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Study of Periodicity in Some Meteorological Parameters and Solar Indices Over Some Stations in Nigeria

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Abstract
Periodicities of the mean monthly values of some meteorological parameters and solar indices over some stations in Nigeria have been examined. We used maximum and minimum temperature, rainfall, relative humidity, evaporation, sunshine duration, solar radiation and windspeed data as climate parameters and sunspot numbers and F10.7cm radio solar flux data as solar activity indicators. The Ikeja, Ilorin and Maiduguri stations were chosen as case studies based on the geographical locations in Nigeria to cover various climatic region from the coastal region in the south to the arid region in the north. The Fourier analysis technique Scargle periodogram was used to study the spectral characteristics of the meteorological variables and solar indices for these three stations. 124months/cycle periodicity, in wind speed, was found for the Ikeja station corresponding to the 125months/cycle of solar activities, showing the influence of solar activities on climate. It was established that solar forcing was very significant over Nigerian climate.
Keywords: periodicity, solar activity, Sun-climate relations

INTRODUCTION

The type of analysis most commonly applied to the periodic variations of the meteorological parameter is "harmonic analysis". Such an analysis helps in the physical understanding of the regular fluctuations. According to mathematical principles, any function that is given at every point in the interval can be represented by a series of sine and cosine functions. This series is called a Fourier series, and the method of finding the functions, Fourier analysis.

The exact periodicity can be estimated using appropriate computing tools. The knowledge about these periodic values helps us to know the physical state of the atmosphere responsible for the observed periods. This will in turn serves as a means of predicting, in advance, the hazardous effects the variables may have on the earth and bio-sphere in general. Whether a particular process is chaotic or harmonic in nature can also be judged from these studies.

The complexity of climate change in Nigeria makes it imperative for the understanding and evaluation of the various meteorological parameters and processes that forces them. So that we can take action when necessary to curb possible negative effects we might have control over. It will also assist the government to respond to early warning as a result of better preparedness. The cumulative effect will be seen in better socio-economic activities.

The objective of this work is to study the periodicity of the mean monthly values of some meteorological parameters and solar indices data over some stations in Nigeria.

Site Description

The study sites, in Nigeria, include the following stations Ilorin, Ikeja, and Maiduguri, representing the various climatic belts in the country. Ikeja represents the coastal influence, Ilorin represents the savannah belt as well as the central point of the country and Maiduguri represents the extreme North East (see Figure 1).

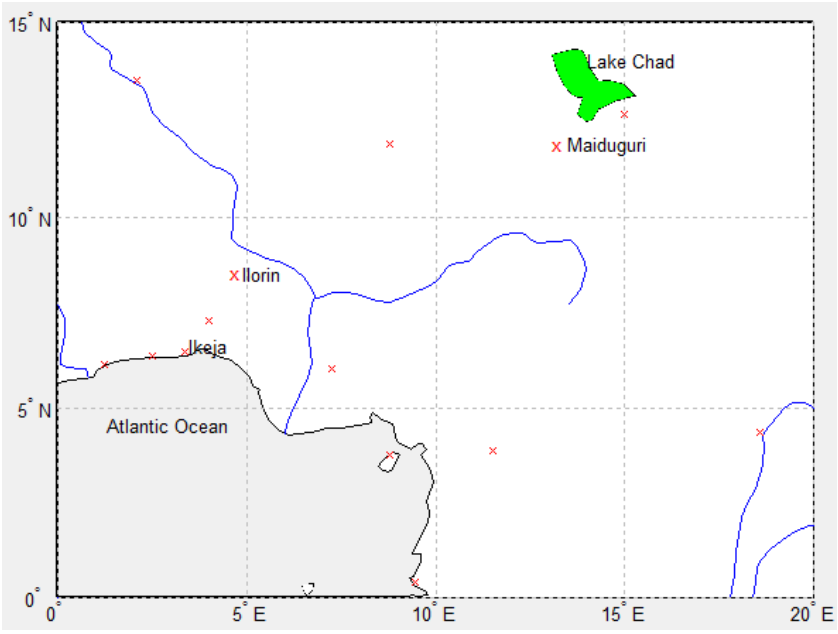

Figure 1: Geographical locations of the Study Sites, in Nigeria.

