

**UV-BIOMETER - A BROAD-BAND INSTRUMENT COMPLEMENTING
OZONE MEASUREMENTS WITH GROUND BASED UV EXPOSURE.***

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Abstract.

Stratospheric ozone is known to be the most important atmospheric factor determining clear sky UV-B radiation reaching the Earth's surface. The potential increase of UV-B exposure is the cause of mounting concern about the ozone layer. There are, however, other effects that influence the UV radiative energy transfer: cloud cover, aerosols, tropospheric ozone, and other gaseous pollutants. The relationships between various phenomena taking place in the atmosphere are complex and not known well. Therefore, the ground based UV measurements are necessary to explore atmospheric changes and resultant effects on the biosphere. The UV-Biometer, a broad band instrument with a spectral response following the Erythema Action Spectrum was developed, combining latest technology with the principles proven useful in the Robertson-Berger network. Among others, new features incorporate a temperature stabilized detector, improved and stable spectral response, repeatable angular response close to the cosine function and high degree of functionality provided by a microprocessor controlled data acquisition system.

1. The path of solar ultraviolet to the Earth's level.

From the point of view of biological effectiveness the most important UV region is from about 290 to 320 nm. The solar radiation in that region has enough energy to induce significant effects and the biological effectiveness for some important processes increases rapidly towards shorter wavelengths. Wavelengths shorter than 200 nm are absorbed at very high altitudes by oxygen and other gases.

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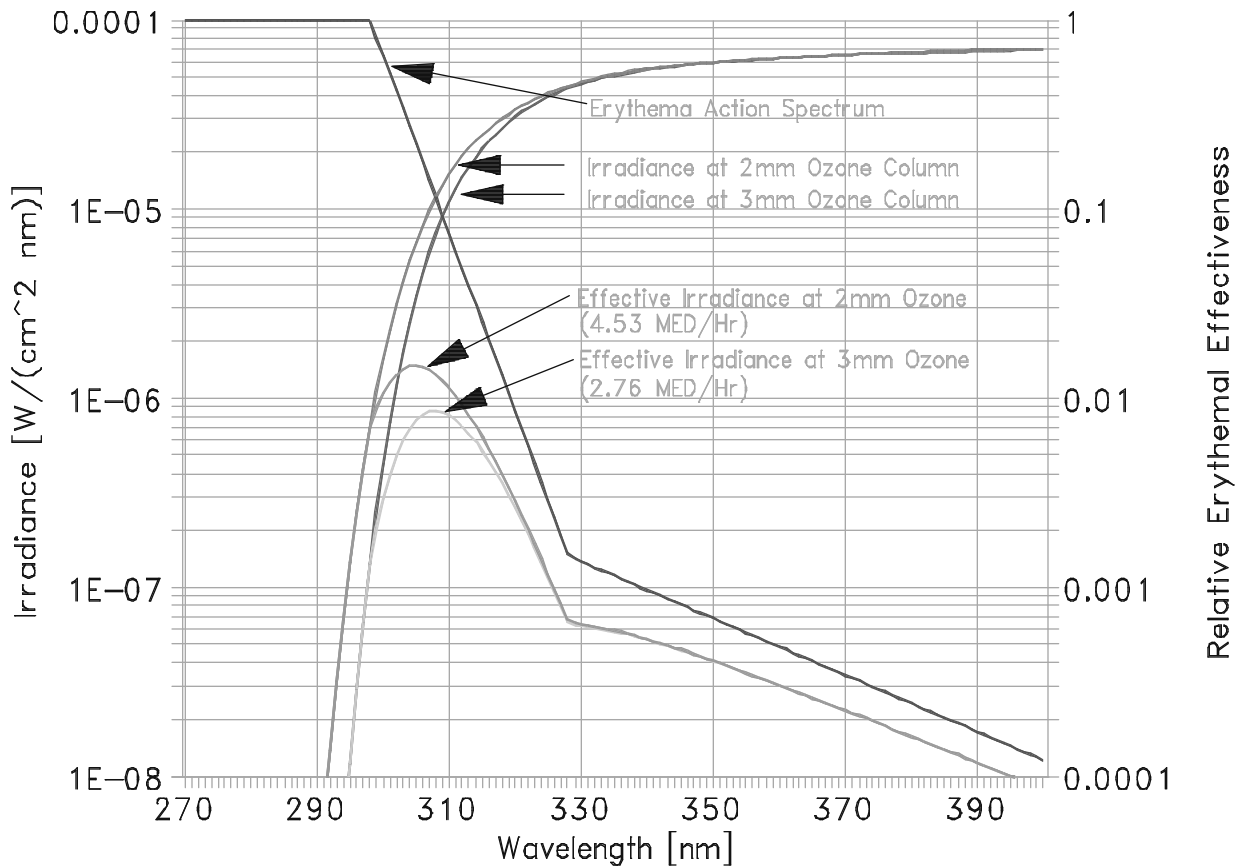


