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Implementation of Web Software for the monitoring of Ultraviolet Radiation Based on the GUV 2511 Radiometer

Implementación de un Software Web para la Radiación Ultravioleta Basada en el Radiómetro GUV 2511

Implementação de um Software Web para Radiação Ultravioleta Baseado no Radiômetro GUV 2511

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Abstract

Introduction: This article is the product of the research " Implementation of Web Software for the monitoring of Ultraviolet Radiation Based on the GUV 2511 Radiometer", developed at the Fundación Universitaria los Libertadores in 2018.

Problem: The information downloaded from the GUV2511 radiometer, representing the levels of UV-B rays coming from the sun, is currently stored on the server and requires that the data be downloaded manually, with the danger that the information may be lost during transcription.

Objective: To implement web software, based on data from the GUV2511 radiometer, in order to determine the characteristic UV index values for the city of Bogotá.

Methodology: The Scrum methodology is used in the research, giving the user an easy way to consult and quickly understand the results.

Results: The software captures data from the GUV2511 radiometer through an ETC process. The captured data is graphed, making different queries.

Conclusion: The implemented web software presents the data and shows the graphs that are generated from the UV index based on factors such as the time of day, the month and the season of the year.

Originality: This research supports and strengthens the work developed in the radiometry laboratory for IDEAM in its data collection role.

Limitations: The software is currently at a "first phase" level of development and requires validation by experts in a second phase.

Keywords: GUV 2511 Radiometer, ultraviolet radiation, Web information system, data, graphical representation.

Resumen

Introducción: Este artículo es producto de la investigación "Implementación de un Software Web para la Radiación Ultravioleta Basada en el Radiómetro GUV2511", desarrollada en la Universidad los Libertadores en el año 2018.

Problema: La información bajada del radiómetro GUV2511, es almacenada en el servidor y, en forma manual, se descarga los datos, representando la cantidad de rayos UV-B provenientes del sol, con el peligro que la información pueda perderse durante la transcripción.

Objetivo: Implementar un software web basado en el radiómetro GUV2511 con el objeto de determinar los valores del índice UV característico para el área de Bogotá.

Metodología: La metodología empleada en la investigación es Scrum, entregando al usuario, una forma fácil de consulta y de rápida comprensión, en los resultados.

Resultados: El software captura datos del radiómetro GUV2511 a través de un proceso ETC. Se grafican los datos capturados, realizando diferentes consultas.

Conclusión: Se implementó un software web, el cual presenta los datos y muestra las gráficas que se generan del índice UV. Además, la cantidad de luz que alcanzan los rayos ultravioletas, en Bogotá, basada en factores como la hora del día, el mes y la temporada del año.

Originalidad: Esta investigación apoya y fortalece el trabajo desarrollado en el laboratorio de radiometría para ser un lugar de apoyo al IDEAM en su toma de datos.

Limitaciones: El software se desarrolla a partir de la solicitud hecha por el laboratorio de radiometría como primera fase y es necesario realizar una segunda fase para la validación con expertos.

Palabras clave: Radiómetro GUV 2511, radiación ultravioleta, sistema de información web y representación de datos y gráficos.

Resumo

Introdução: Este artigo é o produto da pesquisa "Implementação de um software web para radiação ultravioleta baseado no radiômetro GUV2511", desenvolvido na Universidad los Libertadores em 2018.

Problema: As informações baixadas do radiômetro GUV2511 são armazenadas no servidor e, manualmente, os dados são baixados, representando a quantidade de raios UV-B provenientes do sol, com o perigo de que as informações se percam durante a transcrição.

Objetivo: Implementar um software web baseado no radiômetro GUV2511 para determinar os valores característicos do índice UV para a área de Bogotá.

Metodologia: A metodologia utilizada na pesquisa é o Scrum, proporcionando ao usuário uma forma fácil de consultar e entender rapidamente os resultados.

Resultados: O software captura os dados do radiômetro GUV2511 através de um processo ETC. Os dados capturados são plotados, realizando diferentes consultas.

Conclusão: Foi implementado um software web, que apresenta os dados e mostra os gráficos que são gerados a partir do índice UV. Além disso, a quantidade de luz que os raios ultravioleta atingem, em Bogotá, com base em fatores como hora do dia, mês e estação do ano.

Originalidade: Esta pesquisa apoia e fortalece o trabalho desenvolvido no laboratório de radiometria para ser um local de apoio ao IDEAM em sua coleta de dados.

Limitações: O software é desenvolvido a partir da solicitação feita pelo laboratório de radiometria em uma primeira fase e é necessário realizar uma segunda fase para validação com especialistas.

Palavras-chave: Radiômetro GUV 2511, radiação ultravioleta, sistema de informação web e representação de dados e gráficos.

1. INTRODUCTION

Sunlight is electromagnetic radiation from the sun and is the main source of ultraviolet radiation on the planetary surface [1]. Limited exposure to UV radiation is essential in the production of Vitamin D in humans and, under normal conditions in vegetation, it cooperates in the photosynthesis process; however, excessive exposure to this kind of radiation is damaging to biological systems.

In order to investigate the processes of UV-B radiation in the atmosphere, the Radiometry Station of the Fundación Universitaria los Libertadores has been equipped with the Biospherical Instruments Inc. GUV 2511 radiometer. The GUV 2511 radiometer is a Ground-Based UV / PAR Radiometer which determines spectral amounts of irradiance at six wavelengths within the UV spectrum.