Table 1: The Geographical Coordinates of the Stations Used in this Study.

S/N	Stations(site)	State	Latitude (^{O}N)	Longitude (^{O}E)	Elevation (m, asl)
1	Ikeja	Lagos	06.58	03.33	39.4
2	Ilorin	Kwara	08.48	04.58	307.4
3	Maiduguri	Borno	11.85	13.08	353.8

Research Methodology

The monthly mean meteorological data for the period of January 1980 to December 2010 for eight meteorological parameters: Maximum Temperature, Minimum Temperature, Wind speed, Sunshine duration, Solar Radiation, Evaporation, Rainfall, Relative Humidity and Average Temperature were obtained from the Nigerian Meteorological Agency, Oshodi Lagos. Also the solar indices data were obtained from NGDC, Boulder, Colorado through their website (http://www.pmodwrc.ch/pmod.php?topic=tsi/composite/SolarConstant) for the three synoptic meteorological stations covering the same period.

To investigate the periodicity of the meteorological variables and solar indices at each station, the Fourier analysis technique, Scargle periodogram (Scargle, 1982) was applied to the monthly running means of the meteorological variables and solar indices. Applying suitable functions in MATLAB®, the power spectra (periodograms) of the various meteorological parameters at all the stations were obtained and reported in Figures 2 – 5, with the prominent periodicities observed in the periodograms for various variables indicated in Table 2.

RESULTS AND DISCUSSION

The power spectra(periodograms) of the meteorological variables for Ilorin, Ikeja and Maiduguri stations are reported in Figure 2(a, b, c, d, e, f, g, h) to Figure 4(a, b, c, d, e, f, g, h) and Figure 5(a & b) respectively.

Figure 2(a, b, c, d, e, f, g, h) to Figure 4(a, b, c, d, e, f, g, h) and Fig.5(a & b) show similarities in power spectra for the climatic parameters in the three stations, the prominent periodicities observed in the periodograms for various variables in the three meteorological stations are reported in Table 2.

The prominent periodicities in Table 2 show variability from one station to another. From the Table, modal periodicities of 6 and 12 months/cycle were observed for all the climatic parameters at all the meteorological stations except for wind speed in Ikeja. The periodicity of 4 months /cycle is also quite prominent for Rainfall at all the stations. It is quite obvious that the meteorological variables consistently demonstrate modal periodicities of 6-month and 12-month values across the three stations. This may be considered as an evidence of solar control on climate. Higher model periodicities of 186 months/cycle at Ikeja and Maiduguri, and 371 months/cycle are also observed for wind speed and solar Radiation.

Hence, Figure 2(a, b, c, d, e, f, g, h) to Figure 4(a, b, c, d, e, f, g, h) and Figures 5(a & b) as reported in Table 2 show evidence of semi-annual (6 months) and annual (12 months) effects in the atmosphere due to solar activity. The semi-annual changes in the atmosphere have been related to solar activity by Russell and

McPherron, (1973) and Gonzalez *et al*. (2001). Rabiu (2004) observed semiannual variation in the upper atmosphere and attributed this to the semiannual changes in the ionospheric heating and ionization; the IMF-effect in the solar wind-magnetosphere coupling; favored alignment of the magnetospheric boundary with respect to the solar wind interaction at equinoxes; and equinoctial/semiannual increase in solar wind speed. It is possible that the three separate and independent components, viz. A semi-annual, an annual and a Sun-Earth-distance determined component, all of which can be accurately determined from solar-terrestrial geometry alone, (Chaman-Lal, 2000), can account for the observed modal periods of 6- and 12-months.

This is an evidence of solar signature on terrestrial climate. Therefore, from the periodicity analysis of the meteorological variables across each of the three synoptic stations considered in this research, influences of solar activity may be established on some of the climatic variables.

