Why do UV levels vary?

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Have you ever suffered the excrutiating pain and discomfort of a severe sunburn followed by the unsightly peeling of the skin? Have you ever wondered why you may receive a sunburn even on a partially cloudy day? There are a number of factors that influence the amount of solar ultraviolet radiation reaching the earth's surface.

Terrestrial Solar UV

The factors that influence the terrestrial UV levels are both natural and human induced. They are:

- *The solar elevation angle or height of the sun above the horizon.* This depends on the latitude of the location and changes over the course of a day and during a year. The higher the sun is in the sky, (the smaller the solar zenith angle) results in the sun's radiation travelling through less of the earth's protective atmosphere and consequently, the higher the UV levels. Furthermore, at low solar elevation angles, the sun is shining obliquely on a surface and as a result, the radiation directly from the sun is spread out over a larger surface area as shown in the Figure giving a lower energy per unit area. As the solar elevation angle increases, the atmospheric cutoff wavelength shifts towards shorter wavelengths. Specifically, more of the shorter wavelength UV which has a higher biological effectiveness for producing skin damage reaches the earth's surface.
- *The annual variations in the earth-sun distance.* This is a result of the elliptical orbit of the earth around the sun with the earth closest to the sun in the Southern Hemisphere summer and furthest from the sun in the Northern Hemisphere summer. This results in a 3.5 percent variation in the earth-sun distance. If all other factors influencing terrestrial UV are the same, the earth-sun distance variation produces a higher UV intensity in the Southern Hemisphere summer compared to the Northern Hemisphere summer.
- *The chemistry of the atmosphere.* the constituents of the atmosphere such as the ozone levels, molecules and the amount of suspended aerosols, for example sea-salt particles, soot, mineral dust and ammonium sulfate. Absorption by stratospheric and tropospheric ozone occurs predominantly for wavelengths shorter than 320 nm or the UVB and UVC wavelengths (see previous article on Ozone and Ultraviolet Radiation). The molecular scattering increases with the fourth power of decreasing wavelength and as a result is significant in the shorter UVB wavelengths. Aerosols affect the UV radiation by both scattering and absorbing the solar UV radiation.
- *Clouds.* Cloud cover is one of the most variable factors influencing the terrestrial UV levels. Clouds have a high temporal, spatial and structural variability. Total cloud cover will reduce the incoming solar UV radiation to practically zero, whereas the effects of scattered cloud are variable and may even at times enhance the UV levels due to the concentrating influence of reflections from the cloud sides.
- *Reflecting power of the surface.* The albedo (reflecting power) of the ground and surroundings is the ratio of the reflected to the incident energy. The surface albedo varies with ground covering and with wavelength. It is generally low in the UV

waveband for most surfaces at approximately 1% for grass, but may be as high as 80% or more for snow covered terrain. Water and concrete also have a high albedo for UV wavelengths at approximately 10% with beach sand at approximately 15%. Any human activity in these high UV albedo areas will result in a higher UV exposure due to the combined action of the normal UV and the UV reflected directly from the environment to the subject and also indirectly by the UV reflected back to the atmosphere from below which can then scatter the UV back to the subject.

- *Altitude above sea level*. In high altitude alpine areas, the pathlength of the solar UV through the atmosphere is shorter and has as a result undergone less scattering and absorption with resulting higher UV levels compared to low altitude sites. Furthermore, in high altitude snow covered mountains there is the added influence as a result of the high albedo surface.

Additionally, the 11 year cycle in solar activity also causes variations in the solar flux above the atmosphere due to the sun emitting more energy. This has a larger effect in the UVC (wavelengths shorter than 280 nm) which is absorbed in the earth's atmosphere and is minimal (less than 1%) for the UV wavelengths reaching the earth's surface.

The solar UV levels are unrelated to temperature. It is not possible to feel UV radiation. The sensation that is felt is heat or infrared radiation which is at the long wavelength end of the visible waveband in the electromagnetic spectrum (see previous article on Ozone and Ultraviolet Radiation). Generally, it is natural to associate receiving a sunburn with hot weather and the beach, however, it is possible to receive a sunburn even in winter.

Direct and Diffuse

The total global UV radiation at the earth's surface consists of a direct component and a diffuse component comprising between thirty and seventy-five percent. The direct component comes in a direct path from the sun, whereas diffuse radiation is scattered by the atmosphere, clouds and the surroundings. Diffuse radiation is measured by means of a shadow band to shield the detector from direct sunlight. The diffuse share of global radiation progressively increases towards the shorter UV wavelengths due to the higher degree of molecular scattering at these wavelenghts as previously mentioned. As this is scattering rather than absorption, a proportion of this scattered radiation is present at ground level as diffuse radiation. Due to this high diffuse component, clouds will generally reduce global UVB and UVA radiation to a lesser extent than visible radiation. As a result, even in shade, it is possible to receive an appreciable UV exposure.

