

# **The Contribution of Sahara Dust Particles, Weather Variables on Global Warming at Birnin Kebbi Metropolis, Kebbi State, Nigeria.**

## **Abstract**

The issue of the response of global warming due to weather variable at Birnin Kebbi Metropolis was investigated considering global and regional climate changes that may occur. The principal response identified can be summarized as follows: It could easily be observed from Figure 4.1a that the distributions of the monthly average wind speed for the three years are fairly similar, peaking in the month of October /November 2014, November/December 2015, November/December 2016, and having minimum values in February and April 2014, February and March 2015, January and February 2016. Figures 4.2 revealed that the month of June presents the least global solar radiation in 2014 followed by the month of January 2015 and June in 2016. The variation between maximum and minimum is said to be great in the months of January to March where there is an increase in the intensity of heat as there is a strong expectation of precipitation events that become extremely high in the month of August/September 2016. The slight difference between maximum and minimum in the period before April and after October suggests a different seasonal period between the regime of large difference and low difference in the Relative Humidity in the year. December/January are months of severe hamattan when the Temperature is low and the Relative Humidity is similarly low. This is to say that the combination of low relative humidity and low temperature occurring simultaneously produce the hamattan season spell which is responsible for the severity of hamattan cold usually experienced. For instances we investigate potential due to increases and decrease in dry and wet, as well as

changes in precipitation inter-annual variability, and changes in the potential predictability of precipitation events that occur differently with some years

**Key Words:** warming, climate, precipitation, Humidity, hamattan.

## **Introduction**

Global warming refers to a rise in the average temperature of Earth's climate system. Since 1971, 90% of the warming has occurred in the oceans, Despite the ocean's dominant role in energy storage, the term "global warming" is also refer to increases in average temperature of the air and sea at Earth's surface. Since the early 20<sup>th</sup> century, the global air and sea surface temperature has increased in about 0.8<sup>0</sup> C [1.4<sup>0</sup> f] with about two-third of the increase occurring since 1980. each of the three decades has been successively warmer at the earth surface than any preceding decade, since 850 scientific understanding of the cause of global warming has been Increasing. In its fourth assessment [AR4 2007] of the relevant scientific literature, the international panel on climate change [IPCC] reported that scientist were more than 90% certain, most of the global warming was being caused by increasing concentration of greenhouse gases produce by human activities Kamla-Raj (2009). In 2010 that finding was recognized by the national science academics of all major industrialized nations lie pert, [Fabian 1994]. Affirming these findings 2013, the (IPCC) stated that the largest driver of global warming is carbon dioxide [Co<sub>2</sub>] emissions from the fossil fuel combustion, cement production, and land use change such as the deforestation, bush burning.

The ozone layer in the stratosphere helps to decrease the level of the temperature rise on the earth surface, so, when the carbon dioxide, been emitted by the human activities rises up on reaching the ozone layer depleted the layer, due to the reaction of carbon dioxide molecules with

the ozone molecules. So the radiation from the sun will pass the layer very easily reaching the earth surface, when this happened the temperature of the earth surface rises and make the earth surface to be warm which is global warming. Scientist believe that the more ozone layer depleted the more the temperature rises on the earth surface, thereby causing the environment to be warm.

In (2013) report state that human influence has been detected in warming of the atmosphere and the ocean, in changes with global water cycle, in reduction in snow and ice, global mean sea level rise and in changes in some climate extremes. This evidence of human influence has grown since AR4. It is extremes likely (95% to 100%) that human influence have been the dominant cause of the observed warming since the mid-20<sup>th</sup> Century (IPCC) (AR5) (WGI) summary for police makers climate model projection were summarized in the 2007 fourth assessment (AR4) by the intergovernmental panel on climate change (IPCC). They indicated that during the 21<sup>st</sup> century the global surface temperature was likely to rise a further 1.1<sup>0</sup>c to 2.9<sup>0</sup>c (20<sup>0</sup>c to 5.2<sup>0</sup>f) for their lowest emission scenario and 2.4<sup>0</sup>c to 6.4<sup>0</sup>c (4.3<sup>0</sup>c to 11.2<sup>0</sup>f) for the highest.

The ranges of these estimates arise from the use of models with differing sensitivity to greenhouse gas concentrations. Future climate change and associated impacts will vary from region to region around the globe. The effect of an increase in global temperature include a rise in sea levels and a change in the amount and pattern of precipitation, as well as a probable expansion of subtropical deceits, warming is expected to be strongest in the Arctic, with the continuing retreat of glaciers, and sea ice. Other likely effect of the warming include more frequent extremes weather events including heat waves, drought and heavy rainfall, ocean acidification; species extinctions due to shifting temperature regimes effect significant to human, include the threat to food security from the decreasing crop yield and the loss of habitat from inundation proposed policy responses to global warming include mitigation by emission

reduction, adaptation to its effects, and possible future climate engineering. Most countries are parties to United Nations framework convention on climate change (UNFCCC), whose ultimate objective is to prevent the dangerous human induced climate change. Parties to the (UNFCCC) have adopted a range of policies designed to reduce greenhouse gas emission and to assist in adoption in global warming. Parties to the (UNFCCC) has agreed that deep cuts in emissions are required, and that future global warming should be limited to below 2.0<sup>0</sup>c (3.6<sup>0</sup>f) relative to pre-industrial level. Reports published in (2011) by the United Nations environment programmed and International Energy Agency suggest that efforts as of the early 21<sup>st</sup> century to reduced emissions may be inadequate to meet UNFCCC's 20<sup>0</sup>c target. Emission of greenhouse gases grew 2.2% per year between (2000) and (2010) compare with 1.3% per year from (1970) to (2016) seasonal rainfall patterns have changed, in the Southern parts of the sub-Sahara Africa, floods and erosion are now common. The southern states and middle belt areas of Nigeria, including Delta, Edo, the western and South Eastern States all experience flooding and massive soil erosion on a yearly basis. The northern states all experience drastic lack of rain and loss of vegetation on a regular basis. Sea Level rise, Nigerian states bordering the Atlantic Coast are all suffering from sea level rise. Unless the immediate steps are taken, much of the infrastructure development planned or now taking place may will be drowned out by sea-level rise in the not suffer distant future. The most recent studies predict a sea level rise of up to six feet in the next twenty (20) to fifty (25) years.