Table 2: Periodicities in Months of Climatic Parameters Ilorin, Ikeja and Maiduguri Stations

CLIMATIC PARAMETERS	IL0RIN	IKEJA	MAIDUGURI	MODE
Max. Temp.	4,6,12	6,12,371	4,6,12	4,6,12,
Min. Temp.	4,6,12	12,186,371	6,12,124	6 ,12,
Rel. Humidity	6,12,18	11,12,371	4,6,12	6 ,12
Rainfall	4,6,12	4,6,12	4,6,12	4,6,12
Wind speed	12,13,371	74,124,371	12,186,371	12,371
Evaporation	6,12,29	6,12,186	4,6,12	6,12
Solar Radiation	4,6,12	6,12,371	6,186,371	6,12,371
Sunshine Hour	4,6,12	6,12,186	4,6,12	4,6,12

CONCLUSIONS

In this study, it was found that cycles of 6 and 12 months were present in all the climatic parameter for all stations (Ikeja, Ilorin and Maiduguri), this is an evidence of semi-annual and annual solar cycle.

The modal of 4 months periodicity in relative humidity in Maiduguri, Sunshine hour in Maiduguri and Ilorin, Solar radiation, Maximum and Minimum Temperature in Ilorin, and Rainfall in all stations are observed.

The 11 year solar cycle that is evident in all the solar indices, is also observable in Minimum Temperature for Maiduguri, Wind speed for Ikeja as 124 months/cycle that is also closer to the 125 months/cycle for solar cycle and may be considered as an evidence of solar influence on climate.

Impact of solar activity forcing is more pronounced on wind speed than any other meteorological variable because of the high variability in its periods.

Therefore, there is significant relationship between some meteorological variables and solar indices or related solar activities over some cities in Nigeria, West Africa.

Recommendation

Further studies are necessary for more meteorological stations so as to obtain more comparable results in different geographical locations in the country.

