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CLIMATOLOGICAL INDICATOR OF SUNSHINE HOURS IN ASSOCIATION WITH OTHER CLIMATIC FACTORS IN NIGERIA

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Abstract

The amount of sunshine hours serves as a climatological indicator since it is conceivable that solar variability plays a role in altering weather and climate at some yet unspecified level of significance.

The changes in sunshine duration in association with the amount of rainfall, relative humidity and average temperature over Nigeria were examined for 1980 – 2010 to examine its significance. The sunshine duration hour (hr), the amount of rainfall(mm), relative humidity (%), as well as the average temperature (^{o}C) data were obtained for the six geographical synoptic meteorological stations from the Nigerian Meteorological Agency (NiMeT) for the period of 1980-2010) for Sokoto (12.55^{o}N, 5.12^{o}E), Maiduguri (11.51^{o}N, 13.05^{o}E), Ilorin (8.26^{o}N, 4.30^{o}E), Ikeja (6.35^{o}N, 3.20^{o}E), Port Harcourt (5.01^{o}N, 6.57^{o}E) and Enugu (6.28^{o}N, 7.34^{o}E). All climatologically data were processed and the quality controlled archived. The monthly, annual and seasonal means were calculated for the stations where the estimation of the monthly mean values of parameters, Pearson's correlation, Mann-Kendall test (detect trend) and Sen's Slope (magnitude of the trends), anomalies and annual, seasonal decadal were examined.

The mean monthly, annual and seasonal sunshine duration suggests that the highest long term monthly daily sunshine duration occur in the months of November to February ranging from 6-7 hours per day. With the minimum daily sunshine recorded in July and August at approximately 4 hours per day. The Sunshine duration over Nigeria has decreased from the months of April to July (ranging from 2.26hours/day and 0.75hours/day) then peaked at August (increased) and starts decreasing again at September (0.32 hours/day) with the rest of the year showing increasing trend. Sunshine duration has a strong negative correlation with the amount of rainfall and relative humidity (0.84 and 0.86 respectively at 0.01 significance level) and a strong positive correlation with the average temperature (0.9 at 0.01 significance level) across the country.

The sunshine duration's trend across the country varies with upward and downward trend for temporal variation (anomaly) but while carrying out the Mann Kendall trend test it showed an upward trend in sunshine duration.

Key words: Sunshine Duration, Amount of Rainfall, Relative Humidity, Average Temperature, Trend, Mann-Kendall, Nigeria.

1. Introduction

Sunshine duration is a climatological indicator, measuring duration of sunshine for a given period (usually a day or a year) and a given location on earth, typically expressed as an average value over several years. The simplest information about radiation is available from sunshine duration and the knowledge of its variation at earth's surface is of major importance not only from the climatological point of view but from agriculture, environment and other related scientific/engineering fields. The sun provides essentially all the energy that drives the earth's climate system, it is obvious that solar variations have the potential to directly alter climate. Change in insolation on a variety of time scales have been suggested as causes of known climate change from the (Milankovitch) orbital cycles of thousands of years (Hays *et al*., 1976), to the decadal-to-century scale fluctuations typified by the little Ice Age .

The variation and changes of the world's climate system over time have been reported globally and many of these changes have been attributed to anthropogenic influences (IPCC, 2007). As a result the atmospheric conditions in a given area or country which accounts for its weather conditions (climate) changes, which includes the state of the sky, temperature, winds, pressure, precipitation, and humidity. These factors initiate and influence the atmospheric processes (Ayoade, 1993). As the sun provides essentially all the energy that drives the earth's climate system, the solar radiation reaching the earth's surface has become important, since its variation might show some indications of anthropogenic disturbance (Ramanathan *et al*., 2001).