The project was conceived in response to the need to have real information from a ground station, with high-quality instrumentation, in the city of Bogotá, thereby providing its inhabitants with reliable and safe data with which to make informed decisions when considering issues related to solar radiation. This article will demonstrate the use of the GUV 2511 radiometer for data collection and the means by which the web information system requests the ultraviolet information before finally presenting the data of the ultraviolet index.

Warnings issued by both the World Meteorological Organization - WMO [2], a specialized agency of the United Nations and in charge of establishing models, procedures and useful practices to carry out the standardization and validation of climatological data at the international level; and the World Health Organization - WHO [14] on the effects of excessive exposure of solar radiation to humans, have led to the development and implementation of software that is visible on the Internet and is intended to be used by individuals and organizations engaged in activities to limit the damage caused by UV radiation, as well as by meteorology centers and the media that report on the UV index - UVI [3].

The Fundación Universitaria los Libertadores has a Radiometry laboratory and a Radiant SPIN OFF[1], identified as a pioneer and one of the most important in the field of new green energies, being recognized by the Ministry of ICT in the advice, design, implementation, operation and training of systems, based on alternative energy sources. Currently, it has three stations: ultraviolet, solar and meteorological, powered by solar panels. This required that a software application be made to show the behavior of each panel system for data collection, where solar panel exposure to photovoltaic solar radiation and the output generated are measured. In addition, having a National Center for Solar Radiation (NCSR) that has developed projects such as the calibration of radiometers at IDEAM's meteorological facilities, the development of the Atlas of ultraviolet solar radiation and ozone (which presents the ultraviolet radiometer spectrum), with filters to precisely measure the spectral bands of ultraviolet UV-A and UV-B radiation, and the direction and evaluation of wind speed that were developed by IDEAM's Wind Atlases.

The Solar Radiometry Laboratory of the NCSR investigates the material processes of interaction of solar radiation with different elements and gases, suspended in the atmosphere [4]. It also adds other environmental variables such as UV-B ultraviolet radiation, vertical ozone distribution, atmospheric turbidity, total ozone column, aerosol concentration, UV indices, and acid rain.

1 More information available: https://www.ulibertadores.edu.co/investigacion/spin-off-radiant-expertos-radiacion/

Therefore, to carry out this project, a collaboration agreement was drawn up with the Institute of Hydrology, Meteorology and Environmental Studies (IDEAM) [5], with the aim of managing scientific and technical information from a ground station with instruments duly calibrated that provide daily, monthly and annual information on the intensity of ultraviolet radiation, with wavelengths.

The objective of the research is to implement a web software that will be in charge of displaying the UV radiation and the UV index data captured in the GUV 2511 radiometer. The type of research is applied and the agile Scrum methodology is used, which offers the user an easy way to quickly view and understand results.

1.1 Literature Review or Research Background

Many countries currently have sovereign entities in charge of ensuring everything related to UV radiation and how it has affected people's lives. Universities have shown great interest and supported these entities with the setting up of radiometry laboratories for the study of said topic and how it can contribute to this study on UV radiation and the GUV 2511 radiometer.

Several databases were reviewed during the implementation of this project, such as ScienceDirect, Scielo, Google Academic search engine and Redalyc, finding published articles as can be seen in the references, making it possible to review the progress of the subject studied. In addition, information was drawn from some articles, books and texts studied in the field of ultraviolet radiation on the GUV 2511 radiometer.

Taking into account the associated concepts, such as ultraviolet radiation, the UV index and the GUV 2511 radiometer, Orte [6] proposes how to process the signals of a millimeter wave radiometer for the acquisition of ozone profiles and a narrow band radiometer GUV-41 for the analysis of UV radiation on the ground and the performance of atmospheric measurements.

Similarly, Hernández, Morera and Wright [7], propose the use of a technique to evaluate the UV index data, with the quantified values of UV-B solar radiation, carried out in San José, Costa Rica. The UV index is a measure of the ultraviolet radiation of the Sun, on the earth's soil and is a quantitative signal of the result of this type of radiation on human skin.

Also, Placencia [1] presents a viable method to calculate the amount of UV radiation coming from the sun, in order to estimate a UVI, typical of the Cumbayá region, Ecuador. The study was carried out with average figures of fifteen minutes in the months of July, August and September 2015, at the Atmospheric Measurement Station of the University of San Francisco, Quito. The final values have been contrasted with the UV index figures measured at the Ministry of the Environment, located in Quito, using a multichannel radiometer that estimates the UV index, forming a linear mixture of the radiometer's irradiance.

Likewise, Pettazzi and Souto [8] discover how UV-B radiation processes behave in the atmosphere, when acquiring a GUV 2511 radiometer at the atmospheric observation station in Santiago de Compostela, Spain. They have managed to develop a procedure for the determination of the values of liquid water column, total ozone column and UV index. The results obtained have been accepted using different methodologies, depending on the measure deduced.

In addition, González [9] presents the results and the study of a sequence of evaluations of solar ultraviolet radiation, carried out in Bogotá. The objective was to estimate the danger of exposure to solar ultraviolet radiation, through the UVI, in the midst of the La Niña phenomenon and to contrast it with records from historical databases, usable in the city of Bogotá.

