

## SIMILARITIES IN PERIODS OF METEOROLOGICAL VARIABLES OVER KENYA AND SOLAR ACTIVITY PERIODS

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### ABSTRACT

*Using the fast Fourier transform (FFT) method, we determined the spectral characteristics of some meteorological variables over Kenya and identified the prominent periodicities associated with the variables. The meteorological variables studied are the maximum temperature, minimum temperature, average temperature, wind speed, precipitation, relative humidity, solar radiation intensity, evaporation and sunshine duration. Data from five terrestrial stations, representing the regional climatic zones in Kenya, were employed in the study. The result reveals periods that are associated with solar activity. It is established that solar forcing is very significant over the Kenyan climate. The Sun-Climate relations were influenced at some locations by local effects such as orography and vegetation.*

**Keywords:** *periodicity, solar activity, Sun-climate relations*

### INTRODUCTION

Many meteorological variables are well known for their periodicities. Many geological records of climatic and environmental change based on various proxy variables exhibit distinct cycles that have been attributed to extraterrestrial forcing (Anderson 1982, Dean 2006). The seasonal effects are more pronounced across the variables. The exact periodicity can be estimated using computing tools. The knowledge about these periodic values help us to know the physical state of the atmosphere responsible. This will in turn serve as a means of predicting, in advance, the hazardous effects the parameters may have on the earth and bio-sphere in general.

In addition the study of the periodic behavior of meteorological variables gives insight into the various mechanisms involved in the different processes responsible for variability of parameters of interest. Whether a particular process is chaotic or harmonic in nature can also be judged from these studies. This present effort investigated the spectra behavior of meteorological variables, include maximum temperature, minimum temperature, average temperature, wind speed, precipitation, relative humidity, solar radiation intensity, evaporation and sunshine duration; obtained from archives of Kenya Meteorological Department (KMD) by subjecting them to fast Fourier transform (FFT).

**Research Methodology**

According to Bai (2003), Valde's-Galicia and Mendoza (2005), Prestes *et al.* (2006); to study periodicity in a regular time series  $X_j + X(t_j)$ , a series of measurements made at times  $t_j$  separated by regular intervals, one often uses Fourier spectral analysis. For an irregular time series, Scargle (1982) developed a periodogram calculated by the following equation:

$$P_x \nu = \frac{1}{2} \left\{ \frac{\left[ \sum_{j=1}^N X_j \cos 2\pi\nu t_j - \tau \right]^2}{\sum_{j=1}^N \cos^2 2\pi\nu t_j - \tau} + \frac{\left[ \sum_{j=1}^N X_j \sin 2\pi\nu t_j - \tau \right]^2}{\sum_{j=1}^N \sin^2 2\pi\nu t_j - \tau} \right\} \quad (1)$$

Where  $\tau$  is defined by the relation:

$$\tan 4\pi\nu\tau = \frac{\left( \sum_{j=1}^N \sin 4\pi\nu t_j \right)}{\left( \sum_{j=1}^N \cos 4\pi\nu t_j \right)} \quad (2)$$

To examine periodicity of different kinds of solar events, Rabiou *et al.* (2007) have used the Fourier transformation by expressing a signal  $g(t)$  by a trigonometric Fourier series over any interval of duration  $T_o$  as:

$$g(t) = a_o + \sum a_n \cos(n\omega_o t) + \sum b_n \sin(n\omega_o t) \quad (3)$$

Where  $n = 1$  to infinity and  $\omega_o = 2\pi/T_o$ . While  $a_o$ ,  $a_n$  and  $b_n$  are the Fourier coefficients.

Monthly data records of maximum temperature (MAT), minimum temperature (MIT), average temperature (AVT), wind speed (WIS), precipitation (RNF), relative humidity (RH), solar radiation intensity (SRA), evaporation (EVA) and sunshine duration (SUD) for the years 1986 – 2005 were obtained at five terrestrial stations representing the regional climatic zones under

the management of the Kenya Meteorological Department (KMD). Table 1 presents the geographical coordinates of the stations whose data were used in this study.

