Bima Journal of Science and Technology, Vol. 8(1B) Apr, 2024 ISSN: 2536-6041

DOI: 10.56892/bima.v8i1.633

Impacts of Some Meteorological Parameters on Diffuse Solar Radiation Across the Coastal Region of Nigeria

Salifu, S. I.[1]*, Akpootu, D. O.[2], Kola, T. A.[2], Nouhou, I.[3], Agidi, O. E.[2], Yusuf, A.[4], Aliyu, M. A.[5] and Idris M.[6]

[1]Department of Physics, Kogi State College of Education Technical Kabba, Nigeria
[2]Department of Physics, Usmanu Danfodiyo University Sokoto, Nigeria
[3]Dėpartment de Physique, Facultė des Sciences et Techniques (FST), Universitė Dan Dicko Dankoulodo, Maradi Rėpublique du Niger
[4]Department of Science Education, Ibrahim Badamasi Babangida University, Lapai, Nigeria
[5]Sokoto Energy Research Centre (SERC), Usmanu Danfodiyo University Sokoto, Nigeria.
[6]Department of Physics, Bayero University Kano, Nigeria

Corresponding Author: imaben22@gmail.com

ABSTRACT

This study examines the interplay between meteorological parameters and diffuse solar radiation across various coastal locations. A key finding is the inverse relationship between atmospheric pressure and diffuse solar radiation which implies that higher atmospheric pressure correlates with lower diffuse solar radiation and vice versa. Additionally, mean temperature tends to give a reflection of diffuse solar radiation patterns, suggesting higher diffuse solar radiation with elevated temperatures. Seasonal analysis reveals distinct variations in diffuse solar radiation across locations: Warri experiences its peak (10.6298 $MJm^{-2}day^{-1}$) in March and a dip in July (8.3896 $MJm^{-2}day^{-1}$); Benin observes its highest level in April (10.7804 $MJm^{-2}day^{-1}$) and lowest in December (8.5304 $MJm^{-2}day^{-1}$); the maximum value for Ikeja was found in March (10.4285 $MJm^{-2}day^{-1}$) and minimum in December (8.4420 $MJm^{-2}day^{-1}$) occur during the dry season; and Ogoja records its highest in March (10.9047 $MJm^{-2}day^{-1}$) and lowest in December (7.8235 $MJm^{-2}day^{-1}$).This indicates significant seasonal impact on solar radiation in these coastal regions. The highest and lowest monthly averaged mean diffuse solar radiation was recorded in Ogoja and Ikeja respectively.

Keywords: Atmospheric pressure, diffuse solar radiation, mean temperature, seasonal variations, wind speed.

INTRODUCTION

Solar radiation data forms the cornerstone of a wide array of technologies that harness solar energy, as emphasized by Liu *et al*., (2018), this data is not merely a collection of numbers; it is a critical resource in the realm of solar energy applications. It plays a pivotal role in numerous stages of solar technology utilization, including the initial design phase, the intricate process of simulation, and the thorough analysis of device performance. Among the various elements of solar radiation, diffuse solar radiation (H_d) stands out due to its significant importance (Liu *et al*., (2018).

Solar radiation, encompassing both direct and diffuse components, is a crucial measure in understanding Earth's energy balance and climate dynamics. Direct solar radiation arrives straight from the Sun, while diffuse radiation is sunlight scattered by molecules and particles in the atmosphere (Iqbal, 1983). Ground-based measurements of this combined solar influx are accurately captured using pyranometers. Additionally, for broader spatial coverage, satellite-based remote sensing offers an effective method for measuring solar radiation. These satellites, equipped with advanced sensors, can continuously monitor and record solar radiation levels across

DOI: 10.56892/bima.v8i1.633

various parts of the Earth, providing valuable data for climatological studies, solar energy applications, and environmental monitoring (Katiyar and Pandey, 2013; Olomiyesan *et al*., 2017). Several studies have been carried out to develop solar radiation models around the globe. More recently Akpootu *et al*. (2019a,b,c,d); Akpootu and Abdullahi (2022); Akpootu *et al*., (2022); Akpootu *et al*., (2023) and Salifu *et al.,* (2024) among others, developed new models for estimating global solar radiation across some selected locations in Nigeria.

Previous studies such as Okundamiya and Nzeako, 2011; Adaramola, 2012; Sanusi and Abioye, 2013; Akpootu and Mustapha, 2015; Akpootu *et al*., 2015 and Alkasim *et al*., 2017 has developed models for estimating/predicting diffuse solar radiation. However, no record of study investigating the influence of meteorological parameters on diffuse solar radiation across the coastal region of Nigeria has been found.

The aim of this study is to investigate the impact of some meteorological parameters on diffuse solar radiation across the coastal region of Nigeria.

THEORETICAL CONSIDERATIONS

Renewable energy can be defined as energy sources that are not depleted over time rather are naturally replenished and have little or no negative environmental impact like the non-renewable sources. Examples of renewable energy sources are: biomass, geothermal, hydropower, solar energy and wind energy (Myers, 2013).

Solar energy is the energy produced and radiated by the sun. This energy is radiated in the form of electromagnetic waves. This energy consist of UV radiation, visible light, infrared radiation and radio waves (Myers, 2013).

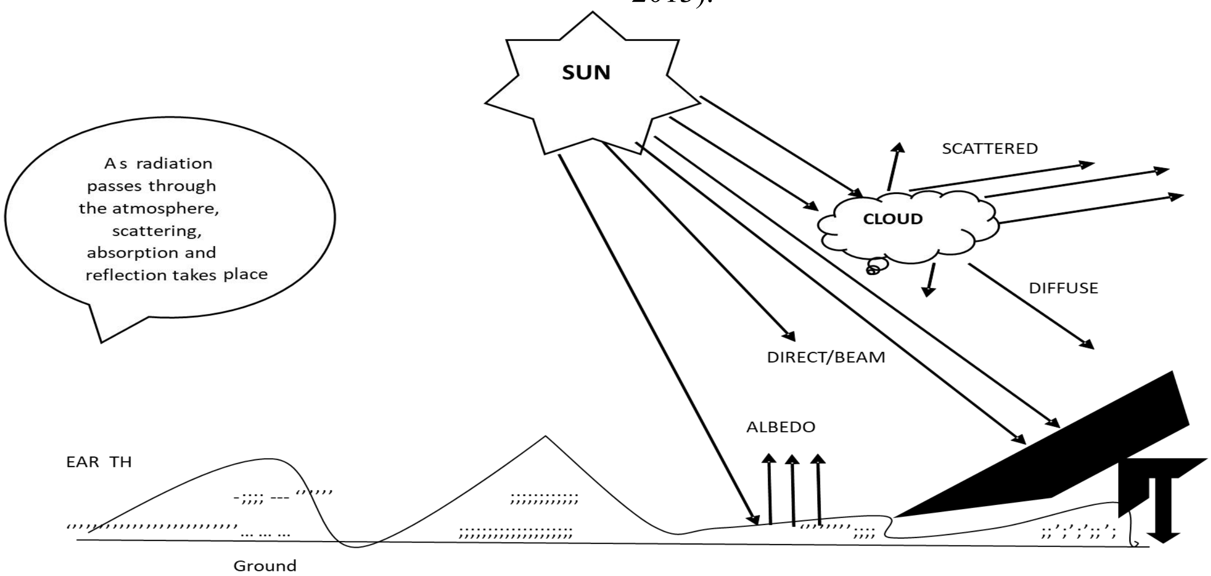

Figure 1: Solar radiation components segregated by the atmosphere and surface.

Figure 1 shows how the solar radiation from the sun reaches the earth, bringing about the direct, reflected and diffuse solar radiation. Extraterrestrial solar radiation is defined as the solar radiation incident on the outer atmosphere of the earth. On average, the extraterrestrial irradiance is 1367 Wm^{-2} (Iqbal, 1983). On the other hand, terrestrial solar radiation is the solar radiation that reaches the earth surface after passing through the earth's atmosphere. The intensity of terrestrial solar radiations is far lesser than that of extraterrestrial due to the atmospheric absorption, scattering and reflection that takes place in the atmosphere and earth's surface (Goswami, 2015).

