

# OZONE AND ULTRAVIOLET RADIATION

**Alfio Parisi, Michael Kimlin**

*Imagine if the earth's protective atmosphere did not exist and the earth was subjected to the harmful ultraviolet energy from the sun. Life as we know would not exist. Changes in the earth's layer of atmospheric ozone may be occurring as a result of human activities. This is generating concerns in the community about increases in terrestrial ultraviolet radiation and the associated adverse effects on humans, plants and animals.*

## **Solar Radiation**

Energy from the sun in the form of electromagnetic radiation sustains life on earth and determines the earth's climate. The solar energy comes from nuclear fusion reactions inside the sun which have the net result of converting hydrogen to helium with the release of vast amounts of energy. The surface temperature of the sun is approximately 5700 °C. At this temperature, the peak intensity of the energy from the sun is in the visible waveband along with emission in the ultraviolet (UV) and infrared wavebands.

The UV above the earth's atmosphere consists of wavelengths from 200 to 400 nm (where 1 nm is one thousand millionth of a meter). These wavelengths are shorter than the visible wavelengths. The UV waveband is sub-divided into UVC (200 to 280 nm), UVB (280 to 320 nm) and UVA (320 to 400 nm). At the earth's surface, no UVC is present and only part of the UVB. This reduction of the UV is due to attenuation by the earth's atmosphere resulting from absorption and scattering by molecules and aerosols. Cloud cover influences the terrestrial UV significantly. The terrestrial UV also depends on how far the sun's electromagnetic radiation must travel through the earth's atmosphere and is dependent on the solar elevation angle or the angle of the sun above the horizon. This varies with time of day and with season.

Efficient absorption by atmospheric ozone and oxygen removes all the UVC. This high energy, short wavelength UV will continue to be completely attenuated even if the thickness of the ozone layer were significantly reduced. The UVB waveband is where ozone absorption is significant and is the portion of the UV spectrum that will increase due to reductions in atmospheric ozone. At the longer UVA wavelengths, absorption by ozone is so weak that changes in ozone are of no consequence. In addition to stratospheric ozone, ozone also occurs as a result of pollution in the troposphere, the layer of the atmosphere between the earth and the stratosphere. Tropospheric ozone also absorbs UV radiation, however, it is a pollutant that can damage lung tissue and plants.

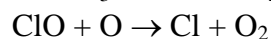
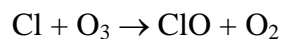
## **Stratospheric Ozone**

Ozone is an atmospheric trace gas that exists predominantly in the stratosphere between altitudes of 15 and 35 km. At these altitudes the gas is formed by the breakdown of oxygen molecules to single atoms of oxygen by UV radiation and the subsequent combination of the single oxygen atoms with other diatomic oxygen molecules to form triatomic oxygen molecules or ozone. Under normal conditions, ozone is continually produced and destroyed in an equilibrium or steady-state process. The concentrations present are at most 10 parts per million by volume but the gas is important biologically due to its absorption of UV radiation

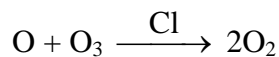
and re-emittance of thermal infrared radiation. Atmospheric ozone is measured in Dobson units, defined as the physical thickness of the ozone layer if it were brought to the Earth's surface at a standard temperature and pressure (STP) of 0 °C and 1 atmosphere respectively. The figure of 300 DU is equivalent to 0.3 cm of ozone at STP.

Studies by airplane, balloon, satellite and ground based measurements have confirmed that a portion of the earth's protective layer of ozone is being depleted. A dramatic loss of ozone occurs over Antarctica in springtime and to a lesser extent over the Arctic. Over Antarctica, the extent of the springtime ozone depletion is conveyed by considering the lowest daily value of total ozone measured over Halley in October. This has dropped to approximately a third of the value 35 years ago.

Of the chemical pollutants responsible for the loss of stratospheric ozone, the major group is the chlorofluorocarbons (CFCs) which are employed as refrigeration and air conditioning gases, solvents, degreasing compounds, fire suppressants and propellents in spray cans. Developed countries of the world have agreed to phase out the production of CFCs. The signees to the agreement have granted permission to the developing nations to delay their compliance with the control measures of the agreement. Upon release into the atmosphere, these chemicals take approximately thirty years to reach the stratosphere (some CFC's already released have still to reach the stratosphere) where they are decomposed in a reaction involving short wavelength UV to produce free chlorine (Cl) which acts in the catalytic breakdown of ozone as follows:



The overall reaction is:



with the Cl atom not consumed in the reaction and free to repetitively act as a catalyst in the breakdown of ozone.

