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ANALYSIS OF TREND AND VARIABILITY OF SUMMER SEASON VISIBILITY AND TEMPERATURE IN SAHEL ZONE OF NIGERIA

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ABSTRACT

The variation of climate in the past on different time scale in Nigeria has generated a lot of concern and is still posing a threat to life and properties. Meteorologist and climatologist in Nigeria are working hard to address this problem. This study assessed the recent trend and variability of summer season`s visibility and temperature for Sahel zone of Nigeria. The long-term (1988-2017) summer seasons meteorological data derived from National Oceanic Atmospheric Agency-National Climate Data Centre (NOAA-NCDC) were used. A significant decreasing trend in visibility and increasing trend in temperature were detected during the entire period of study. The overall averages were 14.71 ± 4.17 km and 24.54 ± 4.19 ℃ respectively. The trends were found more significance in the last ten years. The Decades` means are 19.38± 3.05, 13.76 ± 2.09, 10.98 ± 1.28 km and 20.60 ± 4.72◦C, 25.78 ± 2.54 ◦C and 27.25 ± 0.79 ◦C for the first, second and third decades respectively. Standardize anomaly chart revealed that over the period of study, positive visibility anomaly correspond to negative temperature anomaly and vice visa. Their correlation at $p< 0.05$ significant level showed a negative relationship of 0.54 over the thirty years period. However, decade analysis showed a positive correlation of 0.47 and negative correlations of 0.61 and 0.74 for the first, second and third decades respectively. These suggest that summer season of the recent decades are dustier than the previous ones and that, summer season of the recent decades become hotter than the previous decades.

Keywords: Summer season, Sahel zone, Visibility, Temperature, Trend.

INTRODUCTION

Recently, aerosol emission (dust inclusive) has been gradually increasing globally (Balarabe, 2018) and is now considered as a crucial factor in the earth climate system (Ashley 2010; Balarabe et al., 2015a; Balarabe, 2018; Balarabe & Isah 2019). Nigeria is closer to Sahara and Sahel (world biggest natural reservoir for dust particles) where dust particles are been uplifted and transported across the country. This transport is a seasonal phenomena, that occurs towards Atlantic Ocean during the month of November to March of the following year (Harmattan season) (Anuforom, 2007) and Sahara during the month of April to October of every year (summer season). Harmattan season`s weather is very dry which is also essential for dust aerosol production, distribution, and transport at local level (Balarabe and Isah, 2019) in Nigeria. It also correspond to a period ofsoil excavation for Agricultural and irrigation purposes that can also contribute to local dust emission. It is therefore esterblished that dust transported from Sahara and anthropogenic dust aerosol is the principal pollutant in Nigeria.

It is documented in many literatures (Wolfgang and Brigitta, 2007; Chineke and Chiemaka, 2010; Balarabe et al., 2015) that in Nigeria, dust pollutant are responsible for low visibility which affects seriously the economy, the health, and climate of the regions (Kaufman et al., 2002, Anuforom et al., 2007; Ogunjobi et al., 2012; Balarabe et al., 2015b). The authors uses dust concentration indicator (Aerosol index (AI)) from the Total Ozone Mapping Spectrometer (TOMS) and Ozone Monitoring Instrument (OMI) as well as Aerosol Optical Density (AOD) from Aeronet Robotic Network (AERONET) to complement visibility at the ground level. Anuforom et al. (2007) and Ogunjobi et al. (2012) obtained a significant negative relationship (R = 0.92 and R = 0. 80) between TOMS AI and visibility during Harmattan period in Sahel zone of Nigeria. Similarly, Balarabe et al. (2015b) also obtained a significant statistical correlation between TOMSAI and visibility on one hand and Ozone Monitoring Instrument (OMI AI) and visibility on the other hand during both Harmattan and summer in Sahel zone of Nigeria. Using AERONET AOD and visibility data at Ilorin Nigeria, a statistically significant relationship was obtained in the work of Balarabe et al. (2015b & Balarabe and Isah, 2019). According to the authors, these significant relationships between visibility and dust aerosol concentration during at all seasons suggest that poor visibility in the region is an integral of high dust concentration.

