MEASUREMENT OF REFLECTED, TOTAL AND DIFFUSE SOLAR ERYTHEMAL ULTRAVIOLET RADIATION

Alfio Parisi and **Michael Kimlin**

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

An experimental program was devised by the authors to firstly, provide students with practical 'hands-on' experience of concepts of physics, and secondly, increase awareness of the dangers of UV radiation by a series of scientific measurements on UV irradiance levels. A group of grade 10 students undertook the experiment and sample results are presented.

Photo (AP)

Dr Alfio Parisi *is a physicist in the Faculty of Sciences, at the University of Southern Queensland (USQ). As a member of the USQ Centre for Astronomy and Atmospheric Research, his particular research interests are the measurement of terrestrial UV radiation and the effects of UV on plants and humans.*

Photo (MK)

Michael Kimlin *is a physicist whose main area of research is the effect climate has on human UV exposure as well as human UV exposure distribution measurements. He is an associate member of the USQ Centre for Astronomy and Atmospheric Research.*

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INTRODUCTION

The risk of developing non melanoma skin cancer is related to the cumulative ultraviolet (UV) exposure and the risk of melanoma increases with the number of sunburns, specially during childhood. The highest incidence rates of non-melanoma skin cancer and cutaneous malignant melanoma in the world are in Australia (Parisi and Kimlin, 1997a). Queensland has low latitudes, relatively fine, warm weather and the population enjoys an outdoor lifestyle with resulting high skin cancer rates. The quantification of solar UV levels is an important part of increasing the awareness of the public to excessive UV exposure. Furthermore, the measurement of ultraviolet radiation may be used in the instruction of science students with regards to the concepts of measurement, the electromagnetic radiation spectrum, the energy of electromagnetic radiation, data analysis, molecular absorption and scattering.

EXPERIMENTAL

An experimental program was devised by the authors to firstly, provide students with practical ‘hands-on’ experience of the above concepts, and secondly, increase awareness of the dangers of UV radiation by a series of scientific measurements on UV irradiance levels. A group of seven students from Harristown High School, Toowoomba, undertook the project with a series of measurements to determine the reflected, direct and diffuse solar UV radiation.

The UV waveband is comprised of the UVA (320 - 400 nm), UVB (280 - 320 nm) and UVC (200 - 280 nm) wavelengths. No UVC is present at the earth’s surface as a result of efficient absorption by oxygen and ozone in the atmosphere. The solar UV radiation at the earth’s surface comprises of a direct and a diffuse component (Parisi and Kimlin, 1997b). The direct component comes in a direct path from the sun, whereas diffuse radiation is scattered by the atmosphere, clouds and the surroundings. The molecular scattering increases with the fourth power of decreasing wavelength and as a result scattering is more significant at the shorter UV wavelengths compared to the longer visible wavelengths. Combined, the diffuse and direct UV radiation make up the total or global solar UV radiation. The reflected UV radiation is the UV reflected from any surface. In this case it will be referred to as the UV reflected from the ground surface. The specific aims of the project were:

1. To expose the students to the basic physics principles of ultraviolet radiation
2. To measure the solar erythemal UV reflectance over grass and asphalt
3. To measure the direct solar erythemal UV and the diffuse solar erythemal UV irradiances

Apparatus

- A UV meter. 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.
- Holder for the meter that may be made by the manual arts section of the school.
- Retort stand (Science Department)
- School ruler or equivalent to shade the meter for providing a diffuse erythemal UV reading.

Measuring UV Reflectance

1. The BW10 UV meter has been designed to have a response that approximates the response of human skin to UV radiation. Consequently, the meter is measuring the erythemal UV irradiance or the UV irradiance weighted with the response of human skin (Parisi and Kimlin, 1997a). This response (known as the erythemal action spectrum) is wavelength dependent with the shorter wavelengths being the most damaging (producing greatest erythema). The ability of UV wavelengths to produce erythema drops by approximately a factor of 1000 for the UVA wavelengths compared to the UVB wavelengths.
2. The students took two readings per day, namely, one at morning tea (approximately 10.30 am Eastern Standard Time) and the other at lunch time (approximately 1.00 pm Eastern Standard Time) over a period of two weeks. It was important to standardise as much as possible in the experiment so that each series of measurements was taken in the same fashion. For example, the students took the readings at the same time each day, at the same location and used the UV meter at a set height above the ground.
3. Two of the students and one of the authors are shown in Figure 1 with the UV meter in the holder and held by the retort stand.
4. The total solar erythemal UV irradiance readings were taken with the meter perpendicular to the ground, pointing upwards.

