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Ultraviolet Radiation Index over Abuja, Nigeria

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Abstract

The sunlight that gets to the earth's surface is composed of three major types of radiation. The Infrared radiation is what gives sunlight its warmth. Visible light helps us see. And lastly the ultraviolet radiation (UV) which poses the most damaging effects of the sunlight cannot be seen nor felt. The UV data over Wuse, Abuja, Nigeria (9.08˚N, 7.48˚E) was recorded with the Davis wireless vantage pro2 weather station for the year 2020. The research showed that the UV index was higher at the first half of the year and lower at the second half of the year. Months like March, April and May had the highest values of UV index as they contained days of high and very high category of UV index which could pose great damage to the skin and the eye when exposes to the Sun for long. It was also observed that the daily UV index peak hours for the year were between 11:00 hrs-14:00 hrs. The result showed that the UV index experienced significant reduction on days when it rained. Abuja experienced a high UV in the first half of 2020 and a moderate UV radiation during the second half of the year. A mathematical model was developed for the prediction of the Rainfall for the year 2020, using the data of the daily UV index and the monthly UV mean of the same year. The result was found to be very effective.

Subject Areas

Radiology

Keywords

UV Index, Ultraviolet Radiation, Peak Time, Electromagnetic Radiation

1. Introduction

The electromagnetic (EM) spectrum is the range of frequencies of electromagnetic radiation and their respective wavelengths and photon energies. The Electromagnetic radiation comes mainly from the sun and it is transmitted in waves or particles at different wavelengths and frequencies. The EM spectrum is divided into seven different band ranges in order of decreasing wavelength and increasing energy and frequency [1]. The EM spectrum classifications are: radio waves, microwaves, infrared (IR), visible light, ultraviolet (UV), X-rays and gamma-rays. The main focus here is the ultraviolet (UV) light/radiation, which is part of the electromagnetic radiation with a wavelength from 10 nm to 400 nm [2]. Its wavelength is shorter than that of visible light but longer than the X-ray; it is also not felt or visible to humans. The UV constitutes about 10% of the total sunlight. From this percentage, only one-third penetrates the atmosphere to reach the earth surface. UV light can also be generated by artificial sources such as tanning booths, black light, germicidal lamps, fluorescents, some lasers, mercury lamps, welding torches etc. [3].

The UV is divided into three (3) sub-bands: the UVA, UVB and UVC according to [2]. The UVA has the longest wavelength and lowest energy, while, the UVC has the shortest wavelength and the highest energy. According to [2], 95% of the UV that gets to the equator is UVA, and 5% is UVB, while the UVC is totally absorbed by the atmosphere (Ozone, molecular oxygen, and water vapor). Therefore, majority of the UV radiation reaching the Earth's surface is composed of UVA, with a little amount of UVB component. Solar UV radiation is well known to be responsible for the synthesis of vitamin D, but excessive exposure to it causes sunburn, eye problems (such as cataracts, pterygium), skin aging, skin cancer and immune depression [4]. Solar UV also affects the aquatic system: both the marine and fresh water [5]. It has also been shown that the UV-B suppresses the body immune response to Herpes simplex virus, leads to skin lesion development and may also affect the spleen [6]. The UV-B causes cataract and snow blindness because the eyes are more vulnerable [6]. Majority of the damage due to solar UV is as a result of this little but intermittent and cumulative absorbed doses, that turn out to affect, the body in later stages of life (*i.e.*, chronic effects). The chronic exposure gives rise to accelerated skin aging process and increases the risk of developing skin cancer (both melanoma and non-melanoma) [3]. In agriculture, the presences of UV-B increase plant's susceptibility to diseases [7].

Market arenas, playgrounds, tourist sites, farmlands, work and construction sites in Nigeria are the places that present significant health risks to most people who expose their bodies to UV without adequate protection [7]. The strength of the UV rays is stronger at the equator and places closer to the equator such as Nigeria [7]. The length of exposure time also affects the human body based on the UV index strength which is between 1 to 11+ according to [8]. The higher the number, the more dangerous it is and the lesser the time needs to be spent under direct sun rays. Luckily, for brown and dark skin colored people, we have a higher resistance to UV. But some places with UV indexes of 7 and above, such as Abuja, need to be monitored and well researched, due to its high probability of causing damages to the human body when exposed for some time. The UV index is a scale that shows UV intensity. The values of the index ranges from zero upward, the higher index value the greater its potential damage to the skin and eye in lesser time of exposure. The UV index scale was developed by Canadian scientists and then adopted and standardized by an international effort which includes the World health organization (WHO), the United Nations Environment Programme, and the World Meteorological Organization to create awareness on sun exposure and its harmful health effect.

Table 1 shows the UV index scale, which displays an exposure category to the sun in relation to its UV index range. The exposure category tolerance is also influenced by the skin color, as people with lighter skin need to be more careful due to their skin's low tolerance, while the people with darker skin may be able to tolerate more exposure [9]. For example, a research was carried out on UV index over Ota, Ogun State, Nigeria by [9] over a period of approximately two years. The research revealed that the mean UV index was 5.37 over the two-year period. Thus, the study showed that the UV index over Ota during the period under review is in the moderate range. Section 2 described the instrumentation (the earlier part of the section) and method (the later part of the section) used in this study, followed by the results and discussions on the UV index for the year 2020 (January-December) presented in Section 3. Finally, Section 4 presents the conclusions.

