e-ISSN 2308-7862
Bluefields Indian & Caribbean University (BICU)

Revista del Caribe Nicaragüense
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Exposición de la radiación ultravioleta UVB solar en la bahía de San Juan del Sur, Rivas en el periodo 2023

Ultraviolet radiation exposure solar UVB in San Juan del Sur bay, Rivas in the period 2023

Fecha de Recepción*: día-mes-año*
Fecha de Aprobación*: día-mes-año*

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ABSTRACT

The Global UVB Solar Index was developed as a tool to inform the public about the intensity of solar ultraviolet (UVB) radiation in different regions of the world. In this context, exploratory research was conducted in San Juan del Sur Bay, Nicaragua, during 2023, with the aim of evaluating UVB radiation levels and their relationship with environmental and astronomical variables from a physical-medical perspective focused on public health. Measurements were taken at different times of the day, with emphasis on the period between 10:00 a.m. and 2:00 p.m., when solar radiation is most intense. Pearson's correlation coefficient was applied for the analysis, finding a strong positive correlation between UVB radiation and solar altitude, and a negative correlation with cloudiness. Although no direct relationship with diseases such as skin cancer or cataracts was identified, individual protection and genetic factors are recognized as influencing their onset. The results allowed for the identification of time zones and areas of greatest risk, and preventive measures were proposed, such as avoiding direct sun exposure during peak hours, using sunscreen, appropriate clothing, and UV-filtering lenses. This study contributes useful evidence for the design of public health strategies and the promotion of safer and more sustainable tourism in Nicaragua, especially in coastal areas with high sun exposure.

Key words: radiation effect, UV radiation index, sun protection, public health, coastal zone

INTRODUCCIÓN

Exposure to ultraviolet radiation remains a matter of global concern due to its health effects. Humans' constant exposure to numerous genotoxic agents (chemical, physical, or biological substances) can damage the genetic material (DNA) of cells.

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Ultraviolet (UV) radiation, emitted primarily by the sun, is one of the main causes of damage to human skin. There are three types of UV radiation: UVA, UVB, and UVC; however, only UVA and UVB rays penetrate the Earth's atmosphere, causing acute and chronic effects on the skin. Several studies have shown that prolonged, unprotected exposure to UVB rays can cause sunburns, which are an inflammatory response of the skin to cellular damage (World Health Organization [WHO], 2022). These burns are not only painful but also significantly increase the risk of developing serious skin diseases in the future.

The link between ultraviolet radiation exposure and skin cancer has been widely documented in the scientific literature. According to the American Cancer Society (2023), more than 90% of non-melanoma skin cancer cases are related to sun exposure, with basal cell carcinoma and squamous cell carcinoma being the most common. Furthermore, the International Agency for Research on Cancer (IARC) has classified solar radiation as a group 1 carcinogen, meaning that there is conclusive evidence that it causes cancer in humans (IARC, 2020). This information underscores the importance of promoting prevention strategies, such as the use of sunscreen, appropriate clothing, and avoiding sun exposure during peak hours.

The Sun emits various types of radiation such as X-rays, ionizing radiation, ultraviolet radiation (UVR), visible light, infrared radiation, among others. From a photobiological point of view, the solar spectrum at the Earth's surface (sea level) is made up of radiation with electromagnetic energy wavelengths between 290 and 3000 nm. Due to this great diversity, in clinical practice it is considered that the solar spectrum is composed of ultraviolet radiation (290–400 nm), visible light (400–760 nm) and infrared radiation (>1800 nm) (AEMET, n.d.).

This study, conducted in San Juan del Sur Bay in 2023, aims to measure the intensity of ultraviolet radiation and correlate it with solar position to understand exposure patterns. The relationship between this exposure and dermatological problems such as sunburn and skin cancer was explored. A comparison was made between UV radiation intensity and safe exposure thresholds according to the World Health Organization recommendations. Based on the results obtained, protective and awareness-raising measures are proposed to reduce health risks for the population.

The UV Index as a predictor of UV-related health risks. The UV Index, which can be measured or calculated, is a standardized way of representing the amount of UVR reaching the Earth at a given time and place.