Some studies have examined the trends in sunshine hours in the context of climate change. Durlo (2006) examined the multiannual variation of the effective sunshine duration in the Beskid Sadecki mountain over 35 year period (1971 – 2005) using the linear regression model for trend testing and estimation. SanchezLorenzo *et al*, (2009) analyzed trends in sunshine duration and total cloud cover over the Iberian Peninsula for the period 1961 – 2004 using the least square linear fitting and the Mann-Kendall non-parametric test for trend estimation and significance testing respectively. Similar studies have been carried out in different parts of the world over various periods (e.g. Rahimzadeh *et al*, 2014; Kitsara *et al*, 2013; Angell, 1990;

Stanhill and Cohen, 2005). The results from these studies indicate existence of trends at different spatial and temporal scales.

These changes over time has been discovered not to be only associated with the variation of solar radiating on the earth but the major change in earth's climate is now really dominated by human activity as well as other factors which include latitude, elevation, nearby water, ocean currents, topography, vegetation and prevailing winds. Nigeria, like the rest of West Africa and other tropical lands has only two seasons (These are the dry season and the rainy season) and the climatic factors associated with Nigeria from the year 1980-2010 have been considered for this study from six (6) states each located differently for all the 6 geopolitical zones in Nigeria considering the amount of sunshine hours, amount of rainfall, relative humidity and average temperature daily, monthly and annually is used in this study.

2.0 Data and Methodology

The sunshine duration (hr), the amount of rainfall(mm), relative humidity (%), as well as the average temperature (^oC) data were obtained for the six synoptic meteorological stations from the Nigerian Meteorological Agency (NiMeT) for the period of 1980-2010 .The data were processed and the quality controlled were archived.

Several methods were used to evaluate climatology and trends using available meteorological and geographical parameters. From the monthly time series of the stations, average Nigerian monthly, annual and seasonal sunshine hour, rainfall, relative humidity and average temperature were evaluated to examine the country as a whole.

Based on statistical premise and interpretation of data such as the estimation of monthly mean values of parameters, Pearson's correlation, Mann-Kendall test (detect trend) and Sen's Slope, anomalies and annual, seasonal decadal evaluation were used. The annual and two seasons , January to December (annual), November to March (dry season), and April to October (rainy season) were also adopted for the analysis. For the correlation analysis, the Pearson's correlation was adopted to find how strong a relationship is between the two data .

The Mann-Kendall (MK) trend test, a non-parametric test to determine whether a time series has a monotonic upward or downward trend was used in order to detect the trends. Correlation analysis was carried out on the sunshine hour (sunshine duration) with other climatic factors used in this study "amount of rainfall (ARF), relative humidity (RH), and average temperature (TEM)”. From the monthly time series of stations, average Nigeria monthly, annual and seasonal SSH, ARF, RH and TEM data series were prepared for 1980-2010 to examine country as a whole trend. The Mann-Kendall trend test was performed on these data series at 95% significance level.

3. Results and Discussions

The monthly, annual and seasonal mean for sunshine duration (SSH), amount of rainfall (ARF), relative humidity (RH) and average temperature (TEM) for Nigeria for the period 1980-2010 is as presented in Figure 1.