2. Instrumentation and Method

The Atmospheric parameters in Abuja such as the UV index, temperature, dew point, humidity, wind speed and precipitation rate (rain) were measured with the help of a meteorological instrument called Davis Vantage Pro 2 Wireless Weather Station. The instrument records atmospheric parameters in one package called the integrated senor suit (ISS). A standard version of the ISS contains a rain collector, temperature sensor, humidity sensor and anemometer. In addition to the standard weather features, the ISS Plus adds a pre-installed solar radiation sensor and a UV sensor. Temperature and humidity sensors are mounted in a passive radiation shield to minimize the impact of solar radiation on sensor readings. The Davis Vantage Pro 2 was used to record atmospheric parameters in Wuse 2 (9.08˚N, 7.48˚E), on the top of a pole at an elevation of approximately 493 m above the sea level. The data was saved on the data logger affixed to the Davis vatange Pro2 console; the data logger also provides an interface for direct

Table 1. UV index scale.

UV INDEX RANGE	EXPOSURE CATEGORY
0 - 2	LOW
3 - 5	MODERATE
6 - 7	HIGH
8 -10	VERY HIGH
11+	EXTREME

access to the weather station recorded data. The 6510 data logger USB variant was used alongside with the WeatherLink software to store the data on a local computer and also to upload the data to WeatherLink cloud. The UV index data recorded was collected throughout the day from 00:00 hour to 23:00 hour at intervals of 5 minutes all through the year 2020. The UV index is time dependent; limiting its observation period to a time frame during the day which happens to be within the hour of 06:00 to 18:00 local time (GMT + 1:00). The UV index scale was used to categorize the daily exposure of the UV for simplicity. The daily average data obtained was converted to monthly average data per hour, this was computed by taking the hourly UV index average for the total number of days in a month. The data from the rain gauge was also average into an hourly data.

3. Results and Discussion

This section shows the results of the UV index data over Abuja in the year 2020 (January-December). Table 2 shows the time, day and the UV index of the three strongest days (in terms of values of UV index) of each month during the months of the dry season.

One of the things that were observed from Table 2 is that all the days clearly had its peak at 12:00 hours throughout the months of the dry season. Another obvious fact from this table is that the occurrence of the peaks "moved" majorly from the first 17 days of every month (except on 30th) at the early stage of the dry season (Nov. and Dec.) to the last week of each month in the latter

Table 2. Top three daily UV index peak in each month of the Dry season.

MONTH	DAY	TIME	UVI
NOV.	16	12:00	5.2
	17	12:00	7.8
	30	12:00	5.1
DEC.	7	12:00	5.1
	8	12:00	4.8
	10	12:00	5.0
JAN.	24	12:00	6.0
	25	12:00	6.0
	26	12:00	6.0
FEB.	22	12:00	6.0
	23	12:00	6.0
	24	12:00	7.0
MAR.	24	12:00	9.0
	27	12:00	8.0
	28	12:00	8.0

part of the dry season (Jan. till Mar.). The values of the peak UV index varied in the early months of the dry season. While, the months in the latter part of the dry seasons showed almost the same peak, with the Peak in the month of March being the strongest.

There was no consistency in the days of occurrence of the peak in the months of the raining season unlike in months of the dry season as showed by **Table 3**. On the other hand, the time of occurrences varied from 11:00 till 14:00 hrs. There were stronger peak values at the early months in the raining season (April and May) than the latter months (June till October). However, the month of August showed consistently low values of the "peak" when compared with other months. The month had the least among the peaks in the months of the raining season.

On the other hand, **Figure 1** and **Figure 2** is the graphical representation of the hourly average UV index for the dry and rainy season respectively. The knowledge of the monthly UV index is of great importance as it stretches through the seasons and the year in general. The split of UV index into seasons

Table 3. Top three daily UV index peak in each month of the Rainy season.

MONTH	DAY	TIME	UV INDEX
APR.	12	12:00	8.8
	25	12:00	8.1
	29	12:00	8.8
MAY.	13	12:00	9.3
	16	13:00	8.4
	17	12:00	9.2
JUN.	6	12:00	7.5
	7	12:00	7.2
	18	12:00	7.2
JUL.	1	11:00	6.9
	13	12:00	7.8
	14	12:00	7.7
AUG.	15	12:00	5.8
	17	14:00	5.8
	29	11:00	6.4
SEP.	7	12:00	7.0
	8	11:00	6.4
	24	11:00	5.7
OCT.	2	12:00	6.3
	12	11:00	5.9
	18	12:00	6.1

helps to know more about its seasonal effect/characteristics in Abuja Nigeria. Figure 1 is composed of dry season months. These months were represented with different colored plots; November (red), December (yellow), January (black), February (blue) and March (green). November is the first month in the dry season. November (red) trend had a maximum average daily UV index peak of approximately 5.0 at 12:00 noon, the trend had a sharp fall after 12:00 hrs as it dropped rapidly to an average of 1.5 at the 14:00 hrs. This was followed by a gradual reduction as the sunlight recedes. The UV index was 0.3 at 16:00 hrs, the UV index became infinitesimal after this. December (yellow) had a maximum average daily UV index peak value of approximately 3.9 at 12:00 noon, although a smaller trend, December had a similar pattern with the November trend. The value at 12:00 hrs fall sharply where it dropped to an hourly average of approximately 0.5 UV index at 14:00 hrs. The UV index was also infinitesimal by 16:00 hrs. January (black) had a maximum average daily UV index peak value of approximately 4.4 at 12:00 noon. Unlike in November and December, the normally sharp fall after 12:00 hrs was absent in January. The UV index however extended till 18:00LT, unlike November and December before disappearing. February (blue) had a maximum average daily UV index peak value of approximately 5.0 at 12:00 noon.

