

# UV Index estimation from global radiation and total ozone observations in Azores

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**Abstract.** A method for UV Index estimation from global radiation and total ozone observations is described. The method was calibrated with simultaneously measurements carried out by Brewer spectrophotometer (for UV and ozone) and pyranometer (global radiation) as part of the AZONET (AZores Observation NETwork) setup in the José Agostinho Observatory. Results show a good adjustment ( $r = 0.97$ ) with a standard deviation of 0.5 for the UV Index estimation, small enough to be used for public information in a real-time basis.

## 1 Introduction

The UV Index (UVI) is public-oriented meteorological information that pretends to indicate, in a quantitative simple way, the damaging ultraviolet radiation levels at the ground [1]. Its use started to be as popular as: temperatures highs; wind chill; fire risk index; air quality index; and other meteorological indexes or parameters. The UVI is defined as follows:

$$\text{UVI} = E_{\text{eff}} (\text{Wm}^{-2}) \times 40, \quad (1)$$

Where where  $E_{\text{eff}}$  is the effective UV radiation responsible for the occurrence of an erythema or sunburn, given by:

$$E_{\text{eff}} = \int_{290 \text{ nm}}^{400 \text{ nm}} E_{\lambda} \cdot S_{\lambda} d\lambda \quad (2)$$

$E_{\lambda}$  and  $S_{\lambda}$  are, respectively, the incident spectral irradiance and the action spectra for the erythema at wavelength  $\lambda$ . The action spectra used for the erythema is the one defined by CIE or McInlay-Diffey [2].

The UVI scale was defined by World Health Organization (WHO) [3] in order to provide a correspondence between UVI levels and protective measures to avoid damaging effects on humans. This information can be classified into five categories: LOW (1-2), MODERATE (3-5), HIGH (6-7), VERY HIGH (8-10) and EXTEREMELY HIGH (11 or greater). However, UVI is usually given in integer values, so the required precision for the public must be less or equal 0.5.

While UV dependence on ozone is well understood and easy to model, UV dependence on clouds is difficult to model and its effect on daily variability. In addition, atmospheric UV measurements are more expensive than global radiation and therefore fewer are available. However, global radiation is much less dependent on ozone and its variability depends essentially on the cloud coverage, therefore, global radiation measurements could be used to correct a simple radiative transfer model for clear sky conditions with respect to the actual cloudiness. The scope of this work is to find an approach to derive UVI from global radiation and ozone measurements with acceptable error for public awareness.

## 2 Instruments

Most part of atmospheric UV radiation measurements are currently done by two types of instruments spectral and broadband. Spectral instruments are generally spectrometers or spectroradiometers with high spectral resolutions of few nanometers or less. Broadband instruments are generally sensors with a response curve similar to the erythema action spectra but with wider spectral ranges of several nm. Because spectral instruments are more complex than broadband ones they are also more expensive and need more qualified operators and maintenance. Global radiation instruments or pyranometers are basically radiometers with a wide spectral range, from 0.3  $\mu\text{m}$  to 3  $\mu\text{m}$ , and used on meteorological stations for meteorological and/or climatological purposes. Because they are less complex than UV instruments, they are also less expensive and easy to maintain. Global radiation data is also easier to find and therefore it is a potential source of information to better explain spatial and time radiation variability due to clouds.

Global radiation records in Azores started in the 1940's at the Observatory José Agostinho (38°39'32" N, 27°13'23" W, 85 m), located in Angra do Heroísmo city on Terceira Island. In the scope of the research project CLIMAAT (Interreg IIIb), a more complete radiation monitoring system was acquired and installed in this site. This

system consists of one automatic sun tracker equipped with one pyranometer for global radiation and two shadow balls for a second pyranometer (diffuse radiation) and for a pyrgeometer (longwave atmospheric radiation). It was also installed one NIP pyreliometer (direct radiation) and a four-wavelength photometer for aerosol optical depth measurements. An automatic Brewer MKII spectrophotometer was also installed at the same place (Figure 1) to perform spectral global UV irradiance (290-325 nm) to allow the total column ozone calculations several times a day.



