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Solar Activities over the Rainfall Pattern and Temperature Ranges in Nigeria

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Abstract:
The impact of Sunspots Number (SSN)andTotal Solar Irradiance(TSI) on temperature and rainfall in Nigeria from 1970 to 2014, covering four synoptic stations: PortHarcourt (PH) (4.51^{0}N, 7.10^{0}E), Enugu (ENU) (6.28^{0}N, 7.33^{0}E), Ilorin (IRN) (8.29^{0}E, 4.35^{0}E) and Sokoto (SKT) (13.01^{0}N, 5.15^{0}E) are here presented. The annual relationship between the climatic parameters is compared with the solar parameters graphically using annual mean of both variables. A non -parametric statistical correlation was used to delineate the degree of dependence of the climatic parameters on the solar parameter. The result obtained from the graphical comparison strongly indicates that temperature increases with increased in solar activities and vice versa. It is found that precipitation exhibits significant increase with decreasing solar activity. The correlation results signify a positive correlation between solar activities and temperature and an inverse correlation between solar activity and precipitation. From the analysis, we infer that, despite human activities, solar activities play important roles in climate change observed in Nigeria this effect should not be ignored in analyzing the pattern of temperature and temperature in Nigeria.

Keywords: *Solar activity, sunspots number, total solar irradiance, climatic parameters, temperature and rainfall*

1. Introduction

Historical and geological records have shown that the Earth's climate is constantly changing and have attracted tremendous interest from both scientific research and public debate. This is as a result that climate change affects man, his environment and the ecosystems on which humanity depends. Globally, many scholars have engaged in studying various climate parameters to understand the present pattern and characteristic of climate as to mitigate the consequences of climate change to the environment.

Thechange in the output of the sun has been observed to affect weather and climate. The most crucial well observed and long term recorded aspect of the solar activity is the dark regions on the solar disk know as Sunspots. Which appear and disappear around the limb of the Sun. They are clearly thought to be a depression in the atmosphere of the Sun. The temperature within the Sunspot is about 4600K, they are the coolest part of the Sun and this low temperature is thought to be due to lack of convention which brings hot plasma to the surface of the Sun [1].

The average number of visible sunspots varies on a regular cycle of about 11years. The part of the cycle with low sunspot number is refers to as solar minimum, while the part with high sunspot number is refer to as solar maximum. When the cycle is in its maximum phase, there are important terrestrial consequences such as the higher solar emission of extreme ultra violet flux, which can modulate the upper and middle terrestrial atmosphere and TSI hence affecting the terrestrial climate [2].Although the Earth's cloud – the source of rainfall variability on Earth – are tropospheric phenomena and are close to the Earth's surface, the sun can still influence the Earth's rainfall variability in many ways, one of which is through the increase of clouds which is as a result of the mediating Galactic Cosmic Ray (GCR), an anti-sunspot phenomena [3].

Recent studies have revealed that stratospheric and tropospheric weather systems are widely influenced by solar cycle which shows the dependence of climate on solar activities. [4]found positive correlation between solar activities and climatic variability for long term time scale (22years) and negative or very low correlation coefficient for 11years time scale. [5], analyses more than 130 years of temperature data (1830-1965) for three places in England (Edinburgh, Greenwich and Wakefield), he found that temperature showed negative correlation with solar activity from 1880 to 1930 and a positive correlation for other years.

[6], while examining the relationship between solar activity and the annual precipitation in the Beijing area concluded that the annual precipitation is closely related to the variation in sunspot numbers, and that solar activity probably plays an important role in influencing the precipitation on land. However,researchers have shown relationship between solar activity and precipitation is very complicated and varies with time and probably also with geographic position; on the global scale, the correlation between sunspot numbers and precipitation may be positive, negative, or even zero. Their finding was based on long term observations covering several decades.[7], examined the solar relative variability forcing of climate change in seasonal to decadal scale of five cities in Kenya (Kisumu, Kerico, Nairobi, Garrissa and Mombasa) and found out that there is positive solar forcing on climate for cities close to water body and vice – versa.

In Nigeria [8], correlated SSN and climatic parameters for six regions in Nigeria (Ikeja, Porthacourt, Enugu, Ilorin, Sokoto and Maiduguri) observed a low positive correlation coefficient for minimum temperature and negative correlation coefficient for maximum temperature, hence they concluded that the recent climate change in Nigeria may not be attributed to solar activities.