The reason for the springtime hole over the polar regions is that during winter, the meteorological conditions over Antarctica allow the formation of the polar vortex (winds rotating clockwise in a whirlpool) with very cold temperatures in the stratosphere. The CFC molecules are absorbed on the surface of the tiny ice crystals that form with a subsequent breakdown of the CFC molecules due to surface catalysis. This is a phenomenon in which the rate of a chemical reaction taking place on the surface of a solid (in this case ice crystals) is increased. The result is a release of chlorine atoms which remain on the ice crystals till spring when the crystals melt and release Cl atoms which now act as catalysts in the breakdown of ozone. This process is in addition to the photochemical production of chlorine atoms. During early summer, there is a breakup of the polar vortex with consequent filling of the ozone hole with movement of ozone rich air to the polar regions and transport of ozone-poor air to middle latitudes. In other words, the spring time ozone hole over the Antarctica affects the levels of stratospheric ozone over populated regions. This thinning of the ozone layer over middle latitudes has generated concerns about the increased levels of terrestrial UV.

### ***Terrestrial Effects***

Exposure to solar UV radiation is linked to the incidence of skin cancers and some eye disorders in humans. Reduction of the skin cancer incidence rates requires both the reduction of cumulative lifetime UV exposure and prevention of sunburn. The highest incidence rates in the world of non-melanoma skin cancer (NMSC) and cutaneous malignant melanoma occur in

Australia. Some of the factors contributing to this are the generally outdoor lifestyle of the population, relatively clear skies, parts of Australia are at a much lower latitude than Europe and North America, lightly pigmented skin of a majority of the population and the elliptical orbit of the earth around the sun. The latter factor means that the earth is the 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, namely, latitude, atmospheric constituents and cloud cover are the same, the earth-sun distance variation produces a higher UV intensity in the Southern Hemisphere summer compared to the Northern Hemisphere summer.

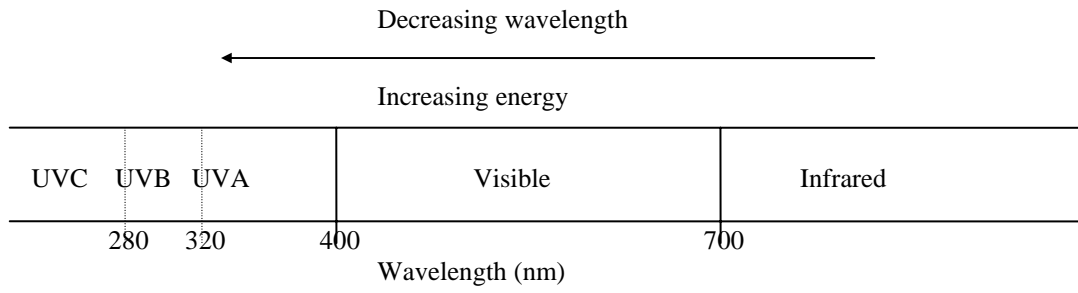
The ability of UV radiation to produce reddening of human skin or erythema is highly dependent upon the radiation wavelength and is expressed by the erythema action spectrum. The UV wavelengths that are most damaging for producing erythema are the UVC and UVB wavelengths with a decrease in the ability to induce erythema by a factor of approximately 1000 for the UVA wavelengths. As mentioned, there is no terrestrial UVC, however any reduction in ozone will result in an increase in the amount of UVB irradiance where the erythema action spectrum is high.

The energy from the sun along with the earth's atmosphere are essential for life on earth. To what degree will ozone depletion impact on human, animal and plant life and on the deterioration of plastics and paints? The science of the atmosphere is complex and there are many variable factors in the atmosphere. Increased research in the measurement and analysis of the incoming UV will allow the monitoring and understanding of the complexities and consequences of UV and ozone depletion.