February although a bigger trend had a similar pattern to that of January. March (green) had a maximum average daily UV index peak value of approximately 6.6 at 12:00 noon, March had a bigger trend with similar pattern to January and February.

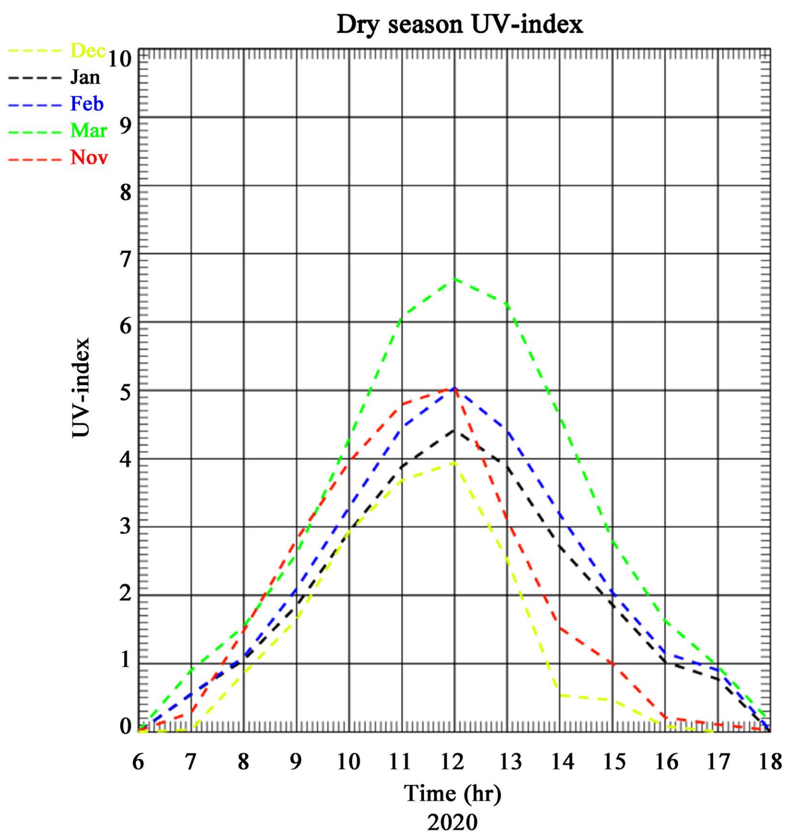


Figure 1. Hourly average of UV index for the months in the dry season (2020).

March had the biggest trend in the whole of the dry season. A huge gap seen between the March trend and the other trends in the months of the dry season clearly shows that. The results show distinctively that, there was a similar trend in the UV index in the months at the beginning of the dry season (November and December). And another trend at the latter part of the dry season (January to March). Another point to be noted is that there seems to be a progressive increase in the monthly UV index trend as the dry season progress towards the rainy season except the trend in November. The month of November (which is the first month of the dry season) and February (which is the peak of the dry season (last month) at the location) had the same UV index peak (5) even though the two exhibited different trends. This occurred only in these two months during the season. The very strong increase of about 132% in the UV index from February to March might be as a result of the position of the sun around that time at the location of the station. This is in agreement with [10] that state that the Sun crosses the Equator and moves northward in the month of March, thereby, making the air temperature and invariably the UV in March and April at the location to be very high when compared to the previous and following months. The fact that the trend in the hourly average of UV index of January and February are the same can be said to be in agreement with the works of the [11] [12] [13] which state that the migration of the Inter-Tropical Convergence Zone ITCZ (which leads to the seasonal patterns will have), led to it being at the southernmost position in Nigeria around January and February, during which the influence of the north-east winds prevails during the dry season. Another point worthy of note is that, it was only November and February that has the same hourly average peak (5). The first month of the dry seasons (November) and the last month of the dry season (February). **Figure 2** is composed of the UV index months in the rainy season. These months were represented with different colored plots; April (black), May (dark blue), June (green), July (red), August (yellow), September (purple) and October (light blue). April is the first month in the rainy season.

Therefore, such month is bound to show a transitional trend. That is, a little similarity with the months in dry season as the atmosphere of the station moves deeper into the rainy season. The month of April from the graph clearly showed that April represented by the black trend had a sharp maximum average daily UV index peak value of approximately 7.1 at 12:00 noon.

The UV index was still present till 18:00 hrs before it disappeared. The trend is clearly similar to the month of March. The month of April had the highest average UV Index of all the months in the rainy season. The month of May (dark blue) had a sharp maximum average daily UV index peak value of approximately 6.4 at 12:00 noon. May although a little smaller trend, had a similar pattern to that of April. June (green) had a maximum average daily UV index peak value of approximately 5.0 at 12:00 noon. In this month, there was a gradual drop between 12:00 hrs to 14:00 hrs, before it eventually dropped till 18:00 hrs thereafter

