LOW COST UV MEASURER

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Abstract: Information on the ultraviolet solar irradiation (UV) in Brazil and throughout the world is scarce mainly due to the high costs of equipment and sensors, besides the operational costs in the implementation of a measurement station. The knowledge of the UV irradiation levels for a given region is of great importance, once this radiation affects not only the living beings but also the external usage material. This work aims to introduce a microcontrolled low cost ultraviolet measurer , capable of storing information on the global radiation (G) in minute scale and by means of a statistical correlation (UV/G), calculate the UV (A+B) radiation. Preliminary tests have shown good statistical performance when compared to data collected from a second set of sensors coupled with commercial datalogger (CR1000). In minute scale, the UV (A+B) estimate by the UV measurer, has shown RMSE% of 13.0%, and 6.90% in hourly scale.

KEYWORDS*:* UV, Relationship between global and UV solar irradiation, Estimative.

1. INTRODUÇÃO

The intensity of UV radiation on top of the Earth's atmosphere represents basically 7% of the solar spectrum. The spectrum of this radiation is normally subdivided in three intervals: UVA(320-400 nm), UVB(280-320 nm) and UVC(100-280 nm). Radiations UVA and UVB reach the Earth's surface, but UVC is totally absorbed in the stratosphere, where a great quantity of ozone is concentrated. The effects produced by UV radiation are beneficial to human beings, since they stimulate the production of vitamin D. However, the excessive exposure to this radiation can cause severe diseases such as skin cancers and cataract. The Nacional Cancer Institute (INCA, 2009) has estimated a total of 114,000 cases of non-melanoma type cancer and 5,930 cases of melanoma type cancer in Brazil in 2010. Besides the biological effects, UV radiation is responsible for the degradation of materials for external usage (coatings, eletric insulators, wood, plastic). Thus, knowing the incidence levels of this radiation is important for both population and industry. Extensive bibliographical researches have shown that information regarding UV (UVA + UVB) solar radiation in Brazil and throughout the world is very scarce and it's spatial and temporal coverage are very reduced (BARBERO et. al., 2006; ESCOBEDO et. al., 2007; CAÑADA et. al., 2008). This fact is due, among others, to the high costs of mediation equipment. Before such a fact, the FAE group in the Universidade Federal de Pernambuco has developed a portable and low cost data collector to gather global radiation and to calculate UV (A+B) radiation considering statistical models generated by the state of Pernambuco.

2. MATERIAL AND MÉTHODS

Measurement Station and Parameters

Table 1 shows the UV radiation and global solar radiation measurement station, their geographical coordinates, climatic characteristics and measurement time.

Stations	Geographical Coordinates			Climate	Period
	Lat.	Long.	Alt.(m)		
Pesqueira –PE	-8^0 24’	-36^0 46’	639	Tropical – semi-arid	September 08 / December 10

Table 1 – UV and Solar Global radiation Measurement Stations.

The solar UV (A + B) radiation was measured with a TUVR (The Total Ultraviolet Radiometer) pyranometer manufactured by Eppley, and the global solar radiation was measured with a black and white pyranometer also from Eppley. The sensors were connected to a Campbell’s data acquisition system CR-10X model. These instruments were programmed to carry out instant readings at each second, amounting to 60 readings a minute. From the arithmetical average of these readings, we come to 1440 daily values.

Ultraviolet solar fractions (F_{UV})

The relation between daily UV solar radiation and the daily global solar radiation for a certain region results in the F_{UV} ultraviolet solar fraction. The ultraviolet solar fraction enables us to estimate the UV radiation in places where there is no data about it, although there is data on global solar radiation. In those cases, the UV radiation can be easily calculated through the following expression:

$$I_{UV} = F_{UV} \cdot I_G \qquad (1)$$

where, I_{UV} and I_G é are, respectively, the UV solar radiation and the global solar radiation.

It is important to highlight that this estimation method is restricted to the place where the measurements originate from and to regions with very similar climatic characteristics.