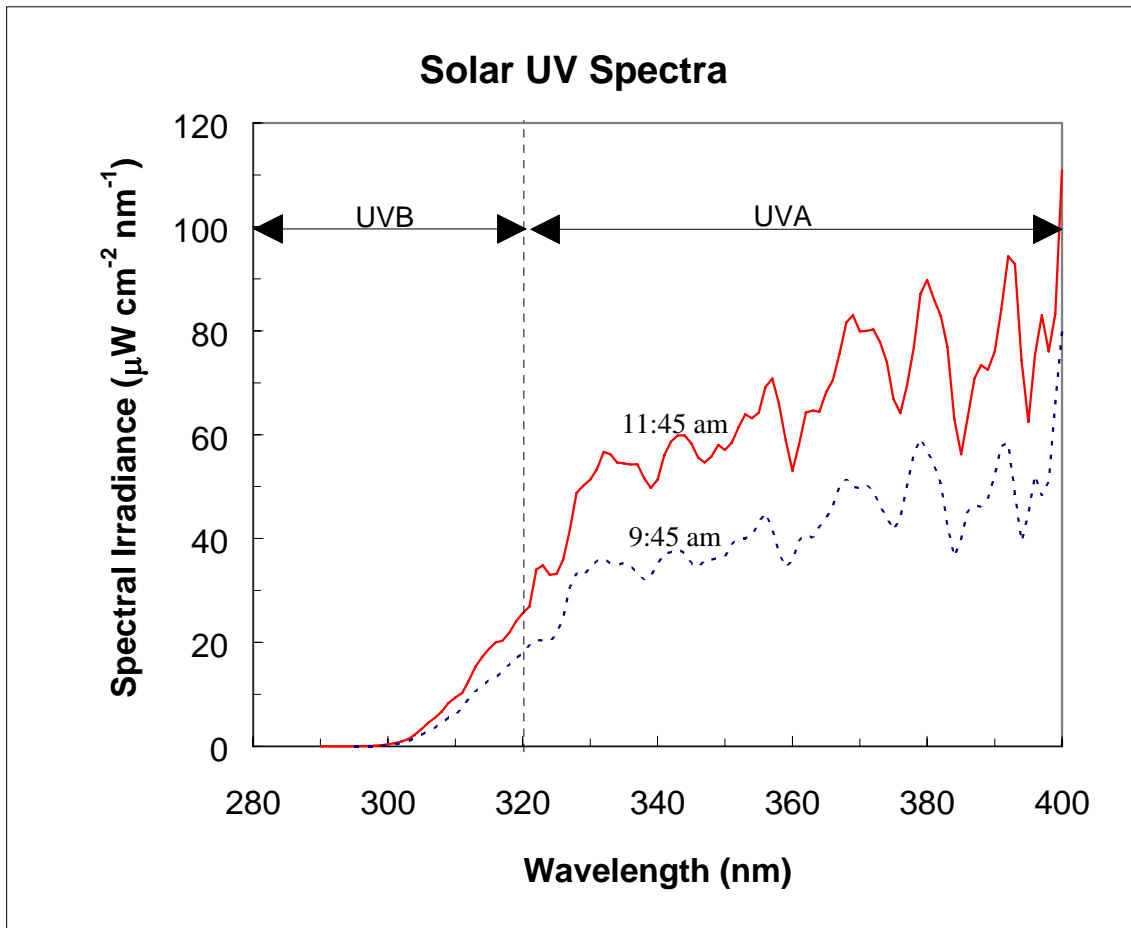
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