DOI: 10.56892/bima.v8i1.633

Global solar radiation is the sum of direct (beam) radiation and diffuse solar radiation (Iqbal, 1983).

Reflected solar radiation is the amount of solar radiation reflected from the surface of the earth or objects with reflective affinity which brings about a term known as Albedo (Akpootu and Iliyasu, 2017; Akpootu *et al*, 2020; Akpootu *et al*., 2023b,c).

Albedo is the measure of the fraction of solar radiation reflected by a surface. Albedo is a dimensionless quantity that ranges from 0 – 1. A perfect black body has an albedo of 0, while a perfect white body has an albedo of 1. The average albedo of the earth is 0.3 i.e 30% of solar radiation that reaches the earth is reflected back into the atmosphere/space (Goswami, 2015).

Direct solar radiation is also known as Beam radiation; it is the solar radiation that reaches the surface of the earth without being diffused or scattered. Direct solar radiation is most intense when the sun is directly overhead. It can be measured by the aid of a pyrheliometer (Klucher, 1991). Diffuse solar radiation is also known as sky radiation (or scattered radiation). It is the radiation that reaches the earth's atmosphere after being scattered by any of air molecules, water vapour, clouds, dust, pollutants from power plants, forest fires, and volcanoes emissions in the atmosphere. Atmospheric aerosols also plays a significant role in scattering and absorption of incoming solar radiation. They have impact on the earth's radiation balance (Tijjani and Akpootu, 2012; Akpootu and Gana, 2013; Meseke *et al*., 2022; Sharafa *et al*., 2023; Akpootu *et al*., 2023d,e). Diffuse solar radiation is measured with the aid of a Pyranometer. The intensities of diffuse solar radiation can be affected by some factors namely: Sun Angle, cloud cover, atmospheric compositions and the albedo of the underlying surface. On the sun angle, the intensity of diffuse solar radiation is higher when the sun is closer to the horizon, while in terms of the cloud cover, the intensity is higher when there are dense cloud cover which enhances more scattering. On the atmospheric composition, it is the quantity/concentration of aerosols and other particles in the atmosphere that significantly affects the intensity of diffuse solar radiation. Finally, the earth's surface reflectivity influences the amount of diffuse radiation that reaches a particular location. That's the reason why dark surfaces absorbs more diffuse radiations while bright surfaces reflects more diffuse radiation (Iqbal 1983; Myers, 2013; Duffie and Beckman, 2013).

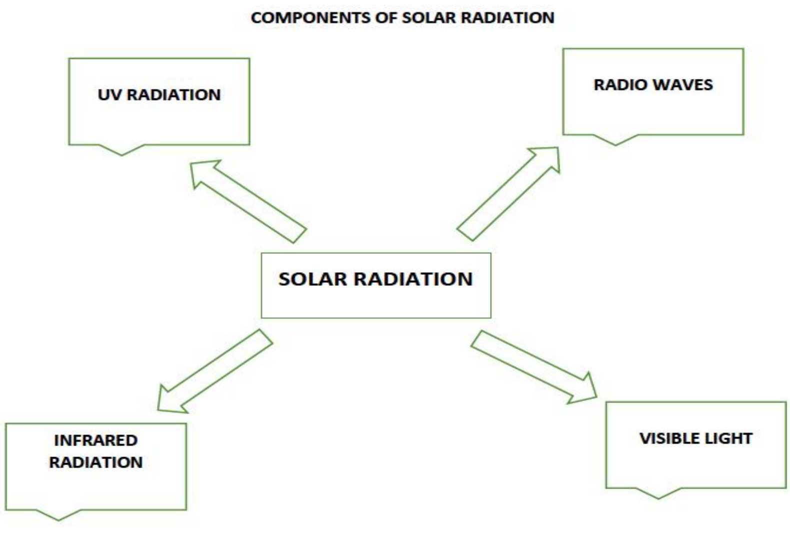

Figure 2: Components of Solar Radiation (Authors)

DOI: 10.56892/bima.v8i1.633

Figure 2 shows the distinctive components of solar radiation: Visible light, infrared, UV and radio waves. Visible light plays a crucial role in photosynthesis; UV radiation have both beneficial and harmful effects on human health whereby exposure to UV can stimulate vitamin D while excess exposure can lead to sun burns, skin care and eye damage; Infrared radiation is responsible for the warmth we feel from sunlight alongside other roles played in heating, remote sensing and communications; Radio waves plays vital role in radio communications, navigation and satellite imagery (Liou, 1980; Iqbal, 1983).

Diffuse radiation data serves multiple important functions across various fields. In solar energy assessment, this data is critical for evaluating solar energy potential at specific locations. It's particularly vital for ensuring consistent power generation in cloudy conditions, as diffuse radiation significantly contributes to the energy yield of solar photovoltaic (PV) systems, especially when direct sunlight is scarce. In the realm of climate modeling, diffuse radiation data is integrated into models to enhance the understanding and prediction of climate change. Accurate representation of sunlight scattering in the atmosphere enables these models to more effectively simulate the impact of clouds, aerosols, and other atmospheric elements on solar radiation, aiding in the development of strategies for climate change mitigation and adaptation (Goswami, 2015).

Furthermore, in agricultural planning, knowledge of diffuse solar radiation assists in determining the suitability of crops, scheduling irrigation, and maximizing agricultural output under different cloud cover scenarios. This type of radiation is particularly important for the growth of shade-tolerant crops, which flourish in lower-intensity light. Farmers utilize this information to make strategic decisions about crop types, planting times, and irrigation methods to boost productivity. In weather forecasting, diffuse radiation data enhances the accuracy of predictions regarding cloud cover, precipitation, and temperature changes. This is essential for various sectors like transportation, agriculture, and energy to anticipate and mitigate weather-related impacts. Lastly, in building design and energy efficiency, understanding diffuse radiation aids in creating buildings that efficiently use natural light and energy. Architects and engineers use this data to optimize natural light usage, decreasing artificial lighting needs and energy consumption. Additionally, the application of diffuse radiation in passive solar design contributes to heating and cooling buildings, thereby increasing energy efficiency and reducing dependence on traditional energy sources (Iqbal, 1983; Myers, 2013; Goswami, 2015).

METHODOLOGY

Data Collection and Processing

For this study, twenty-two (22) years (2001-2022) monthly average climatic data for Warri, Benin, Ikeja and Ogoja, all of which are coastal areas of Nigeria, was acquired. The data include measurements of diffuse solar irradiance, global solar radiation, wind speed, mean temperatures, surface pressure, and relative humidity. The data was obtained from the National Aeronautics and Space Administration (NASA) website. The diffuse solar radiation and global solar radiation data was in $Kwhm^{-2}day^{-1}$ which was converted to $MJm^{-2}day^{-1}$ by a conversion factor thus, 1 $Kwhm^{-2}day^{-1}$ = 3.6 $MJm^{-2}day^{-1}$ (Akpootu and Rabiu , 2019). The surface pressure in kPa was converted to hPa: by multiplying with 10. The wind speed is in ms^{-1}, mean temperature in (^oC) and relative humidity in (%).

DOI: 10.56892/bima.v8i1.633

Table 1: The studied locations geographical parameters

Coastal Zone	Latitude	Longitude	State	Elevation (m)
Warri	5.52 °N	5.73 °E	Delta	6.10
Benin	6.32 °N	5.10 °E	Edo	77.80
Ikeja	6.58 °N	3.33 °E	Lagos	39.40
Ogoja	6.67 °N	8.80 °E	Cross River	117.00

Graph Plotting

The Origin Pro software version 2018 was employed to plot the graphs. The Double – Y plots was carried out between the diffuse solar radiation and other meteorological parameters to investigate their impact on the diffuse solar radiation.