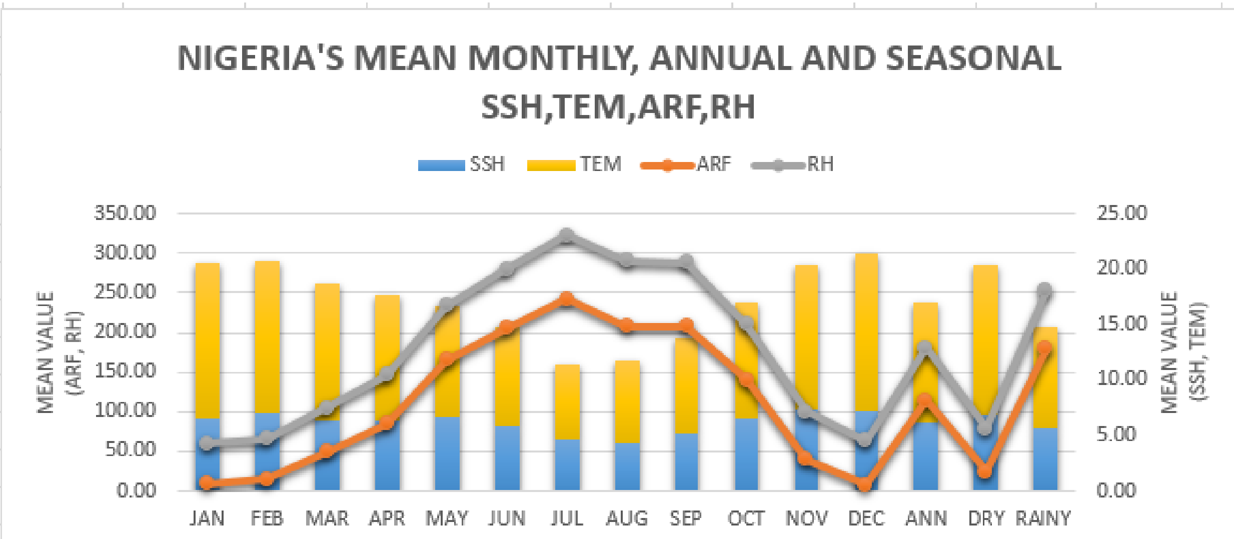

Fig 1: Mean monthly, annual and seasonal sunshine hour (SSH in hours), temperature (TEM in ^{o}C), amount of rainfall (ARF in mm) and relative humidity (RH in %) for Nigeria 1980-2010.

The decadal variations for annual and seasonal means of SSH, ARF, RH and TEM for 1980-1989 (D1), 1990-1999 (D2) and 2000-2010 (D3) decades are shown in Fig. 2. Temporal variations of SSH, ARF, RH and TEM as anomalies from 1980 – 2010 means for Nigeria are shown in Fig 3. Average Nigeria monthly, annual and seasonal mean and trend for SSH, ARF, RH and TEM are given in Figure 4. and Table 1 presents all Nigeria monthly, annual and

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seasonal means and trends in sunshine duration (SSH), amount of rainfall (ARF), relative humidity (RH) and average temperature (TEM) from 1980-2010.

