

TRENDS AND CYCLES OF RAINFALL AND TEMPERATURE IN NIGERIA: IMPLICATIONS FOR WATER RESOURCES AND AGRICULTURE

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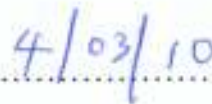
CERTIFICATION

This is to certify that this work was carried out by ALLI, ADEKUNLE ADEDEJI (AGE/97/9115) in the Department of Agricultural Engineering, Federal University of Technology, Akure, in partial fulfillment of the requirements for the award of Master of Engineering in Agricultural Engineering (Soil and Water Engineering Option), Federal University of Technology, Akure. It has not been submitted elsewhere for the award of any other degree or diploma.



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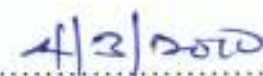
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DEDICATION

This project is dedicated to Almighty God who always proves Himself in my life and family. God has been guiding me with pillar of fire in the night and pillar of cloud in the day, therefore my journey was safe before and during the course and it will continue to be safe in Jesus Name.



ABSTRACT

Trends and cycles of rainfall and temperature in Nigeria since 1960 were studied on annual, seasonal and monthly bases and implications for water resources and agriculture were discussed. Data used for this study were collected from the Nigerian Meteorological Service, Oshodi Lagos. Rainfall and temperature data were available between 1960 and 2006 (47 years) for twenty stations in Nigeria. Mann-Kendall test was used to evaluate trends while Auto correlation spectral analysis was used to detect cycles, respectively.

The result showed that dominant peaks in rainfall and temperature return at various rates. For instance, Abeokuta, Akure, Enugu, Iseyin and Maiduguri stations were decreasing in trends of annual temperature at the rate of $0.080^{\circ}\text{C}/\text{mo}/\text{yr}$, $0.040^{\circ}\text{C}/\text{mo}/\text{yr}$, $0.030^{\circ}\text{C}/\text{mo}/\text{yr}$, $0.110^{\circ}\text{C}/\text{mo}/\text{yr}$ and $0.120^{\circ}\text{C}/\text{mm}/\text{yr}$ respectively with return periods between 1-2 years and 7-10 years. Akure, Benin, Calabar, Maiduguri and Yola stations were decreasing in trends of annual rainfall at rate of $1.084\text{ mm}/\text{mo}/\text{yr}$, $0.03\text{ mm}/\text{mo}/\text{yr}$, $1.80\text{ mm}/\text{mo}/\text{yr}$, $0.75\text{ mm}/\text{mo}/\text{yr}$, and $0.12\text{ mm}/\text{mo}/\text{yr}$ respectively with return periods between 1-2 years and 7-10 years. However, annual temperature showed increasing trends in 15 out of 20 stations studied. The return period ranged between 1-2 years to 13-15 years. Similarly, rainfall trends increased in about 75 % of the locations with return period of dominant peaks varying between 1-2 years and 15 years.

Abuja station recorded the highest peak in rainfall trends in the month of October at the rate of $4.7\text{ mm}/\text{mo}/\text{yr}$ with return period of 1-2 years while Benin station recorded the highest peak in trends of temperature in the month of September at the rate of $3.390^{\circ}\text{C}/\text{mo}/\text{yr}$ with return period of 1-2 years.

This result indicates different spatial effects on ecosystem and agriculture. Some of the implications of this trend on agriculture and water resources vary from one station to another, depending on the trends and magnitude of return period of both rainfall and temperature. For instance, Bauchi and Minna cities are expected to experience serious desertification and high level of depletion of underground water due to the continuous monotonic increase in trend of annual temperature and zero change in trend of rainfall. Agricultural activities are expected to thrive in stations like Ibadan, Gusau, Osogbo and others that have moderate increase in trends of rainfall and temperature.

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CHAPTER ONE: GENERAL INTRODUCTION

1.1 INTRODUCTION.

Environmental variability is the key issue when addressing agricultural production in arid and semi-arid regions. Alternating periods of variable length of relatively dry and wet years are also common in these regions (Duce et al, 2003) and Climate variability, which mainly affects rainfall, is inherently part of the regions like wise. Considerable effort has been expended in studies on large-scale and general circulation modeling to assess climatic risk. However, downscaling to the local level to assess climatic risk for agricultural areas and crops has proven difficult (Parry and Carter, 1988; Rosenzweig, 1982). In addition, there have been few attempts to account for inter-annual climate variability (Van Lanen, 1992; Hudson and Birnie, 1999; Motroni et al, 2002).

Smith (2000) reported that the great challenges for the coming decades will be the task of increasing food production to ensure food security for vastly growing world population, particularly in countries with limited water and land resources. While on a global scale, water resources are still ample and serious water shortages are developing in the arid and semi-arid regions. An increasing number of countries face serious water deficiencies as existing water resources are fully exploited. The dependency on water for agriculture has become a critical constraint for development. Over 30 arid and semi-arid countries are expected to be 'water scarce' by 2025, meaning an annual water availability of less than 1000m^3 per capita, which will slow down development, threaten food supplies and aggravate rural poverty (Crowley, 2000).

Burroughs (1992) reported that one of the approaches to resolve various intrigues and complexities of climate system is time series investigations. For example by

detecting cycles or trends and their variations within some time scale. Oguntunde et al (2006) reported that understanding trends and variations of current and historical hydro-climatic variables is important to the future development and sustainable management of water resources of a given region. Information regarding hydro-climatologic issues is important within the context of global warming, water and energy cycles and the increasing demand for water due to population and economic growth. There is a broad scientific consensus that global climatic change is a real problem and that it will alter the hydrological cycle in a variety of important ways (World Resources Institute Report 2000). However the impacts of future climatic changes on water resources and wetlands will depend on many non-climatic factors such as regional demographic factors, water policies and rule of operating complex system such as dam (IPCC, 2001a). To achieve long-term water resources planning and management, trends and variability in hydrological variables such as precipitation and temperature must be quantified.

1.2 Water Resources Issue

Nigeria is well drained with a close network of rivers and streams. The major rivers are River Niger and Benue with the other smaller ones in the north which are seasonal. The following are the principal surface water basins in Nigeria.

1. The Niger Basin has an area of 584193 km² within the country. The most important rivers in the basin are the Niger and its tributaries, Sokoto and Kaduna.
2. The Lake Chad Basin in the Northeast with an area of 179282 km² is the only internal drainage basin in Nigeria. The major rivers in the basin are Komadongou Yobe and its tributaries, Hadejia, and Kom

3. The Southwestern littoral basins have an area of 101,802km², which is the total area of the country. The rivers originate in the hilly areas to the west of the Niger River.
4. The Southeastern littoral basins have an area of 58,493 km² which receive much of their runoff from the plateau and mountain area of Cameroon border.
5. Nigeria has extensive groundwater resources, located in eight hydrological areas together with local ground water shallow (Fadama) aquifer adjacent major rivers.
6. The Sokoto Basin Zone comprises sedimentary rock in Northwest Nigeria. The yield range from below 1.0 to 5.0 l/s.
7. The Chad Basin Zone comprises sedimentary rock.
8. The middle Niger Basin Zone comprises sandstone aquifers. Borehole yields are about 1.2 to 1.6 l/s from unconfined aquifer and 1.5 to 2.1 l/s from the confined aquifer.
9. The Benue Basin Zone is the least exploited basin in Nigeria extending from Cameroon border to the Niger-Benue confluence. It is a sandstone aquifer.
10. The Southwestern Zone comprises sedimentary rocks bounded in the coastal alluvium and in the North by the basement complex.
11. The South central Zone is made up of cretaceous and tertiary sediment in the Niger Delta.

Source: www. AQUASTAT-FAO

1.2.1 Water Management in Nigeria.

The Federal Ministry of Water Resources (FMWR) but now Ministry of Agriculture and Water Resources is the major coordinating body in the water sector in Nigeria. Its principal functions are to;

- formulate and implement national irrigation policy.
- develop and support irrigated agriculture.
- coordinate the development and utilization of water resources for irrigation purposes.
- update and implement the water resources master plan.
- collect, store, analyze and disseminate hydro-meteorological and hydrological data.
- support, monitor and evaluate programmes and performances of the River Basin Development Authority (RBDAs) and National water.
- formulate appropriate water resource legislation.
- undertake studies and investigation to allow the efficient use of water resources.

There are other agencies both at Federal and State levels that are responsible for water resources management in Nigeria. Local governments also play a vital role in the water resource issues.

1.2.2 Policy and legislation related to water resources in Nigeria.

For efficient service delivery in water sector, government at various levels had between 1975 and 1995 formulated and established various policies and legislations, although these legislations and policies have undergone one or two forms of reform by various successive governments. The functions and roles of any agency in the sector must also be legislated before such an agency can perform its assigned task. The functions of the River Basin Development Authorities (RBDAs) related to irrigation are defined in the Development Authorities Act No. 35 of 1986. The water Resources Decree No. 101 of 1993 gives the Federal Ministry of Water Resources (FMWR) significant roles to control and coordinate activities for proper water shed management and water resources protection. The Environmental Impact Assessment

Decree No. 86 of 1992 made it compulsory to carryout environmental impact assessment before any irrigation could be executed.

1.2.3 International Water Issues

Nigeria is a member of two regional authorities dealing with the shared water resources;

(i) The Niger Basin authority (NBA) was formed in 1964, and is made up of

Countries that share the Niger basin (Guinea Cote D'ivore, Mali, Benin, Algeria, Niger Burkina Faso, (Cameroon) and the principal aim of the Authority is to promote integrated development of the basin.

(ii) The Lake Chad Basin Commission (LCBN) comprises representative countries, which are Central African Republic of Chad, Niger and Nigeria. Its objective is to ensure safe and equitable development of natural resources, including water of the region (FAO, 2000). Nigeria has not been left out on International discourse on water issues. On several occasions, the government of Nigeria has expressed its readiness and determination to accomplish UN, Millennium Development Goals on making safe drinking water available to all by year 2015. Moreover, Nigeria is a member of WTO (World Trade Organization) that ratified both the convention on biological diversity (CBD) and the bio-safety protocol. Nigeria is also a party to the convention on International Trade in Endangered species of Wild Fauna and Flora (CITES).

From a regional perspective, Nigeria has signed the revised convention for the establishment of the Niger Basin Authority (convention revise portent a la creation de l'autorite du Basin du Niger N'djamena, 1987) which replaces the Niger River Commission at the convention concerning the development of the Chad Basin held in Yaounde in 1984 (Ingram et al.,2002).

1.3 Government Efforts toward Efficient Service Delivery in Water Sector

In the past, various methods and equipment were used with little or no thought being given to the sustainability of the systems and the ability of the benefiting communities to operate and maintain them. The strategy and action plan prescribe standards for the methods and equipment to be used. The National water supply policy was completed and approved at the National Council on water resources and rural development meeting at Kaduna in November 1995. It provides the guidelines for water supply development up to the year 2015 and formed the basis for the subsequent reforms in the sector. The Ministry has made significant progress in the drinking water supply and sanitation programme aftermath the completion and approval of the National Water Supply policy through some local and International activities. These activities include the production of the national rural water supply and sanitation sector strategy and action plan; the nation-wide rural water supply programme; hand pump development; the joint rural water supply and sanitation programme; the development of the national water supply policy; participation in the International sanitation, and the UN water supply and sanitation collaborative council as Agenda 21 Nigeria (FAO 1994)

Among the various reform project embarked upon by the Federal Government of Nigeria to revamp the stagnation cycle of Water Agencies in the country is the Public Private Partnership (PPP) for water supply services. The PPP project is designed to address the following problems in the water sectors; low operational efficiencies, low revenue generation, insufficient financial resources for capital investment, agency infrastructures, low institutional capacity, energy problems and Peri-urban pressure.



The concept of Private Public Partnership (PPP) project is to ensure partnership between the private and public sectors in the urban and rural water supply to achieve the following development objective;

- improve reliability of water supply through increase in operating capacity and hours of operations.
- increase access to piped network through increase in numbers of house connections.
- improve commercial viability of the urban utilities to the extent that operating cost is recovered from water sales revenue.
- to put in place enabling environment for sustainable service delivery.

1.3.1 Financing

Most of the projects in water sector are being financed by the Federal Government. Many donors both local and international have been showing interest in Nigeria water sector to ensure system expansion, sustainable efficient service delivery and capacity building since water issue has become a global issue. Among the donors are European Commission, World Bank, African Development Bank, United Nation and several other foundations. In 1991, African Development Bank (ADB) funding was sought for equipment purchase and expert training for Regional Laboratories and two Reference laboratories located at Dadin Kowa, Minna, Akure, Enugu, Lagos and Kaduna respectively. The World Bank and the European Commission have not been found wanting in area of financing water projects in Nigeria.

1.4 OBJECTIVES OF THE STUDY.

The main aim of the study was to detect significant trends and periodicities in the inter-annual and intra-annual series of rainfall and temperature over Nigeria.

The specific objectives of the study are to:

- i detect the presence of significant monotonic increasing and decreasing trends in rainfall and temperature
- ii determine the magnitude of trends and variability in rainfall and temperature series.
- iii investigate the periodicity of rainfall and temperature series.
- iv discuss the implications of trends on water resources and agriculture.

1.5 JUSTIFICATION FOR THE STUDY

The need for the analysis of trends and cycles of rainfall and temperature in Nigeria cannot be over emphasized. In the recent years several extreme events have caused large losses of life, as well as tremendous increase in economic losses from weather hazards. These losses have led to the alarm raised on the possibility that the adverse events were due to a climate change. Further more, agriculture that is the mainstay of Nigerian economy depends largely on spatial and temporal distribution of rainfall and temperature. Thus valuable historical record of hydrologic patterns over complex terrain as Nigeria will assist the understanding anthropogenic and climate effects on the large-scale terrestrial agro-ecosystems.

CHAPTER TWO: LITERATURE REVIEW

2.1 Regional Impacts of Climate Change: An Assessment of Vulnerability

Human activities (primarily the burning of fossil fuel and changes in land use cover) are increasing the atmospheric concentrations of greenhouse gases, which invariably warm the atmosphere by altering radioactive balances. In some regions, aerosols which have an opposite effect on radioactive balance and cool the atmosphere. At present, in some locations primarily in the Northern Hemisphere, the cooling effects of aerosols can be large enough to more than offset the warming due to green house gases (IPCC., 1996). These changes in greenhouse gases and aerosols, put together are projected to lead to regional and global increases in temperature, precipitation and other climate variables, that result in global changes in soil moisture, global mean sea level, and prospect for more severe extreme high temperature events, floods and drought in many places (IPCC 1996, WGI). Article 2 of the United Nation Frame Convention on climate change acknowledged the importance of natural ecosystems, food production and sustainable economic development. The reported assessment of regional vulnerability to climate changes focuses on ecosystems, hydrology and water resources, food and fiber production, human settlements and health and other systems which include the climate system and coastal system. Variation in the vulnerability of similar sectors or systems is to be expected across regions, as a consequential difference in local environmental conditions, pre-existing stresses to ecosystems and current resources.

2.1.1 Rainfall and Runoff Variability

Assessment of surface water resources in a basin for planning and development of water projects is always carried out on the basis of long term flow characteristic (Hydro project Czechoslovakia, 1986). Long term data sets incorporate low and high

flows inherent in natural hydrological series and are able to depict the true characteristics of the flows in the basin. Human activities such as deforestation and those associated with the emissions of greenhouse gases have a permanent influence on the climate. Such changes need to be evaluated for the management of existing water resource systems and planning and development of future ones (Oppku-Ankomah et al., 1998). The present study examined the temporal variation and changes in the extended runoff series and the water resources of the river system. In order to gain a clear understanding of possible changes in the runoff, rainfall series in the basin were also examined. A couple of studies have been carried out to examine runoff variability in West Africa and these include Aka et al (1996) and Lavender and Anderson (1984). Aka et al (1996) found a break in the series of annual mean discharges at the beginning of the 1970's for some flows in La coted Ivoire. Lavender & Anderson (1984) in their study, however, did not find any declining trend of runoff in Africa but rather a strong periodic fluctuation between wet and dry periods.

2.1.2. Climate change

Climate change is assuming great dimensions but is just one of the factors that put pressure on the hydrological cycle and freshwater ecosystems (Oyebande et al., 2001). Population growth, land use change, the change in the industrial sector, and demands for ecosystem protection and restoration are all exerting pressures simultaneously on the hydrological cycle with various feed back mechanisms. There is a broad scientific consensus that global climatic change is a real problem and that it will alter the hydrological cycle in a variety of important ways (World Resource Institute Report., 2002). However, the impacts of future climatic changes on water resources and wetlands will depend on many non-climatic factors such as regional demographic

factors, water policies and rule of operating complex system such as dam (IPCC., 2001a & b).

The stochastic nature of the complexity and uncertainty of climate change have impacts on the environment (Oyebande, et al., 2001). Cooper (1994) reported that physical change in the hydrological cycle in the case of reduced rainfall or increased evaporation would disconnect rivers from their flood plains and wetlands, slow water velocity in riverine systems and convert that into a chain of connected reservoirs or pools. These in turn impact the migratory patterns of fish species and the composition of riparian habitat, open the way for exotic species, and contribute to an overall loss of fresh water biodiversity and inland fishery resources (World Resources Institute Report., 2000).

2.2 Warming and Temperature.

The results of Climate modeling using the new available green house gas emissions scenarios for temperature show that climate will change with greater proportion during the next century (Nakicenovic et al, 2000). Observed record indicate that African continent is warmer than it was 100 years ago (Kelly and Farmer, 1991) and the warming rate during the 20th century is about 0.05^oc per decade (Helmut .et al, 1982). Hulme (1992) tested the new greenhouse gas emissions scenarios by using General Circulation Models and it was found that annual warming across Africa may range from 0.2^oC to more than 0.5^oC per decade. Hughe and Diaz. (1994) reported that the main feature of the series is the dramatic rise in temperature during the 20th century, thus making it the warmest of the millennium. The 1990s are the warmest decade and 1998 the warmest year. Uncertainties are greater earlier in the millennium and we can only say that 1601 was probably the coldest year. The coolest centuries were the 17th and 19th with the former coldest over North America (Crowley

and lowery, 2000). The first five centuries were warmer than the 16th to 17th but were clearer cooler than the 20th. Knowledge of this variability is vital in detection and attribution studies of recent climate change which seek to explain the 20th century rise as a result of anthropogenic activities. Much of the record can be explained in terms of three mechanisms.

- Changes in solar output
- Changes in the number and severity of explosive volcanic eruption.
- Changes in atmospheric composition as a result of human activities (increase in green house gases)

Natural forces from the sun and volcanoes dominate the pre-1850 part of the record and only human activities appear to adequately explain the rise in temperature during the 20th century (Crowley, 2000). Global warming is commonly explained by the anthropogenic green house effect caused by the emission of CO₂ as well as sulphate emitted from fossil fuels which has greatly affected agricultural water availability in many regions (Gerhard, 2005). In Egypt, 92% of the energy sector depends on fossil fuels (oil and natural gas). The energy is the main source of green house emission, followed by the agricultural sector mainly from enteric fermentation and rice cultivation. Industrial emissions of CO₂ was chiefly from the steel and cement industries. The main source of methane is waste resulting from anaerobic bacterial decomposition of organic matter in land fill and open dumps (Egyptian Environmental Affairs Agenda, 1999).

2.3 Evaporation and Transpiration

Penman (1978) reported that evaporation, transpiration and temperature variability are closely related. An increase in temperature implies an increase in potential evaporation and transpiration. Projected temperature increases are likely to

lead to increased open water and soil water evaporation (Olufayo and Alatise, 2006). Exactly how large this increased evaporative loss will be would depend on factors such as physiological changes in plant biology, atmospheric circulation, and land-use patterns (Michael, 1978). Oguntunde et al (2007) reported that the ability to accurately measure or estimate Evapo-transpiration will enhance water resources and environmental management of a given catchment's or basin. In arid regions, full irrigation is needed for survival while irrigation is supplemental in the humid regions (Servat and Shakho, 1998). The cost of obtaining water is high and therefore the irrigation should aim at applying only quantity that is necessary. To do this effectively, it is necessary to predict crop water requirement and the exact time irrigation becomes necessary. Among formulae that exist to estimate ET are simple empirical equations and physically based complex equations such as Penman and Penman-Monteith equation as well as Blaney-Morin-Nigeria proposed under Nigeria condition by Duru (1984). Oguntunde (1998) compared BMN with other ET equations in humid and sub-humid stations of Nigeria and found BMN performing better than Penman as claimed by Duru (1984).

2.4 Methods of Analysis

2.4.1 Trend

The Mann- Kendall test (Kendall and Stuart., 1961) and the Residual mass curve (WMO, 1966) were used to analyze trends. The Residual mass curve is a statistical procedure commonly applied in studies of climatic fluctuations. It is a graph of the cumulative departures from a given reference, such as the mean versus time or date. This curve has mostly been applied to rainfall series which are highly variable so that long-term trends in them are well hidden by the most rapid variations. When such series are converted to series of cumulative deviations, they appear to be much less

variable and give the impression of suppressing the amplitude and the rapid variation, so that the slower ones show through more clearly. A rising trend corresponds to a run off below average values in the same part of the original series, and a concave-upward shape corresponds to an upward trend in the original series.

2.4.2 Spectral Analysis

The spectral analysis is used to analyze cycles of precipitation data. The power spectra of annual, seasonal and monthly anomalies were analyzed using the Auto-correlation Spectral Analysis ASA (Blackman and Turkey, 1958; WMO., 1966), Multi-taper method-MTM (Thompson, 1982; Parker et al., 1987) and maximum entropy spectral analysis-MESA (Burg., 1975). A variety of spectral analysis techniques have been widely employed in the analysis of geophysical processes. There is no best spectral estimate (Kay., 1988) thus it is advisable to apply several independent estimation procedures. The Auto Spectral Analysis is obtained by applying the Discrete Fourier Transform (DFT) algorithm to the correlation functions derived from the time series, taking as a smoothing function of classical Hamming window. The ASA is smoother and more accurate than the Fast Fourier Transformation (FFF) but the amplitude relationship is poorly reflected (Padmanabhan, 1991).

More sophisticated methods have recently been developed which are more effective in their underlying assumptions to the irregular oscillatory behavior expected in precipitation. Among such methods is the MTM approach which makes use of multiple orthogonal data tapers to describe structures in time series that are modulated in frequency and amplitude. The purpose of non-parametric MTM is to compute a test of independent and significant estimates of the spectral density in order to improve the results obtained with single-taper methods. This method provides a spectral

estimate with an optimal trade-off between resolution and variance. According to Parker et al (1987), only the first $S = 2P - 1$ tapers are usefully resistant to spectral leakage, where p is the time-frequency bands width parameter. In the context of climate studies, the choice $P = 2$ and hence $S = 3$ provides a good compromise between the resolution appropriate to resolve climatic signals, and the variance of the spectral estimate (Mann and Park, 1994; 1996).

2.5. Large Scale Climate Variability on Agriculture.

Sultan et al (2003) reported that agriculture in the Sudan Sahelian zone is heavily dependent on the seasonal characteristics of rainfall. More over, rural populations which depend primarily on agricultural production, an activity that is considered as the most weather-dependent of all human activities, are exposed to the impact of climate variability (Oram, 1989; Hansen, 2002). The monsoon system across India and West Africa and ENSO influence over many other parts of the world are part of the high variability in climate that affect the less economically developed countries in the tropics (Challinor et al., 2003). UNDP (2004) reported that in addition to climate variability, crop growers are also faced with poverty which increases the risk and impact of natural disasters such as flood, draught and so on. The growers have a very limited means of control to improve their system due to the poorly developed or malfunctioning subsidies, agricultural credit, seed sector and extension (Forest and Clopes, 1994).

Irrigation and other cultural practices that can aid optimal use of water resources and minimize drought risks are crucial for monsoon cropping in West Africa (Diop, 1996; Sivakumar et al., 2000). Rainfall over West Africa is linked to the Meridional migration of the Inter-Tropical-Convergence Zone (ITCZ). Following the seasonal excursion of the Sun, the monsoon develops over this part of the African continent

during the Northern spring and summer, bringing the ITCZ and the associated rainfall Maxima to their Northern most location in August (Heistenrath, 1995). Most studies on the subject have investigated the inter-annual time scale over West Africa through the role of surface characteristics (Zheng and Eltahir, 1998) and in particular the interactions between ocean and atmosphere (Folland et al.,1986; Janicot et al., 2001) which are the base of seasonal fore casts of rainfall amounts(Ward,1998; Fontaine et al.,1999) with potential benefits to agriculture (Sivakumar et al.,2000). How ever, the seasonal and intra-seasonal time scales are poorly documented in spites of their importance for agricultural strategy. Indeed, Ingram et al (2002), in a recent study on several villages of Burkina Faso, classified in order of declining priority the most salient rainfall parameters in agricultural strategy for farmers. They were (1) timing of the onset and end of the rainy season, (2) rainfall distribution and water deficits within the season, and the lowest priority, (3) total amounts of rainfall.

2.6 Intra-Seasonal Variability of Rainfall.

Cooley and Tuckey (1965) reported that Fourier Transformation (FT) is a well-known technique to study oscillation in time series which provides frequency components of the signal studied. The wavelet analysis is an extension of this transformation providing time and frequency information simultaneously (Mallat, 1999). Information is obtained on both the amplitude of 'periodic' signal within the series and the variability of this amplitude varies with time (Terrence and Campo, 1998). This tool is particularly adapted to the analysis of mixed time scales in rainfall variability in west Africa from day to day fluctuations due to mesoscale convective systems (Hodges and Thorncroft, 1997; Mathon and Laurent, 2001). The rainfall time series show a seasonal cycle with the highest values during summer and smaller values during spring and autumn. Day-to-day fluctuations are also evident from the

index time series and wavelet analysis, with the highest values observed between 3 and 8 days, more over, the onset of the monsoon, defined by the shift of the ITCZ on the 27 June, seems to be part of an intra-seasonal mode of variability at low frequencies with two maxima in the second part of July and at the end of August, and a dry spell centered in the beginning of August.

2.6.1 Impact of Inter-Annual Variability of Rainfall.

The impact of inter-annual variability of annual rainfall can be measured or determined on attainable yield simulated with the threshold method, the regional monsoon onset method and the 'Ideal' sowing date. A strong correlation is to be observed between the maximum yields obtained with the 'Ideal' sowing date with total annual rainfall. If on the other hand, no significant correlation is found when using the threshold method, therefore it can be concluded that wet years were sometimes associated with low yield. This is in many cases due to very early sowings followed by isolated rain storms.

Sultan et al., (2005) reported that the impact of inter-annual variability on rainfall affects mostly the yields. The year 1975 which was regarded as dry year witnessed high attainable yield while 1990 which was noted as a wet year experienced low attainable yield. Taking into account the regional onset of monsoon, which seems to improve the relationship between water available and water used by the plant and thus seems to potentially increase crop water use. However, it needs to be pointed out that several years have particular properties that contribute over proportionally to the residual variability of the relationship between attainable yield and annual rainfall total.

CHAPTER THREE: RESEARCH METHODOLOGY

3.1 Geography, climate and population of Nigeria



Nigeria is located in West Africa between latitude 4° - 14° N and longitudes 2° - 15° E and has a total area of $925,796 \text{ km}^2$. The ecological zones of the country are broadly grouped into three, which are; Sahel, Savannah and the Guinea zones as shown in figure 1. The climate is semi-arid in the north and humid in the south and also humid strip along the coast with rainfall averages over 2000 m. It rains almost all year round with highest peak in the period of June to September. In 2002 Nigeria cultivated areas of 33 million ha, of which arable land covered 30.2 million ha and permanent crops 2.8 million ha. About two thirds of the cropped area is in the North, with the rest areas distributed between the middle belt and the South. According to the results of 2006 census, Nigeria is by far the most populous country in Africa with over 140 million in population and population density of 138 inhabitants per km^2 .

3.2 Data Sourcing and Processing

The data used for this study were collected from the Nigerian Meteorological service, Oshodi, Lagos. Data on rainfall and temperature used in this study are available between 1960 and 2006 (47 years) for twenty (20) stations as summarized in the table 1 below.

Data collected were processed into annual, monthly and seasonal for analytical convenience. The seasons are April, May and June (AMJ); July, August and September (JAS) and October, November and December (OND). The fourth season, which is January February March (JFM) was assumed to be period of no rainfall and therefore neglected.

Table 1: Available Data on Rainfall and Temperature for various Stations

Stations	Temperature	Rainfall
<i>Abeokuta</i>	<i>1980-2006</i>	<i>1980-2006</i>
<i>Abuja</i>	<i>1980-2006</i>	<i>1980-2006</i>
<i>Akure</i>	<i>1960-2006</i>	<i>1960-2006</i>
<i>Bauchi</i>	<i>1960-2006</i>	<i>1960-2006</i>
<i>Benin</i>	<i>1960-2006</i>	<i>1960-2006</i>
<i>Calabar</i>	<i>1960-2006</i>	<i>1960-2006</i>
<i>Enugu</i>	<i>1960-2006</i>	<i>1960-2006</i>
<i>Gusau</i>	<i>1960-2006</i>	<i>1960-2006</i>
<i>Ibadan</i>	<i>1960-2006</i>	<i>1960-2006</i>
<i>Ikeja</i>	<i>1965-2006</i>	<i>1960-2006</i>
<i>Iseyin</i>	<i>1980-2006</i>	<i>1960-2006</i>
<i>Lagos</i>	<i>1960-2006</i>	<i>1960-2006</i>
<i>Maid</i>	<i>1960-2006</i>	<i>1960-2006</i>
<i>Minna</i>	<i>1960-2006</i>	<i>1960-2006</i>
<i>Osogbo</i>	<i>1965-2006</i>	<i>1965-2006</i>
<i>P/Harcourt</i>	<i>1960-2006</i>	<i>1960-2006</i>
<i>Sokoto</i>	<i>1960-2006</i>	<i>1960-2006</i>
<i>Warri</i>	<i>1960-2006</i>	<i>1960-2006</i>
<i>Yelwa</i>	<i>1980-2006</i>	<i>1960-2006</i>
<i>Yola</i>	<i>1960-2006</i>	<i>1960-2006</i>

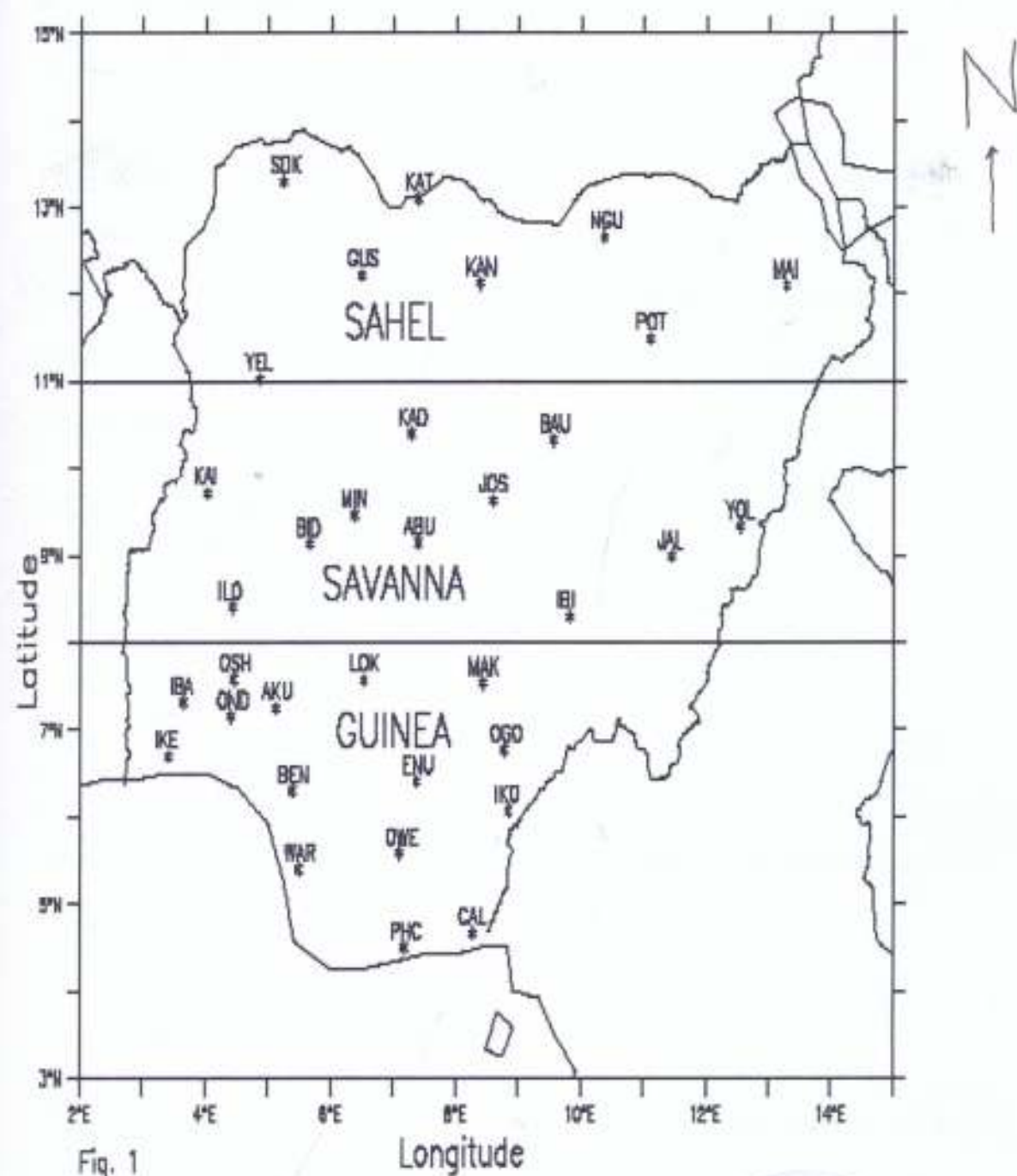


Fig. 1

Longitude

Scale: Interval of 2°N and 2°E

Figure 1. Map of Nigeria showing ecological zones.



3.3. Description of statistical tests used.

3.3.1 Mann-Kendall test

The Mann-Kendall test is applicable in cases when the data values x_i of a time series can be assumed to obey the model;

$$\chi = f(t) + \sum \tau, \quad (1)$$

Where $f(t)$ is a continuous monotonic increasing or decreasing function of time and the Residual $\sum \tau$ can be assumed to be from the same distribution with zero mean.

The Mann-Kendall test statistic S is calculated as it was in Oguntunde et al, (2006), using the formula.

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^n \text{sgn}(x_j - x_k) \quad (2)$$

Where x_j and x_k are the annual values in years j and k , $j > k$, respectively, and

$$Z = \begin{cases} \frac{S - 1}{\sqrt{\sigma^2(S)}} & \text{if } S > 0 \\ 0 & \text{if } S = 0 \\ \frac{S + 1}{\sqrt{\sigma^2(S)}} & \text{if } S < 0 \end{cases} \quad (3)$$

The variance of S is computed by equation below to take care of ties that may be present.

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

Here q is the number of tied groups and t_p is the number of data values in the p th group. The presence of a statistically significant trend is evaluated using the Z value. A positive (negative) value of Z indicates an upward (downward) trend. The statistic Z has a normal distribution.

3.3.2 Slope estimate- Sen's method

To estimate the true slope of an existing trend (as change per year) the Sen's nonparametric method is used. The Sen's method can be used in cases where the trend can be assumed to be linear. This means that $f(t)$ in equation (1) is equal to

$$\hat{f}(t) = Qt + B \quad (5)$$

Where Q is the slope and B is a constant.

To get the slope estimate Q in equation (6) we first calculate the slopes of all data value Pairs

$$Q_i = \frac{x_j - x_k}{j - k} \quad (6)$$

Where $j > k$. If there are n values x_j in the time series we get as many as $N = n(n-1)/2$ slope estimates Q_i . The Sen's estimator of slope is the median of these N values of Q_i . The N values of Q_i are ranked from the smallest to the largest and the Sen's Estimator is $Q = Q_{[(N+1)/2]}$ if N is odd

Or $Q = 1/2 (Q_{[N/2]} + Q_{[(N+2)/2]})$ if N is even.

3.3.3 Discrete Fourier Transform and the FFT

The Fourier Transform

The Fourier transform was used to transform a continuous time signal into the frequency domain. It describes the continuous spectrum of a non-periodic time signal.

The Fourier transform $X(f)$ of a continuous time function $x(t)$ can be expressed as;

$$X(f) = \int_{-\infty}^{\infty} x(t) e^{-i2\pi ft} dt \quad (8)$$

The inverse transform is

$$x(t) = \int_{-\infty}^{\infty} X(f) e^{j2\pi ft} df \quad (9)$$

The Discrete Fourier Transform

This was used in the case where both the time and the frequency variables are discrete (which they are if digital computers are being used to perform the analysis). Let $x(nT)$ represent the discrete time signal, and let $X(mF)$ represent the discrete frequency transform function. The Discrete Fourier Transform (DFT) is given by

$$X(mF) = \sum_n x(nT) e^{-jnm2\pi FT} \quad (10)$$

where

$$x(nT) = \frac{1}{N} \sum_m X(mF) e^{jnm2\pi FT} \quad (11)$$

The Fast Fourier Transform

The fast Fourier transform (FFT) is simply a class of special algorithms which implement the discrete Fourier transform with considerable savings in computational time. It must be pointed out that the FFT is not a different transform from the DFT, but rather just a means of computing the DFT with a considerable reduction in the number of calculations required.

