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To cite this article: T.E. Arijaje *et al* 2022 *IOP Conf. Ser.: Earth Environ. Sci.* **993** 012025

IOP Conf. Series: Earth and Environmental Science **993** (2022) 012025 doi:10.1088/1755-1315/993/1/012025

Analysis of Solar Ultraviolet radiation Index over Nigeria, West Africa

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Abstract. UV solar radiation are essential for living here on earth, however, at extreme levels, it becomes harmful to all organism with negative effects on humans due to UV-A and UV-B penetrating the earth's surface. UV radiation index was analyzed over Nigeria, using ten years daily data extracted from the archive of the Ozone Monitoring Instrument (OMI) on-board the EOS Aura spacecraft at a coordinate of $9.08^o\ N, 9.67^o\ E$. The result showed that solar UV radiation is at its peak at local noon time from January 2010 to December 2019. The peak value was observed in the month of November, December, January, February, and March. Hence, the study revealed that the ultraviolet index over Nigeria's varies from high to extreme (i.e., from the Southern to the Northern regions). In conclusion, our findings will create an awareness on those regions with extreme UV radiation and measures such as using sun glasses, umbrellas and putting on protective clothes against the harmful effect of UV radiation.

Keyword: Nigeria; ultraviolet radiation; ultraviolet Index; radiation; West Africa

1. Introduction

UV radiation is around 5% of the electromagnetic (EM) spectrum releasedby the Sun, and these emitted rays reach the surface of the Earth [1-2]. Light energy from the Sun is composed of continuous electromagnetic (EM) spectrum with three major wavelength regions, such as the infrared, visible, and ultraviolet (UV) radiation. The visible radiation is seen as light; the infrared is felt as heat, while the UV radiation is can neither seen as light or felt as heat [3]. According to [4], UV radiation is classified between 100 nm to 400 nm into three spectral bands such as UV-A with a wavelength of 320-400 nm, UV-B, 280-320 nm, and UV-C, 200-280 nm. UV-A radiation has a total of 95% of the solar UV radiation, reaching the earth's surface. UV-C and UV-B are mostly absorbed by the ozone layer in the stratosphere because of the filtering effect of the earth's atmosphere [5-9]. However, the spectrum levels of both UV-A and UV-B increases on the earth's surface due to human activities such as environmental pollution [9,10].

Several effects are cause on human body as a result of overexposure to UV radiation [9,11]. Daily exposure to UV radiation in a small amount is essential for human development due to vitamin-D production for healthy bones [9, 12-14]. Furthermore, UV radiation is used in medical sciences to treat

diseases such as lupus vulgaris, rickets, osteoporosis, psoriasis, vitiligo, etc [15-17]. On the other hand, excessive exposure to UV radiation causes chronic, acute, and prolong effects on the eye and skin. The most common effects are aging skin (wrinkles), sunburn), nevi, and photodermatoses [9, 18-19]. Other effects include cataracts and melanoma cancers, which affect the eye and skin cancer [20-24]. The ICNIRP (International Commission on Non-Ionizing Radiation Protection) identifies UV radiation as the main factor that exposes human tissues to photobiological risk. The IARC (International Agency for Research on Cancer) also recognizes UV radiation to be cancer-causing to humans but it is a non-ionizing radiation because it cannot deeply penetrate the human body although, they can have effect on the skin [25-27]. Seasonal changes also affect the intensity of UV-B [25].
The total absence of UV radiation exposure would lead to a deficiency of vitamin-D (i.e., skeletal diseases), although, it is not a solution for the complete eradication of aforementioned photobiological risks. Global estimation of illnesses resulting from environmental hazards have been investigated by the WHO[15]. Regarding the UV solar radiation, a comprehensive guide for assessing the challenge of diseases at local or country-level is given by [12]. It is important to know the levels of exposure to UV radiation by an individual because of the information on UV radiation received by the individuals over time, so as to take adequate and corrective measures [9, 28]. The optimum level of UV radiation exposure is the acceptable level for vitamin-D production, which is achieved by minimal exposure to the Sun in most countries during the summer. At the same time, the risks to overexposure are minimized. UV radiation's strength tends to be maximum during the summer months when the clouds cover is minimum. Cloud cover reduces the UV radiation level, although it depends on the cloud cover thickness; even though the energy from the Sun is intense on a cloudy day, the lesser the heat felt by one. The rays of the Sun are intensified at the earth's center, and the UV radiation travels through the atmosphere to the earth's surface [9, 28].
Ultraviolet radiation Index (UVI) measures the erythemal potential of solar UV energywhich causes sunburn to human is an adverse effect resulting from overexposure to UV radiation. At sea level, UVI estimates the UV radiation and, at the same time, serves as an indicator of the potential damage to the skin. According to the technical standards of CIE S007/E, UVI is defined by the mathematical expression given by Equation 1 [29]:

