DETERMINATION OF THE SOLAR

ULTRAVIOLET RADIATION IN TREE SHADE

A.V. Parisi[1] and M.G. Kimlin[1]

[1]Centre for Astronomy and Atmospheric Research, Faculty of Sciences, University of Southern Queensland, Toowoomba, 4350. Qld. Ph: 07 46 312226, FAX: 07 46 312721, Email: parisi@usq.edu.au

ABSTRACT

The experiment described in this paper provides students the opportunity to study the Physics of electromagnetic radiation and its interaction with the physical environment and also illustrates that Physics exists outside the school laboratory. The amount of solar ultraviolet radiation in tree shade is measured at different times of the day and compared with changes in illumination levels and temperature.

DETERMINATION OF THE SOLAR

ULTRAVIOLET RADIATION IN TREE SHADE

INTRODUCTION

Ultraviolet (UV) exposure to humans is due to sunlight received as direct radiation and diffuse radiation (Parisi and Kimlin, 1998). This diffuse radiation is sunlight that has been scattered by the molecules, aerosols and clouds in the Earth's atmosphere and by the surrounding environment. The diffuse proportion of the total global radiation progressively increases towards the shorter wavelengths (Parisi and Kimlin, 1997). The reason for this is that molecular scattering of electromagnetic radiation, known as Rayleigh scattering, increases with the fourth power of decreasing wavelength. For a given location, the relative percentage of diffuse UV radiation compared to the total global radiation varies with atmospheric conditions, surroundings (such as buildings), season and time of day. The factors of season and time of day are due to variations in the solar elevation angle influencing the pathlength of the UV radiation through the Earth's atmosphere with an effect on the amount of atmospheric scattering.

The diffuse radiation may form a significant contribution of the UV exposure to human's eyes and skin as it is incident from all directions and difficult to minimise with the usage of hats and shade structures. Protection may be provided by the shade of trees from sun burning solar UV radiation during outdoor sporting and recreational activities. Despite the intuitive understanding that the shade of a tree with the associated cooler temperatures will reduce the exposure to solar UV radiation (Kimlin et al., 1998), the question is how much protection is provided from the sun in the shade of a tree. There is personal exposure to UV radiation as a result of the diffuse radiation along with any penetration of UV radiation through the tree canopy due to flecks of sunlight in the shade. The experiment described provides a ‘hands-on’ measurement by science students of the amount of solar UV radiation in tree shade and in the process exposes students to the Physics and concepts of electromagnetic radiation, measurement and data analysis.

EXPERIMENTAL

The specific aims of the experiment are:

1. To provide students the opportunity to study basic Physics principles of UV radiation;
2. To assess the amount of solar UV radiation in tree shade.

Apparatus

- A UV radiometer. A cost effective model is the Bluewave BW10 model available from Diagnostic Instruments Pty Ltd, PO Box 159, Victoria Park, Perth, WA 6100 or Imbros Pty Ltd, PO Box 427, Moonah, Tas 7009 at a cost of $300 to $400. The BW10 meter employs filters to produce a response approximating the human erythemal action spectrum (CIE, 1987, Parisi and Kimlin, 1999). The erythemal action spectrum is the effectiveness of UV radiation to produce reddening of human skin or erythema and is wavelength dependent.
- A LUX meter to measure the visible waveband radiation. A LUX meter measures the illumination levels and possesses a response to visible radiation approximating that of the average human eye. A typical model is available from Walsh & Co. Pty Ltd, 3 Broadwater Tce., Redland Bay, Qld 4165.

- A standard laboratory thermometer or thermocouple device.

UV Radiation Measurement

The shade ratio, T_S (Parisi et al., 1999) is defined as:

$$T_S = \frac{UVBE_S}{UVBE} \tag{1}$$

where $UVBE_s$ is the erythemal irradiance measured with the BW10 meter in tree shade on a horizontal plane and UVBE is the ambient erythemal exposure to an unshaded horizontal plane.