UV measurer

The devised measurer is portable and has low cost. It is capable of collecting global radiation, calculating UV radiation based initially on models generated for the state of Pernambuco and downloading the stored data through a serial PC output. For this study, a model generated through information obtained by a measurement station at the IFPE in Pesqueira city, located in the Agreste zone of the state, 214 km away from the capital, Recife, was used. Figure 1 shows the physical aspect of the collector and of the sensor used in the data gathering. The LCD allows to visualize the date, hour, UV (A+B) and global radiations. Figure 2.

Figure 1 – Front view the mesurer and pyranometer spectral Vista frontal do coletor de dados e o sensor para medição da radiação global.

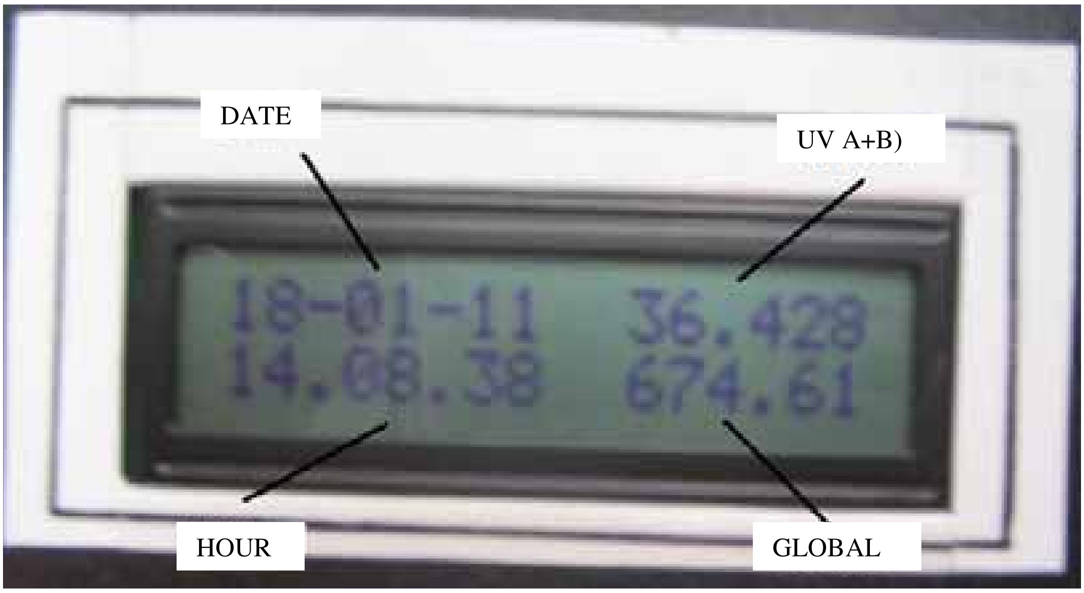


Figure 2 – Display shows date, time, UV (A+B) and global radiation.

Statistical comparasions

In order to determine and adopt a collector conversion factor, analysis in scales of minutes, hours and days were made. The data collected in hourly and daily scale, between September 2008 and December 2010, were mixed randomly and divided in two groups. The first period was used to model the estimate equation of the hourly and daily F_{UV} fraction. The second period for validation. The same approach was applied for the minute data, however, a day was chosen at random every month.

The validation of the equation was made from statistical indicators MBE% (mean bias error) and RMSE% (root mean square error)

$$MBE = 100\frac{\sum_n (H_{UV-CALCULED} - H_{UV-MEASURED})}{\sum_n H_{UV-MEASURED}}\% \tag{2}$$

$$RMSE = 100\frac{\sqrt{\frac{\sum_n (H_{UV-CALCULED} - H_{UV-MEASURED})^2}{n}}}{\sum_n \frac{H_{UV-MEASURED}}{n}}\% \tag{3}$$

3. RESULTS AND DISCUSSION

Statistical comparison between the UV mesurer and the CAMPBELL CR1000 data acquisition system

The UV measurer was calibrated to work with an Eppley precision spectral pyranometer (PSP). In order to measure the statistical performance of the collector, a second PSP sensor also from the Eppley manufacturer was attached to a CAMPBELL CR1000 measurement system. The simultaneous measurements from both devices have resulted in the graphic seen on Figure 3.

