

Solar Ultraviolet Radiation and Geographical Parameters in Some Selected States in Nigeria

^{*1}Iledare Taiwo Abigail, ²Baba Alfa and ³George Danlami Wey

¹Department of Physics, Federal University of Technology, Minna, Niger State, Nigeria.

²Department of Physics, Ibrahim Badamasi University, Lapai, Niger State, Nigeria.

³Dermatology Department, General Hospital, Minna, Niger State, Nigeria.

*Corresponding author's email: kingsolx@futminna.edu.ng Phone: +2348058227785

ABSTRACT

Solar ultraviolet (UV) radiation is an important environmental factor with significant implications for human health and ecosystems; however, its spatial variability across Nigeria remains insufficiently characterised. This study investigated the spatial distribution of solar ultraviolet radiation and its relationship with selected geographic parameters across Nigeria. Twenty years (2002–2022) of satellite-derived hourly ultraviolet index (UVI) data obtained from the National Aeronautics and Space Administration (NASA), 8765 data points were collected for each year for the selected 12 states, which are Kebbi, Niger, Kaduna, Kogi, Edo, Oyo, Osun, Anambra, Abia, Bayelsa, Gombe, and Adamawa. UVI data were fitted to the hour 10 AM to 4 PM, which represents peak solar exposure. Descriptive statistics, spatial analysis, scatter-plot analysis, and linear regression were employed to assess variations in mean UVI and its relationships with latitude, longitude, and elevation. The results demonstrated substantial spatial variation in mean UVI across the selected states, with generally higher values in northern locations than in southern locations. In general, UVI is usually strongest at the equator and decreases towards the pole. Therefore, the increase in UVI in the northern locations reported in this study is a local phenomenon. Regression analysis revealed strong positive relationships between mean UVI and latitude ($R^2 = 0.7574$, $B = 0.2728$, $p < 0.001$) and elevation ($R^2 = 0.7420$, $B = 0.00320$, $p < 0.001$). Longitude exhibit a weaker positive relationship with mean UVI ($R^2 = 0.3153$), which was not statistically significant at the 5% level ($p = 0.0575$). These findings indicate that geographic factors, particularly latitude and elevation, are strongly associated with the spatial variability of solar UV radiation across the selected Nigerian states. The results provide valuable baseline information for identifying areas of elevated UV exposure, and support public health planning, environmental monitoring, and future assessments of UV-related health risks in Nigeria.

Keywords:

Ultraviolet radiation,
UV index,
Latitude,
Spatial Variation,
Nigeria.

INTRODUCTION

Solar radiation is radiant energy emitted by the Sun from nuclear fusion reactions and is a form of electromagnetic energy (Usikalu et al., 2018). UV radiation is classified between 100 nm and 400 nm into three spectral bands: UV-A, 320-400 nm; UV-B, 280-320 nm; and UV-C, 200-280 nm (Codrean et al., 2025). UV-A radiation accounts for 95% of the solar UV radiation reaching the Earth's surface. UV-C and UV-B radiation are primarily absorbed by the ozone layer in the stratosphere due to Earth's atmospheric filtering (Derebe et al., 2019). However, the

spectral levels of both UV-A and UV-B increase on the Earth's surface due to human activities such as environmental pollution (Blunden & Arndt, 2012). Solar UV radiation has both beneficial and harmful effects. While it is responsible for vitamin D synthesis, excessive exposure causes eye problems like cataracts, pterygium, skin ageing, skin cancer, sunburn (erythema) and immune suppression (Akande et al., 2017; Badosa, 2005). The deleterious effects on humans are of public health concern and demand constant global monitoring (Akande et al., 2017). Health effects such as skin cancer, cataracts, and

