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TRENDS AND VARIATIONS OF MONTHLY MEAN MINIMUM AND MAXIMUM TEMPERATURE DATA OVER NIGERIA FOR THE PERIOD 1950-2012.

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ABSTRACT: *The monthly mean maximum and minimum temperature data were analysed with the aim of revealing spatial and temporal pattern of long-term trends in the variables. The study is based on the data collected from Nigeria Meteorological Agency's network of meteorological stations spread across Nigeria spanning from 1950-2012. A total of 20 meteorological stations spread across Nigeria were used for the analysis. Statistical techniques such as time-series plots, correlation analysis, descriptive statistics and Mann-Kendall's test were used for the analysis. These analyses were executed using the R programming language, MATLAB and SPSS computer software packages. The results show latitudinal dependence of basic temperature characteristics with the northern part of the country exhibiting higher temperature variability than the south. The Mann-Kendall tests indicate that 17 stations (representing 85%) show significant increasing trends in the minimum temperature at the 0.01 level of significance while 16 stations (representing 80%) show significant increasing trends in the maximum temperature at the 0.01 and 0.05 significance levels. Port Harcourt and Ikeja have greatest trend coefficients among the 20 stations. The minimum temperatures have higher trend coefficients than the maximum temperatures for almost all the stations. The interstation spatial coherence revealed by correlation coefficients indicates that almost all the station's minimum and maximum temperatures are positively correlated with others at the 0.01 level of significance. The Mann-Kendall's test results show a general warming trend across the stations.*

KEYWORDS: *Trends, maximum temperature, minimum temperature, Mann-Kendall, variability, Nigeria.*

INTRODUCTION

The global atmosphere is undergoing a period of rapid human – driven change, with no historical precedent in either its rate of change or its potential absolute magnitude (IPCC, 2002), in Malhi and Wright (2004). Human activities are continuing to affect the earth's energy budget by changing the emissions and resulting atmospheric concentrations of radiatively important gases and aerosols, and by changing land surface properties. One of the most common indicators of climate change is the surface air temperature. There are a vast amount of research papers that examined changes in global and regional mean temperatures over time (Karabulut *et al*., 2008, Turkes *et al*., 2002; Olofintoye and Sule, 2010; Jain and Kumar, 2012; Gil-Alana, 2008; Jones *et al*., 2013; Ewona and Udo, 2008). Global climate has changed significantly in the last century. Global mean surface temperature has increased by 0.74^{o}C during the last century (IPCC, 2007).

Trend detection in temperature and precipitation time series is one of the interesting research areas in climatology. Precipitation and temperature changes are not uniform. Regional variations can be much larger, and considerable spatial and temporal variations may exist between climatically different regions (Yue and Hashino, 2003). A number of studies have evaluated the trends in temperature on different spatial and temporal scales (Ogolo and Adeyemi, 2009; Odjugo, 2011; Malhi and Wright, 2004; Kiladis and Diaz, 1989; Klein-Tank and Konnen, 2003).

Climate change over a region would have a significant impact on agricultural production and related sectors, water resources management and overall economy of the country. Food and energy security are crucially dependent on the timely availability of adequate amount of water and a conducive climate. Temperature and its changes impact a number of hydrological processes including rainfall, and these processes in turn impact temperature e.g cooling due to rain or snow (Jain and Kumar, 2012; Ewona and Udo, 2011). Today, climate change has direct effects on increasing global temperature, alter precipitation patterns, alter pattern of agriculture, increase size and number of forest fires etc (Karaburun *et al*., (2012). Climate change also has indirect effects on human health, caused by infectious disasters such as water – borne and vector – borne disasters, and socio-economic effects caused by environmental change and ecological disruption (WHO, 2003) in Karaburun *et al*., (2012). Although regional effects of climate change vary based on location of regions, there is a growing consensus that temperatures are on the rise. Analysis of worldwide air temperature changes have shown that temperature has increased in both northern and southern hemispheres over the last century with warming more dominant in the northern hemisphere since the 1950s (Rebetez and Reinhard, 2008) in Karaburun *et al*., (2011).

Many regional studies have also found a positive trend in temperature, although the changes vary slightly from one region to another (Abatzoglou *et al*, 2009; Karaburun *et al*, 2011; Ustaoglu, 2012; Liu *et al*., 2006; Abudaya, 2013; Karaburun *et al*., 2012). Urbanization makes significant changes in the surface parameters which have the potential to change the local climate in cities (Ezber *et al*, 2007) in Ustaoglu (2012). Ustaoglu (2012) further posited that population growth and urbanization have warming effect on climates. A number of different methods have been used to evaluate the changes in mean, maximum and minimum temperatures with changing pattern from region to region (Duffy *et al*., 2001; Peterson and Vose 1997; Jones and Moberg, 2003; Karaburun *et al,* 2012; Sonali and Kumar (2013). Several parametric and non-parametric statistical tools are used to analyze trends in climate change studies. Mann-Kendall trend test, Sen's slope estimator and spearman's rank order correlation tests are used to analyze the direction, magnitudes and significance of possible trends in observed data.

The current goal of applied climate science is to improve knowledge at regional and local levels. The smaller the scale at which information can be provided, the greater the relevance to users for most applications. Therefore, the basic objectives of the study are:

I To infer the nature of spatial and temporal variations of minimum and maximum temperature over Nigeria from 1950 – 2012 period using 20 synoptic stations.

II To examine the trends of monthly mean minimum and maximum temperatures from 1950 – 2012 for the 20 synoptic stations spread across Nigeria.

Trends have become the most commonly used technique to detect climatic variability in regional and local basis. In this study, Mann-Kendall's rank correlation test and other statistical tools were used. Some trend studies in instrumental records of temperature have been conducted in Nigeria, the most comprehensive being Abiodun *et al*, (2011) which covered a period of 30 years (1971 – 2000) in 40 weather stations across Nigeria. This study extended the evaluation of temperature trends to cover a period of 63 years (1950 – 2012) for 90% of the stations selected for the study.

STUDY AREA

Nigeria lies between latitude 4^0N and 14^oN, and between longitude 2^0E and 15^oE. It coordinates on 10.00^oN and 8.00^oE. It has a total area of 923.77km^2 and land mass coverage of 910.77km^2. Nigeria is composed of various ecotypes and climatic zones, defining different temperature regimes. The Nigerian climate is dominated by the influence of the Tropical Maritime (TM) air mass and the Tropical Continental (CT) air mass. The TM air mass originates from the southern high-pressure belt located off the Namibian Coast, which then picks up moisture from over the Atlantic Ocean, thus becoming a moisture – laden air mass (Abiodun *et al*, 2011). The CT air mass originates from the high pressure belt, north of the Tropic of Cancer and is always dry. It travels towards Nigeria over the Sahara desert. The TM and CT air masses converge at a place called the Inter Tropical Convergence Zone (ITCZ) also called the Inter Tropical Discontinuity (ITD). The seasonal northward and southward migration of the ITD dictates the weather pattern of Nigeria. Figure 1 is Map of Nigeria showing the locations of the stations used in the study.

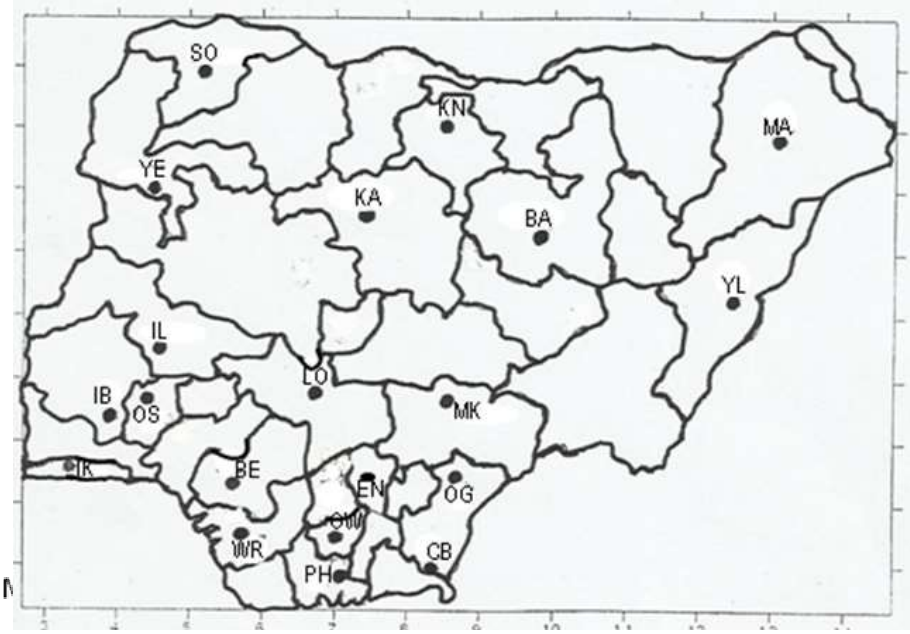


Fig 1: Map of Nigeria showing meteorological locations for the study

THE DATA

Monthly mean values of daily minimum and maximum temperatures for the period 1950 – 2012 at 20 synoptic stations spread across Nigeria were obtained from the archives of the Nigerian Meteorological Agency, (NIMET) Oshodi, Lagos, Nigeria. Table 1 below gives the details of the station locations and the data length.

Table 1: Description of weather stations and data used

Station No	Station Name	Latitude (^{o}N)	Longitude (^{o}E)	Elevation (m)	Period	Sequence length (month) Max T	Min T
1.	Yelwa	10.53	4.45	244	1950 - 2012	756	756
2	Sokoto	12.55	5.12	351	1950 - 2012	756	756
3	Kaduna	10.42	7.19	645	1950 - 2012	756	756
4	Kano	12.03	8.32	476	1950 - 2012	756	756
5	Bauchi	10.17	9.49	591	1950 - 2012	756	756
6	Maiduguri	11.51	13.05	354	1950 - 2012	756	756
7	Ilorin	8.26	4.3	308	1950 - 2012	756	756
8	Yola	9.16	12.26	191	1950 - 2012	756	756
9	Ikeja	6.35	3.2	40	1950 - 2012	756	756
10	Ibadan	7.22	3.59	234	1950 - 2012	756	756
11	Oshogbo	7.47	4.29	305	1950 - 2012	756	756
12	Benin	6.19	5.36	77.8	1950 - 2012	756	756
13	Warri	5.31	5.44	6	1950 - 2012	756	756
14	Lokoja	7.48	6.44	113	1950 - 2012	756	756
15	Port Harcourt	5.01	6.57	18	1950 - 2012	756	756
16	Owerri	5.25	7.13	91	1974 – 2012	444	468
17	Enugu	6.28	7.34	142	1950 - 2012	756	756
18	Calabar	4.58	8.21	62	1950 - 2012	756	756
19	Makurdi	7.42	3.37	113	1950 - 2012	756	756
20	Ogoja	6.4	8.48	117	1976 – 2012	444	444

METHODOLOGY

Data Check and Smoothening

Quality check was carried out on the data. Only the Owerri data have missing values of 24 months in maximum temperature which represents 5% of the data length. Missing entries were not replaced as there were no nearby enough stations to help in estimating them. Shongwe *et al*, (2006) suggested the use of data from stations with missing values not exceeding 5%. Ngongondo *et al* (2011) recommended the use of data with up to 10% missing entries for cases of data scarce region. The stations' meta data were not available. Inhomogeneities observed were very likely related to the long term fluctuations and trends, which are accepted within other non-randomness characteristics of the series of climatological observations (Syners, 1990; Turkes, 1999). The data were smoothened by the moving average technique to get rid of fluctuations.