3.3.4. The Residual Mass Curve.

The Residual mass curve is a statistical procedure commonly applied in studies of climatic fluctuations (WMO, 1966). It is a graph of the cumulative departures from a given reference such as the mean, versus time or date. This curve has mostly been applied to rainfall series, which are highly variables so that long-term trends in them are well hidden by most rapid variations. When such series are converted to series of cumulative deviations, they appear to be much less variable and somehow give the impression of suppressing the amplitude of the rapid variation so that the lower ones show through clearly

CHAPTER FOUR: RESULTS AND DISCUSSIONS

4.1 Spatial distribution and trends of rainfall and temperature over Nigeria

Table 2: The Summary of the Result of Mann-Kendall and Auto-correlation Spectral Analysis

Stations	Temperature Peak ($^{\circ}$ C/mo/yr)/ Month	Rainfall Peak (mm/mo/yr)/month	Annual Temperature Cycles (years)	Annual Rainfall cycles (years)
Abeokuta	-0.078/ March	1.76 / May	1-2 & 3-4 yrs	1-2 yrs
Abuja	0.031 November	4.66 / October	1-2 & 4-5 yrs	3-5 yrs
Akure	-0.037 / March	-1.084 / October	5 & 20-25 yrs	2 & 20-25 yrs
Bauchi	0.033 / January	1.139 / June	3-5	3-5 & 13-15
Benin	3.39 / September	-0.033 / August	1-2 & 15-20	3-5
Calabar	0.025 / May	-1.97 / October	7-10 & 15-25	6-7
Enugu	-0.03 / March	0.18 / July	5-6 & 10- 14	2-3 & 3-4
Gusua	0.008 / April	0.10 / August	6-7 & 20-25	1-2 & 3-4
Ibadan	1.82 / April	2.614 / July	2-3 & 10-13	5-7
Ikeja	0.037 / April	0.753 / April	1-2 & 3-6	1-2 & 7-10
Iseyin	-0.105 / April	0.45 / April	5-7 & 10-15	3-5
Lagos	0.055 / January	0.82 / June	3-5	1-2
Maiduguri	-0.119 /February	-0.75 / June	7-10	1-2 & 3-4
Minna	0.0055 / March	0.2 / June	1-2 & 20-25	5-6
Oshogbo	0.129 / January	2.196 / September	3-4 & 7-10	1-2 & 3-4
PortHarcourt	0.034 / February	1.138 / October	2-3	5-6 & 8-10
Sokoto	0.01 / February	0.867 / July	13-15	1-2, 4-5 &
Warri	0.067 / January	1.133 / March	1-2	13-15
Yelwa	0.1 / December	0.33 / May	5-6	2-3
Yola	0.11 / April	-0.1 / July	5-7	1-2 & 3-4 4-5

-Ve and +Ve signs show decreasing and increasing trends respectively.

The summary table shows that Benin recorded the highest annual temperature peak at the rate of $3.39\text{ }^{\circ}\text{C/mo/yr}$ in the month of September, with return period of 1-2 years, followed by Ibadan with the highest annual temperature peak of $1.82\text{ }^{\circ}\text{C/mo/yr}$ in the month of April and return period of 2-3 years. Mean while, the lowest annual temperature peak of $0.006\text{ }^{\circ}\text{C/mo/yr}$ was recorded for Minna in the month of March with cycles of 1-2 years. Abuja recorded the highest annual rainfall peak of 4.66 mm/mo/yr in the month of October with cycle of 1-2 years, followed by Ibadan that has annual rainfall peak of 2.614 mm/mo/yr in the month of July with cycle of 5-7 years. Benin recorded the lowest annual rainfall peak of 0.03 mm/mo/yr in the month of August with cycle of 3-5 years.

Table 3 shows the Mann-Kendall test statistics summary of monthly rainfall and mean monthly temperature for Abeokuta station. The months of May, July and December showed no change in trends of mean monthly temperature while months of January, March, April and September were increasing at the rate of $0.006\text{ }^{\circ}\text{C/mo/yr}$, $0.078\text{ }^{\circ}\text{C/mo/yr}$, $0.004\text{ }^{\circ}\text{C/mo/yr}$ and $0.005\text{ }^{\circ}\text{C/mo/yr}$ respectively with various significance levels. The remaining months have witnessed decrease in mean monthly temperature trends. The months of February, June, August, October, and November had decreased in temperature at the rate of $0.025\text{ }^{\circ}\text{C/mo/yr}$, $0.031\text{ }^{\circ}\text{C/mo/yr}$, $0.008\text{ }^{\circ}\text{C/mo/yr}$, $0.007\text{ }^{\circ}\text{C/mo/yr}$ and $0.125\text{ }^{\circ}\text{C/mo/yr}$ respectively. The months of January, February, March, April, July, September, October, and December showed no change in trends of rainfall. The months of May, and November were increasing in rainfall trends at the rate of 1.760 mm/mo/yr and 0.083 mm/mo/yr , while months of June and August decreased in rainfall trends at the rate of 0.140 mm/mo/yr and 1.118 mm/mo/yr . The highest temperature was recorded in the month of March and month of May witnessed the highest rainfall.

Table 3: Mann-Kendall test statistics for monthly rainfall and mean monthly temperature for Abeokuta station

Time series	First year	Last year	Test Z		Slope Q	
			Temp	Rainfall	Temp	Rainfall
Jan	1980	2006	2.95*	0.45	0.067	0.000
Feb	1980	2006	-1.13	0.47	0.025-	0.000
March	1980	2006	2.58*	0.08	0.078	0.000
April	1980	2006	0.36	-0.21	0.004	0.000
May	1980	2006	-0.15	1.05	0.000	1.760
June	1980	2006	-1.47	-0.42	-0.031	-0.140
July	1980	2006	0.00	-0.25	0.000	0.000
Aug	1980	2006	-0.82	-0.63	-0.008	-1.118
Sept	1980	2006	2.37*	-0.21	0.050	0.000
Oct	1980	2006	-0.95	-0.08	-0.007	0.000
Nov	1980	2006	3.65***-	0.67	-0.125	0.083
Dec	1980	2006	0.21	-0.89	0.000	0.000

*** if significance level (a) is 0.001, * if significance level(a) is 0.01

Table 4 shows the Mann-Kendall test statistics of mean monthly temperature and monthly rainfall for Abuja station. The month of January showed no change in mean monthly temperature trends while the months of November and December were increasing in temperature at the rate of 0.03 °C/mo/yr and 0.029 °C/mo/yr with significance level of 0.1. The months of February, march, April, May, June, July, August, September and October were decreasing in temperature trends at the rate of 0.009 °C/mo/yr, 0.023 °C/mo/yr, 0.038 °C/mo/yr, 0.028 °C/mo/yr, 0.025 °C/mo/yr, 0.02 °C/mo/yr, 0.021 °C/mo/yr, 0.03 °C/mo/yr, and 0.025 °C/mo/yr respectively. The months of January, November and December showed no change in trends of rainfall while the months of August, September and October were increasing in rainfall at the rate of 1.78 mm/mo/yr, 1.273 mm/mo/yr, and 4.660 mm/mo/yr respectively. The results show that the highest rainfall occurred in the month of October while the month of November experienced the highest temperature.

Table 4: Mann-Kendall test statistics for monthly rainfall and mean monthly temperature for Abuja station

Time series	First year	Last year	Test Z		Slope Q	
			Temp	Rainfall	Temp	Rainfall
Jan	1960	2006	0.13	-1.77*	0.000	0.000
Feb	1960	2006	-0.58	-2.21*	-0.009	-0.124
March	1960	2006	-1.06	4.54***	-0.023	-1.538
April	1960	2006	-1.99*	-3.94***	-0.038	-1.904
May	1960	2006	-1.94+	-2.35*	-0.028	-1.961
June	1960	2006	-3.55***	-2.05*	0.025-	-2.129
July	1960	2006	-3.07**	-0.28	-0.020	-0.380
Aug	1960	2006	3.24***	2.07*	-0.021	1.780
Sept	1960	2006	-2.95**	1.56	-0.030	1.273
Oct	1960	2006	-2.41*	5.51***	-0.025	4.660
Nov	1960	2006	3.17**	2.00*	0.031	0.000
Dec	1960	2006	2.79**	-2.07*	0.029	0.000

*** if signific. level (a) is 0.001, ** if (a) is 0.01, * if (a) is 0.05, + if (a) is 0.1

Table 5 shows the Mann-Kendall test statistics of mean monthly temperature and monthly rainfall of Akure station. The months of May and July showed no change in temperature trends while the months of March, April and June were increasing at the rate 0.037 °C/mo/yr, 0.01 °C/mo/yr and 0.024 °C/mo/yr with various significance levels. Mean while, months of January, February, August, September, October, November and December were decreasing in temperature at the rate of 0.018 °C/mo/yr, 0.003 °C/mo/yr, 0.021 °C/mo/yr, 0.073°C/mo/yr and 0.059 °C/mo/yr respectively. The months of January and December showed no change in trend of rainfall while months of October and November were increasing in trends of rainfall at the rate of 1.083 mm/mo/yr and 0.436 mm/mo/yr. The months of February, March, April, May, June, July, followed by August and September were decreasing in rainfall at the rate of 0.888 mm/mo/yr, 1.375 mm/mo/yr, 0.609 mm/mo/yr, 1.392 mm/mo/yr, 0.5 mm/mo/yr, 0.263 mm/mo/yr, 1.264 mm/mo/yr and 0.963 mm/mo/yr with various significance levels. The results show that the highest temperature was recorded in the month of March while the month of October experienced the highest rainfall.

Table 5: Mann-Kendall test statistics for monthly rainfall and mean monthly temperature for Akure station

Time series	First year	Last year	Test Z		Slope Q	
			Temp	Rainfall	Temp	Rainfall
Jan	1960	2006	-1.53	-0.56	0.018-	0.000
Feb	1960	2006	-0.62	-1.73+	0.003	-0.888
March	1960	2006	2.67**	-1.58	0.037	-1.375
April	1960	2006	0.84	-1.30	0.010	-0.606
May	1960	2006	-0.15	-1.62	0.000	-1.392
June	1960	2006	1.61	-0.83	0.024	-0.500
July	1960	2006	0.52	-0.68	0.000	-0.268
Aug	1960	2006	-2.92**	-1.45	-0.021	-1.264
Sept	1960	2006	3.06-***	-1.78+	-0.024	-0.963
Oct	1960	2006	-2.43*	1.45	-0.021	1.083
Nov	1960	2006	4.09***-	1.34	-0.073	0.436
Dec	1960	2006	-4.12***	0.41	-0.059	0.000

*** if significance level (a) is 0.001, ** if (a) is 0.01, * if (a) is 0.05, + if (a) is 0.1

Table 6 shows the Mann-Kendall test statistics summary of monthly rainfall and mean monthly temperature for Bauchi station. The month of March showed no change in trend of mean monthly temperature while the month of February decreased in temperature at the rate of 0.007 °C/mo/yr. The remaining months were increasing in temperature at different rate and significance levels. The months of January and July were increased in temperature at the rate of 0.033 °C/mo/yr and 0.028 °C/mo/yr. The months of April, May, October, and December showed monotonic increasing trend at the rate of 0.001 °C/mo/yr, 0.012 °C/mo/yr, 0.013 °C/mo/yr and 0.004 °C/mo/yr respectively while months of June, August, September and November increased in temperature at the rate of 0.024 °C/mo/yr, 0.008 °C/mo/yr, 0.013°C/mo/yr and 0.017 °C/mo/yr. The months of January, February, March, June, July, October, November and December showed no change in trend of rainfall while the month of September decreased in rainfall at the rate of 0.335 mm/mo/yr. The months of April, May, and June were increasing at the rate of 0.15 mm/mo/yr, 0.221 mm/mo/yr and 1.139

mm/mo/yr. The results showed that the highest change in temperature occurred in the month of January while the month of June experienced the highest change in rainfall.

Table 6: Mann-Kendall test statistics for monthly rainfall and monthly mean temperature for Bauchi station (Savannah zone)

Time series	First year	Last year	Test Z		Slope Q	
			Temp	Rainfall	Temp	Rainfall
Jan	1960	2006	2.98**		0.033	
Feb	1960	2006	-0.55		-0.007	
March	1960	2006	-0.06		0.000	
April	1960	2006	0.42	1.03	0.001	0.150
May	1960	2006	1.53	0.74	0.012	0.221
June	1960	2006	2.19*	1.26	0.024	1.139
July	1960	2006	2.71**	-0.12	0.028	0.000
Aug	1960	2006	2.20*	0.27	0.008	0.000
Sept	1960	2006	2.19*	-0.78	0.013	-0.335
Oct	1960	2006	0.96	0.14	0.003	0.000
Nov	1960	2006	1.99*		0.017	
Dec	1960	2006	0.46		0.004	

** if significance level (a) is 0.01, * if (a) is 0.05.

Table 7 shows Mann-Kendall test statistics for Benin mean monthly temperature and monthly rainfall. The months of January, February, March, April, and May showed no change in rainfall trends while months of February, March, November, and December experienced no change in temperature trend. The months of January, June, July, August and September increased in temperature at the rate of 0.014 °C/mo/yr, 0.28 °C/mo/yr, 2.330 °C/mo/yr, 3.360 °C/mo/yr, and 3.390 °C/mo/yr respectively. The month of August increased in rainfall trend at the rate of 0.036 mm/mo/yr. Months of April, May and October were decreased in temperature at the rate of 0.620 °C/mo/yr, 0.980 °C/mo/yr and 0.620 °C/mo/yr respectively. The months of June, July, September, October, November and December were decreased in rainfall trends at the rate of 0.4 mm/mo/yr, 0.834 mm/mo/yr, 0.744 mm/mo/yr, 0.641 mm/mo/yr, 0.500 mm/mo/yr, and 0.500 mm/mo/yr respectively. The results show that the month of

September recorded highest temperature and month of August recorded the highest rainfall.

Table 7: Mann-Kendall test statistics for monthly rainfall and mean monthly temperature for Benin station

Time series	First year	Last year	Test Z		Slope Q	
			Temp	Rainfall	Temp	Rainfall
Jan	1960	2006	1.52		0.014	
Feb	1960	2006	0.00		0.00	
March	1960	2006	0.00	-0.45	0.00	0.000
April	1960	2006	-0.62	-0.19	-0.62	0.000
May	1960	2006	-0.96	0.24	-0.96	0.000
June	1960	2006	0.28	-0.66	0.28	-0.400
July	1960	2006	2.33	-1.18	2.33	-0.834
Aug	1960	2006	3.36*	0.28	3.36	0.036
Sept	1960	2006	3.39***	-0.85	3.39	-0.744
Oct	1960	2006	-0.62**	-0.86	-0.62	-0.641
Nov	1960	2006	0.00	-0.76	0.00	-0.500
Dec	1960	2006	0.00	-0.35	0.00	-0.050

*** if significance level (a) is 0.001, ** if (a) is 0.01, * if (a) is 0.05, + if (a) is 0.1.

Table 8 shows Mann-Kendall test statistics for Calabar mean monthly temperature and monthly rainfall. The months of January, February, September and December showed no change in rainfall trend while month of August showed no change in temperature trend. The months of June and July decreased in temperature at the rate of 0.014 °C/mo/yr and 0.001 °C/mo/yr. Months of April and November experienced decrease in rainfall at the rate of 0.035 mm/mo/yr and 1.8 mm/mo/yr, while the months of January, February, March, April, May, September, October, November and December experienced monotonic increase in temperature trends at the rate of 0.013 °C/mo/yr, 0.006 °C/mo/yr, 0.008 °C/mo/yr, 0.008 °C/mo/yr, and 0.012 °C/mo/yr respectively. The months of March, May, June, July, August, and October were increased in rainfall at the rate of 0.059 mm/mo/yr, 0.95mm/mo/yr, 1.35 mm/mo/yr, 0.038 mm/mo/yr, 0.944 mm/mo/yr, and 1.97 mm/mo/yr respectively. The results showed that the

highest temperature was recorded in the month of May and month of October witnessed the highest rainfall.

Table 8: Mann-Kendall test statistics for monthly rainfall and mean monthly temperature for calabar station

Time series	First year	Last year	Test Z		Slope Q	
			Temp	Rainfall	Temp	Rainfall
Jan	1960	2006	1.76+		0.013	
Feb	1960	2006	0.65		0.006	
March	1960	2006	1.01	0.77	0.008	0.059
April	1960	2006	1.42	-0.44	0.008	-0.035
May	1960	2006	1.86+	1.11	0.025	0.950
June	1960	2006	1.69+	1.40	0.014-	1.350
July	1960	2006	-1.02	0.36	-0.010	0.038
Aug	1960	2006	0.11	0.98	0.000	0.944
Sept	1960	2006	0.71	-0.08	0.004	0.000
Oct	1960	2006	1.86+	1.50	0.011	1.971
Nov	1960	2006	1.31	-1.02	0.008	-1.800
Dec	1960	2006	2.42+	-0.27	0.012	0.000

+ if significance level is 0.1

Table 9 shows the Mann-Kendall test statistics of Enugu mean monthly temperature and monthly rainfall. For temperature, the month of May showed no change while the months of January, June, July, August, September, October, November, and December were decreasing in temperature at the rate of 0.011 °C/mo/yr, 0.02 °C/mo/yr, 0.032 °C/mo/yr, 0.042 °C/mo/yr, 0.038 °C/mo/yr, 0.025 °C/mo/yr, 0.014 °C/mo/yr and 0.028 °C/mo/yr respectively. The months of February, March and April were increasing in temperature at the rate of 0.017 °C/mo/yr, 0.03 °C/mo/yr and 0.009 °C/mo/yr. For rainfall, the months of January, February, November and December showed no change. The months of March, April, May, June, July, August, September and October were decreasing in rainfall at the rate of 0.774 mm/mo/yr, 0.267 mm/mo/yr, 0.18 mm/mo/yr, 0.316 mm/mo/yr, 0.863 mm/mo/yr/ 0.034 mm/mo/yr, 0.503 mm/mo/yr and 0.396 mm/mo/yr respectively. The results showed that month of March recorded the highest temperature and month of July witnessed the highest rainfall.

Table 9: Mann-Kendall monthly rainfall and mean monthly temperature for Enugu station

Time series	First year	Last year	Test Z		Slope Q	
			Temp	Rainfall	Temp	Rainfall
Jan	1960	2006	-0.56	-0.35	-0.011	0.000
Feb	1960	2006	1.07	-0.27	0.017	0.000
March	1960	2006	1.57	-1.23	0.030	-0.774
April	1960	2006	0.53	-0.48	0.009	-0.267
May	1960	2006	0.00	-0.51	0.000	-0.180
June	1960	2006	1.81+	-0.62	-0.02	-0.316
July	1960	2006	-2.49*	-0.77	-0.03	0.863
Aug	1960	2006	2.97**	-0.31	-0.04	-0.345
Sept	1960	2006	-2.57*	-0.48	0.038-	-0.503
Oct	1960	2006	1.86+	-0.93	-0.025	-0.396
Nov	1960	2006	-1.16	-0.01	-0.014	0.000
Dec	1960	2006	-2.23*	0.64	-0.028	0.000

** if significance level(a) is 0.01, * if (a) is 0.05, + if (a) is 0.1

Table 10 shows Mann-Kendall test statistics for monthly rainfall and monthly temperature for Gusua station. The month of January to month of March showed no change in the trends of rainfall. Likewise, month of June to month of December showed no change in rainfall trends. The months of April and May were decreased in rainfall at the rate of 0.01 mm/mo/yr and 0.08 mm/mo/yr. The months of January, February, May and July showed no change in the trends of temperature. Months of March, June, August, September, October and November were decreased in temperature at the rate of 0.041 °C/mo/yr, 0.018 °C/mo/yr, 0.028 °C/mo/yr, 0.023 °C/mo/yr, 0.042 °C/mo/yr and 0.013 °C/mo/yr respectively. The month of April increased in temperature at the rate of 0.08 °C/mo/yr. The results showed that month of April witnessed the highest temperature. The twelve months witnessed no change effect and negative trends in rainfall

Table 10: Mann-Kendall test statistics for Gusua mean monthly temperature and monthly rainfall

Time series	First year	Last year	Test Z		Slope Q	
			Temp	Rainfall	Temp	Rainfall
Jan	1960	2006	0.24		0.000	
Feb	1960	2006	0.13		0.000	
March	1960	2006	-1.01		0.041-	
April	1960	2006	0.88	-0.41	0.008	-0.010
May	1960	2006	-0.32	-0.40	0.000	-0.083
June	1960	2006	-1.45	-0.04	-0.018	0.000
July	1960	2006	-0.17	0.05	0.000	0.000
Aug	1960	2006	-2.20*	0.10	-0.028	0.000
Sept	1960	2006	-1.52	-0.25	-0.023	0.000
Oct	1960	2006	3.20**	0.00	0.042-	0.000
Nov	1960	2006	-0.64		-0.013	
Dec	1960	2006	0.00		0.000	

** if significance level is 0.01, * if significance level is 0.05.

Table 11 shows Mann-Kendall test statistics for monthly rainfall and mean monthly temperature for Ibadan station. The months of January, February, March and April were increasing in temperature at the rate of 0.088 °C/mo/yr, 0.057 °C/mo/yr, 0.12 °C/mo/yr, and 0.182 °C/mo/yr respectively while months of January, March, April, November and December were decreasing in rainfall at the rate of 0.15 mm/mo/yr, 0.33 mm/mo/yr, 1.21 mm/mo/yr, 0.523 mm/mo/yr, and 0.537 mm/mo/yr respectively. Meanwhile, the month of November showed no change in temperature and the months of May, June, July, August, September, October, and December were increasing in temperature at the rate of 0.15 °C/mo/yr, 0.094 °C/mo/yr, 0.033 °C/mo/yr, 0.011 °C/mo/yr, 0.017 °C/mo/yr and 0.188 °C/mo/yr respectively. The months of February, May, June, July, August, September and October were also increasing in rainfall at the rate of 0.234 mm/mo/yr, 1.443 mm/mo/yr, 2.023 mm/mo/yr, 2.64 mm/mo/yr, 1.809 mm/mo/yr, 0.977 mm/mo/yr and 1.008 mm/mo/yr respectively. The results showed that month of April witnessed the highest temperature and month of July recorded the highest rainfall.

Table 11: Mann-Kendall test statistics for monthly rainfall and mean monthly temperature for Ibadan station.

Time series	First year	Last year	Test Z		Slope Q	
			Temp	Rainfall	Temp	Rainfall
Jan	1970	2006	3.26**	-1.12	0.088	-0.150
Feb	1970	2006	3.37***	0.45	0.057	0.236
March	1970	2006	5.06***	-0.26	0.120	-0.333
April	1970	2006	5.47***	-1.43	0.182	-1.121
May	1970	2006	4.48***	1.81+	0.150	1.443
June	1970	2006	3.62***	1.47	0.094	2.023
July	1970	2006	4.45***	1.74+	0.098	2.614
Aug	1970	2006	2.48*	2.16*	0.033	1.809
Sept	1970	2006	1.03	0.65	0.011	0.977
Oct	1970	2006	1.69+	1.22	0.017	1.006
Nov	1970	2006	0.33	-1.44	0.000	-0.523
Dec	1970	2006	5.76***	-1.67+	0.168	-0.537

*** If significance level (a) is 0.001, ** if (a) is 0.01, * if (a) is 0.05 and + if (a) is 0.1

Table 12 shows Mann-Kendall test statistics for mean monthly temperature and monthly rainfall for Ikeja. The month of May showed no change in temperature while the months of January, June, July and December showed no change in rainfall. The months of April showed positive trend in temperature at the rate of 0.037 °C/mo/yr and months of February, March, April, May, September and November also showed positive trends in rainfall at the rate of 0.388 mm/mo/yr, 0.205 mm/mo/yr, 0.753 mm/mo/yr, 0.494 mm/mo/yr, 0.225 mm/mo/yr, and 0.076 mm/mo/yr respectively. The months of January, February, March, June, July, August, September, October, November and December showed negative trends in temperature at the rate of 0.05 °C/mo/yr, 0.05 °C/mo/yr, 0.002 °C/mo/yr, 0.037 °C/mo/yr, 0.026 °C/mo/yr, 0.05 °C/mo/yr, 0.042 °C/mo/yr, 0.035 °C/mo/yr, 0.052 °C/mo/yr, and 0.042 °C/mo/yr respectively. The months of August, and October also showed negative trends in rainfall at the rate of 0.108 mm/mo/yr, and 0.217 mm/mo/yr. The results showed that the highest rainfall was witnessed in the month of April while the highest temperature was recorded in the month of April.

Table 12: Mann-Kendall test statistics for monthly rainfall and mean monthly temperature for Ikeja station

Time series	First year	Last year	Test Z		Slope Q	
			Temp	Rainfall	Temp	Rainfall
Jan	1966	2006	1.94+	0.40	-0.050	0.000
Feb	1966	2006	-2.14*	0.87	-0.050	0.338
March	1966	2006	-0.34	0.47	-0.002	0.205
April	1966	2006	2.01*	0.87	0.037	0.753
May	1966	2006	-0.16	0.61	0.000	0.494
June	1966	2006	1.80+	0.02	0.026-	0.000
July	1966	2006	2.71**	0.23	-0.050	0.000
Aug	1966	2006	-1.81+	-0.51	-0.042	-0.108
Sept	1966	2006	-2.13*	0.40	-0.035	0.225
Oct	1966	2006	-1.95+	-0.65	-0.042	-0.217
Nov	1966	2006	-2.58*	0.34	-0.052	0.076
Dec	1966	2006	-1.81+	0.15	-0.041	0.000

* if significance level is 0.05, + if sig level is 0.1, **

Table 13 shows the Mann-Kendall test statistics for monthly rainfall and mean monthly temperature for Iseyin station. The months of January, February, March, May, June, July October, November and December showed no change in rainfall trends. The months of January, February, July, August, September, October, November and December were decreasing in temperature at the rate of 0.100 °C/mo/yr, 0.088 °C/mo/yr, 0.033 °C/mo/yr, 0.069 °C/mo/yr, 0.084 °C/mo/yr, 0.052 °C/mo/yr, 0.082 °C/mo/yr and 0.15 °C/mo/yr respectively. The month of August also decreased in rainfall at the rate of 0.443 mm/mo/yr while months of April, May and June experienced increase in temperature trend at the rate of 0.105 °C/mo/yr, 0.073 °C/mo/yr, and 0.012 °C/mo/yr respectively. The months of April and September also increased in rainfall at the rate of 0.459 mm/mo/yr and 0.218 mm/mo/yr. The results showed that month of April recorded the highest rainfall and temperature.

Table 13: Mann-Kendall test statistics for monthly rainfall and mean monthly temperature for Iseyin station

Time series	First year	Last year	Test Z		Slope Q	
			Temp	Rainfall	Temp	Rainfall
Jan	1975	2006	-2.55*	-0.61	-0.100	0.000
Feb	1975	2006	-1.90+	0.76	-0.086	0.000
March	1975	2006	0.96	-0.16	0.030	0.000
April	1975	2006	3.65***	0.78	0.105	0.459
May	1975	2006	2.84**	-0.13	0.073	0.000
June	1975	2006	0.50	0.23	0.012	0.000
July	1975	2006	-2.05*	-0.20	-0.033	0.000
Aug	1975	2006	-3.3***	-0.72	-0.069	-0.443
Sept	1975	2006	3.34***	0.49	-0.084	0.218
Oct	1975	2006	-1.78+	0.20	-0.052	0.000
Nov	1975	2006	-1.90+	-0.42	-0.082	0.000
Dec	1975	2006	-2.99**	0.32	-0.150	0.000

*** if significance level (a) is 0.001, ** if (a) is 0.01, * if (a) is 0.05, + if (a) is 0.1

Table 14 shows Mann-Kendall test statistics for mean monthly temperature and monthly rainfall for Lagos. The months of April, July, August, October, November and December showed no change in rainfall trends. The twelve months were increasing in temperature. The month of march witnessed decrease in rainfall trend at the rate of 0.308 mm/mo/yr. The months of January, February, March, April, May, and June increased in temperature at the rate of 0.035 °C/mo/yr, 0.024 °C/mo/yr, 0.041 °C/mo/yr, 0.015 °C/mo/yr, 0.008 °C/mo/yr and 0.008 °C/mo/yr. The months of January, February, May, June and September also increased in rainfall at the rate of 0.158 mm/mo/yr, 0.218 mm/mo/yr, 0.292 mm/mo/yr, 0.820 mm/mo/yr and 0.351 mm/mo/yr respectively. The months of July, August, September, October, November and December were increasing in temperature at the rate of 0.018 °C/mo/yr, 0.10 °C/mo/yr, 0.022 °C/mo/yr, 0.038 °C/mo/yr, 0.038 °C/mo/yr and 0.034 °C/mo/yr respectively. The results showed that the month of June experienced the highest rainfall and the month of January witnessed highest temperature.

Table 14: Mann-Kendall test statistics for monthly rainfall and monthly temperature for Lagos station

Time series	First year	Last year	Test Z		Slope Q	
			Temp	Rainfall	Temp	Rainfall
Jan	1960	2006	5.77***	1.24	0.055	0.158
Feb	1960	2006	3.56***	0.70	0.024	0.218
March	1960	2006	4.59***	-0.67	0.041	-0.306
April	1960	2006	1.34	0.00	0.015	0.000
May	1960	2006	0.54	0.51	0.008	0.292
June	1960	2006	0.54	0.60	0.008	0.820
July	1960	2006	2.08*	-0.17	0.018	0.000
Aug	1960	2006	1.97*	-0.28	0.010	0.000
Sept	1960	2006	3.00**	0.69	0.022	0.351
Oct	1960	2006	3.78***	-0.33	0.038	0.000
Nov	1960	2006	4.27***	0.29	0.038	0.000
Dec	1960	2006	3.27**	0.04	0.034	0.000

*** if significance level (a) is 0.001, ** if (a) is 0.01, * if (a) is 0.05,

Table 15 shows Mann- Kendall non parametric test for monthly rainfall and mean monthly temperature for Maiduguri. The twelve months show increase in temperature trends while only five months show increase in rainfall trends. The months of January, February, March, April, May and June showed increase in temperature trends at the rate of 0.068 °C/mo/yr, 0.119 °C/mo/yr, 0.11 °C/mo/yr, 0.045 °C/mo/yr, 0.009 °C/mo/yr, and 0.004 °C/mo/yr respectively, while months of April, may, June, August and October also showed increasing trends of rainfall at the rate of 0.026 mm/mo/yr, 0.39 mm/mo/yr, 0.76 mm/mo/yr, 0.289 mm/mo/yr and 0.177 mm/mo/yr, respectively. The months of July, August, September, October, November and December showed increase in trends of temperature at the rate of 0.023 °C/mo/yr, 0.031 °C/mo/yr, 0.047 °C/mo/yr, 0.046 °C/mo/yr, 0.055 °C/mo/yr and 0.078 °C/mo/yr respectively. The results showed that highest temperature occurred in the month of March and month of June recorded the highest rainfall.

Table 15: Mann-Kendall test statistics for monthly rainfall and mean monthly temperature for Maiduguri station

Time series	First year	Last year	Test Z		Slope Q	
			Temp	Rainfall	Temp	Rainfall
Jan	1960	2006	2.41*		0.068	
Feb	1960	2006	4.37***		0.119	
March	1960	2006	4.43***		0.110	
April	1960	2006	4.01***	0.70	0.045	0.026
May	1960	2006	0.43***	1.22	0.009	0.390
June	1960	2006	0.30	1.41	0.004	0.750
July	1960	2006	2.05*	0.00	0.023	0.000
Aug	1960	2006	4.28***	0.78	0.031	0.289
Sept	1960	2006	4.63***	0.01	0.047	0.000
Oct	1960	2006	3.33***	0.81	0.046	0.177
Nov	1960	2006	3.05**		0.055	
Dec	1960	2006	4.63***		0.078	

*** if significance level (a) is 0.001, ** if (a) is 0.01, * if (a) is 0.05

Table 16 shows Mann- Kendall test statistics for monthly rainfall and mean monthly temperature for Minna station. The months of January, February, March, April, October, November and December showed no change in rainfall trends while the month of August was decreasing in trend of rainfall at the rate of 0.103 mm/mo/yr. The months of May, June, July, and September were increasing in trends of rainfall at the rate of 0.105 mm/mo/yr, 0.2 mm/mo/yr, 0.1 mm/mo/yr and 0.041 mm/mo/yr respectively. The months of August and September showed no change in trends of temperature. The months of January, February, March, April, May, and June showed increase in temperature trends at the rate of 0.037 °C/mo/yr, 0.039 °C/mo/yr, 0.055 °C/mo/yr, 0.017 °C/mo/yr, 0.044 °C/mo/yr, and 0.009 °C/mo/yr, respectively. Months of July, October, November and December also showed increase in trends of temperature at the rate of 0.1 °C/mo/yr, 0.012 °C/mo/yr, 0.006 °C/mo/yr, and 0.019 °C/mo/yr respectively. The results show that month of June witnessed the highest rainfall and month of July experienced the highest temperature.

Table 16: Mann-Kendall test statistics for monthly rainfall and mean monthly temperature for Minna station

Time series	First year	Last year	Test Z		Slope Q	
			Temp	Rainfall	Temp	Rainfall
Jan	1960	2006	2.07*		0.037	
Feb	1960	2006	3.38***		0.039	
March	1960	2006	4.27***		0.055	
April	1960	2006	0.78	0.03	0.017	0.000
May	1960	2006	3.31***	0.41	0.044	0.105
June	1960	2006	1.71+	0.52	0.009	0.200
July	1960	2006	1.46	0.36	0.010	0.100
Aug	1960	2006	-0.05	-0.43	0.000	-0.103
Sept	1960	2006	0.33	0.43	0.000	0.041
Oct	1960	2006	1.81+	-0.30	0.012	0.000
Nov	1960	2006	0.65		0.006	
Dec	1960	2006	2.18*		0.019	

*** if significance level (a) is 0.001, * if (a) is 0.05, + if (a) is 0.1.

Table 17 shows Mann-Kendall test statistics for monthly rainfall and mean monthly temperature for Oshogbo. The months of March, June, August, September and November showed no change in temperature trends. The month of December also showed no change in rainfall trends. Months of February, April, May, and December were decreasing in temperature trends at the rate of 0.071 °C/mo/yr, 0.033 °C/mo/yr, 0.011 °C/mo/yr, 0.041 °C/mo/yr and months of January, February, March, and April also witnessed decreasing monotonic trends of rainfall at the rate of 0.012 mm/mo/yr, 0.044 mm/mo/yr, 1.31 mm/mo/yr, and 1.396 mm/mo/yr. The months of January, July and October witnessed an increase in trends of temperature at the rate of 0.129 °C/mo/yr, 0.065 °C/mo/yr and 0.045 °C/mo/yr. Like wise, months of May, June, July, August, September, October, and November had experienced increasing monotonic trends of rainfall at the rate of 0.739 mm/mo/yr, 1.694 mm/mo/yr, 0.176 mm/mo/yr, 0.461 mm/mo/yr, 2.196 mm/mo/yr, 0.55 mm/mo/yr and 0.008 mm/mo/yr respectively. The results showed that January witnessed the highest temperature and month of September experienced the highest rainfall.

Table 17: Mann-Kendall test statistics for monthly rainfall and mean monthly temperature for Oshogbo station

Time series	First year	Last year	Test Z		Slope Q	
			Temp	Rainfall	Temp	Rainfall
Jan	1965	2006	4.18***	-2.44*	0.129	-0.012
Feb	1965	2006	-2.10*	-0.29	-0.071	-0.044
March	1965	2006	-0.26	-1.70+	0.000	-1.131
April	1965	2006	-1.10	-2.57*	-0.033	-1.396
May	1965	2006	-0.75	1.24	-0.011	0.739
June	1965	2006	0.33	1.98*	0.000	1.694
July	1965	2006	4.31***	0.10	0.065	0.176
Aug	1965	2006	0.52	0.58	0.000	0.461
Sept	1965	2006	1.24	2.27*	0.000	2.196
Oct	1965	2006	3.38***	0.70	0.045	0.550
Nov	1965	2006	0.00	0.19	0.000	0.008
Dec	1965	2006	-2.02*	-1.06	-0.041	0.000

*** if significance level (a) is 0.001, ** if (a) is 0.01, * if (a) is 0.05, + if (a) is 0.1

Table 18 shows Mann-Kendall test statistics for monthly rainfall and mean monthly temperature for Port Harcourt station. The months of April, May, June, September, and October showed no change in trends of temperature. Months of February, September and December also showed no change in trends of rainfall. Months of January, March, and December showed decreasing monotonic trends of temperature at the rate of 0.022 °C/mo/yr, 0.002 °C/mo/yr and 0.017 °C/mo/yr respectively. Likewise, months of January, March, April, May, June, July, and August were decreasing in trends of rainfall at the rate of 0.013 mm/mo/yr, 0.262 mm/mo/yr, 0.042 mm/mo/yr, 0.171 mm/mo/yr, 0.369 mm/mo/yr, 0.895 mm/mo/yr, 1.128 mm/mo/yr, 1.128 mm/mo/yr, 1.138 mm/mo/yr and 0.778 mm/mo/yr respectively. Months of February, July, August and November witnessed increase in temperature at the rate of 0.034 °C/mo/yr, 0.01 °C/mo/yr, 0.026 °C/mo/yr and 0.007 °C/mo/yr respectively. The results showed that month of February witnessed the highest temperature and month of July witnessed highest rainfall.

Table 18: Mann-Kendall test for monthly rainfall and monthly mean temperature for Port Harcourt station

Time series	First year	Last year	Test Z		Slope Q	
			Temp	Rainfall	Temp	Rainfall
Jan	1960	2006	-1.99*	-1.39	-	-0.013
Feb	1960	2006	2.74**	-0.13	0.034	0.000
March	1960	2006	-0.65	-0.47	-	-0.262
April	1960	2006	0.54	-0.22	0.000	-0.042
May	1960	2006	-0.39	-0.20	0.000	-0.171
June	1960	2006	-0.02	-0.42	0.000	-0.369
July	1960	2006	2.05*	-0.77	0.010	-0.895
Aug	1960	2006	3.01**	-1.03	0.026	-1.126
Sept	1960	2006	-0.39	-0.12	0.000	0.000
Oct	1960	2006	0.20	-1.08	0.000	-1.138
Nov	1960	2006	1.63	-1.56	0.007	-0.778
Dec	1960	2006	-	-0.36	-	0.000

** if (a) is 0.01, * if (a) is 0.05, + if (a) is 0.1

Table 19 Shows Mann-Kendall test statistics for monthly rainfall and mean monthly temperature for Sokoto. Nine out of the twelve months were decreasing in trends of mean monthly temperature while three months were increasing in trends. The months of January, March, April and December were decreasing in temperature trends at the rate of 0.005 °C/mo/yr, 0.014 °C/mo/yr, 0.014 °C/mo/yr and 0.018 °C/mo/yr respectively. The months of May and June were decreasing in temperature at the rate of 0.024 °C/mo/yr and 0.025 °C/mo/yr, while the months of July and August decreased at the rate of 0.03 °C/mo/yr and 0.025 °C/mo/yr. The months of February, October and November were increasing in trend at the rate of 0.01 °C/mo/yr, 0.005 °C/mo/yr and 0.003 °C/mo/yr respectively. The months of January, February, March, April, November and December showed no activities as result of no change in rainfall trend, while the months of June was decreasing in trend of rainfall at the rate of 0.569 mm/mo/yr. The months of May, July, August, September and November increased in

rainfall trend at the rate of 0.44 mm/mo/yr, 0.867 mm/mo/yr, 0.208 mm/mo/yr, 0.694 mm/mo/yr and 0.05 mm/mo/yr. respectively. The results showed that the month of February experienced the highest temperature and the highest rainfall occurred in the month of July.