1. Adopt appropriate personal UV protective strategies, namely, clothing, hat, sunscreen and sunglasses as this experiment involves some time in the sun.
2. Select two trees with shade that is clear of other shade and the trees preferably of two different species with a canopy width of approximately 3 m or more. Utilise a day with less than two eights of the sky covered in cloud or at least a period with the cloud free of the solar disc. The following measurements should be undertaken in the morning, for example 9 am and repeated at noon in order to investigate the effect of the different solar altitude angles on the UV radiation in the tree shade.
3. Place the BW10 radiometer on the ground on a horizontal plane with the white sensor facing up and the user standing on the south side of the instrument in order to reduce any shading of the sensor. Measure the $UVBE_S$ with the BW10 at 5 locations in the shade of one tree. Immediately after measure the UVBE in full sun with the radiometer on the ground on a horizontal plane. This measurement should be undertaken at least 2 m from the tree shade.
4. In a similar manner, repeat the measurement of $UVBE_S$ and UVBE for the second tree.

5. At the same time as the previous two steps, a second group of students may be measuring the visible illumination levels with the LUX meter on the ground on a horizontal plane at 5 locations in the tree shade of the same two trees and in full sun at least 2 m from the tree shade. A third group of students can measure the ground temperature with the thermometer in the tree shade and in the full sun.
6. Employ Equation (1) to calculate the erythemal UV shade ratio for each tree for both the morning and noon measurements. Similarly, calculate the ratio of the illumination levels and the temperature in the tree shade compared to that in sunlight.
7. Repeat the experiment on another day when there is cloud cover over the solar disc.

Sample Results

A sample of results is provided in Figure 1. The units of erythemal UV irradiance are based on the meter readings with the meter providing a number between 0 and 9.9 with 9.9 corresponding to 250 mW m^{-2} of erythemal UV. In this case, tree 1 is a gum tree and tree 2 is a she oak. The results show that there is a higher amount of UV in the shade of the gum tree compared to the she oak tree. This is due to the denser foliage of the she oak tree compared to the gum tree. The results obtained by the students may vary from these according to the types of trees employed.

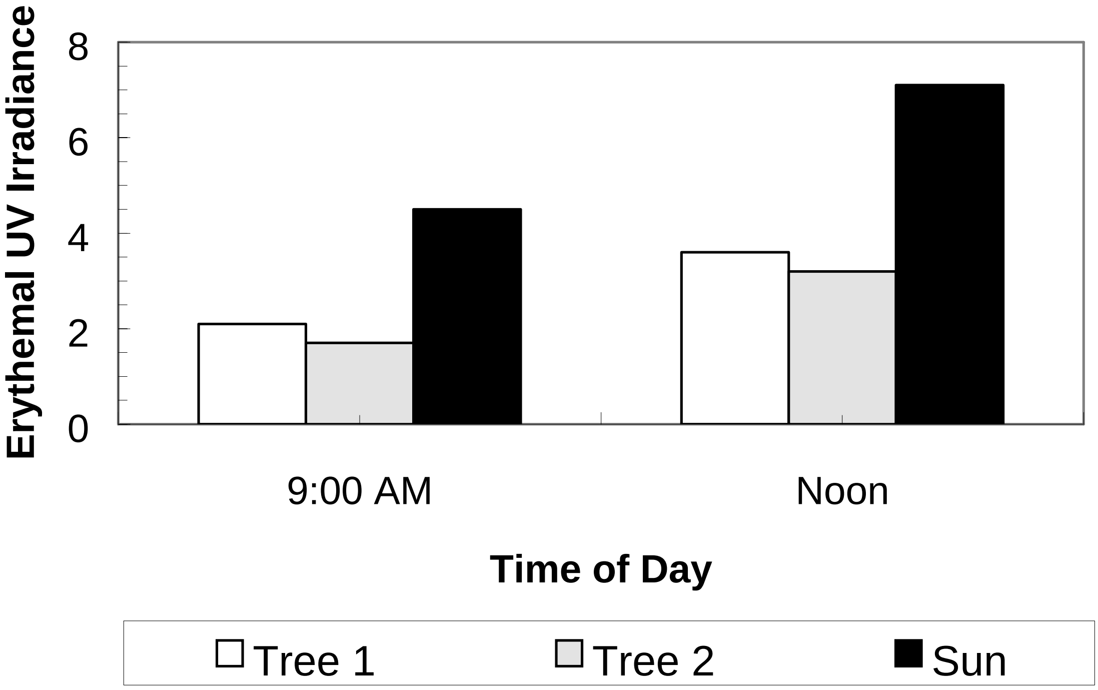

Figure 1 – Sample results of the erythemal UV irradiances in the tree shade of the two types of trees and in full sun for both times of the day.