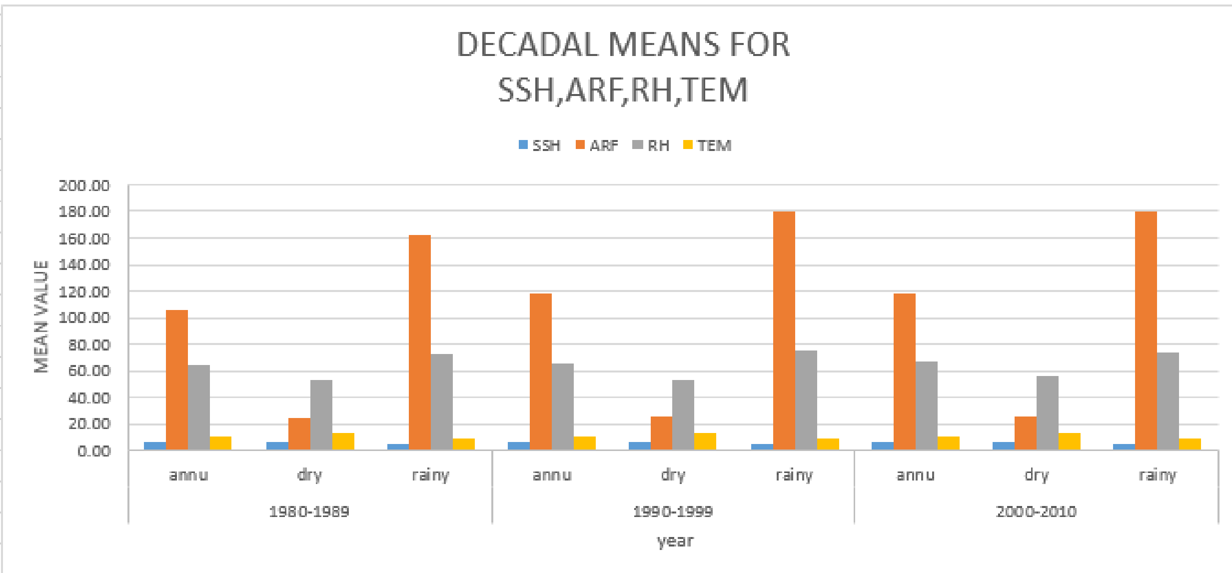
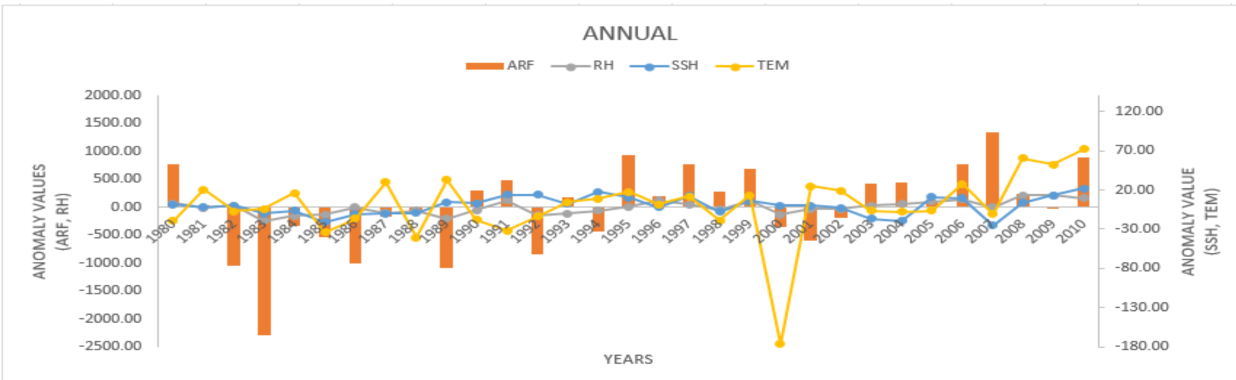
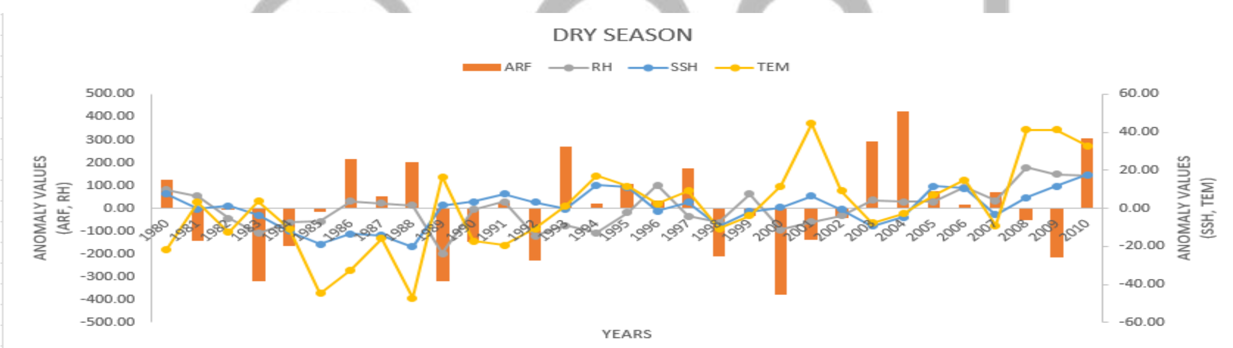


Fig 2: Decadal mean distribution showing annual and seasonal sunshine hour (SSH), amount of rainfall (ARF), relative humidity (RH) and average temperature (TEM) for the period 1980-2010.