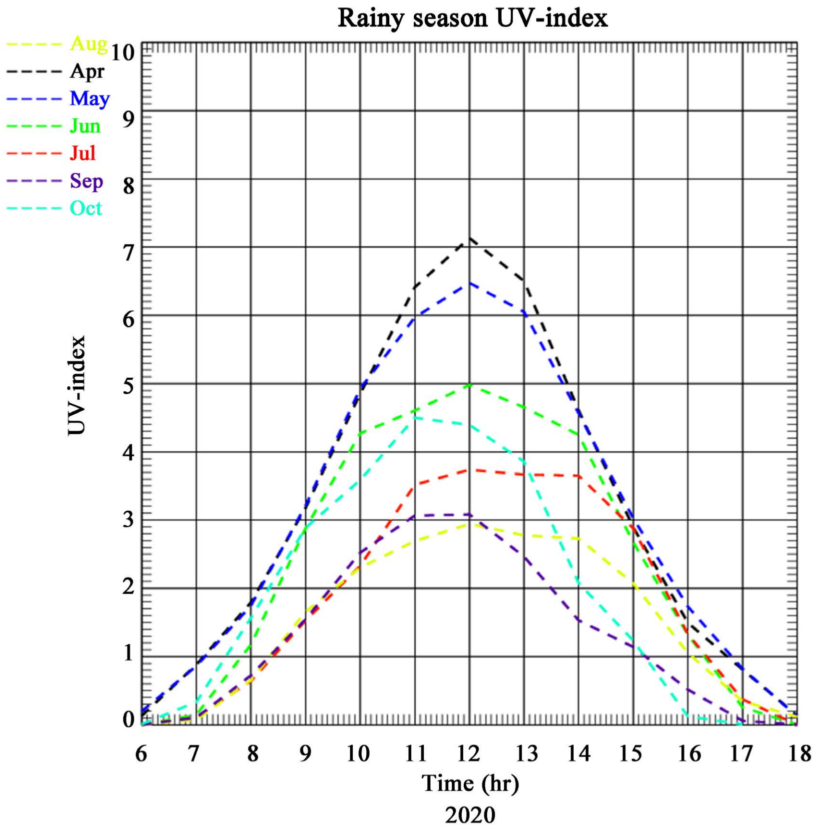
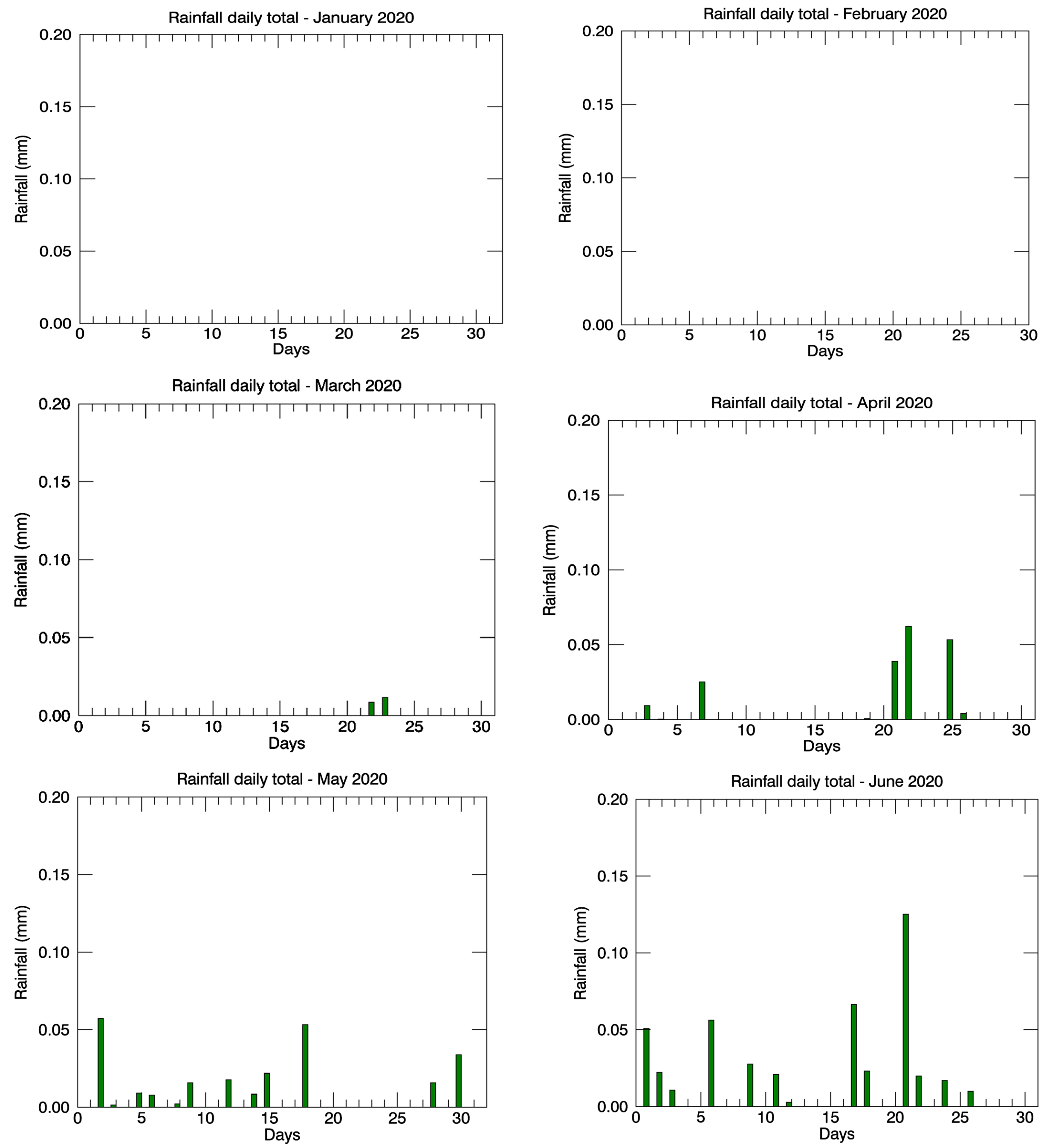