$$UVI = k_{er}.I_{er} = k_{er}.\int_{250\ \mathrm{nm}}^{400\ nm} I(\lambda).S_{er}(\lambda)d\lambda \qquad 1$$

Where k_{er} is known as a constant given as 40m^2/W, I_{er} is irradiance of the erythemal UV expressed in W/m^2, $I(\lambda)$is the irradiance of the UV spectral at a given wavelength λ, $S_{er}(\lambda)$ is the erythemal spectrum action, and $d\lambda$ is the wavelength interval used for the integration. 400 nm and 250 nm are the upper and lower limit of the integration, respectively. The UV radiation effects on the body of humans are functions of a specific wavelength. Several action spectra have been established in the past years with different weighting functions to account for the UV radiation effects at distinct wavelengths. The erythema action spectrum $S_{er}(\lambda)$provides a representation that is internationally accepted for the erythema-induced impact on the skin of humans because it has been chosen by WHO as the basis of UVI used for the awareness of public health [9, 30-31]. Hence, the UVI can use tool to create public awareness of the adverse effects of overexposure to UV radiation and the importance of taking into account protective measures. Figure 1 shows the hours of the day when the ultraviolet radiation index is above a given threshold value. This is because the value may reach 'MODERATE' in some days for 30 minutes and above, while for some other day, the value may rise above 'MODERATE' for more than a few hours. The greater the values of the UVI, the higher the risk and damage to the eye and skin, as shown in Table 1 [9]. Nigeria is one of the West African countries that lies within equator, which makes her a good location for observing the UV radiation index. Hence, this work aimed to analyze the UV radiation index over Nigeria, West Africa.

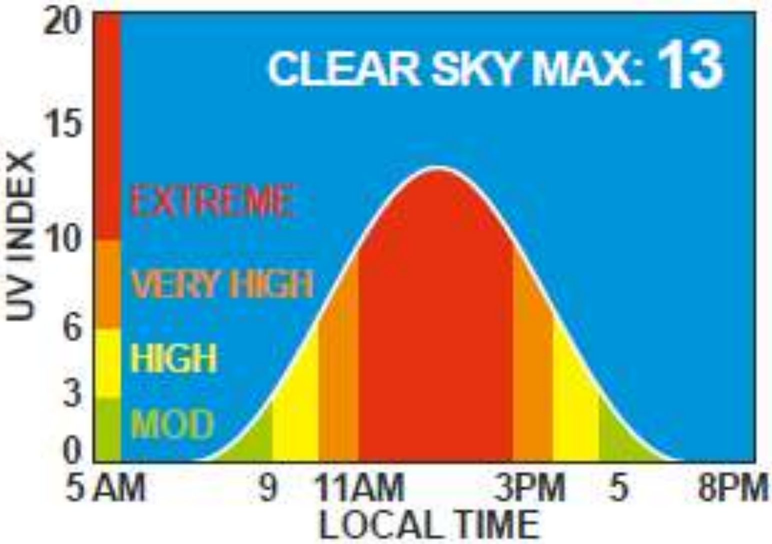


Figure 1: Graphic representation of dangerous hours [15].

Table 1: Levels of exposure and their corresponding UV index numbers [3, 9].