Equation 1, used to derive the UV index, is given by WHO (2022):

$$I_{UV} = k_{er} \times \int E_{\lambda} \times S_{er}(\lambda) d\lambda \qquad (1)$$

donde I_{UV} is the UV index, whether measured or calculated; E_{λ} is the solar spectral intensity, measured or calculated in wavelength λ; y S_{er} (λ) is the erythematous efficacy of the CIE at the wavelength λ. Using erythematous efficacy, the UV index takes into account the biological effects of incident solar UVR radiation to determine the potential hazard to the skin of sun-exposed individuals.

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UV index forecasts are disseminated in many countries to inform the public in advance and help manage the risk of UVR exposure. Most commonly, these UVI predictions are created by modeling UV irradiance that takes into account relevant atmospheric parameters (total ozone, aerosol optical properties, and cloud cover). The predictive models used vary in complexity and accuracy, but all depend on a good understanding of actual atmospheric parameters, which is often lacking, according to Vanicek et al. (2000).

Occupational skin cancer is characterized by presenting consequences after long latency periods, from years to decades, and the diagnosis can be obtained when the worker is no longer occupationally exposed (even after retirement), making it difficult to establish the association of the disease with the workplace (even with intense occupational exposure).

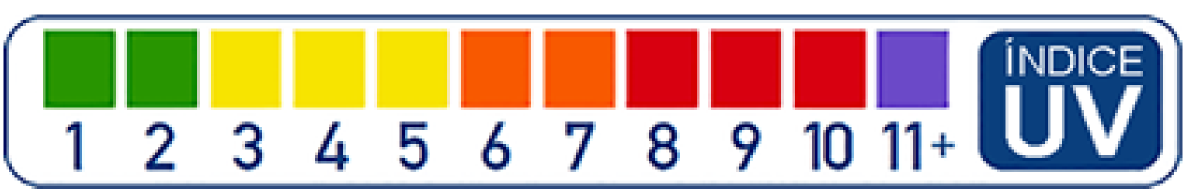
One of the objectives of this research is to quantify the intensity of UV radiation present on the Bay's coasts during the measurement period, in order to assess the potential health risk to the local population. Furthermore, radiation intensity was correlated with the altitude of the sun, which allowed us to understand diurnal and seasonal exposure patterns, which are essential for developing effective prevention strategies.

Direct measurements of the UV Index using spectroradiometers or broadband detectors can be used to support and evaluate predictive models. Worldwide, a large number of institutions measure the UV Index using a wide range of measurement systems. The sensitivity of these instruments is high in the UVB region, similar to the action spectrum of erythema, so their measurements are convertible to erythemal irradiance units. The instruments available for measuring the UV Index vary in reliability, accuracy, and cost-effectiveness, and calibration and quality control are required.

The UV Index scale used in the United States conforms to the international guidelines for reporting ultraviolet (UVI) measurements established by the World Health Organization (WHO). (EPA, 2024).

Figure 1 presents the UV index scale proposed by the EPA.

Figura 1
Escala de índice UV



Note: UV Index reading. Source: (EPA, 2024).

0 to 2: Low: A UV Index reading of 0 to 2 means low risk of UV damage from the sun's rays for the average person.

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3 to 5: Moderate: A UV Index reading of 3 to 5 means a moderate risk of damage from unprotected sun exposure.
6 to 7: High: A UV Index reading of 6 to 7 means a high risk of damage from unprotected sun exposure. Skin and eye protection are essential to prevent damage.
8 to 10: Very High: A UV Index reading of 8 to 10 means a very high risk of damage from unprotected sun exposure.
11 or higher: Extreme. A UV index reading of 11 or higher means an extreme risk of damage from unprotected sun exposure.

Because the UV Index is based on the reference action spectrum for UV-induced erythema on human skin, its primary function is to predict skin damage and is less direct in predicting the effects of UV rays on the eyes or the immune system. The individual health risk from UVR at any given value on the UVI scale depends on personal factors including duration of exposure, skin type, age, genetics, and the use of protective measures.

Exposure to ultraviolet (UV) radiation is a growing environmental concern, especially in coastal regions such as San Juan del Sur Bay. To understand and assess the associated risks, a comprehensive study was conducted from 2023. This analysis focused on determining UV radiation intensity in the aforementioned bay and correlating it with solar position, thus providing a deeper understanding of seasonal and diurnal patterns.