Figure 2. Hourly average of UV Index for the months in the rainy season 2020.

and then disappears. There was a huge reduction in the trend (the values of the maximum average daily UV index) from May to June. July (red) had an almost flat top in its trend, with the maximum average daily UV index peak value of approximately 3.7 (which was from 11:00 hrs to 14:00 hrs). The UV index in this month was noted to have started at about 7:00 hrs (This was totally different from the earlier trends) and till 18:00 before disappearing. August (yellow) had a maximum average daily UV index peak value of approximately 3.0 at 12:00 noon (average peak was high between 12:00 hrs to 14:00). The month of August showed an almost flat top in its trend like July. This month like the month of July also had the UV index starting at about 7:00 hrs till 18:00 hrs before disappearing. The graph showed that this month had the lowest average UV index in the rainy season. September (purple) had a very short flat maximum average daily UV index peak value of approximately 3.1 between 11:00 hrs and 12:00 hrs. The average UV index in this month started at about 7:00 hrs (like July and August) and till 17:00 hrs (one hour earlier than July and August). October (light blue) unlike other months October had its maximum average daily UVI peak at 11:00 hrs with a value of approximately 4.5. The average UV index in this month started at about 6:00 hrs (like the earlier months before July, August and September) and till 16:00 hrs (earlier than any other months discussed). Unlike the dry season where there seems to be an increase in the monthly UV index as the dry season progress towards the rainy season. However, there was a noticeable reduction in the monthly UV index as the raining season progresses from April till June. From July till October was when the scenario changed drastically as the intensity of the rain greatly increases. The fact that only April and May showed similar pattern in their hourly average UV index in the raining season revealed that the same "situation" must have contributed to the trend in the UV index in the two. However, a critical look at the trends of July, August and September revealed a flatness at the crest of each trend. This might be as a result of the position of the ITCZ and the Sun at the location of the station according to [10] [11] [12] [13]. Having the ITCZ in the northernmost position which happens in July leads the precipitation (rainfall) increases in the North of Nigeria (location of the station). Thereby, leading to a rainfall peak in the North. However, [10] revealed that the temperature and UV of Nigeria rises as the Sun crosses the Equator and moves northward in the month of March, making the air temperature and UV in March and April to be very high. This however reduces, as the Sun moves back southward leading to another high set of temperatures and UV in October and November. The combination of the position of the Sun and that of the ITCZ at the same time might be the reason for the scenario of July, August, September and October.

Figure 3 shows the volume of daily rainfall for each month of the year 2020. It can be seen that the rain started in the month of March (smallest in terms of volume and just two days) till October (12 days), with September having the highest number of days of rainfall and in terms of volume of rainfall too. March is a considered a month in the dry season but it experienced rain in the year under study. A relationship between the UV index and rain data was analyzed. This analysis was done on the days with rainfall, with the aim of observing the direct effect of the rain on the UV index data of the same day. After properly accessing all the rainy days and their effects on the UV index, two particular rainy days coupled with its UV index counterpart data were selected in representation of the rainfall effect on the UV index for the year. The day selected was July 16th 2020. **Figure 4** shows the effect of the rain before and after the maximum peak hours. The data from 16th of July was used as a case study since it contained rain showers before and after the UV peak hours. **Figure 4(a)** shows a bar plot of rain at the early hours of the day, from 1:00 hrs to 5:00 hrs and later in the day by the hours of 18:00 hrs and 19:00 hrs. The effect of this rain and invariably its cloud on the UV can be understood, when, it is coupled with the hourly average UV data for the month. The early hour rain which stopped by 6:00 hrs had little or no reduction effect on the UV data shown in **Figure 4(b)**. Comparing these results, it is safe to say that the influence of the rain before, and after the UV index peak hour, had no reduction effect on the UV data. On the other hand, there seems to be an increase in the UV index immediately after the rain stopped which could be as a result of the presence of the little or no clouds. This occurrence is in agreement with [14], which proclaimed that in a situation whereby the Sun is not dimed by the cloud, the reduction is very little and there can also be enhancements of up to 25% if there are bright clouds in the field of view. Also, according to [15], surface UV is usually reduced under thin clouds provided the clouds are evenly distributed in the horizontal. The volume of the rain determines the extent to which the UV is reduced. In most cases, the UV index is reduced by the cloud prior to a forthcoming rain. Its reduction effect could take place an hour or two earlier depending on the thickness of the cloud cover.

Figure 5 shows the effect of the rain during the peak hours of the UV index. The data from 21st of September was used as a case study. From **Figure 5(a)** the rain was recorded within the hour of 11:00 hrs to 13:00 hrs. The volume of the