Index number (UV)	Exposure
< 3	LOW
3-5	MODERATE
5-6	HIGH
6-8	VERY HIGH
8-10	EXTREME
≥11	EXTREMELY HIGH

2. Methodology

2.1 Study area

The area under consideration is Nigeria (Figure 2), a West Africa country on coordinate $9.08^o N, 8.67^o E$. Nigeria is bounded in the southern, western, eastern, and northern parts by the Gulf of Guinea, Republic of Benin, Cameroon, and the Republic of Niger, respectively. The total land area is approximately $923300\ km^2$ [32]. Nigeria's climate is generally hot through the year, with a little variance between wet and dry season. Nigeria's climate is divided into two major seasons such as the Dry and Wet seasons. The wet-season span between April and October; while, the dry-season span between November and March. Also, between the months of June and September, the weather condition is raining, humid, and hot [32].

Three vital atmospheric phenomena dominate the climate of Nigeria, such as the continental tropical (cT) air mass, maritime tropical (mT) mass of air, and equatorial easterlies [32]. The air temperature across the country differs from one region to the other. There are essential marked differences between the lowlands and high plateau and between the interior and the coastal areas. The annual average temperature value ranges from $21\ ^oC$ to $27\ ^oC$ on the Plateau. The yearly average temperatures on the interior lowlands are more than $27\ ^oC$ while that of the coastal fringes are lower than the interior lowlands. The ranges of the seasonal temperature are low as other tropical countries with a mean value of $6\ ^oC$. The temperature in the southern regions may be as low as $3\ ^oC$ [32].

Figure 2: Map of Nigeria (Wikipedia)

2.2 Data Source

The data source used in this work was extracted from the Ozone Monitoring Instrument (OMI) on-board the EOS Aura spacecraft. The instrument was launched on July 15, 2004, on a nadir pointing hyper-spectral imaging sensor. The instrument provides daily global measurement of the earth-atmosphere backscattered radiances in 1560 wavelength bands in the visible and ultraviolet (UV) regions from 264 nm to 504 nm at a spatial resolution of 13 x 24 km. Furthermore, the OMI provides measurements at a resolution of 13 x 12 km in a spatial zoom mode once a month. These global measurements are in the retrieval of column amount of NO2, O3, Aerosols, and SO2 (four of USEPA six criteria pollutants), as well as BrO, HCHO, OCIO, Surface Erythemal UV-B Irradiances, Effective Cloud Fraction and Pressure and Ozone Profiles [33]. The data allows us to analyze, determine and predict the characteristic behaviour of the data accumulated. The daily data extracted from the OMI spanned between January 2010 and December 2019 at the coordinate of $9.08^o N, 8.67^o E$ and spatial resolution of $1^o x\ 1^o$ for the UV indexes per second for these time frame.

For compressibility and the purpose of simplicity, the daily average dataset extracted from the Geospatial Interactive Online Visualization And analysis Interface (GIOVANNI) site, was converted to a monthly average for the analysis of the dataset, so as to see the trend of the peak UV radiation index over the period under consideration. From the site, the dataset (OMTO3d.003) to be analyzed is chosen from the OMI database. Temporal and spatial resolution were selected as daily and $1^o x\ 1^o$ respectively, in order to have access to more data point in the study area. An online software known as Grid Analysis and Display System (GrADS) imbedded on the GIOVANNI site is then instructed to generate or plot the time average map for each month by averaging the daily data into monthly average for the period (2010-2019) under consideration. All of these, are accepted by GrADS, as input variables and the results are generated as output variables shown in Figure 3.

3. Results and Discussion

The UV index shown in Table 1 is used to classify UV radiation's degree over a specific region. The ultraviolet index defines the different levels of daily intensity of ultraviolet radiation. The greater the UV radiation index, the greater it is unsafe for human health.This will help to predict the period of the day that is unsafe for outdoors activities or overexposure to UV rays. It is better to be indoors or under shade during the local noontime. This is because overexposure to high UV index can severely affect some areas of the human body, such as the eyes, skin etc. Table 2 showed the meantime of each month for 2010-2019 with a higher ultraviolet index regarding its level of exposure for the period under