RESULTS AND DISCUSSIONS

Diffuse Solar Radiation with Meteorological Parameters for Warri

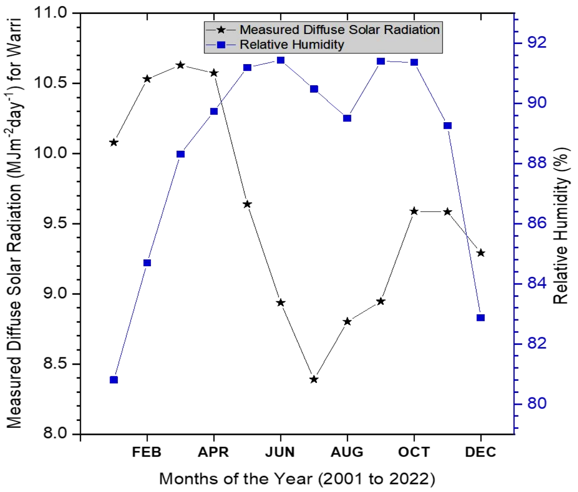

Figure 3: Monthly Variation of Measured Diffuse Solar Radiation with Relative Humidity during the period of twenty- two years (2001 – 2022) for Warri.

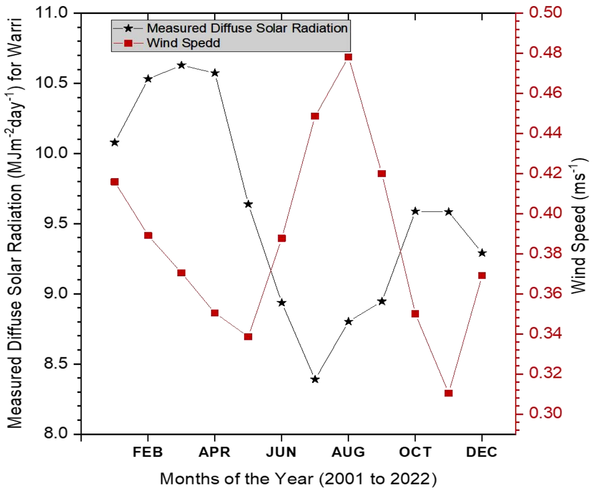

Figure 4: Monthly Variation of Measured Diffuse Solar Radiation with Wind Speed during the period of twenty- two years (2001 – 2022) for Warri.

Figure 3 shows the monthly variation of the measured diffuse solar radiation with relative humidity for Warri during the period of study. Clear observations shows that both the measured diffuse solar radiation and relative humidity increased from the month of January to March, when the diffuse solar radiation decreased steadily to its minimum with value 8.3896 $MJm^{-2}day^{-1}$ in the month of July, the relative humidity was increasing from March to its peak with the value of 91.4450 % in the month of June, it decreased to September, increased thereafter to October and later decreased steadily to December. The average relative humidity during the rainy and dry seasons were respectively 90.7342 % and 85.1925 % indicating that the atmospheric moisture content is higher in the rainy season than the dry season.

Figure 4 shows the monthly variation of the measured diffuse solar radiation with wind speed for Warri during the period of study. Clear observations shows that the wind speed decreased from the month of January to May, then, increased steadily to the month of August where it peaked with the value 0.4782 ms^{-1}, from August there was a deep decrease to November. The measured diffuse solar radiation was observed to increase from January to March where it peaked with the value 10.6298 $MJm^{-2}day^{-1}$, then, it decreased deeply down to its minimum with the value 8.3896 $MJm^{-2}day^{-1}$ in the month of July. The average measured diffuse solar radiation during the rainy and dry seasons were 9.2679 $MJm^{-2}day^{-1}$ and 10.0231 $MJm^{-2}day^{-1}$ respectively, which indicates that the diffuse solar radiation is higher during the dry season than the rainy season for the location under study. The average wind speed during the rainy and dry seasons were respectively 0.3962 ms^{-1} and 0.3710 ms^{-1}, which implies that the wind speed is higher during the rainy season than the dry season.

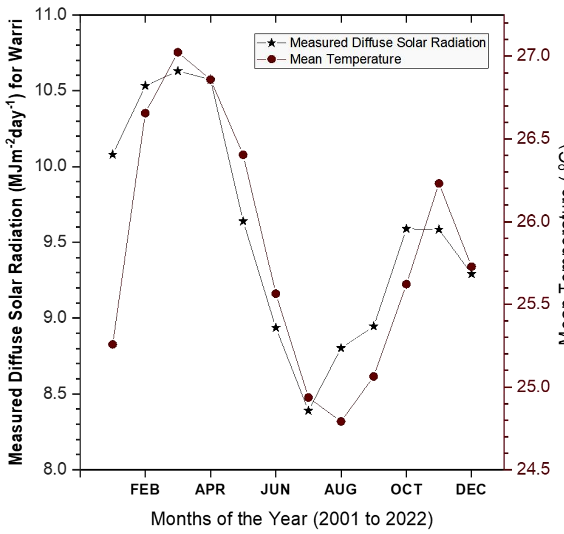

Figure 5: Monthly Variation of Measured Diffuse Solar Radiation with Mean Temperature during the period of twenty- two years (2001 – 2022) for Warri.

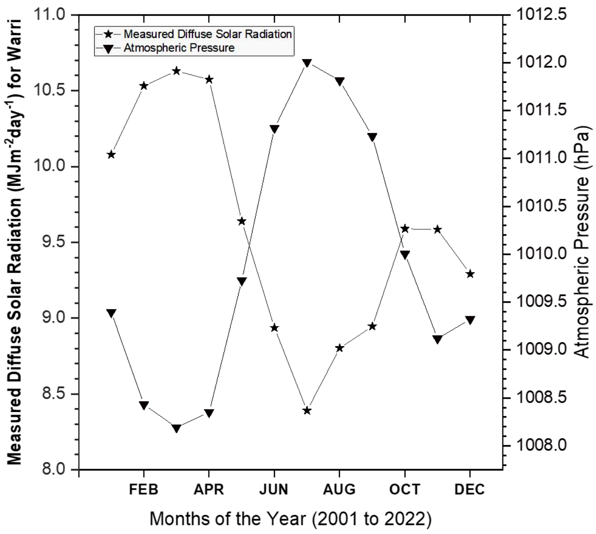

Figure 6: Monthly Variation of Measured Diffuse Solar Radiation with Atmospheric Pressure during the period of twenty- two years (2001 – 2022) for Warri.

Figure 5 shows the monthly variation of the measured diffuse solar radiation with the mean temperature for Warri during the period of study. Clear observations shows that both the measured diffuse solar radiation and the mean temperature increased from January to March, where they both got peaked with the respective values of 10.6298 $MJm^{-2}day^{-1}$ and 27.0241 °C. Both equally decreased from March to July. The mean temperature and the diffuse solar radiation were observed to also increase from August to October. The average mean temperature during the rainy and dry seasons were 25.6059 °C and 26.1793 °C respectively, which implies that the mean temperature is higher during the dry season than the rainy season.

Figure 6 shows the monthly variation of the measured diffuse solar radiation with the atmospheric pressure for Warri during the period of study. Observation shows that while the measured diffuse solar radiation increased from January to March, the atmospheric pressure decreased along same months. So more, while the atmospheric pressure increased from March to July, the measured diffuse solar radiation decreased along same months. When diffuse solar radiation increased from July to October, the atmospheric pressure decreased along same months. While the atmospheric pressure peaked with 1012.0091 hPa in July, the diffuse solar radiation was at its minimum with 8.3896 $MJm^{-2}day^{-1}$. Likewise, when the diffuse solar radiation peaked with the value of 10.6298 $MJm^{-2}day^{-1}$ in the month of March, the atmospheric pressure was at its minimum with value 1008.1909 hPa. The average atmospheric pressure during the rainy and dry seasons were 1010.6364 hPa and 1008.8918 hPa respectively indicating that the atmospheric pressure is higher during the rainy season than in the dry season. For the location under study. The atmospheric pressure and the measured diffuse solar radiation as evident seen in the figure above are exhibiting inverse relationships.