Similarly, Buntounga, Janjaia, Nunez, Choosria, Pratummasoota and Chiwpreecha [22] investigate the factors that affect the relationship between erythemal ultraviolet radiation (UVER) and broadband irradiance (G), were used to investigate the UVER relationship / G in response to geometric and atmospheric parameters.

Similarly, Park, Kim, Oh and Lim [24] study and design a band-type device to measure UV irradiance in everyday life. They provide accurate information on the UV index and UV-B irradiance that can influence people.

In the same way, Castanedo-Cázares, Torres-Álvarez, Portales-González, Martínez-Rosales and Hernández-Blanco [25] carry out a study about UV intensity in various representative regions of Mexico, the average annual UV dose of the Mexican populations and the potential benefit of applying a sunscreen at different ages.

Also, Wright [26] comments that the project used a UV-B radiometer to measure solar radiation in the spectral range 280-315 nm, and a RUV radiometer, which measures solar radiation in the spectral range 280-385 nm. The measured UV-B values were compared with the values predicted by a spectral atmospheric model, which uses as input data: altitude, latitude, time of day, atmospheric turbidity, Earth-Sun distance, albedo surface and atmospheric ozone.

Thus, Basset and Korany [27] study the relation between UV-B radiation and global radiation over Egypt. The relationships between the global solar radiation and UV-B radiation at four stations in Egypt have been studied and linear empirical formulas for estimating UV-B from global radiation at these stations has been deduced.

Likewise, Bilbao and Miguel [28] analyze a series of UV-B broadband solar irradiances, 280-315 nm, measured during the period 2002 to 2011 in Valladolid, Spain. This has led to the daily UV-B values following the pattern of the solar elevation angle.

Similarly, Escobedo, Reynoso, González and Alarcón [29] analyze a series of measurements of UV-A and UV-B ultraviolet solar radiation, obtained from December 2015 to February 2017, in the city of Durango, Mexico. The daily radiation behavior of the months of the winter and summer seasons was analyzed. The accumulated daily energy and the monthly average were calculated.

Finally, Piedehierro, Cancillo and Bogeat [30] propose the analysis of the UVI obtained by a GUV-2511 multichannel radiometer (Biospherical Instruments Inc.). The UV index has been calculated using a linear combination of irradiance values of three and four GUV channels.

The contribution to this research lies in the fact that this web information system will serve to store all the information generated by the GUV 2511 radiometer on the UV radiation generated during the day to be studied and allow recommendations to be made on the handling of this type of radiation in the lives of the population of Bogotá. In addition, it is intended that the Radiometry laboratory of the Fundación Universitaria los Libertadores be a benchmark in topics such as UV radiation, the Ultraviolet Index, the amount of UV-B radiation that reaches the surface, broadband irradiance and the contributions towards the elaboration of an atlas of solar radiation in coordination with Colciencias.

2. Materials and Methods

2.1 Solar Radiation

Solar radiation is defined as the energy produced by the Sun, which propagates in various directions through space through electromagnetic waves. This type of energy is the engine that establishes the dynamics of climate and atmospheric processes. Energy from the Sun is electromagnetic radiation supplied by hydrogen reactions within the Sun as the result of nuclear fusion before subsequently being released from the solar surface [17] [34].

Solar electromagnetic radiation occupies a wide range of wavelengths, from radio waves through infrared, visible and ultraviolet, to gamma rays (γ) and X-rays. Actually, the radiation emitted by the Sun per unit of time is constant. Solar energy per unit area and unit time, outside the Earth's atmosphere at the time when the planet is on an average path of the Sun and the rays are common to the area, is called the solar constant and its value is ~ 1360 W / m^2 [6] Ninety-nine percent of the energy in solar radiation is in a wavelength band ranging from approximately 150 nm to 4000 nm and includes the ultraviolet, visible and infrared region, with an extreme value close to 500 nm (the green region).

The quantification of solar radiation is essential for a wide range of applications in the areas of meteorology, architecture, engineering, human health, agriculture and livestock; notably in the design and use of water systems, heating and electricity generation, the application as an alternative source of energy, infrastructure and construction design, plant growth monitoring, food dehydration, health implications as curative treatments for skin cancer, irrigation analysis and evaporation, its fundamental role in air quality prototypes and prediction of climate and climate itself, and other applications and various uses that use solar radiation as one of their energy sources [17] [35][36][37][38].

2.2 Solar Ultraviolet (UV) Radiation

The ultraviolet (UV) region occupies the wavelength range from 100 to 400 nm and is distributed in three zones: UV-A (315—400 nm), UV-B (280—315 nm) and UV-C (100-280 nm). By the time solar UV radiation crosses the atmosphere, the UV-C element is fully absorbed, while only 10% of UV-B reaches the earth's surface. UV-A radiation is not as affected by the atmosphere [6]. Therefore, the UV radiation that reaches the terrestrial environment is composed primarily of UV-A and a small component of UV-B. However, UV-B radiation is organically safer than UV-A radiation.