A number of studies have also been conducted (IPCC, 1990; Mabo, 2006; Ikhile, 2007; Karmalker et al., 2009; Onyenechere, 2010; & Imo and Ekpenyung, 2011) both regionally and temporally to asses the the fluctions of climatic parameters (visibility and temperature inclusive). Anuforom et al. (2007); Ogunjobi et al. (2012) and Balarabe et al. (2015b) have revealed the changes of visibility trends over time in Nigeria. IPCC, (1990) and Onyenechere, (2010) described temperature as the most important parameter in earth climate. These authors have argued on the global temperature increase in the past and future projection. Therefore, constant monitoring and evaluations of visibility and temperature at different regions and time are necessary. A long-term (1988-2017) study on these parameters and their relationship were previously carried out in the work of Balarabe, 2018 but only for Harmattan season. To complement this effort, summer seasons visibility and temperature of the same period need to be investigated. Therefore, this work focuses on the summer seasons of the most recent thirty years to evaluate the trend and variability of visibility and temperature in Sahel zone of Nigeria. The goal was to explore whether any significant regional climatic change has occurred during the recent thirty years (1988-2017) summer seasons. This will enable us to analyzes temperature seasonal dependence and examine possible shift in the mean condition caused by aerosol particles. This is important as there are no measures as to the number of years a phenomenon occurs to cause a shift in any of the meteorological parameter.The result can serve as a base for future studies on the irradiative aspect of aerosol in the Sahel zone of Nigeria. It is expected to provide a new perspective/theoretical basis for assessing regional climate variability which is essential for future plan.

DATA AND METHODOLOGY

In this study, visibility and temperature data used were obtained from NOAA-NCDC Website. The data files were in ASCII format and inported into excel spread sheet for further processing and analysis. For this study, 8 meteorological stations across the Sahel zone of Nigeria (Anuforom 2007, Balarabe et al., 2015) based on 75% data availability were downloaded. A scaled physical map of Nigeria is provided to show the different zones including Sahel which is the study area (Latitude 11–14°N). The stations includes Sokoto, Gusau, Katsina, Kano, Nguru, Potaskum, Maiduguri and Zaria respectively.

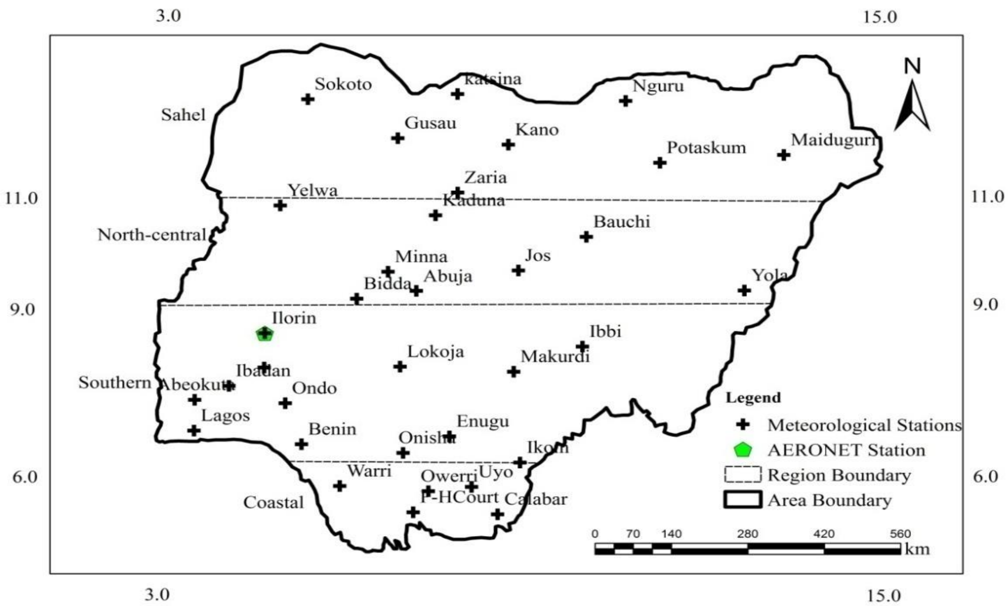


Figure 1. The distribution of meteorological stations over the study location.