Most of the development now taking place in Lagos, Delta, Bayelsa, Rivers and Cross Rivers States will be deserted. Nigerians and their rulers must take sea-level developments, Nigerians fresh water fish and vegetation may be negatively impacted as the salt water of the oceans inundates the rivers and takes. Mangrove forests and fish may be reduced to extinction. The already polluted

water in oil production area of Nigeria likely more north wards and cause havoc in the only land areas spared in the north which desertification is already wiping out. Both the Arctic and the Antarctic sea ice are melting and this phenomena cannot be stopped. This means all of Nigeria's coastal regions stretching from the north to the east will be affected. Millions will be displaced, infrastructure destroyed. Diseases will become rampant leading to further civil unrest. Population displacement and dislocation. Nigeria and much of western Africa is already experiencing population dislocation, mostly from our neighbors to the north and within. These forced migrations are putting huge pressure on the already large population in these in terms of water, food shortages and disease such as malaria, leprosy, river blindness and a host of others will become even more common. But the governments are trying to eradicate pollution in their countries. Sea level rise and flooding will create even greater problems as Nigeria's south harbor the highest population density. The South Eastern state have erosion problems dating from several years and this problem is continuing growing. Recently emergency taken by the governors of the South eastern states called on the federal government of Nigeria to declare an emergency to the South east zone for an erosion intervention measures. They specifically proposed massive forestation project, water channelization master plan, and the sustainable land. The Drought Nigeria's National Emergency Management Agency (NEMA) is alerting her northern states that the measures must be taken to stop the spread of erosion in the Areas. States include the study area i.e. (Kebbi fig 1), Gombe, Bauchi and Adamawa are suffering the effects of the climate change. Inadequate preparation will lead to water and food shortage nationally. Health and welfare diseases-adverse health effects from warmer temperature-Diseases typically found in certain zones like the hotter desert area's or flood prone areas are likely spread in the region where these diseases were previously unknown, thereby adversely affecting the general

population. Examples include aerosolized dust or soil contact disease; like Lassa fever, food or water borne diseases, bacterial and protozoa diarrhea, hepatitis A, B and E and typhoid fever. Respiratory diseases, meningococcal meningitis and animal contact diseases, rabies climate change may also lead to massive increases and migration in disease vectors such as mosquitoes, rats, mice, cockroaches, etc. transportation networks are vital to any nation's economy, safety, communication and change impact pose significant challenges to Nigeria's existing and proposed transportation system our existing sea-port and airport at Lagos Warri Port-hacort, Kano and Calabar as well as the proposed rail system in the country, the road network linking all the states in the federation would be threatened if adequate planning is not put in place. The main aims of this research is to determine the effects of Sahara dust particle and some weather variables to the global warming using Birnin Kebbi Local Government Area of Kebbi State of Nigeria. The objective are:

1. To measure temperature, wind speed and solar radiation.
2. To get three (3) years data for temperature, wind speed, solar radiation and rainfall from the international airport Birnin Kebbi, Kebbi State Nigeria.

### **Description of the Study Area**

Nigeria is a country with diverse ethnic groups practicing different cultures, and having variations in farming and religion beliefs. The country can primarily be divided into two major geographical zones namely the North and South, though that has historical underlying (Obot et al., 2010). Furthermore, both the North and South are segmented into three regions each, making a total of six geopolitical zones. These six geopolitical zones in the country are; North East, North West, North Central, South West, South East and South South. Policies, resource

allocations, sites of infrastructures and even political and other appointments are mostly considered by zoning in Nigeria. Birnin Kebbi is in Kebbi State which is in North West geopolitical zone of Nigeria. Kebbi State came into being on August 27, 1991. It was created out of the old Sokoto State. The capital is Birnin-Kebbi. Its major towns include Birnin-Kebbi, Argungu and Yelwa. The state has a population of 3,630, 931 and has a total land area of 36,800 km<sup>2</sup>. Kebbi State shares boundaries with Sokoto State on the North- Eastern axis, Zamfara State on the Eastern part, Niger state on the Southern part and Republic of Niger on the Western part. Kebbi State is divided into 21 local government areas, four emirate councils (Gwandu, Argungu, Yauri and Zuru), and 35 districts. The climate is semiarid with a zone of savannah-type vegetation as part of the sub-Saharan Sudan belt of West Africa. (Fig 1), the study was carried out at Kebbi State of Nigeria and various data collected was gotten from the Nigeria Meteorological Agency, Kebbi State International Airport Birnin Kebbi. The method of data collection was on a daily basis for the three (3) years, i.e. for the year 2014, 2015, and year 2016 respectively. The data used in this study were direct data of the minimum temperature, solar radiation and rainfall and the wind Speed.