To investigate the periodicity of the meteorological variables at each station, the Fourier analysis technique was applied to the monthly running means of the meteorological variables and the Scargle's periodograms obtained (Scargle, 1982). Applying a suitable program in MATLAB, the power spectra (periodograms) of the various meteorological parameters at all the stations were obtained.

**RESULTS AND DISCUSSION**

The power spectra (periodograms) of the meteorological variables for Kericho station are reported in Figures 1 to 9.

The prominent periodicities observed in the periodograms for various variables in the five meteorological stations are reported in Table 2. Table 3 gives the summary of literature reported periodicities of the solar indices and/or solar related activities that are comparable to the modal periodicities of the meteorological variables reported in Table 2.

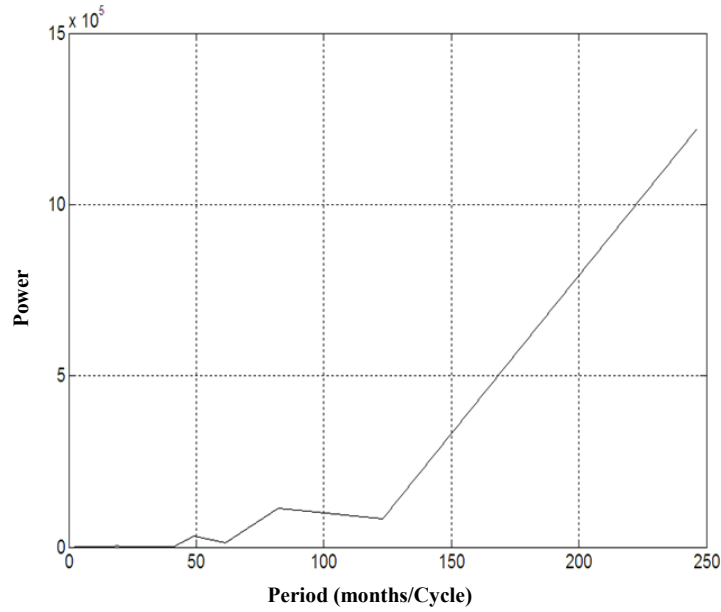
From Table 2, model periodicities of 6 and 12 months/cycle are observed for all the climatic parameters at all the meteorological stations except Kericho. The modal 6 and 12 months/cycle for these parameters had been observed by Rabiou *et al.* (2007). However, a periodicity of 3 months / cycle is also quite prominent for RH, MAT, WIS, RNF and AVT at the stations apart from Kericho.

The prevailing climate in KER can account for their peculiar periods of 50 and 82 months in

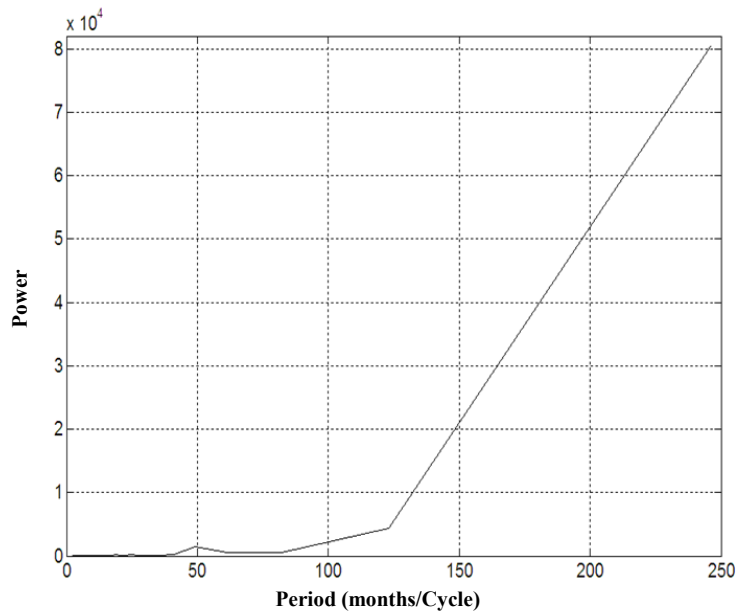
**Table 1: Geographical coordinates of the meteorological stations**