Bima Journal of Science and Technology, Vol. 8(1B) Apr, 2024 ISSN: 2536-6041

DOI: 10.56892/bima.v8i1.633

Diffuse Solar Radiation with Meteorological Parameters for Benin

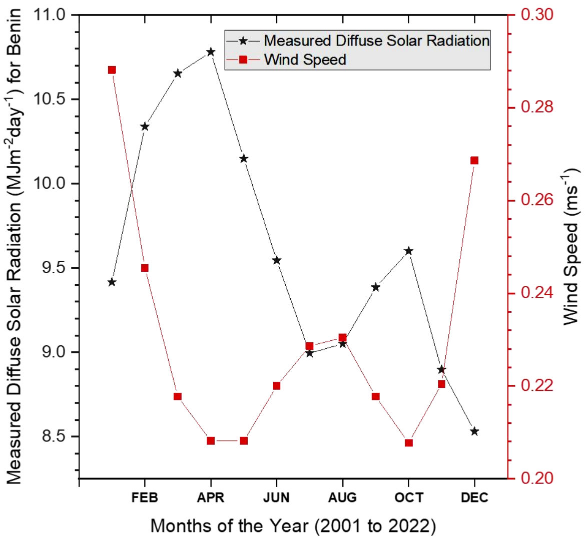

Figure 7: Monthly Variation of Measured Diffuse Solar Radiation with Wind speed during the period of twenty- two years (2001 – 2022) for Benin.

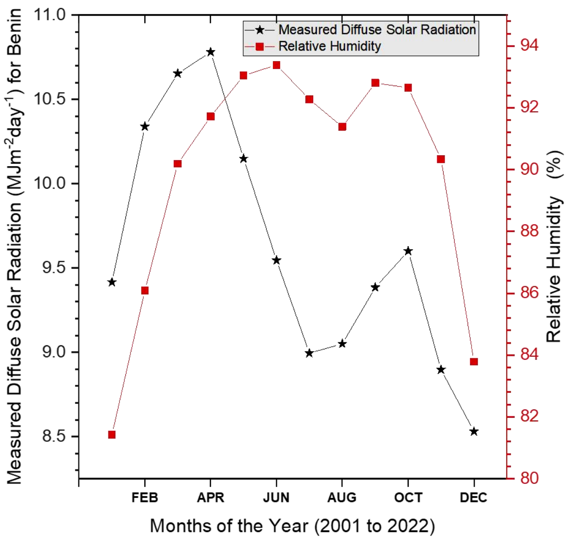

Figure 8: Monthly Variation of Measured Diffuse Solar Radiation with Relative Humidity during the period of twenty- two years (2001 – 2022) for Benin.

Figure 7 shows the monthly variation of the measured diffuse solar radiation with wind speed for Benin during the period of study. It was observed that as diffuse solar radiation increases from January to April (where it peaked at a value of 10.7804 $MJm^{-2}day^{-1}$) wind speed decreases within same months. While diffuse solar radiation was decreasing from April to July, the wind speed was increasing from the month of April to August. When the measured diffuse solar radiation peaked at the value 10.7804 $MJm^{-2}day^{-1}$ in April (which is the rainy season), the wind speed peaked at 0.2882 ms^{-1} in January (which is dry season). The average wind speed during the rainy and dry seasons were observed to be 0.2173 ms^{-1} and 0.2481 ms^{-1} respectively, indicating that the wind speed is higher in the dry season than the rainy season. Wind speed had its lowest value of 0.2077 ms^{-1} in October. The average diffuse solar radiation during the rainy and dry season were found to be 9.6436 $MJm^{-2}day^{-1}$ and 9.5668 $MJm^{-2}day^{-1}$ respectively which implies that the diffuse solar radiation is higher during the rainy season.

Figure 8 shows the monthly variation of the measured diffuse solar radiation with relative humidity for Benin during the period of study. It is observed that the diffuse solar radiation and relative humidity increased from January to April; while the diffuse solar radiation peaked in April, the relative humidity peaked in June with a value of 93.3877 %. The lowest value of relative humidity was observed in January with a value of 81.4205 % while that of diffuse solar radiation was in December with a value of 8.5304 $MJm^{-2}day^{-1}$. Both diffuse solar radiation and relative humidity were seen to decrease from October to December. A trough was observed for both diffuse solar radiation and relative humidity from the month of June to September with the lowest point of both troughs being in August during the expected August break. The average value of relative humidity for the rainy and dry season are 92.4651 % and 86.3648 % respectively, which indicates that the atmospheric moisture contents are higher during the rainy season than the dry season as this was expected.

Bima Journal of Science and Technology, Vol. 8(1B) Apr, 2024 ISSN: 2536-6041

DOI: 10.56892/bima.v8i1.633

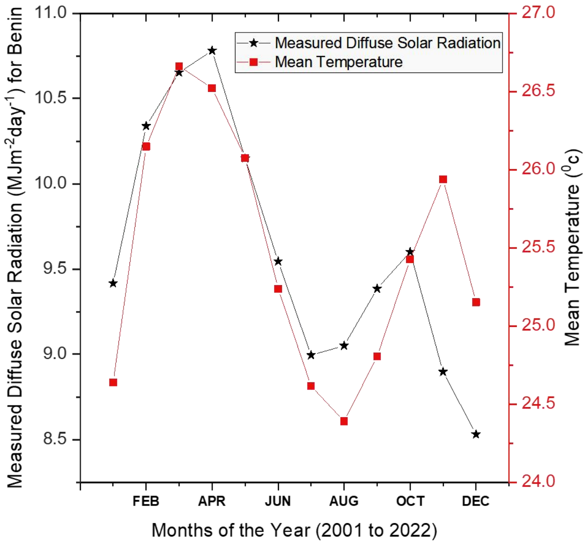

Figure 9: Monthly Variation of Measured Diffuse Solar Radiation with Mean Temperature during the period of twenty- two years (2001 – 2022) for Benin.

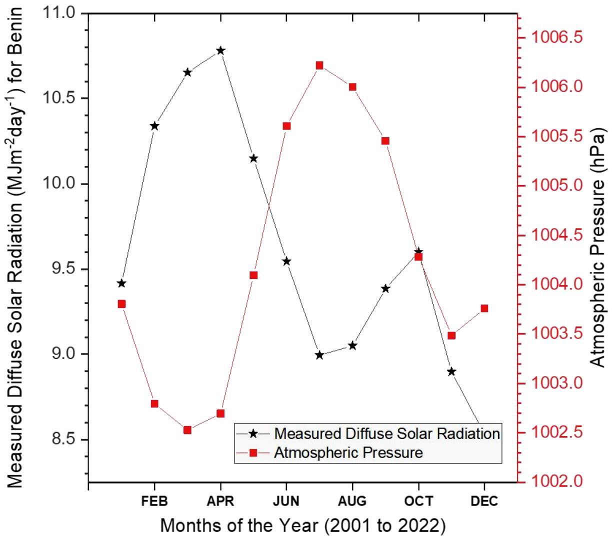

Figure 10: Monthly Variation of Measured Diffuse Solar Radiation with Atmospheric Pressure during the period of twenty- two years (2001 – 2022) for Benin.

Figure 9 shows the monthly variation of the measured diffuse solar radiation with mean temperature for Benin during the period of study. It was observed that both the mean temperature and measured diffuse solar radiation increased from January to March while the mean temperature peaked at 26.6614 °C in March, the diffuse solar radiation increased further to peak at 10.7804 $MJm^{-2}day^{-1}$ in April while the mean temperature was already decreasing steadily to its lowest value at 24.3900 °C in August and later increased in November (the beginning of the dry season) and then dropped to December. The average value of the mean temperature in the rainy and dry season are 25.2957 °C and 25.7076 °C respectively, which shows that the mean temperature are higher during the dry season than the rainy season for the location under study.