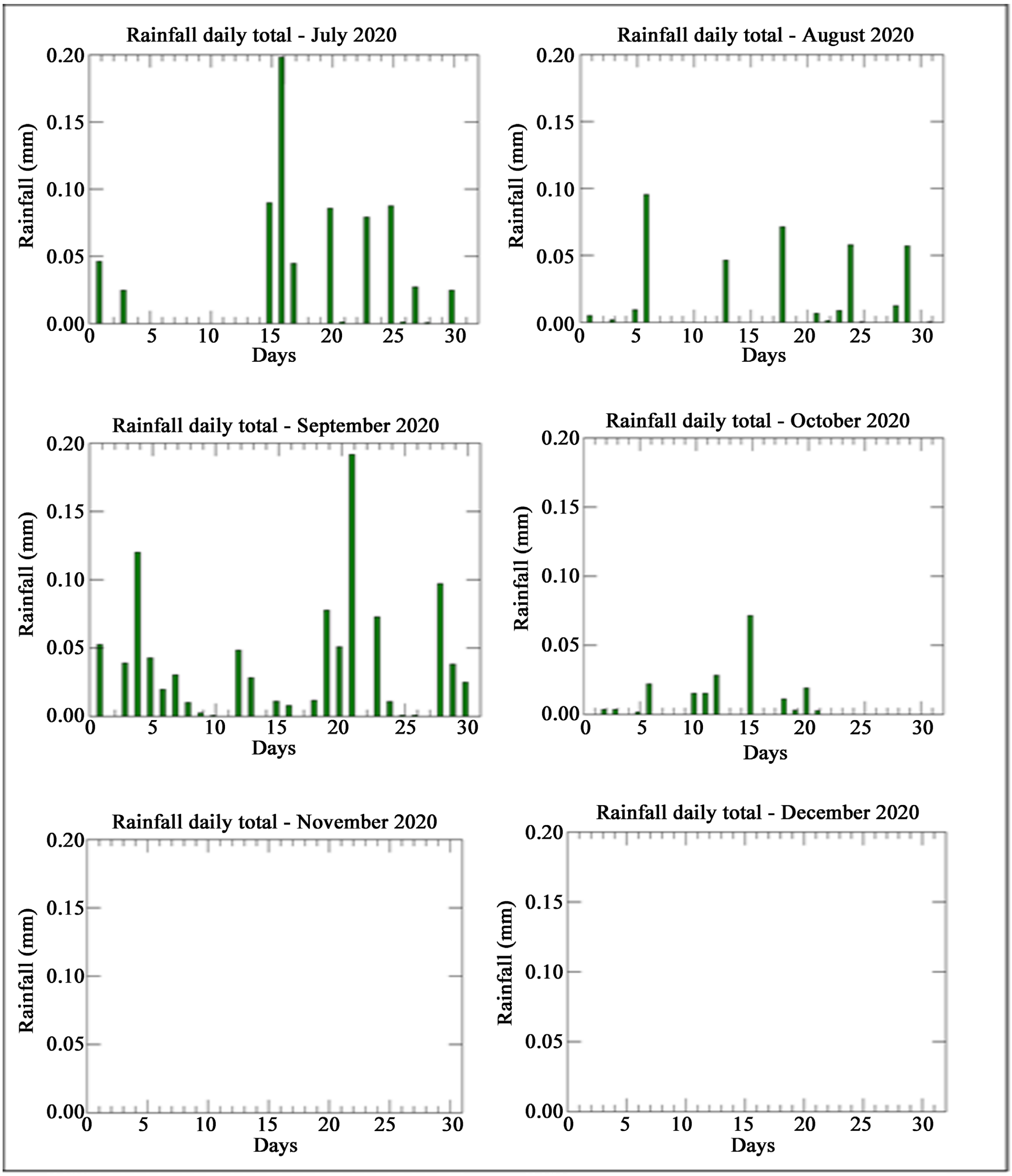


Figure 3. The rainfall pattern for each month of the year 2020.

rainfall at 12:00 hrs was the heaviest on that day, and it is expected to have the strongest reduction effect on the UV index. This same period should be the peak hour of the UV index for that day. Therefore, the reduction effect of the rainfall should be more pronounced at this time of the day. However, Figure 5(b) shows the UV index for the same day. It is clear from the graph that, there was no UV index recorded at 11:00 hrs and 12:00 hrs. The UV index of less than 0.2 was recorded at 13:00 hrs. The volume of the rain at 11:00 hrs was 1.2 m and that at 12:00 hrs was 3.1 m. This means that 12:00 hrs had 2.58 times more rainfall than

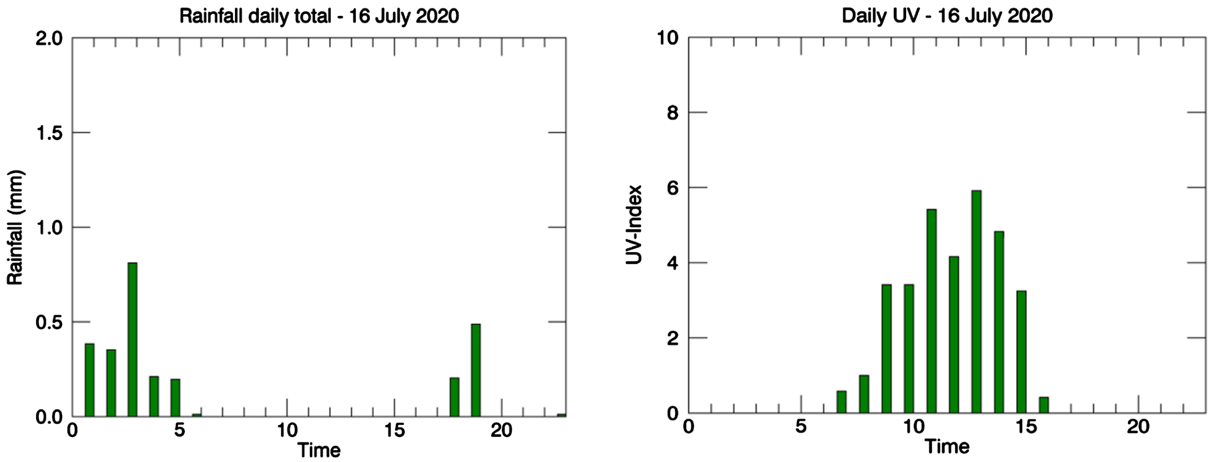


Figure 4. Relationship between the daily rain and the UV index before and after peak hours of UV radiation on 16th July 2020. (a) Rain (b) UV index.