Figure 1 Solar radiation at sea level, zero albedo, 40°SZA, calculated from model (Green, 1979).

The main absorption bands of Ozone (Hartley and Huggins bands) fall into the region of 200-320 nm and are responsible for virtual elimination of wavelengths shorter than 295nm from the UV reaching the Earth's surface. Figure 1 illustrates the erythemal effect of ozone column change from 3mm to 2mm. The rapid increase of the Erythema Action Spectrum amplifies the solar spectrum change and results in a 64% increase of erythemal effectiveness. Other biological processes with steeper action spectra, as DNA damage for example, will be affected even more.

As much as 95% of the UV radiation can be absorbed by the cloud cover. Their variety of forms and variability make it difficult to model the UV transmission through clouds. Clouds absorb and scatter UV changing the distribution from different directions. They also reflect back some UV reflected from the Earth's surface. Figure 2 shows the erythemal effectiveness of solar radiation during sunny and cloudy day just 4 days apart. Since the average cloud cover can change along with local and global climate changes, it cannot be ignored when studying the impact of ozone related UV changes.

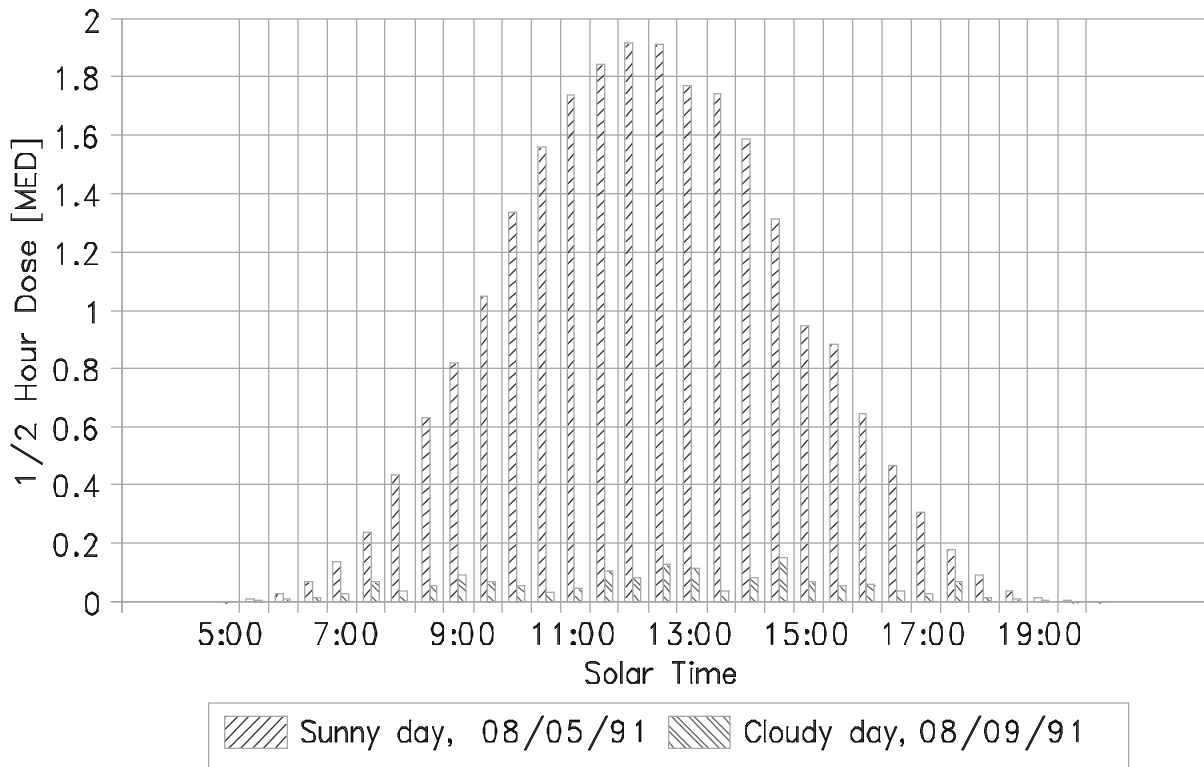


Figure 2 Effect of cloud cover on erythemal effectiveness of solar radiation. Measurements performed in Philadelphia using UV-Biometer.

Air pollutants produced by human activities and natural processes also affect UV reaching the ground. Burning of fossil fuels and volcanic activity are the most commonly known sources of pollutants. The atmospheric pollution can change the UV exposure both locally and globally. It was shown (Slomka, 1978) that there is a difference of UV-B exposure between urban area and rural area located approximately 50km (31miles) apart (Figure 3). It can be expected that in some areas the effect of stratospheric ozone drop may be effectively screened by increasing air pollution reducing the concern of the scientific community and of public opinion to the ozone reduction problem. Consequently, the UV measuring network has to be dense enough to cover a variety of climates and microclimates to produce data representative of a given area.