Table 19: Mann-Kendall test statistics for monthly rainfall and mean monthly temperature for Sokoto station (Sahel Zone)

Time series	First year	Last year	Test Z		Slope Q	
			Temp	Rainfall	Temp	Rainfall
Jan	1960	2006	-0.51		-0.005	
Feb	1960	2006	0.28		0.010	
March	1960	2006	-0.71		-0.014	
April	1960	2006	-1.49	0.36	-0.014	0.000
May	1960	2006	-1.67+	1.59	-0.024	0.444
June	1960	2006	-1.73+	-0.90	-0.030	-0.569
July	1960	2006	-2.24*	1.31	-0.025	0.867
Aug	1960	2006	-2.35*	0.20	-0.019	0.208
Sept	1960	2006	-0.43	1.30	-0.004	0.694
Oct	1960	2006	0.27	0.88	0.005	0.050
Nov	1960	2006	0.20		0.003	
Dec	1960	2006	-1.21		-0.018	

- if significance level(a) is 0.05, + if (a) is 0.1

Table 20 shows Mann-Kendall test statistics for monthly rainfall and mean monthly temperature for Warri station. The table shows that the months of January, February, March, April, May, and June were increasing in trends of temperature at the rate of 0.067 °C/mo/yr, 0.019 °C/mo/yr, 0.029 °C/mo/yr, 0.023 °C/mo/yr, 0.023 °C/mo/yr, 0.025 °C/mo/yr and 0.014 °C/mo/yr respectively, while months of January, February, April, May and June were decreasing in rainfall at the rate of 0.109 mm/mo/yr, 0.05 mm/mo/yr, 0.518 mm/mo/yr, 0.05 mm/mo/yr and 1.725 mm/mo/yr respectively. The months of July, August, September, October, November and December were increasing in temperature at the rate of 0.025 °C/mo/yr, 0.022 °C/mo/yr, 0.03 °C/mo/yr, 0.043 °C/mo/yr, 0.051 °C/mo/yr and 0.042 °C/mo/yr respectively.

Months of March, July, September, and December also increased in rainfall trends at the rate of 1.133 mm/mo/yr, 0.347 mm/mo/yr, 0.714 mm/mo/yr and 0.510 mm/mo/yr respectively. Mean while, months of August and October were decreased in rainfall trends at the rate of 1.105 mm/mo/yr, and 0.208 mm/mo/yr and month of December showed no change in rainfall trends. The results showed that November recorded the highest temperature and the highest rainfall was recorded in the month of September.

Table 20: Mann-Kendall test statistics for monthly rainfall and mean monthly temperature for Warri

Time series	First year	Last year	Test Z		Slope Q	
			Temp	Rainfall	Temp	Rainfall
Jan	1960	2006	5.49***	-0.74	0.067	-0.109
Feb	1960	2006	2.61**	-0.15	0.019	-0.050
March	1960	2006	3.52***	1.60	0.029	1.133
April	1960	2006	2.60**	-0.61	0.023	-0.546
May	1960	2006	3.07**	-0.06	0.025	-0.050
June	1960	2006	2.47*	-1.70+	0.014	-1.725
July	1960	2006	3.45***	0.22	0.025	0.347
Aug	1960	2006	3.20**	-0.61	0.022	-1.105
Sept	1960	2006	2.88**	0.47	0.030	0.714
Oct	1960	2006	3.66***	-0.11	0.043	-0.208
Nov	1960	2006	4.58***	0.73	0.051	0.510
Dec	1960	2006	3.68***	0.07	0.042	0.000

*** if significance level (a) is 0.001, ** if (a) is 0.01, * if (a) is 0.05, + if (a) is 0.1

Table 21 shows Mann-Kendall test statistics for Yelwa mean monthly temperature and monthly rainfall. The months of January, February, March and April witnessed no change in trends of rainfall. The months of October, November and December also showed no change in trends of rainfall. The months of May, June and July increased in trends of rainfall at the rate of 0.339 mm/mo/yr, 2.498 mm/mo/yr and 0.228 mm/mo/yr while months of August and September were decreased in trends of rainfall at the rate of 0.235 mm/mo/yr and 0.44 mm/mo/yr respectively. The months of January, February, March, June, July and September were decreasing in trends of temperature at the rate of 0.026 °C/mo/yr, 0.025 °C/mo/yr, 0.109 °C/mo/yr, 0.07

$^{\circ}\text{C}/\text{mo}/\text{yr}$, $0.025\text{ }^{\circ}\text{C}/\text{mo}/\text{yr}$ and $0.026\text{ }^{\circ}\text{C}/\text{mo}/\text{yr}$ while the months of April, May, August, November and December were increasing in temperature trends at the rate of $0.06\text{ }^{\circ}\text{C}/\text{mo}/\text{yr}$, $0.041\text{ }^{\circ}\text{C}/\text{mo}/\text{yr}$, $0.01\text{ }^{\circ}\text{C}/\text{mo}/\text{yr}$, $0.098\text{ }^{\circ}\text{C}/\text{mo}/\text{yr}$ and $0.1\text{ }^{\circ}\text{C}/\text{mo}/\text{yr}$ respectively. The results showed that months of June and December witnessed the highest rainfall and temperature respectively.

Table 21: Mann-Kendall test statistics for monthly rainfall and mean monthly temperature Yelwa station

Time series	First year	Last year	Test Z		Slope Q	
			Temp	Rainfall	Temp	Rainfall
Jan	1975	2006	-0.90		0.026-	
Feb	1975	2006	-0.45		-0.025	
March	1975	2006	3.19**		-0.109	
April	1975	2006	0.42	0.05	0.006	0.000
May	1975	2006	1.32	0.78	0.041	0.339
June	1975	2006	-0.37	1.63	-0.007	2.408
July	1975	2006	-1.16	0.34	-0.025	0.228
Aug	1975	2006	1.00	-0.27	0.010	-0.293
Sept	1975	2006	-1.60	-0.47	-0.026	-0.440
Oct	1975	2006	0.31	-0.24	0.000	0.000
Nov	1975	2006	2.95**		0.098	
Dec	1975	2006	2.54*		0.100	

*** if significance level (a) is 0.001, ** if (a) is 0.01, * if (a) is 0.05, + if (a) is 0.1

Table 22 shows Mann-Kendall test statistics for Yola station. The months of April, June, August, and October were increasing in trends of rainfall at the rate of $0.816\text{ mm}/\text{mo}/\text{yr}$, $1.2\text{ mm}/\text{mo}/\text{yr}$, $0.401\text{ mm}/\text{mo}/\text{yr}$ and $0.05\text{ mm}/\text{mo}/\text{yr}$. The months of May and September showed increasing monotonic trends of rainfall at the rate of $0.04\text{ mm}/\text{mo}/\text{yr}$ and $0.574\text{ mm}/\text{mo}/\text{yr}$. Months of January, February, March, April, May, June and July were increasing in trends of temperature at the rate of $0.014\text{ }^{\circ}\text{C}/\text{mo}/\text{yr}$, $0.006\text{ }^{\circ}\text{C}/\text{mo}/\text{yr}$, $0.063\text{ }^{\circ}\text{C}/\text{mo}/\text{yr}$, $0.011\text{ }^{\circ}\text{C}/\text{mo}/\text{yr}$, $0.076\text{ }^{\circ}\text{C}/\text{mo}/\text{yr}$, $0.061\text{ }^{\circ}\text{C}/\text{mo}/\text{yr}$ and $0.058\text{ }^{\circ}\text{C}/\text{mo}/\text{yr}$. The month of November decreased in temperature trends at the rate of $0.001\text{ }^{\circ}\text{C}/\text{mo}/\text{yr}$. Months of August, September, October and December also increased in temperature at the rate of $0.043\text{ }^{\circ}\text{C}/\text{mo}/\text{yr}$, $0.035\text{ }^{\circ}\text{C}/\text{mo}/\text{yr}$, $0.033\text{ }^{\circ}\text{C}/\text{mo}/\text{yr}$ and

0.013 °C/mo/yr respectively. The results showed that months of September and April witnessed highest rainfall and temperature respectively.

Table 22: Mann-Kendall test statistics for monthly rainfall and monthly mean temperature for Yola station

Time series	First year	Last year	Test Z		Slope Q	
			Temp	Rainfall	Temp	Rainfall
Jan	1960	2006	1.57		0.014	
Feb	1960	2006	0.51		0.006	
March	1960	2006	3.82***		0.063	
April	1960	2006	5.41***	-1.78+	0.110	-0.816
May	1960	2006	4.13***	0.04	0.076	0.040
June	1960	2006	4.48***	-1.73+	0.061	-1.200
July	1960	2006	6.08***	0.34	0.058	0.100
Aug	1960	2006	5.10***	-0.47	0.043	-0.401
Sept	1960	2006	3.51***	0.49	0.035	0.574
Oct	1960	2006	2.82**	-0.16	0.033	-0.050
Nov	1960	2006	-0.17		-0.001	
Dec	1960	2006	1.61		0.013	

*** if significance level (a) is 0.001, ** if (a) is 0.01

Table 23 shows the annual rainfall and temperature for twenty stations over Nigeria. The following stations; Abuja, Lagos, Minna, Port Harcourt, Sokoto, Warri, and Yola were increasing in temperature at the rate of 0.087 °C/mo/yr, 0.157 °C/mo/yr, 0.082 °C/mo/yr, 0.032 °C/mo/yr, 0.053 °C/mo/yr, 0.026 °C/mo/yr, and 0.046 °C/mo/yr respectively, while Bauchi, Calabar, Gusua, Ibadan, Oshogbo, and Yelwa stations were also increasing in temperature at the following rate; 0.007 °C/mo/yr, 0.014 °C/mo/yr, 0.019 °C/mo/yr, 0.02 °C/mo/yr, 0.082 °C/mo/yr, 0.012 °C/mo/yr, and 0.004 °C/mo/yr respectively. Meanwhile, Abeokuta, Akure, Benin, Enugu, Iseyin, and Maiduguri were decreasing in temperature at the rate of 0.021 °C/mo/yr, 0.01 °C/mo/yr, 0.002 °C/mo/yr, 0.007 °C/mo/yr, 0.029 °C/mo/yr, 0.014 °C/mo/yr and 0.01 °C/mo/yr. The various significance levels at which they are increasing or decreasing are shown in table 22. For rainfall, Bauchi, and Minna showed no change while Abuja, Akure, Benin, Calabar, Lagos, Maiduguri, and Yola were decreasing in rainfall

at the rate of 0.939 mm/mo/yr, 0.438 mm/mo/yr, 0.095 mm/mo/yr, 0.303 mm/mo/yr, 1.553 mm/mo/yr, 0.379 mm/mo/yr, 1.271 mm/mo/yr respectively. Abeokuta, Enugu, Gusua, Ibadan, Ikeja, Iseyin, Oshogbo, Port Harcourt, Sokoto, Warri and Yelwa stations were increasing in rainfall at the rate of 0.607 mm/mo/yr, 0.151 mm/mo/yr, 0.519 mm/mo/yr, 0.187 mm/mo/yr, 0.674 mm/mo/yr, 0.066 mm/mo/yr, 0.110 mm/mo/yr, 0.138 mm/mo/yr, 0.062 mm/mo/yr, 0.025 mm/mo/yr, and 0.036 mm/mo/yr respectively. Lagos has the highest annual temperature followed by Abuja, and Minna while Ikeja has the highest rainfall followed by Abeokuta and Gusau.

Table 23: Mann-Kendall test statistics for annual rainfall and annual temperature for twenty stations in Nigeria

Time series	First year	Last year	Test Z		Slope Q	
			Temp	Rainfall	Temp	Rainfall
<i>Abeokuta</i>	1980	2006	-1.21	0.75	-0.021	0.607
<i>Abuja</i>	1980	2006	3.62***	-1.42	0.087	-0.939
<i>Akure</i>	1960	2006	-1.13	-2.09*	-0.010	-0.438
<i>Bauchi</i>	1960	2006	0.89	0.13	0.007	0.000
<i>Benin</i>	1960	2006	-0.17	-0.51	-0.002	-0.095
<i>Calabar</i>	1960	2006	-2.41*	-1.69+	0.014	-0.303
<i>Enugu</i>	1960	2006	-1.03	0.37	-0.007	0.151
<i>Gusau</i>	1960	2006	-2.04*	2.50*	0.019	0.519
<i>Ibadan</i>	1960	2006	1.92+	0.90	0.020	0.183
<i>Ikeja</i>	1965	2006	-2.00*	2.15*	-0.029	0.674
<i>Iseyin</i>	1980	2006	-0.60	0.33	-0.014	0.066
<i>Lagos</i>	1960	2006	7.00***	-1.86+	0.157	-1.553
<i>Maid</i>	1960	2006	-2.09*	-1.75+	0.010-	-0.379
<i>Minna</i>	1960	2006	3.31***	-0.04	0.082	0.000
<i>Osogbo</i>	1965	2006	1.49	0.86	0.012	0.110
<i>P/Harcourt</i>	1960	2006	4.98***	0.45	0.032	0.138
<i>Sokoto</i>	1960	2006	6.2***	0.41	0.053	0.062
<i>Warri</i>	1960	2006	4.37***	0.15	0.026	0.025
<i>Yelwa</i>	1980	2006	0.50	0.13	0.004	0.036
<i>Yola</i>	1960	2006	5.30***	3.88***-	0.046	-1.271

*** if significance level (a) is 0.001, ** if (a) is 0.01, * if (a) is 0.05, + if (a) is 0.1

Gusau, Ibadan, Ikeja, Iseyin, Oshogbo, Port Harcourt, Sokoto, Warri and Yelwa stations were increasing in rainfall at the rate of 0.607 mm/mo/yr, 0.151 mm/mo/yr, 0.519 mm/mo/yr, 0.187 mm/mo/yr, 0.674 mm/mo/yr, 0.066 mm/mo/yr, 0.110 mm/mo/yr, 0.138 mm/mo/yr, 0.062 mm/mo/yr, 0.025 mm/mo/yr, and 0.036 mm/mo/yr respectively. Lagos has the highest annual temperature followed by Abuja, and Minna while Ikeja has the highest rainfall followed by Abeokuta and Gusau.

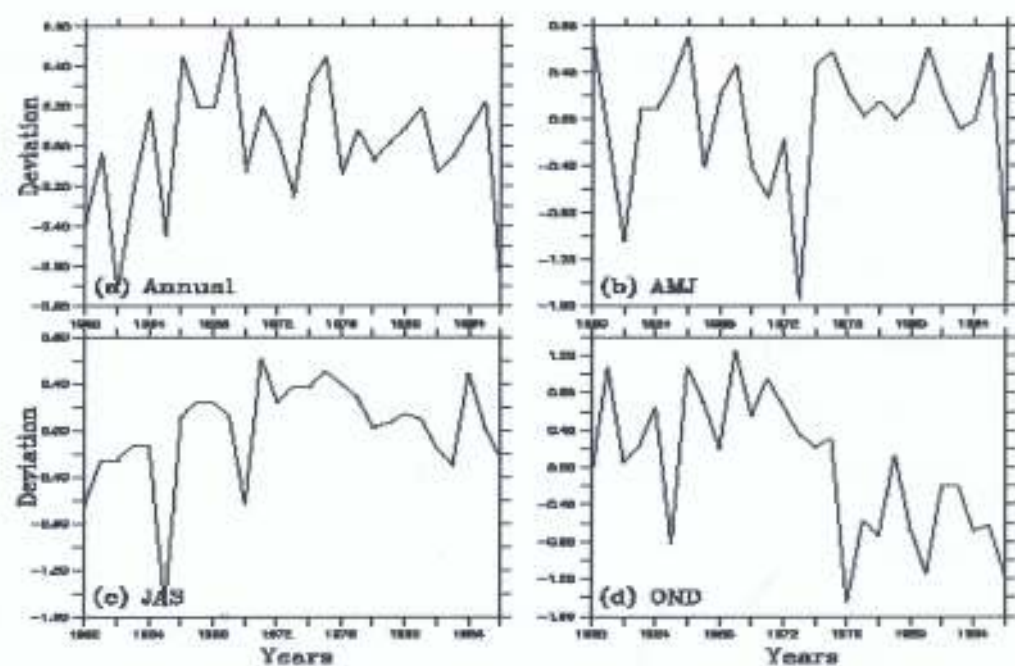
Table 23: Mann-Kendall test statistics for annual rainfall and annual temperature for twenty stations in Nigeria

Time series	First year	Last year	Test Z		Slope Q	
			Temp	Rainfall	Temp	Rainfall
<i>Abeokuta</i>	1980	2006	-1.21	0.75	-0.021	0.607
<i>Abuja</i>	1980	2006	3.62***	-1.42	0.087	-0.939
<i>Akure</i>	1960	2006	-1.13	-2.09*	-0.010	-0.438
<i>Bauchi</i>	1960	2006	0.89	0.13	0.007	0.000
<i>Benin</i>	1960	2006	-0.17	-0.51	-0.002	-0.095
<i>Calabar</i>	1960	2006	-2.41*	-1.69+	0.014	-0.303
<i>Enugu</i>	1960	2006	-1.03	0.37	-0.007	0.151
<i>Gusau</i>	1960	2006	-2.04*	2.50*	0.019	0.519
<i>Ibadan</i>	1960	2006	1.92+	0.90	0.020	0.183
<i>Ikeja</i>	1965	2006	-2.00*	2.15*	-0.029	0.674
<i>Iseyin</i>	1980	2006	-0.60	0.33	-0.014	0.066
<i>Lagos</i>	1960	2006	7.00***	-1.86+	0.157	-1.553
<i>Maid</i>	1960	2006	-2.09*	-1.75+	0.010-	-0.379
<i>Minna</i>	1960	2006	3.31***	-0.04	0.082	0.000
<i>Osogbo</i>	1965	2006	1.49	0.86	0.012	0.110
<i>P/Harcourt</i>	1960	2006	4.98***	0.45	0.032	0.138
<i>Sokoto</i>	1960	2006	6.2***	0.41	0.053	0.062
<i>Warri</i>	1960	2006	4.37***	0.15	0.026	0.025
<i>Yelwa</i>	1980	2006	0.50	0.13	0.004	0.036
<i>Yola</i>	1960	2006	5.30***	3.88***-	0.046	-1.271

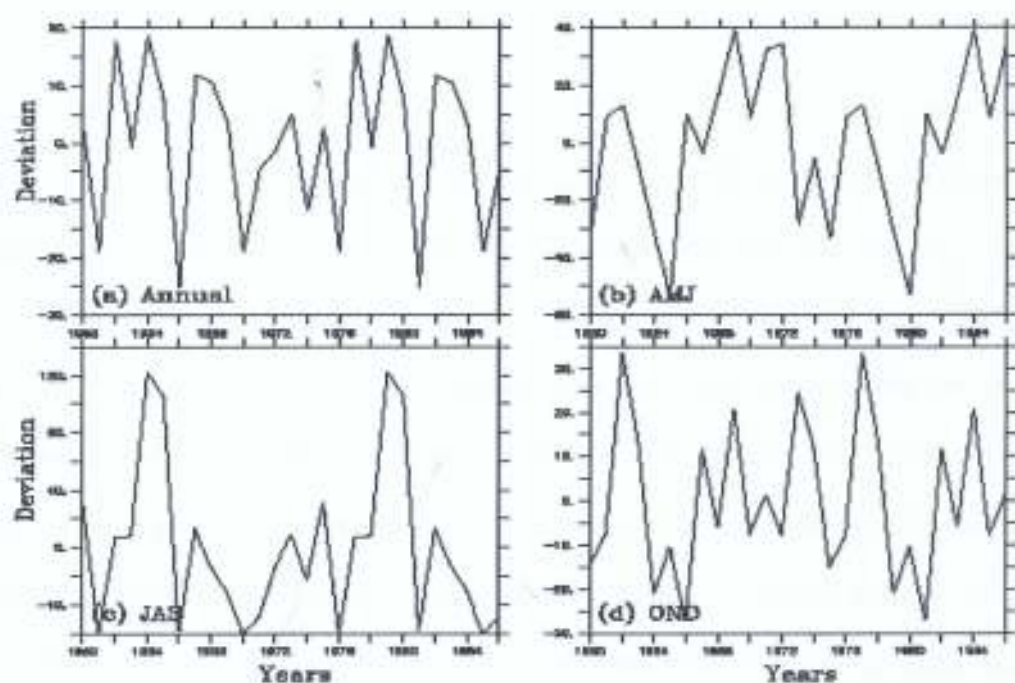
*** if significance level (a) is 0.001, ** if (a) is 0.01, * if (a) is 0.05, + if (a) is 0.1

4.2 Inter-annual trends of rainfall and temperature

Figure 2 shows the residual mass curve for Abeokuta mean monthly temperature and monthly rainfall. There was a negative trend in annual mean monthly temperature between 1960 and 1964. Thereafter the temperature started experiencing positive trends until 1984 to the end of observed year. Mean while, annual monthly rainfall in Abeokuta had witnessed increase in trend from 1964 to 1968, and negative trends set in from 1970 to 1975 and 1980 to 1986. The year 1968 experienced the highest annual mean monthly temperature. Months of AMJ experienced positive trends in mean monthly temperature between 1962 to the end of observed year 1984, and increase in monthly rainfall from 1980 to end of observed year. Between 1968 and 1972, Abeokuta experienced highest AMJ monthly rainfall. Abeokuta JAS monthly rainfall had experienced negative trend except 1964 and 1978 that witnessed abnormal rainfall. There was a positive trend in JAS mean monthly temperature between 1964 to the end of observed year. The OND mean monthly temperature had experienced negative trend between 1965 to end of observed year. There was an increase in trends of Abeokuta OND monthly rainfall between 1966 and 1978, and 1982 to end of observed year.



(i)

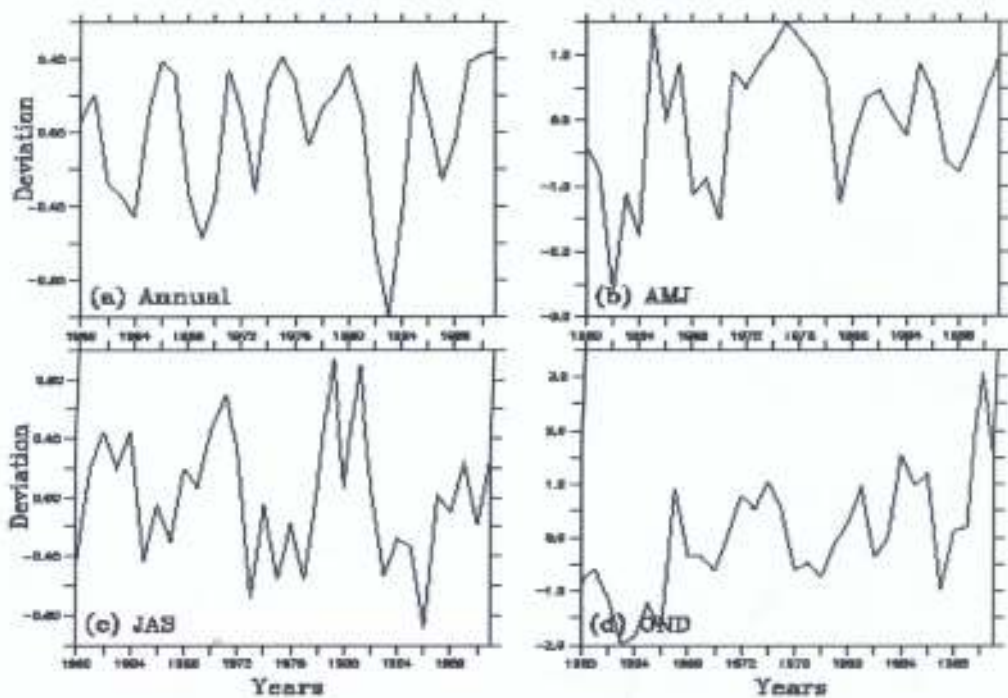


(ii)

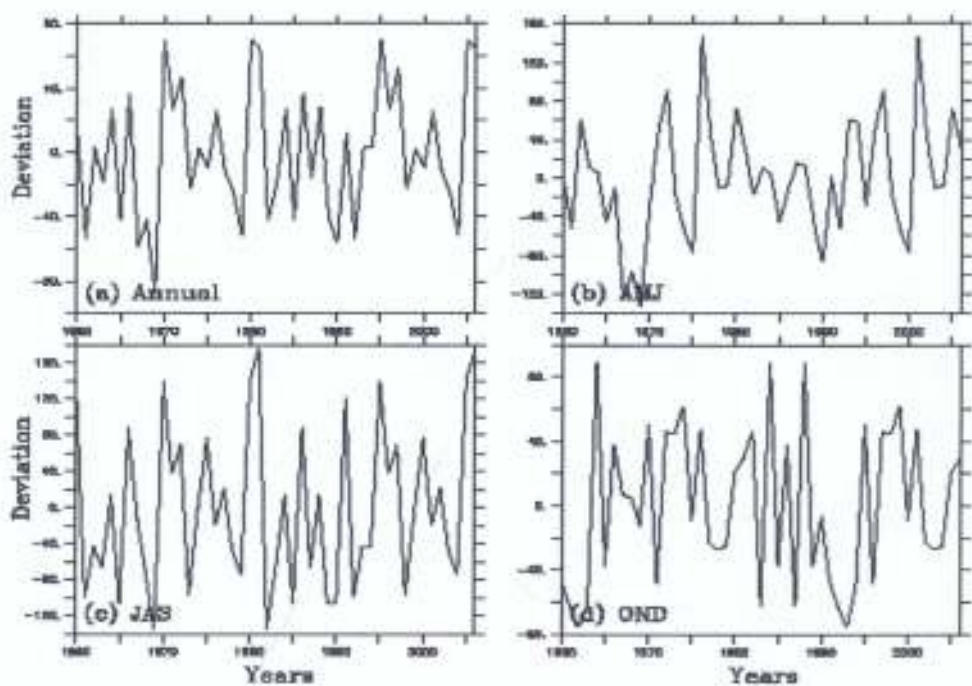
Figure 2: Residual mass curve for Abeokuta (i) mean monthly temperature and (ii) monthly rainfall for, (a) Annual, (b) AMJ, (c) JAS & (d) OND

Figure 3 shows the residual mass curve of Abuja mean monthly temperature and monthly rainfall. For annual, there was decrease in rainfall from 1980 until 2000 and thereafter the trend became positive. The highest rainfall occurred in 1965 and 2004, while the last two decades have experienced slight increase in temperature and 1970s experienced highest temperature. In AMJ months, the last two decades had experienced slight increase in temperature while decrease in rainfall was observed in the last two decades. For JAS months, there was increase in rainfall in the last two decades with highest rainfall in early 2000, while slight increase in temperature was observed in the last two decades with highest temperature in 1960s. In OND months, there was increase in temperature from late 1960s until late 1980s and the last one and half decades had experienced slight increase in temperature while increase in rainfall was observed in 1978 until 2006 with highest rainfall in 1980.

Figure 4 shows residual mass curve of Akure mean monthly temperature and monthly rainfall for (a) annual (b) AMJ (c) JAS (d) OND. There was slight decrease in annual temperature in the last one and half decades while the last two decades had experienced decrease in annual rainfall. There was a positive trend in temperature between 1980 and 2000 followed by slight decrease until 2006 while the last one and half had experienced negative trend in rainfall for AMJ months. For JAS months, there was a negative trend in temperature in the last one and half decades while rainfall also experienced negative trend in the last decade. For OND months, there was decrease in temperature in the last two decades and increase in rainfall in the last one and half decades

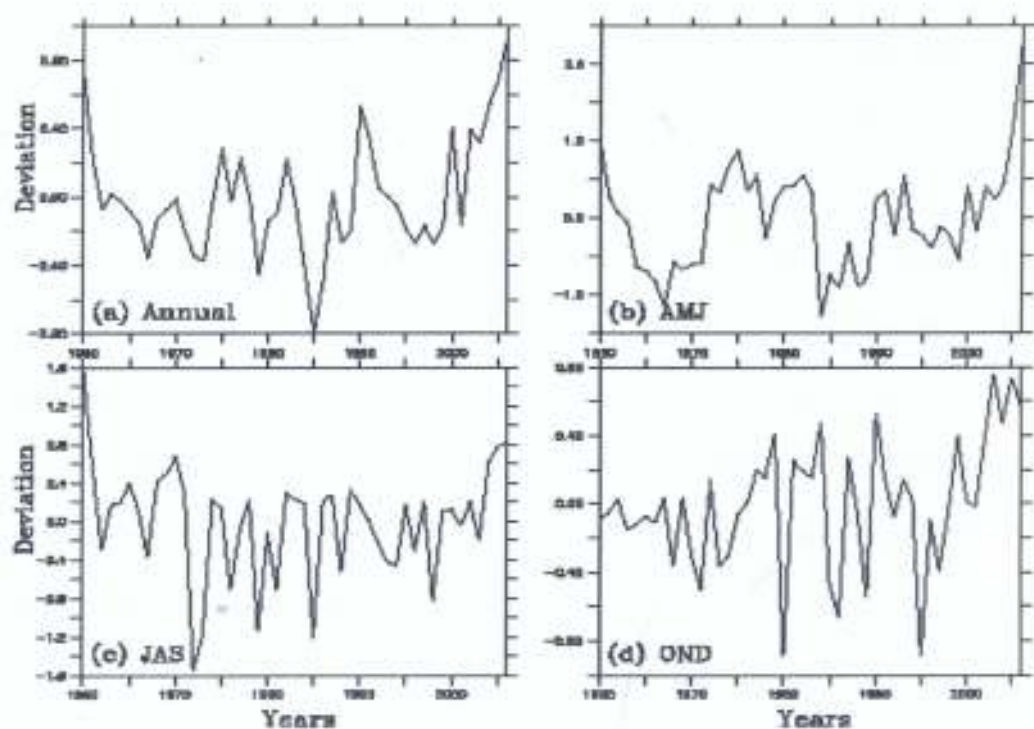


(i)

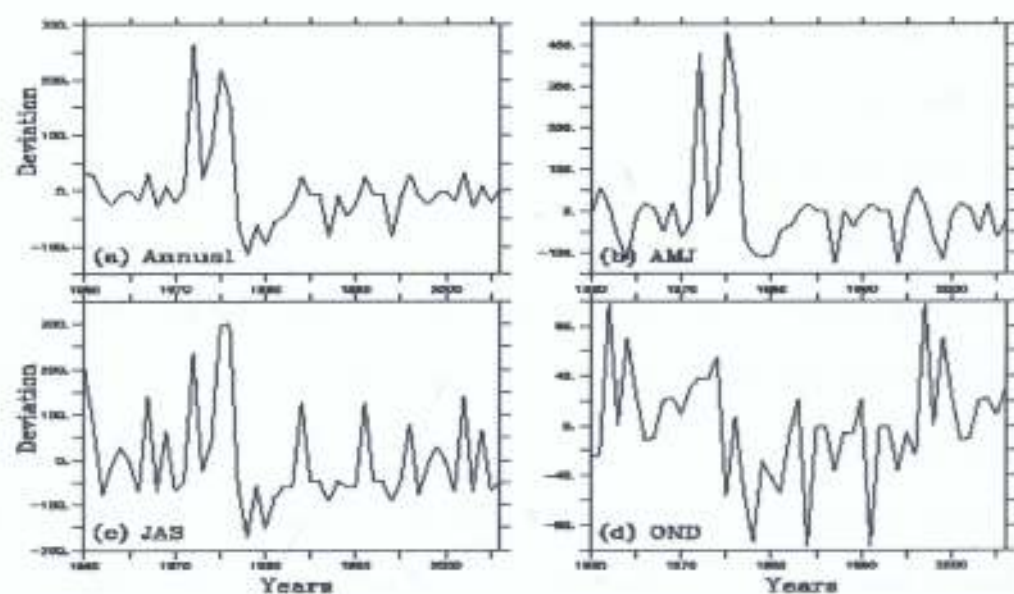


(ii)

Figure 3: Residual mass curve of Abuja (i) mean monthly temperature and (ii) monthly rainfall for, (a) Annual, (b) AMJ, (c) JAS & (d) OND



(i)

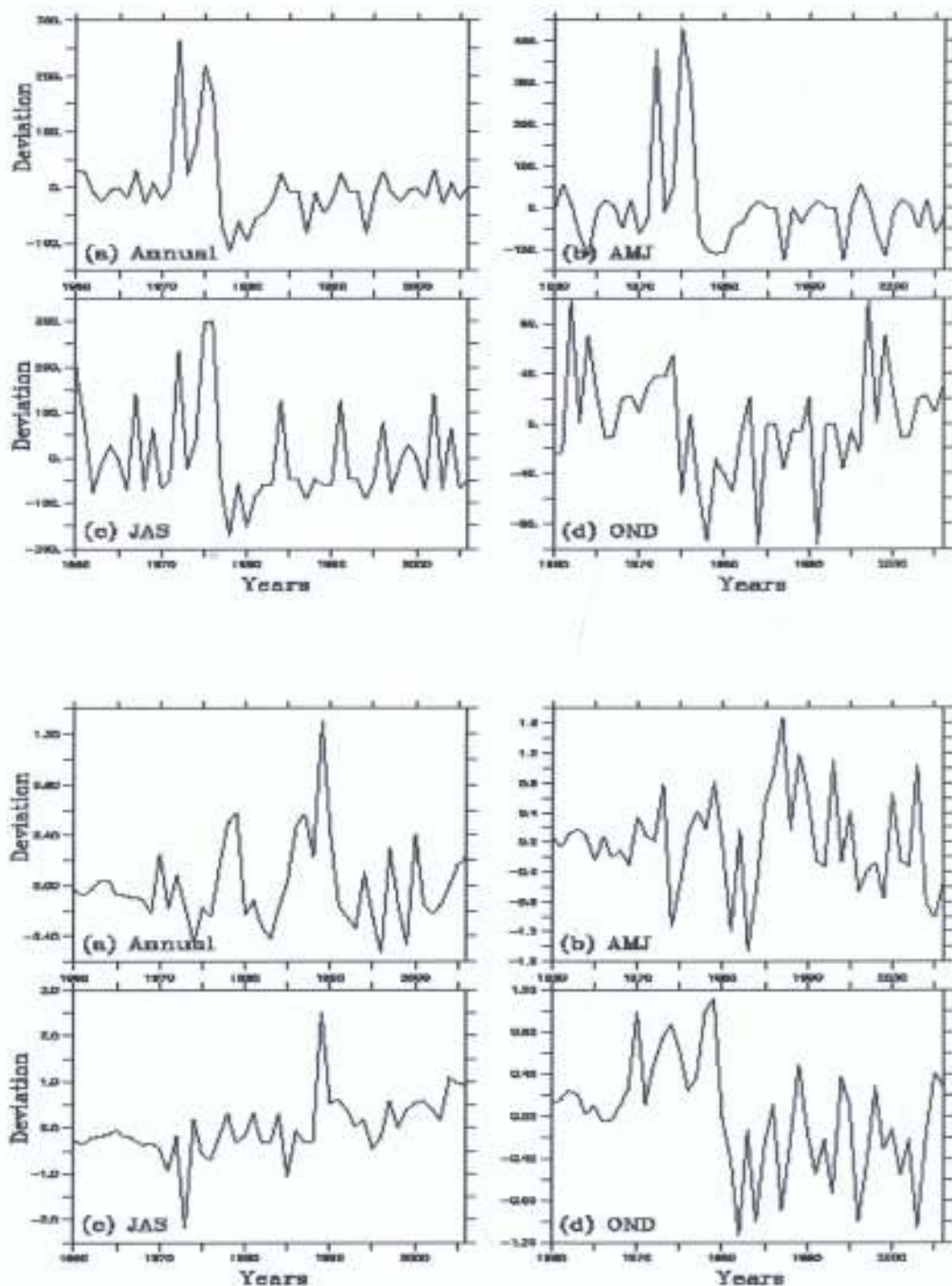


(ii)

Figure 4: Residual mass curve of Akure (i) mean monthly temperature and (ii) monthly rainfall for (a) Annual (b) AMJ (c) JAS & (d) OND

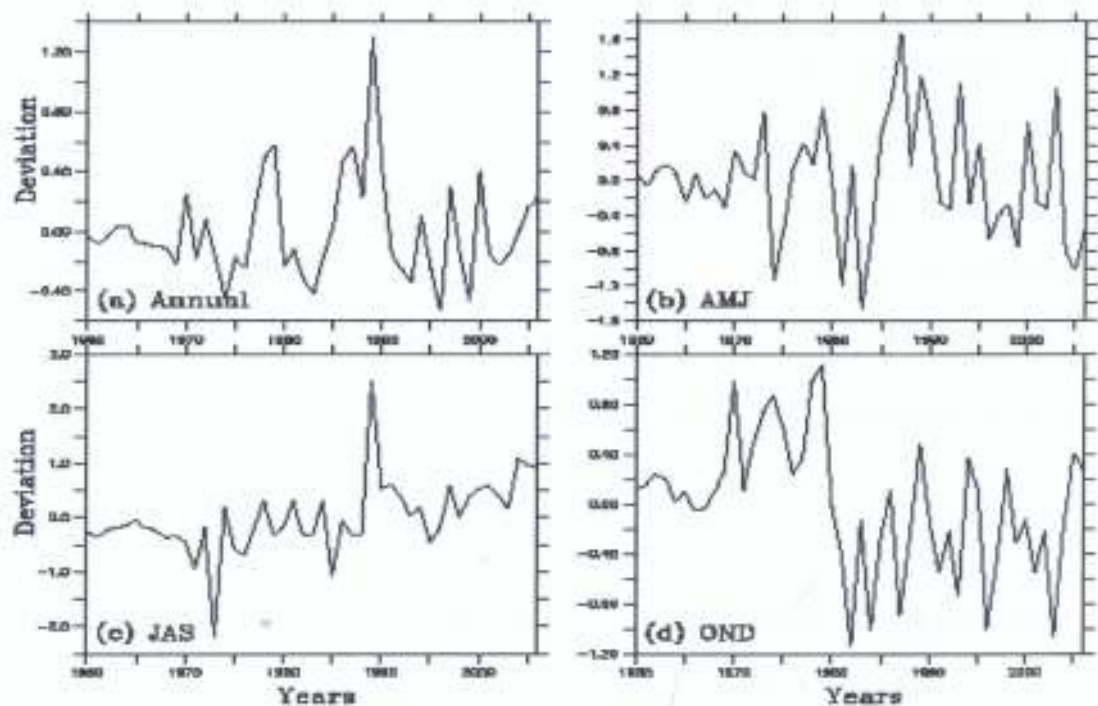
Figure 5 shows the residual mass curve for Bauchi mean monthly temperature and monthly rainfall for; (a) Annual (b) AMJ (c) JAS (d) OND. Annual temperature has experienced monotonic decreasing trend in the last three decades while annual rainfall experienced decrease between 1975 and 1980 and started increasing until late 1990s when decreasing monotonic trend set in again. AMJ months experienced increase in temperature and slight increase in rainfall in the last two and half decades. JAS months had experienced decrease in temperature in the last three decades and decrease in rainfall from 1960s to 1980 and started increasing until 1990 when negative trend set in. The last two and half decades had experienced in decrease both in rainfall and temperature for OND month.