DATA PROCESSING

SPSS computer software package was used to evaluate the descriptive statistics of the temperature distributions to reveal the minimum and maximum temperature characteristics of the stations. The Bar charts were produced to give the seasonal variation of temperature of the stations over the entire period using the R programming language. The Pearson's Product moment correlation coefficients were carried out using the SPSS computer package to give the spatial correlations of the minimum and maximum temperatures of the stations. The Time series plots with trend lines were done using MATLAB software. The non-parametric Mann-Kendall's test was applied to detect trend direction and trend significance. The non-parametric Mann-Kendall's test is superior to the parametric tests (Karaburun *et al*, 2011; Ustaoglu, 2012; Karabulut, 2008) because Mann-Kendall test allows for missing values in time series data; it does not require to conform to any particular distribution; and it is robust to the effect of outliers (single data errors) (Turkes, 1999).

The Mann-Kendall's Rank Correlation Test

For n size data set such that $n \geq 10$, and assuming that the time series is independent, the Mann-Kendall's test statistic S is calculated according to the following formula.

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} \operatorname{sgn}\left(x_j - x_k\right) \qquad (1)$$

where x_j and x_k are the sequential data for the i^{th} and j^{th} terms, where $j>k$.

$$\operatorname{sgn}\left(x_j - x_k\right) = \begin{cases} 1 \; if \;\; x_j - x_k > 0 \\ 0 \; if \;\; x_j - x_k = 0 \\ -1 \; if \;\; x_j - x_k < 0 \end{cases} \qquad (2)$$

A high positive value of S is an indicator of increasing trend while a large negative value of S is an indicator of decreasing tend. The variance of S, VAR(S), where there are no ties (ie j=k does not exist) is computed as

$$\text{VAR} = \frac{n(n-1)(2\mathbf{n}+\mathbf{5})}{\mathbf{18}} \qquad (3)$$

In the presence of ties, VAR(S) is expressed thus:

$$\text{VAR (S)} \quad = \frac{1}{18}\left[n(n-1)(2n+5) - \sum_{p=1}^{q} t_p(t_p-1)(2t_p+5) \right] \qquad (4)$$

q is the number of tied groups (where j = k) and tp is the number of data values in the pth group. The values of S and VAR(S) are used to compute the test statistic Z as:

$$Z \quad = \begin{cases} \frac{S-1}{\sqrt{VAR(S)}} \ if \ S > 0 \\ 0 \qquad if \ S = 0 \\ \frac{S+1}{\sqrt{VAR(S)}} \ if \ S < 0 \end{cases} \qquad (5)$$

Z follows a normal distribution.
The null hypothesis H_o for a two-tailed test is that there is no trend, and that the data are randomly ordered. The alternative hypothesis H_1 is that there is a trend. The null hypothesis is rejected when the Z value determined by eqn (5) is greater in absolute value than the critical (table) value $Z_{\alpha/2}$ at the α level of significance, ie $/Z/ > Z_{\alpha/2}$. Otherwise the null hypothesis is not rejected. The Z value is tested at 5% and 1% levels of significance. The trend is positive (increasing) if Z is positive and negative (decreasing) if Z is negative.

In statistics, the Kendall rank correlation coefficient, commonly referred to as Kendall's tau coefficient, is a statistic used to measure the association between two quantities. A tau test is a non-parametric hypothesis test for statistical dependence based on the tau coefficient. Values of tau b statistic range from -1 (100% negative association, or perfect inversion) to +1 (100%. positive association, or a perfect agreement). A value of zero indicates the absence of association.

The *P* – Value

The *p* – value gives the area in the tails of the probability density beyond the observed value of the test static. If a particularly large value for the test statistic is observed, then the *p* – value will be very small. The null hypothesis is rejected if the *p*-value is less than the chosen level of significance, α (ie *p*-value <α) on the ground that the data are inconsistent with the null hypothesis at the chosen level of significance α. Otherwise, the null hypothesis is not rejected since the data are consistent with it.

RESULTS AND DISCUSSION

Table 2a shows the descriptive statistics for minimum temperature. The coefficient of variation (C.V) and the mean show latitude dependence, the C.V being higher at higher latitudes (in the north) and vice verse for the mean. The north shows higher variability in minimum temperature than the south. Maiduguri, followed by Kano have highest values of the coefficient of variation while Calabar has the least. Table 2b shows the descriptive statistics for maximum temperature. The C.V and the mean are also latitude dependent decreasing from higher latitudes (in the north) to lower latitudes (in the south). A cursory

Table 2a – Descriptive Statistics for Minimum Temperature

Station	N	Minimum	Maximum	Mean	Std. Deviation	Range	CV(%)
Yelwa	756	11.10	28.10	21.2851	3.61501	17.00	17.00
Sokoto	756	12.80	29.00	21.8480	3.55526	16.20	16.29
Kaduna	756	11.20	28.90	19.7415	3.11623	17.70	15.81
Kano	756	10.40	26.50	19.7167	3.86243	16.10	19.57
Bauchi	756	9.20	25.90	19.0515	3.44857	16.70	18.11
Maidugiri	756	9.20	34.00	19.9503	4.58402	24.80	22.96
Ilorin	756	11.30	26.20	21.2438	1.67346	14.90	7.86
Yola	756	11.50	29.00	21.8795	3.18133	17.50	14.53
Ikeja	756	16.00	27.80	23.0131	1.27311	11.80	5.52
Ibadan	756	16.40	30.90	22.0951	1.25940	14.50	5.70
Oshogbo	756	13.50	25.70	21.3563	1.62221	12.20	7.59
Benin	756	18.40	32.50	22.7183	1.43535	14.10	6.34
Warri	756	19.30	32.70	23.1000	1.02641	13.40	4.46
Lokoja	756	14.10	33.60	22.8163	2.02941	19.50	8.90
P/ Harcourt	756	14.90	29.50	22.4712	1.12377	14.60	4.98
Owerri	468	17.80	28.10	23.2021	1.10283	10.30	4.74
Enugu	756	16.10	26.50	22.2706	1.38727	10.40	6.24
Calabar	756	20.10	29.70	22.9217	.85390	9.60	3.71
Makurdi	756	13.30	31.70	22.1820	2.39077	18.40	10.78
Ogoja	444	15.90	29.30	22.3829	1.61484	13.40	7.19

Table 2b – Descriptive Statistics for Maximum Temperature

Station	N	Minimum	Maximum	Mean	Std. Deviation	Range	CV (%)
Yelwa	756	28.4	41.1	34.526	2.9531	12.7	8.45
Sokoto	756	21.7	42.2	35.094	3.2697	20.5	9.32
Kaduna	756	21.7	38.0	31.572	2.6273	16.3	8.33
Kano	756	21.0	41.0	33.284	3.3283	20.0	10.00
Bauchi	756	24.9	40.0	32.732	2.7482	15.1	8.40
Maidugiri	756	26.1	42.6	35.183	3.3131	16.5	9.41
Ilorin	756	22.5	37.9	32.173	2.6058	15.4	8.11
Yola	756	28.9	42.3	34.696	3.1039	13.4	8.93
Ikeja	756	25.5	39.0	30.826	1.9662	13.5	6.39
Ibadan	756	23.7	38.0	31.291	2.4202	14.3	7.73
Oshogbo	756	24.5	37.2	31.185	2.4303	12.7	7.79
Benin	756	22.5	37.0	31.269	2.0815	14.5	6.65
Warri	756	17.5	34.8	31.313	1.8848	17.3	6.00
Lokoja	756	24.9	39.4	32.917	2.3640	14.5	7.17
P/ Harcourt	756	24.6	36.3	30.972	1.7952	11.7	5.81
Owerri	444	27.0	36.9	32.033	2.0327	9.9	6.34
Enugu	756	27.3	38.3	31.958	2.0601	11.0	6.45
Calabar	756	26.2	35.2	30.455	1.8069	9.0	5.94
Makurdi	756	27.8	39.5	33.098	2.5582	11.7	7.73
Ogoja	444	27.6	38.5	32.717	2.2725	10.9	6.94

look at the two tables reveals that the minimum temperature suffers higher variability than the maximum temperature across the country.

The Mann-Kendall's test results (table 3) indicate that 17 stations (representing 85%) have significant trends at the 0.01 level of significance for the minimum temperature. Apart from Oshogbo and Ogoja, all the stations show increasing trends in minimum temperature with 16 stations showing significant upward trends. Port Harcourt and Ikeja have the highest trend coefficients in minimum temperature. The table also indicates that 15 stations (representing 75%) show significant upwards trends in maximum temperature at the 0.01 and 0.05 significance levels. Port Harcourt records the highest trend coefficient in maximum temperature. Only Oshogbo and Ilorin show negative trends in maximum temperature that are not statistically significant. Table 3 further reveals that minimum temperature has higher trend coefficients than maximum temperature. The high outstanding trend coefficients observed in Ikeja and Port Harcourt could be attributed to increasing concentration of greenhouse gases and large aerosols in these cities, resulting from industrial activities.

Tables 4 and 5 show the correlation coefficients for minimum and maximum temperatures respectively. Table 4 indicates that most of the stations minimum temperature are positively correlated with others at the 0.01 level of significance. Correlation coefficients of minimum temperature between four pairs are positively correlation at the 0.05 significance level. These pairs are station 12 (Benin) and station 20 (Ogoja); station 9 (Ikeja) and station 20 (Ogoja); station 6 (Maiduguri) and station 12 (Benin); and station 4 (Kano) and station 18 (Calabar). Only two pairs of stations have positive correlation that is not statistically significant.

Table 3: Mann – Kendall's test results for minimum & maximum temperature

Station No	State Name	Minimum Temperature		Maximum Temperature	
		Kendall's *tau b*	*p*-value	Mann – Kendall's *tau b*	*p*-value
1	Yelwa	0.036	0.136	0.049*	0.046
2	Sokoto	0.163**	0.000	0.086**	0.000
3	Kaduna	0.032	0.193	0.070**	0.004
4	Kano	0.106**	0.000	0.024	0.334
5	Bauchi	0.135**	0.000	0.049*	0.045
6	Maiduguri	0.089**	0.000	0.053*	0.029
7	Ilorin	0.149**	0.000	-0.001	0.971
8	Yola	0.141**	0.000	0.027	0.273
9	Ikeja	0.467**	0.000	0.091**	0.000
10	Ibadan	0.235**	0.000	0.105**	0.000
11	Oshogbo	-0.003	0.917	-0.005	0.828
12	Benin	0.297**	0.000	0.080**	0.001
13	Warri	0.241**	0.000	0.072**	0.003
14	Lokoja	0.079**	0.001	0.044+	0.069
15	Port Harcourt	0.339**	0.000	0.135**	0.000
16	Owerri	0.123**	0.000	0.072*	0.025
17	Enugu	0.117**	0.000	0.070**	0.004
18	Calabar	0.260**	0.000	0.110**	0.000
19	Makurdi	0.129**	0.000	0.060*	0.014
20	Ogoja	-0.085**	0.008	0.094**	0.003

** Kendall's *tau b* is significant at the 0.01 level (two – tailed)

* Kendall's *tau b* is significant at the 0.05 level (two – tailed)

+ Kendall's *tau b* is significant at the 0.1 level (two – tailed)

Table 4 – Correlation coefficients for ***Minimum Temperature*** *across the stations*