The visibility and temperature data were documented in miles and degree Fahrenheit but were converted into kilometer, and degree Celsius respectively in accordance with the standard. The hourly data were arranged in to monthly (January-December) for each station and year from which the series of daily averages were calculated using the equation $\overline{V} = \frac{V}{N}$ and $\overline{T} = \frac{T}{N}$. (1)

Where V and T are the visibility and temperature while N is the number of observations

Subsequently, the monthly averages for each year within the period of the daily data were also obtained using equation 1. The monthly averages from each station were arranged so that the corresponding monthly means will be calculate as zonal mean for each month. For this analysis, summer season months were further isolated and simple statistical analysis involving simple regression and time series plots to depict the pattern of summer season variability of visibility and temperature in the study zone were used for simplicity of presentation. The simple regression equations used take the form of

$$V = a_o + bT \tag{2}$$

Where V is the visibility, a_o is the constant, b is the coefficient and T is the temperature. The coefficient of the correlations were obtained using the equation

$$a = \frac{(\sum V^2)\overline{T} - \overline{V}(\sum VT}{\sum V^2 - \sum(V)^2/K} \tag{3}$$

And

$$b = \frac{\sum(V - \overline{V})(T - \overline{T})}{\sum(V - \overline{V})^2} \tag{4}$$

The ten years` interval (i.e., 1988-1997, 1998-2007, 2008-2017) summer seasons` cumulative mean were also calculated in view of analyzing their relationships for the overall period and decades as a means of exploring the hiding information from voluminous record of visibility and temperature. Both the trend and Pearson's correlation analysis were determine at 95% confidence level. Visibility and temperature standardize anomaly has been calculated, and the charts were plotted for comparison.

RESULT ANALYSIS

Summer season trend and variability of visibility and temperature

Over the 30 years period (1988-2017) summer season`s temporal trends of visibility and temperature is revealed in Figure 2.

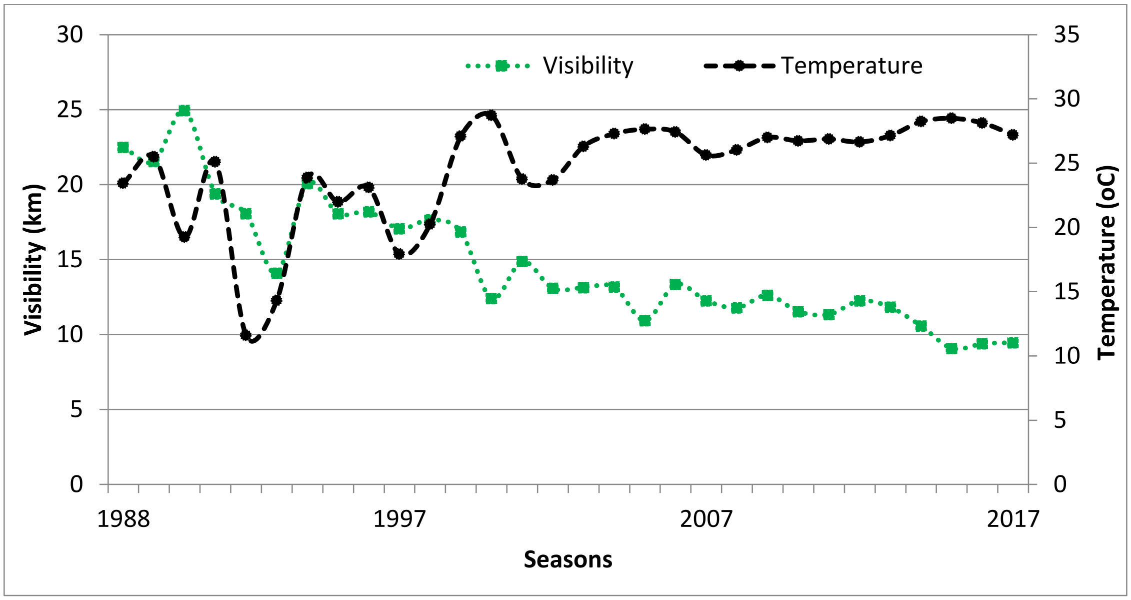


Figure 2. The 30- years summer season mean visibility and temperature trend in Sahel zone.