2. Study Area

Nigeria is located approximately within latitude 4^{0}N and 14^{0}N of the Equator and between 2^{0}E and 14^{0}E of the Greenwich Meridian.As in most West Africa countries, Nigeria's climate is characterized by strong latitudinal zones, becoming progressively drier as one move Northward from the coast. Rainfall is the climatic variable that marked alternation of wet and dry season in most areas. Two air masses control rainfall in Nigeria – Moist Northward moving maritime from the Atlantic and the continental air masses coming South from the Atlantic air mass. The four synoptic stations chosen in this study covers the major climatic zones in the country. Porthacourt (PH) (4.5^{0}N, 7.01^{0}E), Enugu (ENU) (6.28^{0}N, 7.33^{0}E), Ilorin(IRN) (8.29^{0}N, 4.35^{0}E) and Sokoto (SKT) (13.01^{0}N, 5.15^{0}E). The coordinate and locations of the different synoptic stations in Nigeria are shown in Fig 1.

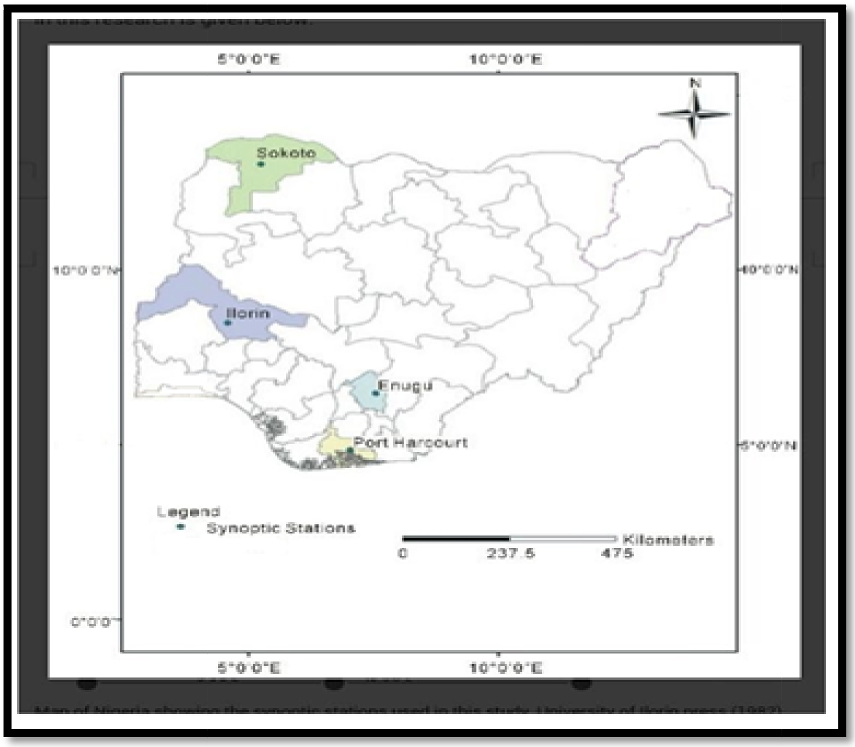

Figure1: Map of Nigeria Showing Areas Used for This Study

3. Methodology

3.1. Data Analysis

The climatic parameters used in this study span through 1970 – 2014 covering 34years of meteorological reading which include Maximum Temperature (MAT), Minimum Temperature (MIT) and Rainfall (RNF). The meteorological data were obtained from the archives of Nigeria meteorological Agency (Nimet), Oshodi Lagos Nigeria.

3.2. Solar Variability Data

The daily solar variables cover the same period as those of the climatic parameters (1970 – 2014). The two solar variables used in this study are the value of the daily sunspot Number (SSN) and the value of the monthly Total Solar Irradiance from Sorce™.

3.3. Data Reduction

The data reduction was done to get the monthly seasonal to decadal values by taking the mean of daily and monthly value of individual parameters. Data reduction was also necessary because the daily data had noise that could not be useful. Equation 1 shows the formula used for reducing the collected data

$$Ag = \sum_{i=1}^{n} \frac{R_1 + R_2 \ldots\ldots\ldots\ldots R_n}{n} \qquad 1$$

where R is the monthly meteorological parameter data at each of the station, n is the number of month or years in view while Ag is the annual meteorological parameter data.

