Deutscher Wetterdienst
Wetter und Klima aus einer Hand

The Global Solar UV Index and Health Effects of UV Exposure

Introduction

Everyone is exposed to Ultraviolet radiation (UV) from the sun as natural source as well as from many artificial sources used in industry and recreation. UV is divided into three bands: UV-A (315 to 400 nm), UV-B (280 to 315 nm), and UV-C (less than 280 nm). Atmospheric ozone shields life at the earth surface from about 90 % of the UV-B and almost all of the UV-C, where as UV-A is only fractionally effected. UV-B is biologically very effective and the most dangerous portion of UV radiation reaching the earth surface.

A marked increase in the incidence of skin cancer has been observed in fair-skinned populations world-wide since the early 1970s (WHO 2002). This is strongly associated with personal habits in relation to sun exposure and its ultraviolet component, and the societal view that a tan is desirable and healthy. Moreover the risk of UV overexposure has increased as a consequence of the depletion of the ozone layer. In response to the appearance of these UV effects national and international organisations have initiated special programmes for the protection of human beings against UV. Thus the WHO (2002), the ICNIRP (1995), the WMO (1995, 1997), and the UNEP collaboratively introduced the harmonised Global Solar UV Index (UVI) to inform the public by an elementary quantity.

UV Index definition

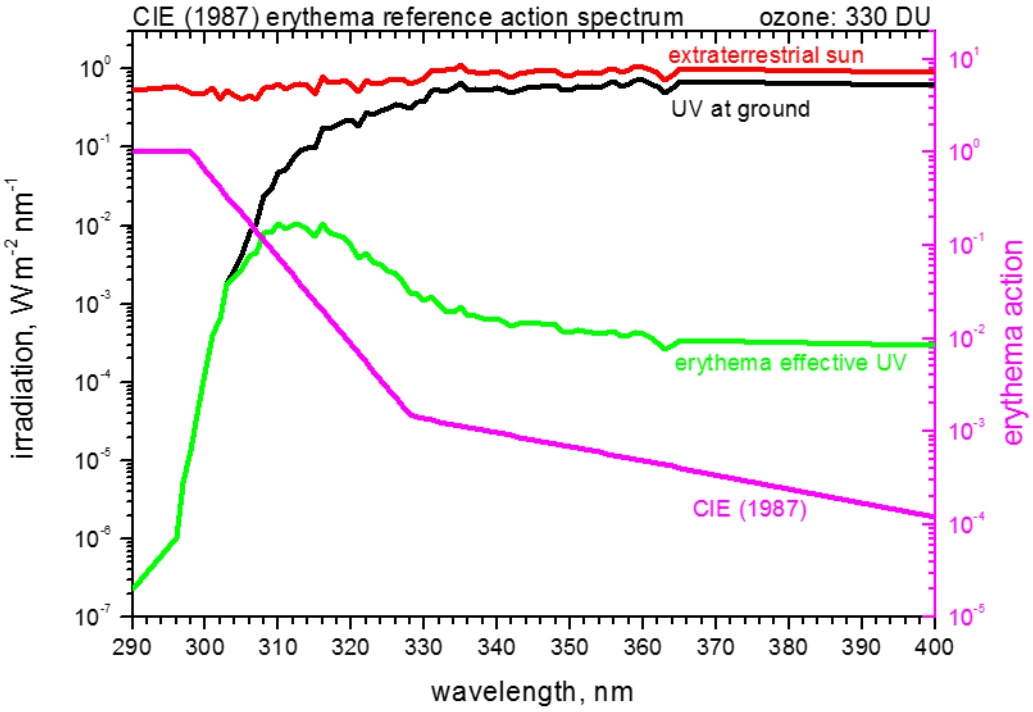
The UV Index is a dimensionless value defined as the integral over the spectral UV irradiance on a horizontal plane in Watt per square metre weighted with the erythemal (sunburn effective) action spectrum (CIE 1987) of the human skin and multiplied by the constant 40 square metre per Watt.

$$UV\ Index\ (UVI) = k * \int_{280\,nm}^{400\,nm} E(\lambda) * s(\lambda) * d\lambda$$

E(λ)	=	spectral solar irradiation on horizontal plane [Watt per square metre und nanometre]
λ, dλ	=	wavelength and wavelength interval [nanometre]
k	=	40 [square metre per Watt]
s(λ)	=	CIE (1987) erythema reference action spectrum
	=	1 für λ ≤ 298 nm
	=	$10^{[0.094\cdot(298-\lambda)]}$ für 298 nm ≤ λ ≤ 328 nm
	=	$10^{[0.015\cdot(139-\lambda)]}$ für 328 nm ≤ λ ≤ 400 nm

The definition is independent from an individual skin type The UV Index can be derived from physical measurements or radiative transfer calculations and can therefore be forecasted by using predictable meteorological parameters.

The erythemal effective UV dose is the erythemal effective (CIE 1987) amount of energy received by a horizontal plane within a time interval, dimension is Joule per square metre. For the forecasts products the integration time comprises one day.