	Stations																			
Stations	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	1																			
2	.862**	1																		
3	.799**	.762**	1																	
4	.891**	.930**	.810**	1																
5	.873**	.892**	.783**	.930**	1															
6	.849**	.884**	.795**	.954**	.900**	1														
7	.689**	.681**	.616**	.659**	.687**	.584**	1													
8	.857**	.854**	.747**	.863**	.879**	.814**	.724**	1												
9	.147**	.236**	.081*	.120**	.198**	.022	.448**	.276**	1											
10	.252**	.297**	.242**	.230**	.243**	.136**	.598**	.327**	.609**	1										
11	.551**	.567**	.475**	.547**	.569**	.482**	.740**	.569**	.331**	.437**	1									

12	.164**	.192**	.167**	.150**	.203**	.087*	.443**	.205**	.594**	.549**	.289**	1								
13	.282**	.346**	.276**	.272**	.289**	.205**	.529**	.356**	.556**	.692**	.395**	.549**	1							
14	.719**	.673**	.631**	.679**	.730**	.613**	.818**	.779**	.400**	.512**	.734**	.358**	.481**	1						
15	.485**	.560**	.492**	.527**	.581**	.469**	.629**	.532**	.490**	.492**	.544**	.439**	.537**	.609**	1					
16	.296**	.311**	.218**	.243**	.291**	.168**	.596**	.378**	.498**	.474**	.556**	.371**	.469**	.556**	.478**	1				
17	.603**	.610**	.527**	.572**	.601**	.505**	.775**	.671**	.456**	.567**	.667**	.397**	.574**	.773**	.660**	.584**	1			
18	.160**	.168**	.190**	.093*	.164**	.041	.435**	.196**	.561**	.529**	.355**	.449**	.477**	.373**	.484**	.592**	.447**	1		
19	.785**	.762**	.692**	.763**	.790**	.702**	.816**	.829**	.337**	.421**	.675**	.299**	.432**	.854**	.614**	.519**	.777**	.311**	1	
20	.504**	.528**	.511**	.533**	.566**	.483**	.551**	.545**	.105*	.212**	.642**	.100*	.263**	.602**	.449**	.331**	.552**	.304**	.637**	1

**** Correlation significant at the 0.01 level of significance ()two – tailed. * Correlation significant at the o.05 level of significance (two - tailed)**

Table 5– Correlation coefficients for ***Maximum Temperature*** *across the stations*

	Stations																	
Stations	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1																	
2	.694**	1																
3	.860**	.744**	1															
4	.511**	.814**	.602**	1														
5	.792**	.871**	.832**	.778**	1													
6	.569**	.882**	.650**	.890**	.838**	1												
7	.829**	.480**	.773**	.253**	.622**	.337**	1											
8	.872**	.730**	.857**	.571**	.822**	.631**	.780**	1										
9	.775**	.439**	.704**	.211**	.581**	.299**	.833**	.716**	1									
10	.817**	.472**	.755**	.259**	.604**	.325**	.865**	.754**	.852**	1								
11	.812**	.441**	.739**	.219**	.589**	.286**	.903**	.752**	.862**	.893**	1							
12	.823**	.502**	.753**	.265**	.626**	.354**	.868**	.769**	.876**	.896**	.905**	1						
13	.822**	.531**	.761**	.300**	.624**	.370**	.843**	.765**	.819**	.864**	.855**	.877**	1					
14	.833**	.524**	.787**	.330**	.667**	.396**	.856**	.811**	.821**	.857**	.868**	.862**	.807**	1				
15	.749**	.426**	.681**	.185**	.537**	.268**	.790**	.689**	.814**	.844**	.827**	.852**	.820**	.800**	1			

16	.758**	.392**	.673**	.119*	.500**	.213**	.875**	.682**	.837**	.865**	.916**	.879**	.848**	.840**	.876**	1			
17	.804**	.444**	.749**	.217**	.578**	.290**	.873**	.767**	.842**	.891**	.895**	.886**	.848**	.888**	.852**	.879**	1		
18	.808**	.482**	.734**	.255**	.597**	.334**	.856**	.745**	.851**	.897**	.886**	.914**	.873**	.856**	.873**	.904**	.899**	1	
19	.835**	.476**	.782**	.249**	.632**	.311**	.884**	.801**	.861**	.890**	.899**	.890**	.831**	.914**	.830**	.878**	.914**	.890**	
20	.792**	.437**	.731**	.168**	.549**	.248**	.868**	.718**	.814**	.865**	.912**	.885**	.835**	.860**	.873**	.909**	.900**	.910**	

**** Correlation significant at the 0.01 level of significance ()two – tailed. * Correlation significant at the o.05 level of significance (two - tailed)**

These are station 6 (Maiduguri) and station 9 (Ikeja) and station 6 (Maiduguri) and station 18 (Calabar). Table 5 indicates that all the stations maximum temperature are positively correlated with others at the 0.01 level of significance. Thus the station to station correlation coefficients have revealed the interstation spatial coherence of temperature over Nigeria.

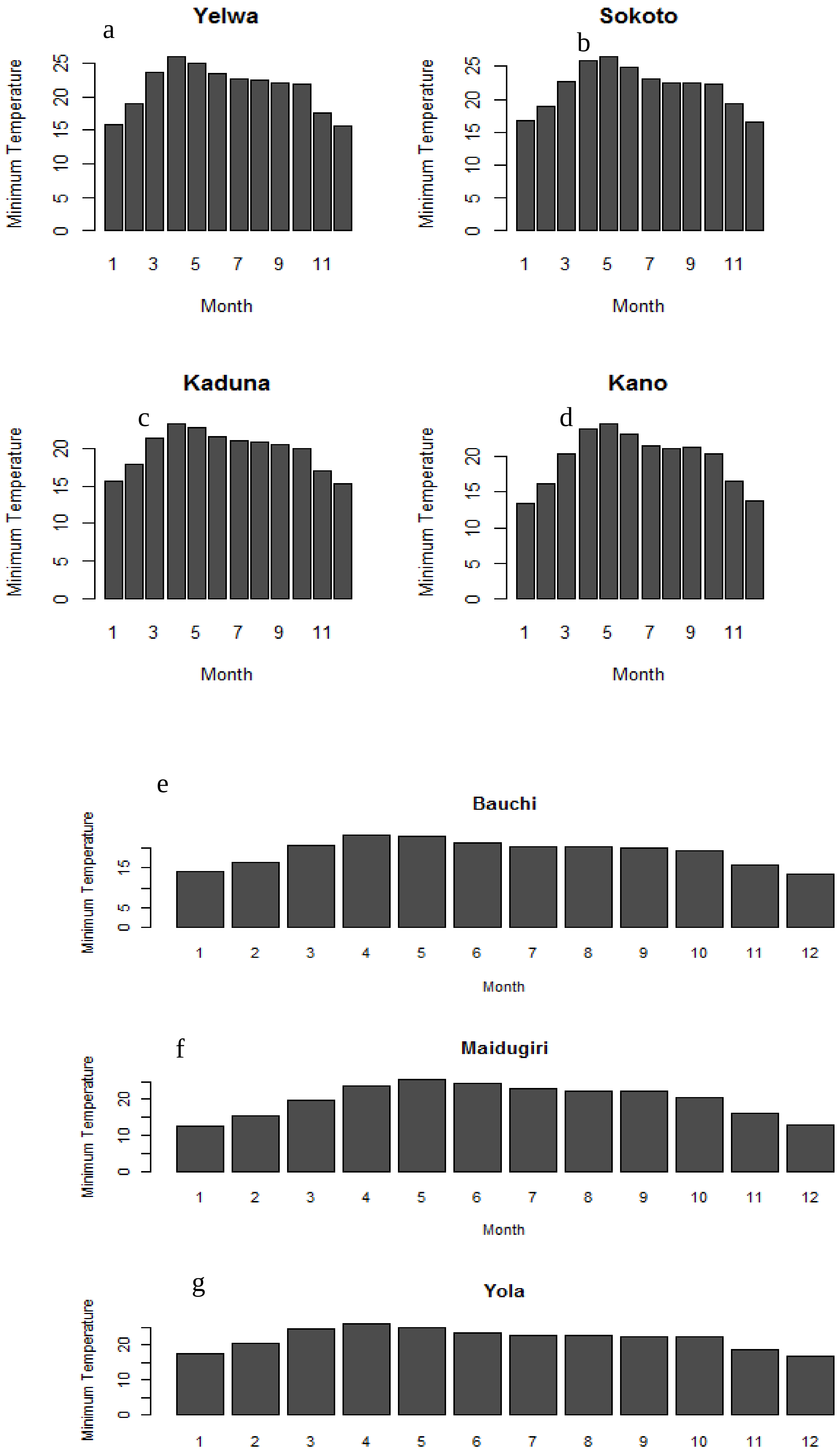
Figs 2a – t show the bar charts describing the seasonal variation of minimum temperature. The charts reveal that minimum temperatures reach their lowest in December and January. This observation could be a consequence of the harmattan period around December and January, during which it gets cold and dry. Minimum temperature record their highest values around April and May across the country. This observation is more evident in the north than in the south where the distribution is more or less flat.

Figs 3a – t give the seasonal variation of maximum temperature depicted in bar charts. The charts show that maximum temperatures increase from January to reach their maxima around March and April, decreasing gradually to their minima in August. The temperature thereafter increases to another high values in November/December. In Yelwa, Sokoto, Kaduna and Kano, the maximum temperatures increased from August to October after which they gradually drop.

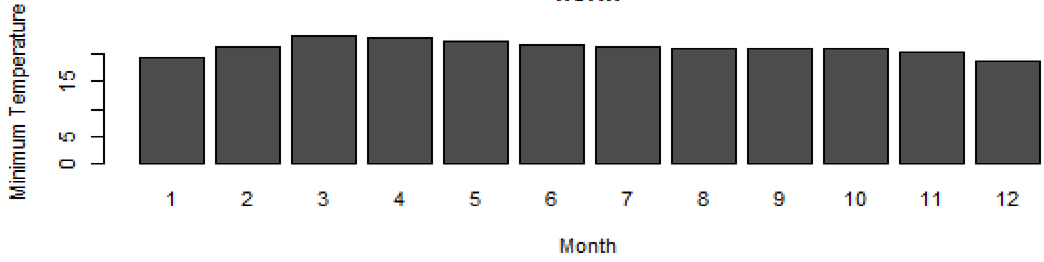
The result of this research is in complete agreement with the result of Abiodun *et al,* (2011) which found a trend in rising temperature in Nigeria which are statistically significant at the 0.05 level of significance from 1971 to 2000 historical record. The result presented in this work agrees in parts with Olofintoye and Sule (2010) that found significant increasing trend in minimum and maximum temperature in Owerri between 1983 and 2008, and found a statistically non significant upward trend in the two variables in Port Harcourt and Calabar.

The result of this study differs with the results of Ogolo and Adeyemi (2009) that found non – significant increasing trend in the series of annual mean temperature in Ibadan, and a non-significance decreasing trend in the monthly mean series in Ibadan for the period 1988 – 1997. These disagreements could stem from differences in data length as well as sources of data used in the analysis.