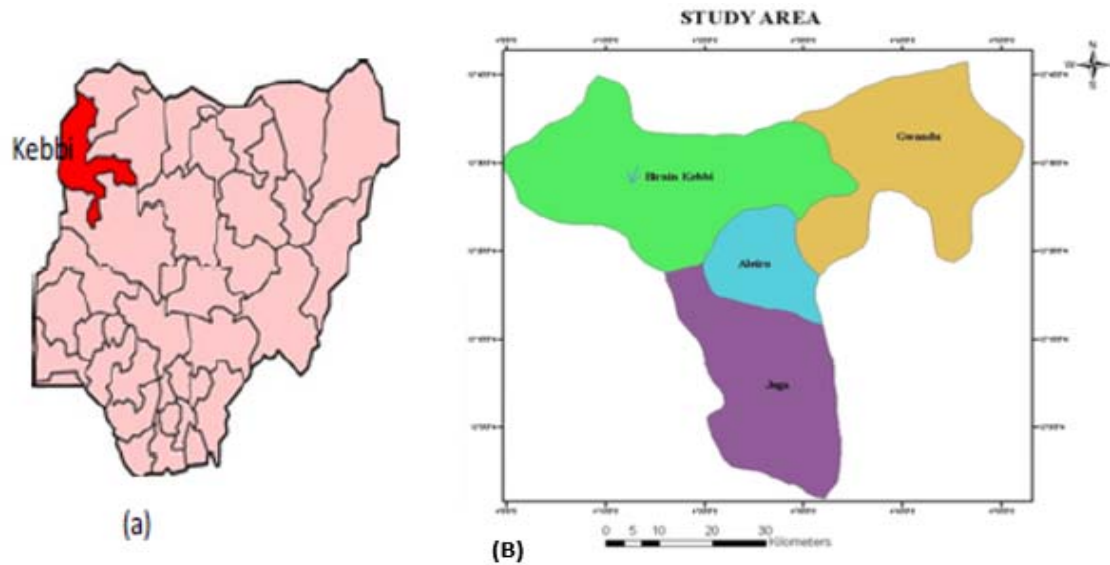


Figure 1: Map of Nigeria

(a) showing kebbi state

(B) Showing Study Location

## Material and Method

The methodology used in carrying out this research is categorized as:

- preliminary investigation
- Acquisition of Data

### Preliminary Investigation

Measurement was carried out at Birnin Kebbi International Airport, Kebbi State on 29<sup>th</sup> April, 2017, parameters to consider are:

- Wind speed

- Solar radiation
- Temperature

### **Data Acquisition**

Three years data (2014, 2015, and 2016), for temperature, wind speed, solar radiation and rainfall was obtained from Meteorological Agency of Birnin Kebbi international Airport Kebbi

#### **Solar Radiation Data:**

Solar radiation can briefly described as energy transmitted in form of rays from the sun. This solar radiation measurements were carried out with the help of an apparatus called pyranometer; A solar radiation sensor used to measure the broad band solar radiation flux density (e.g. in watt per metre) from a field of view of 180 degrees. The first correlation proposed for establishing the average monthly solar radiation of Sokoto based on the method of angstrom.

#### **Rainfall data:**

This can be briefly described as water falling in drops from vapor condensed in the atmosphere. The approach used in this study was to analyze the data for rainfall amount in Birnin Kebbi local government; the data here are secondary data and were obtained in Birnin Kebbi from Nigeria Meteorological Agency, Collage of Agriculture waziri umaru federal polytechnic Birnin Kebbi. This study was for a period of three years in Birnin Kebbi. The individual daily rainfall were added up for each week and month to give the weekly and monthly rainfall total, and the monthly rainfall total for each year added up to give the annual rainfall total, for a particular year.

## **Wind data**

Saharan dust is emitted to the atmosphere in pulses (Kubilay, 2003). Often dust events result from collection of many small-scale dust plumes emerging from separated point sources within an area of a few square kilometers (Koren *et al*, 2003), describe the evolution of dust storms and show that dust is emitted from the Sahara from a few, well defined sources. One of the most vigorous sources for dust in the Sahara is the Bedele depression (17N, 18E) located northeast of Lake Chad, and composed of a series of ephemeral lakes collecting erosion from a few sources (Mounkaila, 2003), the study analyze all the dust storms observed during January-April 2011 and the wind speed and direction of the dust movement.

## **Temperature data:**

The data for both minimum and maximum temperature was collected at the station with the help of a material, the data collected was then sorted by using appropriate formula in the calculation of the data. In this study the average mean for maximum temperature and the average mean for the maximum temperature for study year from 2014 to 2016 in Birnin Kebbi local government were calculated and computed.

## **Theory of Solar Radiation**

The original Angstrom-Prescott type regression equation-related monthly average daily radiation to clear day radiation in a given location and fraction of possible sunshine hours is given by this equation.

$$\frac{H}{H_o} = a + b \left( \frac{S}{S_o} \right) \dots \dots \dots (1)$$

Where

H is monthly average daily solar of Birnin Kebbi on a horizontal surface (MJ/m<sup>2</sup>/day),

H<sub>o</sub> is the monthly average daily hours of bright sunshine,

S<sub>o</sub> is the Monthly average day length

a and b values are the angstrom empirical constants

The monthly average daily extra-terrestrial radiation on a horizontal surface (H<sub>o</sub>) was calculated for the number of days in each month of the year (Iqbal, 1983; Zekai, 2008).

$$H = \left( \frac{24}{\pi} \right) I_{sc} \left[ 1 + 0.033 \cos \left( \frac{360n}{365} \right) \right] \left[ \cos \psi \cos \delta W_s + \left( \frac{2\pi W_s}{360} \right) \sin \psi \sin \delta \right] \dots \dots \dots (2)$$

Where

I<sub>sc</sub> - solar constant (= 137Wm<sup>-2</sup>),

ψ - latitude of the site,

δ - Solar declination and

W<sub>s</sub> - The mean sunrise hour angle form the given month and

n- is the number of the days of the year starting from 1<sup>st</sup> of January to 31<sup>st</sup> of December.

The solar declamation, δ and the mean sunrise hour angle, W<sub>s</sub> can be calculated using the following equation (Zekai, 2008):

$$\delta = 23.4 \sin \left\{ 360 \left( \frac{284+n}{365} \right) \right\} \dots \dots \dots (3)$$

$$W_s = \cos^{-1} (-\tan \psi \tan \delta) \dots \dots \dots (4)$$

For a given month, the maximum possible sunshine duration ( $S_o$ ) can be computed (Iqbal, 1983; Zkai, 2008) by the equation below:

$$S_o = \frac{2}{15} W_s \dots \dots \dots (5)$$

Clearness index ( $K_T$ ) can be defined as ratio of the observed horizontal terrestrial solar radiation  $H$ , to the calculated horizontal extraterrestrial solar radiation  $H_o$ . This gives the percentage % deflection by the sky of the incoming global solar radiation and therefore indicates both level of availability of solar radiation and changes in atmospheric condition in a given environment. The probability density function of the wind data was calculated using the Weibull and Ray light probability density function formula, Russak, V. (1990).

$$F(v) = [k/c] [v/c]^{k-1} \exp-[v/c]^k \dots \dots \dots (6)$$

Where

$F(v)$  - probability density function (m/s),

$K$  - Dimensionless shape factor,

$C$  - Weibull scale factor (m/s).