consideration. Figure 3 shows the monthly mean of UV index for the year 2010-2019. The level of exposure from the Figure gives the variation of ultraviolet radiation across the different regions in the study area. However, the climate varies between wet and dry seasons. In November, December, January, February, and March (Dry season) gives a mean exposure of 'Very High' in South-West (Lagos, Ogun, Ekiti, Oyo, Osun, and Ondo state), 'Very High' (Edo, Edo, Cross River, Akwa Ibom) and 'High' (part of Bayelsa and Port Harcourt) in South-South and 'Extreme' in North-East (Yobe, Borno, Gombe, Bauchi, Adamawa, and Taraba), North-West (Kano, Jigawa, Katsina, Sokoto, Zamfara and Kebbi), North-Central (Niger, Kwara, Abuja, Kogi, Benue, Nassarawa and Plateau) and South-East (Enugu, Ebonyi, Imo, Anambra and Abia) respectively. A UV index value of 6 was observed in some of part of South-South, 6/7 in South-South/South-West, and 9 in South-East, North-Central, North-East, and North-West respectively, for November, December, January, February, and March at a local noon time (12:00) for the years under consideration (2010-2019). This is due to the season (Dry season) when the amount of rainfall decreases drastically from the South to the North within the said months and the cloud cannot absorb most of the UV radiation before reaching the surface of the earth. In the months April, May, June, July, August, September, and October (Wet season) gives similar results with some slight changes in the North-Central (Kogi and Abuja) experiencing a mean exposure of 'Very High,' and the ultraviolet index value was observed to be 7. Between June, July, and August, the country's climate is rainy, humid, and hot. As a result, the cloud absorbs most of the ultraviolet rays from the Sun before reaching the earth's surface.
The result revealed that the peak UV radiation index are those months (November, December, January, February, and March) with ‘Extreme’ values. These are the months where the people living in those regions are exposed to excess UV radiation. Although it is dangerous to their health (Skin burn) but it is a non-ionizing radiation because UV radiation do not enough energy to penetrate the human body as only ionizing radiation has the ability to penetrate the human body thereby damaging the DNA (genes) leading to cancer, owing to their high energy level according to [25-27]. For this reason, the level of exposure and the UV index value decreases from the Southern to the Northern path of the country. Therefore, the day's local noon time is relatively unsafe for outdoor activities especially for the worst months (November, December, January, February, and March) because, during this time, the risk of human health will be very severe. In this regard, it will be advisable to adopt sun-protective devices such as glasses, Hats, Caps, Umbrellas, and staying under shades during outdoor activities.

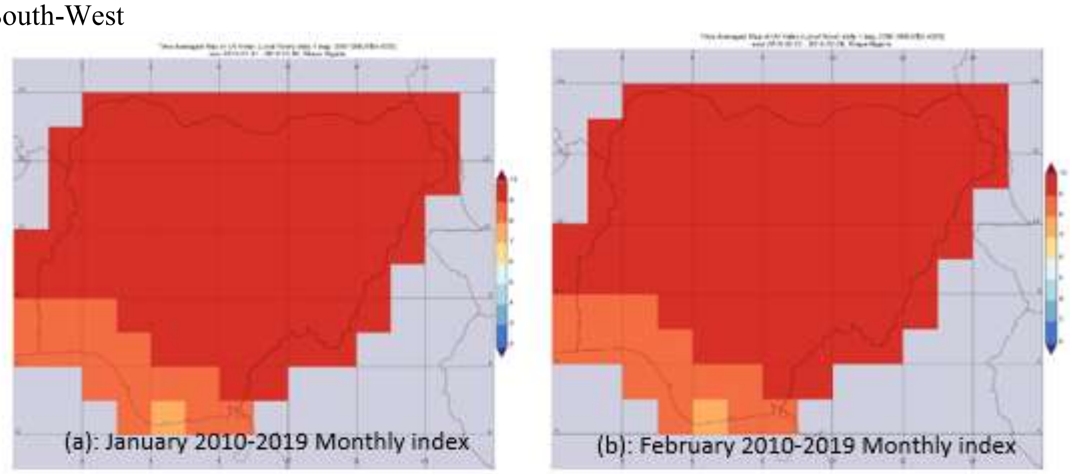
Table 2: Peak time value per average month for each geographical zone for 2010-2019