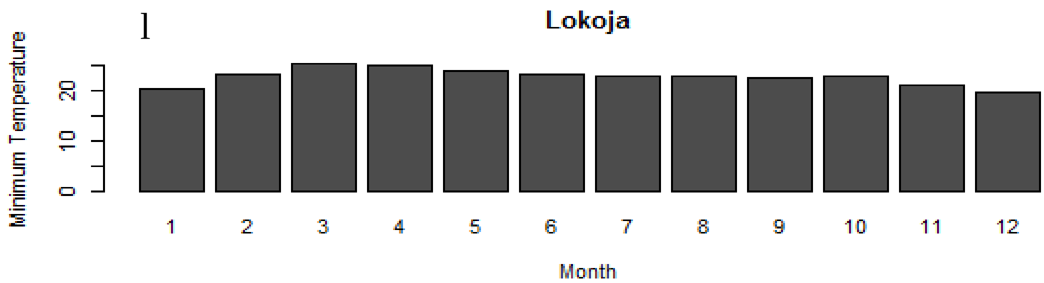
Figs 4a-t and 5a-t are the time series plots for minimum and maximum temperatures respectively. The trend lines indicate upward trends in both variables across the stations, except for Oshogbo and Ogoja. These are more evident in Yelwa, Sokoto, Kaduna, Kano, Benin, Warri, Port-Harcourt, Calabar etc.


a
Yelwa
b
Sokoto
c
Kaduna
d
Kano
e
Bauchi
f
Maidugiri
g
Yola
Minimum Temperature
Month

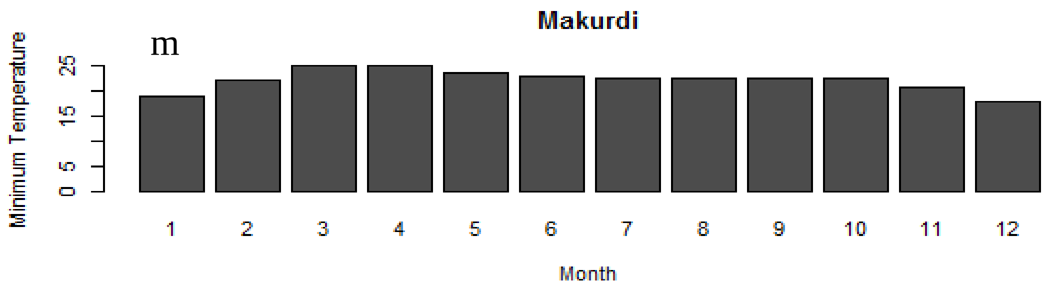
k

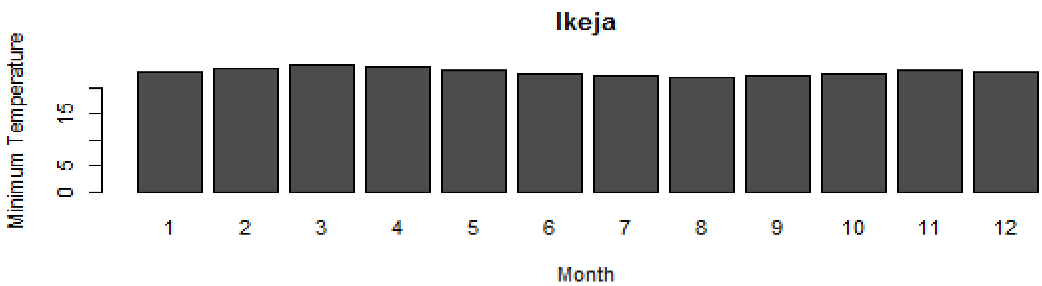

Ilorin
Minimum Temperature
0 5 15
1 2 3 4 5 6 7 8 9 10 11 12
Month

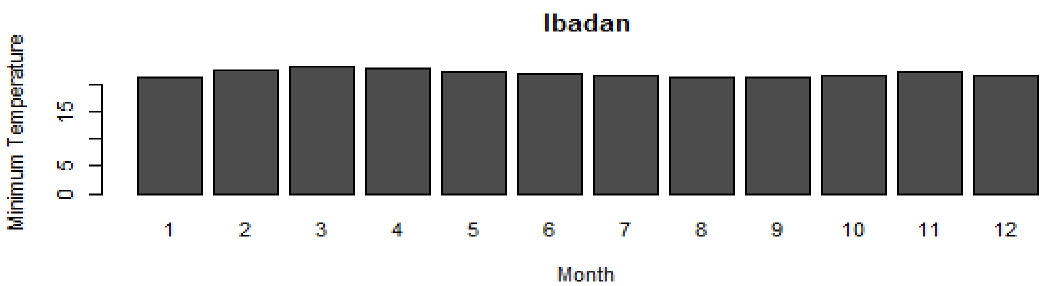
l

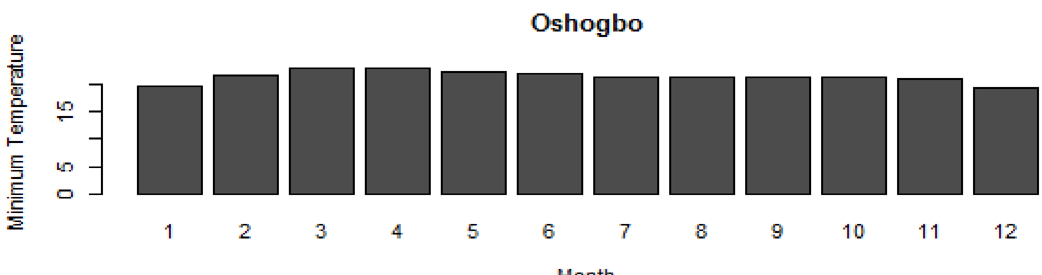

Lokoja
Minimum Temperature
0 10 20
1 2 3 4 5 6 7 8 9 10 11 12
Month

m


Makurdi
Minimum Temperature
0 5 15 25
1 2 3 4 5 6 7 8 9 10 11 12
Month


Ikeja
Minimum Temperature
0 5 15
1 2 3 4 5 6 7 8 9 10 11 12
Month


Ibadan
Minimum Temperature
0 5 15
1 2 3 4 5 6 7 8 9 10 11 12
Month


Oshogbo
Minimum Temperature
0 5 15
1 2 3 4 5 6 7 8 9 10 11 12

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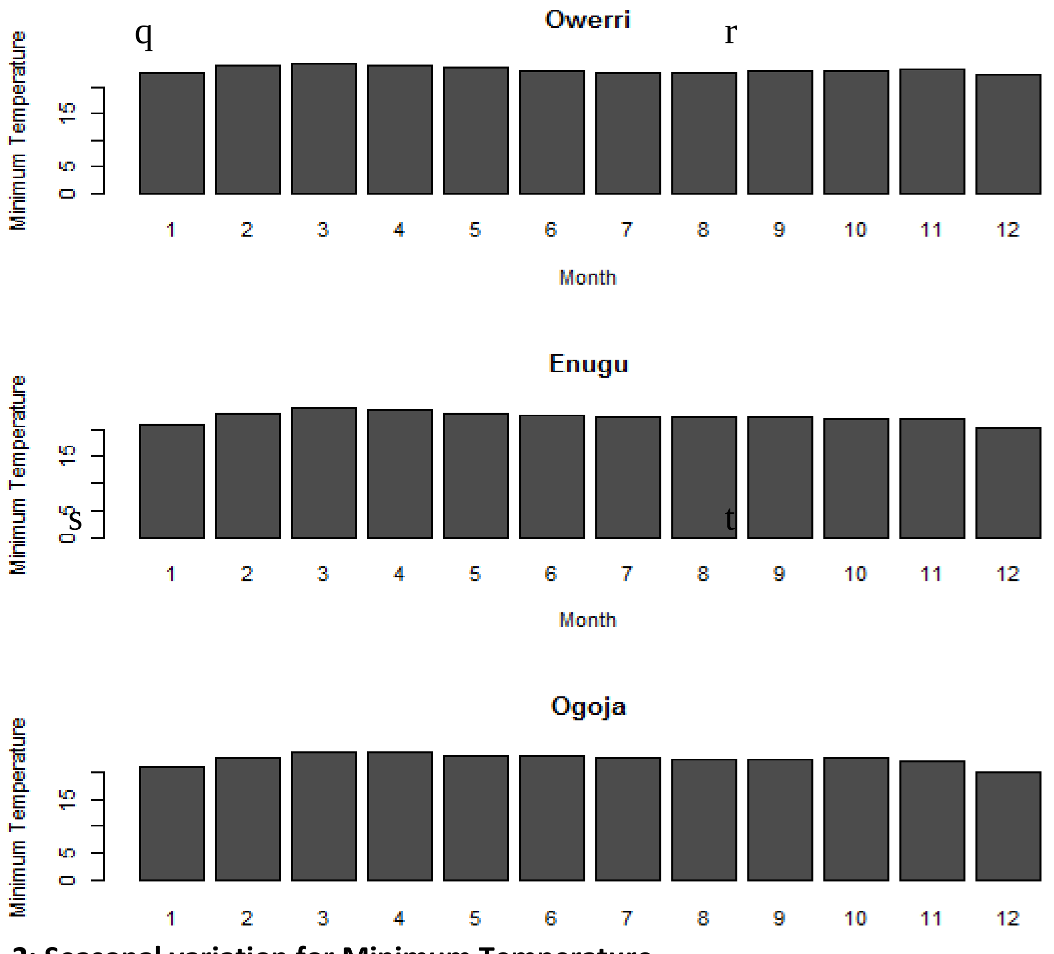
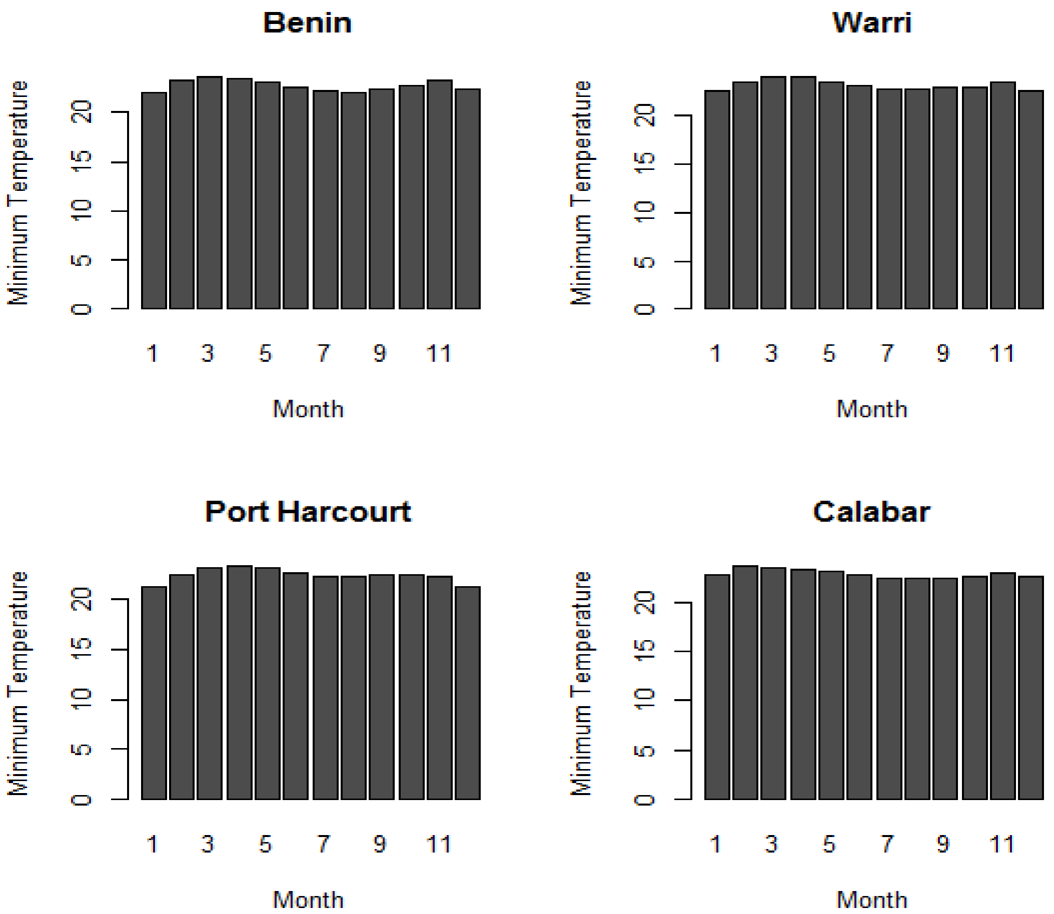
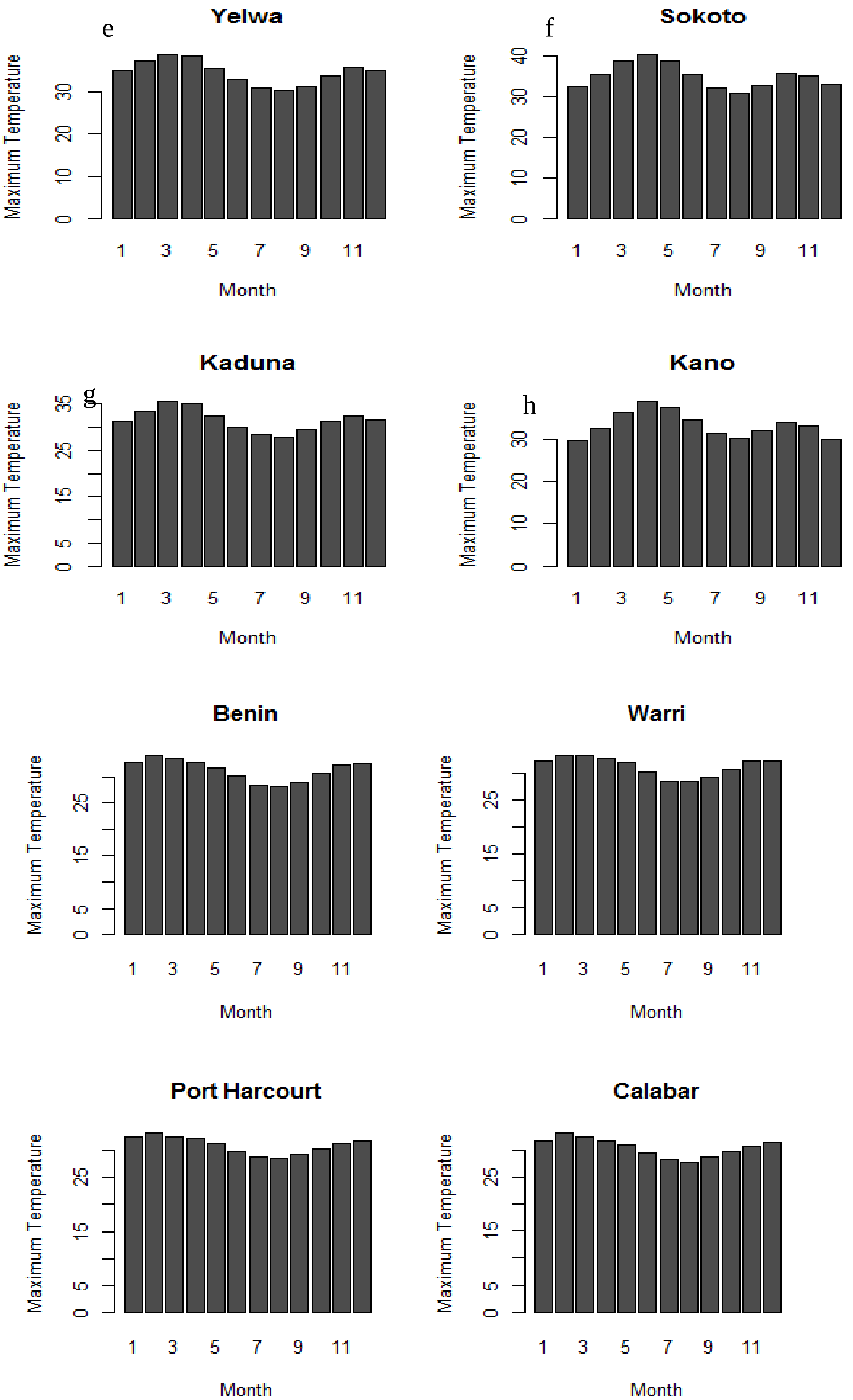