The relationship of  $c$ ,  $k$ , and the average wind speed is given below

$$V_m = \text{or } (1 + [1/k]) \dots \dots \dots (7)$$

Where,

r - Gamma function

K and c be calculated by the linear regression of the cumulative Weibull distribution given below:

$$F(v) = 1 - \exp[-(v/c)^k] \dots\dots\dots (8)$$

Variation of the wind speed with respect to height, a wind speed is greater at higher distance above the ground. This is due to the effects of surface features and then turbulence diminishes as the height increases (Walker and Kekins, 1997). The acceptable expression used in the calculation of wind speed variation is shown below:

$$\frac{V}{V_o} = \left( \frac{h}{h_o} \right) \dots\dots\dots (9)$$

Where

V - Wind speed at required height

V<sub>o</sub> - wind speed at the original height,

h - Wind height;

h<sub>o</sub> - original wind height and

α - surface roughness coefficient (0.143).

The wind potential height is estimated using the formula below.

$$a = 0.2965\rho v^3 t \dots\dots\dots (10)$$

Where

$\rho$  - Density of air in  $\text{K}/\text{gm}^3$

$a$  - available energy for doing the work on the wind turbine.

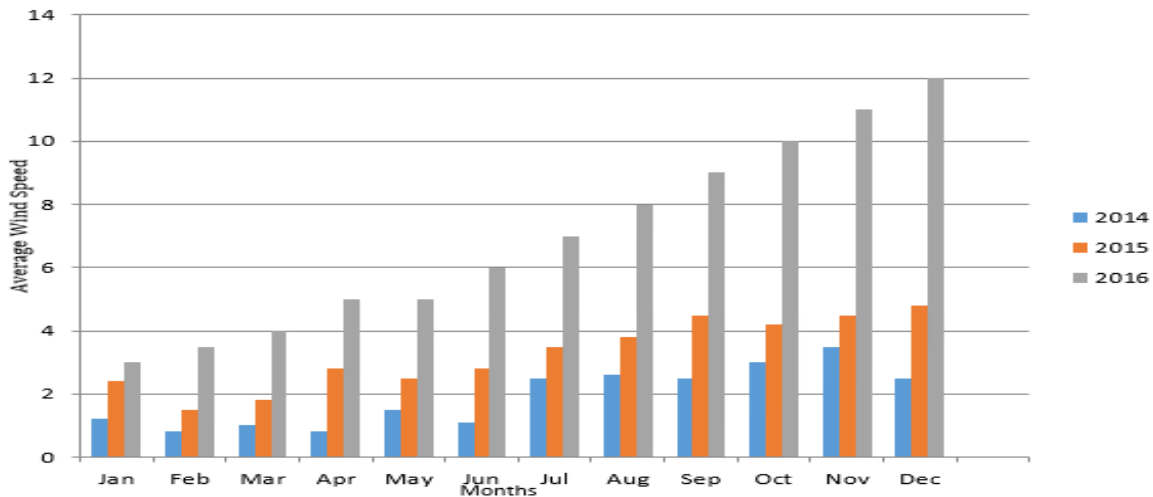
### Results and Discussion

Three years data 2014, 2015, and 2016 for the solar radiation, rainfall, and maximum/ minimum temperatures obtained from Birnin Kebbi international airport Kebbi State, The wind speed recorded is in knots and converted to m/s using the relationship, the average wind speed increase progressively from 1.18m/s in 2014, 2015 and 1.83m/s in 2016.

Note that, 1 knot = 0.515m/s (meter per second).

### Wind Speed

The monthly and annual average wind speed distributions for the three years over the studied period. The table series distributions of the monthly average values for the locations are shown in Figure 4.1a, while the average wind speed values for three days are shown in the appendix. The distributions give annual mean values of 0.72, 0.38.04, 38.04, 0.32 respectively, for 2014, 2015 and 2016. It could easily be observed from Figure 4.1a that the distributions of the monthly average wind speed for the three years are fairly similar, peaking in the month of October November 2014, 2015, 2016, and having minimum values in February and April 2014, February and March 2015, January and February 2016. Perhaps, the result is as expected since difference in wind speed distributions may be related to the difference in altitude between the years and locations.

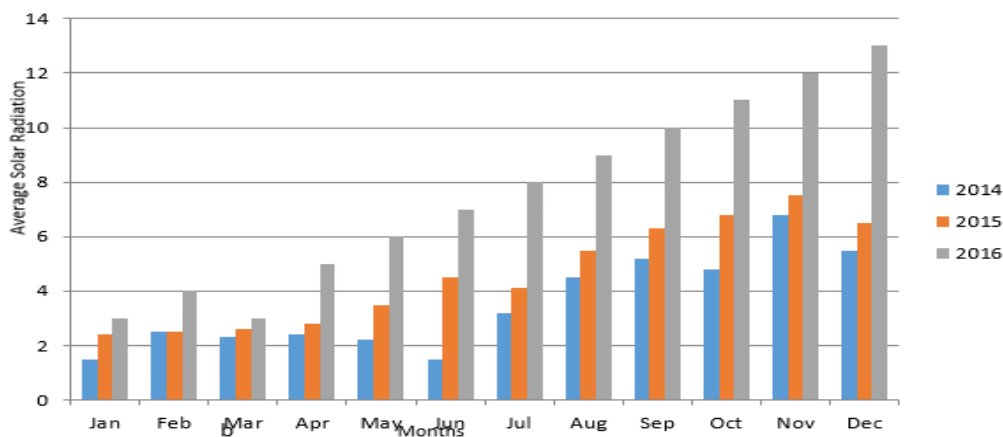


**Figure 4.1; Monthly Average Wind Speeds for 2014, 2015, 2016**

### Solar Radiation

Figure 4.2 depicts the comparison in the monthly mean global solar radiation for each year from 2014-2016. Standard deviation Of 5.4, 1.9 and 0 MJ/ The figures revealed that the month of June present the least global solar radiation in 2014 followed by the month of January 2015 and June in 2016. The average values of global solar radiation for these months as furnished in Appendix 1 (a, b, c) are 15.8, 17. 8 and 0 MJ/m<sup>2</sup>/day, respectively with the standard deviation m<sup>2</sup>/day. This is not expected as these months fall within the dry season of the year when it is always not cloudy and dull as a result of there is no rainfall, this is because the observed values of solar radiation are higher during the dry season compared to the wet season. It has been observed in the distribution of the monthly amount of global solar radiation, which may be due to differences in the atmospheric circulation. Cloud cover, rainfall and relative humidity are the most important atmospheric phenomena limiting solar radiation at the earth surface. It was also observed that the regions with higher cloud density (for example humid regions) receive less solar radiation than