Contiguous to the perceptible spectrum is the ultraviolet (UV) region, in the group of frequencies between 8x1014 Hz to approximately 3x1014 Hz [15]. The powers of UV photons in the range from 3.2 eV to 1.2x103 eV. UV radiation is subjectively distributed in three areas, namely [18]:

- UV-A: Wavelengths that are in the range from 315 nm to 400 nm, called "black light". It is the least harmful to people and is widely used for its ability to make fluorescent materials throw electromagnetic radiation into the perceptible area. Similarly, it is used in tanning and phototherapy machines.
- UV-B: Wavelengths that are in the range between 280 nm to 315 nm. It has enough energy to devastate the biological layers. Largely, the atmosphere hampers large portions of solar UV-B radiation.
- UV-C: Wavelengths that are in the range from 100 nm to 280 nm. Now when UV-C photons collide with oxygen atoms, the exchange energy causes the

formation of ozone, so the solar UV-C is absorbed within a few hundred meters of the atmospheric layer. Artificial ozone lamps are used as air and water purifiers thanks to their ability to eliminate bacteria.

UV-A radiation is the one that reaches, to a considerable extent, the surface of the earth, but is of less intensity, and is the cause of the loss of freshness of the skin. UV-B radiation lands in a smaller proportion, since it is mainly assimilated by stratospheric ozone and is the cause of blisters on the skin. However, UV-C is the most damaging, almost non-existent on the surface since these radiations are assimilated in the air by atmospheric filters such as ozone and oxygen [1].

According to what has been said, the UV radiation that reaches the planet's surface is made up largely of UV-A radiation (95%) and, to a lesser extent, UV-B radiation (5%). UV radiation reaching the troposphere is the gimmick of all photochemical processes in the lower layers of the planet's atmosphere. Photons at the UV wavelength have the ability to break highly stable molecules into highly reactive pieces (photolysis) and consequently initiate chain reactions that would otherwise be unlikely or even impossible [17].

The broader wavelengths, UV-A and UV-B, have different repercussions on the biological processes of planet Earth. In appropriate amounts, these wavelengths support certain functions of living organisms, but in excessive and cumulative amounts, their effects can be very damaging.

The UV radiation indices on terrestrial soil are influenced by several factors, such as [19]:

- Sun height: The higher the sun, the higher the UV radiation index. These radiation rates will depend on the time of day and year. It is close to 60% of the radiation, samples are taken from 10 am to 2 pm.
- Latitude: It depends on how close you are to the equatorial region, the higher the UV radiation index will be.
- Cloudiness: UV radiation indices generally decrease with increased cloud density. However, UV indices can be equally high in the presence of cloudiness; close to 90% of the incident radiation on a cluster can cross it.
- Ozone: It is found in the atmosphere assimilating a large part of the incident radiation. The amount of ozone is contingent depending on the time of day and year.

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- Reflection: UV radiation can be returned or disintegrated in different areas, as is the case, close to 80% of the incident radiation on the snow is returned, meanwhile, 25% of the incident radiation on the sand is returned.
- Elevation above sea level: The UV radiation figures show an increase between 4% and 10% per kilometer above sea level, achieving an average of 5.6% increase in UVR per kilometer of altitude [20].

2.3 Ultraviolet Index (UVI)

The international solar UV index (UVI) is a magnitude of the intensity of solar UV radiation on the planetary surface. There are two feasible perspectives based on measurements: the first is to use a radiometer and estimate the UVI by means of a formula; the second is to use a calibrated broadband detector prepared to supply the UVI [15].

The UVI is used as a signal that relates the intensity of solar ultraviolet radiation incident on the Earth's surface, with possible lesions on human skin. This index makes it possible to reduce the dangers of UV radiation to people and is a guiding measure aimed at promoting appropriate behavior in the community, including beneficial exposure to the sun; as it is essential for different biological processes of the human organism [17].

In 1992, Canada began forecasting UV radiation and established the term UV Index. After a while, various nations began forecasting UV radiation for the next day. The model is the National Weather Service (NWS) and the United States Environmental Protection Agency (EPA), which have been making a daily forecast since 1994 of the UV index, which provides a prediction of UV radiation levels for the next day, in a range from 1 to 11+, so that individuals can verify the appropriate behaviors to protect themselves from the Sun. This involves a calculation that constitutes five classes of data to achieve the amount of radiation that intervenes on the surface of $1m^2$ at the solar noon. The EPA categorizes this simple numerical forecast into five "exposure levels", with the protection standards suggested by the WHO for each level.

The ultraviolet index is a measure that was proposed to notify people about the ultraviolet radiation scale so that it can be explained [6]. The UV index that reaches the planet is influenced by different variables (altitude, atmospheric dispersion, clouds, ozone content, reflection, aerosols). To achieve this index, the spectral irradiance (unit of time, per wavelength -W / m^2 / nm and amount of energy per unit area), is analyzed using the erythemic action spectrum (reaction of the epidermis to UV radiation) stated in accordance with the CIE standard (Commission Internationale de l'Ecleirage). Once analyzed, the irradiance, now called erythemic irradiance, is composed of electromagnetic radiation in the spectral range between 280 and 400 nm (UVA and UVB) [14].

Therefore, we have:

$$IUV = C \int_{280\,nm}^{400\,nm} E(\lambda)A(\lambda)\,d\lambda$$

Fig. 1 Equation to calculate the Ultraviolet Index.
Source: Based on [10]

where:

E_λ is the solar spectral irradiance expressed in W / (m^2 nm) at wavelength λ.

d_λ is the wavelength differential used in the integration.

$S_{er}(\lambda)$ is the reference action spectrum for erythema.