5. In order to calculate the erythemal UV reflectance, the detector was orientated perpendicular to the ground, facing the ground surface and the value recorded. This was repeated for each of the two surfaces.
6. The percentage reflectance (or albedo) of the surface (R%) was calculated using:

$$R\% = \frac{UV_{Ref}}{UV_{Tot}} * 100\%$$

   where UV_{Ref} is the reflected UV measured in step 5 and UV_{Tot} is the total solar UV irradiance measured in step 4.
7. The measurements were taken over grass and asphalt, or alternatively, they may be taken over any other outdoor surfaces.
8. The percentage reflectance of each surface was calculated versus day number for both times of the day.

Figure 1 - Two of the students with one of the authors measuring the UV irradiances.

Measuring Diffuse Erythemal UV

1. The diffuse solar erythemal UV was measured with the meter in the same position as that for measuring the solar erythemal UV with the meter horizontal and pointing upwards. In addition, a ruler was placed 10 cm above the meter in such a way that the ruler's shadow covered the detector.

2. These measurements were repeated at morning tea and lunch for a period of two weeks.
3. The weather conditions were noted at each measurement time.
4. The total solar erythemal UV irradiance and the diffuse solar erythemal UV were plotted versus the date for both times of the day.

Sample Results

A sample of the results collected by the Harristown High students mentioned above are presented here. The percentage reflectance or albedo over the predominantly dead grass and the asphalt measured on each day were averaged for both the morning tea and lunch time measurements over the experiment days to produce an average reflectance of 3.3% and 3.8% for the dead grass and asphalt respectively.

The results in the graph in Figure 2 of the total and diffuse erythemal UV irradiances measured at approximately 1.00 pm each day show a variation in both the total and diffuse UV radiation with atmospheric conditions. The major influencing factor is the amount of cloud cover. The units of erythemal UV irradiance on the y-axis 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. On the overcast days of 7th and 8th May, the diffuse irradiance forms a high relative proportion of the total UV irradiances. In comparison, on the relatively cloud free days of 12th and 13th May, the diffuse UV irradiances formed approximately one third of the total UV radiation. These relative proportions of the diffuse and total UV irradiances will vary with season, surroundings and atmospheric conditions. The variation with season is due to the change in solar zenith angle resulting in a different atmospheric optical path length. This results in a change in the amount of scattering and absorption in the atmosphere.

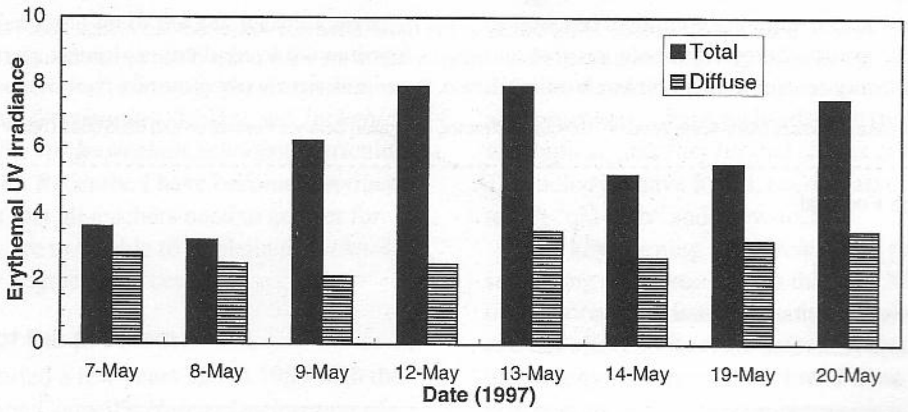

Figure 2 - The total and diffuse UV irradiance measured at approximately 1.00 pm on each day shown.

USEFULNESS OF THE EXPERIMENT

Any students undertaking this project will by collecting scientific data gain a knowledge of some of the factors influencing terrestrial UV radiation. This is important in education programs to increase awareness of UV radiation exposure and for the development of strategies for the minimisation of solar UV exposure. Additionally, students will be exposed to a number of scientific concepts by undertaking an experimental project relevant to everyday life.

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