Figure 10 shows the monthly variation of the measured diffuse solar radiation with atmospheric pressure for Benin during the period of study. It was observed that the atmospheric pressure decreased from January to its minimum value in March with 1002.5273 hPa while the measured diffuse solar radiation increased to April. The measured diffuse solar radiation peaked at 10.7804 $MJm^{-2}day^{-1}$in April and started decreasing downward to the month of July, while atmospheric pressure started increasing from March to peak at 1006.227 hPa in July, thereafter, it started decreasing to November and, then, increased slightly to December. The average values of atmospheric pressure during the rainy and dry seasons are 1004.9097 hPa and 1003.2745 hPa respectively, indicating that the atmospheric pressure are higher during the raining season. It is equally observed that the atmospheric pressure and measured diffuse solar radiation exhibits an inverse relationship.

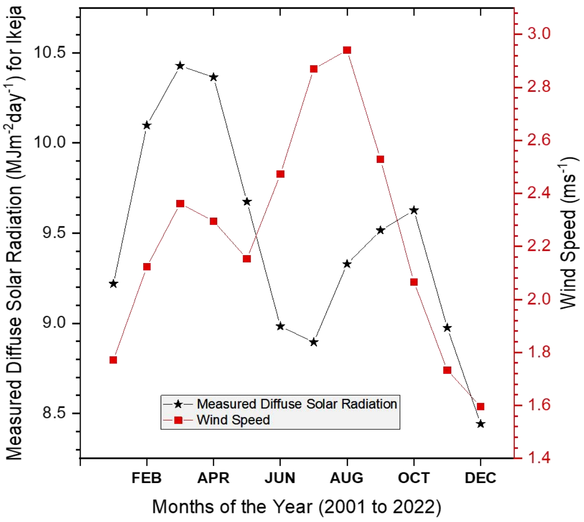

Figure 11: Monthly Variation of Measured Diffuse Solar Radiation with Wind Speed during the period of twenty- two years (2001 – 2022) for Ikeja.

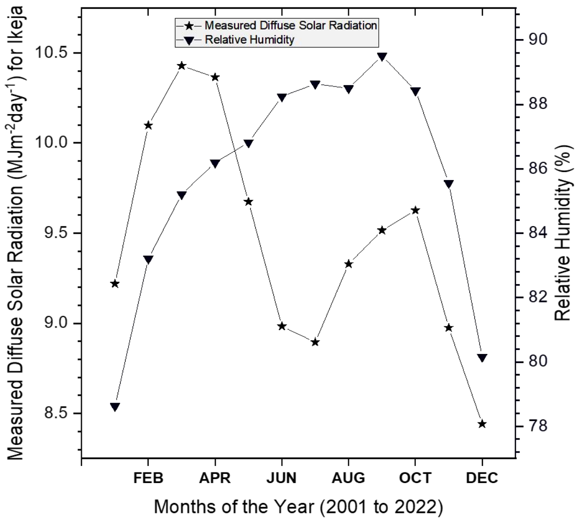

Figure 12: Monthly Variation of Measured Diffuse Solar Radiation with Relative Humidity during the period of twenty- two years (2001 – 2022) for Ikeja.

Figure 11 shows the monthly variation of the measured diffuse solar radiation with wind speed for Ikeja during the period of study. It was observed that both the measured diffuse solar radiation and wind speed increased from January to March, then both later decreased to May; when the diffuse solar radiation decreased further to June, the wind speed increased steadily to peak at 2.9405 ms^{-1} in the month of August before it began to decrease steadily to December. The diffuse solar radiation and wind speed had their respective minimum values of 8.4420 $MJm^{-2}day^{-1}$ and 1.5955 ms^{-1} in the month of December. The average wind speed during the rainy and dry seasons are 2.4751 ms^{-1} and 1.9173 ms^{-1} respectively, indicating that the wind speed is higher during the rainy season. The average diffuse solar radiation during the rainy and dry seasons are 9.4841 $MJm^{-2}day^{-1}$ and 9.4327 $MJm^{-2}day^{-1}$ respectively which shows that the diffuse solar radiation is higher during the rainy season than in the dry season.

Figure 12 shows the monthly variation of the measured diffuse solar radiation with relative humidity for Ikeja during the period of study. It was observed that both the relative humidity and the measured diffuse solar radiation increased from the month of January to March and also from July to October after which they both gradually decrease to the month of December. It was also observed that while the measured diffuse solar radiation peaked in the month of March with the value of 10.4285 $MJm^{-2}day^{-1}$, the relative humidity peaked in the month of September with the value of 89.5077 %. The relative humidity had its minimum value of 78.6286 % in the month of January. The average relative humidity during the rainy and dry seasons are 88.0479 % and 82.5514 % respectively, indicating that the relative humidity is higher during the rainy season than in the dry season.

DOI: 10.56892/bima.v8i1.633

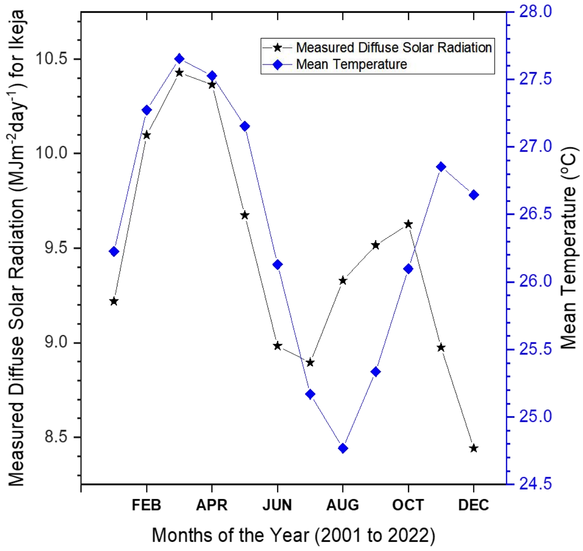

Figure 13: Monthly Variation of Measured Diffuse Solar Radiation with Mean Temperature during the period of twenty- two years (2001 – 2022) for Ikeja.

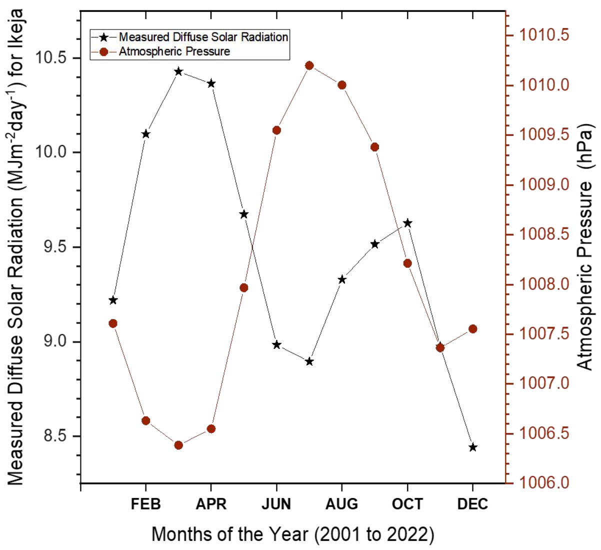

Figure 14: Monthly Variation of Measured Diffuse Solar Radiation with Atmospheric Pressure during the period of twenty- two years (2001 – 2022) for Ikeja.

Figure 13 shows the monthly variation of the measured diffuse solar radiation with the mean temperature for Ikeja during the period of study. It was observed that both the mean temperature and the measured diffuse solar radiation increased steadily from the month of January to March where they both peaked with the values of 27.6523 ^{o}C and 10.4285 MJm^{-2}day^{-1} respectively. A steady decrease was also observed for both the mean temperature and diffuse solar radiation from March to July, the mean temperature decreased further to its minimum in the month of August, later increased to November before it decreased to December. The average mean temperature during the rainy and dry seasons are 26.0265 ^{o}C and 26.9300 ^{o}C respectively which indicates that the mean temperature is higher during the dry season than in the rainy season.