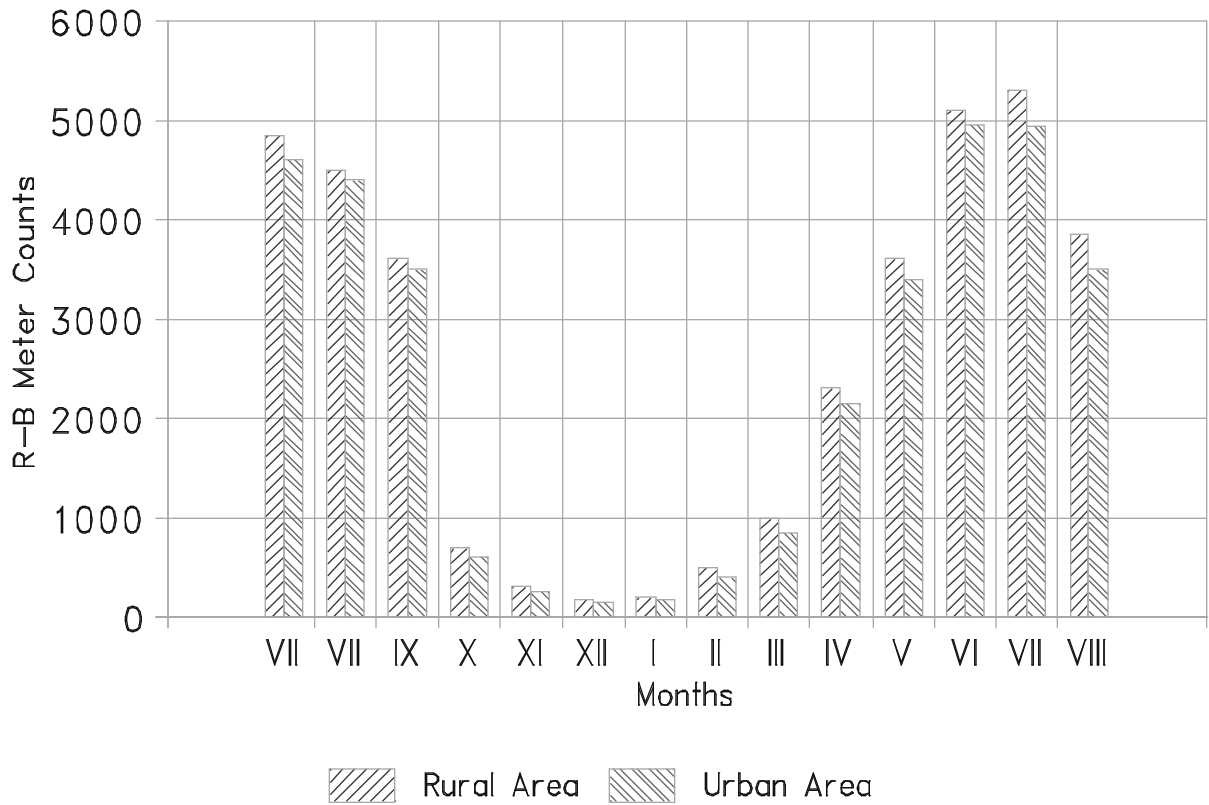


Figure 3 Seasonal variation of UV-B radiation in urban and rural areas. After K.Slomka, 1978.

2. Measuring biologic effect of UV.

The biologic effect of UV has been of great interest for most of this century. Many