In addition, the relationship between cumulative UV radiation exposure and potential dermatological implications, such as sunburn and skin cancer risks, was explored. The research was not limited to quantifying radiation but also considered the recommendations of recognized health organizations, such as the World Health Organization (WHO) (2022).

Another key aspect of the study was establishing the relationship between the intensity of UV radiation obtained and the safe exposure thresholds according to WHO recommendations (EPA, 2024). This comparison provides crucial information on compliance with recommended safety guidelines and the potential health risk to the local population.

Based on the results obtained, protective and awareness-raising measures were proposed to mitigate potential health risks resulting from UV radiation exposure. These recommendations focused on promoting proper sun protection practices and raising awareness of the importance of prevention among the local population.

The study addressed the pressing need to demonstrate safe exposure thresholds, thus contributing to the development of guidelines and directives that minimize the risk of skin damage in the local population. In this context, the presented research highlights the situation in San Juan del Sur Bay and provides valuable data for addressing UV radiation exposure in similar coastal environments and promoting skin health in communities vulnerable to these environmental factors.

MATERIALS AND METHODS

Study type

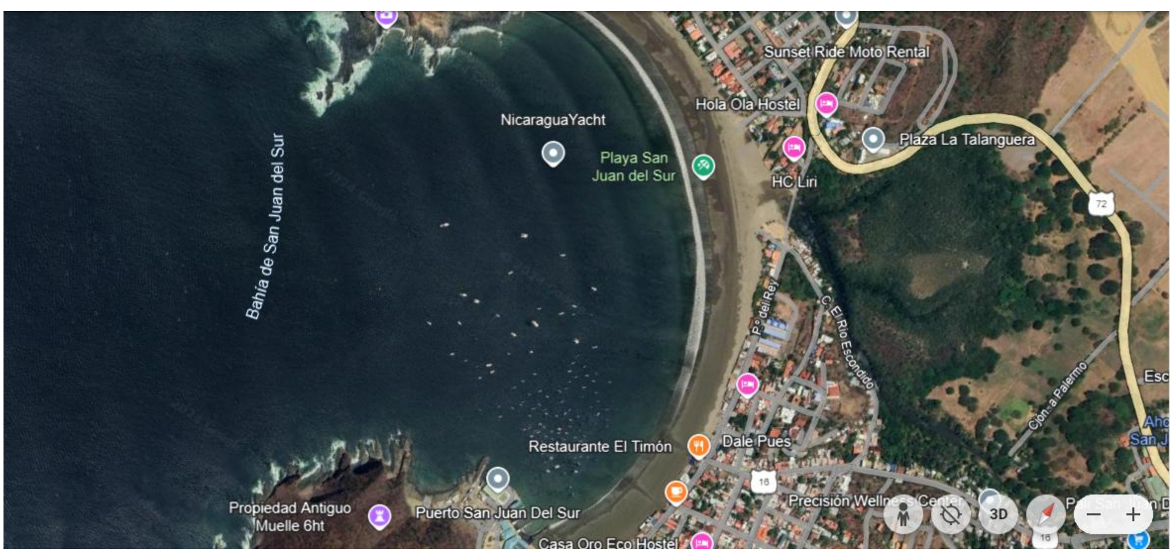
During the period from 2023, a quantitative observational study was conducted to examine exposure to ultraviolet B (UVB) radiation in the Bay of San Juan del Sur, Rivas, Nicaragua. Data collection involved portable GPS devices that allowed for precise georeferencing of the sampling points, along with a digital photometer specialized in the detection of UVB radiation. The methodology included measurements at different times of the day, mainly between 10:00 a.m. and 2:00 p.m., when the highest solar incidence is expected during representative days of each climatic season. The data were subsequently processed and analyzed using statistical tools to determine exposure levels in different areas of the bay and evaluate their correspondence with environmental variables such as cloud cover, altitude, and surface cover. This methodology allowed for the identification of areas of greatest risk due to UVB overexposure, generating useful information for future public health and sustainable tourism strategies in the region.