3.4. Correlation Analysis

The correlation method was applied to calculate the variation coefficient between the various meteorological variable and solar parameter across each station. The correlation equation used in this investigation is shown in equation 2 and have been employed by [9][10]

$$r = \frac{\sum_i[(x_i - M_x)(y_i - M_y)]}{\sqrt{\sum_i(x_i - M_x)\left[\sum_i(y_i - M_y)^2\right]}} \quad 2$$

For any two series x_i and y_i (i=0,1,2...N-1). Where r is the correlation coefficient between x and y, M_x and M_y are the mean of the mean of the corresponding series. SPSS statistical program was used to evaluate the entire correlation and their level of significant.

4. Result and Discussion

The annual variation got from the reduced MAT, MIT and RNF data are compared to the annual variation of the solar parameter in all the four regions under investigations in this research. In Fig 2, there is a clear direct relationship between the solar parameter and MAT variability. A strong direct relationship can be seen in cycle 21 to 23 from 1976 to 2008 for ENU, IRN and SKT while that of PHshows a very weak relationship however direct, the obvious reason for this weak relationship can be attributed to the thick cloud cover that is synonymous to this region. This is in agreement with the finding of (Ndeda, 2007) in Kenya and (Olusengun*et al.*, 2014) in Nigeria.

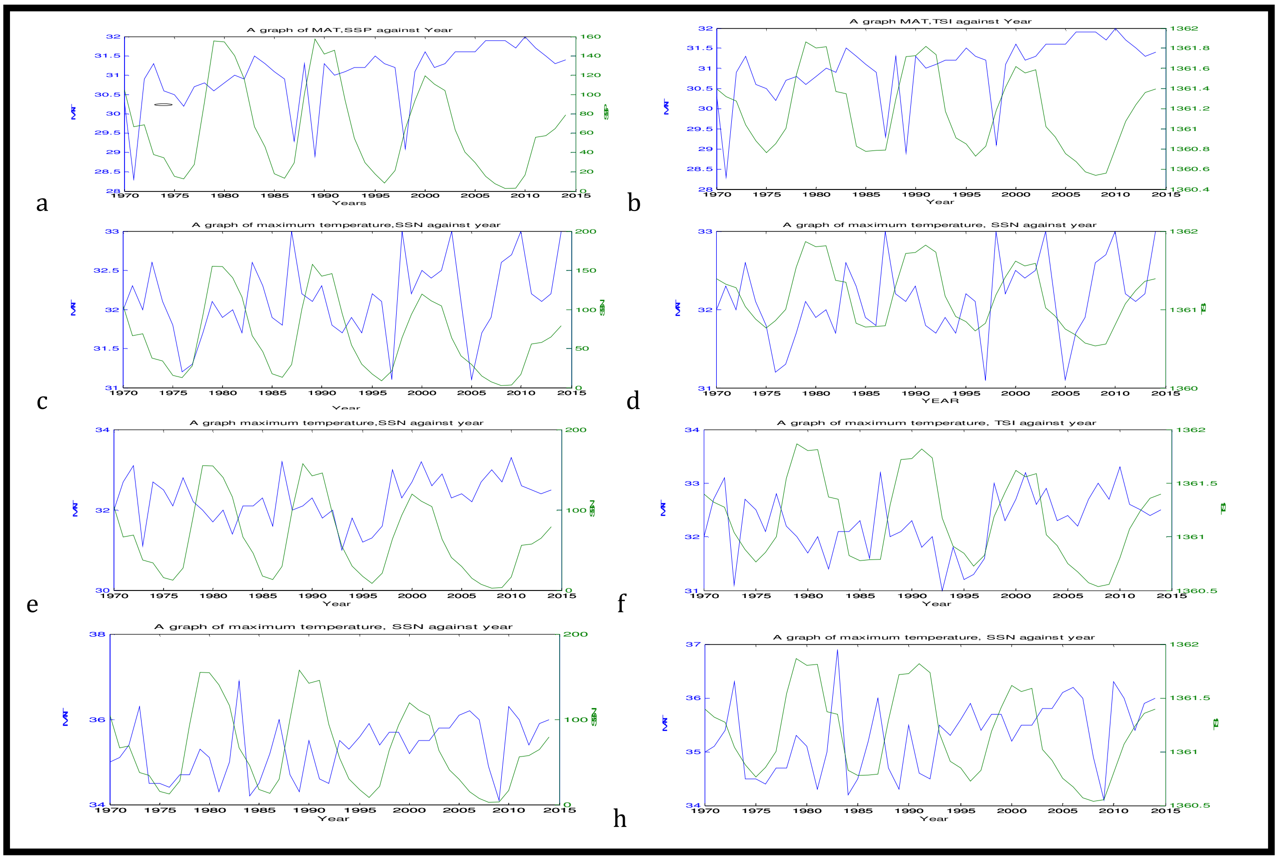

Figure 2: Graphical Representation between SSN and MAT for (a) PH (c) ENU (e) IRN (g) SKT
Graphical Representation between TSI and MAT for (b) PH (d) ENU (f) IRN (h) SKT

Fig 3 shows the graphical relationship between the solar variability and MIT for PH, ENU, IRN and SKT. The trend remains the same as that of the relationship between MAT and solar variable. The solar variability and temperature are in direct relationship with each other. The obvious reason for these parallel trend observed in these regions may be attributed to high temperature in which the Western part of African is been known for. This high temperature brings about clear sky which favors the flow of solar particles. The above trend agrees with the findings of (Olusengun*et al.*, 2014).