A significant decreasing trend in visibility and increasing trend in temperature were detected during the entire period of study. Using student T-test, these trends were found significant at 95% confidence level, even though, more significance in the last ten years. The decreasing trend in visibility over the study period is an indication that there had been an increase in the concentration of dust particles that affect visibility. Similarly, the increasing trend in temperature suggest that the increased dust concentration is responsible for the increase in the heat trapped in the earth surface and eventually increases temperature (Ogunjobi et al., 2012). This is in line with what was observed by Quijano etal., (2000) that the absorbtion of radiation which give rise to temperature increase is predominant in the interaction of saharan dust with solar radiation. These results are also inline with many other global trends documented in various literature (IPCC 1992a; IPCC, 1992b; Mahowald et al., 2002; Mabo, 2006; Onyenechere, 2010; Imo and Ekpenyung, 2011). For most of the years, it was observed that visibility and temperature fluctuations are closely related and the growing rate seems uniform. The high visibility corresponding to high temperature fluctuations may correspond to a period when majority of the dust aerosol layer are confined to a high altitude. These aerosols may not affect visibility at the ground but may increased aerosol absorption which in turn increases temperature. On the other hand, as the aerosol is suspended high in the atmosphere, it is possible to have result to more scattering than absorption as a result of which visibility will be high with corresponding low temperature as revealed in some years (Figure 1). Furthermore, the low visibility and low temperature fluctuations may correspond to the period when majority of the dust aerosol are confined to the lower atmospheric level (Balarabe et al., 2015). Such aerosols influence scattering and reduce the visibility (Anuforom et al., 2007) at the ground.

The overall averages were 14.71 ± 4.17 km and 24.54 ± 4.19 ◦C respectively while Table 1 revealedthe results of the decade analysis of visibility and temperature including their decreasing rate over the study period. The decades means are 19.38± 3.05, 13.76 ± 2.09, 10.98 ± 1.28 km and 20.60 ± 4.72◦C, 25.78 ± 2.54 ◦C and 27.25 ± 0.79 ◦C for the first, second and third decades respectively. These imply that temperature is lowest in the first decade and highest in the last decade. Similarly, visibility is generally highest in the first and lowest in the last decade. This is very consistent, the lower the visibility (higher aerosol concentration) the higher the temperature in the Sahel zone of Nigeria.

Table 1 Ten years interval average visibility and temperature as well as their decreasing rate for Sahel zone of Nigeria