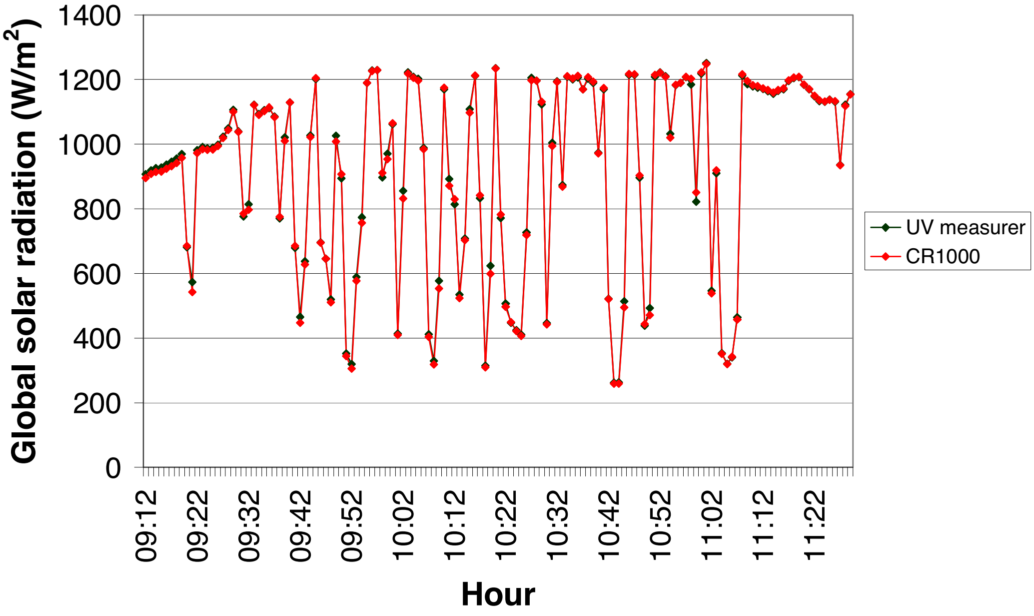
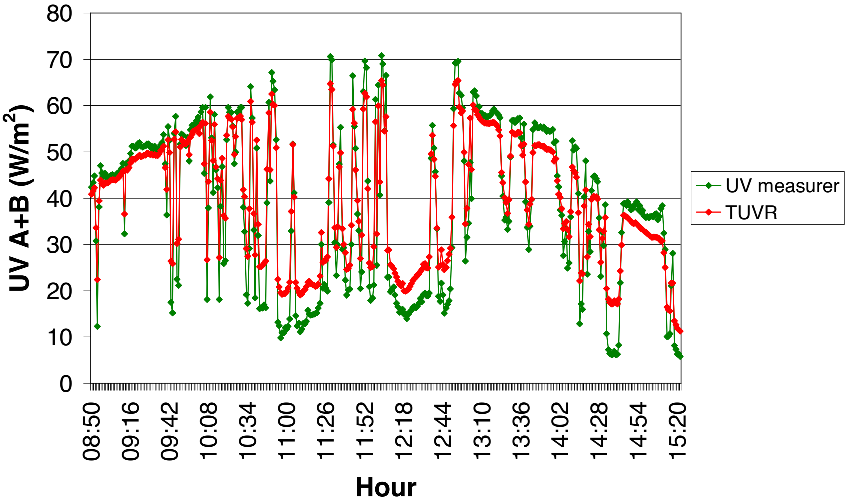


Figure 3 – Curves gerated by UV measurer and CR1000 (julian day 303 of 2010).