K_{er} is a constant equal to 40m^2 / W.

Where λ is the erythematic action spectrum, C is the conversion constant equivalent to 40 and λ is the spectral irradiance of the surface [W / m^2 / nm]. Thus, the ultraviolet index is, at best, an abbreviated setting for the description of erythemic irradiance [10]. Therefore, each unit of UV Index corresponds to 25 mW / m^2.

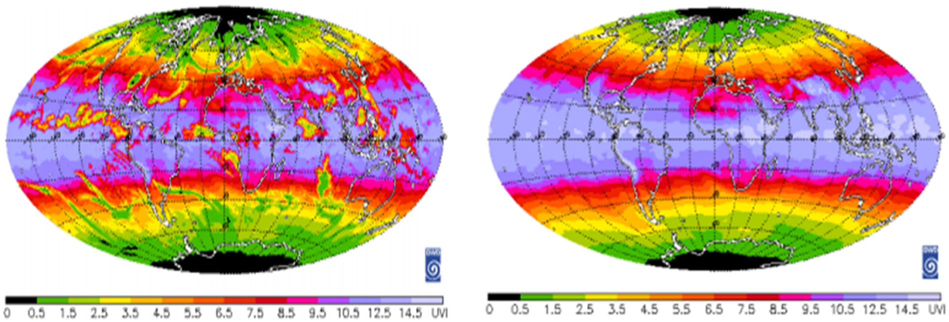
The amounts of the UV index, according to the recommendations made by the World Health Organization (WHO), are classified into categories identified by colors (WHO, 2003). This UV index scale is used in the United States and conforms to the international guidelines for reporting ultraviolet measurements (UVI) established by the World Health Organization [14], as can be seen in the following figure:

Exposure Category	UVI Value Range
Low	< 2
Moderate	3 to 5
High	6 to 7
Very high	8 to 10
Extremely high	11+

Fig. 2 Ultraviolet Index Categories.
Source: Based on WHO [19]

The UVI estimates a change between 0 at night and 11+ in tropical regions and high peaks with clear skies. It should also be mentioned that, while the value of UVI increases, the greater the damage that UV-A and UV-B rays can cause to our eyes and our skin, and the minimum time of exposure to the sun without trauma is minimal [7].

UV indices show the magnitude of UV-B radiation on a scale of one to 11+ (the higher the number, the more damaging UV radiation exposure). According to the image, so that the maximum predicted daily amount of the UV index is shown at the planetary level, taking into account the cloud cover (a) and for clear skies (b), in any case, in the tropics are they can find extreme Ultraviolet Index (UVI) numbers, on the order of 14.5 or higher.



a) UVI considering cloud cover. b) UVI for clear skies.

Fig. 3 Ultraviolet Index Forecast for September 13, 2017 with cloudiness and clear skies.
Source: Based on Deutscher Wetterdienst.

2.4 GUV 2511 Radiometer

It is an instrument of the type GUV (the English acronym for Ground UltraViolet) of high speed, with reference 2511, which is responsible for measuring ultraviolet radiation at the earth's surface. Manufactured by the American company Biospherical Instruments Inc. [11], it belongs to the class of instruments called "multi-wavelength radiometers".

It was acquired with the calibration certificate and is operated in accordance with the procedures of the National Institute of Standards and Technology (NIST). It has been positioned in free space on the terrace of the Santander headquarters, of the Fundación Universitaria los Libertadores (FULL) and is specifically calibrated to capture irradiance values, at four wavelengths: 305, 313, 320, 340 nm within the UV spectrum [9] and in the perceptible broadband spectrum "Photosynthetically Available Radiation "(PAR) that lies in the range of 400 nm to 700 nm. The irradiance quantified by the device has a bandwidth of 10 nm more or less [21].

This tool has turned out to be an appropriate alternative for long-term monitoring of ultraviolet radiation in the area, since it is very stable, robust and temperature-stabilized [8] [21]. Likewise, by combining the calculations of this tool with the calculations of the radioactive transfer models, it is possible to obtain resulting products of enormous scientific utility, such as the optical thickness of the cloud layer, the content of the total ozone column and the UV index [13].

The calculation of the UVI, according to the characteristics of GUV-2511, cannot use the internationally recognized definition of the UVI [13], but rather applies the methodology suggested by Biospherical Instruments Inc. [11]:

$$UVI = I_{305}a_1 + I_{320}a_2 + I_{340}a_3$$

In which, I_{305}, I_{320} and I_{340} denote the radiation (μW / cm^2 nm) corresponding to the wavelengths (in nm) indicated and evaluated according to the average of the measurements at intervals of ten minutes during a clear sky, around noon and with the least possible variability in the conditions of the city of Bogotá. The coefficients that accompany the irradiances are a_1 = 0.8911, a_2 = 0.0818 and a_3 = 0.007751, in units of (cm^2 nm / μW); the UVI is dimensionless.

The collection of the data provided by the GUV 2511, as seen in figure 4, is carried out using software, developed by the research group, installed on a computer connected to the sensor's temperature controller through a RS-232 serial cable [16].

Fig. 4 GUV 2511 Radiometer.
Source: Radiometry Laboratory located at the Fundación Universitaria los Libertadores.