(a) Annual



(b) Dry season



(c) Rainy season

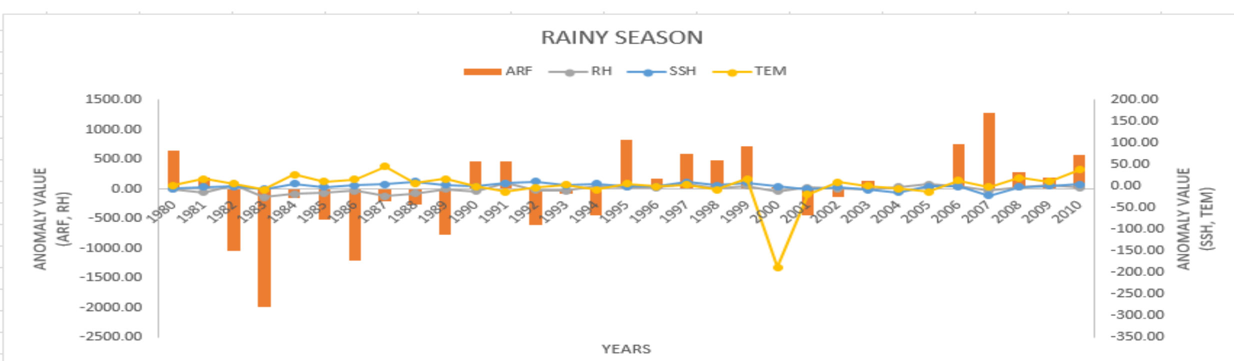


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Fig 3(a-c): Temporal variation of sunshine hour (SSH in hour), amount of rainfall (ARF in mm), relative humidity (RH in %) and average temperature (TEM in ^{o}C) for Nigeria based upon six stations for 1980-2010. Series anomalies from 1980-2010 average for (a) Annual (b) Dry season (c) Rainy season.

Table 1: All Nigeria monthly, annual and seasonal means and trends in sunshine duration (SSH), amount of rainfall (ARF), relative humidity (RH) and average temperature (TEM) from 1980-2010.

	SSH		ARF		RH		TEM	
	Mean	**Trend**	**Mean**	**Trend**	**Mean**	**Trend**	**Mean**	**Trend**
JANUARY	6.6	1.22	8.8	0.77	51.4	1.60	14.0	2.14
FEBRUARY	7.0	2.39*	14.6	0.87	51.2	0.80	13.7	0.94
MARCH	6.3	1.22	49.5	0.17	55.1	0.78	12.4	2.04
APRIL	6.4	-0.78	84.6	1.19	61.2	2.28	11.2	-0.32
MAY	6.7	-0.75	165.2	0.61	69.2	0.68	10.0	0.58
JUNE	5.9	-1.59*	205.2	1.70	74.8	1.28*	9.0	-0.01
JULY	4.7	-2.26	242.4	2.04	80.6	0.32	6.7	0.05
AUGUST	4.2	0.92	208.1	0.75	82.5	1.86	7.5	0.51
SEPTEMBER	5.1	-0.32	208.4	-0.61	79.8	1.67	8.6	-1.00
OCTOBER	6.4	0.89*	140.1	1.05	70.2	1.75	10.6	1.32*
NOVEMBER	7.3	0.43	40.0	0.85	59.6	2.74	13.2	2.03*
DECEMBER	7.2	1.19	7.9	-0.56	55.3	1.46	14.1	2.65
ANNUAL	6.2	1.23	114.6	2.41	65.9	2.64*	10.9	2.16
DRY SEASON	6.9	1.93*	24.2	0.71	54.5	2.28*	13.5	1.57*
RAINY SEASON	5.6	-0.80	179.2	1.89*	74.1	2.75	9.1	0.43