pterygium are predominant in North Central Nigeria, especially among people above 50 years of age (Badosa, 2005). The spatial variation of solar ultraviolet radiation is largely controlled by geographic and atmospheric factors, including latitude, longitude, altitude, cloud cover, and ozone concentration, which determine the amount of UV radiation reaching the Earth's surface (WHO, 2024; Bernhard et al., 2023). These parameters affect the angle of solar incidence, atmospheric path length, and the extent of absorption and scattering of solar radiation within the atmosphere (Egbuim et al., 2022). Longitude also contributes to spatial variability in the distribution of solar ultraviolet radiation, although it does not directly control solar intensity. Latitude affects UV radiation, which is strongest at the equator and declines toward the poles (Park et al., 2015). However, in Nigeria, higher latitudes (northern regions) record higher erythemal ultraviolet radiation (EUVR) values due to differences in climate zones and vegetation cover (Akande et al., 2017). Altitude is another important geographical parameter affecting solar ultraviolet radiation. At higher altitudes, the atmosphere becomes thinner and contains fewer particles capable of absorbing or scattering ultraviolet radiation. Consequently,

ultraviolet radiation intensity increases with elevation. High-altitude regions, therefore, receive greater ultraviolet radiation exposure than lowland regions. (Argungu & Dabai 2017). Ultraviolet radiation Index (UVI) measures the erythemal potential of solar UV radiation, which can cause sunburn in humans and is an adverse effect of overexposure to solar UV radiation. According to the technical standards of the Commission International de l'Éclairage (CIE S013/E), UVI is defined by the mathematical expression below (CIE 2003). The International Global UV Index, UVI, is defined by the formula:

$$IUV = K_{er} \int_{250nm}^{400nm} (E_{\lambda} \cdot (\lambda) S_{erd\lambda}) \quad (1)$$

Where

E_{λ} = is the solar spectral irradiance at wavelength λ ($W \cdot m^{-2} \cdot nm^{-1}$),

$S_{er}(\lambda)$ = is the erythema action spectrum, and

K_{er} = is a constant equal to $40 \cdot m^{-2} \cdot W^{-1}$.

The World Health Organisation (WHO, 2002) adopted a global standardised public health measure for reporting UV irradiance (see Table 1), to carefully ascertain the level of erythemal exposure.

Table 1: The UV Index Categories Colour Code and the Corresponding Erythemal Values (Downs et al., 2016; WHO, 2002)

UVI	Category	Colour code	Erythemal (mW/m^2)
0-2	Low	Green	0 to 75
3-5	Medium	Yellow	75 to 150
6-7	High	Orange	150 to 200
8-10	Very High	Red	200 to 275
11+	Extreme	Purple	275+

MATERIALS AND METHODS

Study Area

The study is carried out in some selected states in Nigeria (Abia, Anambra, Adamawa, Gombe, Niger, Kogi, Kebbi, Kaduna, Osun, Oyo, Edo and Bayelsa) that represent various climatic zones. Nigeria is a West African country with a land area of 923,768 km^2 and a total coastline length of 850 km. It lies between latitudes 4° N and 14° N and longitudes 3° E and 15° E, with 4 major climate zones. Nigeria is bordered to the north by Niger, to the east by Chad and Cameroon, to the south by the Gulf of Guinea of the Atlantic Ocean, and to the west by Republic of Benin. Respectively. Nigeria's climate is generally hot throughout the year, with little variation between the wet and dry seasons. Nigeria's climate is divided into two major seasons: the dry and wet seasons. The wet season spans from April to November, while the dry season spans

from November to March. Between June and September, the weather is rainy, humid, and hot (Olla et al., 2019). Three vital atmospheric phenomena dominate the climate of Nigeria, namely the continental tropical (cT) air mass, the maritime tropical (mT) air mass, and the equatorial easterlies (Olla et al., 2019). Air temperatures across the country vary from one region to another. There are marked differences between the lowlands and the high plateau, and between the interior and the coastal areas. The annual average temperature on the Plateau ranges from $21^{\circ}C$ to $27^{\circ}C$. The yearly average temperatures in the interior lowlands are more than $27^{\circ}C$, while those of the coastal fringes are lower than those of the interior lowlands. The seasonal temperature range is lower than that of other tropical countries, with a mean of $6^{\circ}C$ (Olla et al., 2019).