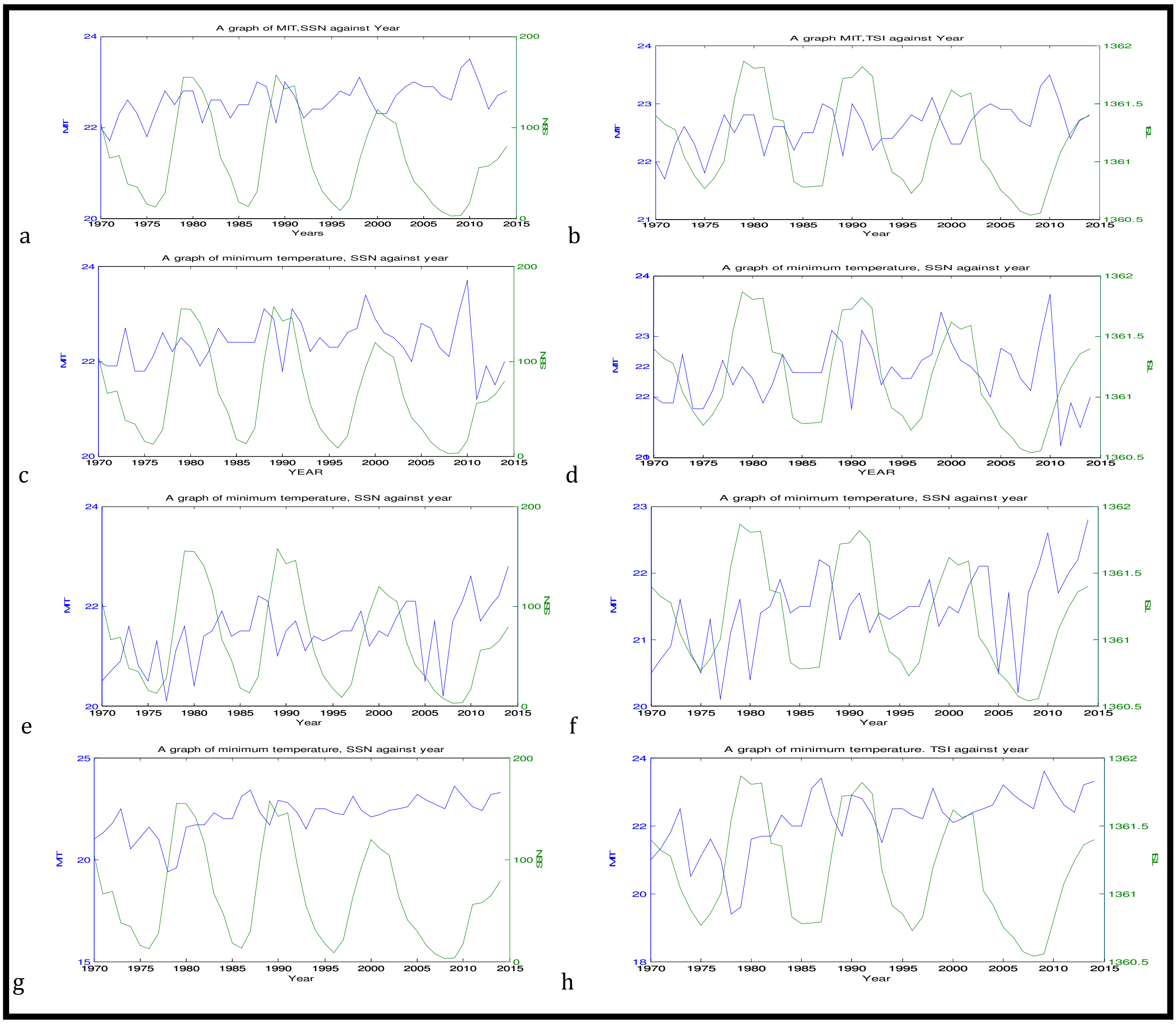

Figure 3: Graphical Representation between SSN and MIT for (a) PH (c) ENU (e) IRN (g) SKT
Graphical Representation between TSI and MIT for (b) PH (d) ENU (f) IRN (h) SKT

Fig 4 shows the graphical relationship between the climate parameter, RNF and the solar variables for the four synoptic stations. There is a clear inverse relationship between the two parameters, this is observed in cycle 22, 23 and 24 from 1987 to 2014, the depression of the solar activities coincide with increase in RNF and vice –versa. The low cloud cover over most area in thecountry may be attributed to the cause of the inverse relationship.