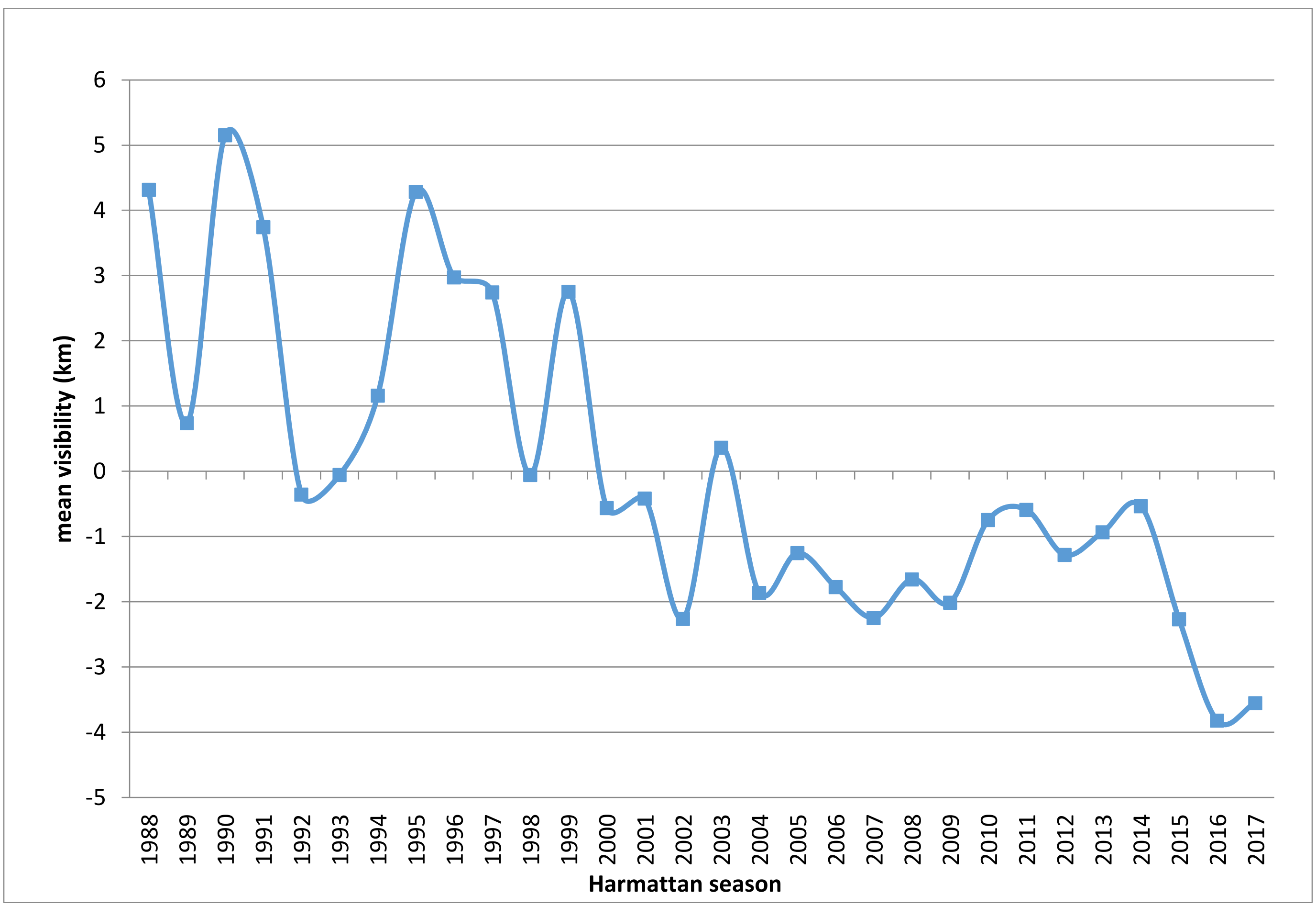
Period	Average visibility (km)	Decreasing rate/decade (km/yr)	Average Temperature(◦C)	Decreasing rate/decade (◦C/yr)
1988-1997	19.38	-0.31	20.60	-0.28
1998-2007	13.76	-0.39	25.78	0.55
2008-2017	10.98	-0.08	27.25	0.12

In the second decade, the pattern of fluctuations varies compared to the first decade (Figure 2). This can be related to changing pattern of the rate at which dust aerosol are emitted as a result of increased anthropogenic activities and transport of dust. During this decade, visibility decreases while temperature increases.

The third decade is characterized by short fluctuations in the seasonal trend pattern (Figure 2).Table 1 show that this decade experiences the lowest visibility values with corresponding highest temperature values. The lowest visibility can be associated with increased dust concentration due to increased emission strength from the dust source regions (Goudie & Middleton, 2001) and regional anthropogenic emission (Anuforom et al., 2007). The decrease in visibility was fastest in the second decade followed by first decade and slowest in the last decade. Interestingly, the temperature increase was also fastest in the second decade and slow in the last decade.

Figure 3 revealed the summer season`s visibility and temperature anomaly. It is evident from the figure that in the first decade, positive visibility corresponds to negative temperature anomaly while in the second and third decade's negative visibility corresponds to positive temperature. These suggest that summer season of the recent decades are dustier than the previous ones and that, summer season of the recent decades become hotter than the previous decade. This could be due to the fact that the absorption ability of the dust aerosol in this region has increased over time. This is similar to the findings of Anuforom et al. (2007) and Ogunjobi et al. (2012) who found an increased trend in Absorbing Aerosol Index in Nigeria.