Month	**Zone**	**Figure**	**Local Noon Time**	**Peak UV**	**Exposure Level**
January	NE	a	12:00	9	Extreme
	NW			9	Extreme
	NC			9	Extreme
	SS			6/7	High/Very High
	SE			9	Extreme
	SW			7	Very High
February	NE	b	12:00	9	Extreme
	NW			9	Extreme
	NC			9	Extreme
	SS			6/7	High/Very High
	SE			9	Extreme
	SW			7	Very High
March	NE	c	12:00	9	Extreme
	NW			9	Extreme

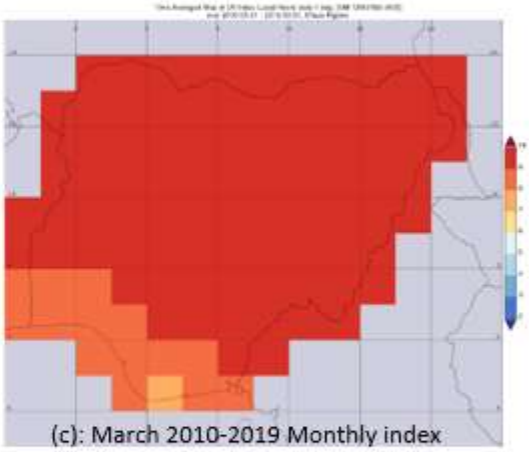
	NC			9	Extreme
	SS			6/7	High/Very High
	SE			9	Extreme
	SW			7	Very High
April	NE	d	12:00	9	Extreme
	NW			9	Extreme
	NC			9	Extreme
	SS			6/7	High/Very High
	SE			9	Extreme
	SW			7	Very High
May	NE	e	12:00	9	Extreme
	NW			9	Extreme
	NC			9	Extreme
	SS			6/7	High/Very High
	SE			9	Extreme
	SW			7	Very High
June	NE	g	12:00	9	Extreme
	NW			9	Extreme
	NC			7/9	Very High/Extreme
	SS			6/7	High/Very High
	SE			9	Extreme
	SW			7	Very High
July	NE	h	12:00	9	Extreme
	NW			9	Extreme
	NC			7/9	Very High/Extreme
	SS			6/7	High/Very High
	SE			9	Extreme
	SW			7	Very High
August	NE	i	12:00	9	Extreme
	NW			9	Extreme
	NC			9	Extreme
	SS			6/7	High/Very High
	SE			9	Extreme
	SW			7	Very High
September	NE	j	12:00	9	Extreme
	NW			9	Extreme
	NC			9	Extreme
	SS			6/7	High/Very High
	SE			9	Extreme
	SW			7	Very High

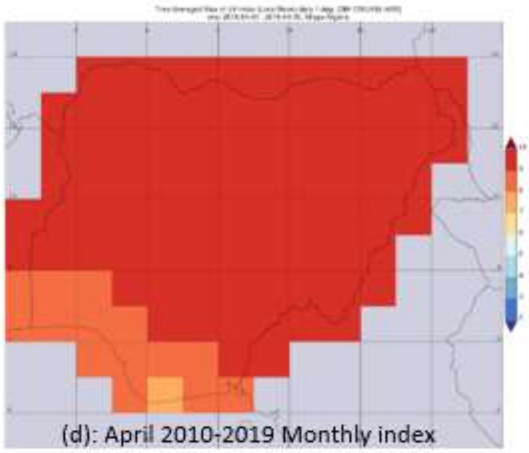
October	NE	k	12:00	9	Extreme
	NW			9	Extreme
	NC			9	Extreme
	SS			6/7	High/Very High
	SE			9	Extreme
	SW			7	Very High
November	NE	l	12:00	9	Extreme
	NW			9	Extreme
	NC			9	Extreme
	SS			6/7	High/Very High
	SE			9	Extreme
	SW			7	Very High
December	NE	m	12:00	9	Extreme
	NW			9	Extreme
	NC			9	Extreme
	SS			6/7	High/Very High
	SE			9	Extreme
	SW			7	Very High