processes have been studied and different action spectra established. It has been shown that there is no single universal action spectrum for biological processes, nevertheless

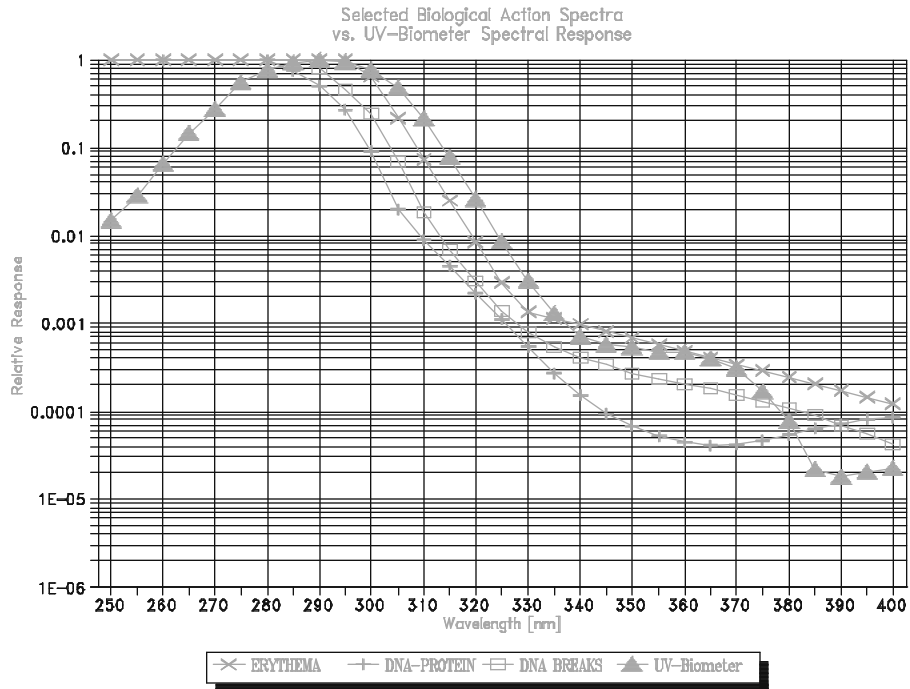


Figure 4 Selected biologic action spectra.