Data was collected using a Sunknown digital UV photometer (0-20 UVI, 0.5 step), a digital GPS, and a pocket compass. The researcher located the most common spots or locations where visitors pass through the bay of San Juan del Sur, Rivas.

Participants and contextualization

The study was conducted in San Juan del Sur Bay, located at latitude 11.25292 and longitude -85.87049, part of the American continent and located in the northern hemisphere. The universe and sample consisted of an area of 1.08 km^2. Measurements were taken once a month to observe behavior throughout the months of the year and its relationship to the seasons, within the time available to the researchers.

Figure 2
Location of the study area



Fuente: (Google Earth)

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Instruments Used
The following instruments were used to collect data in San Juan del Sur Bay:
• **Digital UV Photometer:** A high-resolution Sunknown photometer was used to measure the intensity of ultraviolet radiation in the range of 190 nm to 1100 nm.

• ***Personal protective equipment:*** Safety glasses with UV protection and broad-spectrum sunscreen were used to avoid direct exposure to UV radiation during outdoor measurements.

Methods
• **UV Measurements:** Samples were placed in the spectrophotometer's sample tray, and UV intensity measurements were taken at different wavelengths. Absorbance values were recorded for each sample.
• **Background Corrections:** Background measurements were performed using a blank (no sample) for each wavelength to correct the sample absorbance measurements and eliminate potential interferences.
• **Data Analysis:** Corrected absorbance values were calculated for each sample and analyzed to determine the sample response to UV radiation. Statistical methods were used to assess the significance of differences between samples.
• **Validation of Results:** Repeat measurements were performed, and the standard deviation was calculated to assess the reproducibility of the results. Furthermore, the results obtained were compared with independent measurements performed using alternative methods to validate the accuracy of the UV radiation measurements.

RESULTS AND DISCUSSION

For this research, data were collected at two different times: first, in situ data were collected in San Juan del Sur Bay using portable detectors, and second, NASA's Geovanni platform was used to measure UV radiation levels. Furthermore, dates close to the change of astronomical seasons were chosen due to the relationship between UV intensity and the height of the Sun, and measurements were taken once a month.
The methodology included measurements at different times of the day, primarily between 10:00 a.m. and 2:00 p.m., when the highest solar incidence is expected, during representative days of each season. The data were subsequently processed and analyzed using statistical tools. Pearson's correlation coefficient was applied to evaluate the linear relationship between recorded UVB radiation levels and environmental variables such as cloud cover, altitude, and surface coverage. This analysis determined the extent to which these variables influence sun exposure, identifying areas at greater risk of UVB overexposure.

Table 1
Statistical data of UVB measurements

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Environmental Variable	Correlation coefficient (r)	Significance (p)
Cloud cover (%)	-0.65	0.01
Altitude (msnm)	0.48	0.03
Vegetation cover (%)	-0.70	0.005

The results reflected in Table 1 provide useful information for the design of public health and sustainable tourism strategies in the department of Rivas, Nicaragua.

Table 2
UV index intensity vs. time in San Juan del Sur, Rivas

San Juan Sur, Rivas	Intensity UV	Intensity UV	Intensity UV	Intensity UV	Intensity UV	Intensity UV
Time	22-jul	20-ago	24-sep	20-oct	19-nov	16-dic
09:00:00	5.4	4.2	10.1	10.4	5.4	3.4
10:00:00	5.1	6.2	10.5	10.0	7.8	3.8
11:00:00	4.4	8.0	10.3	9.5	6.0	5.5
12:00:00	3.3	8.6	11.0	12.0	7.1	5.8
13:00:00	8.9	7.7	10.8	12.9	8.6	9.0
14:00:00	7.3	4.0	9.8	10.5	7.3	7.5
15:00:00	6.9	2.1	5.5	6.8	1.8	2.3
16:00:00	4.3	1.3	3.5	4.0	0.8	0.7
17:00:00	1.0	0.3	1.0	2.0	0.5	0.1

Table 2 presents the measurements taken. Hourly measurements were taken at 15-minute intervals and then averaged to obtain better value. Column 1 corresponds to the starting hours from 9:00 a.m. to 5:00 p.m., and columns 2 through 7 correspond to the measured UV intensity and the dates on which it was taken. UV radiation intensity vs. hours indicates the in-situ measurement period from 9:00 a.m. to 5:00 p.m., where a significant increase in radiation intensity recorded at the point is evident, with minimum values of 0.1 to a maximum value of 12.9.