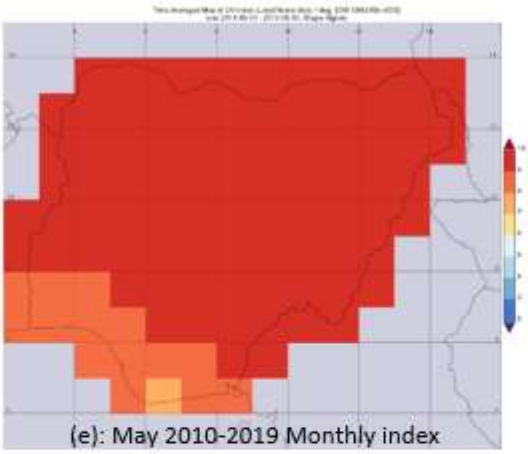
Note: **NE**: North-West, **NW**: North-West, **NC**: North-Central, **SS**: South-South, **SE**: South-East, **SW**: South-West

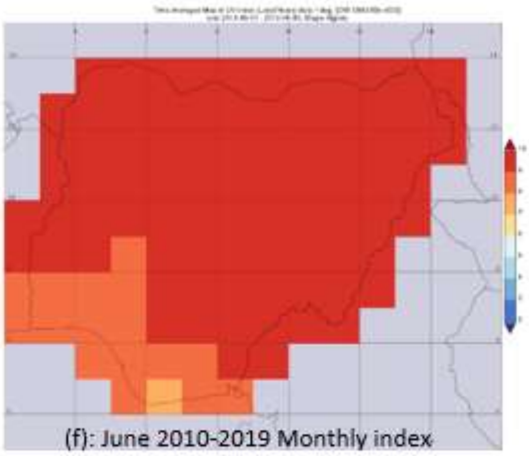


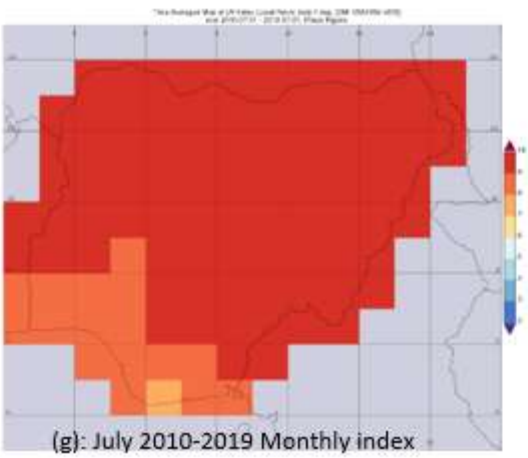
(a): January 2010-2019 Monthly index (b): February 2010-2019 Monthly index