Figure 14 shows the monthly variation of the measured diffuse solar radiation with the atmospheric pressure for Ikeja during the period of study. It was observed that as the measured diffuse solar radiation increased from the month of January to march, the atmospheric pressure decreased along same months. While the diffuse solar radiation peaked with the value 10.4285 MJm^{-2}day^{-1} in March, the atmospheric pressure was at its minimum with value of 1006.3864 hPa. When the diffuse solar radiation began to decrease from March to July, the atmospheric pressure increased steadily along same months and further to more to July where it peaked with the value 1010.2000 hPa. A steady decrease from July to November was observed for the atmospheric pressure while the measured diffuse solar radiation increased from July to October and decreased to December'(its minimum with value 8.4420 MJm^{-2}day^{-1}). The average atmospheric pressure during the rainy and dry seasons are 1008.8383 hPa and 1007.1091 hPa respectively which indicates that the atmospheric temperature is higher during the rainy season than the in the dry season.

DOI: 10.56892/bima.v8i1.633

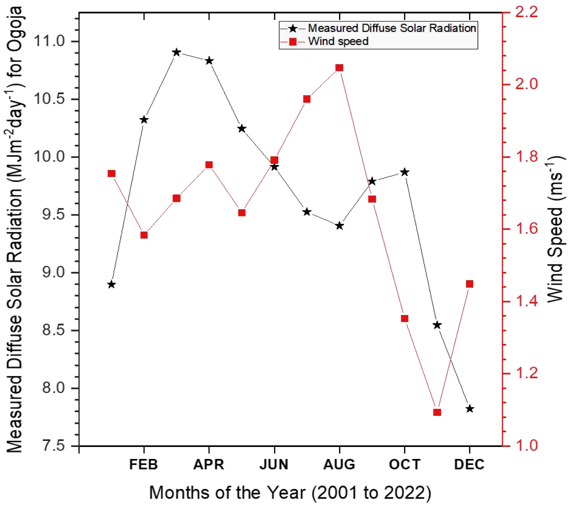

Figure 15: Monthly Variation of Measured Diffuse Solar Radiation with Wind speed during the period of twenty- two years (2001 – 2022) for Ogoja.

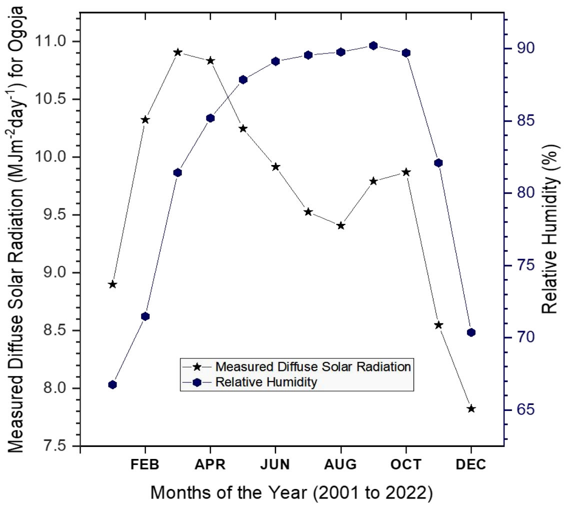

Figure 16: Monthly Variation of Measured Diffuse Solar Radiation with Relative Humidity during the period of twenty- two years (2001 – 2022) for Ogoja.

Figure 15 shows the monthly variation of the measured diffuse solar radiation with wind speed for Ogoja during the period of study. It was observed that while the measured diffuse solar radiation increased from January to March (where it peaked with a value of 10.9047 $MJm^{-2}day^{-1}$) the wind speed decreased from January to February, then increased to April and decreased to May from where it steadily increased to peak with a value of 2.0477ms^{-1} in the month of August then decreased deeply to its minimum with a value of 1.0936ms^{-1} in December. The measured diffuse solar radiation was observed to decrease from March to August, then increased to October before gradually decreasing to its minimum in December with the value 7.8235 $MJm^{-2}day^{-1}$. The average wind speed during the rainy and dry seasons were 1.7516 ms^{-1} and 1.5133 ms^{-1} respectively indicating that the wind speed is higher during the rainy season than in the dry season. The average measured diffuse solar radiation during the rainy and dry seasons were 9.9404 $MJm^{-2}day^{-1}$ and 9.2991 $MJm^{-2}day^{-1}$ respectively, implying that the diffuse solar radiation is higher during the rainy season than in the dry season.

Figure 16 shows the monthly variation of the measured diffuse solar radiation with relative humidity for Ogoja during the period of study. It was observed that both the measured diffuse solar radiation and the relative humidity increased from the month of January to March; the relative humidity increased further to peak with a value of 90.2118 % in the month of September then decreased deeply and steadily to December. Meanwhile, the diffuse solar radiation peaked in the month of March with the value 10.9047 $MJm^{-2}day^{-1}$, it then decreased from March to August and later increased to October before decreasing to its minimum in the month of December. The average relative humidity during the rainy and dry seasons were 88.7747 % and 74.4247 % respectively, which implies that the atmospheric moisture content is higher during the rainy season than the dry season.

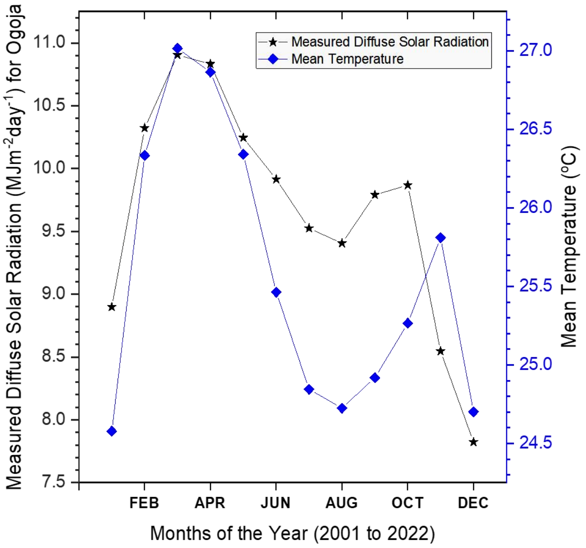

Figure 17: Monthly Variation of Measured Diffuse Solar Radiation with Mean Temperature during the period of twenty- two years (2001 – 2022) for Ogoja.

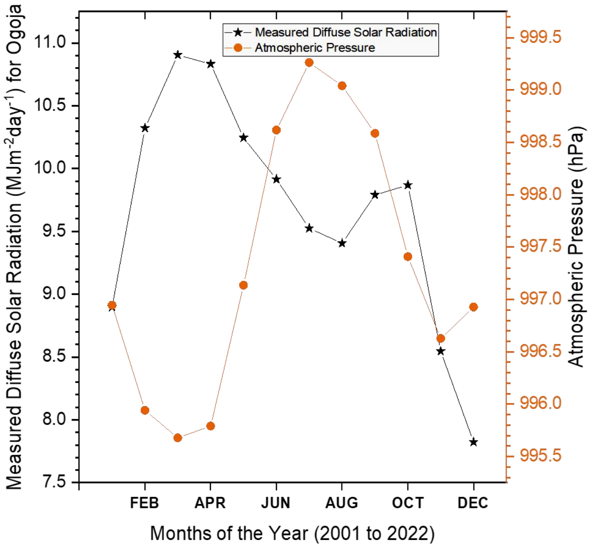

Figure 18: Monthly Variation of Measured Diffuse Solar Radiation with Atmospheric Pressure during the period of twenty- two years (2001 – 2022) for Ogoja.

Figure 17 shows the monthly variation of the measured diffuse solar radiation with the mean temperature for Ogoja during the period of study. It was observed that both the measured diffuse solar radiation and the mean temperature increased from January to March and both peaked with the values of 10.9047 $MJm^{-2}day^{-1}$ and 27.0159 ^{O}C respectively in the month of March and both later decreased from March to August. While the mean temperature increased from August to November, the diffuse solar radiation increased to October and decreased deeply to December which is its minimum with the value of 7.8235 $MJm^{-2}day^{-1}$. The average mean temperature during the rainy and dry seasons were 25.4888 ^{o}C and 25.68791 ^{o}C respectively indicating that the mean temperature is higher during the dry season than the rainy season.