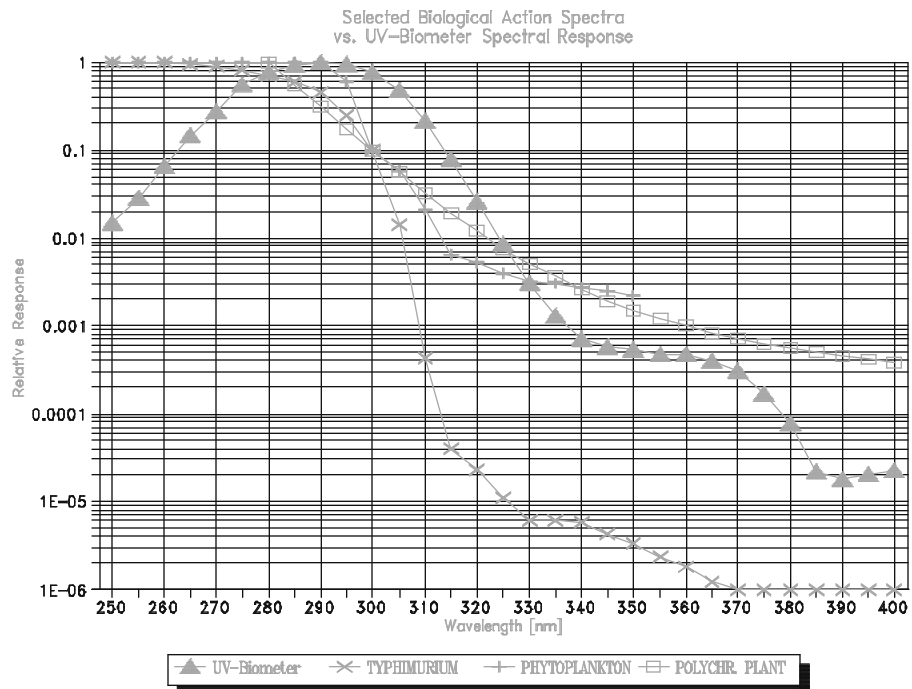


Figure 5 Selected biologic action spectra.

many of them have a lot in common. Characteristic is a sharp increase of biological effectiveness towards short wavelengths in the region of 290-340 nm. Several action spectra that represent the broad variety of different processes are shown in 5 and 5 along with the spectral response of the UV-Biometer.

It is difficult to establish a unique action spectrum for most photobiologic processes because there may be interactions between effects at different wavelengths, repair processes may be significant during irradiation, the end point may be delayed and the biologic measurement usually has a variability greater than $\pm 20\%$.

One way to measure the biologic effect of sunlight is by measuring the spectral irradiance at different wavelengths and then convoluting them by the appropriate action spectrum. It requires a costly spectroradiometer that needs to be maintained and the data processed. For some detailed laboratory studies it is certainly the best tool, but many outdoor measurements can be performed by a much cheaper, simpler and therefore more reliable broad band instrument.

A comparison of the results obtained from the simulation of the UV-Biometer detector under different ozone and Solar Zenith Angle (SZA) conditions are presented on 7, 7 and 8, along with the relative biologic effect calculated by cross-multiplication of the solar radiation and given action spectrum. Then the results are normalized to one arbitrarily selected point and plotted on XY scale. If the UV-Biometer tracks the biologic effect perfectly in the course of the day and for different ozone conditions there would be 45° straight line on the graphs.