***** - Trends significant at 95% level

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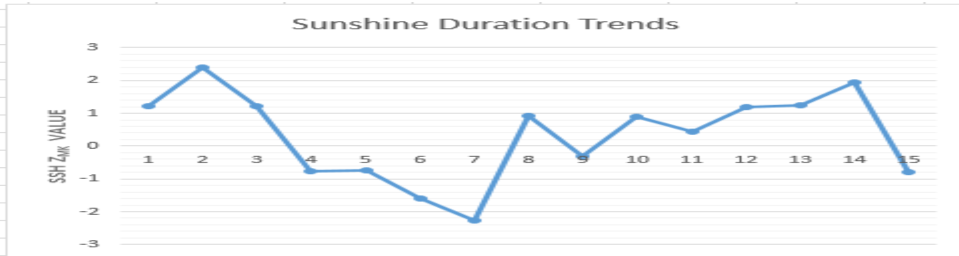
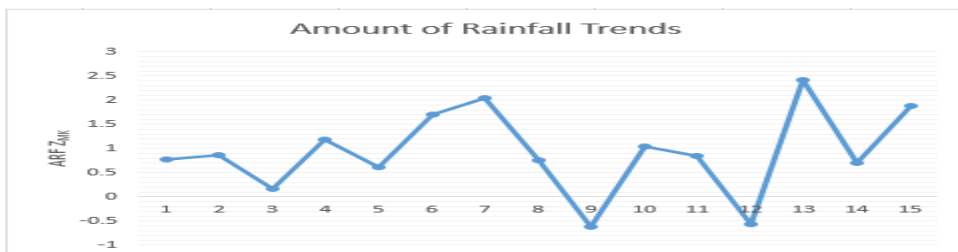
(a)



(b)



(c)

(d)

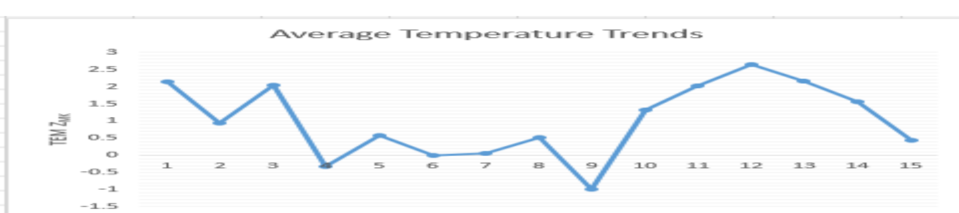


Fig 4(a-d): Trends of sunshine duration (SSH in hour), amount of rainfall (ARF in mm), relative humidity (RH in %) and average temperature (TEM in ^{o}C) for Nigerian stations for 1980-2010.

3.1 Average Nigeria Climatology

As presented in Figure 1. A detailed examination underlines some expected but nevertheless important points. The array (March) of hours of sunshine over Nigeria appears to follow a simple variation with maximum and minimum when amount of rainfall (ARF) and relative humidity (RH) are lowest and highest respectively.

The monthly sunshine hour (SSH) varies between 4.24 hours per day to 7.30 hours per day over Nigeria. Monthly ARF values are in the range of absolutely 7.92mm per month (mostly in the northern part of the country during the dry seasons) and to 242.44mm per month. Similarly, monthly RH are lowest during the dry season i.e. November – March and highest during the rainy season (April - October). Monthly average temperature (TEM) values are usually highest and lowest relative to the period of SSH per day ranging from 6.73^{o}C to 14.09^{o}C across Nigeria.

From average graphical representation of the studied parameters for the 6 stations under consideration, just by mere observation all geographical location of selected stations show similar projections (i.e. Low and high values) as expected for there to be low TEM resulting to high ARF and RH for relatively low SSH which can be observed clearly from April to October (Rainy season) and the reverse case from November to March (Dry season). As we move through the northern and southern part of the country, Sokoto (North West), Maiduguri (North East), Ilorin (North Central), Ikeja (South West), Enugu (South East), and Port Harcourt (South South) a trend in the climatic (overall studied estimate) structure around the country can be observed, which consist of a rise in the ARF with the RH of the atmosphere (seemingly consistent). Closer to the southern region of the country it is observed that the SSH decreases compared to the northern part (evidently during June & July) this could be as a result of the geographical location of the country with the humid winds blowing in from the coastal region (south) and the savanna desert (north).

