radiation*** network, is feasible within the inherent uncertainties of measuring EED.

In conclusion, we must emphasize that the work reported here is based on data collected over less than a year, during which there were occasional interruptions due to difficulties with the biometers. The results should therefore be regarded as tentative. Also, no attempt has been made to consider the effect of daily changes in the total amount of atmospheric ozone. The reason for this omission lies in the aims of the investigation. One aim is to provide day-to-day estimates of EED. There is a considerable delay in calculating total ozone values from the basic observations, so that their inclusion in the published estimates would not be possible. An alternative strategy, namely, using long-term seasonal averages of total ozone adjusted to fit recent monthly means, may be feasible.

Table 1. Frequency distribution of the EED to global ***radiation*** ratio about the regression line of the ratio versus reciprocal airmass.

EED / Global deviation	Frequency (%)
2.2 to 2.6	0.1
1.8 to 2.2	0.1
1.4 to 1.8	0.2
1.0 to 1.4	0.5
0.6 to 1.0	2.0
0.2 to 0.6	8.1
-0.2 to 0.2	87. 1
-0.6 to -0.2	1.8
-1.0 to -0.6	0.1

GRAPH: Fig. 1. Plot of erythemal effective dose (EED) versus global ***radiation***, for all available data pairs. See text for explanation of units used.

GRAPH: Fig. 2. As for Fig. 1, but for cloud-free data pairs. A cubic regression line is plotted with the coefficients shown.

GRAPH: Fig. 3. Plot of EED to global ***radiation*** ratio versus optical airmass, for cloud-free data pairs.

GRAPH: Fig. 4. Plot of EED to global ***radiation*** ratio versus the reciprocal of optical airmass, for cloud-free data pairs. A quadratic regression line is plotted with the coefficients shown.

GRAPH: Fig. 5. As for Fig. 4 but for all available data pairs. The quadratic relationship is still apparent.

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