the cloud-free climates (for example deserts). For any given location, solar radiation reaching the Earth's surface decreases with increasing cloud cover. The highest value of global solar radiation occurs in the month of November 2014, 2015 with mean value of 17.6 MJ/m<sup>2</sup>/day and standard deviation of 2.9 MJ/m<sup>2</sup>/day, 17.9 MJ/m<sup>2</sup>/day, 2.1 MJ/m<sup>2</sup>/day follows by the month of December 2016 with the average value of 0 MJ/m<sup>2</sup>/day and standard deviation of 0 MJ/m<sup>2</sup>/day. It can be inferred from the figure that many years of observed data are required to make a reasonable conclusion on the implementation of any solar power project as a result of wide variation in solar characteristic.



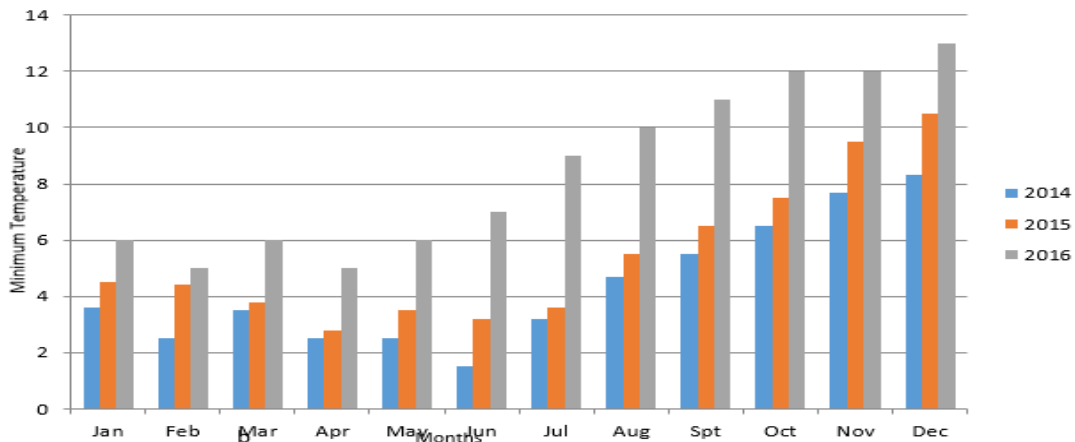
**Figure 4.2: Average Solar Radiation for the Period of 2014, 2015, 2016**

### Minimum Temperature

The monthly data for the 3 year period of temperature was plotted against the month as shown in Figure 4.3. This was examined to select the minimum value of each month over the period. The plot of these minimum points deduced two minima. The first one occurred in April-May before the rainy season sets in 2014, 2015 while the second minimum temperature occurred around July during rainy season. 2016 gave an undulating form in the first three months followed by a gently increasing value that rose to a maximum in the month of May up to the month of December. The

rains occurred between end of May and beginning of November which shows up as continuous drop in Temperature with a minimum between August and September. Looking closely at the behavior of the maximum points, several features could be observed. There is an isolated maximum of relative humidity (RH) occurring in February and a broader maximum in June-December. The first maximum of February is in harmattan season which often leads to condensation and observation of dew in the morning as a result of low temperature. The later maximum that occurred in September is due to high water content from rain and vaporization. As highlighted by Odjugo (2009; 2010). Literatures presents the change in temperature across Nigeria within this period, between 1901 and 1935 the temperature change was  $0.50^{\circ}\text{C}$  ( $28^{\circ}\text{C} - 28.5^{\circ}\text{C}$ ) for the region; between 1936 and 1970 the temperature change was  $0.50^{\circ}\text{C}$  ( $28.5^{\circ}\text{C} - 29^{\circ}\text{C}$ ) and between 1971 and 2006 the temperature change was  $0.50^{\circ}\text{C}$  ( $29^{\circ}\text{C} - 29.5^{\circ}\text{C}$ ) and between 2007 and 2016 the temperature change was  $0.50^{\circ}\text{C}$  ( $29.5^{\circ}\text{C} - 30^{\circ}\text{C}$ ), all these show that there is an increase in temperature of ( $1.5^{\circ}\text{C}$ ). December/January are months of severe hamattan when the Temperature is low and the Relative Humidity is also low. This is to say that the combination of low relative humidity and low temperature occurring simultaneously produce the hamattan season spell which is responsible for the severity of hamattan cold usually experienced. This implies in the remaining part of the year, the behaviors of Relative Humidity and Temperature are opposite to one another. This can be seen from the behaviors of Relative Humidity and Temperature in July-August when the Relative Humidity is high and Temperature is low without the feeling of the severity of the cold as in harmattan period. From the above, two separate seasons have been identified namely, Harmattan and Rainy seasons occurring between November and February, and between May and October respectively of the year. The third season is the Dry season occurring between February and April of the year. Using the parameters

considered, in the harmattan season, both RH and T are low; in the Rainy season, RH is high and steady while T is low and for the dry season, the RH is rising while the T is dropping.