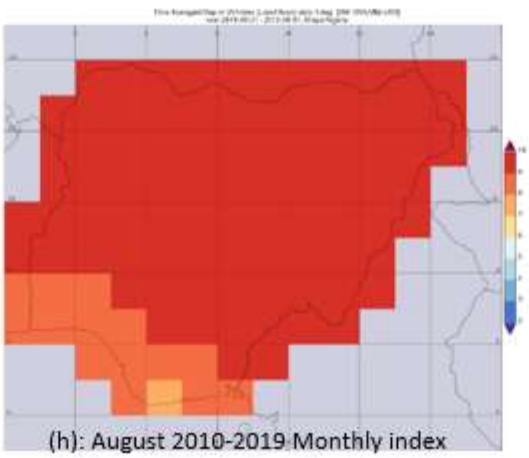

(c): March 2010-2019 Monthly index


(d): April 2010-2019 Monthly index


(e): May 2010-2019 Monthly index


(f): June 2010-2019 Monthly index


(g): July 2010-2019 Monthly index


(h): August 2010-2019 Monthly index

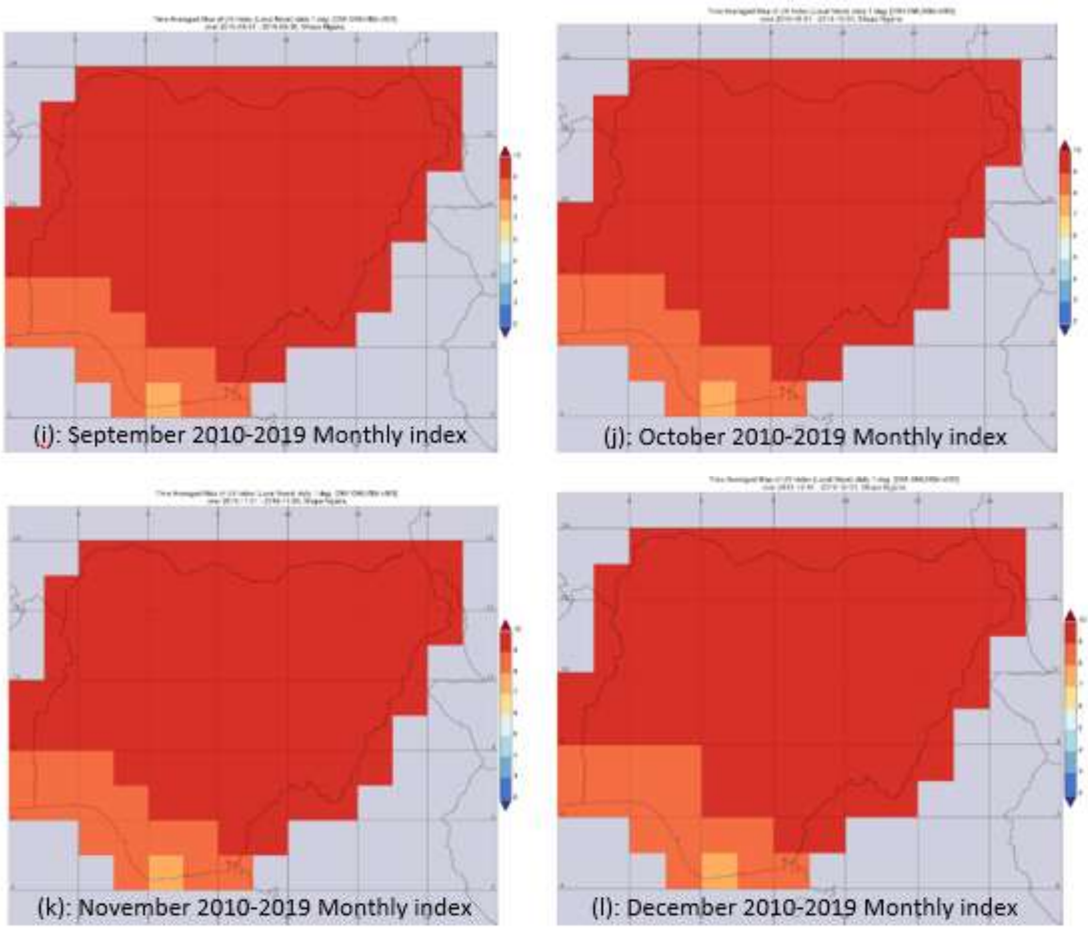


Figure 3: Monthly average of UV index for 2010-2019

4. Conclusion

It can be concluded that an ultraviolet radiation index is an essential tool that can be exploited by an individual to reduce the exposure of humans to UV solar radiation, but this depends effectively on how the information is conveyed to the public for awareness. It was observed that the worst months with ‘Extreme’ values are November, December, January, February, and March. It was also observed that the solar UV radiation is at its peak at local noon time (12:00). Excess exposure to UV radiation at this time can cause skin diseases such as skin burn and rashes in the eyes. However, it has been established in literature according to [3] that protective measures can be taken against harmful effect of UV radiation by applying sunscreen (Sunglasses), Hats, Umbrellas, protective clothes (long sleeve and trousers) and staying under shades where possible for protection against ultraviolet A (UV-A) and ultraviolet B (UV-B) during this time when the UVI is very high. This will help to protect them from direct overexposure to UV radiation during outdoor activities.

Acknowledgment
The authors would like to appreciate the management of Covenant University through the Center for Research Innovation and Discovery (CUCRID) for their research's financial support.

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