3.2 Decadal Variation

As shown in figure 2, the annual mean of SSH shows an increment from the first decade D1 to the second decade D2 with an increment of 0.18 hrs., but decreases for the next decade D3

(-0.10 hrs.). For dry season the SSH experiences a significant increase from ~ 6.7 hrs. to 7.1 hrs. And following the same trend as the decadal annual mean SSH the rainy season for SSH experiences for the D1 to D2 an increment of 0.08 hrs., and decreases for the next D3 at -0.21.

The decadal changes in mean ARF shows annual increment from D1 to D2 at 12.17mm and decreases for D3 at -0.6mm with the dry and rainy season increasing all through from 24.57mm – 26.47mm and 162.02mm – 179.96mm respectively. For the decadal changes in mean RH has increased all through for annual and dry season from 64.83% – 66.87% and 53.64% - 56.06% respectively with the rainy season increasing from D1 to D2 at 1.95% and decreases for D3 at -0.09%. TEM shows annual decrease for the first decade D1 to the second decade D2 at -0.19 ^{o}C but increases for the next decade D3 at 0.2 ^{o}C with a decadal variation in means for dry and rainy season which increases all through from 12.92^{o}C – 13.63 ^{o}C and a decrease all through from 9.35^{o}C – 8.86^{o}C.

3.3 Temporal Variation

Temporal variations of SSH, ARF, RH and TEM as anomalies from 1980 – 2010 means for Nigeria are shown in Fig 3(a-c). Both significant downward (negative anomalies) and upward (positive anomalies) trends were observed for all parameters.

A closer look at all the series anomalies from 1980-2010 shows surprisingly more upward (increasing) SSH but with an inconsistent trend within the period despite the suggestions from other studies that a continuous decline in SSH due to increase in aerosols and anthropogenic pollutants as reported by researchers in India (Dey *et al*., 2004; Singh *et al*., 2004; Prasad *et al*., Ramanathan *et al*., 2005; Venkataraman *et al*., 2005 and Sarkar *et al*., 2006) and in China (Zhang *et al*., 2004 and Qiau *et al*., 2007). But it appears that there are less negative anomalies in SSH for annual and dry season but large negative anomalies in SSH for rainy season.

3.4 All Nigeria Means and Trends

The annual variation of hours of sunshine over Nigeria appears to follow a simple variation with maximum (minimum) sunshine when ARF and RH are lowest (highest). Figure 4 . The monthly SSH varies between 4.2 hours/day (August) and 7.3 hours/day (November) over Nigeria. Monthly ARF values are in the range 7.9mm per month (December) and 242.4mm per

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month (July). Similarly, monthly RH are lowest in February (51.2% per month) and highest in August (82.5% per month). Monthly TEM values are between 6.7 per month and 14.1 per month.

Monthly SSH trends are between -2.26 hours/day and 2.39 hours /day and has significant trends for the months of February, June, October and seasonally during the Dry season. SSH shows a decreasing trend from April to July (ranging from -2.26hours/day and -0.75hours/day) then peaked at August and starts decreasing again at September (-0.32 hours/day) with the rest of the year showing increasing trend. The level of significance for the decrease in trends for SSH only shows for the month of June as in Table 1 (significant at 95% level) and seasonally during the dry season.The monthly ARF trends values ranges from -0.61mm per month to 2.41mm per month and shows a 95% significance level during the rainy season. The amount of rainfall shows only a decrease in trends for the months of December and September (-0.56mm and -0.61mm respectively). Similarly the monthly RH trends shows a strong increase in trend ranging from 0.32% per month to 2.75% per month. RH has 95% level of significance for the month of June (1.28%), annually (2.64%) and seasonally during the dry season (2.28%). Also the monthly average temperature TEM trends ranges from -1 ^{o}C per month to 2.65 ^{o}C per month showing 95% significance for the months of October, November (1.32 ^{o}C and 2.03 ^{o}C respectively) and seasonally during the dry season (1.57^{o}C).