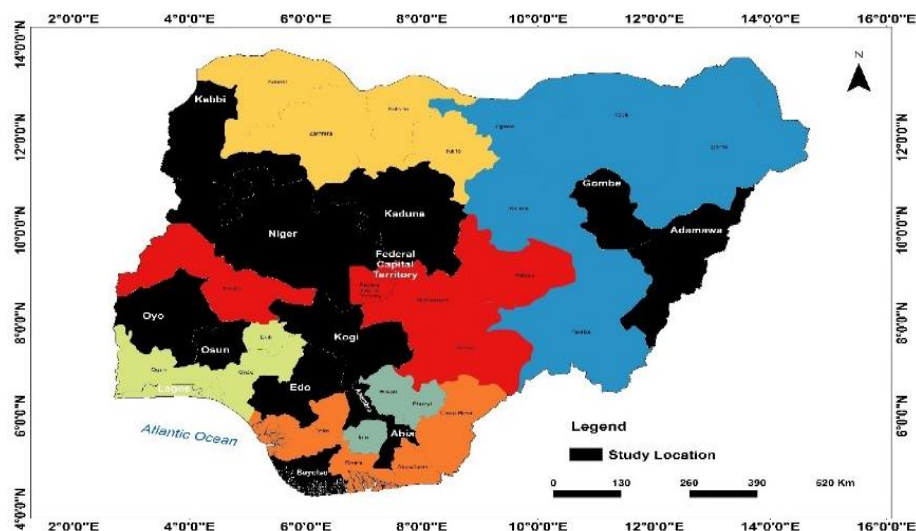


Figure 1: Map of Nigeria showing the study area (Iledare, T.A., 2025)

Data Collection and Analysis.

Meteorological data for twenty years (2002-2022) were obtained from the National Aeronautics and Space Administration (NASA). A total of 8,765 data points was collected for each year across the selected 12 states for twenty years and analysed; the selected states are Kebbi, Niger, Kaduna, Kogi, Edo, Oyo, Osun, Anambra, Abia, Bayelsa, Gombe, and Adamawa. Hourly solar ultraviolet index (UVI) data were collected for each location in the study area. The data were organised into American Standard Code for Information Interchange (ASCII) format and then transformed into an Excel spreadsheet. The data were cleaned and pre-processed to remove errors, inconsistencies, or missing values. Python libraries and Microsoft Excel were used for the analysis. The dataset was filtered to include only records for the hours between 10 AM and 4 PM, ensuring that only peak solar exposure is analysed. The dataset contains UV index measurements for 12 states. Data cleaning involved converting all column headers to uppercase to standardise

naming conventions. Any negative or unrealistic UV index values were removed.

RESULTS AND DISCUSSION

The regression analysis examined the relationship between average UV index values and spatial variables (latitude, longitude, and elevation) across the 12 selected states in Nigeria. Using ordinary least squares (OLS) regression, the study examines how geographical location influences UV exposure. The spatial variables were obtained from Modern-Era Retrospective Analysis for Research and Applications, Version 2 (MERRA-2) data, and the average UV index per state, derived from time-series analyses, served as the dependent variable. The spatial variables are

- i. Latitude: Varies from approximately 4.92° (Bayelsa) to 11.42° (Kebbi).
- ii. Longitude: Ranges from 3.90° (Oyo) to 11.93° (Adamawa).
- iii. Elevation: Ranges from 17.26 m (Bayelsa) to 703.67 m (Kaduna).

Table 2: Geographic Coordinates and Elevation for the 12 States

STATE	Latitude (degree)	Longitude (degree)	Elevation (meters)
ABIA	5.53	7.49	92.75
ADAMAWA	9.91	11.98	316.44
ANAMBARA	6.21	7.07	103.94
BAYELSA	4.92	6.26	17.26
EDO	6.32	5.6	93.92
GOMBE	10.28	11.11	381.62
KADUNA	10.38	7.85	703.67
KEBBI	11.42	4.11	206.69
KOGI	7.8	6.74	167.21
NIGER	9.62	6.55	179.19
OSUN	7.63	4.18	256.41
OYO	7.38	3.9	188.89