The instrument has been calibrated through the referenced spectral irradiance standard of the NIST (National Institute of Standards and Technology) of 100 W type FEL; Also, the manufacturing company advises a periodic measurement per year. An open-air shielded cable that couples the radiometer to an external digital temperature controller complements the device. The controller makes it possible to set the functional temperature of the radiometer [21].

2.5 Web Information System Responsible for Visualizing Ultraviolet Radiation

The UV Index values are calculated automatically and in real time, with the help of a program developed in Java language installed on the server of the radiometry laboratory of the Fundación Universitaria los Libertadores. The captured data is stored in flat files, inside a Linux Ubuntu server and is taken to the PostgreSQL database engine; in addition, using CSS and HTML, through which the information is displayed on the web using a GlassFish web server.

The object-oriented methodology was used for the design and development of the software, as follows:

- Requirements analysis: The functional requirements are defined and the use case diagram is developed to demonstrate their behavior.
- Conceptual design: The application domain model is built, taking into account the requirements reflected in the use cases. The result is the domain class diagram.
- Navigation design: The application's navigation structure is defined with style sheets.
- Presentation design: The design pattern, used in product development, is the Model View Controller (MVC) because it separates the application into three parts: the model represents the application data, the view represents the data model, and the controller allows interaction between the model and the view.

Fig. 5 Web Information System made for the Radiometry laboratory of the Fundación Universitaria los Libertadores.
Source: Radiometry Laboratory located at the Fundación Universitaria los Libertadores.

In addition, Figure 5 shows how the user interacts by showing a main menu with the option "Utraviolet Radiation". Through the filters, the user can select: "View data for the day", "View data for the month", "View data for the year".

If you select an option, you must search for the date by day, month, or year; if you want to see the constructed graph, you can select the option "View graphs" or if you want to see data, choose "View data Ultraviolet Radiation". Similarly, in case you need a report, select "Export data".

3. Results

The project was developed in several phases, namely, the visualization of the UVI data captured by the software. Next, a graphical representation of the Ultraviolet Indices is made, by means of a certain date, where it will show us the average and the maximum of the ultraviolet index. An equation is used to calculate the UVI, thanks to the information captured daily, where the UVI data corresponding to the daily maximums and averages obtained.

The levels of UV radiation at ground level depend on several factors: altitude, cloud cover, latitude, position of the sun, reflection from the ground, and the amount of ozone in the atmosphere.

UV radiation indices change throughout the day and throughout the year; the significant ones are measured on the day when the Sun is at its extreme elevation, which goes between 10 a.m. and 2 p.m. (about 60% of UV radiation is absorbed at this time), while when the angle of the Sun is closer to space, less UV radiation reaches the Earth's surface because it crosses a greater distance in the atmosphere and finds more ozone molecules, leading to huge absorption [17]. Elsewhere, besides the tropics, high values manifest themselves in the summer months around noon. In the tropics, the highest levels of radiation at the end of the atmosphere occur at the beginning of the year, generally around the entire perihelion (when the Earth is closest to the Sun) and the smallest, in the middle of the year during the aphelion (at the time when the Earth is furthest from the Sun).

UV radiation changes according to geographical location on the equatorial region, as is the case in Colombia, solar rays affect more directly than in the middle latitudes, for this reason, UV radiation becomes higher in that area.

The altitude specifies the dose of UV radiation that is taken, because in mountainous regions the atmospheric layer that the solar rays must pass through is thinner, so that, at higher altitudes there is more UV radiation. This means that, on average, for every 1000 meters of increase in altitude, UV radiation increases by approximately 10% to 12%.

Clouds can affect the dose of UV radiation taken by the planetary surface; in general, dense clouds prevent the passage of more UV radiation than less dense clouds.

The UV radiation index that approximates the area of a site is inversely related to the total ozone in the atmosphere (mainly in the area between 18 and 40 km high, where the ozone layer is located); this leads to less ozone and more UV radiation landing on the ground. Consequently, high amounts of UV radiation are received in those places where their ozone volume is lower. The region with the lowest total ozone volume on the planet lies within the tropics, which include vast places in central and northern South America, central Africa and the tropical Atlantic, where averages below 240 DU are recorded. Colombia is included in this site, for this reason, it is exposed to high doses of UV radiation on the surface throughout the year.

Furthermore, it should not be forgotten that a group of similar devices manipulated in this project achieved the Ultraviolet Indices presented in the Colombian Atlas. Therefore, the methodology used should have been the same.

3.1 UV Index Data Display

A software was developed that calculates and displays the ultraviolet radiation index, with different intensity levels, on a scale from 0 to 11+, using data and using colors. In addition, it highlights aspects that are not directly observable. A higher number means a higher risk of UV exposure, and a greater chance of sunburn and skin damage that could lead to skin, eye, or immune system diseases. It indicates the amount of UV radiation that a person can withstand and when it becomes a danger to their health.