Fig. 2: Seasonal variation for Minimum Temperature




e
Yelwa
f
Sokoto
g
Kaduna
h
Kano
Benin
Warri
Port Harcourt
Calabar
Maximum Temperature
Month
1
3
5
7
9
11

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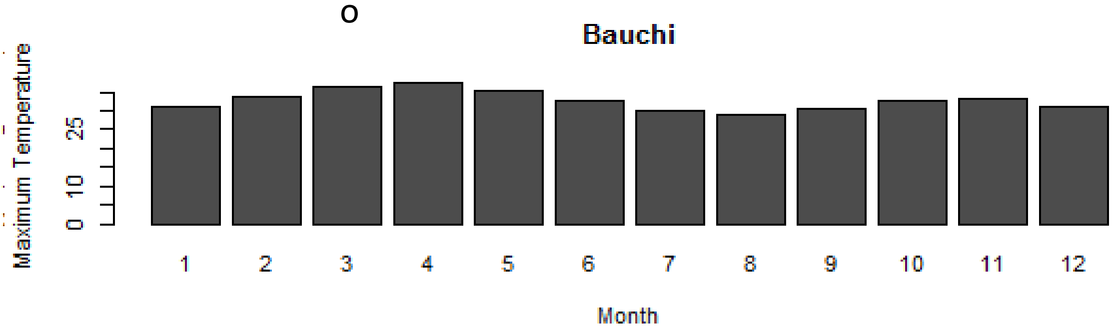

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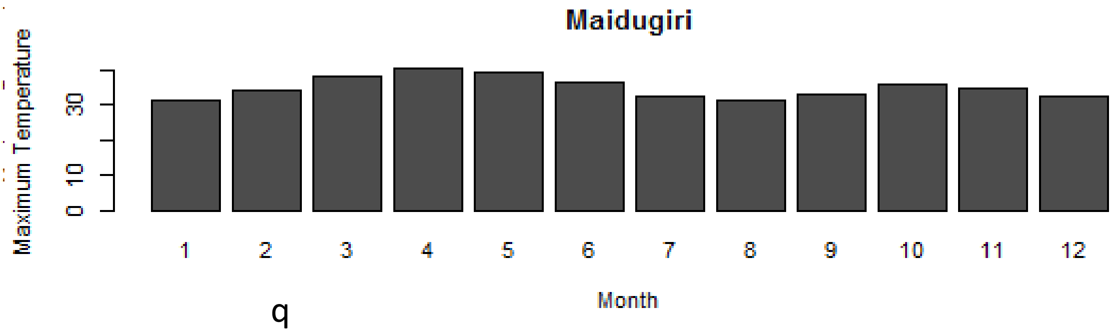

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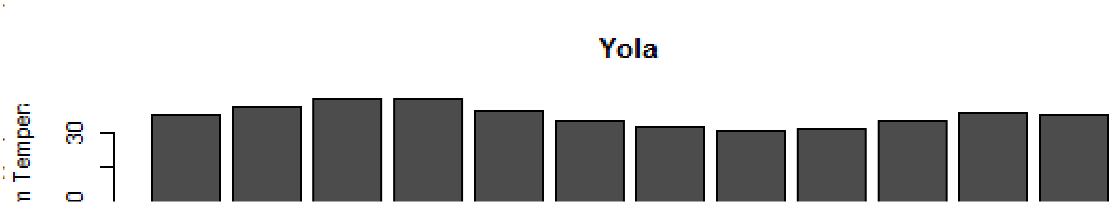

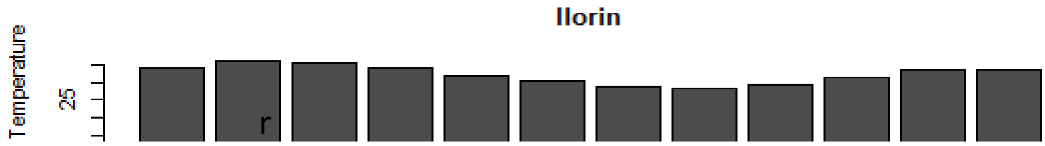

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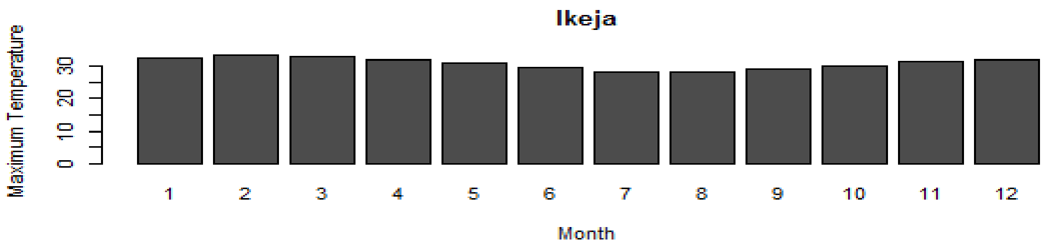

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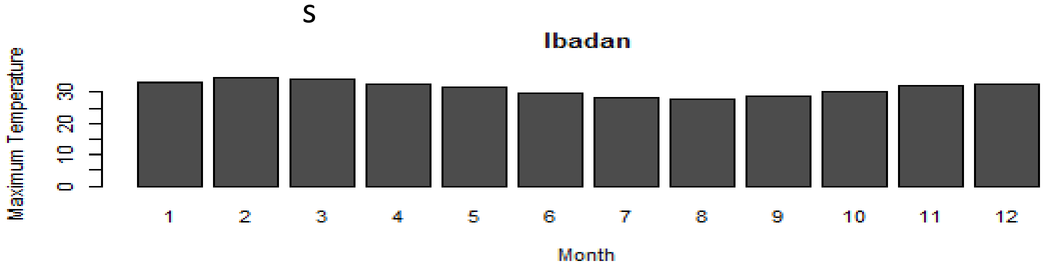

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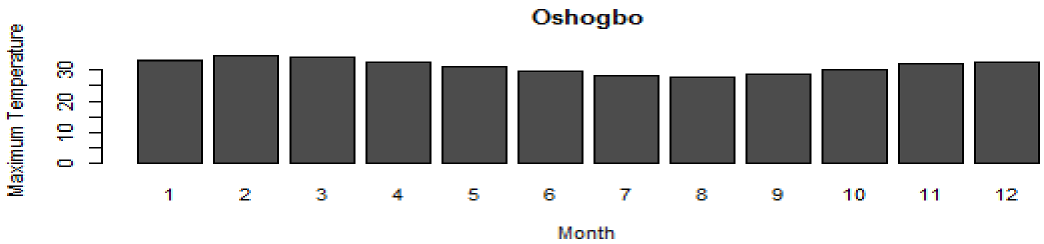