Figure 18 shows the monthly variation of the measured diffuse solar radiation with atmospheric pressure for Ogoja during the period of study. It was observed that while the atmospheric pressure decreased from January to March, the measured diffuse solar radiation increases along same months. When the atmospheric pressure increased from March to July, the diffuse solar radiation decreased from July to August then increased to October and decreased to December. When the diffuse solar radiation peaked in the month of March with the value 10.9047 $MJm^{-2}day^{-1}$, the atmospheric pressure was at its minimum in same March with value 995.6773 hPa. The atmospheric pressure and the measured diffuse solar radiation exhibited an inverse relationship. The average atmospheric pressure during the rainy and dry season were 997.9779 hPa and 996.4236 hPa respectively, indicating that the atmospheric pressure is higher during the rainy season than in the dry season.

Bima Journal of Science and Technology, Vol. 8(1B) Apr, 2024 ISSN: 2536-6041

DOI: 10.56892/bima.v8i1.633

Correlation of the Measured Diffuse Solar Radiation across the Coastal Region of Nigeria

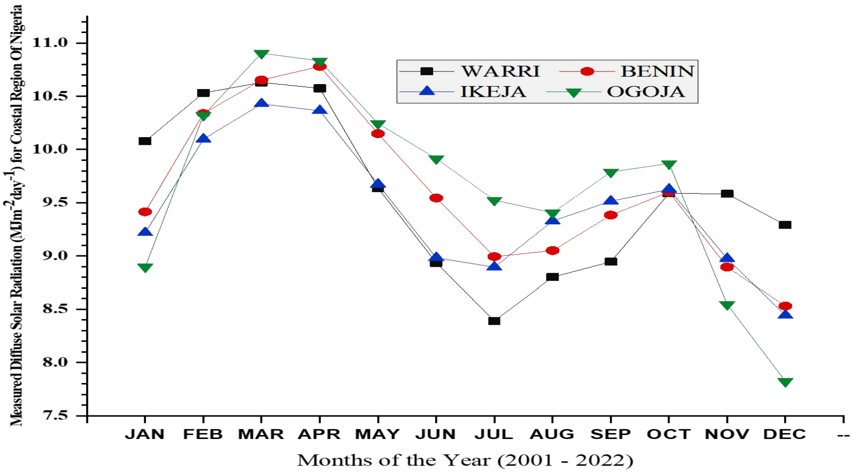

Figure 19: Comparison of the measured diffuse solar radiation across the coastal region of Nigeria under study from the period 2001 - 2022

As depicted in figure 19, in Warri, the analysis of diffuse solar radiation revealed a distinct seasonal pattern. The highest value, reaching 10.6298 $MJm^{-2}day^{-1}$, was recorded in March, coinciding with the dry season. In contrast, the lowest value, dropping to 8.3896 $MJm^{-2}day^{-1}$, occurred in July during the rainy season. The study's findings for Benin showed that the highest level of diffuse solar radiation occurred in April, during the rainy season, measuring 10.7804 $MJm^{-2}day^{-1}$. In contrast, the lowest value was recorded in December, amidst the dry season, at 8.5304 $MJm^{-2}day^{-1}$. In Ikeja, the study revealed that during the dry season, the maximum diffuse solar radiation was recorded in March, reaching 10.4285 $MJm^{-2}day^{-1}$. Conversely, the minimum level was observed in December, with a value of 8.4420 $MJm^{-2}day^{-1}$, also during the dry season. In Ogoja, the study's results showed that the peak and lowest levels of diffuse solar radiation occurred during the dry season. Specifically, the highest value was recorded in March at 10.9047 $MJm^{-2}day^{-1}$, while the lowest was in December, measuring 7.8235 $MJm^{-2}day^{-1}$.

The monthly average mean diffuse solar radiation in the Coastal region were found to be 9.5825 $MJm^{-2}day^{-1}$, 9.6116 $MJm^{-2}day^{-1}$, 9.4627 $MJm^{-2}day^{-1}$ and 9.6732 $MJm^{-2}day^{-1}$ for Warri, Benin, Ikeja and Ogoja respectively indicating that the highest and lowest values of diffuse solar radiation were found to be in Ogoja and Ikeja respectively.

CONCLUSION

The impact of the meteorological parameters and diffuse solar radiation indicates fluctuations in their variations in all locations under study except for the atmospheric pressure that exhibits an inverse relationship with the diffuse solar radiation which indicates that when the atmospheric pressure is high, the diffuse solar radiation will be low and vice versa. In contrast, the mean temperature followed almost the same pattern in variations with the diffuse solar radiation for all the locations in the coastal region, which indicates that when the temperature is high, the diffuse solar radiation is expected to also be high, likewise a low temperature means low diffuse solar radiation. The seasonal variations in diffuse solar radiation across the locations under study shows distinct patterns: Warri peaks in March (10.6298 $MJm^{-2}day^{-1}$) and dips in July (8.3896 $MJm^{-2}day^{-1}$), Benin's highest is in April (10.7804 $MJm^{-2}day^{-1}$) with a December low (8.5304 $MJm^{-2}day^{-1}$), Ikeja reaches its maximum

(10.4285 $MJm^{-2}day^{-1}$) and minimum (8.4420 $MJm^{-2}day^{-1}$) during the dry season, and Ogoja records its highest (10.9047 $MJm^{-2}day^{-1}$) and lowest (7.8235 $MJm^{-2}day^{-1}$) levels in the dry season. This indicates that the highest and lowest values of diffuse solar radiation in the Coastal region of Nigeria were found in Ogoja based on the monthly variation.

Acknowledgements
The authors wish to acknowledge the management and staff of National Aeronautics and space Administration (NASA) for making all the data used in this study available online.

REFERENCES

Adaramola, M. S. (2012). Estimating Global Solar Radiation using Common Meteorological Data in Akure, Nigeria. *Renewable Energy, 47*, 38–44.

Akpootu, D. O. and Abdullahi, Z. (2022). Development of Sunshine Based Models For Estimating Global Solar Radiation Over Kano And Ikeja, Nigeria. *FUDMA Journal of Sciences (FJS)*, 6(3), 290-300. https://doi.org/10.33003/fjs-2022-0603-1001

Akpootu, D. O. and Mustapha, W. (2015). Estimation of Diffuse Solar Radiation for Yola, Adamawa State, North-Eastern, Nigeria. *International Research Journal of Engineering and Technology,* 2(8), 77-82.

Akpootu, D. O. and Rabiu, A. M. (2019). Empirical Models for Estimating Tropospheric Radio Refractivity over Osogbo, Nigeria. *The Open Atmospheric Science Journal*, 13, 43–55. DOI: 10.2174/1874282301913010043

Akpootu, D. O., Aruna, S., Bello, G., Aminu, Z., Isah, A. K., Umar, M., Badmus, T. O., Alaiyemola, S. R., Abdulsalam, M. K., Meseke, N. O and Abdullahi, Z (2023e). The Growth Factor and Bulk Hygroscopicity of Atmospheric Soot of Urban Aerosols. *FUDMA Journal of Sciences (FJS)*., Vol. 7 No. 3, June, 2022, pp 150 – 160. DOI: https://doi.org/10.33003/fjs-2023-0703-1832

Akpootu, D. O**.,** Bello, G., Alaiyemola, S. R., Abdullahi, Z., Aruna, S., Umar, M., Badmus, T. O., Isah, A. K., Abdulsalam, M. K and Aminu, Z (2023d). The Scattering and Absorption Coefficients of Atmospheric Soot in the Hygroscopicity of Urban Aerosols. *Dutse Journal of Pure and Applied Sciences (DUJOPAS)*, Vol. 9 No. 2b June 2023. 86 – 97

Akpootu, D. O., Iliyasu, M. I., Mustapha, W. and Aruna, S. (2015). Developing Empirical Models for Predicting Diffuse Solar Radiation over Yola, Adamawa State, North-Eastern, Nigeria. *International Research Journal of Engineering and Technology, 2(8)*, 113-121