**Fig. 1.** Measuring radiation setup from AZONET (AZores Observation NETwork) at José Agostinho Observatory in Angra do Heroísmo: Brewer MKII spectrophotometer (left) and the sun tracking system setup (right).

### 3 Methods

In order to derive UVI from global radiation  $G$  measurements, it is assumed that the effect of UVI due to presence of clouds is proportional to the effect on global radiation,

$$\frac{\text{UVI}}{\text{UVI}_0} \propto \frac{G}{G_0}, \quad (3)$$

where,  $\text{UVI}_0$  and  $G_0$  are, respectively, the UV index and global radiation in the absence of clouds. While UV radiation is only reflected by the presence of the clouds, global radiation is reflected and absorbed, so the attenuation for global radiation

should be greater than for UV and more depending on the solar zenith angle and cloud thickness. These effects are difficult to model and require a very complete knowledge of the clouds that is not available. However, the attenuation mechanisms in both cases are directly proportional at first order, so the uncertainty of this approach remains at second order.

In this paper,  $UVI_0$  and  $G_0$  are computed by a simple radiative transfer model for clear sky conditions [5], while observed total ozone column and constant conditions for the other attenuation variables are used to determine UVI and G.

Data collected for this study are from 2004, August to 2006, August with some short periods of missing data due to suntracker and/or Brewer malfunction. Because each full UV measurement takes about 3 minutes, the global radiation measurements (5s resolution) were integrated for that period. Daily averages of observed total ozone column were used instead of individual observations to remove air mass instrumental dependence. The spectral integration (Eq. 2) for the UVI computation was corrected for the 325-400 nm range not measured by the Brewer MKII.

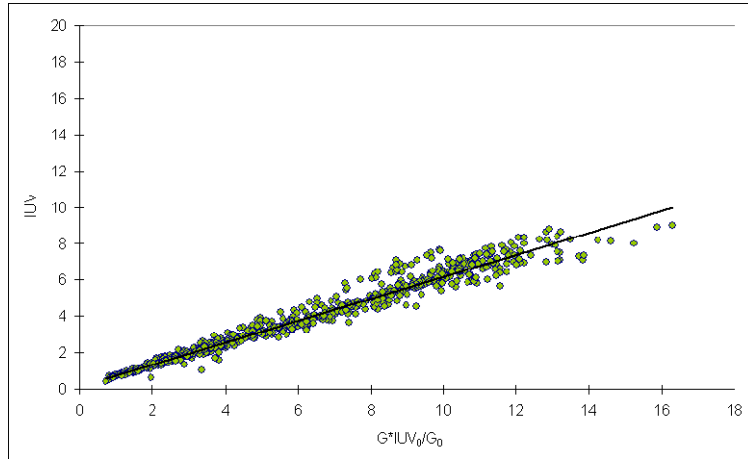
Observed diffuse radiation values were also collected in order to identify periods of radiation intercepted by clouds.

## 4 Results

In this analysis three cases were considered: only direct sun, only cloudy and any conditions. Data where the ratio of the Global/Diffuse radiation were greater or equal than 5, was classified as clearly direct sun while data where this ratio was less or equal than 1.1 were classified as clearly cloudy. Linear regression analyses were done, for the three cases, according to the proposed linear model,

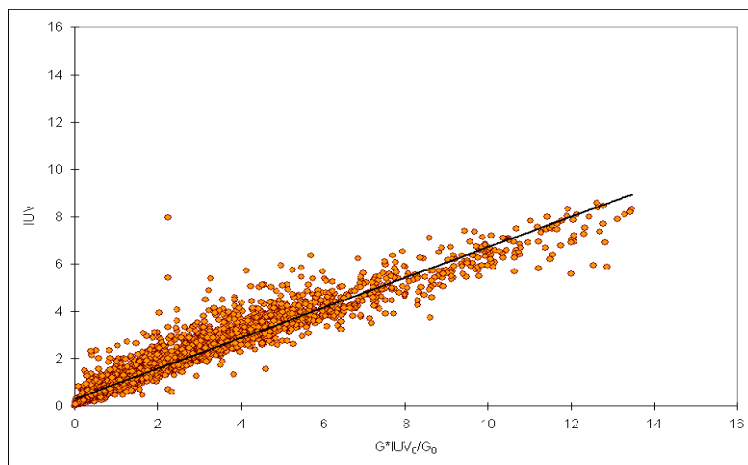
$$UVI = a \left( \frac{G}{G_0} UVI_0 \right) + b, \quad (4)$$