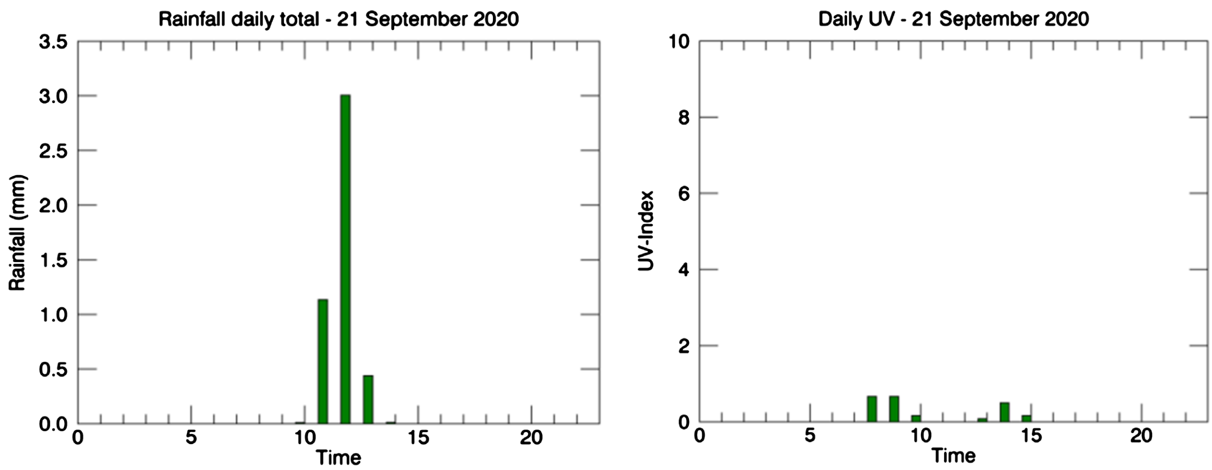


Figure 5. Relationship between the daily rain and the UV index within the peak hours of UV radiation on 21st September 2020. (a) Rain (b) UV index.

at 11:00 hrs. Both were still stronger than that of the rain at 13:00 hrs, which was less than 0.5 mm. This result in a way affirms that the volume of the rainfall determines the reduction rate of the UV index. Another observation worthy of note, is the effect the cloud before the rain had on the UV. From the result of Figure 5, it can be said that the cloud had a huge reduction effect on the UV before the rain, this is in agreement with [16] that postulate that a surface UV irradiance can be strongly reduced up to 95% under heavy clouds (especially cumulonimbus) at wavelengths that are not significantly absorbed by atmospheric ozone.

Table 4 shows the monthly UV index average and their respective Peak time. While the Figure 6 shows the graphical representation of the peak UV index and the months of the year. This work shows that the UV index can be high in both the dry and rainy season. Unlike the mid-latitude regions, whereby a particular season has the higher UV intensity more than others. In this case, it is better to categorize the monthly UV intensity based on the first half of the year (January-June)

Table 4. Monthly UV peak time for 2020.

Month	Time	UV Peak
January	12:00	4.4
February	12:00	5.0
March	12:00	6.6
April	12:00	7.1
May	12:00	6.4
June	12:00	5.0
July	11:00/12:00/13:00	3.7
August	12:00	3:0
September	11:00/12:00	3.1
October	11:00	4.5
November	12:00	5.0
December	12:00	3.9

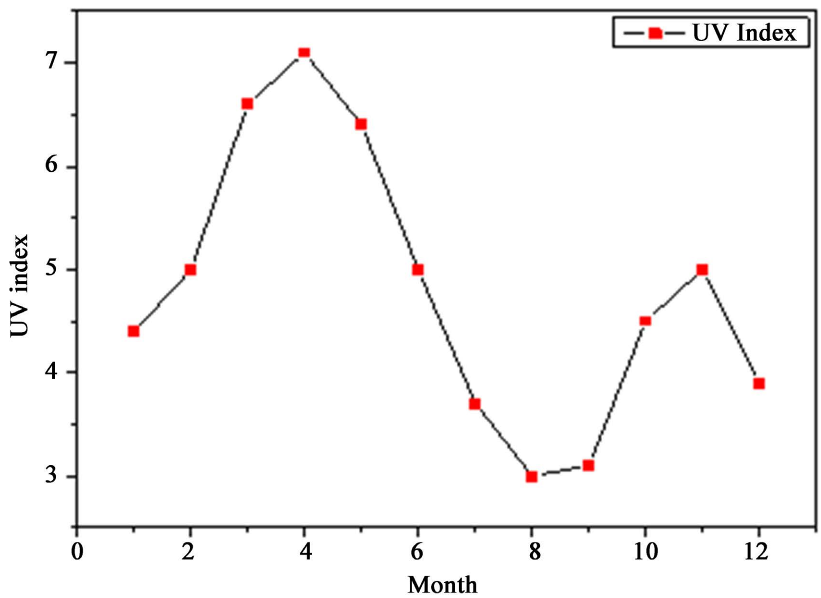


Figure 6. The Monthly UV peak index at the location for the year 2020.

and the latter half of the year (July-December). The monthly Peak UV index were higher at the first half of the year, and lower at the latter half of the year. Months like March, April and May had the highest values of UV index, as they contained days of high, and very high category of UV index which could pose great damage to the skin and the eye when exposes to the Sun for long. It was also observed that the daily UV index peak hours for the year were between 11:00 hrs-14:00 hrs. However, the effect of the rainfall on the UV index, showed that the UV was highly reduced by the presence of the rainfall. In most cases, the UV index was reduced to value of zero (the low category) depending on the strength of the cloud cover (the cloud that preceded the rainfall also had a reduction effect on the UV index), time of the day and the volume of the rainfall for the year were between 11:00 hrs-14:00 hrs.