Figure 2 shows the relationship between average UVI and latitude for the years under review, using a scatter plot. The plot reveals a positive trend, indicating that latitude is a significant predictor of the UV index across the selected locations. The coefficient of determination ($R^2 = 0.7574$) indicates approximately 75.7% strong correlation between UVI and latitude. In other words, latitude is an important geographic factor that influences the solar zenith angle and, in turn, the spatial variation of UVI in the study area. Higher latitudes (in this dataset) correlate with higher UV values. This is consistent with expected solar radiation patterns and atmospheric conditions. States such as Niger (9.610N), Kebbi (12.450N), Adamawa (9.330N), Gombe (10.290N), and Kaduna (10.520N) are at high latitudes. UVI is very high in those areas; this is expected to affect human health (Akande et al., 2017). In Nigeria, higher latitudes (northern regions) record higher EUVR values; this may be due to differences in climate zones and vegetation cover. The positive relationship between latitude and UVI differs from the general global pattern, in which UV radiation tends to decrease with increasing latitude away from the equator. However, this does not necessarily contradict global theory. The

observed relationship may reflect the specific geographical and climatic characteristics of the selected Nigerian states, including differences in atmospheric conditions, cloud cover, aerosols, moisture, seasonality, and other environmental factors. Figure 3 shows a scatter plot that indicates a weak-to-moderate positive relationship between longitude and average UVI. The relatively low coefficient of determination ($R^2 = 0.3153$) indicates that longitude explains only 31.53% of the variation in average UVI. This suggests that longitude is not a strong predictor of UVI variation across the selected locations. Figure 4 shows a scatter plot that demonstrates a relatively strong positive relationship between elevation and average UVI. The upward-sloping trendline indicates that average UVI generally increases with elevation. The coefficient of determination ($R^2 = 0.7420$) indicates that approximately 74.2% of the variation in average UVI is explained by elevation, suggesting that elevation is an important geographic factor associated with the spatial variability of UVI. The combination of geographical and atmospheric factors influences the spatial variation of UVI across Nigeria.

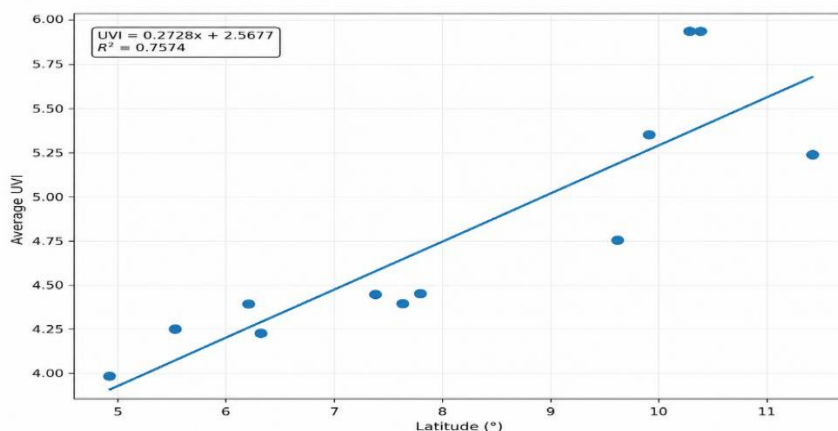


Figure 2: The scatter plot between latitude and average ultraviolet index (UVI)

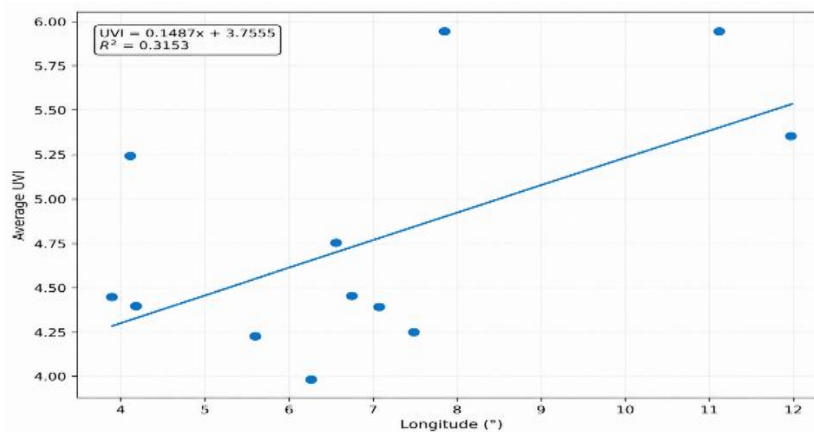


Figure 3: The scatter plot between longitude and average ultraviolet index (UVI)