Akpootu, D. O., Iliyasu, M. I., Olomiyesan, B. M., Fagbemi, S. A., Sharafa, S. B., Idris, M., Abdullahi, Z. and Meseke, N. O. (2022). Multivariate Models for Estimating Global Solar Radiation in Jos, *Nigeria. Matrix Science Mathematic*, 6(1), 5–12. http://doi.org/10.26480/mkmk.01.2022.05.12

Akpootu, D. O., Tijjani, B. I., and Gana, U. M. (2019c). New temperature dependent models for estimating global solar radiation across the midland climatic zone of Nigeria. *International Journal of Physical Research,* 7(2), 70–80. https://doi.org/10.14419/ijpr.v7i2.29214

Akpootu, D. O. and Iliyasu, M. I. (2017). Estimation of the Monthly Albedo of the Earth's Atmosphere over Sokoto, Nigeria. *Archives of Current Research International*, 7(3): 1–10. DOI: 10.9734/ACRI/2017/33196

DOI: 10.56892/bima.v8i1.633

Akpootu, D. O., Alaiyemola, S. R., Abdulsalam, M. K., Bello, G., Umar, M., Aruna, S. Isah A. K.,Aminu, Z., Abdullahi, Z., and Badmus, T. O. (2023a). Sunshine and Temperature Based Models for Estimating Global Solar Radiation in Maiduguri. Nigeria. *Saudi Journal of Engineering and Technology*, 8(5): 82-90.
DOI: 10.36348/sjet.2023.v08i05.001

Akpootu, D. O., and Gana, N. N. (2013). The Effect of Relative Humidity on the Hygroscopic Growth Factor and Bulk Hygroscopicity of Water Soluble Aerosols. *The International Journal Of Engineering And Science,* 2(11): 48–57.

Akpootu, D. O., Argungu, G. M., Umar, M., Iliyasu, M. I., Yusuf, A., Muhammad, N., Sidi,S. Sani, M. Y., Ibrahim, M., Abdullahi, Z., and Aruna, S. (2023c). Investigation of the Earth's Albedo Using Meteorological Parameters over Maiduguri, Nigeria. *Asian Journal of Research and Reviews in Physics*, 7(4): 57–67. 10.9734/AJR2P/2023/v7i4149

Akpootu, D. O., Okpala, C. N., Fagbemi, S. A., Iliyasu, M. I., Onwubuya, I. O., Salifu, S. I. and Garba, M. (2020). A Comparative Study on Estimation of the Earth's Albedo and Its Variation with other Meteorological Parameters between two Tropical Stations in Nigeria. *International Journal of Advances in Scientific Research and Engineering (ijasre)*, 6(2): 32–46. DOI: 10.31695/IJASRE.2020.33707

Akpootu, D. O., Umar, M. and Abdullahi, Z. (2023b). Investigation of the Earth's Albedo using Meteorological Parameters over Nguru, Nigeria. *Saudi Journal of Engineering and Technology*, 8(8), 200–208. DOI: 10.36348/sjet.2023.v08i08.002

Akpootu., D. O., Tijjani, B. I. and Gana, U. M. (2019a). A Comparative study of Time series, Empirical Orthogonal Transformation and Descriptive Statistical Analysis on Meteorological Parameters over Ogoja and Maiduguri. *Journal of Energy Research and Reviews*, 3(1), 1-14. https://doi.org/10.9734/JENRR/2019/v3i130088

Akpootu., D. O., Tijjani, B. I. and Gana, U. M. (2019d). New temperature dependent models for estimating global solar radiation across the coastal climatic zone of Nigeria. *International Journal of Advances in Scientific Research and Engineering (ijasre)*, 5(9), 126–141. https://doi.org/10.31695/IJASRE.2019.33523

Akpootu., D. O., Tijjani, B. I. and Gana, U. M. (2019b). Empirical models for predicting global solar radiation using meteorological parameters for Sokoto, Nigeria. *International Journal of Physical Research*, 7(2), 48 – 60. https://doi.org/10.14419/ijpr.v7i2.29160

Alkasim, A., Suberu, A. A. and Baba, M. T. (2017). Empirical Model for the Estimation of Global and Diffuse Solar Radiation in Yola-Nigeria, based on Sunshine Hours. *International Journal of Scientific & Engineering Research, 8*(2), 360–366.
DOI: http://doi.org/10.26480/ecr.02.2023.78.88

Duffie, J. A. and Beckman, W. (2013). *Solar Engineering of Thermal Processes, 4th Edition*. John Wiley and Sons Inc.

Goswami, D. Y. (2015). *Principles of Solar Engineering*. CRC Press.

Iqbal, M. (1983). *An Introduction to Solar Radiation*. Academic Press.

Katiyar, A. K. and Pandey, C. K. (2013). A Review of Solar Radiation Models—

Part 1. *Journal of Renewable Energy, 2013*, Article ID: 168048. https://doi.org/10.1155/2013/168048

Kuo-Nan Liou. (1980). *An Introduction to Atmospheric Radiation*. Academic Press Inc.

Li, D. H. W. and Lam, J. C. (2000). Solar Heat Gain Factors and the Implications for Building Designs in Subtropical Regions. *Energy and Buildings, 32*, 47–55. https://doi.org/10.1016/S0378-7788(99)00035-3

Liu, Z. J., Wu, D., Yu, H. C., Ma, W. S. and Jin, G. Y. (2018). Field measurement and numerical simulation of combined solar heating operation modes for domestic buildings based on the Qinghai-Tibetan plateau case. *Energy Build, 167*, 312–21.

Meseke, N. O., Akpootu, D. O., Falaiye, O. A., and Targema, T. V. (2022). Comparative assessment of particulate matter using low cost sensor: A case study of Abuja and Kano, Nigeria. *FUDMA Journal of Sciences (FJS)*, 6(4): 203-211. https://doi.org/10.33003/fjs-2022-0604-1066

Myers, R. D. (2013). *Solar Radiation: Practical Modeling for Renewable Energy*. CRC Press.

Nwokolo, S. C. and Ogbuezie, J. C. (2017). Modelling the Influence of Cloudiness on Diffuse Horizontal Irradiation under Various Sky Conditions over six Tropical Ecological Zones in Nigeria. *International Journal of Physical Sciences, 5*(2), 91-100. https://doi.org/10.14419/ijpr.v5i2.8312

Okundamiya, M. S. and Nzeako, A. N. (2011). Estimation of Diffuse Solar Radiation for Selected Cities in Nigeria. *International Scholarly Research Notices, 2011*, https://doi.org/10.5402/2011/439410

Olomiyesan, B. M., Oyedum, O. D., Ugwuoke, P. E. and Abolarin, M. S. (2017). Evaluation of some global solar radiation models in selected locations in Northwest, Nigeria. *Open Acc J Photoen, 1*(1): 00001. DOI: 10.15406/mojsp.2017.01.00001

Salifu, S. I., Hamza, B. S., Akpootu, D. O., Kola, T. A. and Yusuf, A. (2024). New Models For Estimation Of Diffuse Solar Radiation Using Meteorological Parameters For Benin, Nigeria. *FUDMA Journal of Sciences (FJS) Vol. 8 No. 1,* pp 155 - 166 https://doi.org/10.33003/fjs-2024-0801-2259

Sanusi, Y. K. and Abisoye, S. G. (2013). Estimation of diffuse solar radiation in Lagos, Nigeria. In *2nd International Conference on Chemical, Environmental and Biological Sciences (ICCEBS, 2013)* March 17-18, Dubai (UAE), pp. 6-9.

Sharafa, S. B., Aliyu, R., Ibrahim, B. B., Akpootu, D. O., Tijjani, B. I., Darma, T. H., Ayedun, F and Sulu, H. T (2023). Analysis of Aerosols in West Africa: Modelling and Radiative Forcing. *Environmental Contaminants Reviews (ECR).,* 6(2), 78 – 88.

Tijjani, B. I. and Akpootu, D. O. (2012). The Effect of Soot and water Soluble in Radiative Forcing of Urban Aerosols. *International Journal of Research and Reviews in Pharmacy and Applied Science*, 2(6): 1128-1143.