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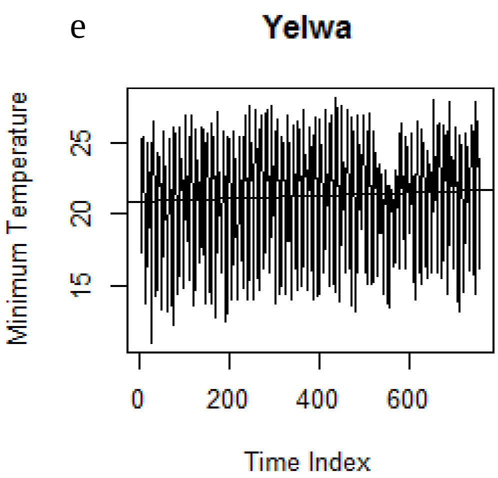
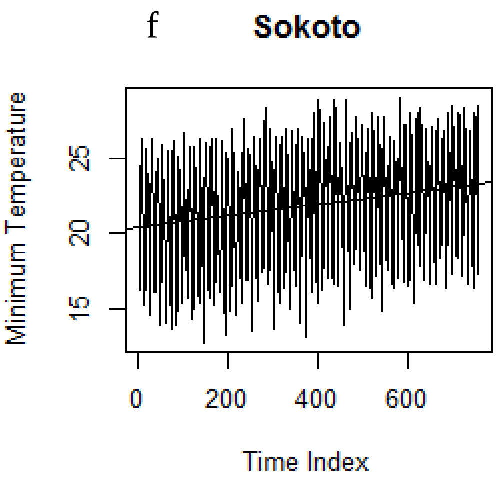
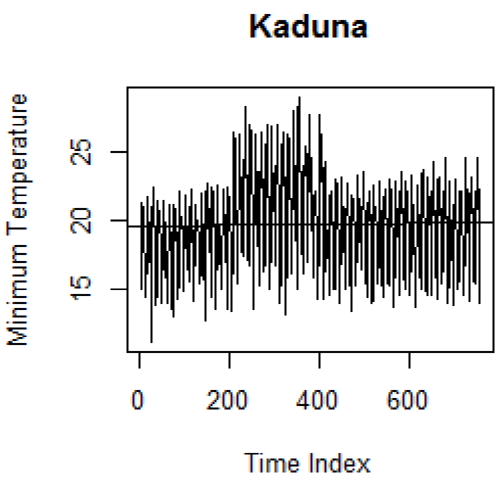

Yelwa
Minimum Temperature
15
20
25
0
200
400
600
Time Index

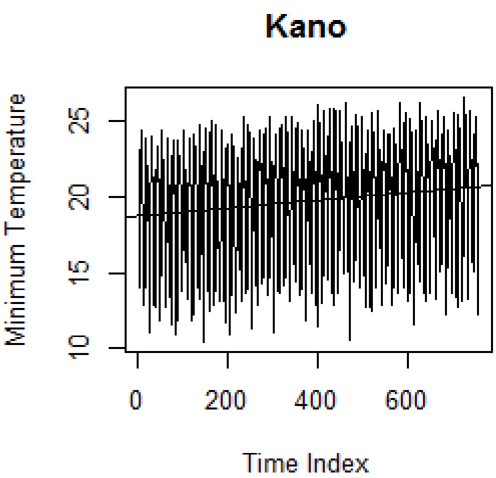
f

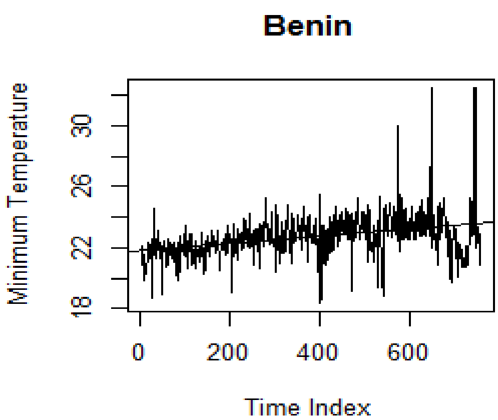

Sokoto
Minimum Temperature
15
20
25
0
200
400
600
Time Index

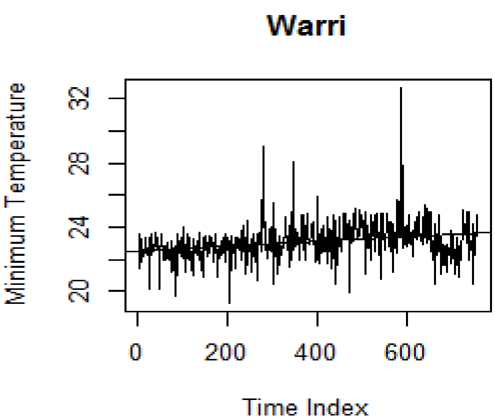
g

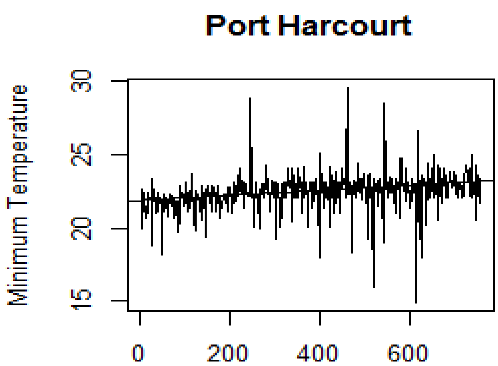

Kaduna
Minimum Temperature
15
20
25
0
200
400
600
Time Index

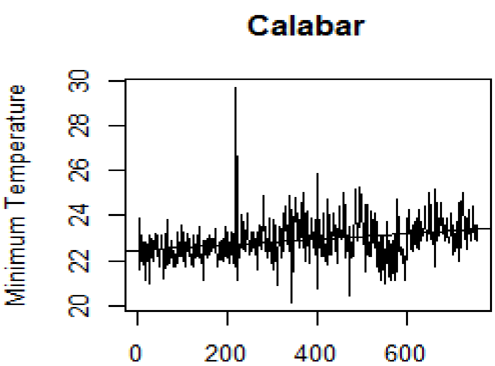
h


Kano
Minimum Temperature
10
15
20
25
0
200
400
600
Time Index


Benin
Minimum Temperature
18
22
26
30
0
200
400
600
Time Index


Warri
Minimum Temperature
20
24
28
32
0
200
400
600
Time Index


Port Harcourt
Minimum Temperature
15
20
25
30
0
200
400
600


Calabar
Minimum Temperature
20
22
24
26
28
30
0
200
400
600

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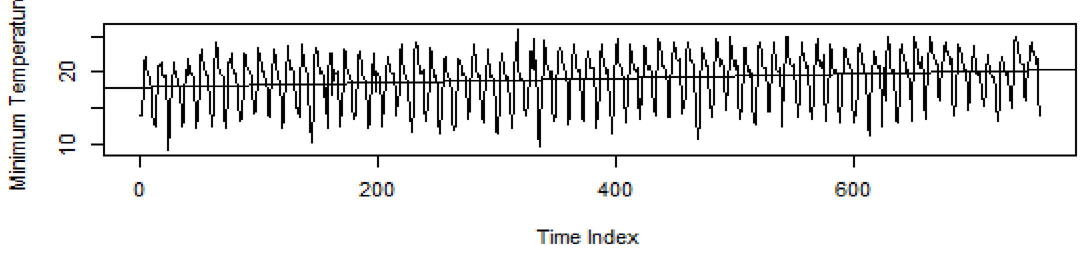
l



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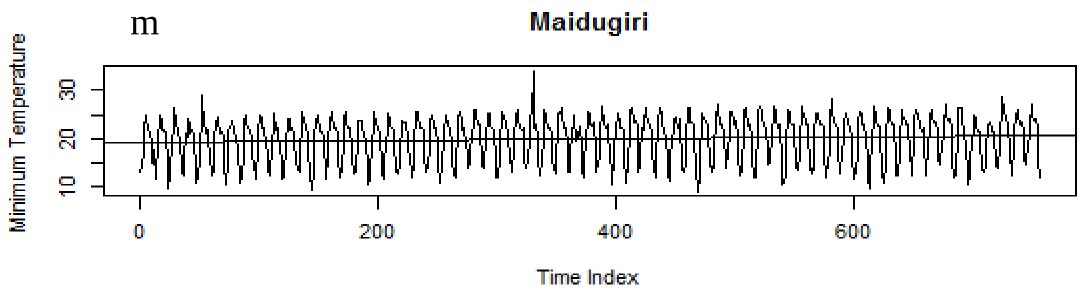

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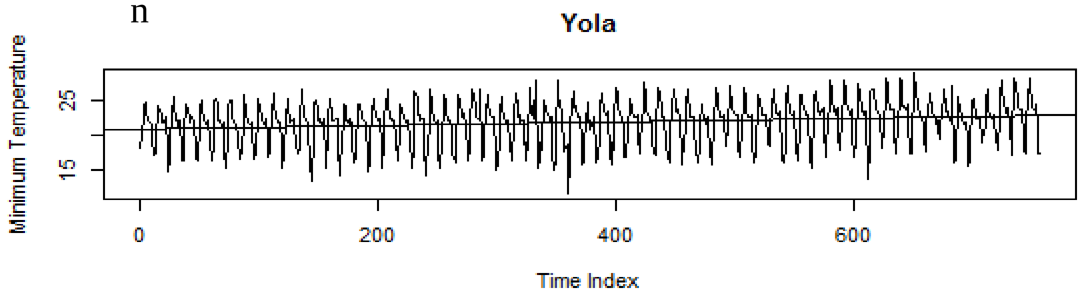
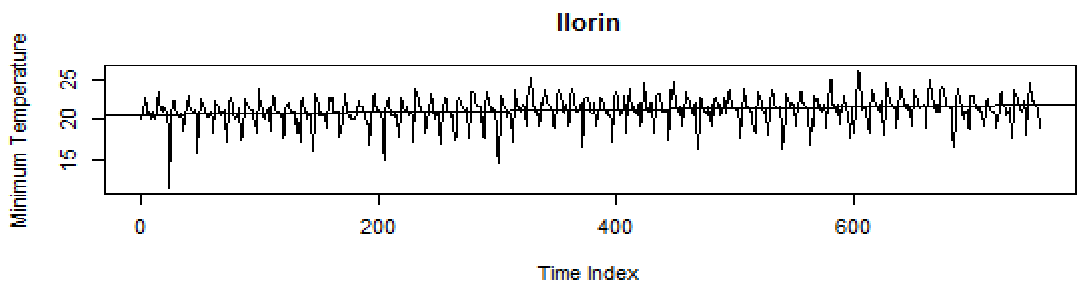
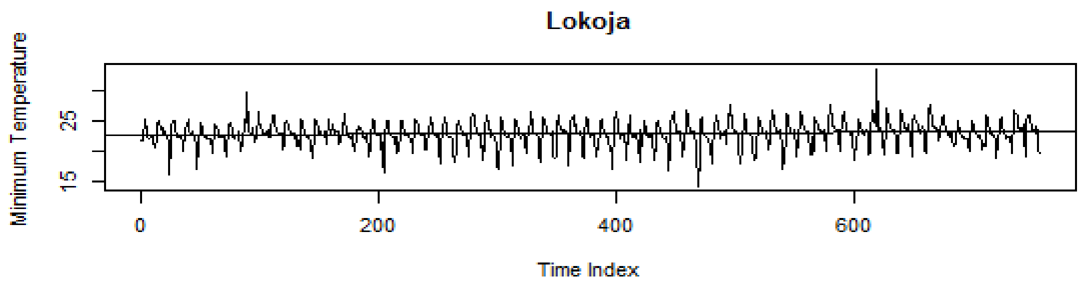
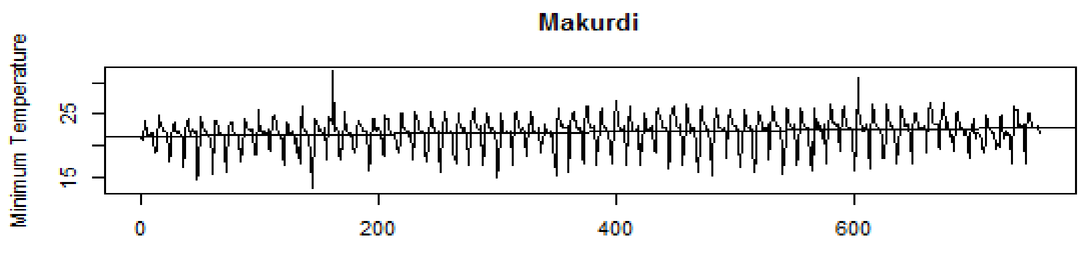