Figure 6 shows residual mass curve of Benin mean monthly temperature and monthly rainfall. Annual mean monthly temperature experienced decrease in temperature trends in the last one and half decades. Likewise annual monthly rainfall experienced slight increase in trend in the last two and half decades with the abnormalities in rainfall that occurred in between 1972 and 1974. The highest annual temperature was noticed in late 1980s. AMJ mean monthly temperature experienced positive in trends between 1970 and 1987, negative in trend between 1991 and 1999 and positive from 2000 to end of observed year. Meanwhile AMJ monthly rainfall experienced decrease in trend in the last two and half decades. There was a slight increase in rainfall in the last two and half decades in JAS monthly rainfall. There was increase in trend of OND monthly rainfall in the last two and half decades. The OND mean monthly temperature had witnessed decrease in the last two and half decades.

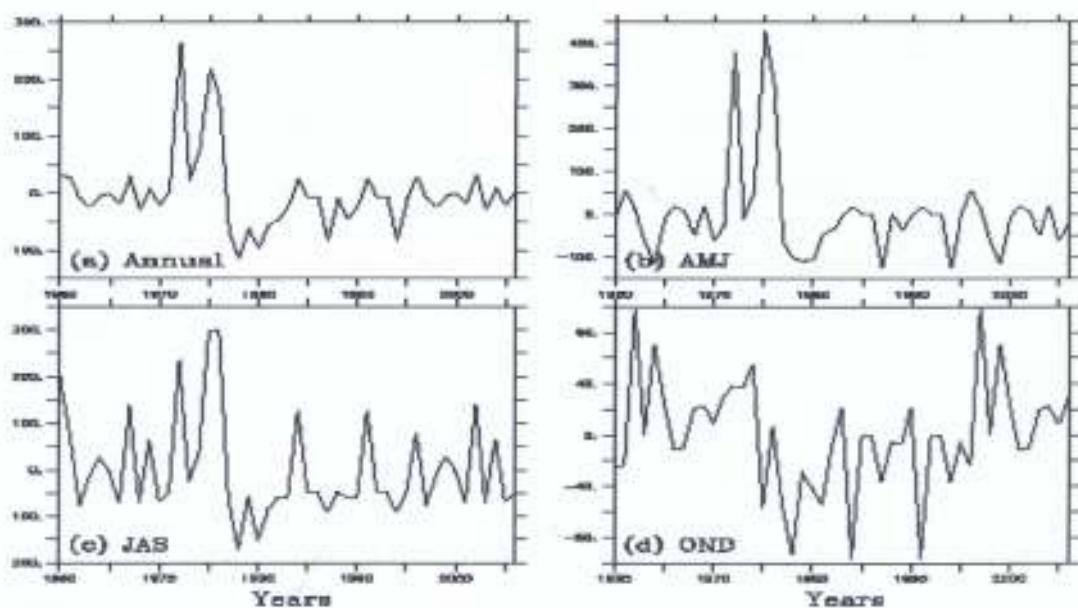


(ii)

Figure 5: Residual mass curve of Bauchi (i) mean monthly temperature ad (ii) monthly rainfall for (a) annual (b) AMJ (c) JAS & (d) OND



(i)

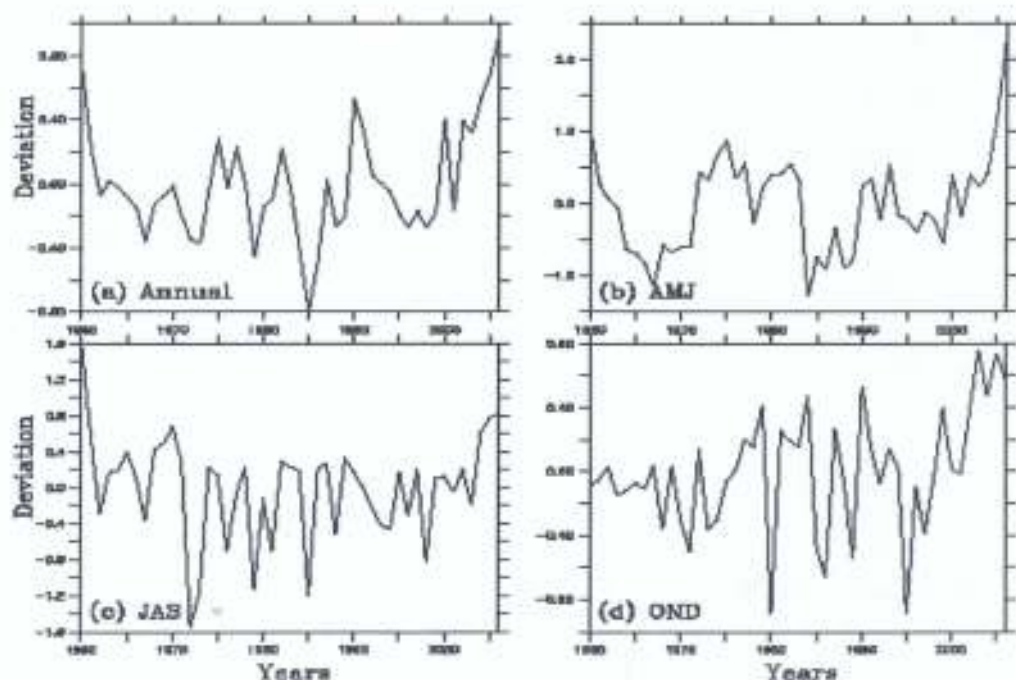


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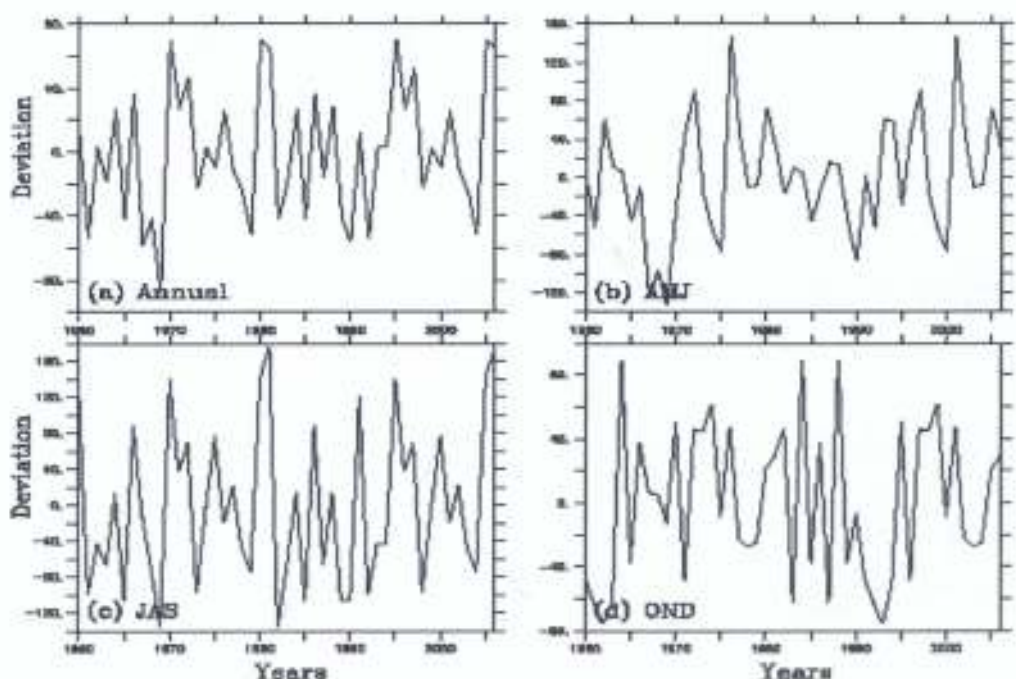
Figure 6: Residual mass curve of Benin (i) mean monthly temperature and (ii) monthly rainfall for (a) Annual (b) AMJ (c) JAS & (d) OND

Figure 7 shows Residual mass curve of Calabar mean monthly temperature and monthly rainfall for Annual, AMJ, JAS and OND. For annual, there was increase in annual mean monthly temperature and monthly rainfall in the last two and half decades. There was increase in trend of AMJ mean monthly temperature and monthly rainfall in the last one and half decades. Both JAS and OND mean monthly temperatures had witnessed slight increase in temperature in the last two and half decades respectively, while JAS and OND monthly rainfall also experienced increase in trends of monthly rainfall in the last two decades.

Figure 8 shows the Residual mass curve of Enugu monthly rainfall and mean monthly temperature for (a) annual (b) AMJ (c) JAS (d) OND. For annual, the last two and half decades have experienced positive trend in temperature and negative trend in rainfall has been observed in the last two decades with highest rainfall within 1978 and 1980. In AMJ, the last two decades have experienced positive trend in temperature while the last 15 years had experienced negative trend. In JAS months, the last 15 years had experienced negative trend in rainfall and temperature. In OND months, the last 15 years had experienced both negative trend in rainfall and temperature.

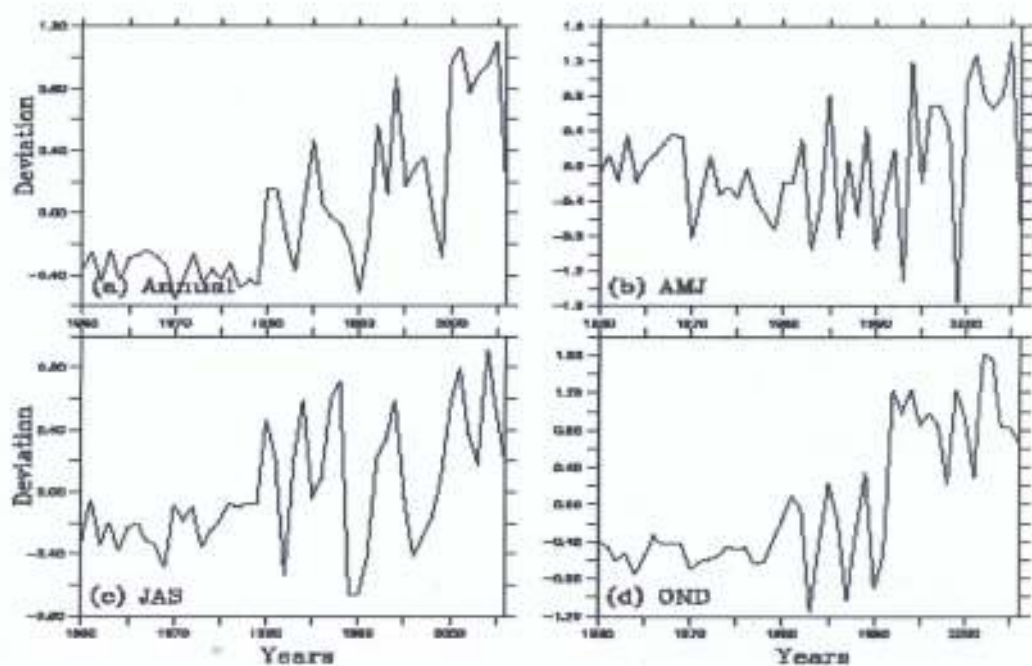


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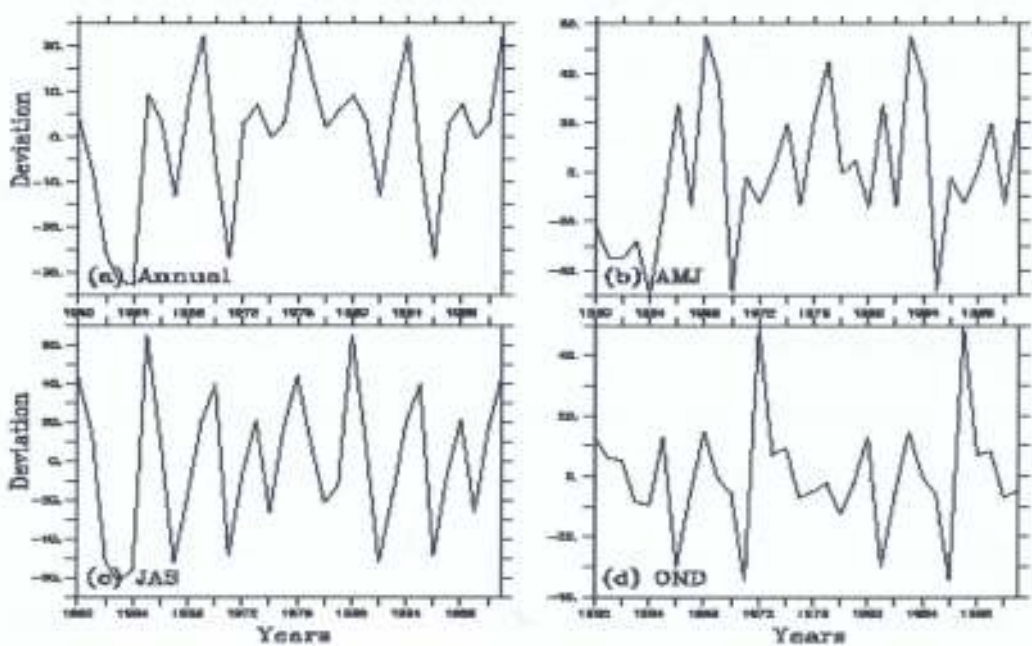


(ii)

Figure 7: Residual mass curve of Calabar (i) mean monthly temperature and (ii) monthly rainfall Annual, AMJ, JAS and OND



(i)

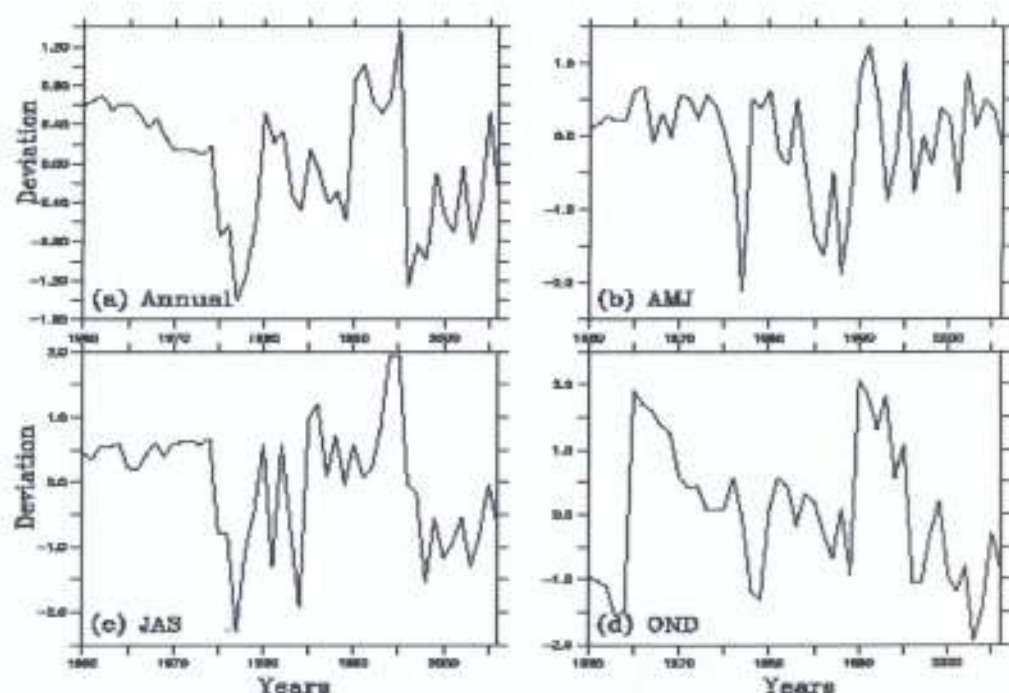


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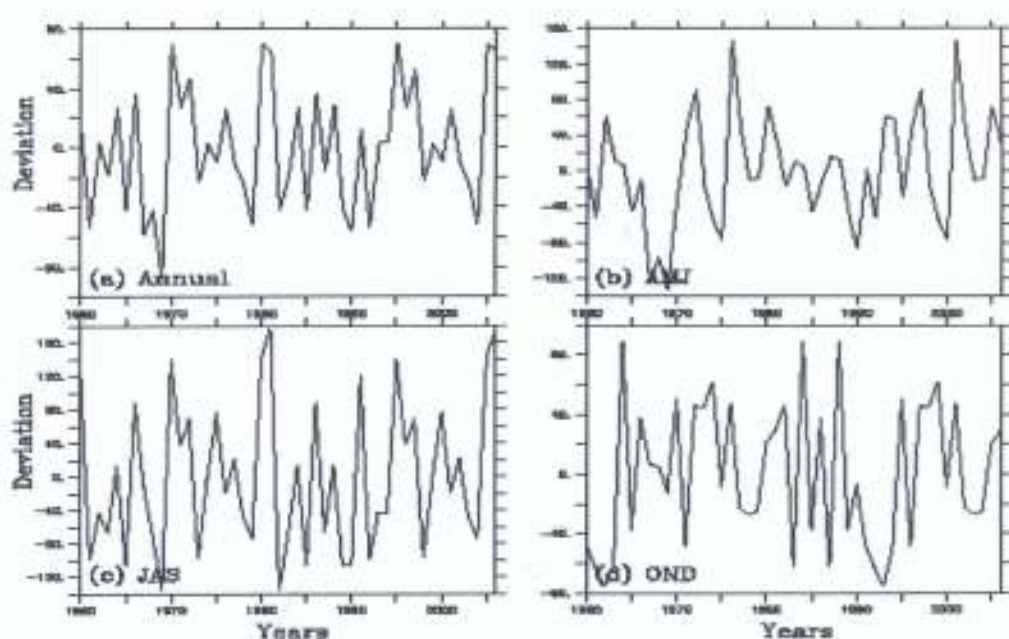
Figure 8: Residual mass curve of Enugu (i) mean monthly temperature and (ii) monthly rainfall for (a) Annual (b) AMJ (c) JAS & (d) OND

Figure 9 shows Residual mass curve of mean monthly temperature and monthly rainfall for Gusua. The annual mean monthly temperature for Gusua had experienced decrease in trend in the last two and half decades with peak temperature in year 1990s while monthly rainfall witnessed decrease in the last three and half decades. The year 1994 witnessed abnormal sunshine and recorded highest mean monthly temperature. Extreme annual rainfall was noticed years 1976, 1990 and 2003. AMJ mean monthly temperature also witnessed a slight increase in trend in the last one and half decades with the highest temperature recorded in the early 1990s, mean while AMJ monthly rainfall decreased in trend in the last three and half decades with extreme rainfall noticed in the years 1978, 1988, and 1992, JAS mean monthly temperature experienced positive trend between 1980 and 1995. The year 1996 to end of observed year had witnessed a decrease in trend of mean monthly temperature. While, the OND mean monthly temperature had witnessed a decrease in trend in the last one and half decades. During JAS and OND seasons, extreme rainfall was noticed in the years 1975, 1992, 1976, 1978, 1988, 1992, 1994 and 2003 respectively.

Figure 10 shows Residual mass curve for mean monthly temperature and monthly rainfall for Ibadan. The Annual, AMJ, JAS and OND seasons had experienced sharp increase in trend of mean monthly temperature between 1972 to end of the observed years. The monthly rainfall for Annual and AMJ season had experienced slight increase in trend from 1980 to 1996 with highest rainfall in the years 1970 and 1986. JAS season witnessed a negative trend in rainfall from 1970 to 1996 OND season also witnessed decrease in trend from 1974 to 1976

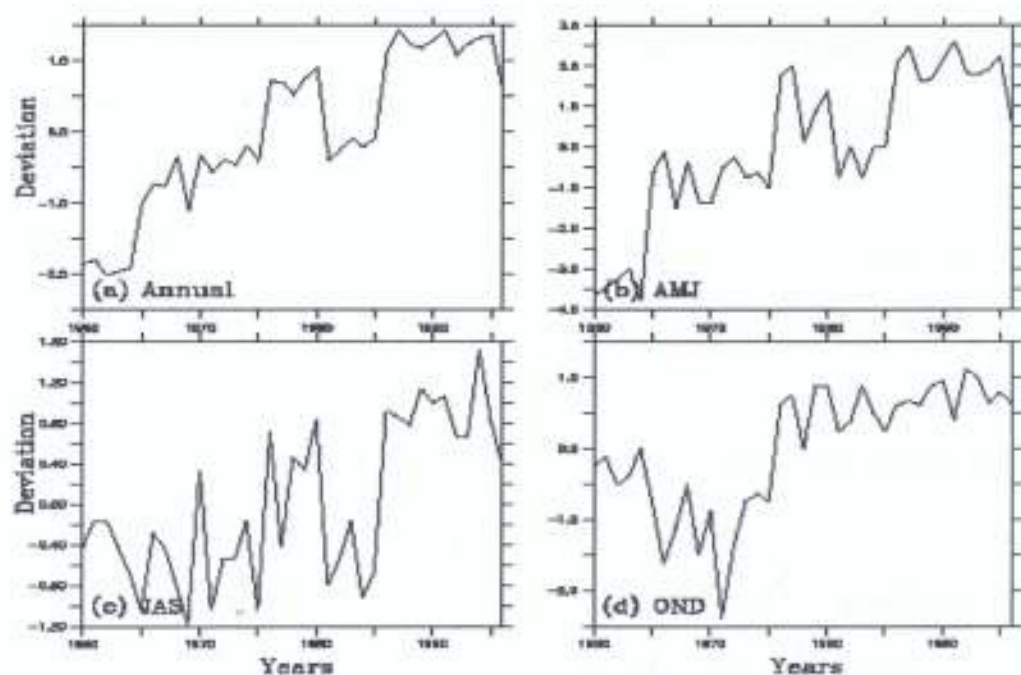


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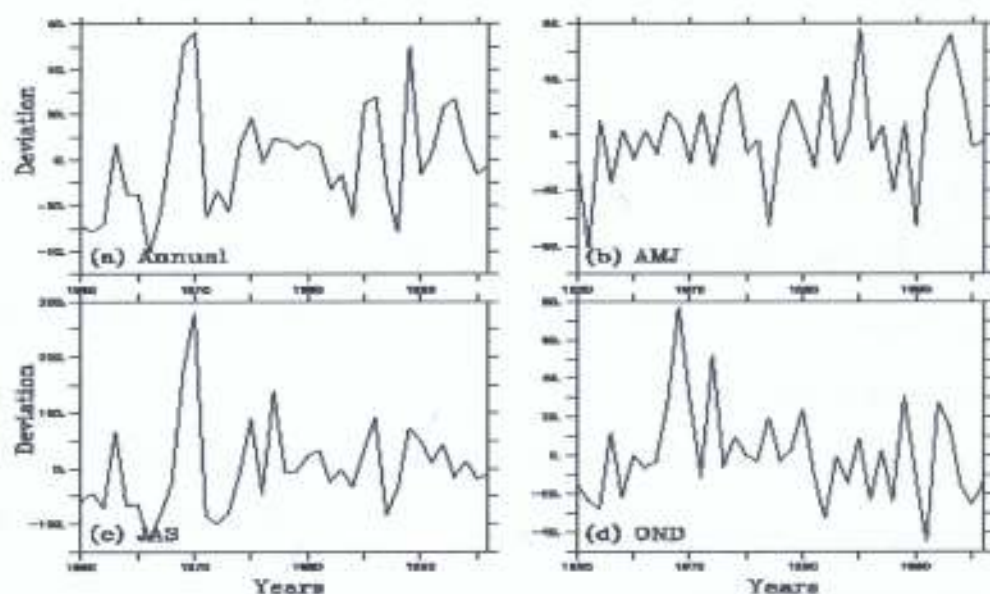


(ii)

Figure 9: Residual mass curve for Gusua (i) mean monthly temperature and (ii) monthly rainfall for; (a) Annual, (b) AMJ, (c) JAS and (d) OND seasons



(i)

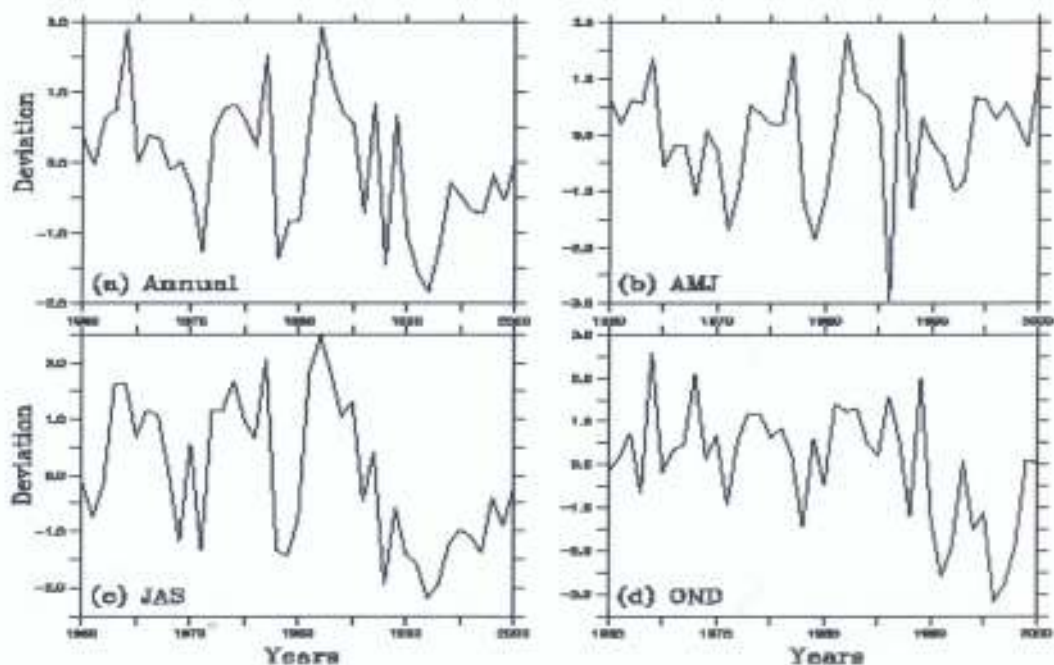


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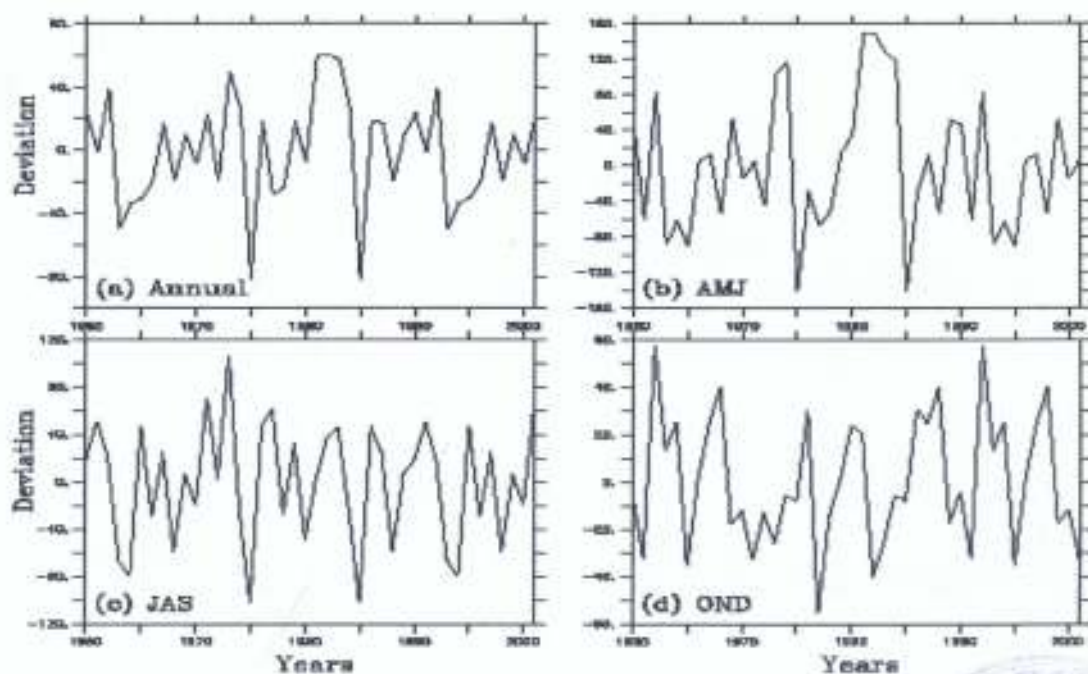
Figure 10: Residual mass curve for Ibadan (i) mean monthly temperature and (ii) monthly rainfall for; (a) Annual, (b) AMJ, (c) JAS and (d) OND seasons

Figure 11 shows Residual mass curve of Ikeja mean month temperature and monthly rainfall for Annual, AMJ, JAS and OND. The annual mean month temperature for Ikeja increased from 1960 to 1980 and started decreasing in trend to end of observed year. The last two and half decades had witnessed decrease in trend of mean monthly temperature, mean while there was an increase in trend of monthly rainfall in the last two decades. AMJ mean monthly temperature had witnessed increase in trend of mean monthly temperature in the last two and half decades and AMJ monthly rainfall also witnessed a slight increase in trend in the last two decades. JAS mean monthly temperature increase in trend from 1960 to 1980, and started decreasing to the end observed year. The JAS monthly rainfall witnessed slight decrease in trend in the last two and half decades. OND mean monthly temperature had witnessed decrease in trend in the last one and half decades. OND monthly rainfall had witnessed increase in trend in the last two and half decades with highest rainfall recorded in year 1962 and 1992.

Figure 12 shows Residual mass curve for Iseyin mean monthly temperature and monthly rainfall for annual, AMJ, JAS and OND. Annual mean monthly temperature for Iseyin witnessed decrease in trend in the last two and half decades while Annual monthly rainfall experienced increase in trend from 1960 to end of observed year 1976 .AMJ mean monthly temperature had experienced positive trend in the last two and half decades. AMJ monthly rainfall experienced a slight increase in trend from 1954 to end of observed year 1988. The JAS mean monthly temperature had witnessed decrease in trend in the last two and half decades. JAS monthly rainfall also witnessed a slight increase in trend from 1960 to end of observed year 1988 and OND mean monthly temperature witnessed decrease in trend between 1972 and 1988 and started increasing till end of the observed year.

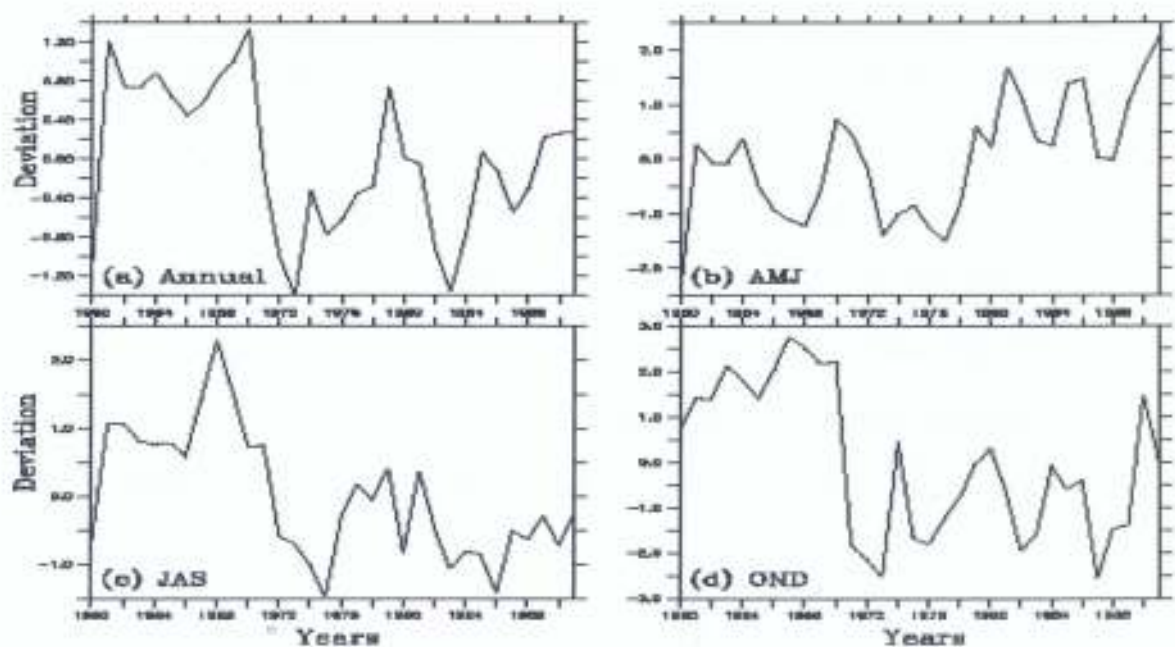


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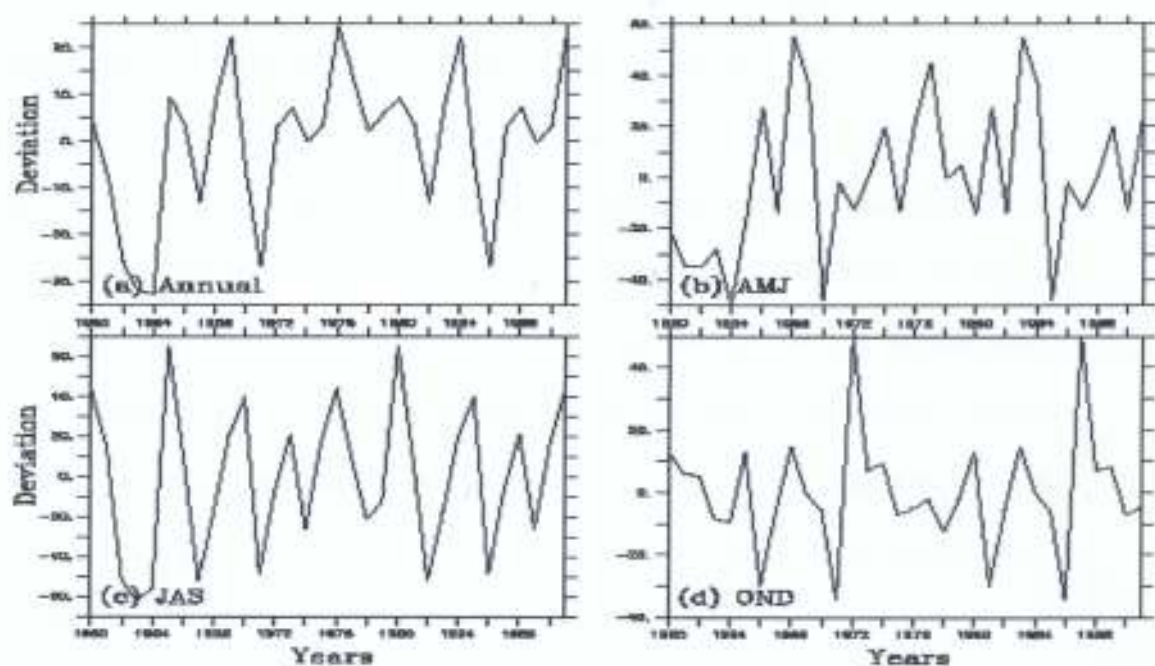


(ii)

Figure 11: Residual mass curve for Ikeja (i) mean monthly temperature and (ii) monthly rainfall for; (a) Annual, (b) AMJ, (c) JAS and (d) OND seasons



(i)

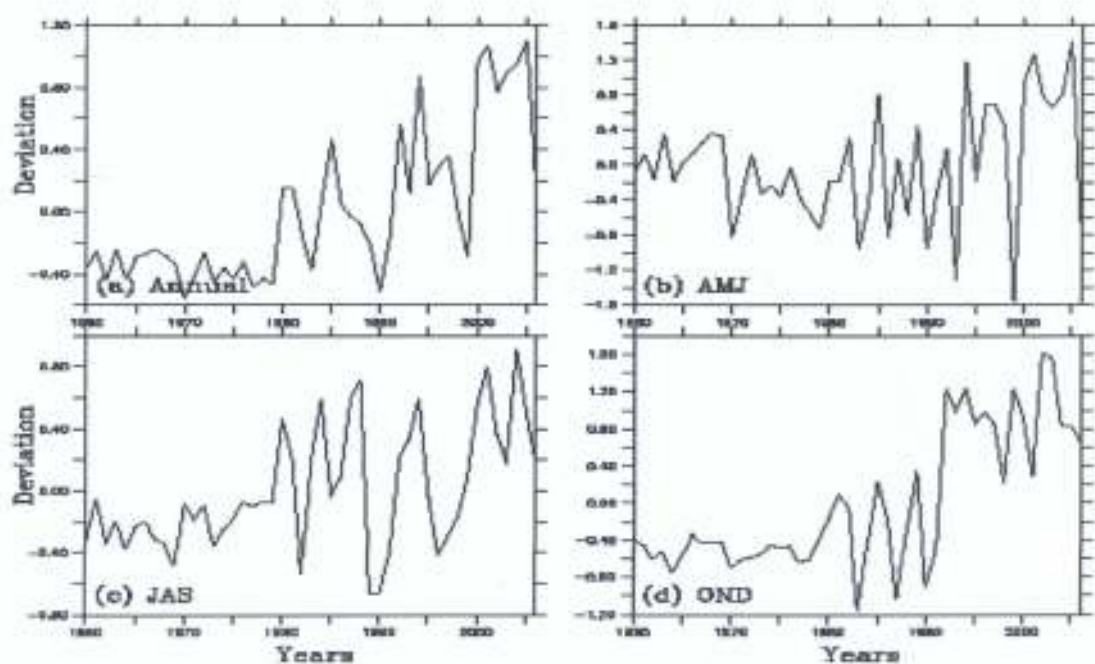


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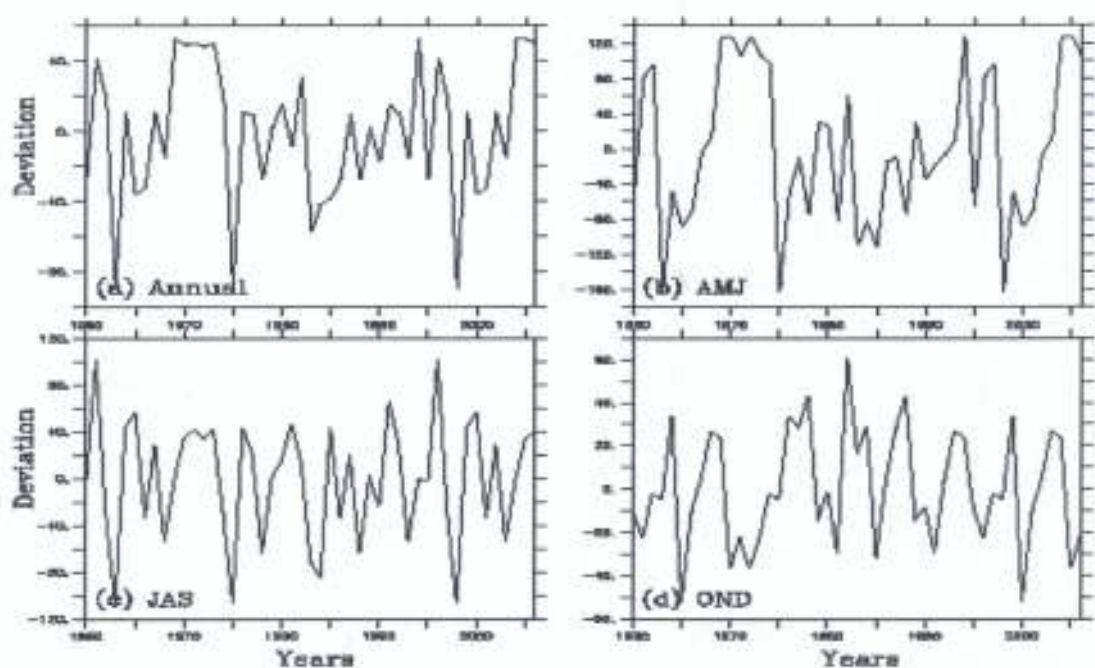
Figure 12: Residual mass curve for Iseyin (i) mean monthly temperature and (ii) monthly rainfall for; (a) Annual, (b) AMJ, (c) JAS and (d) OND seasons

Figure 13 shows Residual mass curve of Lagos mean monthly temperature and monthly rainfall for annual, AMJ, JAS and OND seasons. The annual mean monthly temperature of Lagos had witnessed tremendous increase in trend in the last two and half decades. Like wise AMJ, JAS and OND seasons also witnessed increase in trend of mean monthly temperature in the last two and half decades. The Annual, AMJ and JAS monthly rainfall had witnessed a slight increase in trend in the last two and half decades. The OND season also experienced a slight increase in monthly rainfall from 1960 to 2000 but the last half a decade had witnessed downward trend to end of observed year 2006.