**Tot** **Figure 4.3; Minimum Temperature for the Period of 2014, 2015, 2016**

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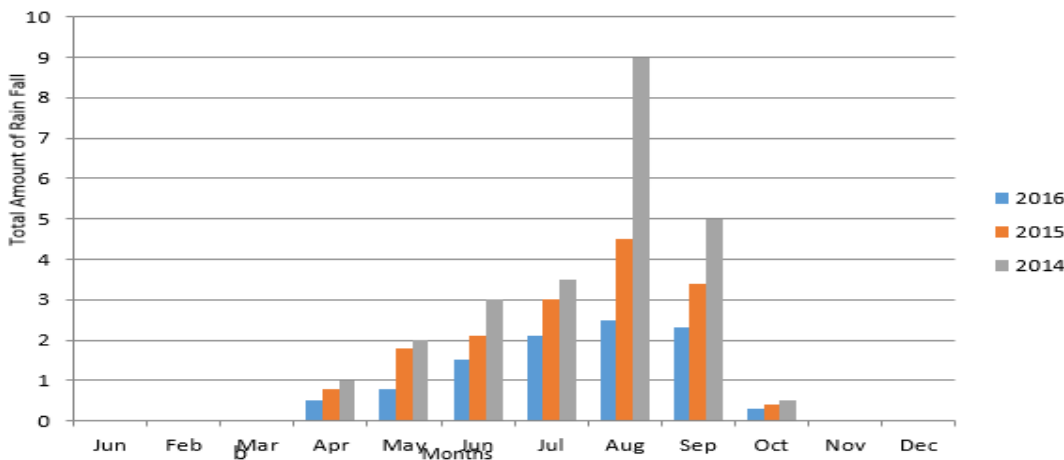
### **Rainfall**

Appendix II (a, b, c) presents monthly mean, median, maximum and minimum rainfalls in the city. The table revealed that the rainy period in Birnin Kebbi is between April and October, with June, July, August and September as significant rainy months. The month of August has the highest magnitude of monthly rainfall with July, September and June in decreasing order. Appendix II (a, b, c) presents total, yearly mean, maximum, minimum and standard deviation (SD) of the rainfall for all years (2014 – 2016). The table shows spatial distribution of the rainfall. From the table yearly total rainfall has a decreasing trend with the strongest downward magnitude in the group of 2015 – 2016. The lowest magnitude in downward trend was in the period of 2016. The same trends were observed for the yearly mean, median and yearly minimum rainfalls. These trends show that there is a decline in the magnitude of rainfall in the

city. Also these results agree with literature such as Adelana *et al.* (2006). These downward trends in rainfall can be attributed to climate change as highlighted in Odjugo (2009; 2010).

### Sequence of the rainfalls

Figures 4.4 present sequential values of the rainfalls in Birnin Kebbi. The figures apparently show decreasing trends in the rainfalls, the downward trends appearance of the yearly total, maximum, minimum and mean rainfalls. In all these cases the appearance of strongest decreasing trend occurred in monthly rainfall 2015, but 2016 show lowest decreasing as compared to 2015. While 2014 present appearance of slightly increasing trends in rainfall within the period (in the months of June, July, August and September), while 2014, 2015, 2016 some months presents neither increasing nor decreasing trends in rainfalls. These trends can be attributed to climate change, which manifest itself in the city as temperature increment and



**Figure 4.4; Total Rain Fall for the Period of 2014, 2015, 2016**

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## **Conclusion**

Sahara dust out breaks have adverse health effects. Further investigation is needed to understand the role of dust particles and mechanism by which Saharan dust increases mortality. In addition to that Sahara is a regional environment threat that is adversely affecting human beings causing health impact in West African counties this has emaciated the composition & characteristics of Saharan dust in Birnin Kebbi. It could easily be observed from Figure 4.1a that the distributions of the monthly average wind speed for the three years are fairly similar, peaking in the month of October November 2014, November December 2015, November December 2016, and having minimum values in February and April 2014, February and March 2015, January and February 2016. Figures 4.2 revealed that the month of June present the least global solar radiation in 2014 followed by the month of January 2015 and June in 2016. The average values of global solar radiation for these months as furnished in Appendix 1 (a, b, c) are 15.8, 17. 8 and 0 MJ/m<sup>2</sup>/day,

respectively with the standard deviation  $m^2/day$ . The difference between maximum and minimum is high in the months of January to March and between November and December 2016. However, the difference is reduced from March before the rain commences in May. The small difference between maximum and minimum in the period of April to October suggests a different seasonal period between the regime of large difference and low difference in the Relative Humidity in the year. December/January are months of severe hamattan when the Temperature is low and the Relative Humidity is also low. This is to say that the combination of low relative humidity and low temperature occurring simultaneously produce the hamattan season spell which is responsible for the severity of hamattan cold usually experienced. Appendix II (a, b, c) presents monthly mean, median, maximum and minimum rainfalls in the city. The table revealed that the rainy period in Birnin Kebbi is between April and October, with June, July, August and September as significant rainy months. The month of August has the highest magnitude of monthly rainfall with July, September and June in decreasing order. Appendix II (a, b, c) presents total, yearly mean, maximum, minimum and standard deviation (SD) of the rainfall for all years (2014 – 2016).

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#### APPENDIX I: Monthly Average Wind Speed

AVERAGE SPEED WIND		AVERAGE WIND SPEED (M/S)				
Months	2014	2015	2016	2014	2015	2016
Jan		9.22	7.60	6.15	4.75	3.91
Feb	7.81	8.76	7.87	4.02	4.51	4.05
Mar	10.12	11.57	6.69	5.21	5.96	3.45
Apr	9.37	9.17	7.74	4.82	4.72	3.99

May	13.06	14.72	12.24	6.73	7.58	6.30
Jun	12.79	12.44	-	6.59	6.41	-
Jul	10.93	8.77	9.34	4.63	4.52	4.81
Aug	7.62	7.10	5.22	3.93	3.66	2.69
Sep	7.88	6.11	4.67	4.06	3.15	2.41
Oct	5.91	4.36	4.29	3.04	2.25	2.21
Nov	7.49	4.90	4.53	3.85	2.52	2.33
Dec	10.17	7.88	-	5.24	4.06	-

**Preliminary Result for the Average Wind Speed for 3 days**

<b>Local time</b>	<b>Solar radiation (w/m<sup>2</sup>)</b>	<b>Wind (m/s)</b>	<b>Ambient temp. (C<sup>0</sup>)</b>	<b>Energy (kwh/m<sup>2</sup>)</b>
8.00 am	310	1.0	30.5	0.16
8.30 am	401	0.7	31.3	0.20
9.00 am	570	0.4	32.3	0.29