The results in Table 1 provide the erythemal UV, illumination levels and temperature in the tree shade and in the sun along with the respective ratios of tree shade to sun for both trees in the morning and at noon. The erythemal UV shade ratio is lower for the she oak compared to the gum as a result of the denser foliage of the she oak. This is illustrated by the ratio of the illumination levels being lower for the she oak compared to the gum. The UV shade ratio for both trees is expected to be higher in the morning compared to noon due to the longer atmospheric pathlength in the morning resulting in a larger amount of molecular scattering and a higher relative proportion of diffuse UV radiation. However, this is not the case with the sample results provided. The reason is that in this case, there was approximately one half of the sky covered in cloud with the solar disc clear of cloud at noon compared to a clear sky for the 9 am readings. Consequently, in this case, the additional scattering by the cloud at noon increased the proportion of diffuse radiation and resulted in the higher than expected UV shade ratio.

The ratio of the illumination levels in the tree shade compared to full sun is less than the shade ratio for the UV radiation. This is due to the higher amount of diffuse radiation at the shorter wavelengths. The illumination levels in the tree shade do not necessarily provide an indication of the skin damaging UV in the shade. The cooler temperatures in the tree shade do not necessarily mean there is no skin damaging UV in the shade. The temperature is a result of the infrared electromagnetic radiation that is at the longer wavelength end of the spectrum compared to visible and UV radiation. Consequently, the temperature may not provide an indication of the UV radiation.

The students can discuss:

- The factors influencing the UV radiation in tree shade;
- Differences in the UV radiation in the shade of the two trees;
- Influences on the shade ratio in early morning compared to noon;
- The factors influencing the amount of variation between the ratio of the visible illumination in the tree shade and full sun compared to the shade ratio of the erythemal UV irradiances.
- The incidence of the experimental results to the incidence of sun related health problems in the community, such as skin cancer and eye damage.

Table 1 – The erythemal UV, illumination levels and temperature in the tree shade and in the sun and the respective ratios of tree shade to sun for both trees at both times.

Time	Tree	Erythemal UV			Illumination			Temperature		
		Tree	Sun	Ratio	Tree (LUX)	Sun (LUX)	Ratio	Tree (^{o}C)	Sun (^{o}C)	Ratio
9 am	1	2.1	4.5	0.47	27500	87500	0.31	21	25	0.84
9 am	2	1.7	4.5	0.38	24000	87000	0.28	22	25	0.88
Noon	1	3.6	7.1	0.51	29500	116000	0.25	26	31	0.84
Noon	2	3.2	7.1	0.45	26400	116000	0.23	25	31	0.81

REFERENCES

CIE (International Commission on Illumination) Research Note (1987). A reference action spectrum for ultraviolet induced erythema in human skin, *CIE J. 6*, 17-22.

Kimlin, M.G., Wong, J.C.F. & Parisi, A.V. (1998). Simultaneous comparison of the personal UV exposure of two human groups at different altitudes. *Health Physics*, *74*(4), 429-434.

Parisi, A.V. & Kimlin, M. (1998). Measurement of reflected, total and diffuse solar erythemal ultraviolet radiation. *Australian Science Teachers' Journal*, *44*(3), 9-11.

Parisi, A.V. & Kimlin, M. (1999). Testing the solar ultraviolet transmission of clothing and materials. in press *Australian Science Teachers' Journal*.

Parisi, A.V., Willey, A., Kimlin, M. & Wong, J.C.F. (1999). Penetration of solar erythemal UV radiation in the shade of two common Australian trees. in press *Health Physics.*

Parisi, A.V., & Kimlin, M. (1997). Why do UV levels vary? *Australasian Science*, *18*(2), 39-41.