The variation of the total global erythemal UV radiation and the diffuse erythemal UV radiation over the course of a typical summer day in Toowoomba is shown in the figure. The data was collected with a Robertson-Berger meter which has a UV response approximating that of human skin. The units are in MED/hr where an MED is defined as the minimum erythemal dose or the amount of UV radiation to produce barely perceptible erythema or skin reddening after an interval of 24 hrs following exposure in people of skin type 1 (always burns and never tans).

Human ultraviolet exposure

For nonmelanoma skin cancer, the cumulative life time exposure to UV is the key risk factor and for melanoma skin cancer, the risk increases with the number of severe UV exposures, namely sunburn, particularly during childhood. People of all skin types from the types that always tan and never burn to those that always burn and never tan need to be aware of the factors influencing terrestrial solar UV in order to minimise their exposure to ultraviolet radiation.

Further Reading

Ambach, W. & Blumthaler, M. 1993, “Biological effectiveness of solar UV radiation in humans,” *Experientia*, vol.49, no.9, pp.747-753.

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Madronich, S. 1993, “UV radiation in the natural and perturbed atmosphere,” in *UV-B Radiation and Ozone Depletion: Effects on Humans, Animals, Plants, Microorganisms, and Materials*, ed. M. Tevini, pp.17-70, Lewis Publishers, Boca Raton.