Figure 14 shows Residual mass curve for Maiduguri mean monthly temperature and monthly rainfall for annual, AMJ, JAS and OND seasons. The annual mean monthly temperature of Maiduguri had increased in trend in the last two and half decades. Likewise AMJ, JAS and OND seasons also experienced increase in trend of mean monthly temperature in the last two decades. Annual monthly rainfall had increased in trend from 1980 to 1992 with highest rainfall recorded in year 1988 and started decreasing until year 2002 and there after started increasing till end of observed year. AMJ monthly rainfall had experienced decrease in trend from 1984 to year 2002 and started increasing there after to end of observed year. There was also a decrease in trend from 1960 to 1980 except the abnormal rainfall in years 1968, 1982, and 2004. JAS season had witnessed slight increase in trend of monthly rainfall from 1960 to end of observed year OND season had also witnessed increase in trend from 1980 to 1992 and started experiencing downward trend till end of observed year. The highest rainfall was recorded in year 1992

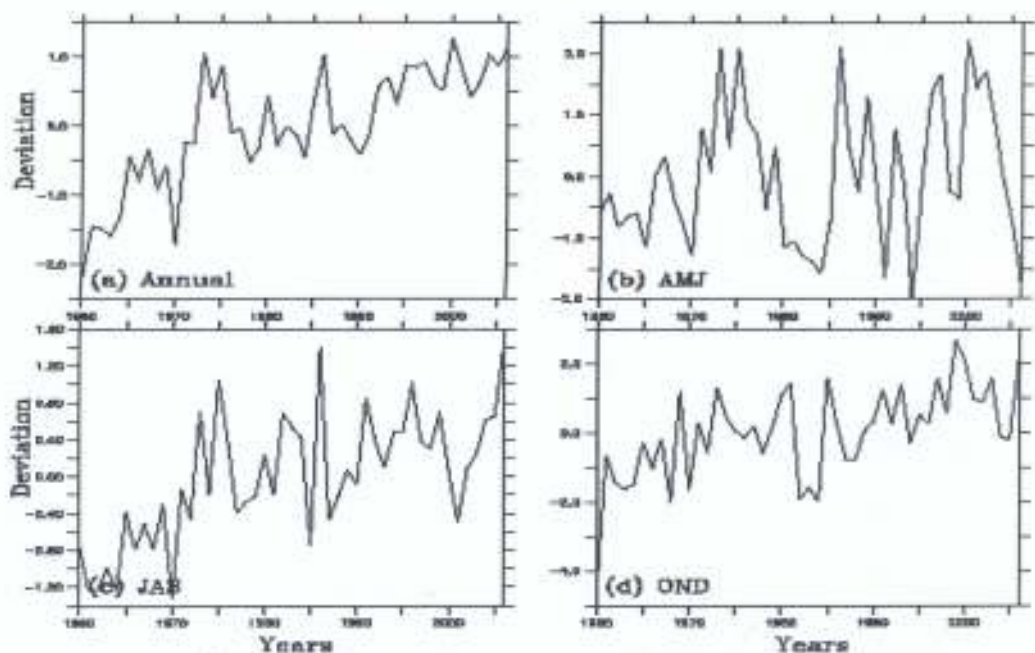


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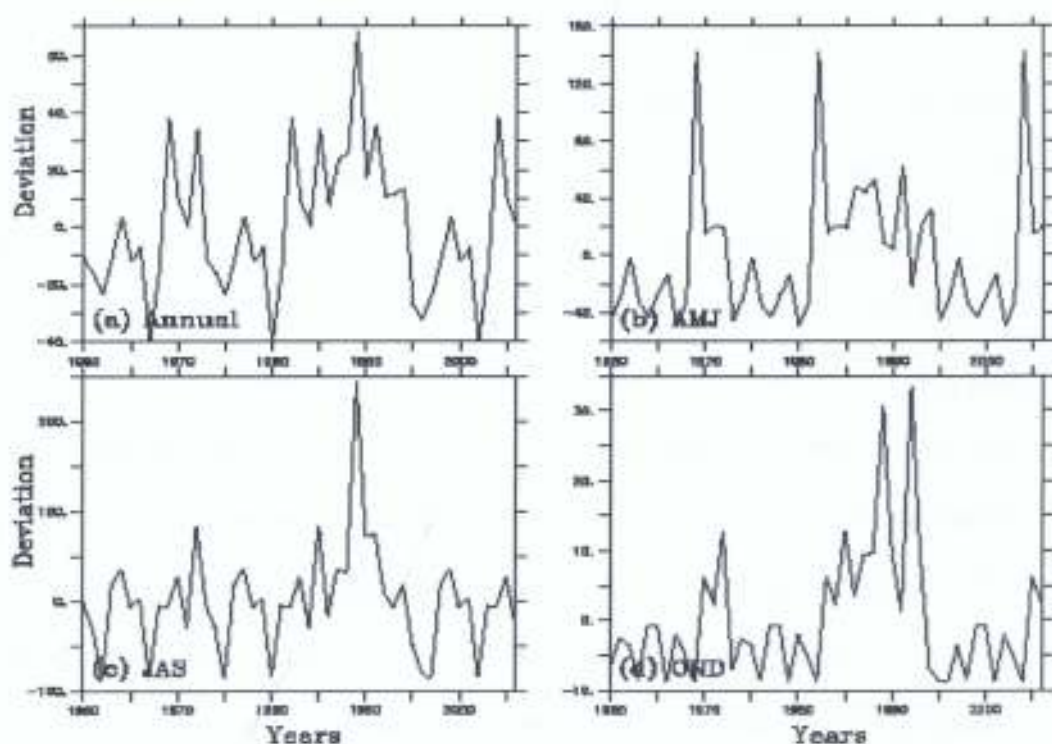


(ii)

Figure 13: Residual mass curve for Lagos (i) mean monthly temperature and (ii) monthly rainfall for; (a) Annual, (b) AMJ, (c) JAS and (d) OND seasons



(i)

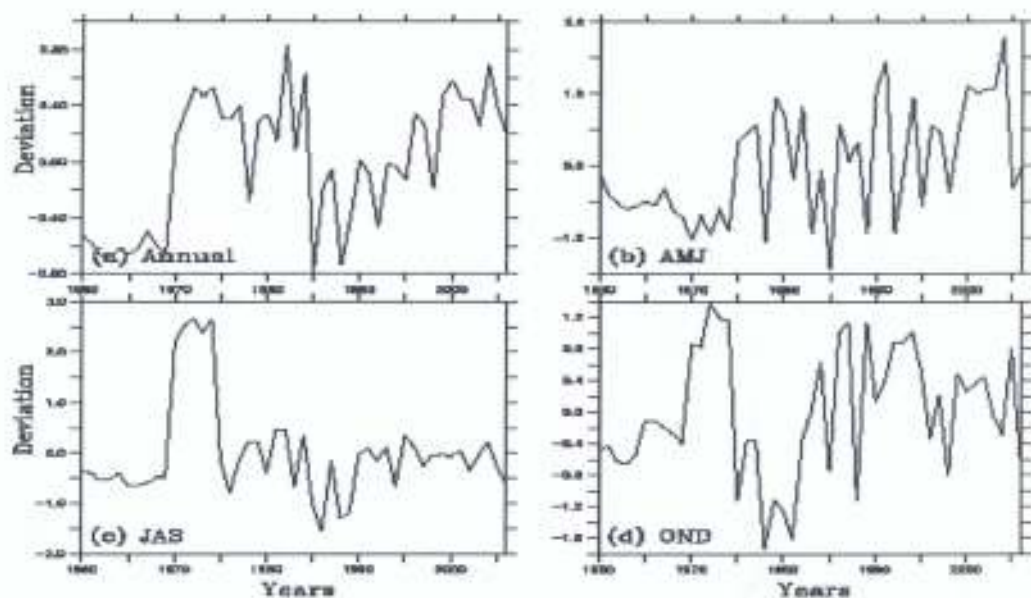


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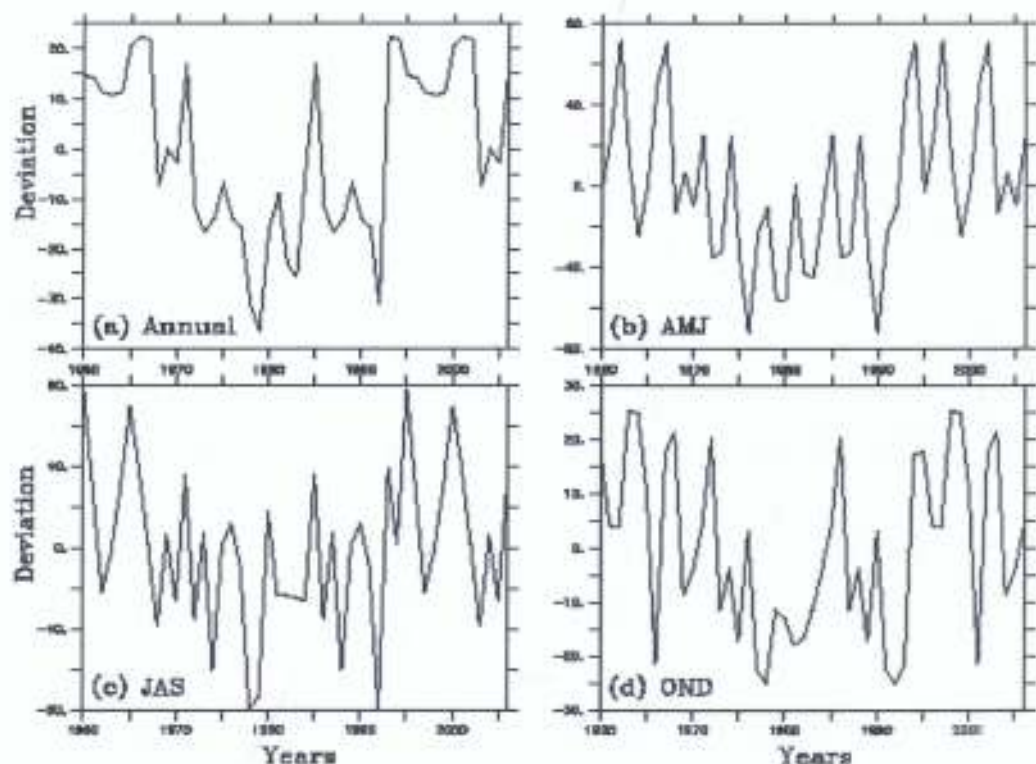
Figure 14: Residual mass curve for Maiduguri (i) mean monthly temperature and (ii) monthly rainfall for; (a) annual, (b) AMJ, (c) JAS and (d) OND seasons

Figure 15 shows Residual mass curve for Minna mean monthly temperature and monthly rainfall for annual, AMJ, JAS and OND seasons. Annual mean monthly temperature had fairly increased from 1970 to 1984 and the last decade had experienced increase in trend. Annual monthly rainfall had experienced increase in trend in the last one and half decades. AMJ season witnessed increase in trend of mean monthly temperature in the last two decades. AMJ monthly rainfall also witnessed increase in trend in the last one and half decades. JAS season witnessed decrease in trend of mean monthly temperature in the last three decades, while OND season witnessed increase in trend of mean monthly temperature in the last two and half decades. JAS and OND seasons had witnessed increase in trend of monthly rainfall in the last one and half decades.

Figure 16 shows Residual mass curve for Oshogbo mean monthly temperature and monthly rainfall for Annual, AMJ, JAS and OND seasons. Oshogbo annual mean monthly temperature had experienced a slight decrease in trend from 1960 to end of observed year except year 1978 that witnessed abnormal sunshine. Oshogbo AMJ season had experienced decrease in trend of mean monthly temperature from 1970 to 1992 and started increasing to end of observed year. Like wise, JAS season had witnessed increase trend in the last one and half decades and OND season had witnessed a slight decrease in trend from 1960 to end of observed. Oshogbo annual monthly rainfall witnessed decrease in trend from 1972 to end of observed year. AMJ season also witnessed a slight decrease in trend of monthly rainfall from 1976 to end of observed year. JAS season witnessed a slight increase in trend of monthly rainfall from year 1960 to 1980 and started decreasing to end of observed year. OND season had witnessed increase in trend of monthly rainfall from 1966 to end of observed year.

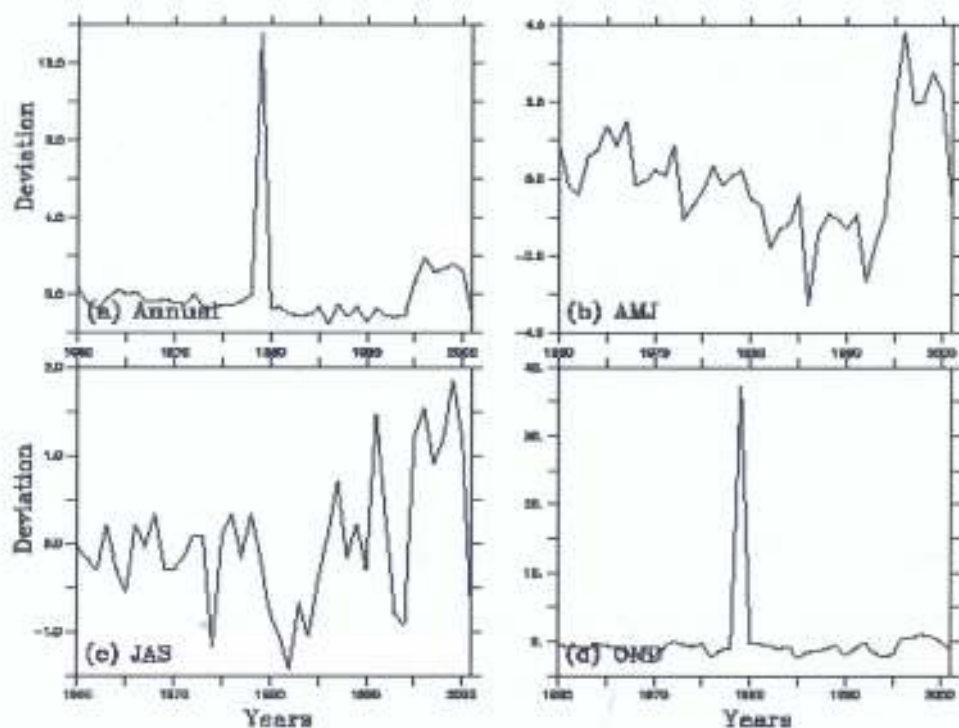


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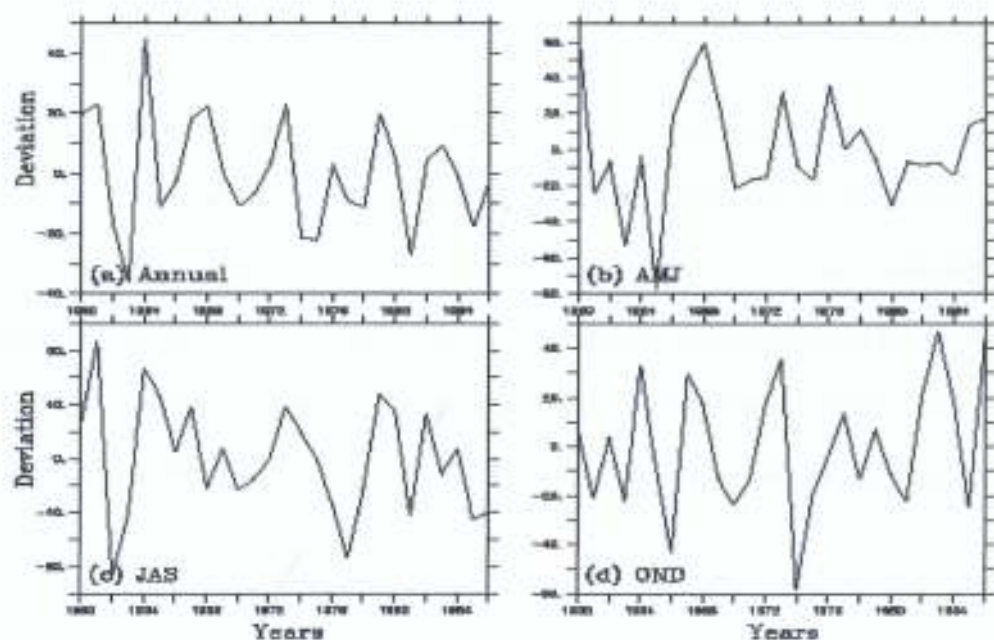


(ii)

Figure 15: Residual mass curve for Minna (i) mean monthly temperature and (ii) monthly rainfall for; (a) Annual, (b) AMJ, (c) JAS and (d) OND seasons



(i)

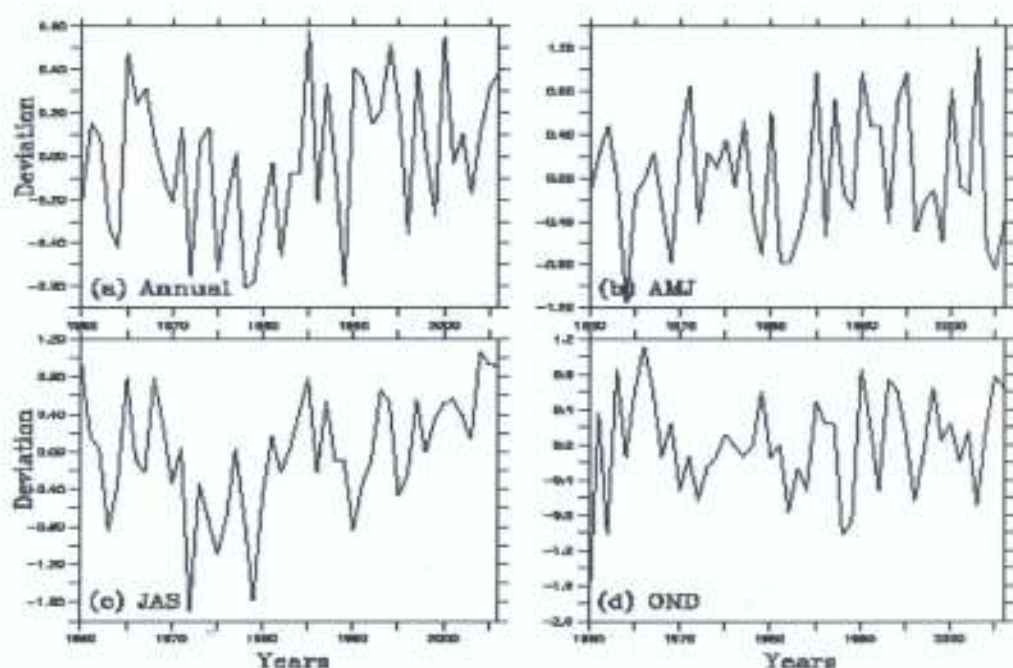


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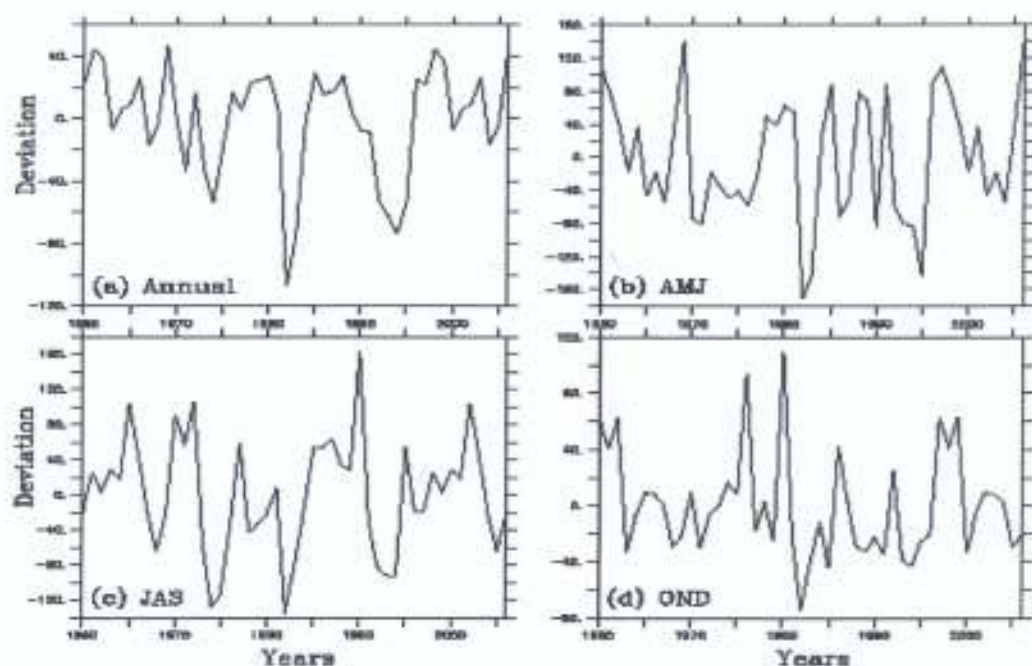
Figure 16: Residual mass curve for Oshogbo (i) mean monthly temperature and (ii) monthly rainfall for; (a) Annual, (b) AMJ, (c) JAS and (d) OND seasons

Figure 17 shows Residual mass curve for Port Harcourt mean monthly temperature and monthly rainfall for annual, AMJ, JAS and OND season. The AMJ, JAS, OND seasons and annual mean monthly temperature for Port Harcourt had experienced increase in trend in the last two and half decades. Likewise, AMJ, JAS, OND seasons and annual monthly rainfall had experienced increase in trend in last two and half decades.

Figure 18 shows the Residual mass curve of mean monthly temperature and monthly rainfall of Sokoto respectively. Annual temperature, in the last two and half decades experienced decrease and the highest temperature occurred in the late 1970s, while annual rainfall experienced increase in trend in the last two decades with the highest rainfall in 1992. AMJ months had experienced increase in rainfall in the last two decades with highest rainfall in 1976 and 1996, and increase in temperature in the last decade with highest temperature in 1968. JAS months had experienced increase in rainfall in the last one and half decades with highest rainfall in the late 1960s and early 2000s and decrease in temperature in the last one and half decades with highest temperature in late 1960s and early 1990s. OND months temperature has increased in the last decade with peak temperature in late 1960s, 1980 and early 1990s. There was decrease in rainfall through out except in 1992 that experienced abnormal rainfall.

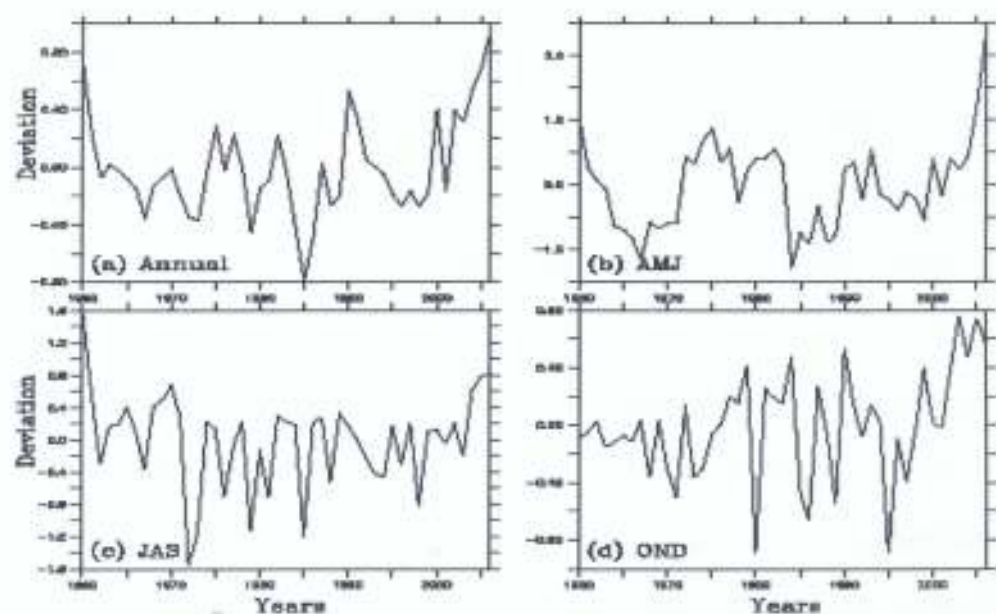


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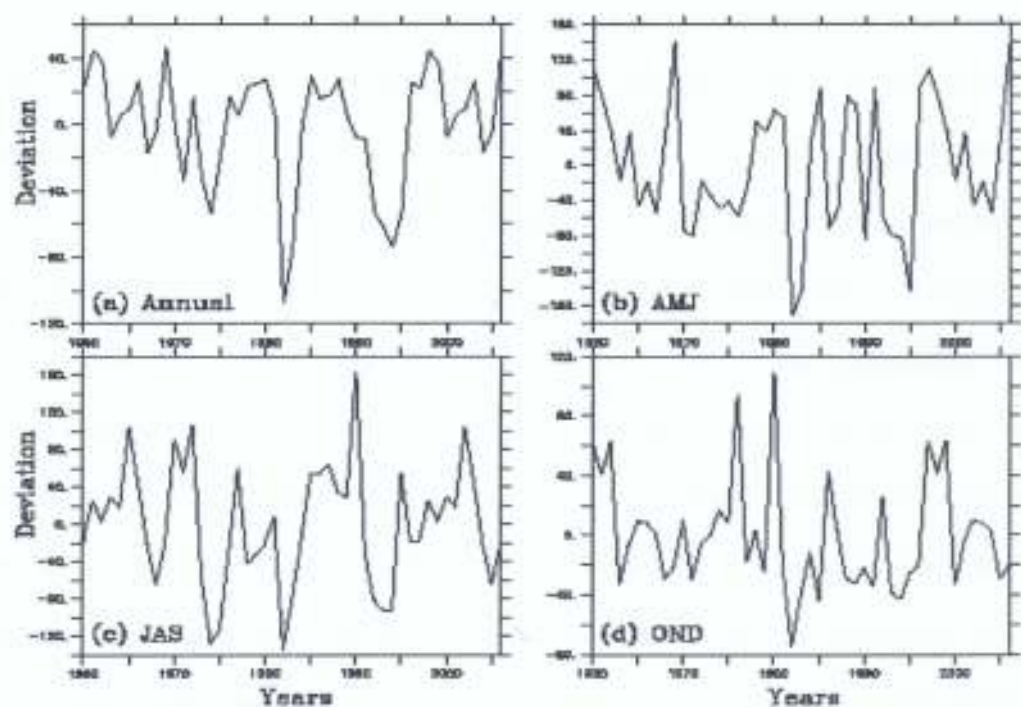


(ii)

Figure 17: Residual mass curve for Port Harcourt (i) monthly temperature and (ii) monthly rainfall for; (a) Annual, (b) AMJ, (c) JAS and (d) OND seasons



(i)

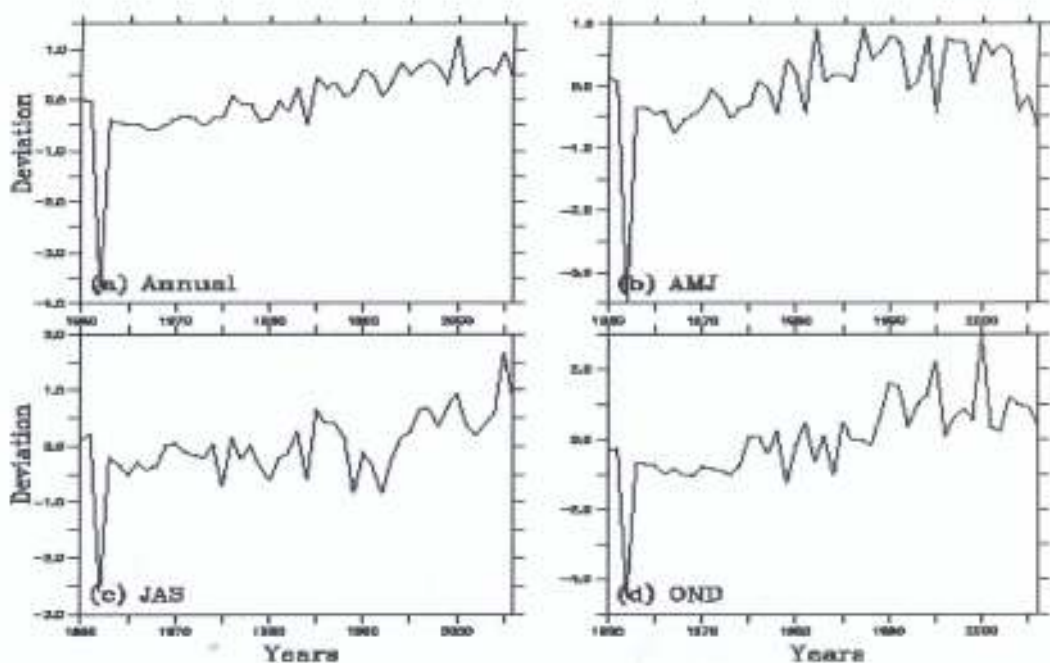


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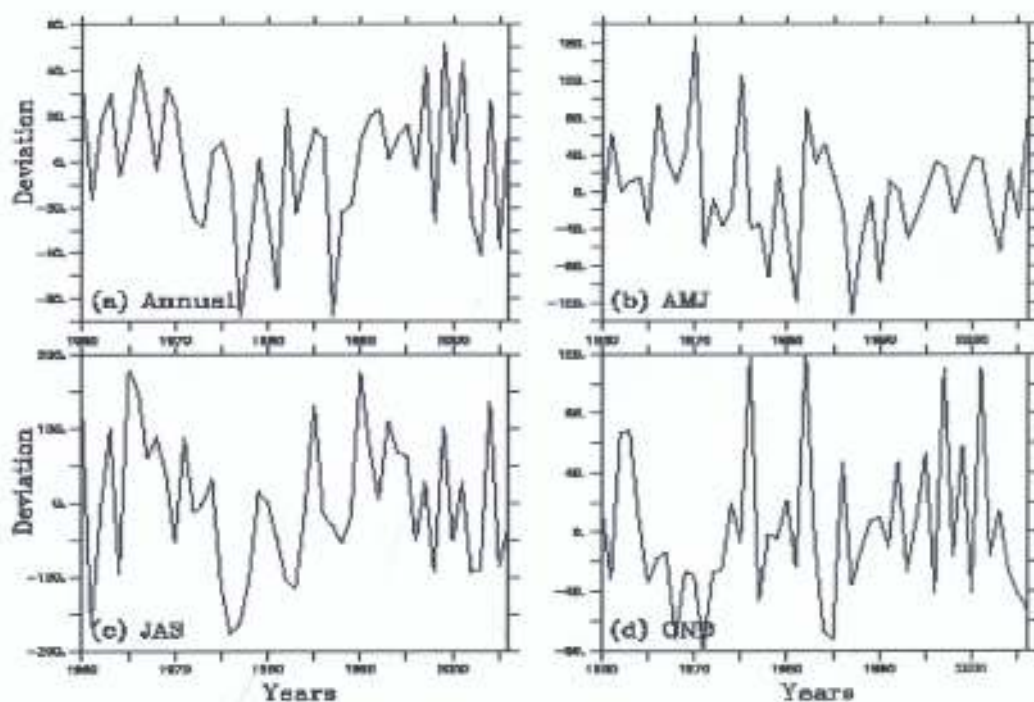
Figure 18: Residual mass curve of Sokoto (i) mean monthly temperature and (ii) monthly rainfall for; (a) Annual, (b) AMJ, (c) JAS & (d) OND

Figure 19 shows Residual mass curve for Warri mean monthly temperature and monthly rainfall for Annual, AMJ, JAS and OND seasons. Annual as well as AMJ, JAS and OND seasons had witnessed increase in trend of mean monthly temperature in the last two and half decades. Annual monthly rainfall of Warri had experienced increase in trend in the last two and half decades. Warri AMJ monthly rainfall had witnessed a slight increase in trend in the last one and half decades. The highest rainfall was recorded in 1970. Warri JAS season experienced a slight decrease in trend of monthly rainfall in last one and half decades. The highest rainfall was recorded in early 1960s. OND season witnessed increase in trend of monthly rainfall from 1990 to 2000 and the last half a decade to end of observed year had experienced downward trend.