TABLA INDICES UV	
Escala	Riesgo
0-2	MÍNIMO
3-5	BAJO
6-7	MODERADO
8-10	ALTO
+11	MUY ALTO

Datos Indice UV del Dia 2019feb04									
	BANDAS ESPECTRALES UV (nm)				Weighting factor				
Hora	305	313	320	340	305	313	I320	I340	INDICE UV
12:24	3,495670000	7,673821000	11,154870000	17,504270000	2,816810886	0,680667923	0,361417788	0,229305937	4,088202534
12:25	3,356875000	7,370354000	10,702300000	16,690590000	2,704969875	0,653750400	0,346754520	0,218646729	3,924121524
12:26	3,297227000	7,229868000	10,485110000	16,257160000	2,656905517	0,641289292	0,339717564	0,212968796	3,850881168
12:27	3,340816000	7,309422000	10,591510000	16,376830000	2,692029533	0,648345731	0,343164924	0,214536473	3,898076661
12:28	3,514534000	7,672062000	11,115180000	17,219940000	2,832011497	0,680511899	0,360131832	0,225581214	4,098236443
12:29	5,502982000	12,077680000	17,717340000	29,097170000	4,434302896	1,071290216	0,574041816	0,381172927	6,460807855
12:30	8,287130000	18,292280000	27,061420000	46,113080000	6,677769354	1,622525236	0,876790008	0,604081348	9,781165946
12:31	8,990798000	19,846750000	29,389430000	50,290830000	7,244785028	1,760406725	0,952217532	0,658809873	10,616219158
12:32	8,995489000	19,857940000	29,408030000	50,330750000	7,248565036	1,761399278	0,952820172	0,659332825	10,622117311
12:33	8,336084000	18,394530000	27,211680000	46,346290000	6,717216487	1,631594811	0,881658432	0,607136399	9,837606129
12:34	8,923160000	19,754120000	29,287340000	50,278910000	7,190282328	1,752190444	0,948909816	0,658653721	10,550036309
12:35	8,768806000	19,457690000	28,868020000	49,656440000	7,065903875	1,725897103	0,935323848	0,650499364	10,377624190
12:36	6,771351000	15,004180000	22,183100000	37,550040000	5,456354636	1,330870766	0,718732440	0,491905524	7,997863366
12:37	4,676856000	10,327880000	15,146360000	24,716260000	3,768610565	0,916082956	0,490742064	0,323783006	5,499218591
12:38	3,624012000	7,982959000	11,621820000	18,319620000	2,920228870	0,708088463	0,376546968	0,239987022	4,244851323

Fig. 6 Consultation of the Ultraviolet Index data downloaded from the GUV 2511 radiometer, on February 4th, 2019 between 12:24 PM and 12:28 PM.
Source: Radiometry Laboratory located at the Fundación Universitaria los Libertadores.

The user visually explores the information accurately and appropriately, where it finds patterns and trends. Human vision works through visual stimuli that are captured by the eye and converted to color and spatial sensations, which the brain interprets.

Figure 6 shows a table with the real data that is constructed from the action executed by the user, where the date February 4th , 2019 is selected, yielding corresponding data between the 12:24 p.m. and 12:28 p.m. bands, the UV index is low; Likewise, in the 12:29 p.m. band, it is observed that the ultraviolet radiation index is moderate. In the 12:30 p.m. range and 12:35 p.m., the ultraviolet radiation index is high and it is harmful to be exposed, in a prolonged way, to solar radiation.

3.2 UV Index Graph Display

In Figure 7 they construct the graph with the corresponding data of Figure 6 and, using certain characteristics of the information display, the perception of the user who is stimulated to understand relationships and recognize patterns is exploited; It is not a question of replacing human capacity in the search for information, but rather it is intended to be used to amplify its effectiveness.

As can be verified, if the highest value is in Figure 6, the reader assumes an effort since all the values have to be compared, while in Figure 7, using visualization mechanisms, the user can verify which of the values is highest. It is concluded that the software developed in the project, with real data, makes the information it represents be perceived unconsciously, effortlessly, in such a way that, with a single glance, as much information as possible can be obtained.

With the color chart, it allows the user to easily determine the ultraviolet radiation index and when UV levels are considered to be dangerous; ranging from red to violet.