4. CONCLUSION

Sunshine duration trends and correlation with other climatic factors were analyzed for six stations in Nigeria from 1980 – 2010. The sunshine duration's trend across the country varies with upward and downward trend for temporal variation (anomaly) but while carrying out the Mann Kendall trend test it showed an upward trend in sunshine duration despite the expected increase in aerosol concentration which proves the uncertainties of the indirect effect of aerosols on clouds and precipitation but nevertheless this could also be a way the country experiences a change in climate. Based upon trend and correlation analysis of sunshine duration and other related parameters, the following conclusion are drawn:

(i) The mean monthly, annual and seasonal sunshine duration suggests that the highest long term monthly daily sunshine duration occur in the months of November to February ranging from 6-7 hours per day. With the minimum daily sunshine recorded in July and August at approximately 4 hours per day.

(ii) It was also deduced that the Monthly, annual and seasonal mean sunshine duration exhibits latitudinal and elevation dependence with the sunshine hours increasing with elevation and increasing latitude.

(iii) Sunshine duration over Nigeria has decreased from the months of April to July (ranging from -2.26hours/day and -0.75hours/day) then peaked at August (increased) and starts decreasing again at September (-0.32 hours/day) with the rest of the year showing increasing trend.

(iv) The average Nigeria sunshine duration is having a strong negative correlation with the amount of rainfall and relative humidity (-0.839 and -0.857 respectively at 0.01 significance level). However having a strong positive relationship with the average temperature (0.897 at 0.01 significance level) across the country.

(v) A detailed examination carried out for this study accordingly, noticeable climatological parameters used show strong correlation between each other with respect to sunshine hour which indicates regional and seasonal variation in factors explaining the long term trends in sunshine duration across Nigeria.

REFERENCE

Ashok J (2009). Sunshine duration climatology and trends in association with other climatic factors over India for 1970-2006 *India Meteorology Department Mausam 60(4):437-454*

Ayoade, J. O. (1983). Introduction to Climatology for the Tropics John Wisley, *London pp 125 - 139.]*

Durło Grzegorz (2006) Multiannual variation of the effective sunshine duration in the Beskid Sadecki mountains *Chair of Forest Protection and Forest Climatology, University of Agriculture in Cracow, Poland*

Hays J. D., John Imbrie, and N. J. Shackleton 1976 Variations in the Earth's Orbit: Pacemaker of the Ice *Ages Science Mag. Org.Vol. 194, Issue 4270, pp. 1121-1132 DOI: 10.1126/science.194.4270.1121*

IPCC, 2007, "Climate change 2007: the physical science basis", contribution of working group I to the fourth assessment report of the *IPCC, Cambridge University Press, Cambridge, United Kingdom.*

Qian, Y., Wang, W., Leung, L. R. and Kaiser, D. P., 2007, "Variability of solar radiation under cloud-free skies in China: the role of aerosols", *Geophys. Res. Lett.*, **34**, L12804.

Ramanathan, V., Crutzen, P. J., Kiehl, J. T. and Rosenfeld D., 2001, "Aerosols, climate, and the hydrological cycle", *Science*, **294**, 2119-2124.

Sanchez-Lorenzo, A., Calbo, J., Brunetti, M., and Deser, C. (2009). Dimming/brightening over the Iberian Peninsula: Trends in sunshine duration and cloud cover and their relations with atmospheric circulation. *Journal of Geophysical Research, 114, D00D09, doi:1029/2008JD011394.*

WMO (2008), *Guide to Meteorological Instruments and Methods of Observation, 7th Edition*, Geneva, Switzerland.

Zhang, Y. L., Qin, B. Q. and Chen, W. M., 2004, "Analysis of 40 year records of solar radiation data in Shanghai, Nanjing and Hangzhou in eastern China", *Theor. Appl. Climatol.*, **78**, 217-227.