Figure 20 shows Residual mass curve of Yelwa mean monthly temperature and monthly rainfall for annual, AMJ, JAS and OND seasons. Annual mean monthly temperature experienced increase in trend from 1960 to end of end of observed year 1972. AMJ and OND seasons also witnessed upward trend in mean monthly temperature from 1966 to end of observed year 1972. While JAS season, witnessed a slight decrease from 1984 to end of observed year 1972 and highest temperature was recorded in year 1976. Annual monthly rainfall witnessed increase in trend in the last one and half decades. AMJ seasonal rainfall witnessed a slight increase in trend from 1960 to end of observed year and highest rainfall was recorded in year 1988. JAS seasonal rainfall witnessed upward from 1960 to 1980 and started decreasing from 1981 to 1991. The last one and half decades had witnessed upward trend. OND seasonal rainfall decreased in trend from 1960 to 1974 and started increasing to 1980.. Upward trend was observed between 1992 and 2000. The last half a decade had witnessed decrease in trend of rainfall



(i)



(ii)

Figure 19: Residual mass curve for Warri (i) mean monthly temperature and (ii)

Monthly rainfall for; (i) Annual, (b) AMJ, (c) JAS and (d) OND seasons

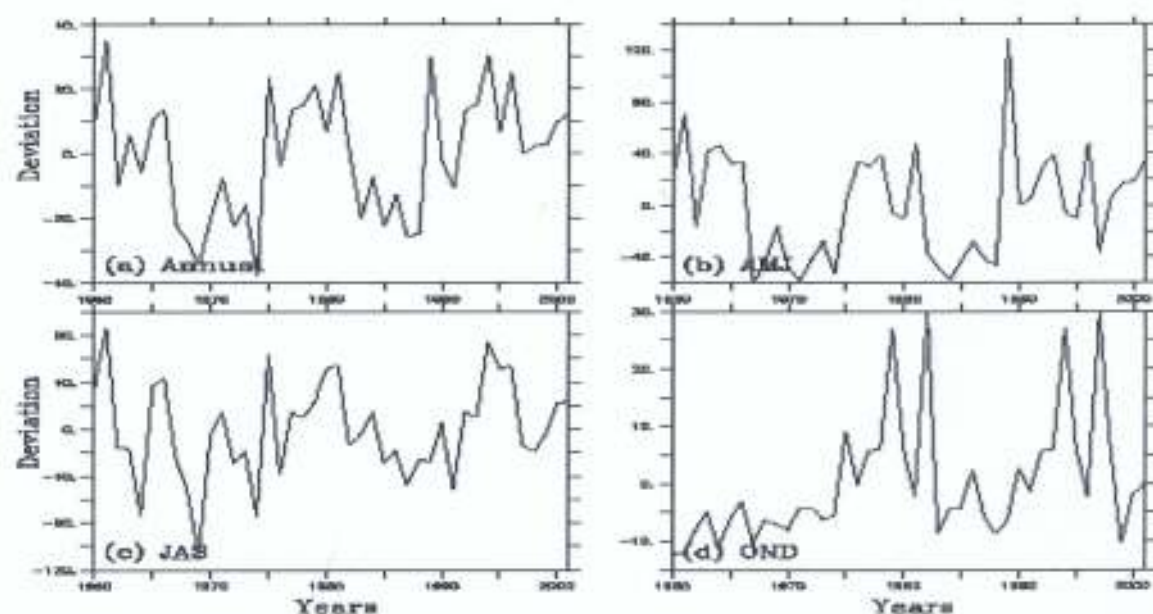
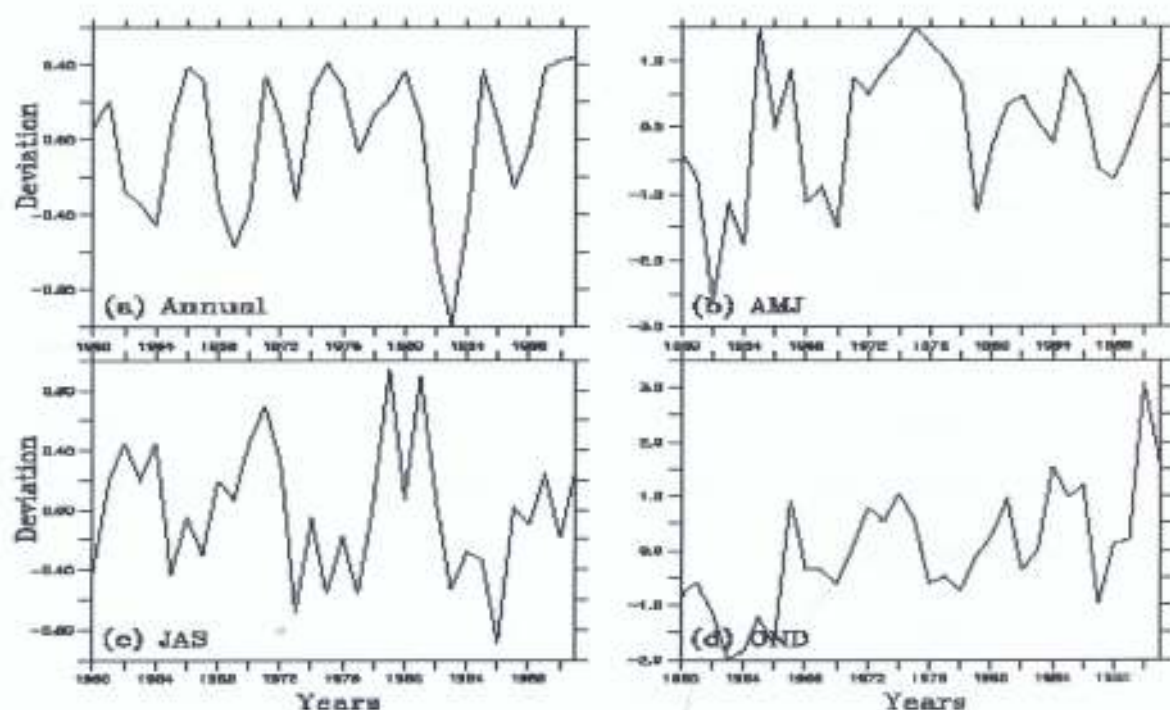
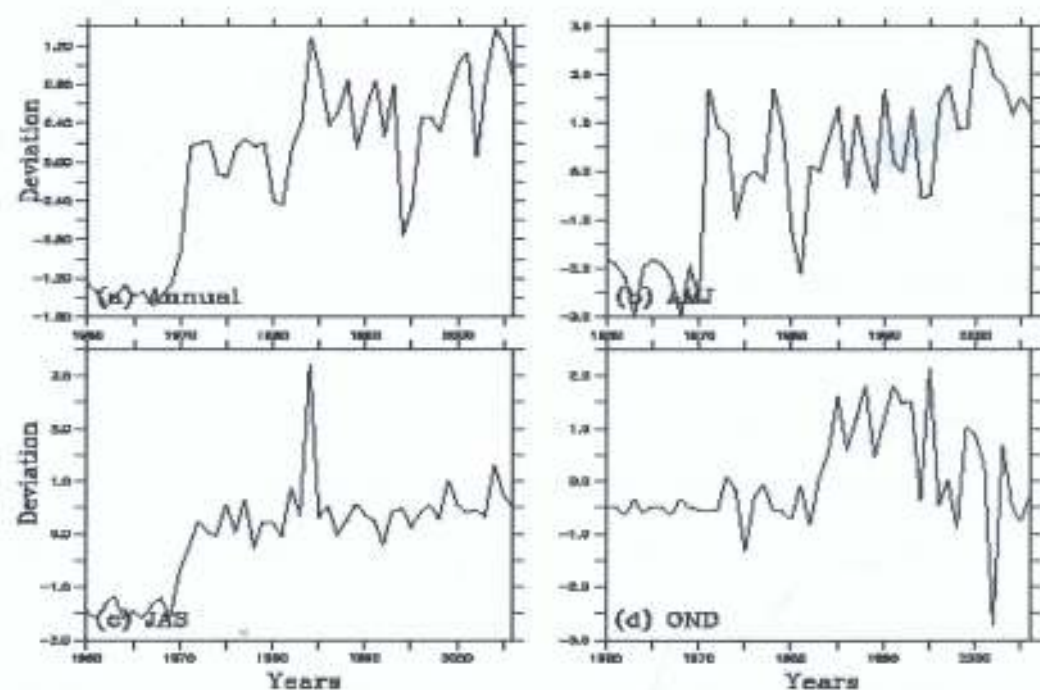
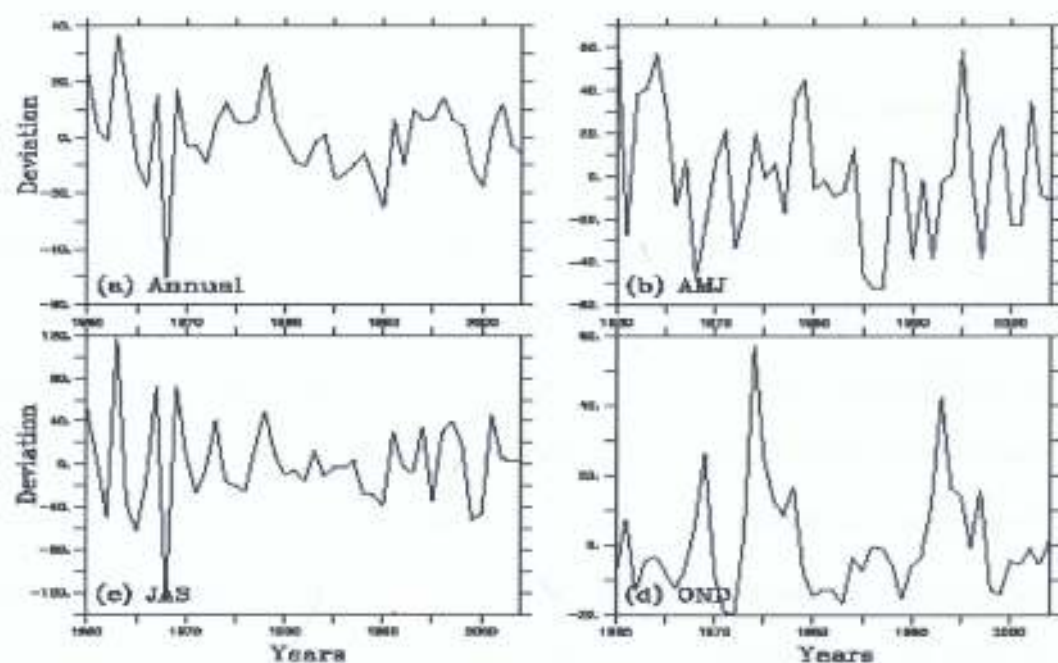


Figure 20: Residual mass curve of Yelwa (i) mean monthly temperature and (ii) monthly rainfall for; (a) Annual, (b) AMJ, (c) JAS and (d) OND seasons

Figure 21 shows Residual mass curve of Yola mean monthly temperature and monthly rainfall for Annual, AMJ, JAS and OND seasons. Annual as well as AMJ and JAS seasons witnessed upward trend of mean monthly temperature in the last two and half decades. OND season experienced a decrease in trend from 1960 to 1980 and started increasing until 1994. The last one decade has witnessed down ward trend. Annual as well as JAS season had witnessed a slight upward trend of monthly rainfall in the last two and half decades. AMJ season also witnessed a slight increase in trend of rainfall in the last two and half decades. The highest AMJ monthly rainfall was recorded in year 1962 and 1994. There were upward and downward trends in OND monthly rainfall. From 1960 to 1966, 1980 to 1988 and 2001 to end of observed year had experienced down ward trend while upward trend was observed from 1967 to 1970, 1971 to 1988 and 1990 to 2000. The highest rainfall was recorded in year 1975



(i)



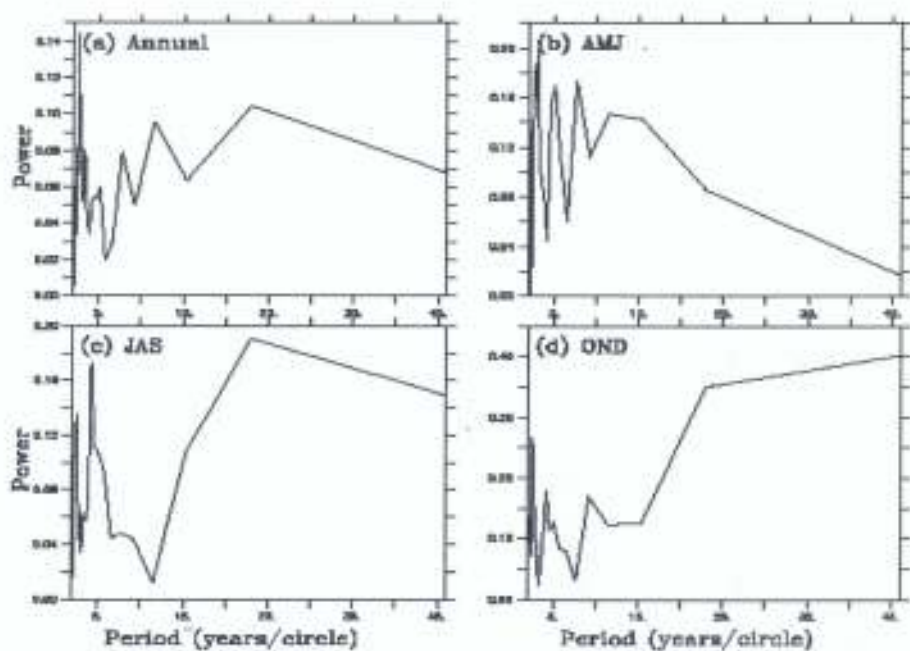
(ii)

Figure 21: Residual mass curve for Yola (i) mean monthly temperature and (ii) monthly rainfall for; (a) Annual, (b) AMJ, (c) JAS and (d) OND seasons

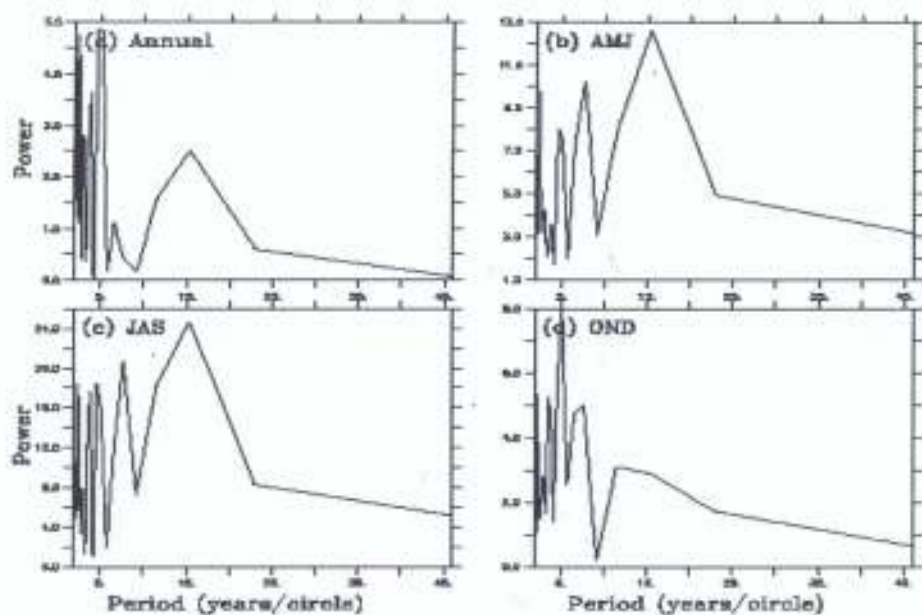
4.3 Rainfall and Temperature Cycles over Nigeria.

Figure 22 shows Auto correlation spectral analysis for Abeokuta mean monthly temperature and monthly rainfall for a) Annual, b) AMJ, c) JAS and d) OND. The annual mean monthly temperature had dominant peak of return period of 2-3 years. Annual monthly rainfall has the dominant peaks of 1-2 years and 4-5 years. AMJ mean monthly temperature has the dominant peaks of return period of 1-2 years, 4-5 years and 6-7 years. AMJ monthly rainfall has the dominant peaks of 1 year, 6-7 years and 14-15 years as return period. JAS mean monthly temperature has the dominant peak of 2-4 years as return period. JAS monthly rainfall has the dominant peaks of 1& 2 years, 5-6 years and 7 years as return period while OND months have dominant peak of 1-2 years return period. OND monthly rainfall has the dominant peak of of 5 years as return period.

Figure 23 shows the auto correlation spectral analysis (ASA) of Abuja mean monthly temperature and monthly rainfall for (a) annual (b) AMJ (c) JAS (d) OND. For annual, the dominant peak in rainfall has 3-5 years as return period while the dominant peaks in temperature have 1-2years and 4-5years as return period. In AMJ months, the dominant peak in temperature has 10-12 years as return period and the dominant peak in rainfall has 6-8years of return period. In JAS months, the dominant peak in rainfall has 5-7 years of return period while the dominant peak in temperature has 5-6 years as return period. In OND months, the dominant peak in temperature has 4-5 years as return period while the dominant peak in rainfall has 10-12 years of return period

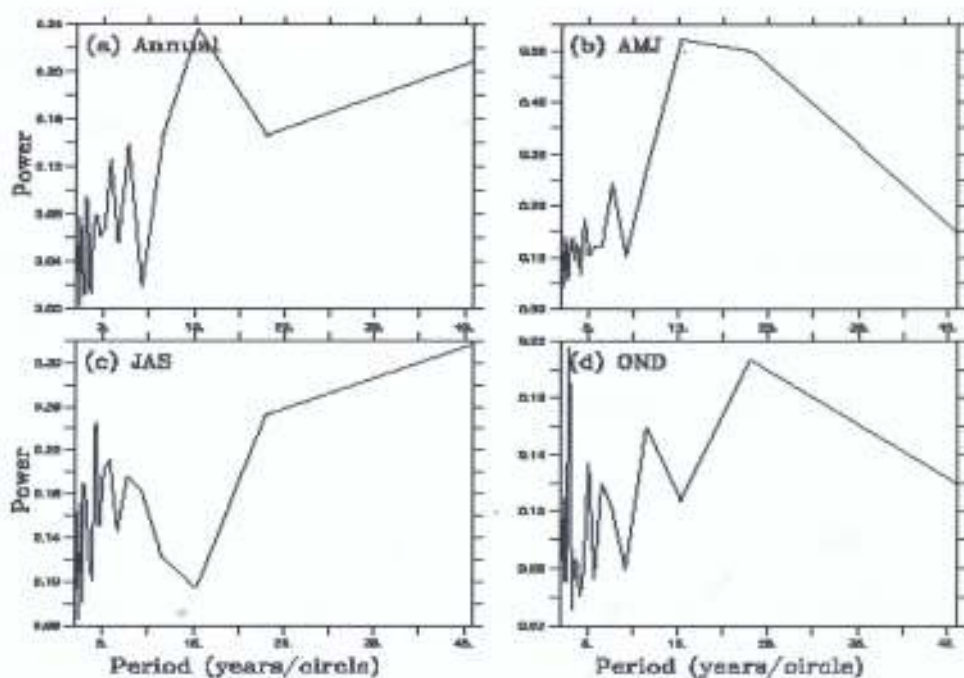


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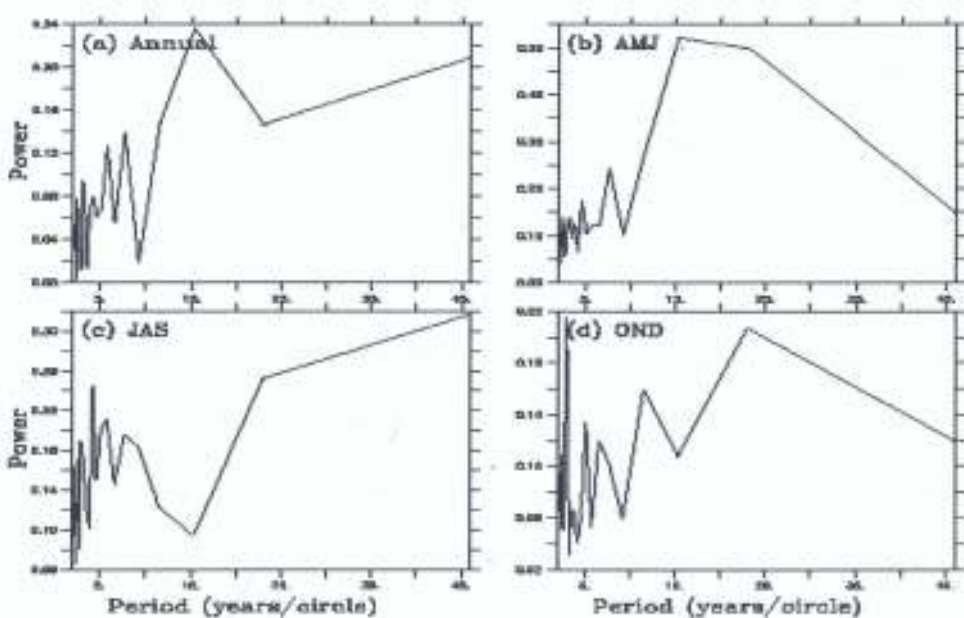


(ii)

Figure 22: Auto correlation spectral analysis for Abeokuta (i) mean monthly temperature and (ii) monthly rainfall for; (a) Annual, (b) AMJ, (c) JAS and (d) OND seasons



(i)



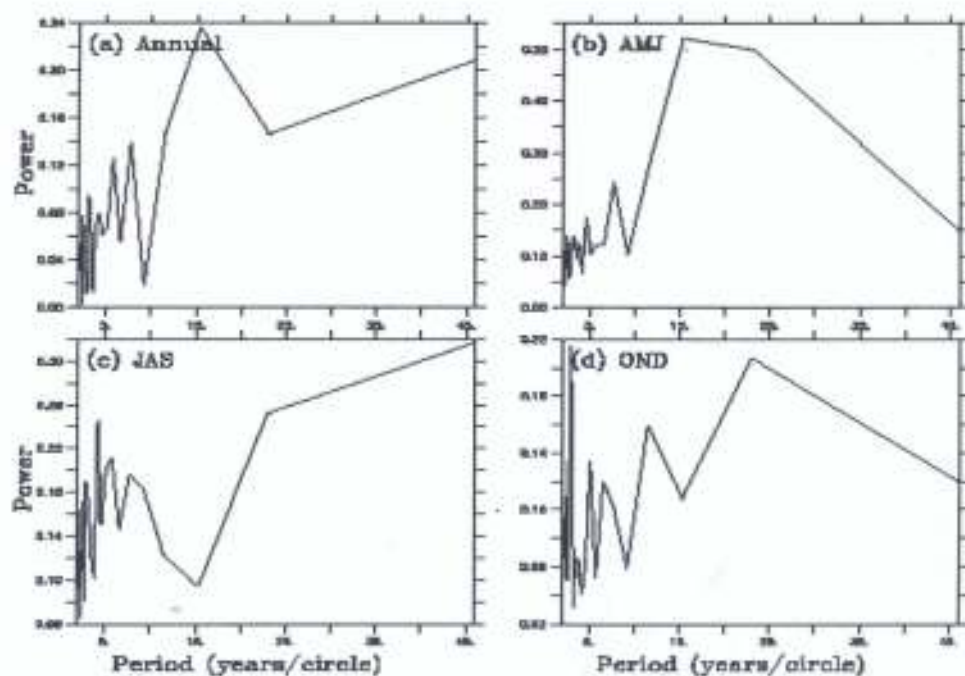
(ii)

Figure 23: Autocorrelation spectral analysis of Abuja (i) mean monthly temperature and (ii) monthly rainfall for; (a) Annual (b) AMJ (c) JAS and (d) OND

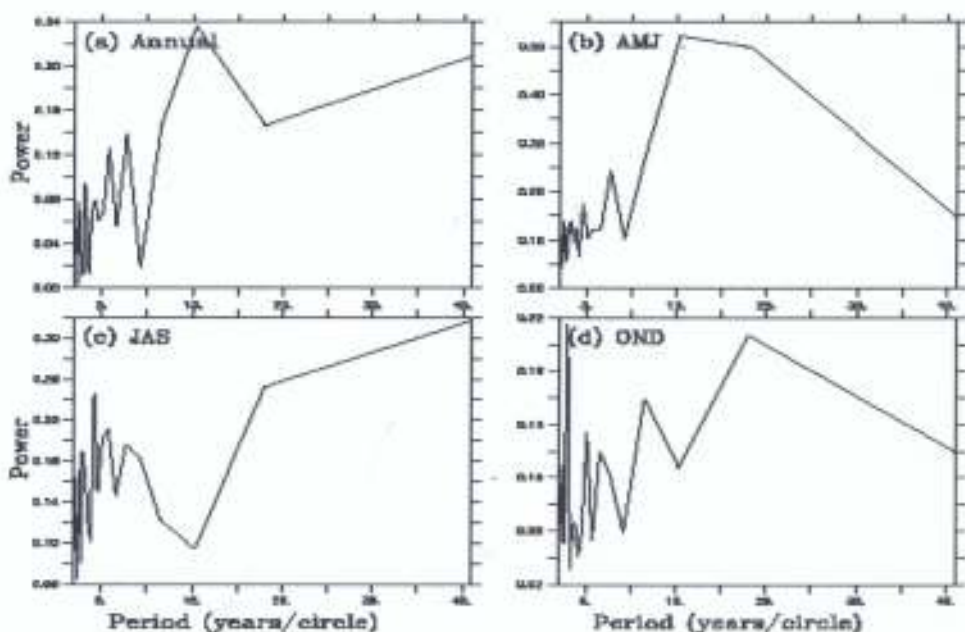
Figure 24 shows auto correlation spectral analysis (ASA) of Akure mean monthly temperature and monthly rainfall for (a) annual (b) AMJ (c) JAS (d) OND. For annual, dominant peaks in temperature have 5 years and 20-25 years as return period while dominant peak in rainfall has periodicity of 25 years. For JAS months, the dominant peak in temperature repeats itself every 3-5 years while the dominant peak in rainfall repeats itself every 20-22 years. For OND months, the dominant peak in temperature has periodicity of 15-17 years while the dominant peak in rainfall has 22-25 years.

Figure 25 shows the Auto correlation spectral analysis for Bauchi mean monthly temperature and monthly rainfall for; (a) Annual (b) AMJ (c) JAS (d) OND. Annual dominant peak in temperature has 3-5 years as return period and rainfall has return period of 13-15 years. AMJ dominant peak in temperature repeats itself every 2-3 years and 20-23 years as return period in rainfall. JAS dominant peak in temperature and rainfall has return period of 5-6 years. OND dominant peak in temperature has 3-4 years as return period and 2-3 years as return period in rainfall.

Figure 26 shows Auto correlation spectral analysis for Benin mean monthly temperature and monthly rainfall. Annual temperature has dominant peaks of 2-3 years and 8-10 years while Annual rainfall has 4-5 years as return period respectively. AMJ temperature has dominant peak of 8-10 years while AMJ rainfall has dominant peak of 2-3 and 14-15 years as return period respectively. The JAS mean monthly temperature has dominant peaks of 1 year and 10-12 while JAS monthly rainfall has dominant peak of 2-3 years as return period respectively. OND mean monthly temperature has 5-6 years while OND rainfall has dominant peak of 1 year as return period respectively

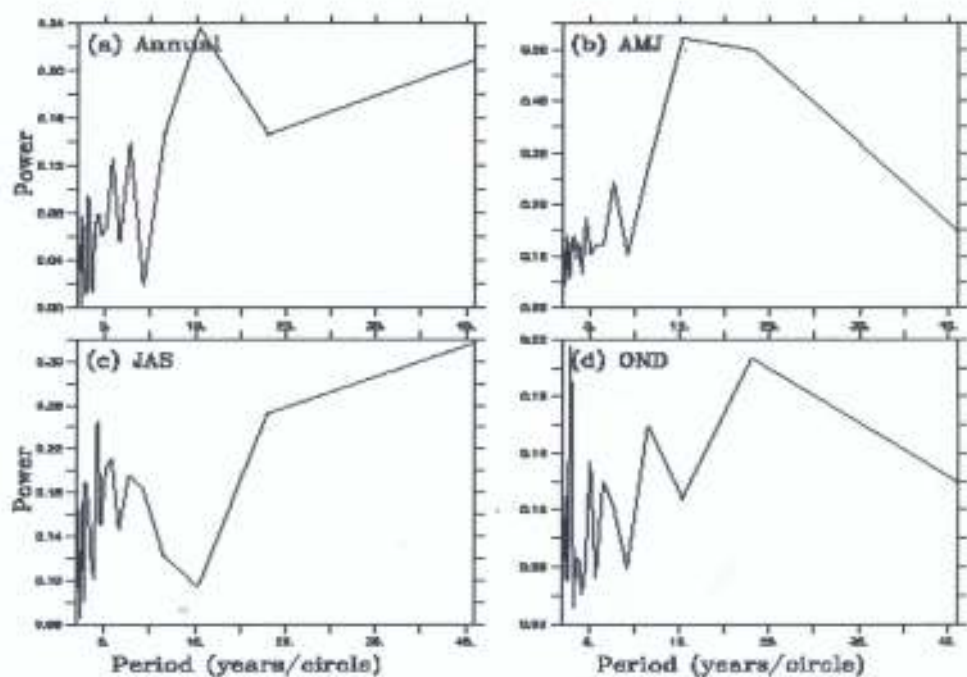


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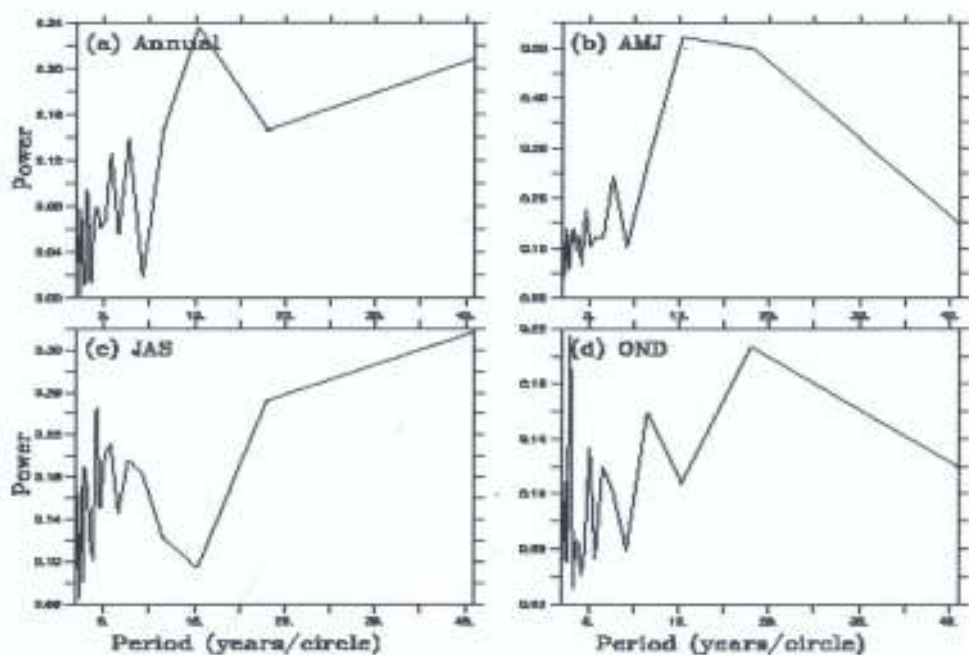


(ii)

Figure 24: Auto correlation spectral analysis of Akure (i) monthly mean temperature and (ii) monthly rainfall for; (a) Annual (b) AMJ (c) JAS & (d) OND

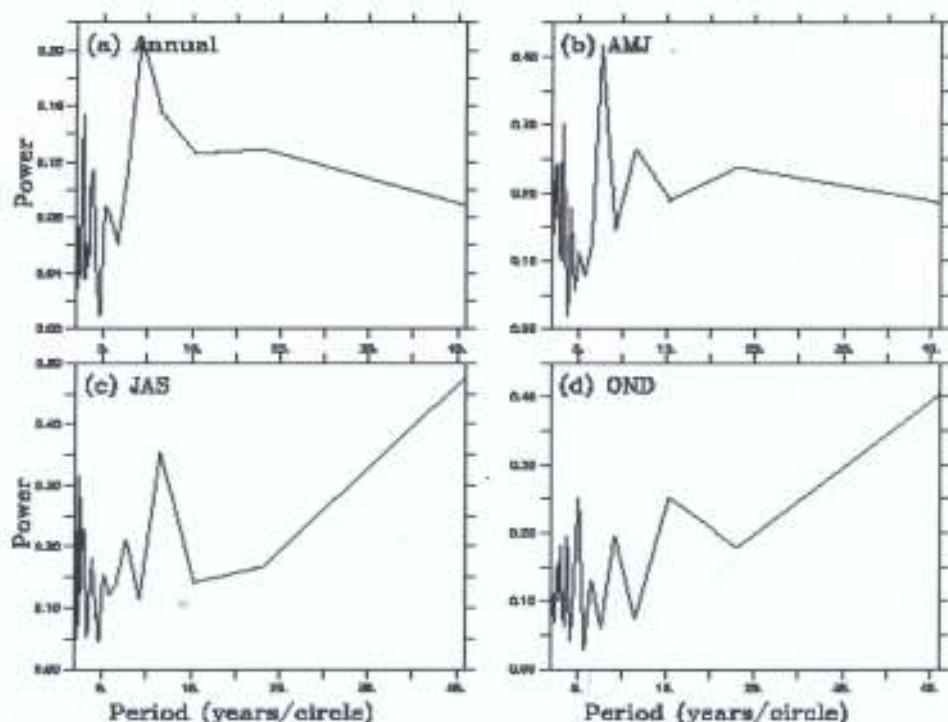


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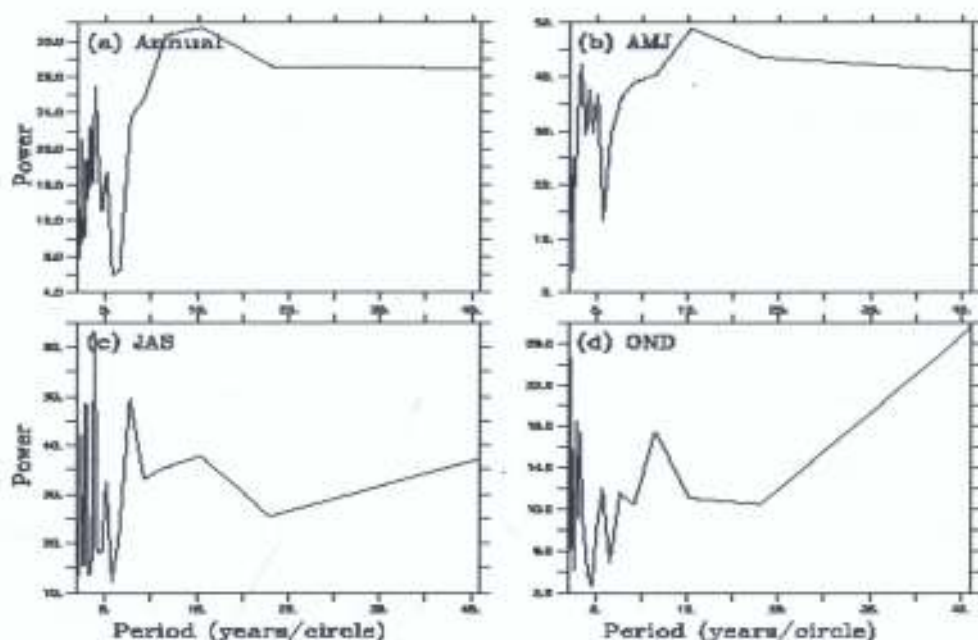


(ii)

Figure 25: Autocorrelation spectral analysis of Bauchi (i) mean monthly temperature and (ii) monthly rainfall for; (a) Annual (b) AMJ (c) JAS (d) OND



(i)



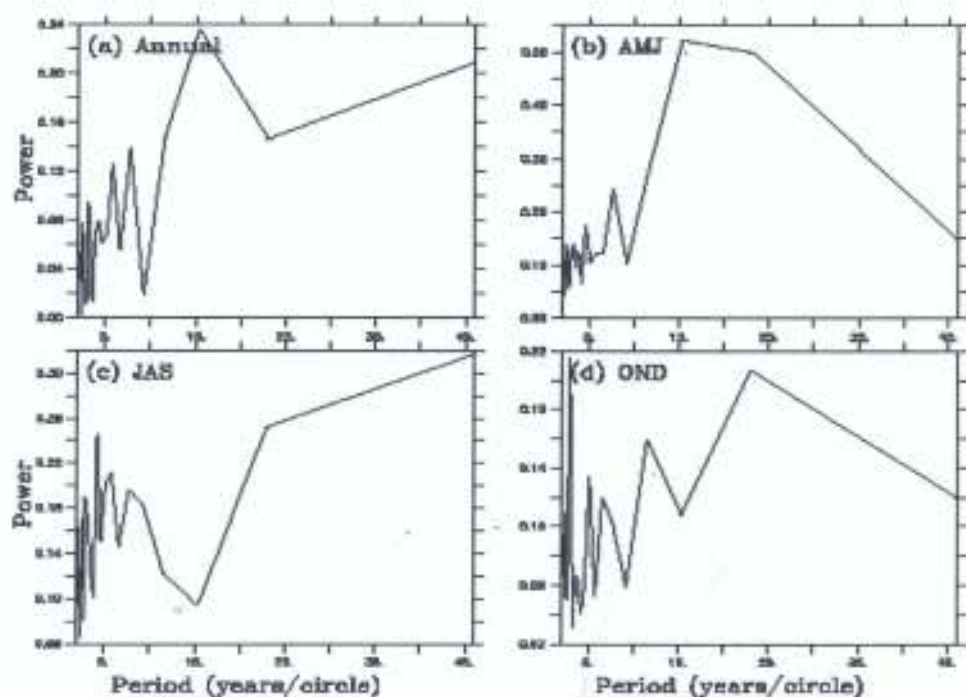
(ii)

Figure 26: Auto correlation spectral analysis for Benin (i) mean monthly temperature and (ii) monthly rainfall for; (a) Annual, (b) AMJ, (c) JAS and (d) OND seasons

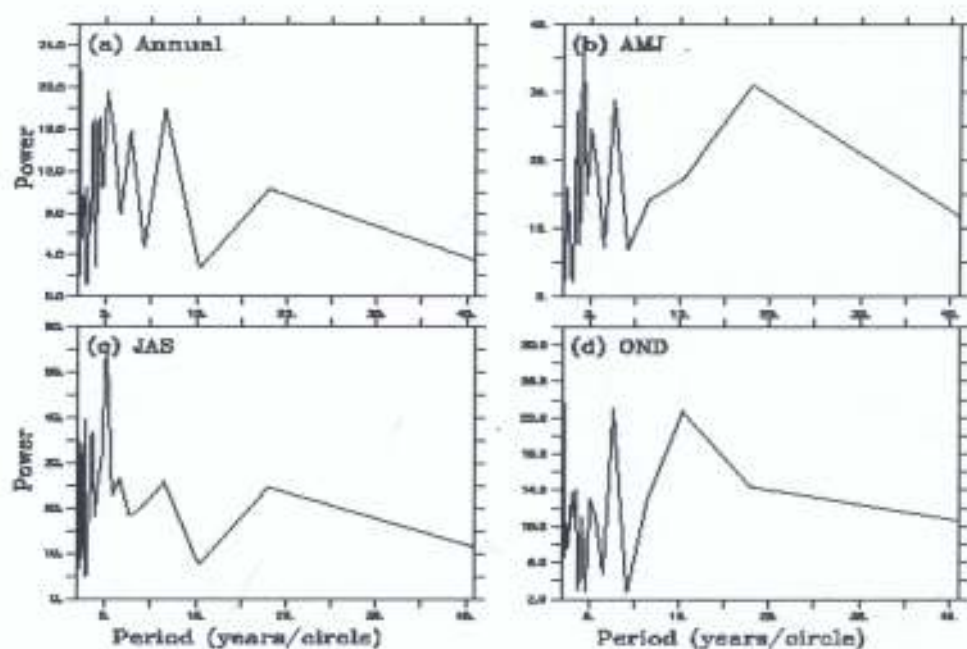
Figure 27 shows auto correlation spectral analysis for calabar mean monthly temperature and monthly rainfall for Annual, AMJ, JAS and OND. Annual temperature has dominant peaks of 5-6, 8-10 and 16-20 while annual rainfall has dominant peak of 5-6 years as return period respectively. AMJ temperature and rainfall have dominant peaks of 6-7 years and 4-5 years as return period respectively. JAS temperature and rainfall have dominant peaks of 4-5 years and 5-6 years as return period respectively. OND temperature and rainfall have dominant peaks of 2-3 years and 8-10 years as return period respectively.