A



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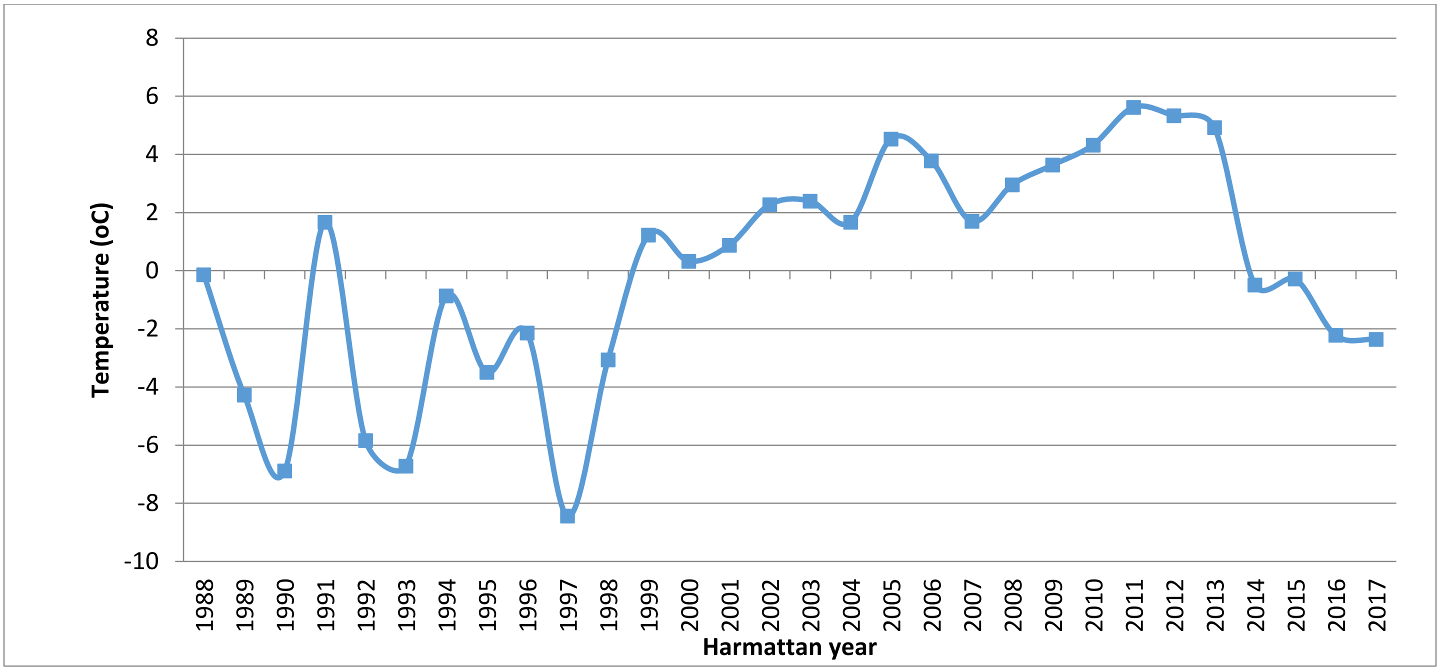

Figure 2. Comparism between summer season mean visibility and temperature anomaly of Sahel zone of Nigeria from 1988-2017.(A. Visibility; B. temperature).

Correlations and simple regression analysis

In order to establish the relationship between visibility and temperature in the Sahel zone of Nigeria, correlation analysisfor the overal data(1988-2017) decades data were analysed in order not to exclude much meteorological information when considering only 30 years data. The result of this analysis is revealed in Table 2 and Figure 3. The result obtained showed that visibility is fairly correlated with temperature in the overall data. By dividing the 10, year's interval. It is expected that much stronger and more significant relationship be obtained. Possibly due to the fact that the relationship between temperature and aerosol is a function of many factors such as concentration, nature of the aerosol, meteorological condition and the size of aerosol in a time and region.The amount of available data for the analysis could equally contribute to the variation in the correlations.

Table 2 Correlation coefficients between visibility and temperature for Sahel zone of Nigeria during Summer season of 1988-2017.

Period (years)	Correlation (r)
1988-2017	-0.54
1988-1997	0.47
1998-2007	-0.61
2008-2017	-0.74

The responses are weak and positive in the first decade, strong and negative in the second and third decades. The magnitude of correlations are higher in the third decade and lowest in the first decade. The negative correlation implies that temperature decreases with decreases with increasing visibility and vice versa. However, the positive correlation revealed that dust concentration results in increasing temperature in the zone. This is similar to what was observed by Junjun et al. (2014) who found a positive relationship between visibility and temperature in Taiwan Strait. The low correlation in the first 10 years can be understood by suggesting that aerosol causes low visibility mostly through scattering (Miller and Tegen, 1998). However, biomass and charcoal burning aerosol, industrial and combustion from vehicle and industries causes low visibilities through absorption. So dust and other aerosol interaction may weakened the relationship as there could be no large amount of smoke to produceequal amount of absorption to scattering the cause by dust particles.