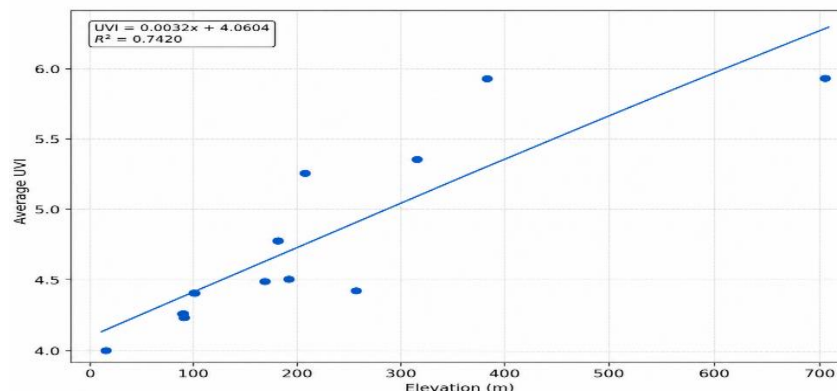


Figure 4: The scatter plot between Elevation and average ultraviolet index (UVI)

Table 3: The Regression Results

Predictor	Coefficient (B)	Standard Error	t-value	p-value	R ²	AdjustedR ²
Latitude	0.2728	0.0488	5.588	0.00023	0.7574	0.7331
Longitude	0.1487	0.0693	2.146	0.05747	0.3153	0.2468
Elevation	0.0032	0.0006	5.363	0.00032	0.7420	0.7138

Latitude: $p = 0.00023 < 0.05 \rightarrow$ statistically significant.

Longitude: $p = 0.05747 > 0.05 \rightarrow$ not statistically significant at the 5% level.

Elevation: $p = 0.00032 < 0.05 \rightarrow$ statistically significant.

Latitude and elevation are significant predictors of average UVI, whereas longitude is not statistically significant at the 5% level.

The UVI Regression Model

The general regression structure is

$$Y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \epsilon \quad (2)$$

Where

Y = dependent variable

β_0 = intercept

x_1, x_2, x_3 = dependent variable

$\beta_1, \beta_2, \beta_3$ = coefficients

ϵ = error terms

$$UVI = \beta_0 + \beta_1(\text{latitude}) + \beta_2(\text{longitude}) + \beta_3(\text{elevation}) + \epsilon \quad (3)$$

$$UVI = 2.6412 + 0.2728(\text{lat}) + 0.1487(\text{long}) + 0.0032(\text{elev}) + \epsilon \quad (4)$$

The simple regression models for each parameter

Latitude:

$$UVI = 2.5677 + 0.2728(\text{lat}) \quad (5)$$

Longitude:

$$UVI = 3.755 + 0.1487(\text{long}) \quad (6)$$

Elevation:

$$UVI = 4.0604 + 0.0032(\text{elev}) \quad (7)$$

The B_0 , which is the intercept in the multiple regression, is different from the one in the individual model because the multiple regression estimates all three predictors. This model can be used to predict the average solar UVI in the study area.

CONCLUSION

This study concludes that the regression model provides a robust framework for understanding the spatial variability of solar ultraviolet radiation and its associated public health implications across the regions characterised by high solar UV exposure. Latitude and elevation emerged as statistically significant predictors of the Ultraviolet Index (UVI) across the study area, with mean UVI increasing at higher latitudes and elevations. In contrast, longitude does not contribute significantly to explaining the spatial variability of UVI within this dataset. These findings highlight the value of integrating geospatial analysis into public health planning and climate-related risk assessment. While the regression results reveal meaningful associations between average UVI and both latitude and elevation, the present findings must be interpreted with due consideration of the relatively limited sample of 12 selected states. Future research covering a larger number of locations is recommended to validate and generalise the relationships between geographic parameters and average solar UVI.