Figure 28 shows auto correlation spectral analysis (ASA) of Enugu mean monthly temperature and monthly rainfall for Annual, AMJ, JAS and OND. Annual temperature and rainfall have dominant peaks of 10-13 years as return period. AMJ temperature and rainfall have dominant peaks of 10-12 years and 2-3 years as return period respectively. JAS temperature and rainfall have dominant peaks of 20-23 years and 1-2 years as return period respectively. OND temperature and rainfall have dominant peaks of 10-12 years and 3-5 years as return periods.

Figure 29 shows auto correlation spectral analysis for Gusua mean monthly temperature and monthly rainfall. Annual temperature and rainfall have dominant peaks of 8-10 years and 2year as return period. JAS and OND temperature have dominant peaks of 7 years and 20 years as return period. JAS and OND rainfall have dominant peaks of 1 and 2 years as return periods

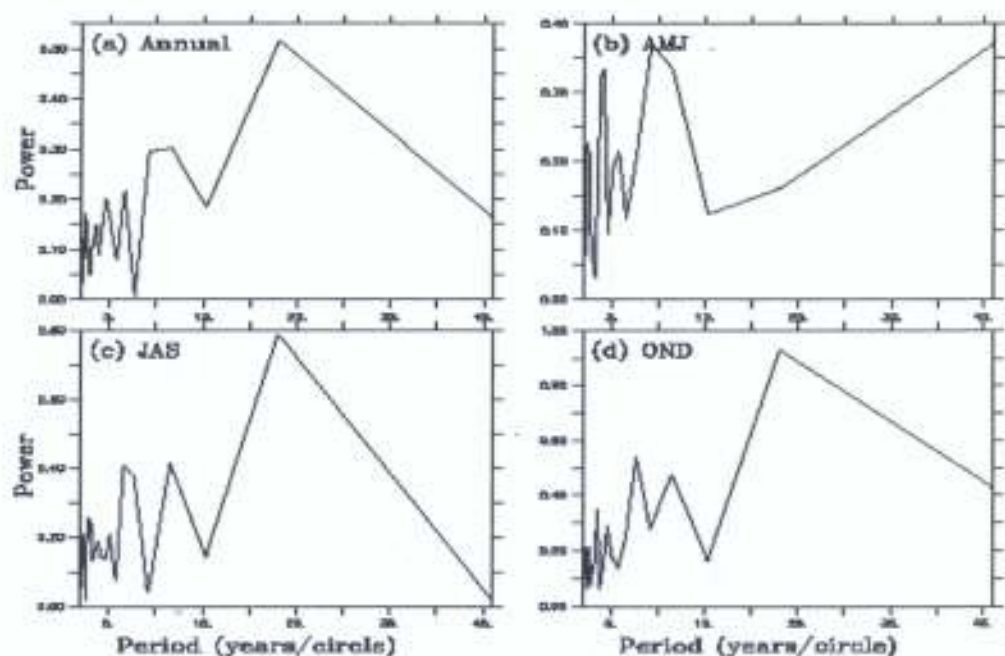


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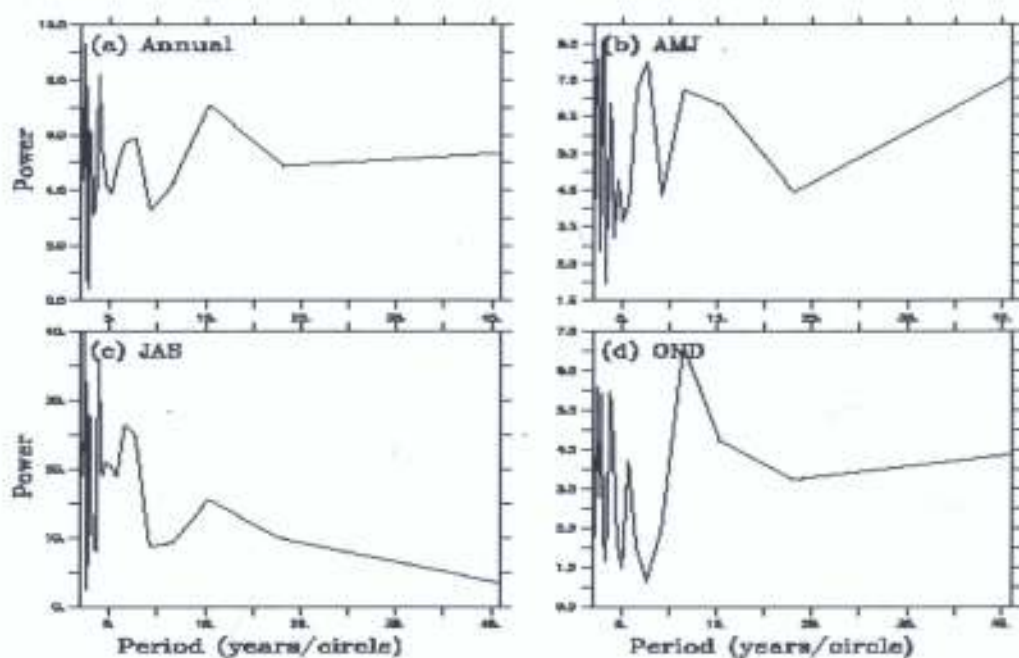


(ii)

Figure 27: Auto correlation spectral analysis for calabar (i) mean monthly temperature and (ii) monthly rainfall for; (a) Annual, (b) AMJ, (c) JAS and OND.

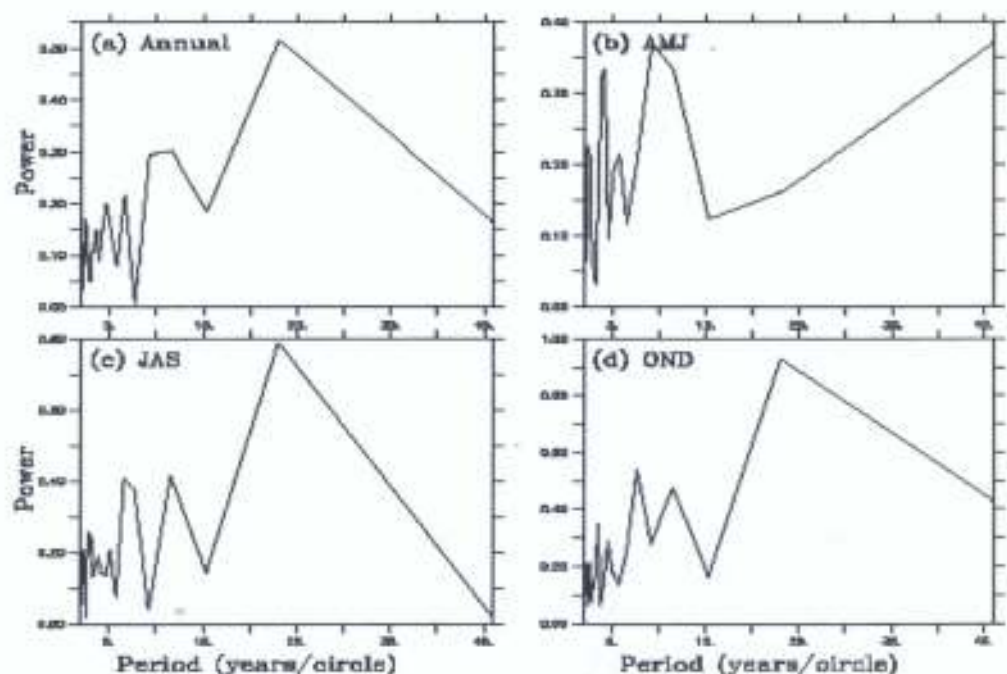


(i)

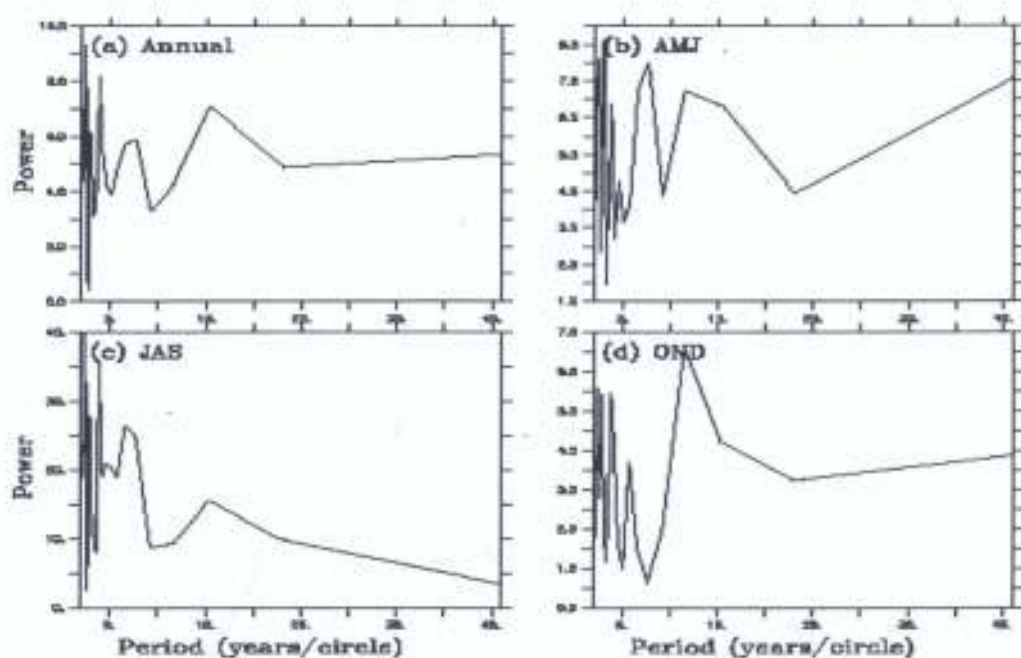


(ii)

Figure 28: Auto correlation spectral analysis of Enugu (i) mean monthly temperature and (ii) monthly rainfall for; (a) Annual (b) AMJ (c) JAS & (d) OND



(i)



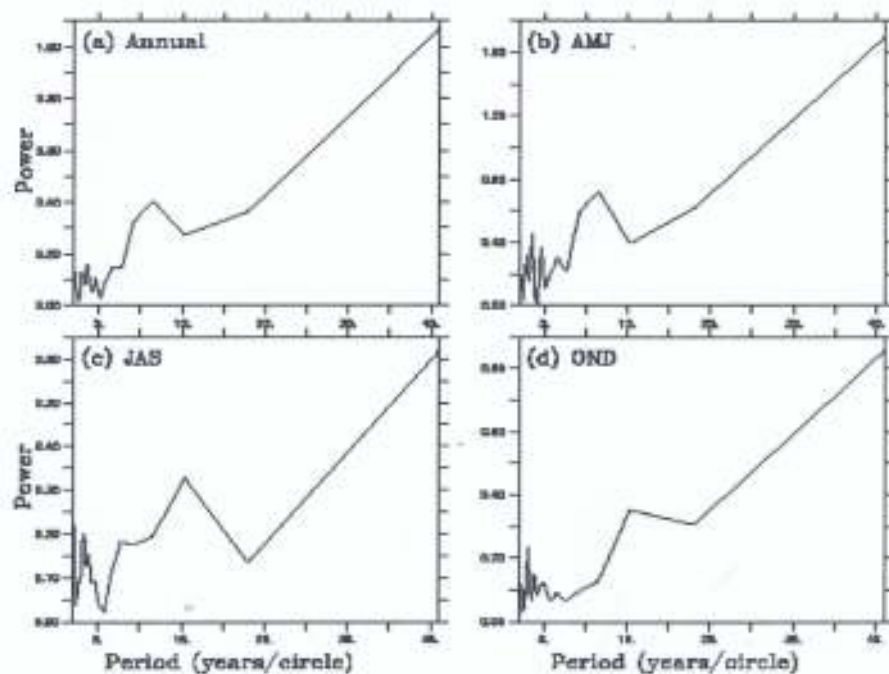
(ii)

Figure 29: Auto correlation spectral analysis of Gusua (i) mean monthly temperature and (ii) monthly rainfall for; (a) Annual, (b) AMJ, (c) JAS and OND seasons

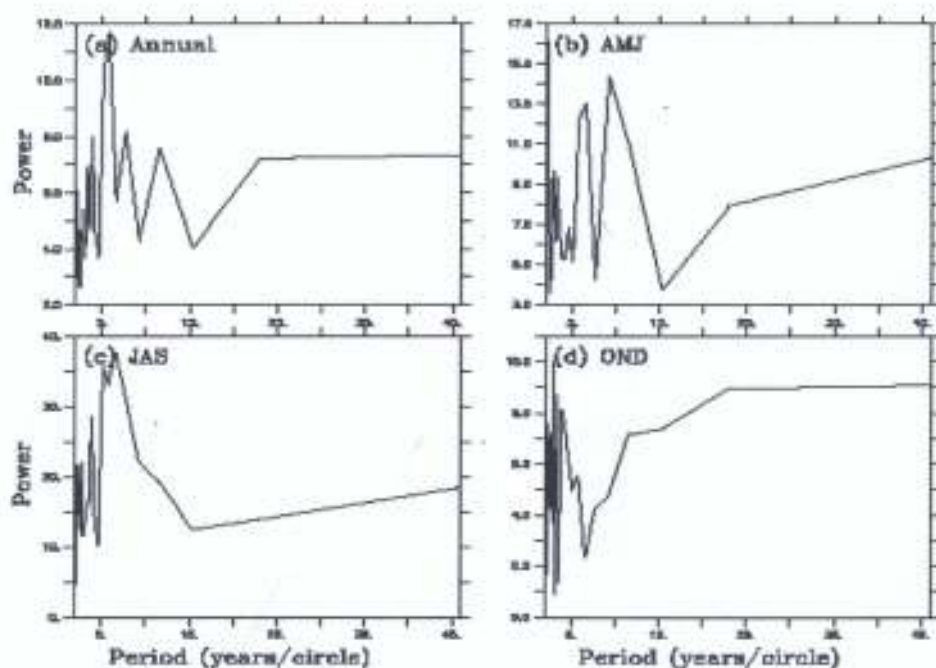
Figure 30 shows auto correlation spectral analysis of Ibadan mean monthly temperature and monthly rainfall. Annual temperature and rainfall have dominant peaks of 3 years, 10 years and 6 years as return periods respectively. AMJ temperature has dominant peaks of 3 years and 10-12 while AMJ rainfall has dominant peak of 6 years and 10 years as return periods respectively. JAS temperature has dominant peaks of 2 years and 15 years while JAS rainfall has dominant peak of 6 years as return periods respectively. OND temperature and rainfall have dominant peaks of 3 years and 2 years as return periods respectively.

Figure 31 shows Auto-correlation spectral analysis of Ikeja mean monthly temperature and monthly rainfall for Annual, AMJ, JAS and OND seasons. Annual temperature has dominant peaks of 2 years, 6 years and 12-13 years while annual rainfall has dominant peaks of 2 years and 10 years as return periods respectively. AMJ temperature and rainfall have dominant peaks of 5-6 years and 2 years as return periods respectively. JAS temperature has dominant peaks of 5-6 years and 10-13 years while JAS rainfall has dominant peak of 3 years and 5-6 years as return period respectively. OND temperature and rainfall have dominant peaks of 2 years and 5-6 years as return periods respectively

Figure 32 shows Auto correlation spectral analysis for Iseyin mean monthly temperature and monthly rainfall for Annual, AMJ, JAS and OND seasons. The annual mean monthly temperature has dominant peaks of 5 years and 10-12 years while Annual monthly rainfall has dominant peak of 2-3 years as return periods respectively. AMJ and JAS temperature have dominant peaks of 8-10 years and 2 years as return period respectively, while AMJ and JAS rainfall have dominant peaks of 2 years and 3-4 years respectively. OND temperature and rainfall have return periods of 5 years and 1-2 years respectively.

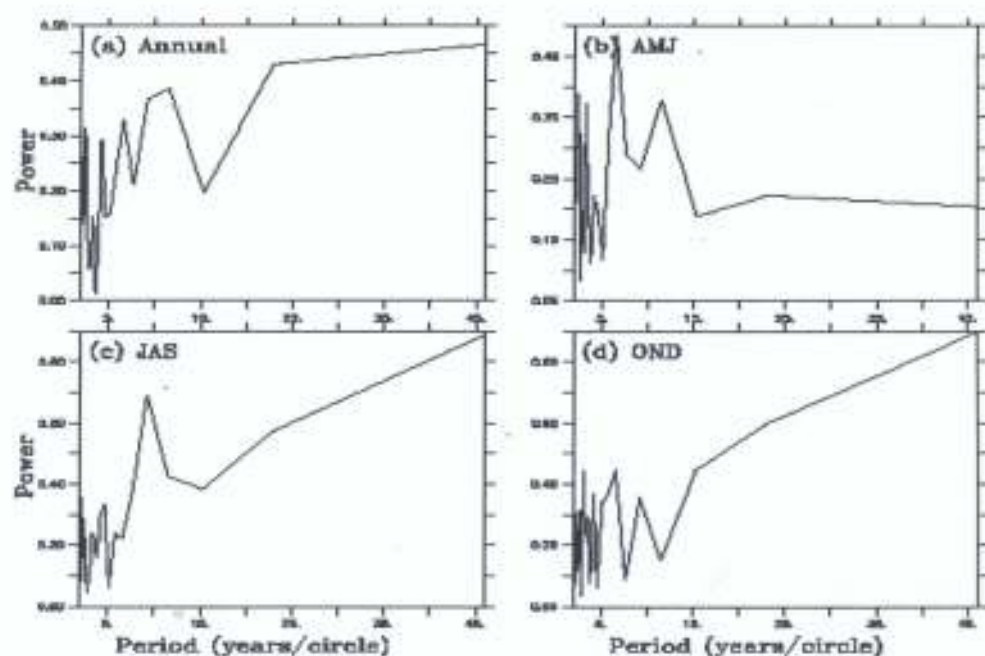


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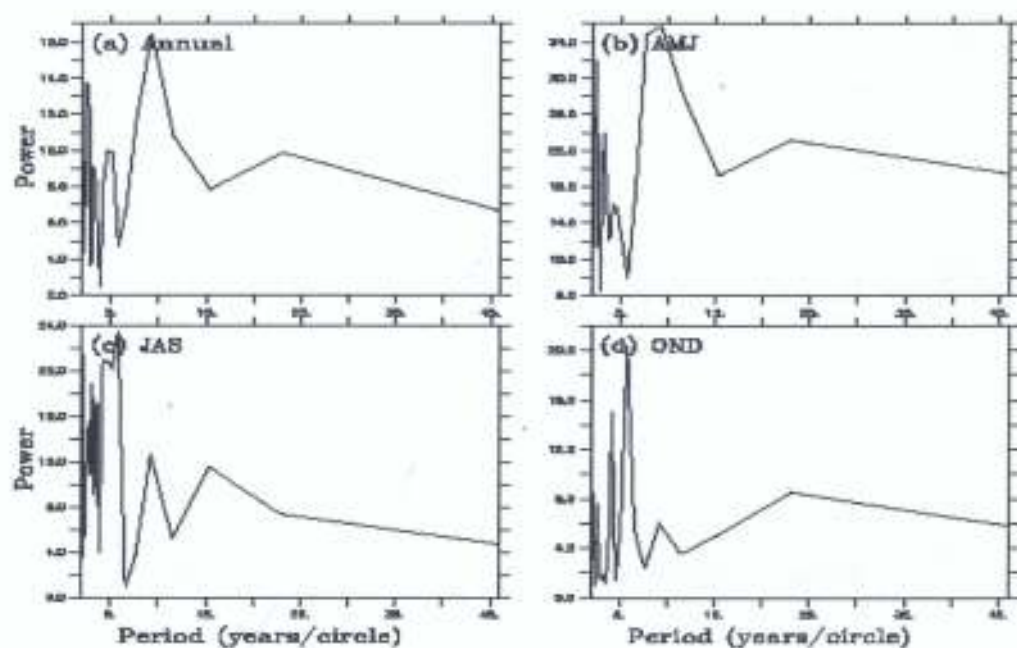


(ii)

Figure 30: Auto correlation spectral analysis of Ibadan (i) mean monthly temperature and (ii) monthly rainfall for; (a) Annual, (b) AMJ, (c) JAS and (d) OND seasons

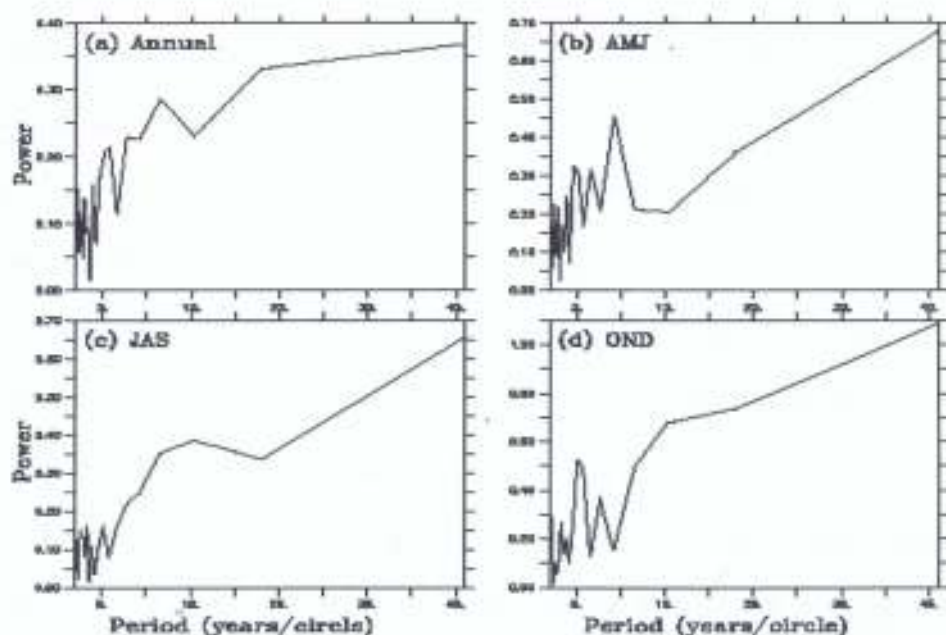


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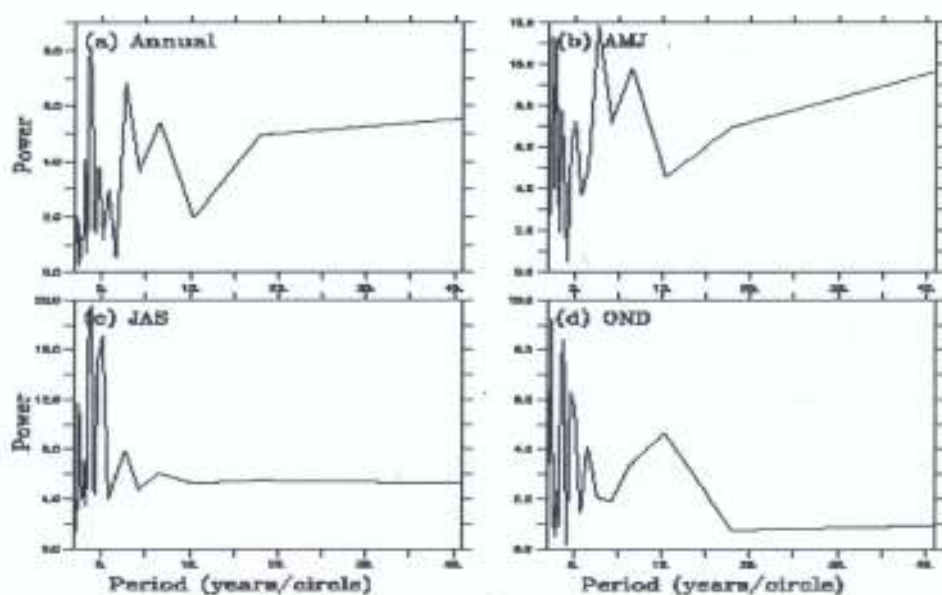


(ii)

Figure 31: Auto-correlation spectral analysis of Ikeja (i) mean monthly temperature and (ii) monthly rainfall for; (a) Annual, (b) AMJ, (c) JAS and (d) OND seasons



(i)



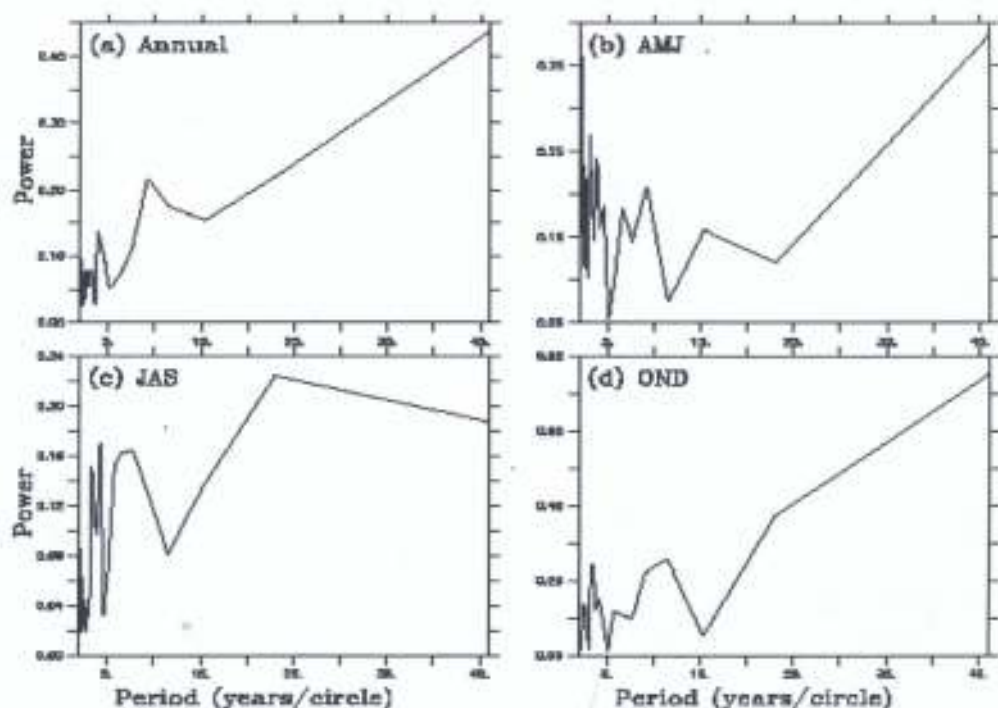
(ii)

Figure 32: Auto correlation spectral analysis for Iseyin (i) mean monthly temperature and (ii) monthly rainfall for; (a) Annual, (b) AMJ, (c) JAS and (d) OND seasons

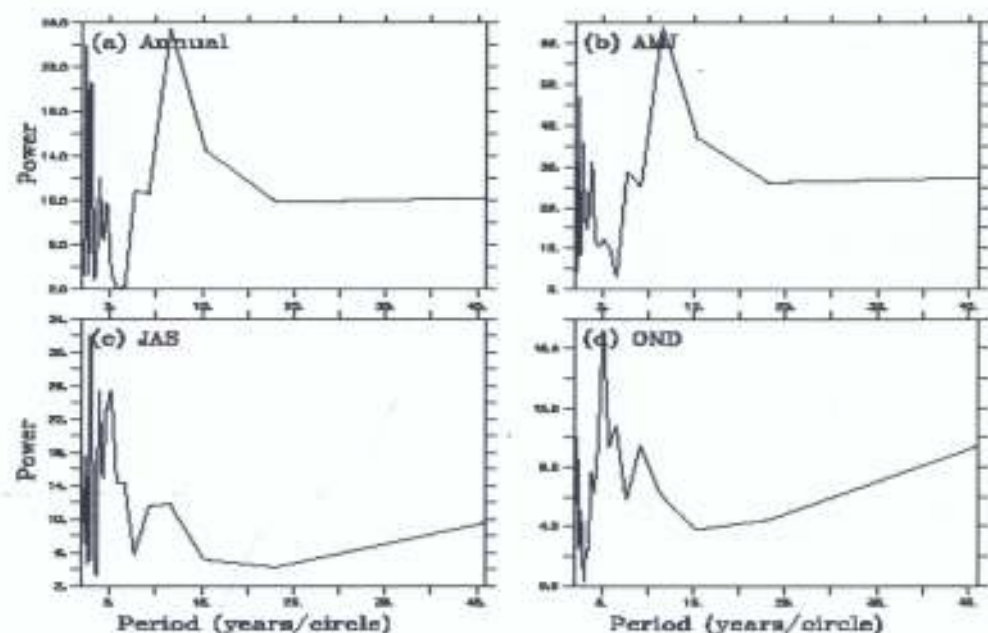
Figure 33 shows auto correlation spectral analysis for Lagos mean monthly temperature and monthly rainfall for annual, AMJ, JAS and OND seasons. Annual temperature has dominant peaks of 4 years and 10-12 years as return period while Annual rainfall has dominant peaks of 2 years and 10 years as return period. AMJ and JAS temperatures have dominant peaks of 2 years and 3 years as return periods. AMJ and JAS rainfalls have dominant peaks of 10-12 years and 2 years respectively. While OND temperature has dominant peak of 2 years as return period, and OND rainfall has dominant peak of 5 years as return period.

Figure 34 show auto correlation spectral analysis for Maiduguri mean monthly temperature and monthly rainfall. Annual temperature and rainfall have dominant peaks of 3 years and 2 years as return periods respectively. AMJ temperature has dominant peaks of 3 years and 10-12 years while AMJ rainfall has dominant peak of 2 years as return periods respectively. JAS temperature has dominant peaks of 3 years and 7-8 years as return period and JAS rainfall has dominant peaks of 3, 5 and 15 years as return periods. OND temperature has dominant peak of 22-25 years of return period and OND rainfall has dominant peak of 2 years and 7 years of return period.

Figure 35 shows auto correlation spectral analysis for Minna mean monthly temperature and monthly rainfall for Annual, AMJ, JAS and OND seasons. Annual temperature has dominant peaks of 2 years and 20-25 years of return period, while Annual rainfall has dominant peak of 5 years as return period. AMJ temperature has dominant peaks of 12-14 years while AMJ rainfall has dominant peak of 4 years as return period. JAS temperature has dominant peaks of 2-3 years and 20-22 years as return period and OND temperature has dominant peaks of 3 years and 12-15 years as return period. JAS and OND rainfalls have dominant peaks of 6 years and 3 years as return periods respectively

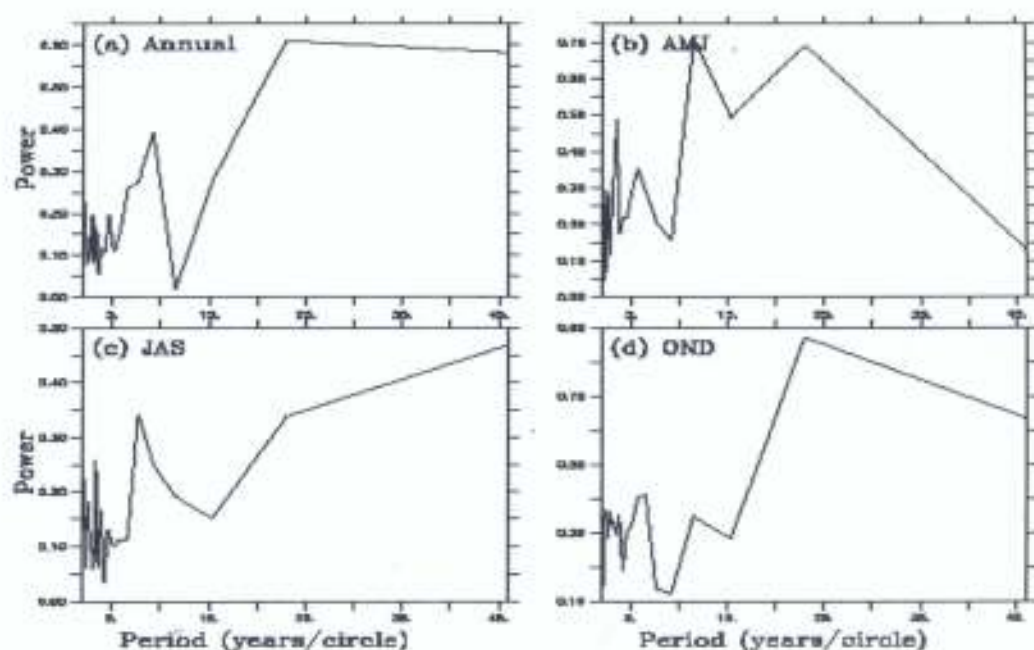


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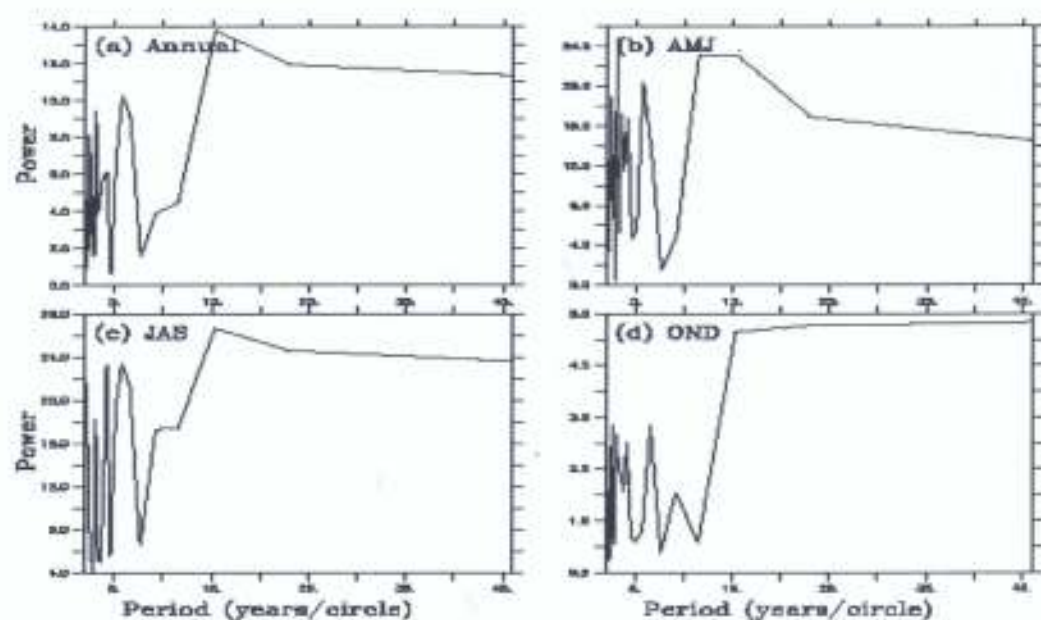


(ii)

Figure 33: Auto correlation spectral analysis for Lagos (i) mean monthly temperature and (ii) monthly rainfall for; (a) Annual, (b) AMJ, (c) JAS and (d) OND seasons