9.30 am	644	0.5	32.6	0.32
10.00 am	680	1.7	34.3	0.34
10.30 am	752	1.0	37.1	0.34
11.00 am	835	0.8	39.3	0.42
11.30 am	881	1.0	39.0	0.44
12.00 p.m	810	1.1	41.0	0.46
12.30 p.m	915	0.8	40.7	0.46
13.00 p.m	899	0.7	421	0.45
13.30 p.m	874	0.4	422	0.44
14.00 p.m	788	0.4	426	0.39
14.30 p.m	725	0.4	41.1	0.36
15.00 p.m	627	0.5	425	0.31
15.30 p.m	542	0.4	429	0.27
16.00 p.m	419	0.8	37.8	0.21
16.30 p.m	344	0.5	37.1	0.17
17.00 p.m	209	0.5	36.4	0.10
Sum 12,325	13.60	13.60	722.80	6.16
mean 6492	0.72	0.38.04	38.04	0.32

**APPENDIX II: Solar Radiation in MJ/m<sup>2</sup> for 2014**

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1.	15.6	17.2	16.8	18.4	219.2	17.4	12.8	16.8	15.8	18.9	18.9	20.0
2	17.4	21.0	15.2	16.7	19.1	18.7	12.4	19.2	11.8	20.4	20.4	19.8
3	17.2	17.4	16.5	12.8	19.2	15.6	14.4	20.8	12.8	19.9	19.9	19.0
4	18.3	12.2	19.8	14.8	19.0	18.8	12.5	16.8	8.1	15.7	15.7	19.0
5	19.2	15.3	17.0	14.8	20.0	15.4	8.3	12.6	16.0	19.3	19.3	17.8
6	16.0	12.6	16.4	18.8	20.5	19.3	12.7	8.8	17.0	6.0	6.0	20.2
7	17.6	16.0	16.6	19.0	17.6	17.0	12.1	13.4	14.9	17.3	17.3	14.5
8	14.8	16.8	17.5	19.6	17.6	15.3	15.4	13.6	15.0	20.2	20.2	16.6
9	8.8	17.3	20.6	20.2	19.2	18.0	9.4	14.7	13.3	15.4	15.4	14.2
10	12.0	17.0	18.5	20.0	19.1	14.5	6.2	13.6	19.5	14.2	14.2	6.2
11	12.0	18.4	20.2	19.1	15.8	15.4	11.2	13.2	20.2	14.0	14.0	14.6
12	17.0	17.2	20.8	16.9	19.7	17.2	12.5	13.4	20.2	14.0	14.0	14.6
13	20.7	16.8	18.0	19.2	8.8	40.0	10.4	9.8	13.7	17.2	17.2	14.6
14	16.0	19.5	19.8	19.8	16.8	16.4	8.3	15.2	17.0	17.8	17.8	16.8
15	15.7	15.2	19.2	22.2	18.2	16.0	10.7	15.9	11.2	17.1	17.1	18.4
16	12.2	18.8	21.4	20.6	16.5	15.8	19.7	15.4	13.9	18.8	18.8	16.9
17	12.4	18.4	19.5	20.8	18.0	15.0	19.7	17.0	17.4	20.2	20.2	17.8
18	18.9	16.0	17.5	19.5	18.6	15.4	19.2	18.2	20.5	18.8	18.8	18.8
19	15.2	21.9	20.2	18.5	18.2	14.4	19.7	17.7	17.6	19.4	19.4	17.0
20	16.8	8.2	18.6	18.5	20.4	11.4	11.6	14.0	19.4	17.5	15.6	14.8
21	15.6	17.4	21.7	17.0	5.4	14.4	18.8	11.2	17.4	15.6	15.5	16.8
22	19.5	16.0	20.8	17.3	15.4	10.6	20.4	12.8	19.4	15.4	15.4	17.3

23	19.4	18.8	17.5	17.5	15.4	9.8	16.4	10.4	16.3	15.5	15.5	16.9
24	17.2	16.2	18.9	18.2	21.5	16.6	8.2	12.2	19.0	17.1	17.1	16.6
25	15.8	18.2	16.0	15.4	15.8	13.3	10.5	13.7	21.8	18.6	18.6	17.2
26	17.0	16.2	17.2	20.6	15.5	14.5	13.9	15.2	17.8	18.6	18.6	15.2
27	20.8	19.0	18.8	20.5	14.4	14.8	19.1	8.4	19.2	19.9	19.9	15,8
28	18..2	13.4	19.0	20.6	13.0	14,3	4.4	13.9	15.4	19.8	19.8	17.4
29	17.9		20.1	19.6	18.8	4.8	5,2	14.2	20.2	20.0	20.0	19.2
30	17.2		18.4	19.0	17.7	14.0	11.7	14.2	17.0	19.0	19.0	19.2
31	18.8		18.8		17.9		17.4	13.1		20.3	20.3	18.9
N	31	28	31	30	31	30	31	31	30	31	31	31
Sum	511.6	468.4	577.3	555.9	532.3	473.9	405.2	441.2	497.3	546.7	546.7	5180.3
Mean	16.5	16.7	18.6	18.5	17.2	15.8	13.1	14.2	16.6	17.6	17.6	16.7
Std Dev	2.7	2.7	1.7	2.1	3.3	5.4	4.6	2.9	3.1	2.9	2.9	2.7

### APPENDIX III: Minimum Temperature for 2014

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1.	30.8	21.0	24.6	19.8	24.4	27.0	26.2	25.2	23.0	25.0	18.6	16.2
1	30.4	21.2	25.0	20.2	25.0	28.2	25.0	25.2	21.8	24.2	19.8	16.8
3	30.8	20.6	26.0	21.4	26.2	28.0	25.7	21.8	23.2	23.4	18.8	16.1
4	30.4	23.2	26.2	22.4	25.4	28.0	25.5	24.2	20.4	24.8	18.2	16.7