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Figure 3.

UV index according to WHO with the respective colors with the intensity

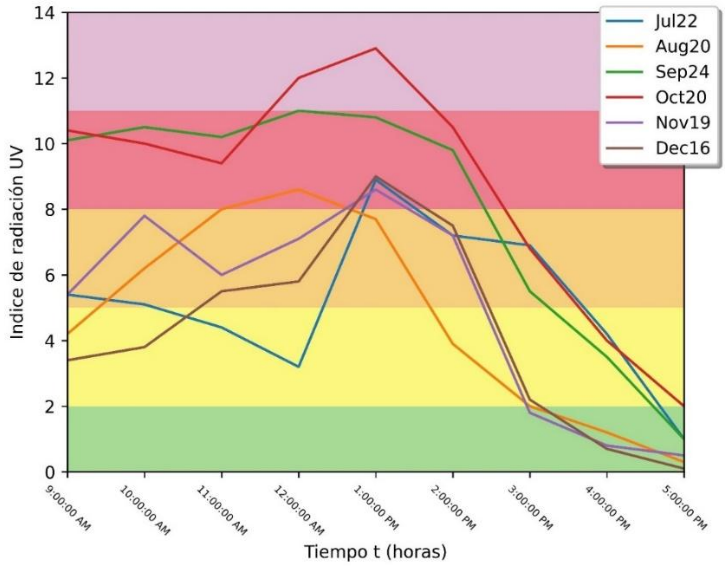

Figure 3 shows the UV index scale and its relationship to the colors according to the EPA and WHO. Green is the lowest on the scale and corresponds to values between 1 and 2. Yellow is the moderate, with values between 3 and 5. Orange is high, with values between 6 and 7. Red is very high, with values between 8 and 10. Extreme violet is associated with very high values of 11 and above (EPA, 2024).

Table 3

Comparison of measured data for Sun height, measurement times and UV intensity

Time	Altitude of the Sun (º)	Intensity UV	Altitude of the Sun (º)	Intensity UV	Altitude of the Sun (º)	Intensity UV	Altitude of the Sun (º)	Intensity UV	Altitude of the Sun (º)	Intensity UV	Altitude of the Sun (º)	Intensity UV
	Rivas / Date											
	22-Jul		20-Ago		24-Sept		20-Oct		19-Nov		16-Dic	
09:00	48.3	5.4	49.2	4.2	50.6	10.1	65.2	10.4	42.4	5.4	38.0	3.4
10:00	62.2	5.1	63.9	6.2	64.1	10.5	56.2	10.0	52.6	7.8	49.8	3.8.
11:00	75.6	4.4	78.5	8.0	75.7	10.3	58.4	9.5	58.5	6.0	54.1	5.5
12:00	81.8	3.3	86.6	8.6	76.5	11.0	76.1	12.0	58.3	7.1	55.1	5.8
13:00	71.5	8.9	72.1	7.7	65.6	10.8	77.1	12.9	51.6	8.6	50.2	9.0
14:00	56.1	7.3	57.4	4.0	51.7	9.8	64.1	10.5	38.6	7.3	41.2	7.5
15:00	43.3	6.6	42.8	2.1	37.6	5.5	60.1	6.8	29.5	1.8	29.5	2.3
16:00	30.2	3.5	28.2	1.3	23.2	3.5	19.1	4.0	19.9	0.8	20.8	0.7
17:00	22.5	0.6	14.1	0.3	8.5	1.0	5.2	2.0	10.2	0.5	9.7	0.1

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Table 3 presents the time, solar altitude, and UV radiation intensity data measured in situ at San Juan del Sur. Column 1 represents the time; columns 2, 4, 6, 8, 10, and 12 correspond to the altitude and date of measurement; columns 3, 5, 7, 9, 11, and 13 represent the UV radiation intensities obtained.

Figure 4

Relationship between UV index, sun height and time

For the analysis of Figure 4, we separated them into two groups. The first group corresponds to the months of July 22 (blue), August 20 (orange), November 19 (purple), and December 16 (brown). July, November, and December present maximum UV radiation peaks of 9 around 1 p.m., while August peaks at noon. It is also important to mention that these months correspond to the period of greatest cloudiness in the country.