Acknowledgements

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POWER SPECTRAL OF METEOROLOGICAL VARIABLES

Power Spectra of Meteorological variables at Ilorin

ILORIN STATION

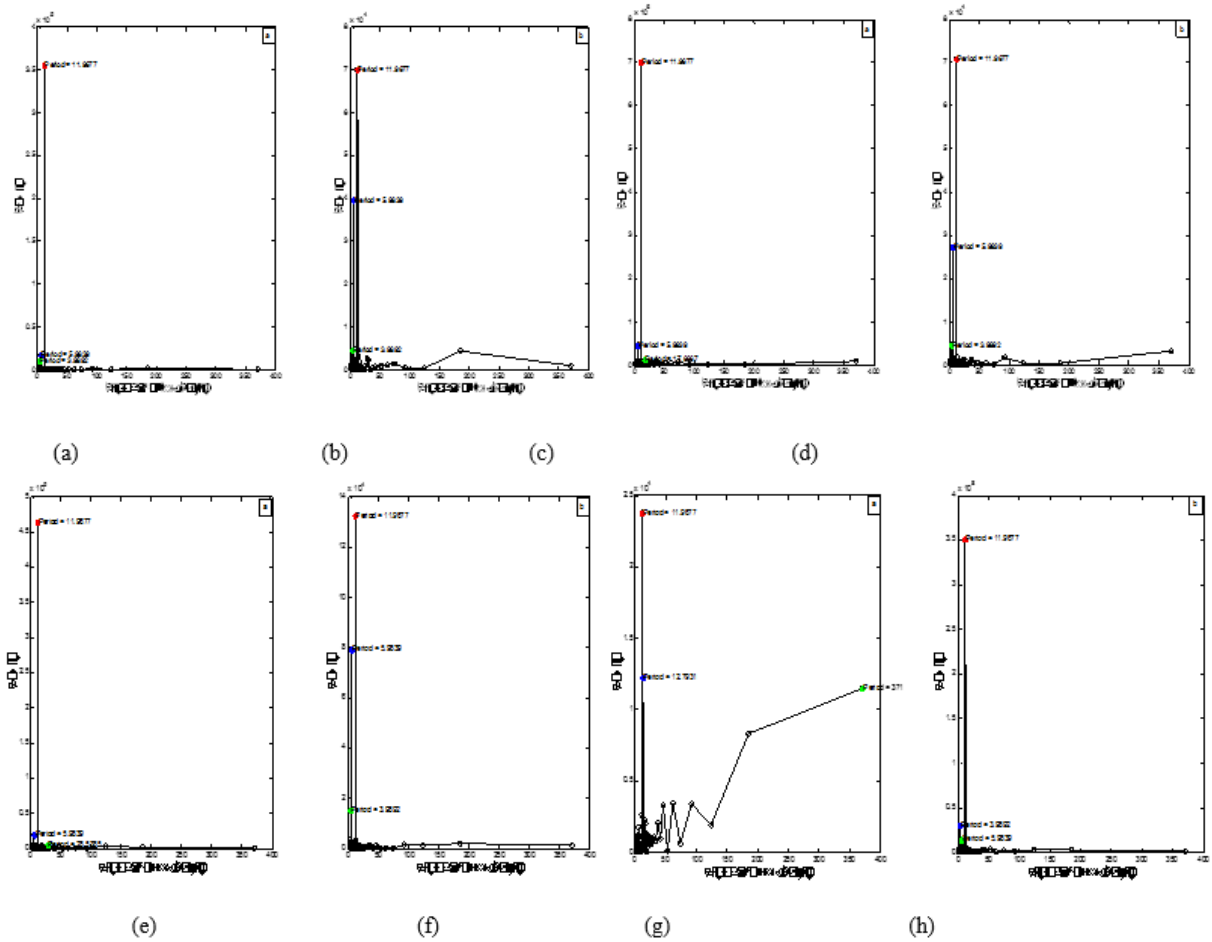

Figure 2(a, b, c, d, e, f, g, h): Spectral Analysis of (a) Maximum Temperature (b) Minimum Temperature (c) Relative Humidity (d) Sunshine Hour (e) Evaporation (f) Solar Radiation (g) Wind Speed (h) Rainfall, in Ilorin from 1980 to 2010.