Influences on the UV Index

UV radiation levels are influenced by

- Sun elevation: The higher the sun, the higher the UV irradiation on a horizontal plane. Thus the UV irradiation vary with time of day and time of year. For clear sky conditions the irradiation is highest around solar noon. The closer to the tropics the higher the UV irradiation.
- Clouds: UV irradiation is highest under cloudless skies but even with cloud cover, UV radiation can be high due to scattering and reflectance by cloud surfaces. UV modification by clouds depends from their optical depth (type and amount of clouds) and in cases of broken cloudiness whether the solar disk is obscured by clouds or not.
- Ozone: Absorption of UV by ozone strongly depends from the wavelength particularly in the UV-B band as can be seen from the figure with the spectral UV distribution. Effective is the total ozone column with a maximum of ozone in the stratosphere between 12 and 30 km. Ozone levels vary over the year and even across the day due to dynamic (especially in moderate and higher latitudes) and chemical processes (e.g. Antarctic ozone hole, mini-holes of the northern hemisphere, ozone depletion).
- Altitude above sea level: With increasing altitude the UV irradiance generally increases due to the reduction of the attenuating material above the observer and the increasing radiation from below, resulting via multiple scattering from increasing albedo.

- Albedo: In the UV, the ground reflection generally is low, only for snow it is markedly high and may reach values higher than 0.9 for freshly fallen snow and a terrain homogeneously covered with snow (Antarctica, Arctic, Greenland inland ice). The albedo of a site is influenced from the albedo of areas up to more than 20 km in distance. Outside the aforementioned regions there are always in part snow free surfaces, e.g. from trees, rocks, roads, roofs and buildings, reducing the albedo to a "regional" value.
- Aerosols: Aerosols scatter and in parts absorb UV radiation. Pure scattering increases the diffuse and decreases the direct UV component; the global UV irradiation is only marginally reduced. The aerosol optical depth is variable and depends from time of the year and from the region. An increased aerosol load with a higher fraction of black carbon can be observed in highly populated and industrialised regions The aerosol optical depth is increased too over the great desserts by mineral dust. Absorption by mineral dust increases in the UV with decreasing wavelength and so reduces the UV load at the ground in cases of a high aerosol optical depth.

Health effects of UV exposure

The WHO (2002) "Global solar UV Index – A Practical Guide" summarises the effects of exposure to UV radiation.

Small amounts of UV radiation are beneficial for people and essential in vitamin D synthesis, a hormone active in the calcium and phosphate budget of the human body and important for their mobilisation in bones. Prolonged exposure, however, may result in acute and chronic health effects of

skin:

- Sunburn and tanning are the best known effects of excessive UV exposure. Sunburn is a skin reddening due to DNA damage resulting in an inflammatory reaction. Tanning is a natural defence in protecting the skin against harmful UV effects and is accompanied by a thickening of the stratum corneum, the outermost skin layer, attenuating UV. Tanning is an indication for increased UV exposure.
- Chronic exposure to UV radiation causes a number of degenerative changes in the cells, fibrous tissues and blood vessels. UV radiation accelerates skin ageing, and the gradual loss of the skin's elasticity results in wrinkles and dry, coarse skin.
- Non melanoma skin cancer (NMSC) comprises basal cell and squamous cell carcinoma. They are rarely lethal but require surgical treatment. Solar UV exposure is a major causal effect and the risk is related to (lifelong) cumulative exposure. This gives reasons for reduced UV exposure even though sunburn is avoided. NMC is most frequently on parts of the body that are commonly exposed to the sun such as face, ears, neck, and forearms.
- Malignant melanoma (MM) comprises the carcinoma of melanocytes and is the major cause of death from skin cancer. High, intermittent exposure to UV appears to be a significant risk, e.g. increased frequencies of sun burn particular in the childhood. The incidence of MM in fair skinned populations rises constantly in the last decades. The risk of MM correlates with genetic and personal characteristics, and a person's UV radiation exposure behaviour. MM is more common with a pale complexion, blue eyes and a large number of atypical nevi (moles).

eyes:

- Photokeratitis and photoconjunctivitis are acute effects of UV radiation exposure. They are comparable to the sunburn of the skin, are reversible and do not result in any long-term damage of the eye. Extreme forms of photokeratitis are "arc-eye" and "snow blindness". Strong ground reflection from snow, sand, and water are associated with an increased risk.
- Cataracts are associated to chronic effects of UV exposure. They are the leading cause of blindness in the world. Even though cataracts appear to different degrees in

most individuals as they age, sun exposure, in particular to UV-B, appears to be a major risk factor for their development.

immune system:

- Immune suppression: There is an increasing evidence for a systematic immuno-suppressive effect of both acute and low-dose UV radiation exposure. The skin defences are altered by complex biological processes affecting levels of urcanic acid, “Langerhans” cells, suppressor and helper T-lymphocytes. People treated with immune suppressive drugs have an increased incidence of squamous cell carcinoma.
- The effectiveness of vaccines may be reduced by high UV radiation levels. Since many vaccine-preventable diseases are extremely infectious, any factor that results in even a small decrease in vaccine efficacy can have a major impact on public health.

Darker skin has more protective melanin pigment, and the incidence in skin cancers is lower in dark-skinned people. However, the risk of UV radiation-related health effects on the eye and immune system is independent of skin type.

References

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German Meteorological Service

Human Biometeorology

Stefan-Meier-Str. 4

D-79104 Freiburg

Germany

email: mm.freiburg@dwd.de