5	30.6	17.2	25.4	24.4	23.2	27.4	26.4	23.3	22.2	24.6	18.5	17.8
6	30.4	20.6	25.2	23.0	24.4	28.2	24.5	21.2	22.8	22.8	19.5	17.0
7	30.4	21.4	27.0	23.2	25.2	17.2	26.1	23.1	22.8	21.7	19.8	18.6
8	30.4	21.2	26.6	19.9	25.2	20.6	26.5	21.4	22.9	24.5	19.2	17.8
9	30.4	20.4	24.4	26.6	25.0	25.4	24.9	24.3	23.5	24.8	20.2	16.8
10	30.2	22.4	24.2	27.0	19.8	36.0	23.4	25.6	23.4	23.4	21.4	17.5
11	30.0	22.6	26.0	25.0	21.2	21.2	24.8	24.4	24.0	23.2	17.9	17.8
12	30.0	23.0	25.0	24.4	20.0	19.8	25.0	24.4	23.4	24.4	19.5	15.8
13	30.0	22.6	25.2	24.0	24.6	18.8	23.2	21.7	21.8	24.0	20.1	15.4
14	30.0	24.4	24.6	23.1	25.0	19.0	25.4	22.2	23.2	23.8	20.5	14.5
15	30.0	25.2	28.2	26.0	26.2	22.2	22.1	21.0	19.5	22.5	17.9	15.5
16	29.8	21.6	24.0	26.4	23.4	22.4	23.0	22.4	22.4	25.0	18.2	15.8
17	29.6	24.2	22.2	25.0	24.4	20.9	25.0	20.2	22.8	23.5	20.8	13.9
18	29.6	22.6	21.2	21.0	24.8	21.2	25.0	21.4	22.2	22.7	18.8	12.8
19	29.2	23.0	23.0	19.4	24.6	18.9	25.2	22.2	23.3	23.4	19.8	15.5
20	29.6	26.4	22.6	19.4	24.8	19.4	28.0	21.5	22.2	22.5	20.5	15.8
21	29.6	25.2	25.0	19.0	23.4	19.0	24.0	23.5	22.8	22.2	21.0	17.2
22	29.4	23.6	23.2	18.8	23.4	22.4	25.0	23.6	24.1	23.1	21.4	16.8
23	29.6	22.4	24.4	18.2	22.6	18.8	25.2	24.1	21.5	24.0	18.3	17.1
24	29.4	22.1	26.1	20.0	26.2	17.8	26.5	20.5	24.1	22.1	17.5	16.2
25	30.0	23.0	26.6	21.2	19.6	17.4	23.5	23.3	22.6	21.0	18.9	15.6
26	29.8	23.2	27.3	22.4	17.8	16.6	23.6	22.8	23.3	22.6	16.0	16.8
27	29.8	24.2	24.2	18.9	17.2	19.8	24.6	23.1	23.0	19.0	17.4	16.5
28	30.2	18.8	24.6	19.6	21.9	20.2	25.7	21.2	23.6	19.5	15.4	15.9

29	30.4		22.8	20.4	18.8	22.6	20.6	23.6	23.2	21.6	16.5	15.9
30	30.6		25.0	21.6	18.6	20.8	23.1	25.6	23.7	21.4	15.2	13.9
31	30.8		19.8		29.4		20.6	21.6		22.3		14.7
N	31	28	31	30	31	30	31	31	30	31	30	31
Sum	932.2	627.3	765.6	661.7	721.7	665.4	763.3	709.3	683.5	713.0	566.2	500.7
Mean	30.1	22.4	24.7	22.1	23.3	22.2	24.6	22.9	22.8	23.01	18.9	16.2
Std Dev	0.4	2.0	1.8	2.6	2.9	4.4	1.6	1.5	1.0	1.5	1.7	1.3

**APPENDIX IV: Yearly Rainfall for, 2014**

Day		Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1.	-	-	-	-	-	-	-	-	-	-	-	-
2	-	-	-	-	-	-	-	4.40	-	-	-	-
3	-	-	-	-	-	-	-	-	7.20	-	-	-
4	-	-	-	-	-	-	-	-	1.90	-	-	-

5	-	-	-	-	-	-	-	9.40	-	-	-	-
6	-	-	-	-	-	-	-	-	-	-	-	-
7	-	-	-	-	-	-	-	-	-	-	-	-
8	-	-	-	-	-	-	-	-	-	-	-	-
9	-	-	-	-	-	38.10	-	-	-	-	-	-
10	-	-	-	-	-	-	-	-	-	-	-	-
11	-	-	-	-	-	-	-	2.60	-	-	-	-
12	-	-	-	-	14.0	-	6.20	2.40	4.90	-	-	-
13	-	-	-	-	-	21.30	-	13.80	-	-	-	-
14	-	-	-	-	-	4.70	-	3.50	53.0	-	-	-
15	-	-	-	-	-	-	-	5.80	0.70	-	-	-
16	-	-	-	-	-	-	-	37.10	5.20	-	-	-
17	-	-	-	-	-	-	-	2.0	-	-	-	-
18	-	-	-	-	-	-	-	-	-	-	-	-
19	-	-	-	-	-	41.40	-	3.10	-	-	-	-
20	-	-	-	-	-	-	-	-	-	-	-	-
21	-	-	-	-	-	-	-	-	-	-	-	-
22	-	-	-	-	-	45.80	-	-	1.10	-	-	-
23	-	-	-	-	-	-	-	87.10	-	-	-	-
24	-	-	-	-	-	-	2.40	-	-	-	-	-
25	-	-	-	-	24.10	-	3.70	-	-	-	-	-
26	-	-	-	-	-	-	-	-	-	-	-	-
27	-	-	-	-	51.10	-	-	-	-	-	-	-
28	-	-	-	-	3.20	-	9.60	-	-	-	-	-

29	-		-	-	-	14.60	2.80	-	-	-	-	-
30	-	-	-	-	-	-	-	-	-	-	-	-
31	-	-	-	-	-	-	-	-	-	-	-	-
N	31	28	31	30	29	30	31	30	29	31	30	31
Sum	-	-	-	-	27.3	161.2	29.4	169.2	31.0	-	-	-
Mean	-	-	-	-	0.9	5.4	0.9	5.6	1.1	-	-	-
Std Dev	-	-	-	-	4.5	13.2	2.3	17.0	3.4	-	-	-

UNDER PEER REVIEW