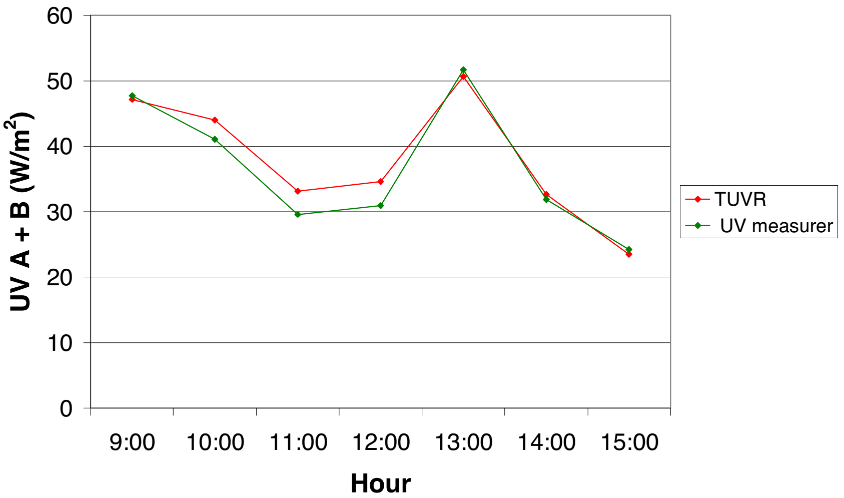
The collector has shown a good statistical performance when compared to the CR1000. The collected data in the minute scale have displayed a MBE% = -0.298% and a RMSE% = 0.99%, which are quite acceptable values, considering the precision of each sensor.

According to the UV and global radiation correlation in scales in minute, hour and day, it was possible to find a conversion factor to be adopted by the UV measurer. The minute, hourly and daily scale models have shown, respectively, a MBE% equal to 2.87%, 2.95%, 0.4% and a RMSE% of 16.10%, 9.99%, and 6.34%. Previously published papers for estimating the hourly and daily UV (A+B) radiation, from the UV fraction, have displayed statistical similar performances and mean fractions of the same order of magnitude (Martinez-Lozano et. Al., 1999; Canadã et. Al. 2003; Escobedo et. Al., 2007). It is expected, thus, that the data calculated by the collector shows a statistical performance similar to that of the models.

Figure 4 (a) and (b) shows, respectively, the curves in the scale of minutes and hours generated by the collector (green) in the city of Pesqueira in the time period from 8:50 hours to 15:20 hours in the Julian day 55 of 2011. In red, the curve generated by a TUVR attached to a CR1000 data acquisition system is highlighted.



(a)



(b)

Figure 4 – Curves in minute (a) and hourly (b) scale generated by a TURV+ commercial datalogger (red) and (green) UV measurer from global solar radiation.

In minute scale, the UV (A+B) estimate by the UV measurer, has shown MBE% = 3.46% and RMSE% = 13.01%, when compared to data colleted by TURV. The hourly mean values shows MBE% = 3.20% e um RMSE% = 6.90%. These results are acceptable, given that the models shown previously indicated a RMSE% = 16.10% and 9.99%.

4. CONCLUSIONS

The measurements carried out in the city of Pesqueira have made it possible to determine the equation for estimating the F_{UV} fraction. From this equation, one can calculate the UV radiation by knowing the global radiation in the regions surrounding the city. Benefiting from such a fact, the FAE group from the Universidade Federal de Pernambuco developed a portable and low cost UV measurer to collect global radiation and calculate UV (A+B) radiation considering the UV fraction. The global radiation data collected in minute scale and processed by the measurer have shown a MBE% = 3.46% and a RMSE% = 13.01% when compared to the data provided by a standard TUVR connected to a CR1000 collector. The results prove a good statistical performance of the measurer, thus being another efficient and low cost tool for measuring and collecting UV radiation.

5. REFERENCES

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