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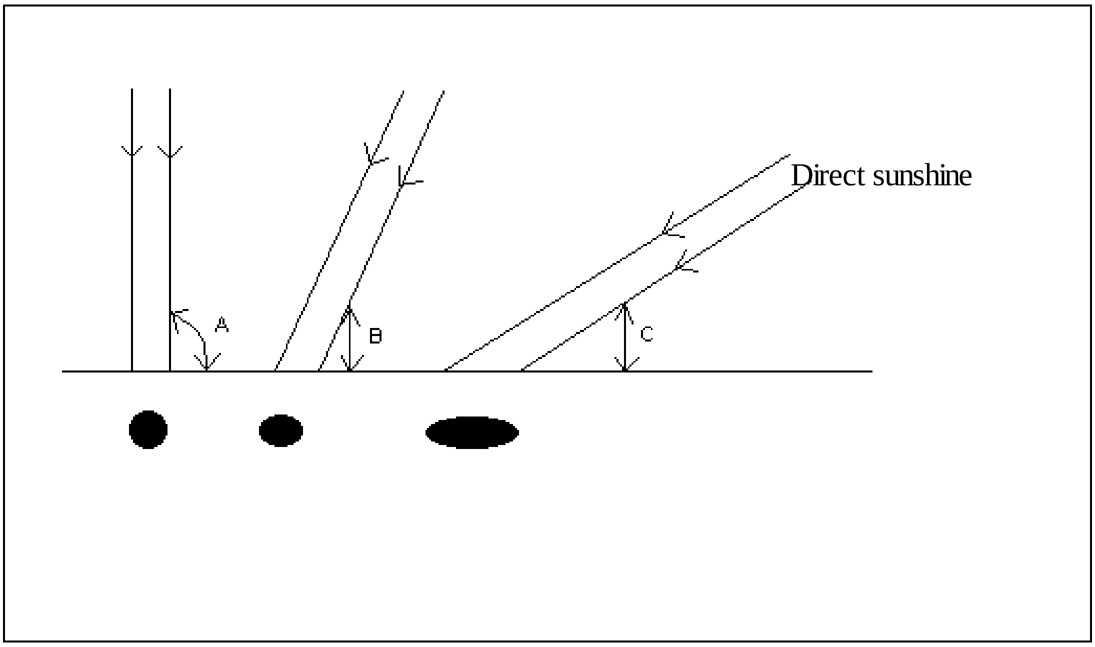
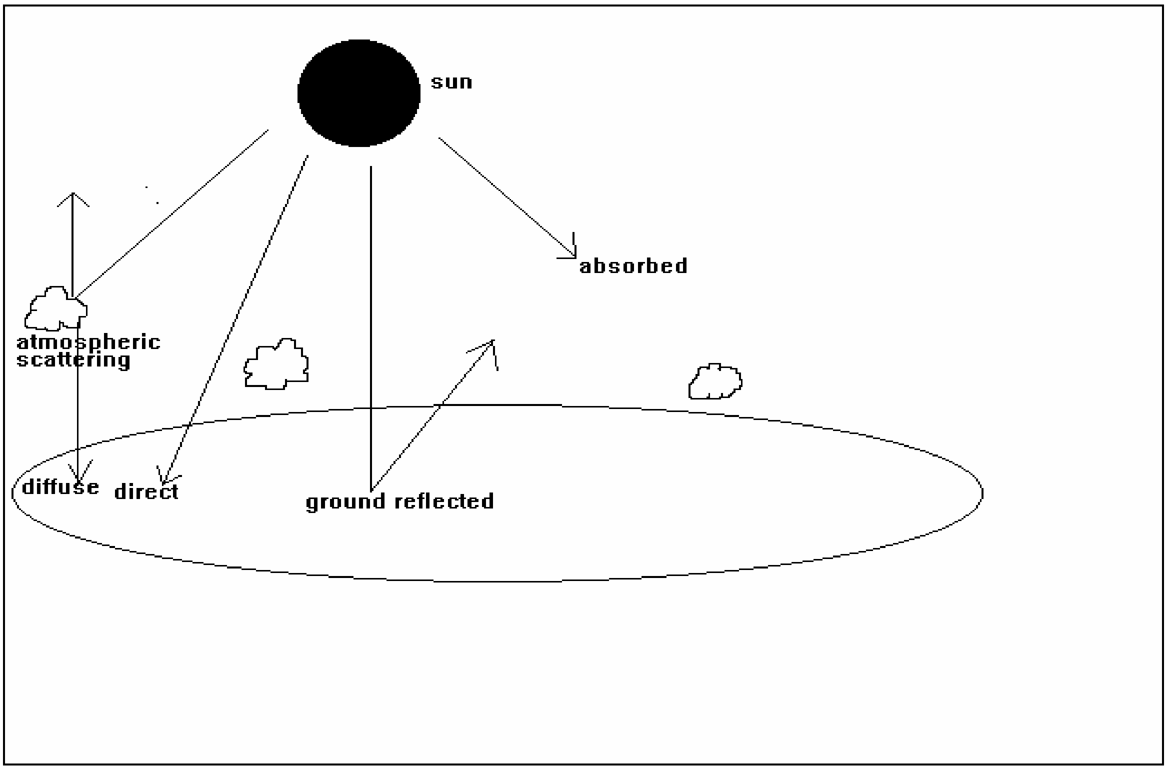
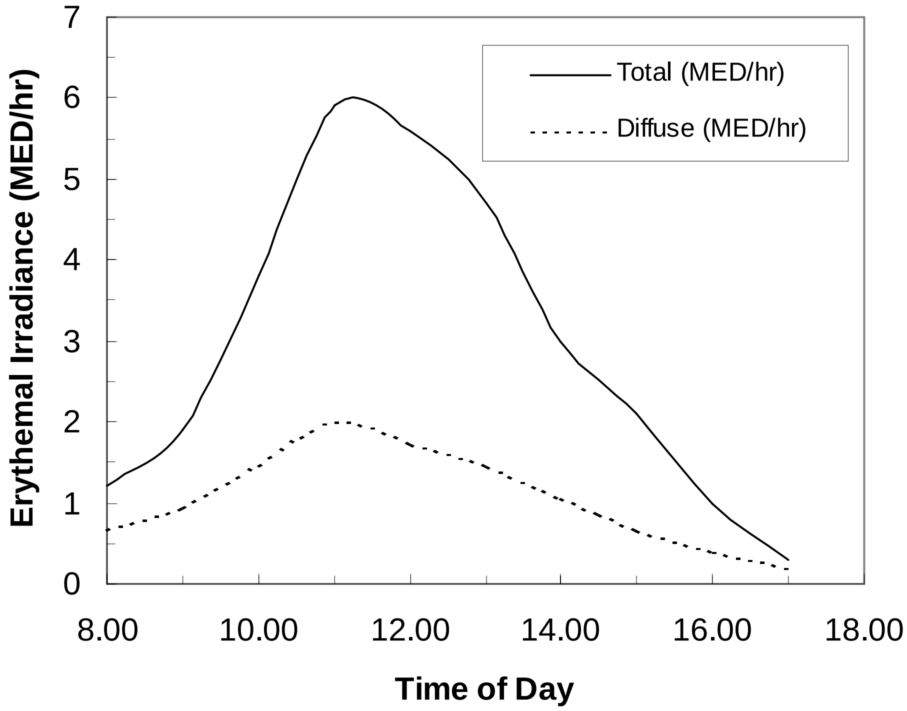


Cross sectional areas of solar radiation reaching the earth's surface for various solar elevation angles, A, B and C.



The various interactions of UV radiation in the atmosphere.



Values of the total and diffuse erythemal UV radiation over a typical summer day.

Skin types and skin reactions

Type	Description	Skin Reaction
I	Fair skin, blue or green eyes, freckles, white skin.	Burns severely, peels, little or no tan.
II	Fair skin, blue eyes, blond or brown hair, white skin	Burns severly and easily, peels
III	White skin, black or brown hair, brown eyes.	Burns moderately, tans somewhat.
IV	Olive or light brown skin, dark brown hair, dark eyes, unexposed skin is brown	Burns minimally, tans easily.
V	Dark brown skin	Rarely burns, tans easily and substantially
VI	Black or dark brown skin, brown eyes, black or dark brown hair.	Burns only with severe exposure

Reference for this table is:

Siegel, M. 1990, “Safe in the sun,” Walter and Company, New York.