Regarding the months of September 25 and October 20, we obtained the highest UV intensity values between 10 and 13. Although, according to the Nicaraguan Institute of Territorial Studies (INETER), the historical regimes reported by the meteorology area are September is a rainy and mostly cloudy month, and October is the month of greatest precipitation and maximum cloudiness. In these months, very little rain and cloudiness predominated due to the influence of the La Niña climate phenomenon, which proved in the country the months did not correspond to its historical data. INETER (2025).

In Figure 5, UV radiation data obtained with NASA's Giovanni platform which uses the Ozone Measuring Instrument (OMI).

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Figure 5

Daily average UV radiation indices obtained with NASA's Giovanni platform

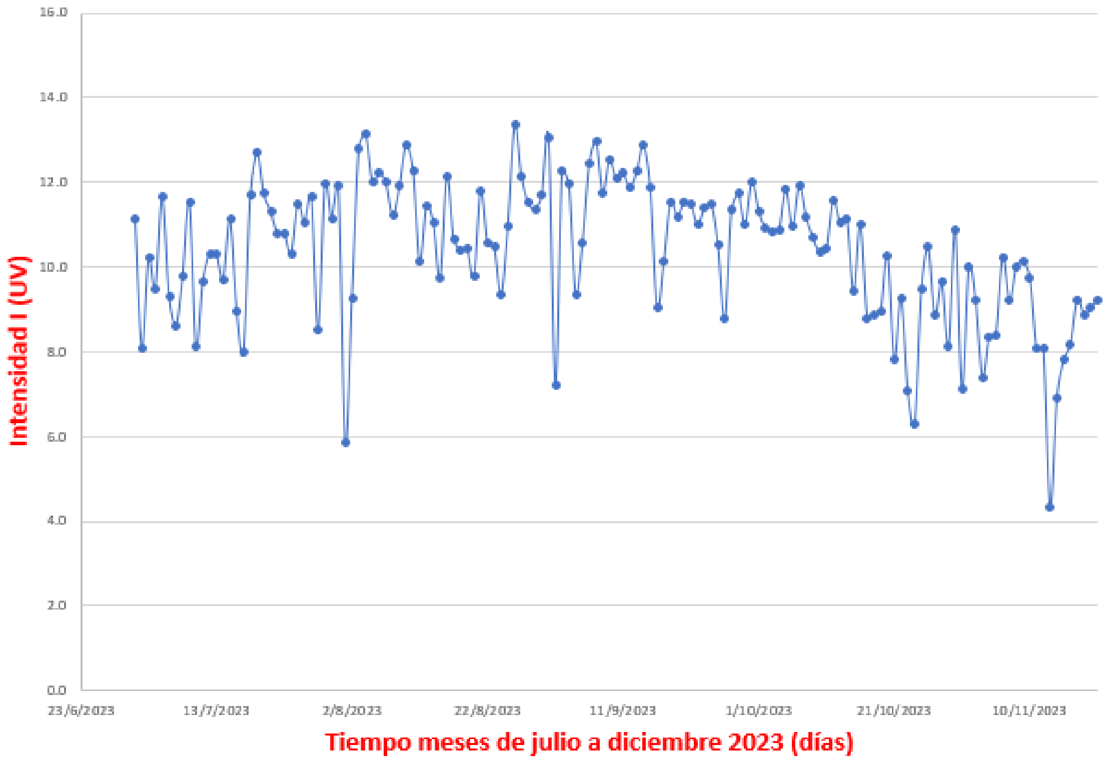

Figure 5 presents the average daily UV intensity maximum data for the months of July through December. These data from the Giovanni platform largely serve as a reference for our in-situ measurements. It is important to mention that this satellite platform conducts observations from space above the clouds and integrates them across an area of approximately 200 km^2.

This graph shows the upward trend in data from July to September, with an average UV index of 10, consistent with the summer season. UV indices then drop in December to an average of 8 as the highest intensity.