Power Spectra of Meteorological Variables at Ikeja
IKEJA STATION

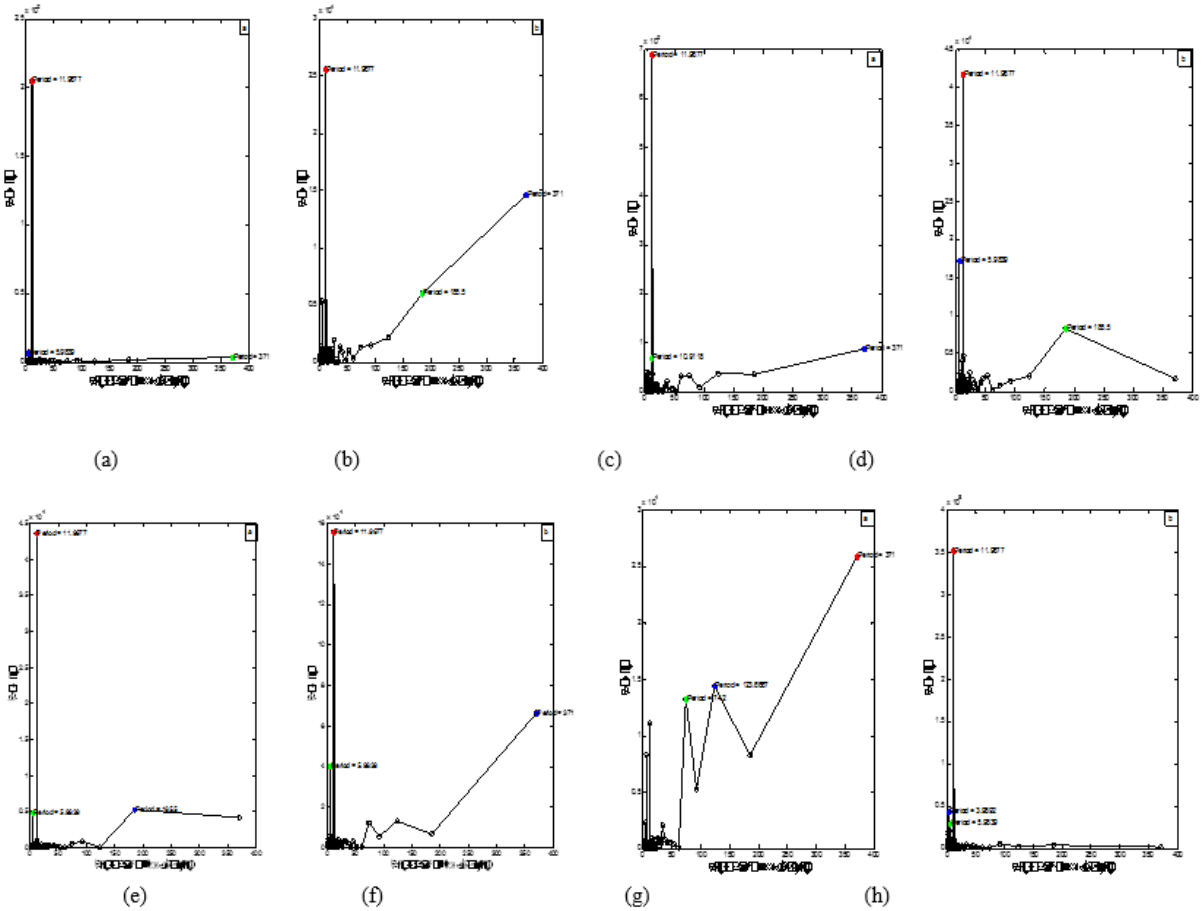

Figure 3(a, b, c, d, e, f, g, h): Spectral Analysis of (a) Maximum Temperature (b) Minimum Temperature (c) Relative Humidity (d) Sunshine Hour (e) Evaporation (f) Solar Radiation (g) Wind Speed (h) Rainfall, in Ikeja, from 1980 to 2010.