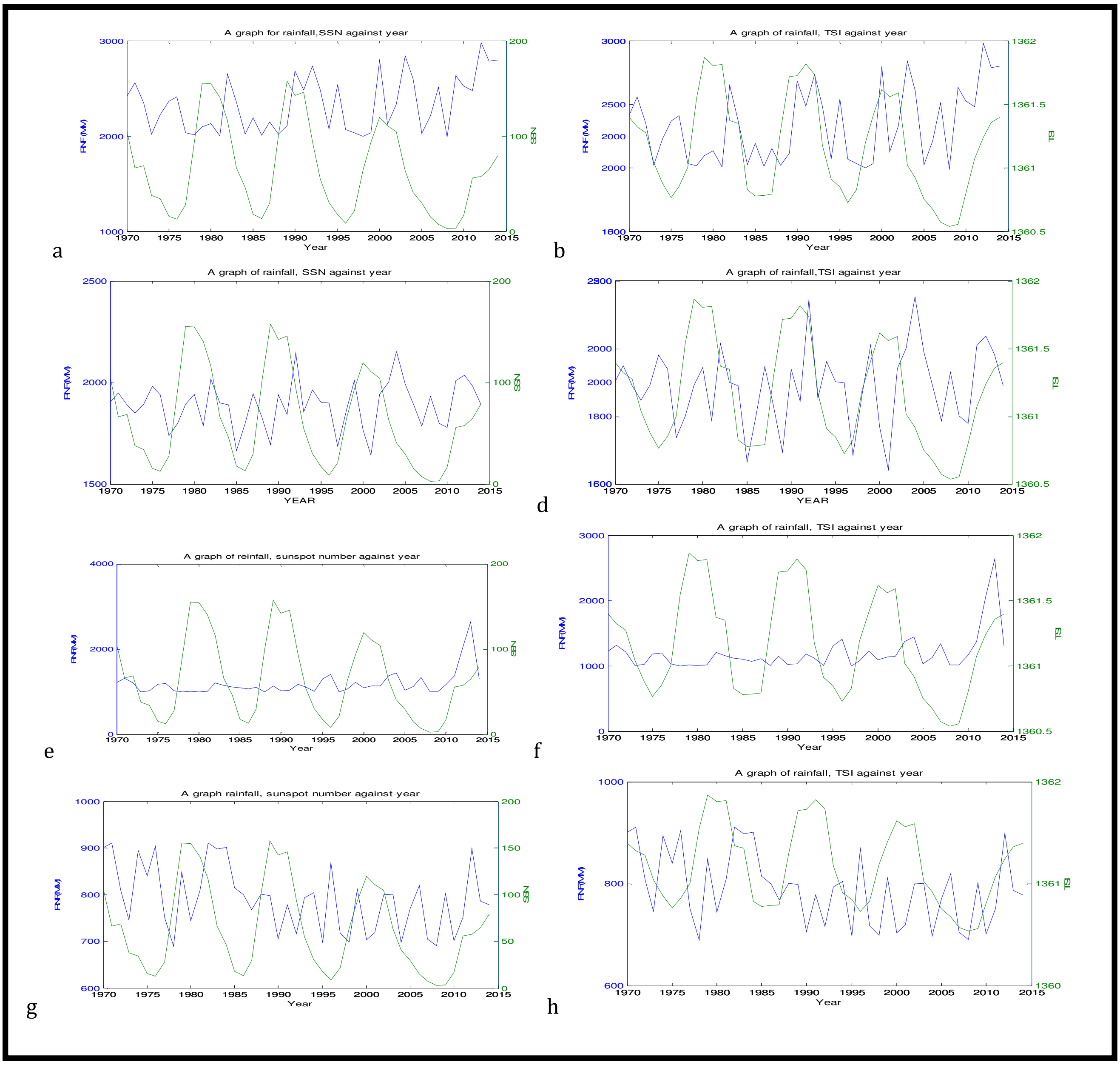

Figure4: Graphical Representation between SSN and RNF for (A) PH (C) ENU (E) IRN (G) SKT
Graphical Representation between SSN and RNF for (B) PH (D) ENU (F) IRN (H) SKT

5. Correlation Result and Discussion

	Porthacourt	Enugu	Ilorin	Sokoto
MAT	-0.243	0.064	-0.105*	-0.149*
MIT	0.178*	0.052	0.047	-0.326**
RNF	-0.075	0.011	-0.093	-0.011

Table 1: Correlation between SSN and MAT, MIT, RNF
**correlation is Significant at 0.01 (2 Tailed) **Correlation Is Significant at 0.05 (2 Tailed)*

Table 1 shows how SSN correlates with MAT, MIT and RNF. The correlation between MAT and SSN shows a positive correlation coefficient in ENU while those of PH,IRN and SKT are inversely correlated. However, only those of IRN and SKT are statistically significant.SSN has a very strong negative correlation coefficient for MIT in SKT and a positive correlation in PH both are statistical significant at 0.01 level and 0.05 level (2 tailed) respectively. SSN correlate weakly with rainfall for all the stations used in this research. Negative correlation coefficient can be seen in PH, IRN and SKT, while a positive correlation coefficient is recorded for PH. None of this correlations is statistical significant.

	Porthacourt	Enugu	Ilorin	Sokoto
MAT	-0.249**	0.041	-0.117*	0.194*
MIT	-0.235*	0.017	0.030	0.308**
RNF	0.138	-0.027	0.005	-0.010

Table 2: Correlation between TSI and MAT, MIT, RNF
**Correlation Is Significant at 0.01 (2 Tailed*
***Correlation Is Significant at 0.05 (2 tailed)*

Table 2 shows how TSI correlated with the climate variables for the entire region used in this research.