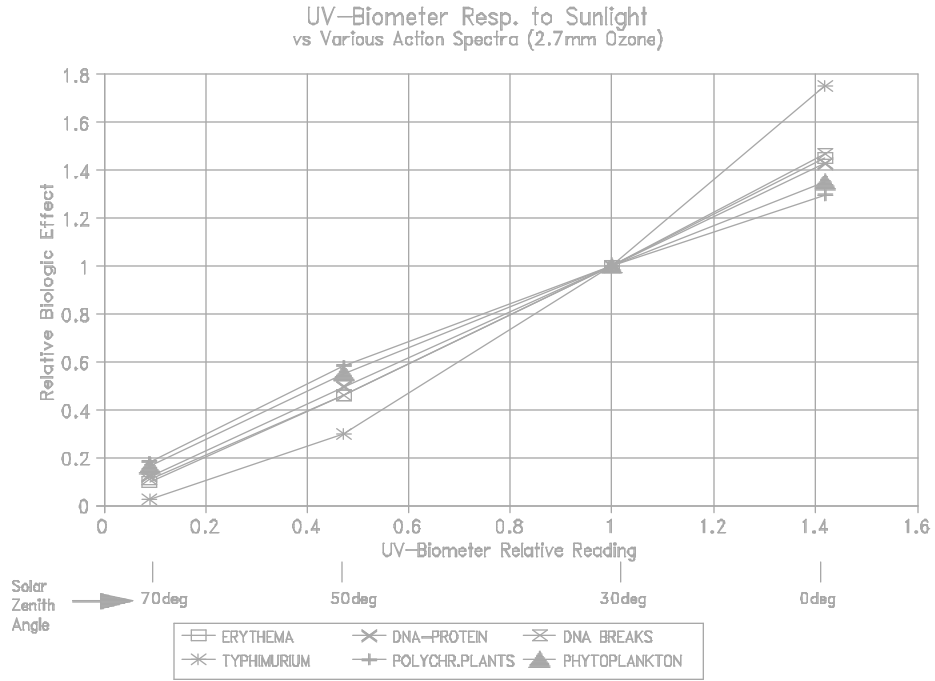


Figure 6 Computer simulation of UV-Biometer measurements vs. biologic effect of

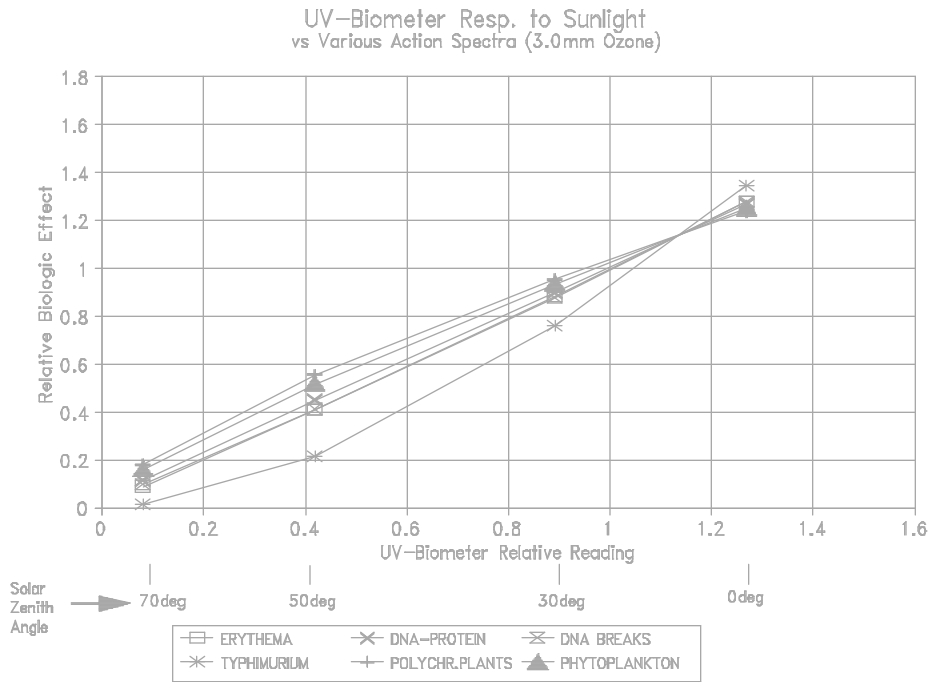


Figure 7 Computer simulation of UV-Biometer measurements vs. biologic effect under 3mm

For some action spectra the tracking of UV-Biometer is very good (Erythema Action Spectrum [8], DNA to Protein Cross-links [10], DNA Breaks[11]). Photobiologic effects that have higher sensitivity to UVA light than that of the meter response are slightly higher than that measured by the UV-Biometer (Polychromatic Action Spectrum for Plants [5], Phytoplankton [9]), but still the results are useful for most studies, especially when the uncertainty of the action spectrum itself is kept in mind.