Power Spectra of Meteorological variables at Maiduguri
MAIDUGURI STATION

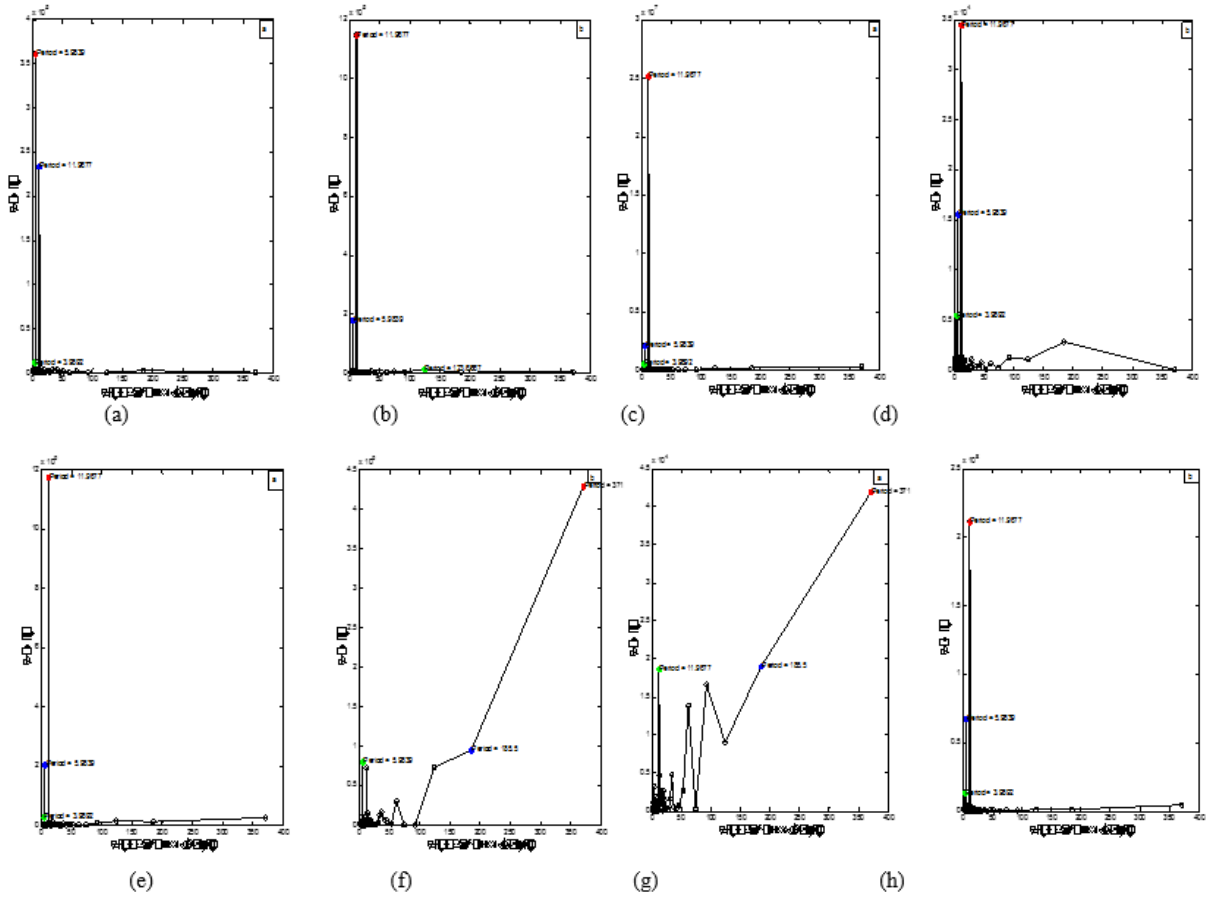

Figure 4(a, b, c, d, e, f, g, h): Spectral Analysis of (a) Maximum Temperature (b) Minimum Temperature (c) Relative Humidity (d) Sunshine Hour (e) Evaporation (f) Solar Radiation (g) Wind Speed (h) Rainfall, in Maiduguri from 1980 to 2010.

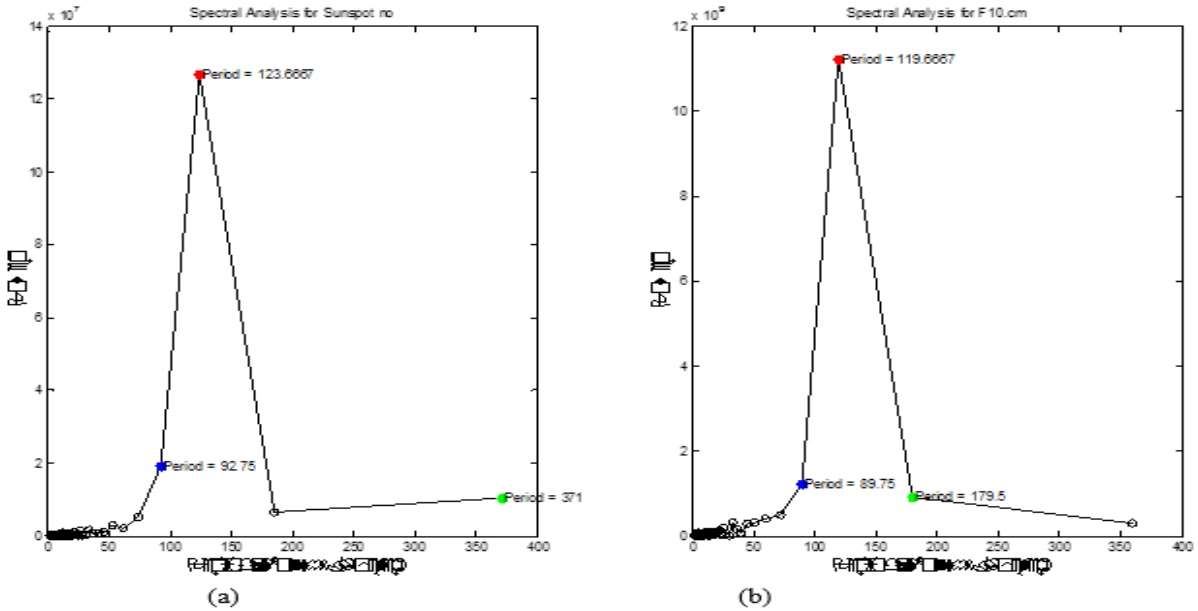

Figure 5 (a and b): Spectral Analysis of Sun spot number and F10.7 cm Solar Radio Flux from 1980 to 2010.

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