Figure 3 revealed the simple regression equation between visibility and temperature at $p< 0.05$ during the study period. From the scatter plot, different lines of fit were tested, and it was found that the trend of visibility and temperature is consistently exponential. These equations are compared well with the linear equations found between visibility and temperature by Usman et al. Usman et al. (2013) and To et al. (2014) at Sokoto Nigeria and Hong Kong China.

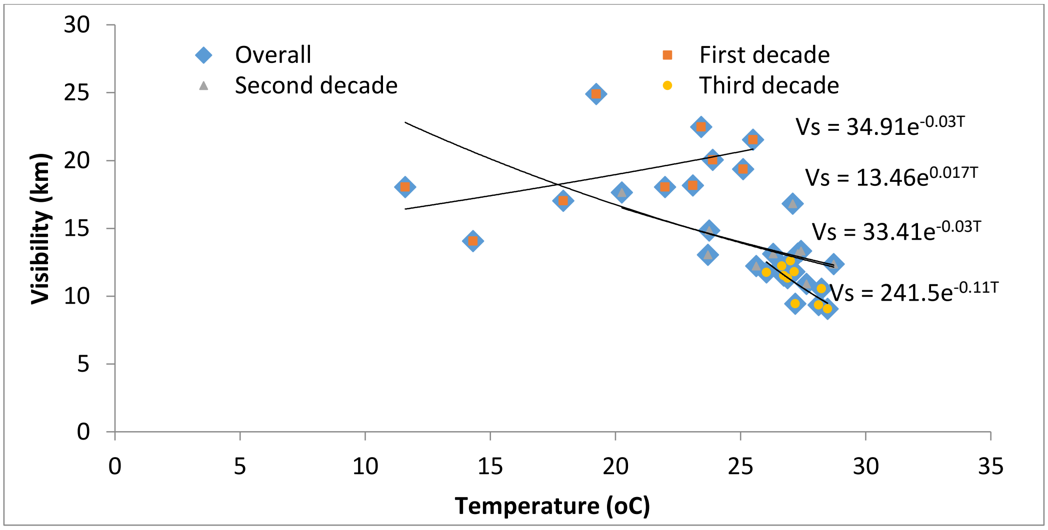

Figure 3: scatter plotts relating visibility and temperature for Sahel zone of Nigeria during summer season for 1988-2017.

CONCLUSION

This study assessed the recent trend and variability of summer season`s visibility and temperature for Sahel zone of Nigeria. The long-term (1988-2017) summer seasons meteorological data derived from National Oceanic Atmospheric Agency-National Climate Data Centre (NOAA-NCDC) were used. The results revealed a significant decreasing trend in visibility and increasing trend in temperature during the entire period of study. Using student T-test, these trends were found significant at 95% confidence level. It is found generally that visibility and temperature changes are closely related. The overall averages were 14.71 ± 4.17 km and 24.54 ± 4.19 ◦C respectively. The trends were found more significance in the last ten years. The decades analysis was carried out and the means were 19.38± 3.05, 13.76 ± 2.09, 10.98 ± 1.28 km and 20.60 ± 4.72◦C, 25.78 ± 2.54 ◦C and 27.25 ± 0.79 ◦C for the first, second and third decades respectively. The most obvious changes happen during the third decade. This decade experiences the worse visibility with highest corresponding temperature. Standardize anomaly chart revealed that over the period of study, positive visibility anomaly correspond to negative temperature anomaly and vice visa. The regression analysis results showed that the relationship between temperature and visibility is a temporal phenomenon (0.54 over the thirty years period),0.47, -0.61 and -0.74 for the first, second and third decades respectively. However, the trend between visibility and temperature is consistently exponential. Since this research is limited to the visibility and temperature trend, variability and characteristic in Sahel zone of Nigeria, quantification analysis is required to determine the impact different aerosol on temperature in the region. Trend analysis involving the use of Mann Kendall analysis is also left open for further research.

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