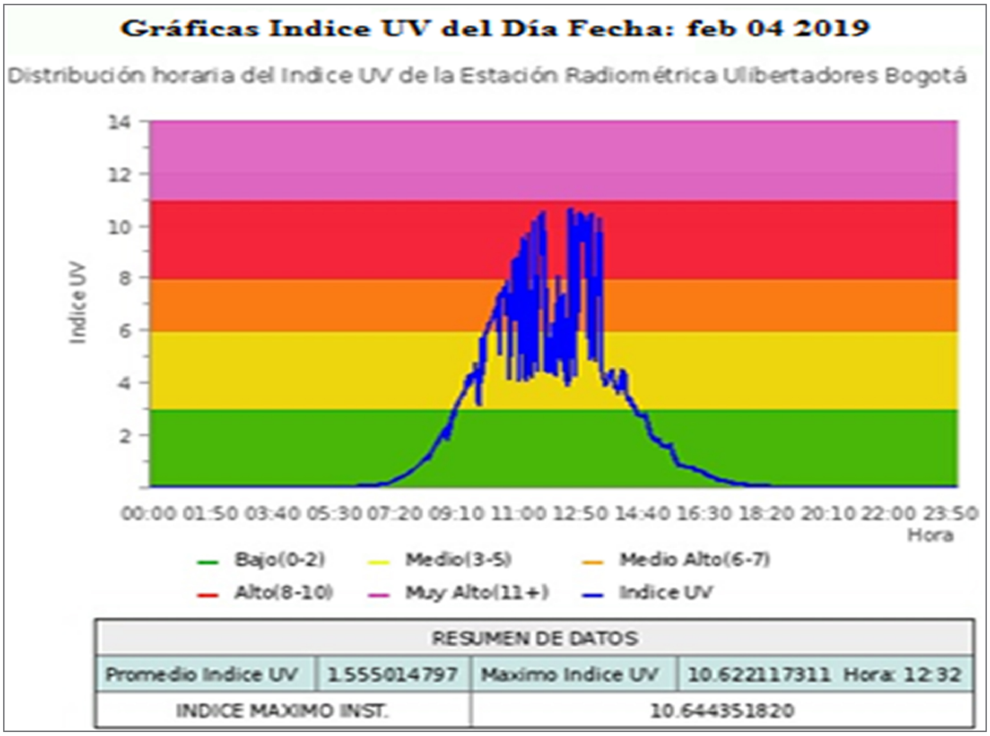


Fig. 7 Graph of the Ultraviolet Index downloaded from the GUV 2511 radiometer, on February 4th, 2019.

Source: Radiometry Laboratory located at the Fundación Universitaria los Libertadores.

Therefore, some recommendations to minimize the negative effects that ultraviolet radiation can cause in humans are [32] [33]:

- Increase the length of stay in the shade.
- Apply sunscreen at least thirty minutes before sun exposure.
- Avoid exercising or playing sports during hours when the sun is at its zenith.
- Avoid exposing children under one year of age to direct sunlight.

4. Discussion and conclusions

The weather in the world has changed gradually and markedly. This has led to the emergence of a series of environmental problems, such as large storms, extreme droughts, frosts, increased solar radiation, among others, which have altered the way of life of man. Therefore, climate change has raised a number of challenges in many respects for all countries on the planet, due to the variations in production and costs associated with this phenomenon [31].

Colombia has conditioned its dissertation on the solar resource to the elaboration of a solar atlas that covers the national territory, but there is no recent research aimed at each geographic area making its own atlas, which makes up a fundamental difference with respect to other nations with greater advances in the photovoltaic sector. The positioning of the systems that are connected, starting from the information offered by this kind of global atlas, is not ideal due to the demand for more exact and precise data. This has led to exceptional investigations for more limited areas such as plateaus, hydrographic basins, valleys or savannas, providing more specific and useful information for the photovoltaic field [39][40].

The variety of devices used to inspect and record the system makes investigation tasks complex, as different programs are used to obtain and store data. This entails collecting and filing the information by segments and later, rigorously, making the manual incorporation that enables its subsequent study and analysis. This series of problems stimulates the search for an answer that first solves the inconveniences in relation to information management and serves as a column for the establishment of services that help control, monitor and study this type of systems.

In this research project, knowledge and training in the management of databases were generated, based on the data recorded by the GUV 2511 radiometer, where the software has been used, developed by the AppMóvil research seedbed, attached to the GUIAS group of the Systems Engineering program, at the Fundación Universitaria los Libertadores.

In addition, the sensor temperature controller was connected to the computer via an RS-232 serial cable. This information is key for the investigation because it will allow us to know the UV index, UV-A solar radiation, UV-B solar radiation and UV-C solar radiation.

Consequently, from the capture of the ultraviolet radiation information, in the district of Chapinero, where the Radiometry laboratory is located, the pertinent and truthful information is displayed to raise awareness among the population of the city of Bogotá, of the importance of having the information regarding the UV index, on the measures that must be taken to avoid damage to the skin and eyes and the consequences of inadequate protection from solar radiation. It should not be forgotten that it can also cause skin cancer, premature aging, terigios, skin burns or affect the immune system itself.

Through radiometric measurements, spectral measurements and mathematical operations, a UV index measurement strategy was promoted in the radiometry laboratory. Various calculations were carried out to establish the spectral irradiance through irradiance measurements and spectral measurements, in order to measure the UV index, typical of the area. The results of the index were contrasted with the indices quantified in IDEAM, in Bogotá.

As soon as the IDEAM ultraviolet index is determined, it is recommended to use an equation, as can be seen in Figure 1, that considers all the wavelengths of the UV range (310 nm to 400 nm) and fully understand the environment of the coefficients used in the radiometer equation, as well as the uncertainty of its data.

The client-server web system, when implemented, displays data and graphics online with parameterized information and can be shown to the public, so that they can be used from different perspectives.

The web software, for data analysis of the Radiometry Laboratory of the Fundación Universitaria los Libertadores, is disseminated so that the population, in general, adopt protection mechanisms against ultraviolet radiation, using appropriate clothing and sunscreen with a good UV filter when they are in recreational or outdoor activities; hence the need to raise awareness about the dangers of sunbathing, without adequate protection mechanisms, against ultraviolet radiation.

Similarly, the web software for data analysis of the Radiometry Laboratory of the Fundación Universitaria los Libertadores, will be used to prepare maps showing the intensity of ultraviolet radiation at the level of the city of Bogotá, and that will serve as a reference point for the elaboration of the solar radiation atlas. The UV index data will be kept per hour, per day and per month, which will be captured with the GUV 2511 radiometer and saved on the radiometry laboratory server. This information will be generated in monthly reports for those companies and entities that consider they need this information to make their forecasts related to the average values shown by the UV index.

Finally, an automation of the measurement process, carried out in this research, is proposed to obtain a greater amount of data, without requiring human intervention throughout the day.

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