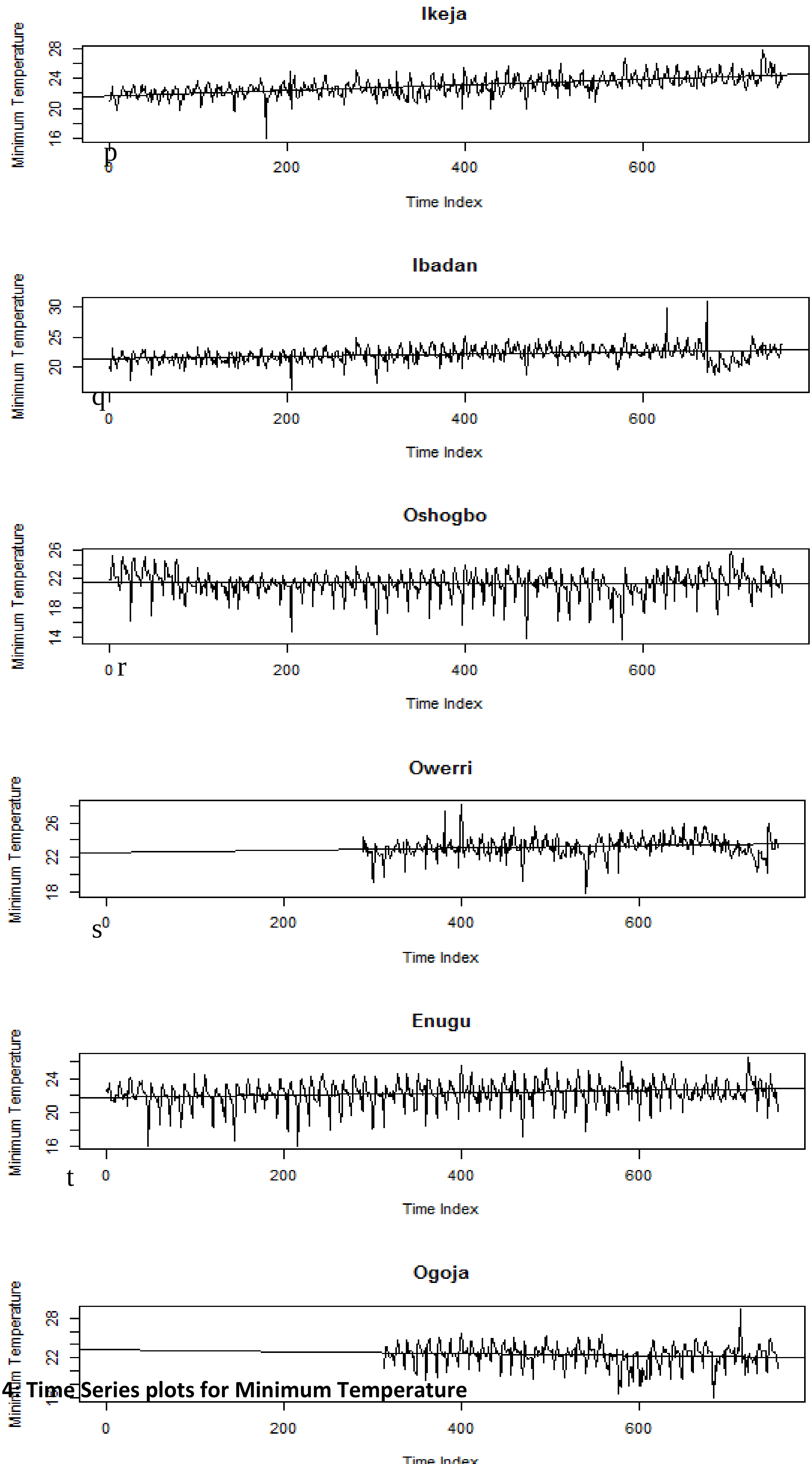
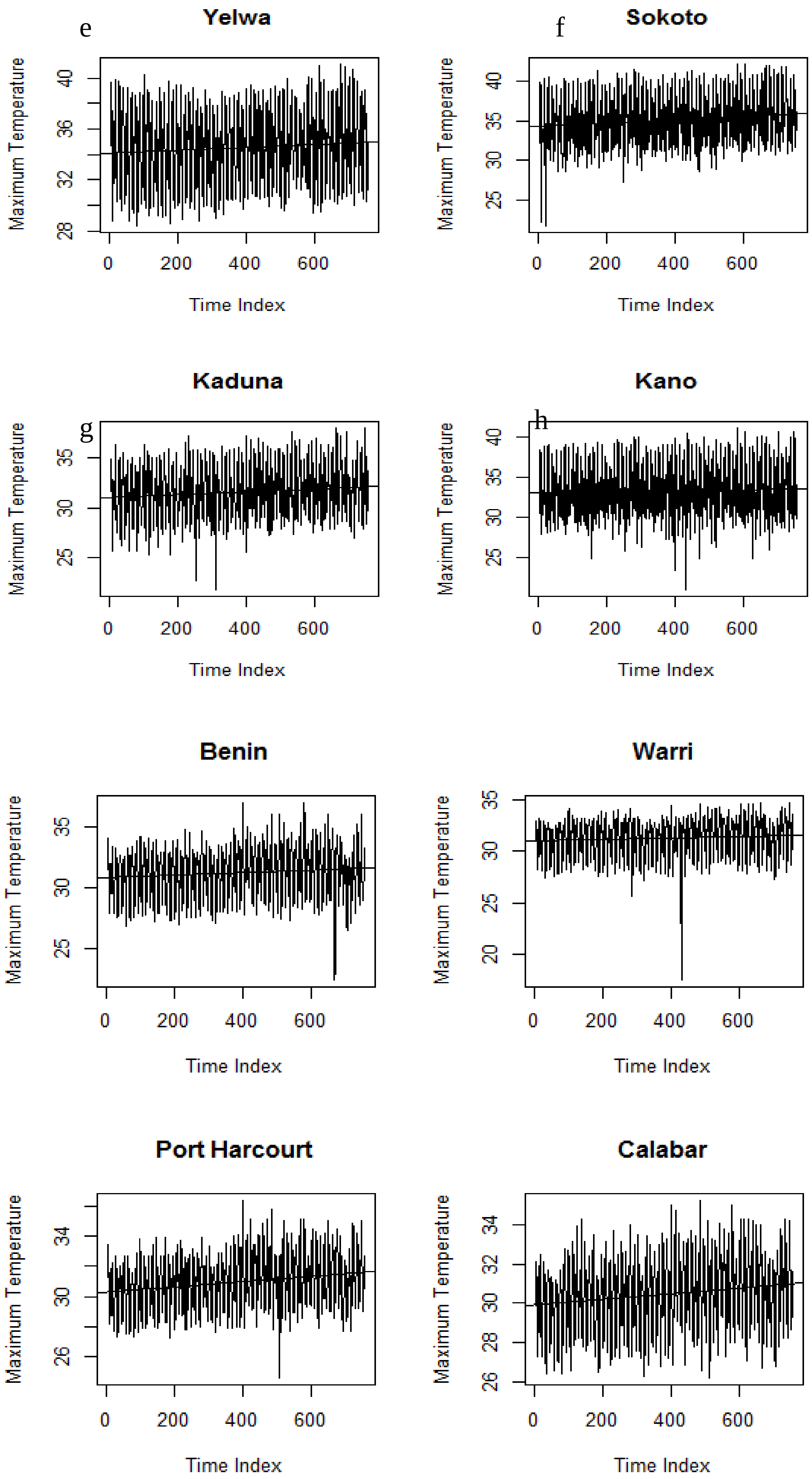
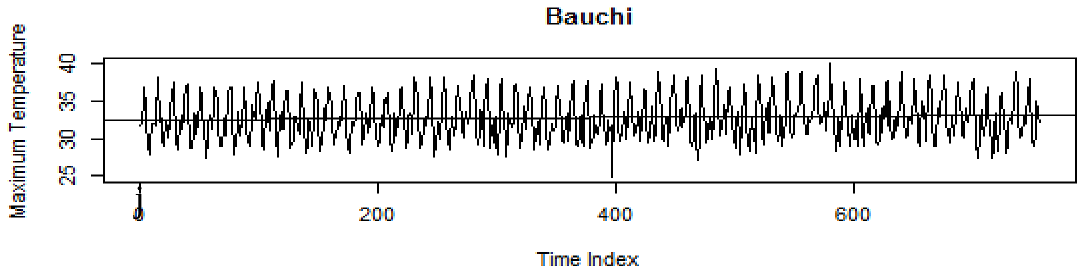
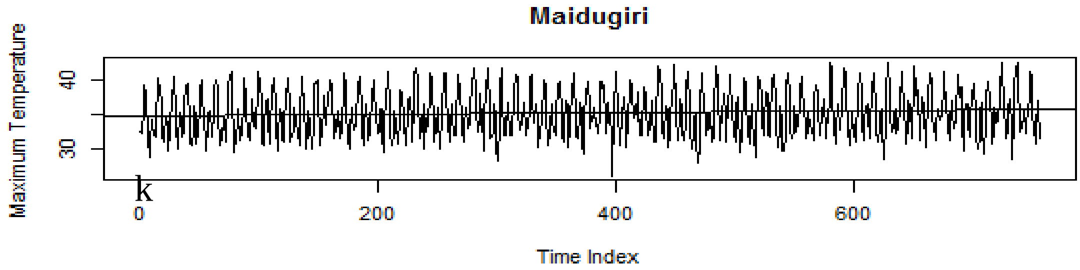


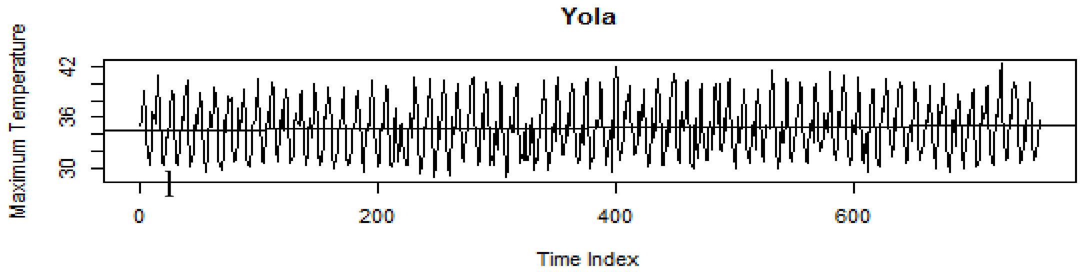
Fig. 4: Time Series plots for Minimum Temperature