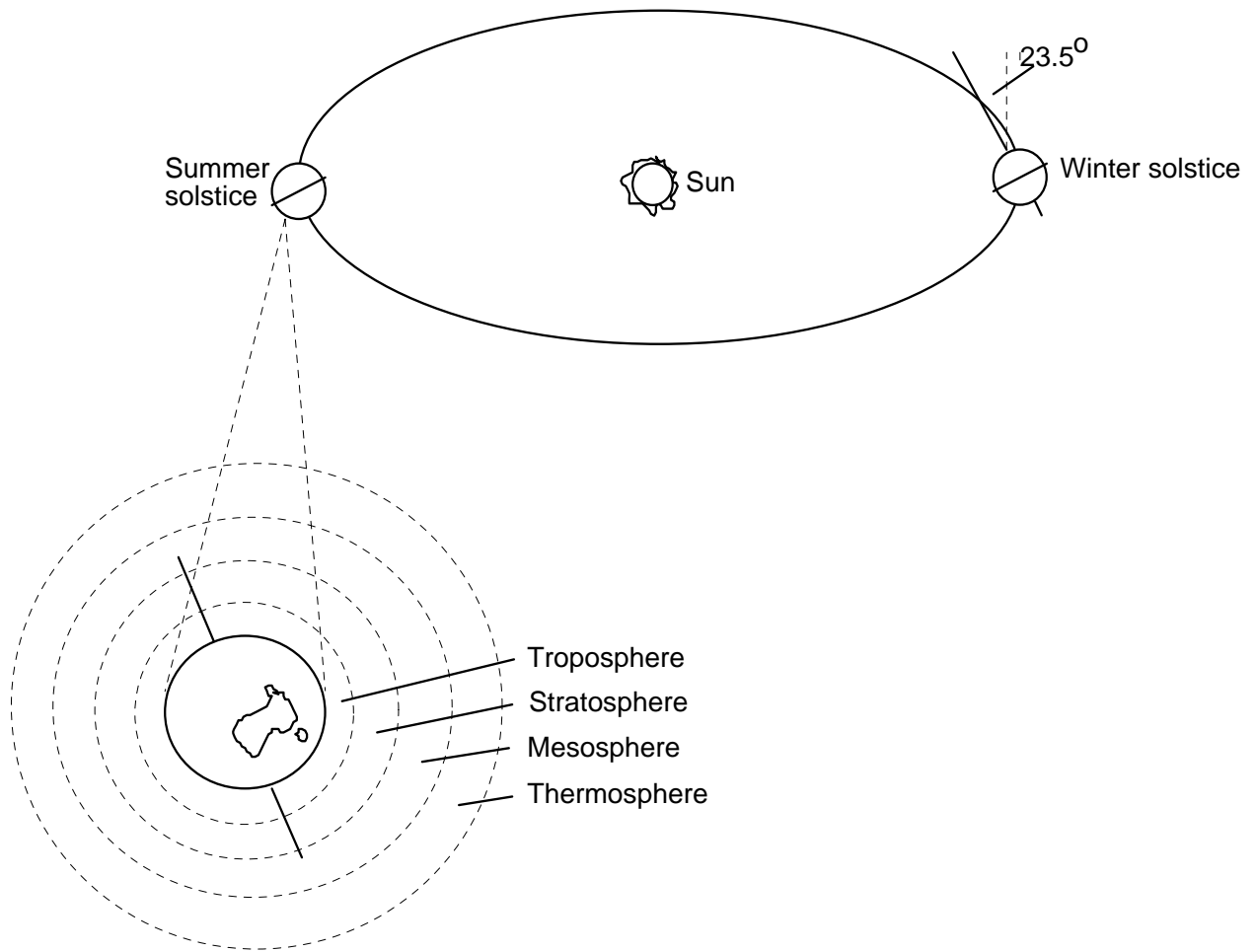
Further articles on UV will appear in future issues.