TSI has a negative correlation with MAT in PH, IRN and a positive correlation with SKT, this inverse correlation is statistically significant at the 0.01 level (2 tailed) for PH and 0.05 level (2 tailed) while the positive correlation with SKT is statistically significant at 0.05 level (2 tailed). TSI has a positive correlation with MIT in SKT which is statistically significant at 0.01 level (2 tailed), other Positive correlation of TSI with MIT can be seen in ENU and IRN while an inverse correlation is seen in PH with statistically significant at 0.05 (2 tailed) [11]. For rainfall, TSI correlated positively with PH and IRN and inversely with ENU and SKT however none of these correlations is statistical significant.

5. Conclusion

This study tends to address the issue of Sunspots Number (SSN) and Total Solar Irradiance (TSI) on temperature and rainfall over four synoptic stations: Port Harcourt (PH) (4.510N, 7.100E), Enugu (ENU) (6.280N, 7.330E), Ilorin (IRN) (8.290E, 4.350E) and Sokoto (SKT) (13.010N, 5.150E) and has shown that climate change is obvious in Nigeria based on the variability of precipitation and temperature which are used as climate change parameters.According to result a parallel relationship between sunspot number and temperature were observed. It is found also that the sunspot number exhibits an inverse relationship with rainfall. The results obtained represent evidence to proof that solar activities may actually deplete cloud cover that aids precipitation and reduces temperature. This suggests that apart from the effects of greenhouse gases, solar activity would play a key role in climate change observed in Nigeria

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