The results show a seasonal trend in UV intensity, with higher values in summer, specifically September and October, and lower values in winter, July and August. This seasonal variation is attributed to the tilt of the Earth's axis, which affects the amount of sunlight reaching different latitudes at different times of the year.

These months are summer months, with part of September occurring; in the case of October, November, and part of December, it is autumn. UV intensity also varies throughout the day, reaching its highest values around midday and lowest values at dawn and dusk. This daily variation is due to the sun's position in the sky, which determines the amount of atmosphere UV radiation must pass through to reach the Earth's surface.

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The maximum UV intensity values in Figure 1, which range around 12 (UV), are within the range considered "extremely high" by the WHO (WHO, 2002), the World Meteorological Organization (WMO, 2025), the United Nations Environment Programme (UNEP) (UNEP, 2025), and the International Commission on Non-Ionizing Radiation Protection (ICNIRP, 2025). These values represent a high risk of sunburn, skin damage, and cataracts, so additional protective measures are advisable on days with a high UV index. On the other hand, the average values, around 8 UV, fall within the range classified as "high," implying a risk of sunburn, especially for individuals with sensitive skin. Sun protection measures are recommended on days with high UV indices.

Likewise, the UV data obtained with the Giovanni platform corresponds specifically to our data with the maximum recorded indices. The central section of Figure 5, corresponding to September and October, also shows these maximum peaks. The advantage of this satellite platform is that it collects data above the clouds and is daily. This means that it is not subject to cloud interference, as in our data. The measurements show a UV index between 8 and 13 at most, depending on the date of our measurements (central section of the graph).

A proportional relationship was found between UV radiation with intensity values higher than 10 and 12 and the height of the sun at the zenith corresponding to 11 a.m. and 2:00 p.m. Furthermore, the seasonal patterns of summer coincide with the peak radiation periods of July through September, and decrease significantly in December with winter.

The results obtained revealed intensity values that exceed safe exposure levels for direct solar radiation. The radiation physics approach complements the relationship between UV radiation and human health, providing practical recommendations and awareness campaigns to protect the population of San Juan del Sur Bay.

Among the recommendations of this study are awareness campaigns for visitors to spas or tourist destinations to protect and promote skin health and reduce exposure to very high intensities of solar radiation, which can cause dermatological problems such as sunburn and, in turn, lead to skin cancer and/or cataracts. Train tourism service providers on sun overexposure and its consequences.

CONCLUSIONES

The results show the highest UV radiation intensity at 1:00 p.m., with a maximum index of 12.9. Some values drop at this time due to cloudiness during Nicaragua's rainy season. Furthermore, the months with the highest UV index were September and October. This is unusual because this year we were under the constant influence of the La Niña climate phenomenon, causing October, historically the rainiest and cloudiest month, to have clear days. Meanwhile, September had the highest average UV index on mornings, with a value of 10.3 compared to the other months measured.

It was verified that the intensity of UV radiation occurred at noon and in the early afternoon, which is when the Sun is at its highest point in the sky. The dates when the Sun passes through our zenith correspond to the month of August. No values were recorded because this month presented the greatest cloudiness of the year. It is true that UV radiation values fall in the last months of November and December, this is because the Sun is at its southernmost point in the sky with a height that does not reach 60 °, this is due to the winter solstice, which this point marks the winter season. September presented the mornings with the highest UV index due to the autumn equinox, which marks the change of seasons from summer to autumn for the northern hemisphere.

The study identified areas with high UVB radiation exposure in different parts of San Juan del Sur Bay, with peak UVB values of up to 12.9 between 11:30 a.m. and 1:30 p.m. However, a direct relationship with the local incidence of dermatological diseases such as sunburn, cataracts, or skin cancer was not established. This limitation is due to the lack of recent epidemiological records in the area that would allow for correlation of exposure levels with clinical diagnoses. Furthermore, it is important to consider that the onset of these conditions depends on external factors such as the use of sunscreen, education about sun exposure, and genetic predisposition.

Therefore, although the results warn of a potential risk of overexposure, especially in areas with little vegetation cover and high surface reflectance (such as light-colored sand or concrete), a high incidence of associated diseases cannot be automatically inferred without an epidemiological basis. It is recommended that these findings be complemented with clinical studies that allow for a more comprehensive view of the risk in the region.

CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

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