The electromagnetic spectrum showing the subdivision of the UV waveband.

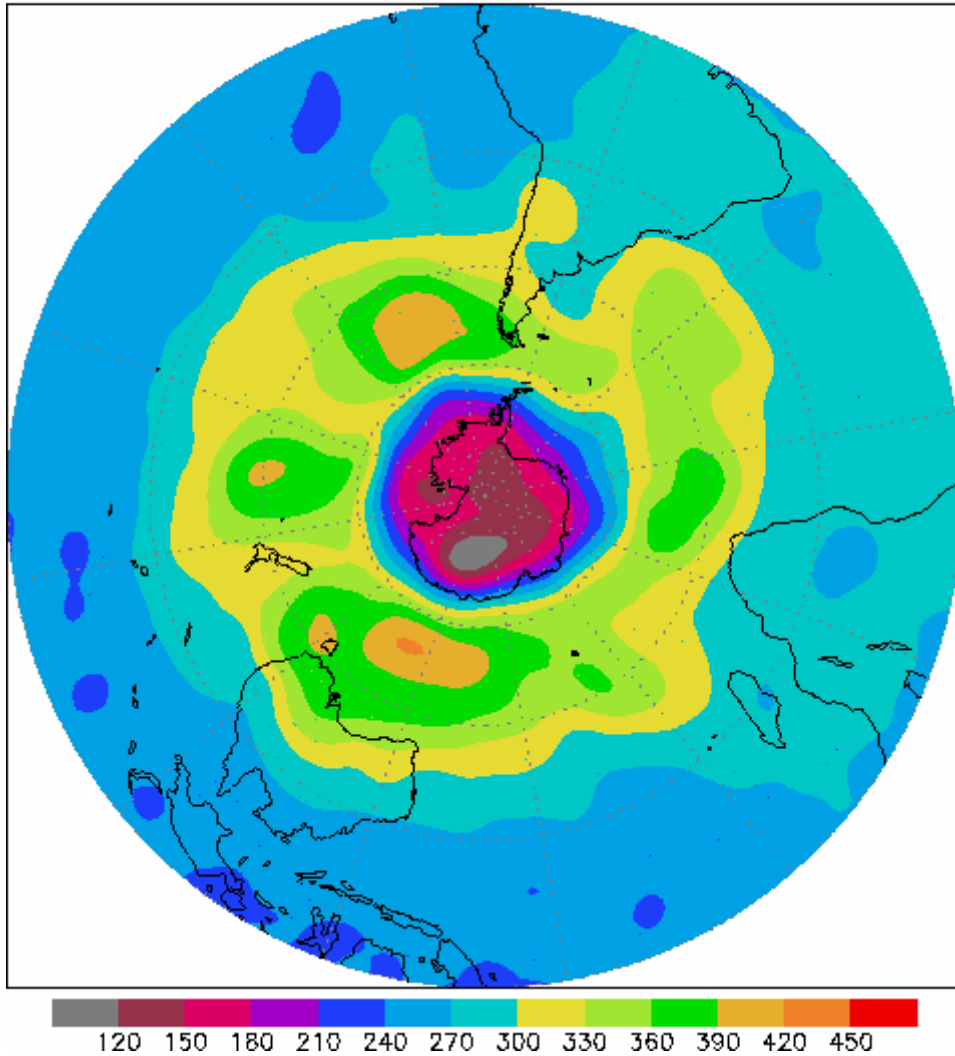


The terrestrial UV spectrum in the morning and noon in autumn at a latitude of  $27.5^\circ$  S. The dips in the spectrum are as a result of the solar Fraunhofer absorption lines.

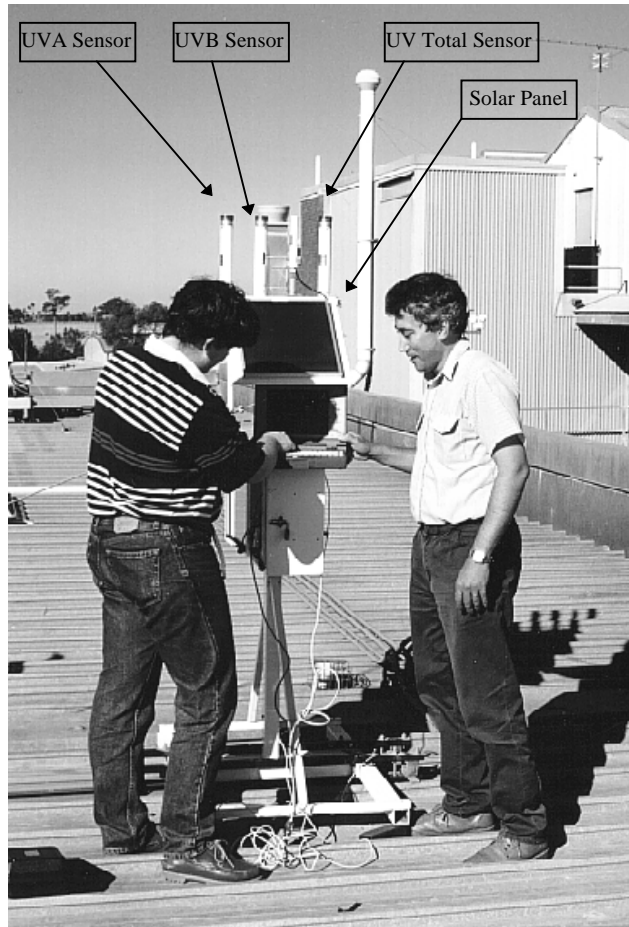


*The tilt of the earth's axis together with the annual orbit around the sun causes the seasons. The daylight side of the earth is tilted toward the sun in summer. (Not drawn to scale)*

TOVS Total Ozone Analysis (matm-cm)  
Climate Prediction Center/NCEP/NWS/NOAA  
09/30/96



*Total ozone thickness (Dobson units) over the Southern Hemisphere for 30 September, 1996. {Courtesy of Climate Prediction Centre/NCEP/NWS/NOAA}*



*Monitoring of the UV levels at the University of Southern Queensland.*