REFERENCES

- Argungu, G. M., & Dabai, K. A. (2017). The application of linear models for estimation of global solar radiation using available meteorological parameters for Sokoto, Nigeria. *International Journal of Advances in Scientific Research and Engineering*. <https://doi.org/10.7324/ijasre.2017.32556>
- Akande, A., Costa, A. C., Mateu, J., & Henriques, R. (2017). Geospatial analysis of extreme weather events in Nigeria (1985–2015) using self-organizing maps. *Advances in Meteorology*, 2017, 8576150. <https://doi.org/10.1155/2017/8576150>

- Bernhard, G. H., Bais, A. F., Aucamp, P. J., & Klekociuk, A. R. (2023). Stratospheric ozone, UV radiation, and climate interactions. *Photochemical & Photobiological Sciences*, 22(4), 937–989. <https://doi.org/10.1007/s43630-023-00371-y>
- Blunden, J., & Arndt, D. S. (Eds.). (2012). State of the Climate in 2011. *Bulletin of the American Meteorological Society*, 93(7), S1–S282. <https://doi.org/10.1175/2012BAMSStateoftheClimate>.
- Badosa, J. (2005). UV Index: Measurement and model agreement uncertainties and limitations [Doctoral dissertation, Universitat de Girona]. Universitat de Girona Repository.
- Blunden, J., & Arndt, D. S. (2012). State of the climate in 2011. *Bulletin of the American Meteorological Society*, 93(8), S1–S282. <https://doi.org/10.1175/2012BAMSStateoftheClimate.1>
- Commission Internationale de l'Éclairage. (2003). International standard global solar UV index (CIE S 013/E: 2003). CIE Central Bureau.
- Codrean, A.F., Bunoiu, O.M., and Paulesu, M (2025). Identifying the signature of the solar UV radiation spectrum. *Atmosphere*, 16(4), 427. <https://doi.org/10.3390/atmos16040427>
- Dalmau, N., Andrieu-Abadie, N., Tauler, R., & Bedia, C. (2018). Phenotypic and lipidomic characterization of primary human epidermal keratinocytes exposed to simulated solar UV radiation. *Journal of Dermatological Science*, 91(2), 97–105. <https://doi.org/10.1016/j.jdermsci.2018.04.008>
- Derebe, A. D., Roro, A. G., Asfaw, B. T., Ayele, W. W., & Hvoslef-Eide, A. K. (2019). Effects of solar UV-B radiation exclusion on physiology, growth and yields of taro (*Colocasia esculenta* (L.)) at different altitudes in tropical environments of Southern Ethiopia. *Scientia Horticulturae*, 256, Article 108563. <https://doi.org/10.1016/j.scienta.2019.108563>
- Downs, N., Parisi, A. V., Galligan, L., Turner, J., Amar, A., King, R., Ultra, F., & Butler, H. (2016). Solar radiation and the UV index: An application of numerical integration, trigonometric functions, online education, and the modelling process. *International Journal of Research in Education and Science*, 2(1), 179–189. <https://eric.ed.gov/?id=EJ1105161>
- Egbum, T. C., Onyeuwaoma, N. D., Okere, B. I., & Okeke, C. E. (2022). Erythral UV radiation across Nigeria: Where do we stand? *Heliyon*, 8(8), e10158. <https://doi.org/10.1016/j.heliyon.2022.e10158>
- Olla, M. O., Oluwafemi, I. B., Akinsanmi, O., & Femijemilohun, O. J. (2019). Fade depth and outage probability due to multipath propagation in Nigeria. *Research Journal of Applied Sciences, Engineering and Technology*, 16(2), 43–55. <https://doi.org/10.19026/rjaset.16.5999>
- Park, S. S., Lee, Y. G., & Kim, J. H. (2015). Impact of UV-A radiation on erythral UV and UV-index estimation over Korea. *Advances in Atmospheric Sciences*, 32(12), 1639–1646. <https://doi.org/10.1007/s00376-015-4231-7>
- Usikalu, M. R., Omotosho, T. V., Ndubuisi, A., & Achuka, J. (2018). Ultraviolet radiation index over Ota, Nigeria. *International Journal of Engineering & Technology*, 7(4.5), 210–212. <https://doi.org/10.14419/ijet.v7i4.5.20047>
- World Health Organization. (2002). Global solar UV index: A practical guide. <https://apps.who.int/iris/handle/10665/42633>
- World Health Organization. (2021, November 22). Ultraviolet radiation and health. <https://www.who.int/news-room/fact-sheets/detail/ultraviolet-radiation>
- World Health Organization. (2024). Ultraviolet radiation. <https://www.who.int/teams/environment-climate-change-and-health/radiation-and-health/ultraviolet-radiation>