However, the effect of the rainfall on the UV index, shows that the UV is highly reduced by the presence of the rainfall.

In most cases, the UV index is reduced to value of zero (the low category) depending on the strength of the cloud cover (the cloud that preceded the rainfall also had a reduction effect on the UV index), time of the day and the volume of the rainfall. The results from this paper show that high UV index can also be recorded in the months of the rainy season. The months with the top three average UV index were March, April and May (Months in the rainy season). And the month with the least average UV index was also recorded in the rainy season (August). Both the dry season and the rainy season had moderate and high monthly average UV index. This led to the conclusion that, the UV index in Abuja, Nigeria, is not primarily influenced by the seasons. The higher the UV Index, the greater the UV dose rate damage it delivers to the skin and the eye. According to [8] estimates, up to 20% cataracts cases of blindness may be caused or enhanced by sun exposure, especially in India, Pakistan and other countries of the "cataract belt" close to the equator. Consequently, the higher the UV Index, the smaller the time it takes before skin or eye damage occurs. The daily UV index for the month of March, April and May contained daily UV index categorized as very high. This category of UV requires lesser exposure in direct sunlight. According to [17], it is advisable to avoid being in direct sunlight for more than 1 to 2 hours. Even though, the dark skin has a better resistance to the UV due to its high melanin which absorb some mount of UV radiation in the body. High and very high UV index category can be harmful with increased exposure which lead to accumulated damages to the DNA over time. **Figure 7** shows the UV Monthly average standard deviation plot of each month of 2020.

The analysis of the UV and the rain data for the year was used in postulating a theory for rainfall predictions as to whether it will rain during a certain time of the day (10:00 hrs-14:00 hrs). This prediction time falls within the peak hour UV period. In making this analysis, the monthly UV mean $\left(\bar{M}\right)$ value was compared with the daily UV index (dUV). The average standard deviation value from the plot in **Figure 7** is within the range of ±2. The positive side (+2) was used in postulating the rainfall theory as shown in Equation (2).

$$\bar{M} = \frac{1}{n}\left(\sum_{i=1}^{n} x_i\right) \tag{1}$$

$$\text{Rainfall} = \left(dUV - \left(\bar{M} + 2\right)\right) \tag{2}$$

A positive output when the daily UV index is inserted into Equation (2) in a rainy month means, there would be no rainfall during the hours predicted even with the presence of a cloudy sky. Equation (2) gave a 100 percent no rain situation when, positive during the hours of 10:00 hrs to 14:00 hrs in year 2020. This means that. this mathematical model only works effectively in predicting rainfall between the hours of 10:00 hrs and 14:00 hrs. The daily UV index usually

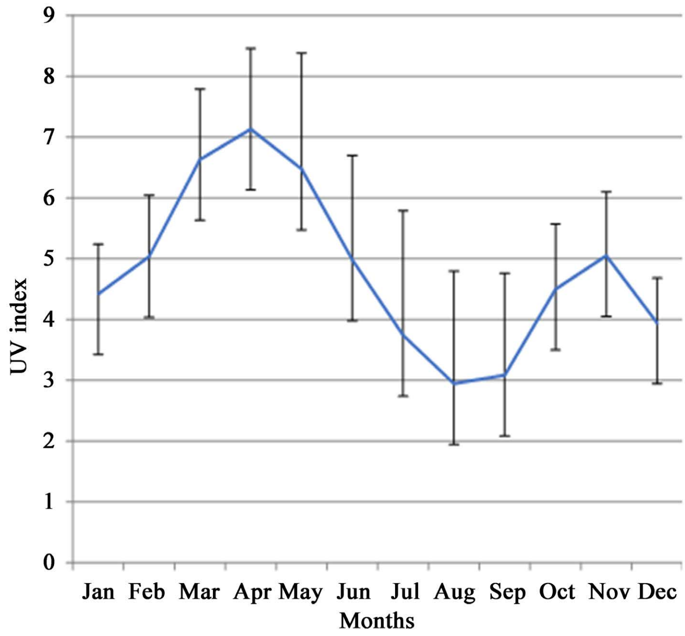


Figure 7. UV Monthly average standard deviation plot in 2020.

represents the UV intensity around the solar noon. The choice of this time range (10:00 hrs to 14:00 hrs) is in agreement with [18] which state that the intensity of UV increases towards the solar noon and decreases after the solar noon. Therefore, the further away from the solar noon, the lesser the strength of the UV, and invariably its effects. This however limits the UV effect to a particular time range of the day.

4. Conclusion

This paper showed the uniqueness of the location of the station as it pertained to the UV measurements. The development of the mathematical model above is also a great step in the study of UV and rainfall patterns of the location. The use of data of many years will conclusively ascertain whether it worked only for the year 2020 or is the standard for the location.

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Conflicts of Interest

The authors declare no conflicts of interest.

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