Biologic action spectra much different from the meter's spectral response like that of Typhimurium Killing [7], may result in too high an error. If , however there is ozone information available (for example , satellite data) a correction can be made.

An error between relative meter values and relative biologic changes indicates whether the biologic action spectrum is steeper or shallower than the meter spectral response.

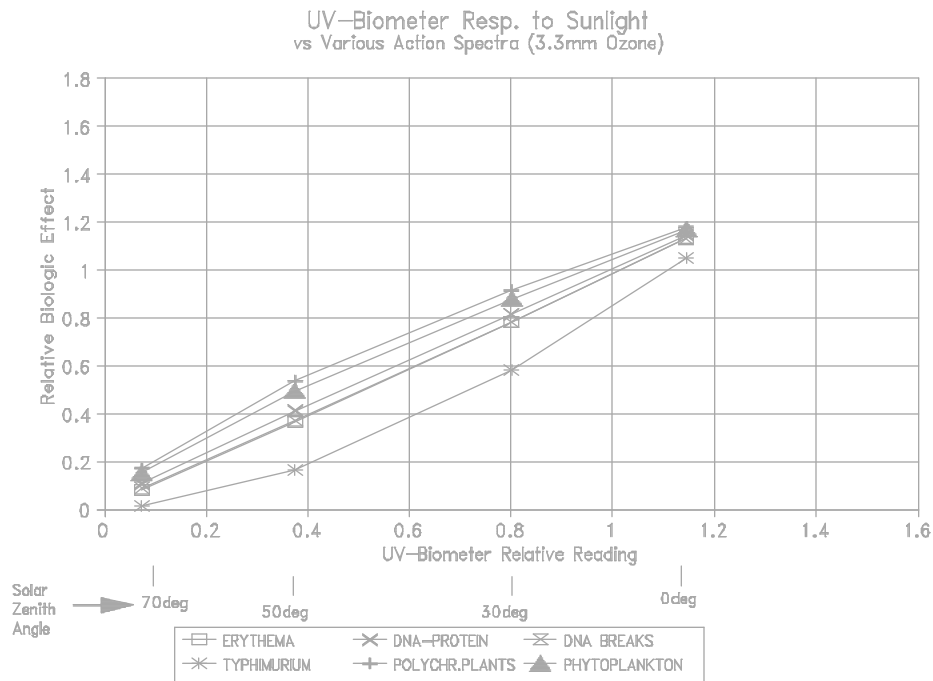


Figure 8 Computer simulation of UV-Biometer measurements vs. biologic effect under

3. UV-Biometer.

The UV-Biometer is based on the same principle as the Robertson-Berger meters that have been employed in the worldwide UV monitoring network since 1973. The Model 501 UV-Biometer has been designed based on the experience gained during the Robertson-Berger meter design (Berger 1976), network operation (Berger 1980, Scotto et al. 1988), and of research focused on temperature dependency of the Robertson-Berger sensor (Blumthaler et. al. 1986, 1989). The primary concerns addressed by this design were:

- an improved spectral response,
- temperature stabilization and compensation of the sensor,
- angular response close to cosine law,
- data storage capabilities and easy transfer to computers,
- flexible setup from the keypad or remote computer,
- compact size and low power consumption, battery operation.

There are two versions of the UV-Biometer available:

- complete system that includes detector with digital output, intelligent data acquisition system with built in communication capabilities, remote setup, temperature stabilization and correction, menu driven user interface.
- stand-alone detector with analog outputs of UV signal and sensor temperature and built in temperature stabilization.

Both systems have the same detector construction and equal metrological parameters. The stand-alone detector is designed to directly interface to commercially available data loggers.

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