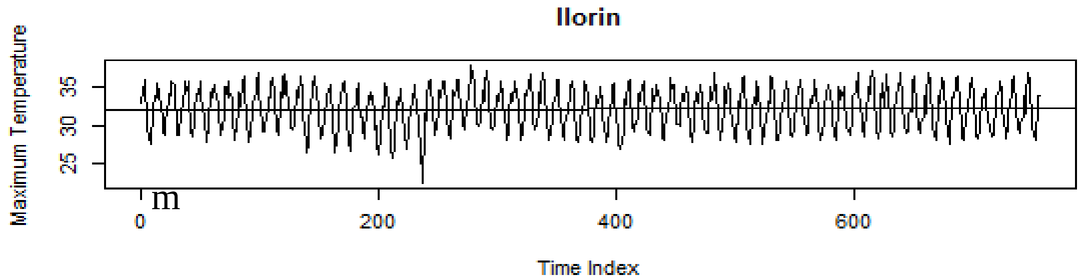

e
Yelwa
Maximum Temperature
Time Index
f
Sokoto
Maximum Temperature
Time Index
g
Kaduna
Maximum Temperature
Time Index
h
Kano
Maximum Temperature
Time Index
Benin
Maximum Temperature
Time Index
Warri
Maximum Temperature
Time Index
Port Harcourt
Maximum Temperature
Time Index
Calabar
Maximum Temperature
Time Index

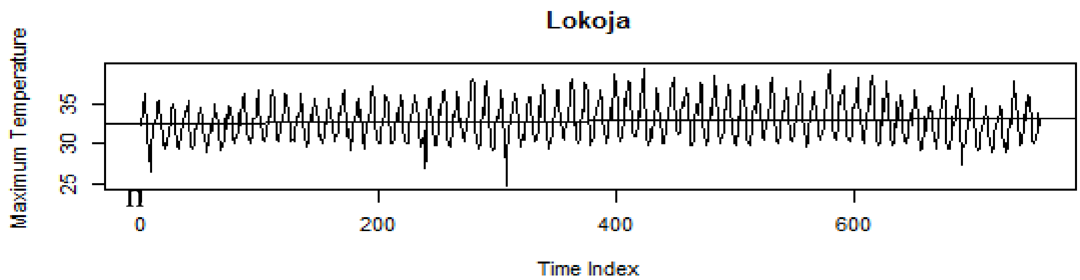
i

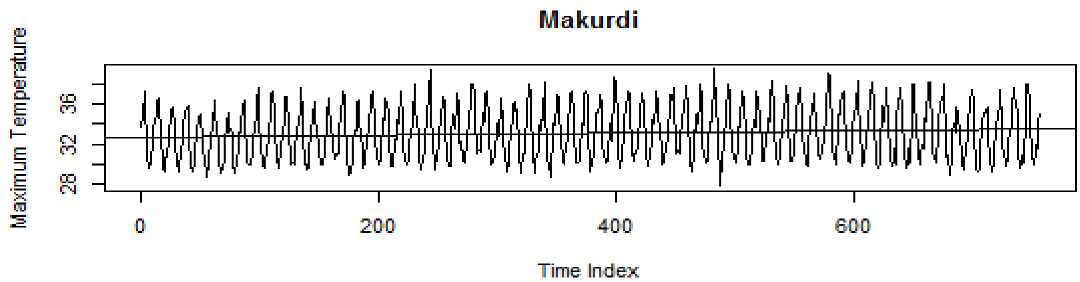

Bauchi
Maximum Temperature
25
30
35
40
0
200
400
600
Time Index
j


Maidugiri
Maximum Temperature
30
40
0
200
400
600
Time Index
k

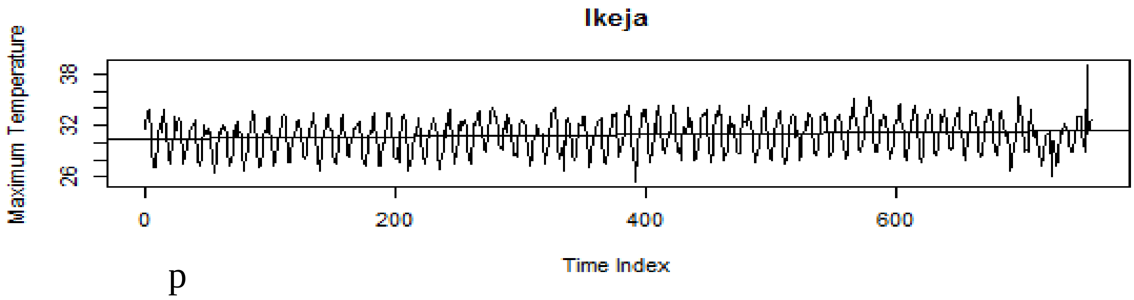

Yola
Maximum Temperature
30
36
42
0
200
400
600
Time Index
l


Ilorin
Maximum Temperature
25
30
35
0
200
400
600
Time Index
m


Lokoja
Maximum Temperature
25
30
35
0
200
400
600
Time Index
n


Makurdi
Maximum Temperature
28
32
36
0
200
400
600
Time Index

o



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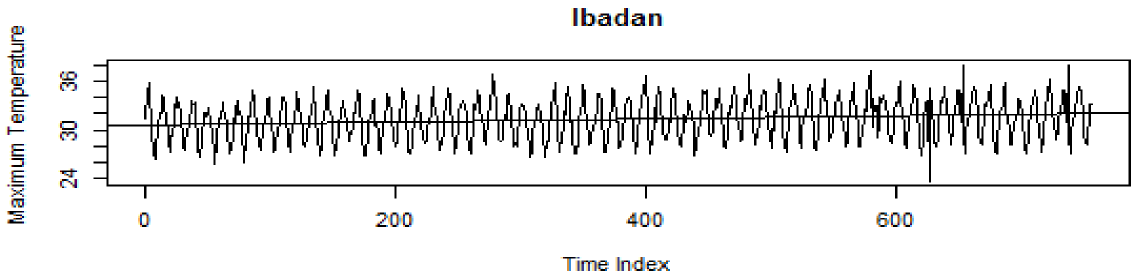

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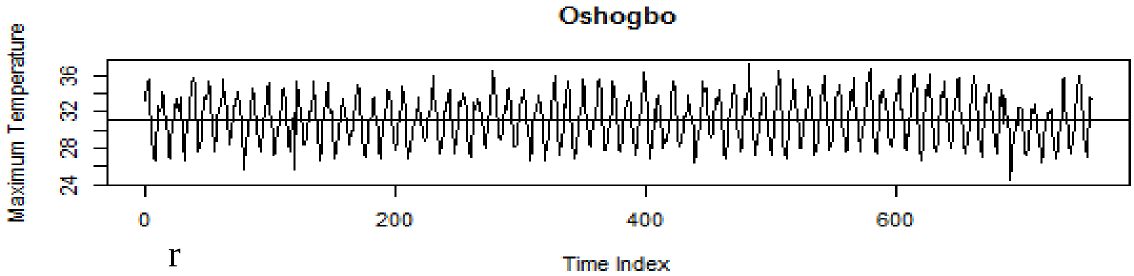

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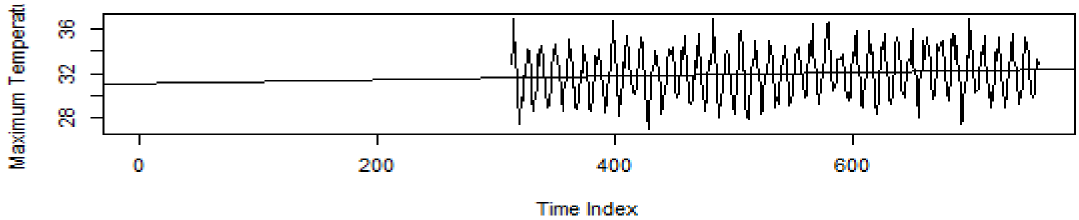
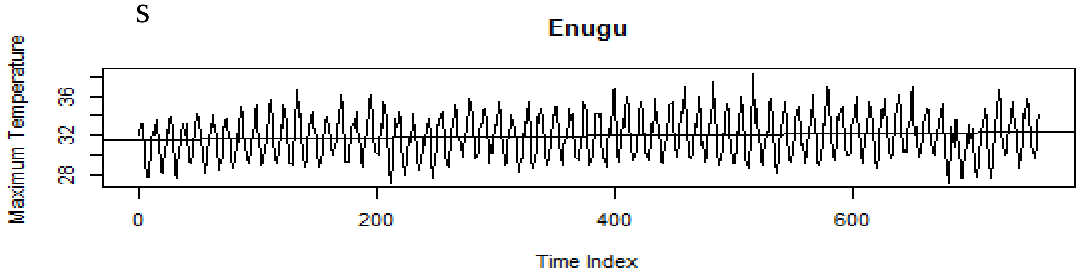


s



t

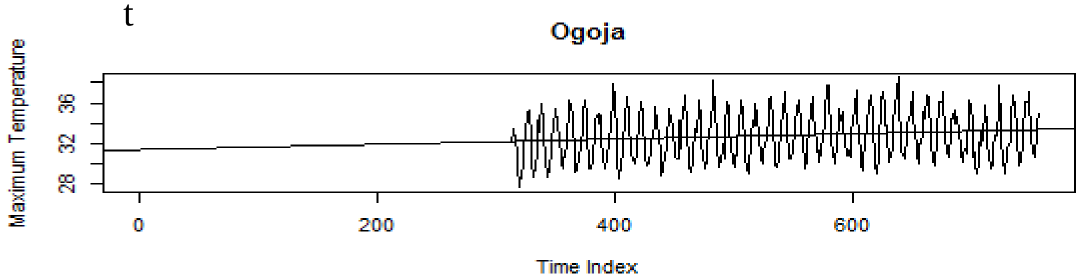


Fig. 5: Time Series plots for Maximum Temperature

CONCLUSIONS

The trends and variability of monthly mean minimum and maximum temperatures over Nigeria have been evaluated for the period 1950 – 2012. The mean and the CV show latitudinal dependence for both minimum and maximum temperatures. Minimum temperature shows greater variability than the maximum temperature along the north-south divide. The north shows higher spatial variability than the south for both variables. The Mann-Kendall's test show that majority of stations have upward trends that are statistically significant at the 1% and 5% levels, with minimum temperature showing greater trend coefficients than the maximum temperature. Port-Harcourt, Ikeja, Calabar and Ibadan show spectacular trend magnitudes as revealed by the trend coefficients. The interstation spatial coherence of the two variables as revealed by the correlation coefficients indicates that almost all the stations temperature time series show significantly positive correlation at the 1% level of significance. The seasonal distribution charts show that both variables are more uniformly distributed across the seasons in the south than in the north. The trends and variations of the temperature data across the stations in Nigeria follow physical boundaries, notably those dictated by coastal and topographic features, as well as latitudinal bands.

This study reveals that Nigeria is experiencing a rise in air surface temperature the implication of this is that Nigeria is susceptible to the attendant consequences of global warming. In this regard the human population in Nigeria dependent on economic activities that are temperature-sensitive such as agriculture are vulnerable to risks.

This paper recommends the provision of accurate and timely weather and climate information for planning in the sectors of the economy that are temperature sensitive such as agriculture, health, water resources management. This would prevent temperature extremes from becoming disasters and threats to livelihoods across Nigeria.

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