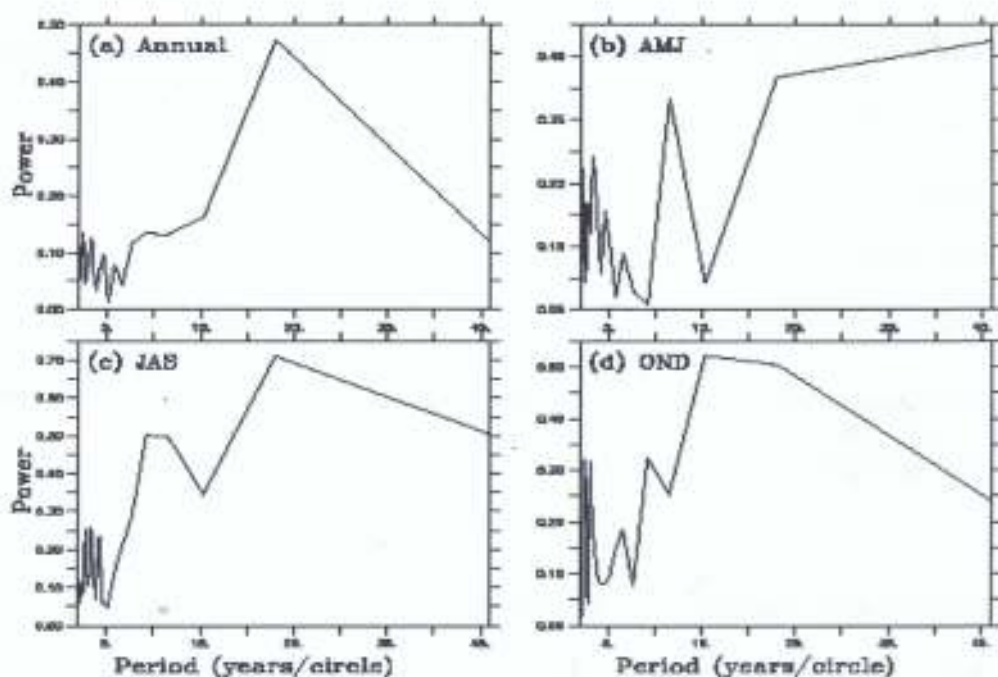


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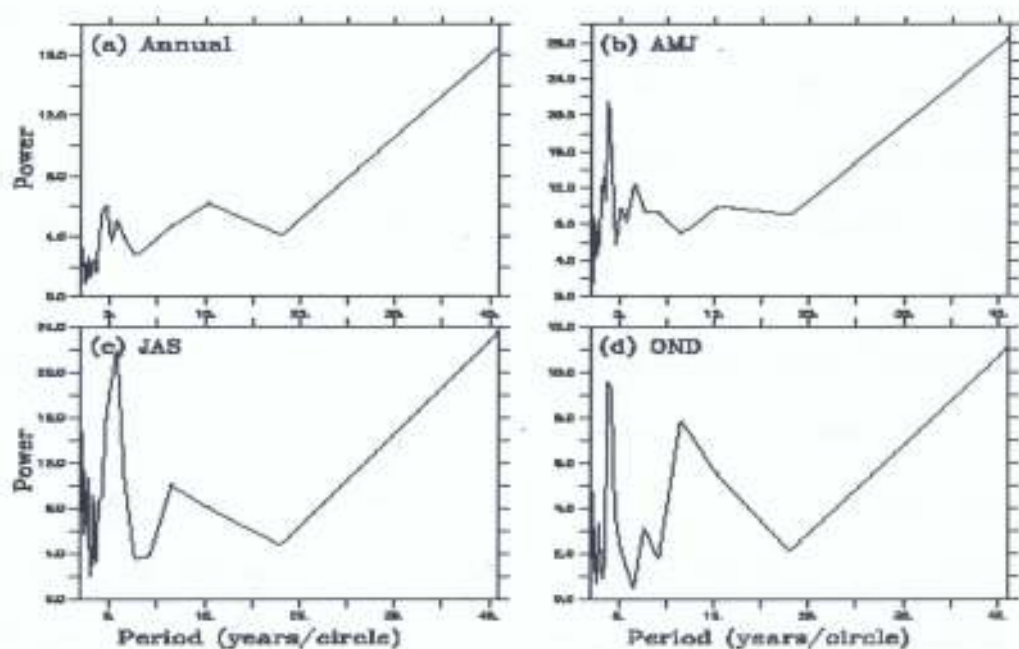


(ii)

Figure 34: Auto correlation spectral analysis for Maiduguri (i) mean monthly temperature and (ii) monthly rainfall for; (a) Annual, (b) AMJ, (c) JAS and (d) OND seasons



(i)



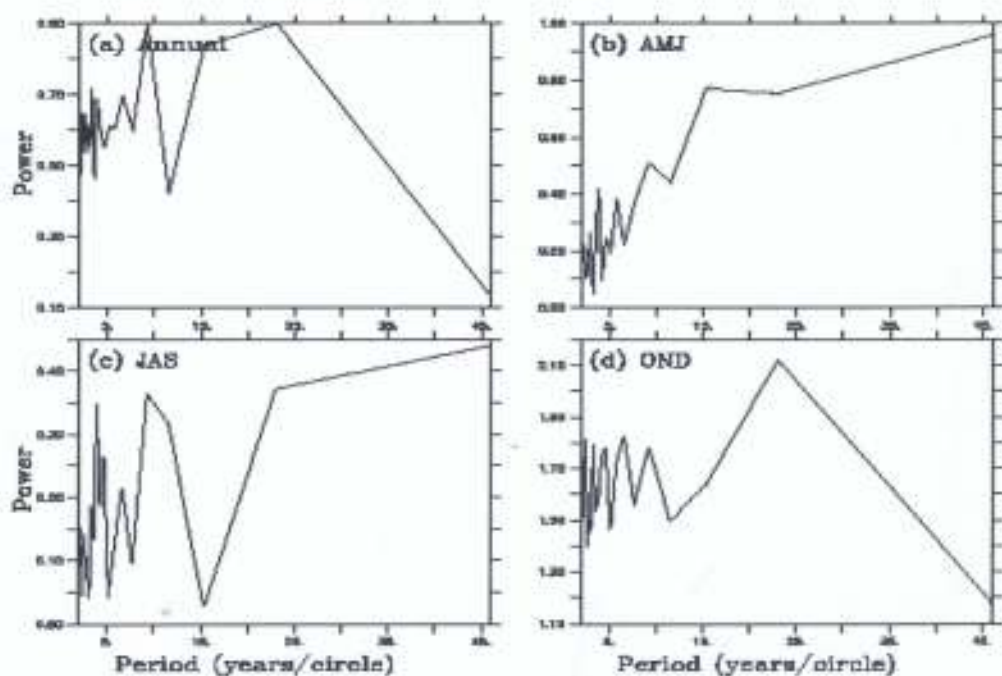
(ii)

Figure 35: Auto correlation spectral analysis for Minna (i) mean monthly temperature monthly rainfall for; (A) Annual, (b) AMJ, (c) JAS and (d) OND seasons

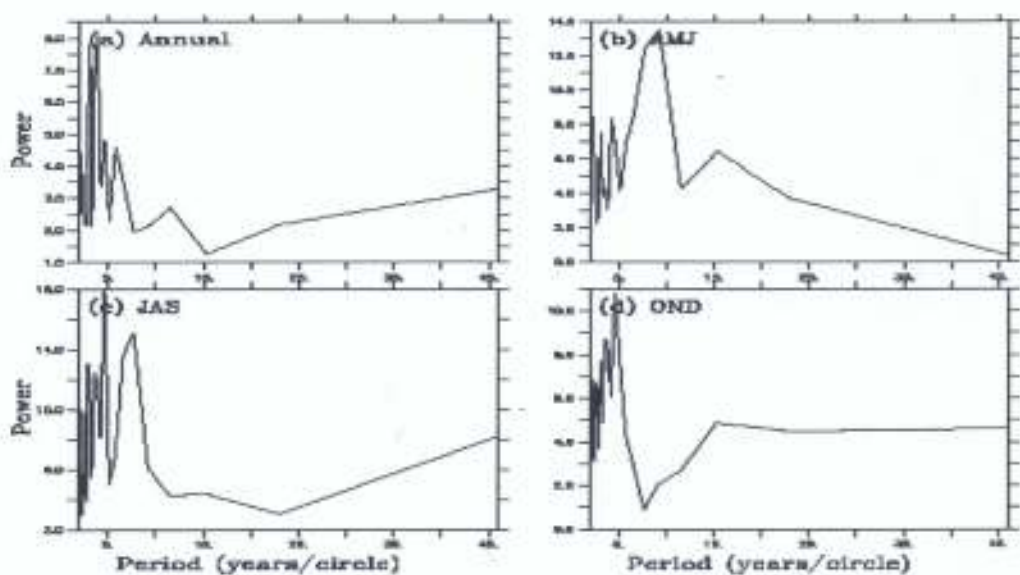
Figure 36 shows auto correlation spectral analysis for Oshogbo mean monthly temperature and monthly rainfall for Annual, AMJ, JAS and OND seasons. Annual mean monthly temperature has dominant peaks of 10 years and 20 years while Annual monthly rainfall has dominant peaks of 2 years and 3 years as return period respectively. AMJ temperature has dominant peaks 3, 15 and 25 years while AMJ rainfall has dominant peaks of 1 and 8-10 years as return period respectively. JAS temperature has dominant peaks of 3 and 10 years as return period. OND temperature has dominant peaks of 2 and 20-22 years of return period. JAS and OND rainfalls have dominant peaks of 4 and 5 years as return period respectively.

Figure 37 shows auto correlation spectral analysis for Port Harcourt mean monthly temperature and monthly rainfall for Annual, AMJ, JAS and OND seasons. The annual mean monthly temperature has dominant peak of 2 years as return period while annual monthly rainfall has dominant peaks of 6 and 10 years as return period. AMJ temperature has dominant peaks of 2 and 5 years as return period and AMJ rainfall has dominant peak of 3 and 10 years of return period. JAS and OND temperatures have dominant peaks of 3 years each as return period respectively. JAS and OND rainfalls have dominant peaks of 10 and 5 years as return period.

Figure 38 shows the auto correlation spectral analysis of Sokoto monthly rainfall and mean monthly temperature. Annual dominant peak in temperature repeats itself every 13-15 years while the dominant peaks in rainfall come back every 1-2, 5-6years and 13-15 years. AMJ dominant peak in temperature has return period of 15 years while the dominant peak in rainfall has 8-10 years as return period. JAS dominant peak in temperature has 1-2 years as return period while the dominant peak in rainfall has return period of 10-12 years. OND dominant peak in rainfall has 8-10 years of return period and the dominant peak in temperature has return period of 15 years.

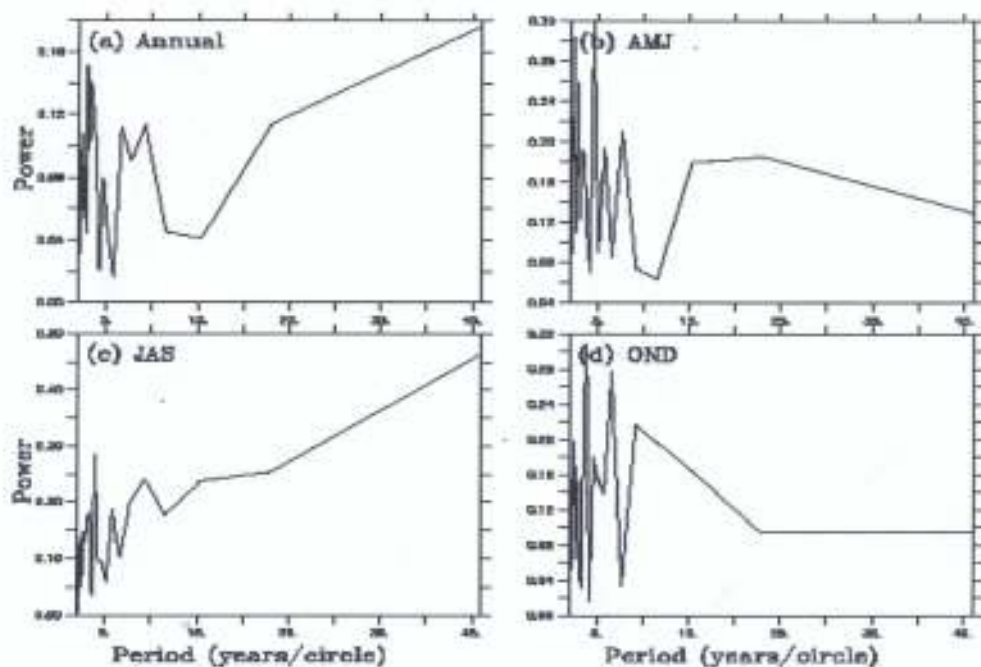


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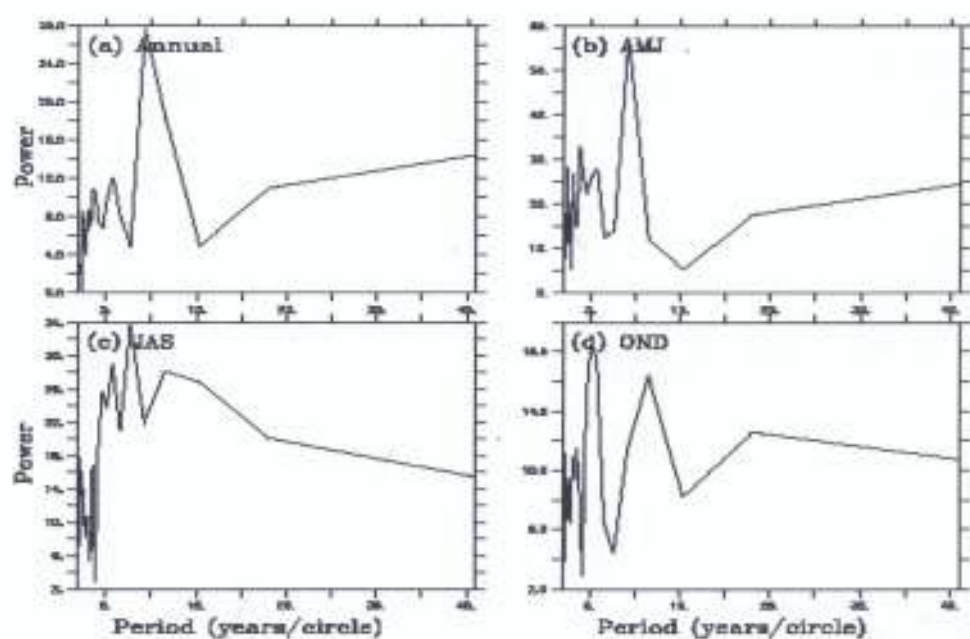


(ii)

Figure 36 shows auto correlation spectral analysis for Oshogbo (i) mean monthly temperature and (ii) monthly rainfall for; (a) Annual, (b) AMJ, (c) JAS and (d) OND seasons

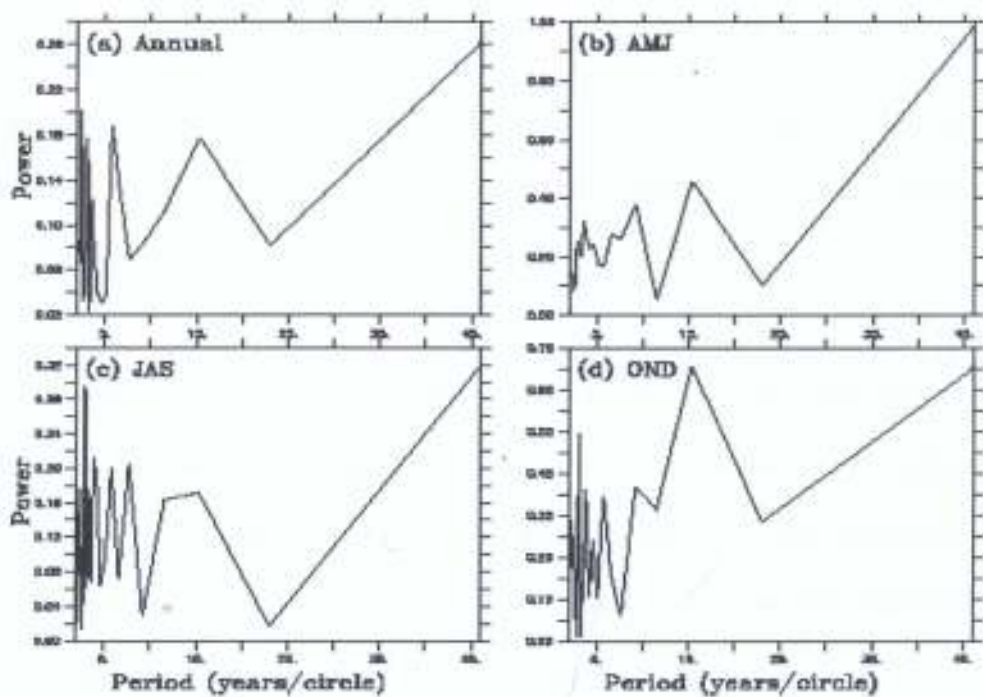


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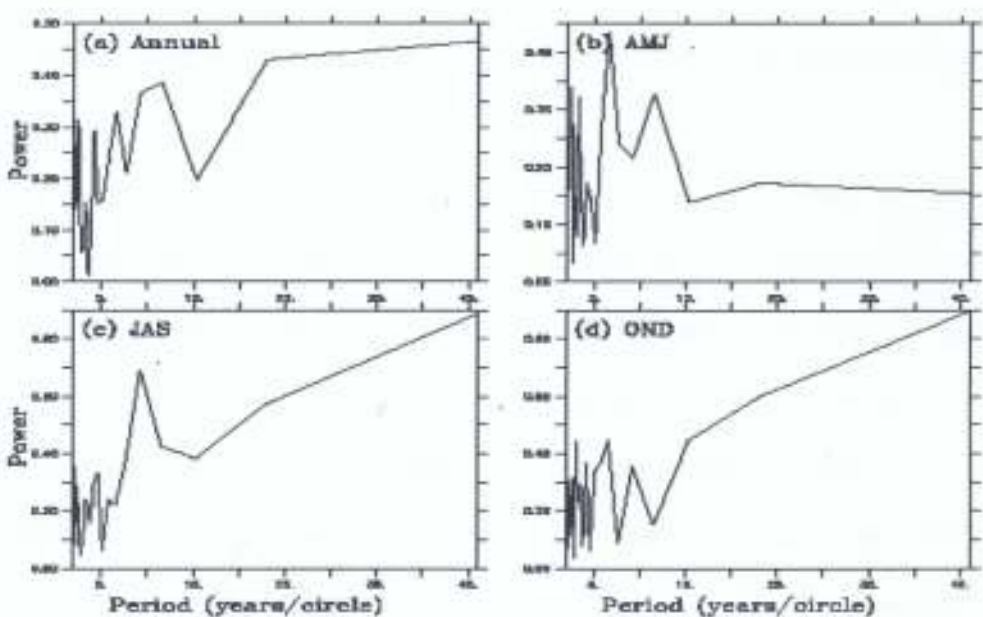


(ii)

Figure 37: Auto correlation spectral analysis for Port Harcourt (i) mean monthly temperature and (ii) monthly rainfall for annual, AMJ, JAS and OND seasons



(i)



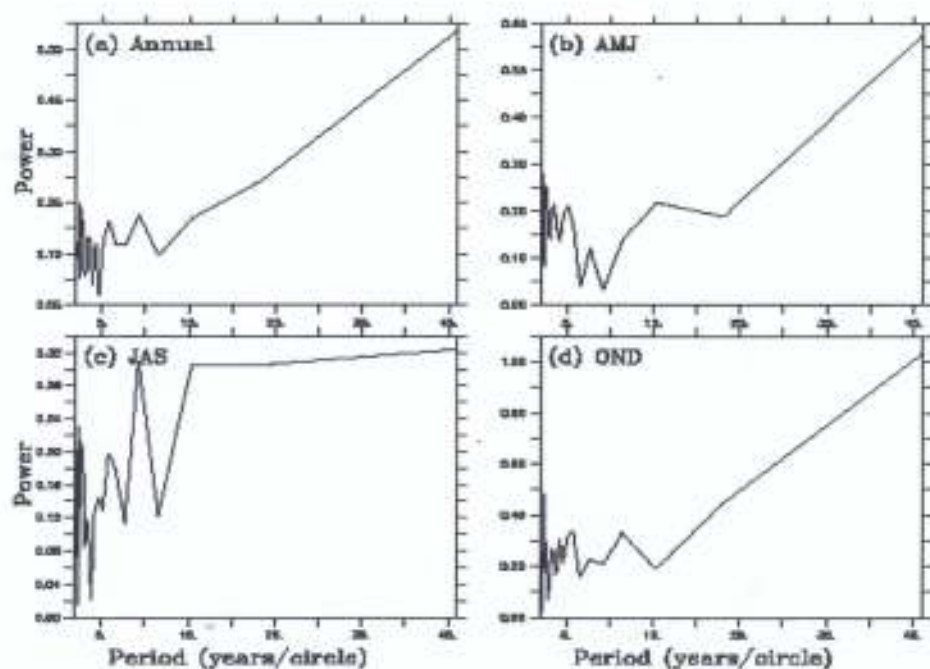
(ii)

Figure 38: Autocorrelation spectral analysis of Sokoto (i) mean monthly temperature and (ii) monthly rainfall for; (a) Annual (b) AMJ (c) JAS and (d) OND

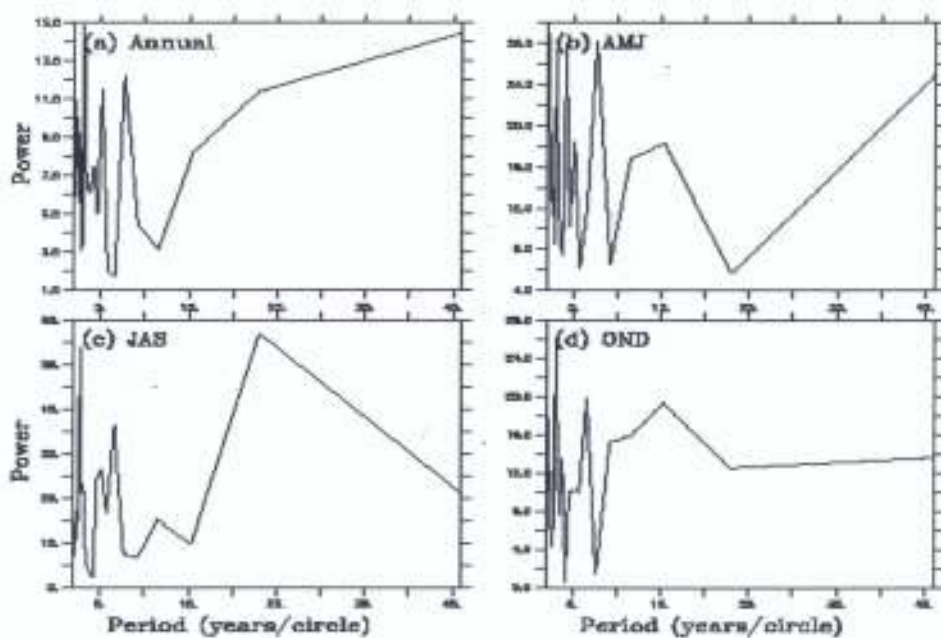
Figure 39 shows auto correlation spectral analysis for Warri mean monthly temperature and monthly rainfall for Annual, AMJ, JAS and OND seasons. Annual temperature as well as AMJ, JAS and OND temperatures have dominant peaks of 1 year of return period each. Annual rainfall as well as AMJ, JAS and OND rainfalls have dominant peak of 1 year of return period each.

Figure 40 shows auto correlation spectral analysis for Yelwa mean monthly temperature and monthly rainfall for annual, AMJ, JAS and OND seasons. The annual temperature has a dominant peak of 5 years as return period. AMJ temperature has a dominant peak of 10 years of return period. JAS temperature has dominant peaks of 1 year and 10years of return period. OND temperature has dominant peaks of 6 years and 15 years of return periods. Annual rainfall has dominant peaks of 1 year and 14 years of return period. AMJ rainfall has dominant peaks of 3 years and 15 years of return period. JAS and OND rainfalls have a dominant peak of 4 years of return period each

Figure 41 shows auto correlation spectral analysis for Yola mean monthly temperature and monthly rainfall for Annual, AMJ, JAS and OND seasons. Annual temperature has dominant peaks of 7 and 15 years of return period. AMJ temperature has a dominant peak of 6 years of return period. JAS temperature has a dominant peak of 6 years of return period. OND temperature has a dominant peak of 4 years of return period. Annual rainfall has dominant peaks of 5 and 15 years of return period. AMJ rainfall has a dominant peak of 1year and 15 years of return period. JAS and OND rainfalls have dominant peaks of 2 years and 8 years as return period respectively.

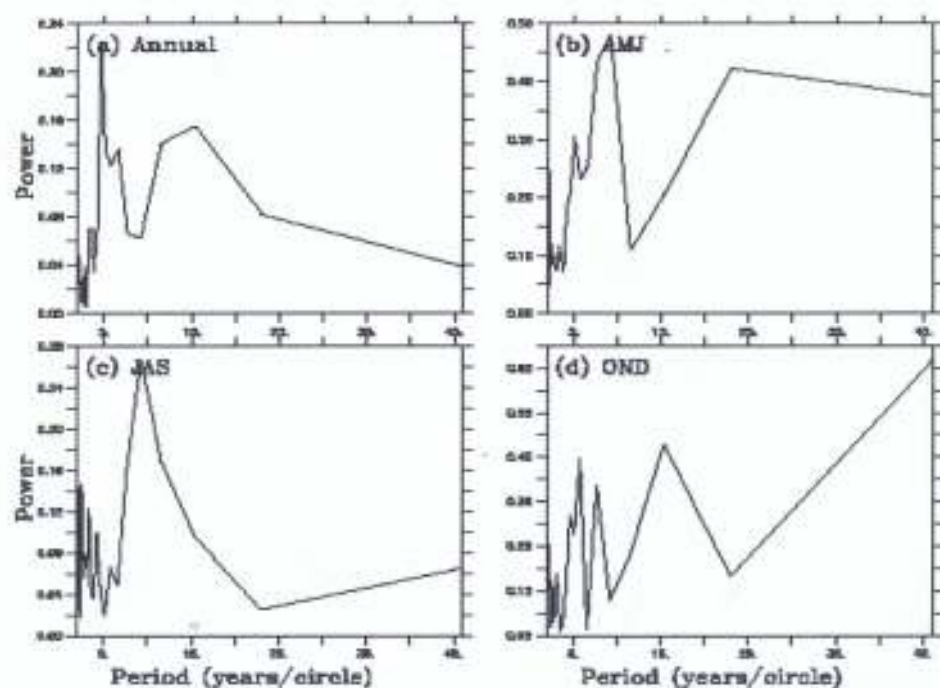


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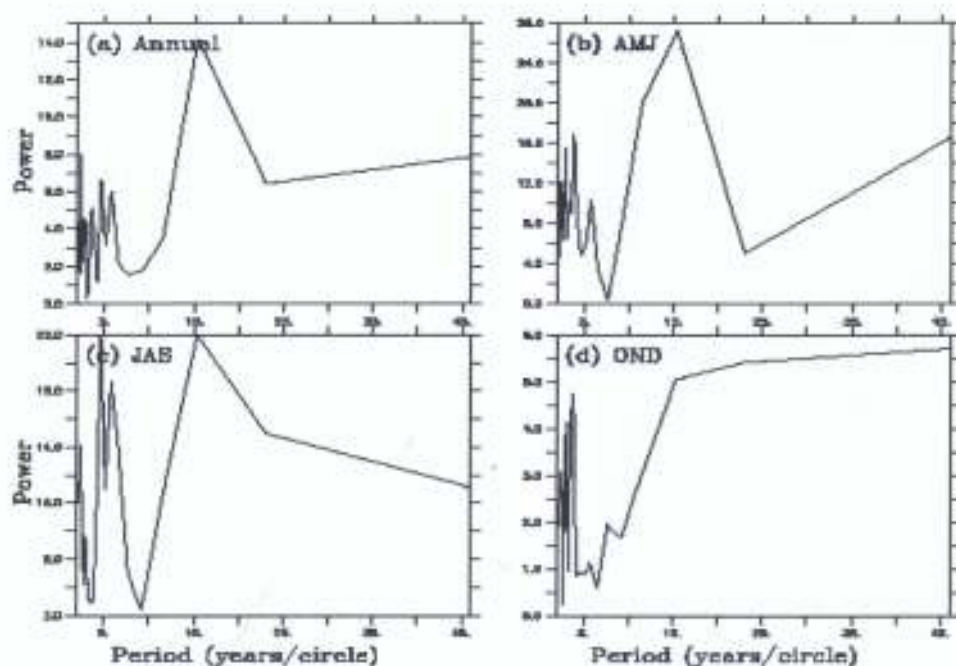


(ii)

Figure 39: Auto correlation spectral analysis for Warri (i) mean monthly temperature and (ii) monthly rainfall for; (a) Annual, (b) AMJ, (c) JAS and (d) OND seasons

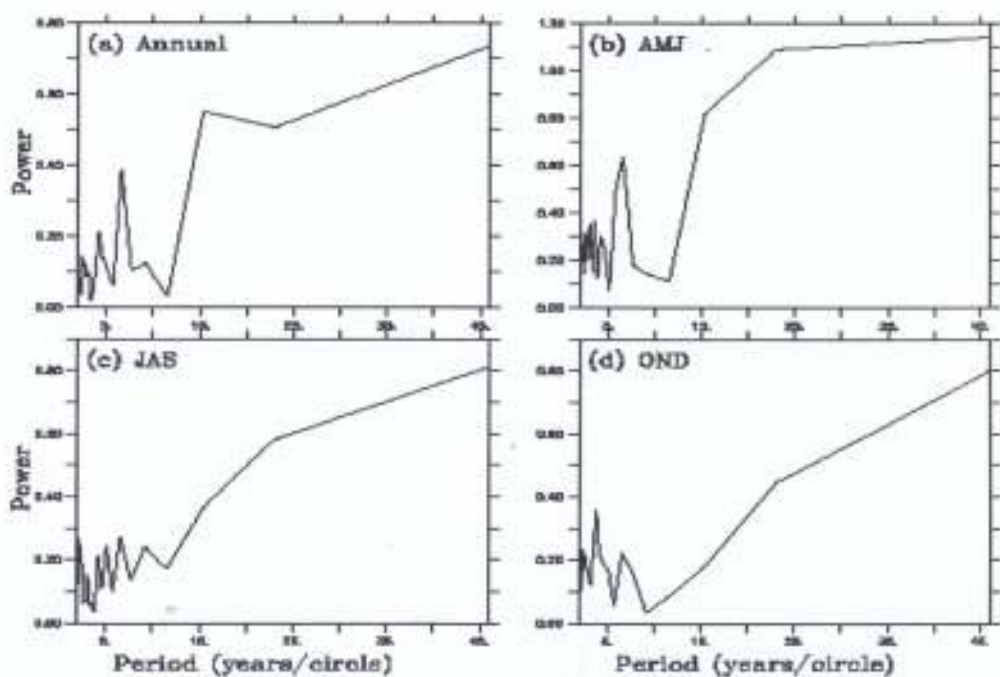


(i)

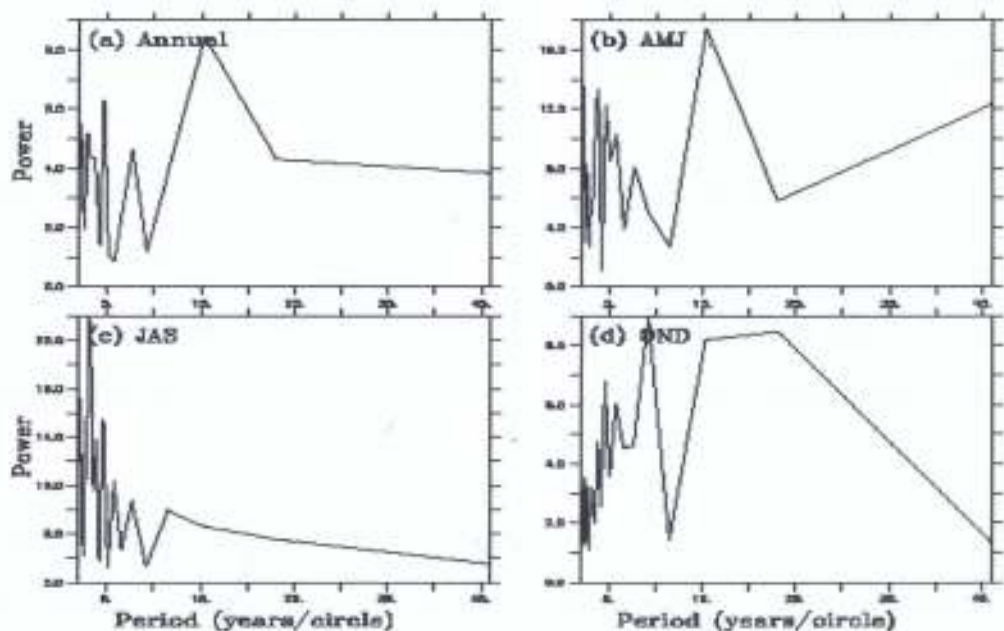


(ii)

Figure 40: Auto correlation spectral analysis for Yelwa (i) mean monthly temperature and (ii) monthly rainfall for; (a) Annual, (b) AMJ, (c) JAS and (d) OND seasons



(i)



(ii)

Figure 41: Auto correlation spectral analysis for Yola (i) mean monthly temperature and (ii) monthly rainfall for; (a) Annual, (b) AMJ, (c) JAS and (d) OND seasons

4.4 DISCUSSION

Table 24: Summary of the Implications of the study on Agriculture and Water Resource

Trends Status	Stations under the Category	Implications on Water Resource and Agriculture
Decrease in temperature and rainfall trends	Akure, Maiduguri	Drought and shortage of moisture content are probable in the stations. Benin is inclusive.
Increase in temperature and rainfall trends	Oshogbo, P/Harcourt, Sokoto, Warri, and Yelwa	Fair weather for Agriculture in the stations, except that Warri, Ibadan and P/Harcourt are likely to experience flood due to excess rainfall
Increase in temperature and decrease in rainfall	Abuja, Benin, Calabar, Lagos and Yola	Desertification and high level of under ground water depletion are probable.
Decrease in temperature and increase in rainfall	Abeokuta, Enugu, Ikeja, and iseyin	Flood is probable.
Increase in temperature and zero trend of rainfall	Minna and Bauchi	Desertification and high level of under ground water depletion are probable

The recent analysis on climate change (IPCC, 1995, 2007) showed that the globally average surface temperatures have increased by 0.6 ± 0.2 °C over the 20th century and likely to increase between 1.1-6.4 °C by the end of 21st century (IITA, 1992). In this study, covering twenty stations in Nigeria, it was observed that the

trends in stations have changed drastically from what the patterns used to be in the past. Reversal of trends was observed in some of the locations.

The results showed specifically that Akure and Maiduguri stations were decreasing in trends of both rainfall and temperature with magnitude of return period put at average of 2 years for rainfall and 5 years for temperature. On the other hand, Osogbo, Port Harcourt, Sokoto, Warri and Yelwa stations experienced upward trends in temperature and rainfall on annual basis. Stations that experienced upward trends in temperature and downward trends in rainfall are Abuja, Benin, Calabar, Lagos and Yola. The following stations; Abeokuta, Enugu, Ikeja and Iseyin experienced upward trends in rainfall and downward trends in temperature, while Minna and Bauchi stations experienced upward trends in annual temperature and rainfall showed no change in trend.

Ogunjobi et al (2004) confirmed and attributed the sharp increase in trends of temperature of Abuja to massive construction that followed relocation of the Federal Capital Territory from Lagos to Abuja. The magnitude of the return period at which the dominant peak of trend of Abuja temperature repeats itself was not stated in the paper. Likewise, from the study conducted in South Africa, it was established that there was a significant increase in mean annual temperature for the period of 1960 to 2003 (Kruger and Shongwe., 2004). Among the various Authors that work on trends of temperature across the globe, only few of them, of course not in Nigeria, established the cycles of return period of the dominant peaks.

Precipitation was noticed to be decreasing in the last two decades (Tosic and Unkasevic, 2000; Oguntinyinbo, 1979). Subbaramayya and Naidu (1992) made a detailed analysis of the monsoon rainfall for various sub-divisions of India using data for 1871-1988. The report showed that, a decreasing trend was noticed till the end of

the previous century and this was followed by an increase trend till the middle of the century. The trends started decreasing till 1970 to end of the observed year. In nutshell, there was a decrease in trends of rainfall in the last two and half decades.

Rainfall remains an important meteorological parameter which has direct influence on agricultural production and other aspects such as water resource (Maidu et al, 1999). Temperature and rainfall are principal controlling elements which determine the growing season and timing of agricultural activities most especially in Nigeria as well as other tropical regions (Odekunle, 2004).

The findings of this study have far reaching implications on both agriculture and water resources as summarized in table 23 above. The stations that experienced downward trends in temperature and rainfall are likely to face problems of drought and shortage of soil moisture content in no distant future. More also, when the rate of decline in trends of rainfall is greater than the rate at which temperature declines. Akure, Benin and Maiduguri stations fall under this category. Other stations that experienced upward trends of temperature and downward trend of rainfall are prone to desertification and depletion of underground water. Abuja, Calabar, Lagos and Yola stations fall under this category but the effect of desertification and depletion of underground water is more felt in Abuja and Yola than in Calabar and Lagos because of sharp increase in trend of temperature and fast decline in rainfall trends. Meanwhile, Lagos and Calabar will take longer years to get to such a worsen situation because there is a little variation at which temperature increases in trend and rainfall decreases in trend. Stations that experienced upward in trends of both temperature and rainfall portend to have fair and clement weather conditions for agricultural activities. Gusua, Ibadan, Osogbo, Port Harcourt, Sokoto, Warri and Yelwa fall under this category except that Port Harcourt, Sokoto and Warri are more prone to flood because

the rate at which rainfall increases in trend is more fast and sharp than the rate at which temperature also increases in trend. Ibadan is likely also to experience the repeat of flood of early 1980s known as "Omiyale" if proper drainage system is not provided in no- distant future and the existing drainages are allowed to be blocked. Mean while, Bauchi and Minna stations are prone to serious desertification and complete depletion of under ground water because of no change in trend of rainfall and continuous monotonic increase in temperature.

IITA Annual Report of 1992 reported that annual rainfall has declined in Nigeria over both time and space. While reductions of 100-313 millimeters occurred, depending on topography and location, each of the isohyets mapped indicated a southward shift (toward the ocean). The shift in balance between increasing temperature trend and decreasing rainfall trend will affect the crops that can be grown on residual soil moisture, thus render post rainy season cultivation extremely risky without supplemental irrigation.

5.1 Conclusion

In this study, trends and cycles of rainfall and temperature over Nigeria were determined through Auto correlation spectral analysis and Mann-Kendall non-parametric test. There were variations in the rainfall and temperature distributions on annual and monthly basis over Nigeria. The rates at which dominant temperature and rainfall peaks return also vary, impacting different effects on climate and agriculture. For example areas experiencing positive trends and dominant rainfall of short return period will likely be prone to flood. Likewise areas experiencing positive trends and dominant temperature peak of short return period will likely be prone to drought and desertification.

5.2 Recommendations

- (i.) Areas experiencing positive trends and dominant rainfall peak of short return period will likely be prone to flood and therefore flood control measures such as drainage structures must be put in place.
- (ii) Likewise areas experiencing positive trends and dominant temperature peak of short return period will likely be prone to drought and desertification and therefore adequate drought and desertification management such as mulching, planting of trees and other cultural practices, as well as irrigation scheme must be put in place to arrest the situation,
- (iii) Further studies must be carried out on other meteorological stations and agro-ecological zones of Nigeria.
- (iv.) Studies must be conducted on long term effects of trends of temperature and rainfall on under ground water.

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