suggested by the experimental observation, represented in Figure 2, for the direct sun case. It can be clearly seen that the linear adjust is satisfactory (Table 1) and that data points are well distributed over all the range. However, modeled values are underestimated by the observations due to the super estimation of the UVI0 model or to a different calibration scale of the instrument.

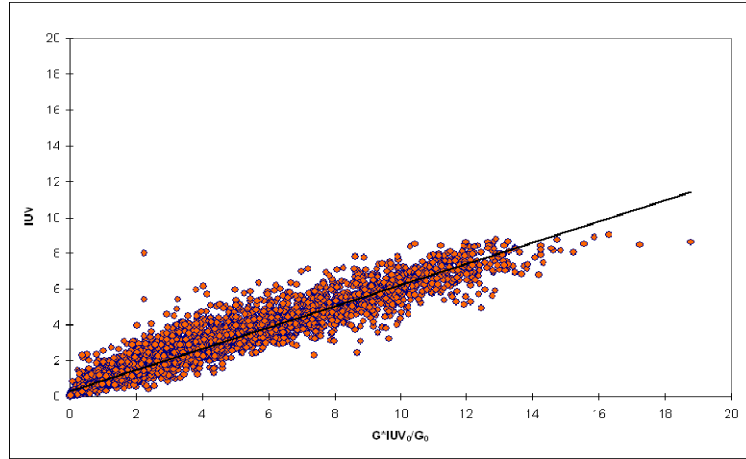


**Fig. 2.** Observed UVI values vs. modeled ( $G \cdot UVI_0 / G_0$ ) for direct sun cases (Global/Diffuse  $>5$ ).

For the experimental representation of the cloudy case (Figure 3) it also shows a behavior that can be also translated by the proposed model (Table 1), although with more dispersion.



**Fig. 3.** Observed UVI values vs. modeled ( $G \cdot UVI_0 / G_0$ ) for cloudy sun cases (Global/Diffuse  $<1.1$ ).



**Fig. 4.** Observed UVI values vs modeled ( $G \cdot UVI_0 / G_0$ ) for any conditions.

Finally, considering any conditions (figure 4) the experimental data points show also a linear correlation, that was also translated by applying the proposed model (Table 1).

**Table 1.** Linear regression information for the three cases.

	<b>R</b>	<b>Std. Error</b>	<b>a</b>	<b>b</b>	<b>N</b>
<b>Direct sun</b>	0.98	0.40	$0.607 \pm 0.004$	$0.11 \pm 0.03$	728
<b>Cloudy</b>	0.97	0.42	$0.643 \pm 0.003$	$0.307 \pm 0.009$	3793
<b>All</b>	0.97	0.50	$0.593 \pm 0.002$	$0.303 \pm 0.008$	7151

Standard error ranges from 0.4 to 0.5 UVI units, respectively, for direct sun and any conditions. This means that the proposed approach can be used for public information purposes. The slope, **a**, is consistent in the three cases and equals to 0.6. The intercept, **b**, is always positive and ranges from 0.11 and 0.31, inside the standard error (0.4–0.5) and therefore statistically zero.

## 4 Conclusions

A setup for radiation monitoring was installed in the AZONET allowing simultaneously measurements of global and diffuse radiation as well as UV spectral irradiances.

Data collected, during two years, were used to analyze the relationships between UVI and global radiation under three types of situations: direct sun; cloudy; and any conditions.

A linear model was used to derive UVI from global radiation data and radiative transfer models using observed total ozone column data.

Results show that the proposed linear model,

$$UVI = (0.593 \pm 0.002) \left( \frac{G}{G_0} UVI_0 \right) + (0.303 \pm 0.008),$$

can be used for public information purposes (UVI uncertainty of 0.5).

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