Stations (Site)	Code	Latitude (°S)	Longitude (°E)	Altitude (m)
Kericho	KER	0.4	35.3	1946.85
Dagoretti (Nairobi)	NBI	1.3	36.8	1771.77
Kisumu	KSM	0.1	34.8	131.83
Mombasa	MSA	4.0	39.6	5.41
Garissa	GRS	0.5	39.6	120.13

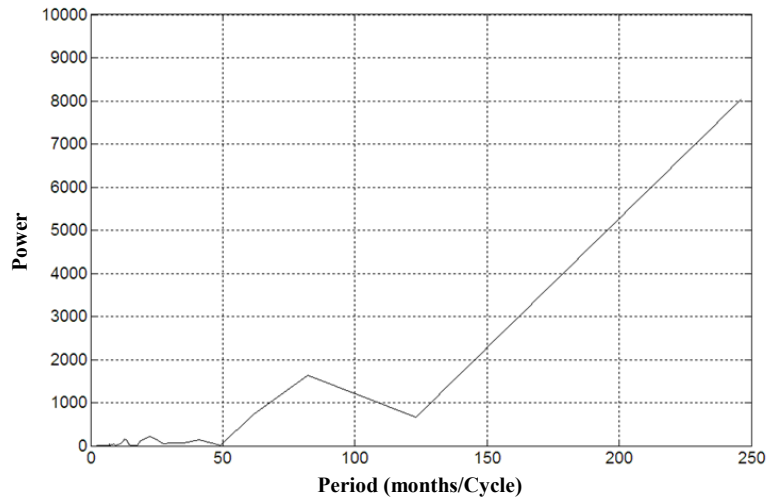
Figures 1 to 9 depict Power Spectra of Meteorological parameters at Kericho



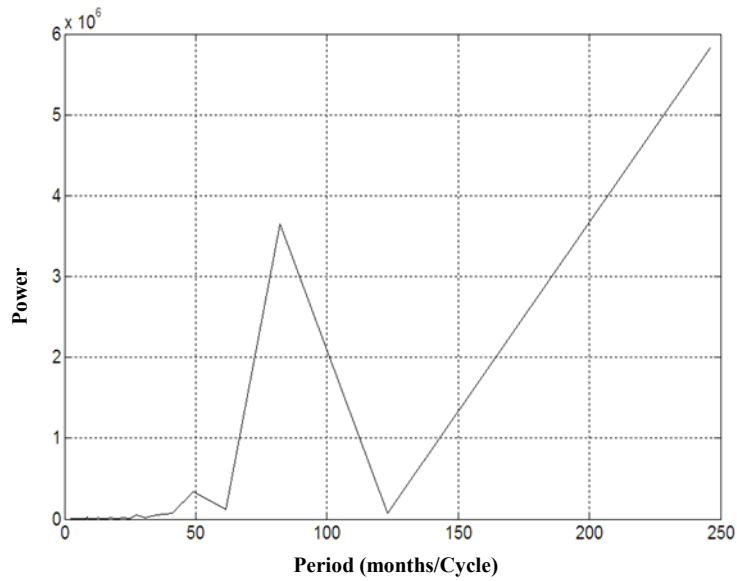
**Fig. 1:** Periodogram of Relative Humidity at Kericho KER. (The peaks indicate the periods)



**Fig. 2:** Periodogram of Maximum Temperature at Kericho KER. (The peaks indicate the periods)



**Fig. 3:** Periodogram of Minimum Temperature at Kericho KER. (The peaks indicate the periods)



**Fig. 4:** Periodogram of Wind Speed at Kericho KER. (The peaks indicate the periods)

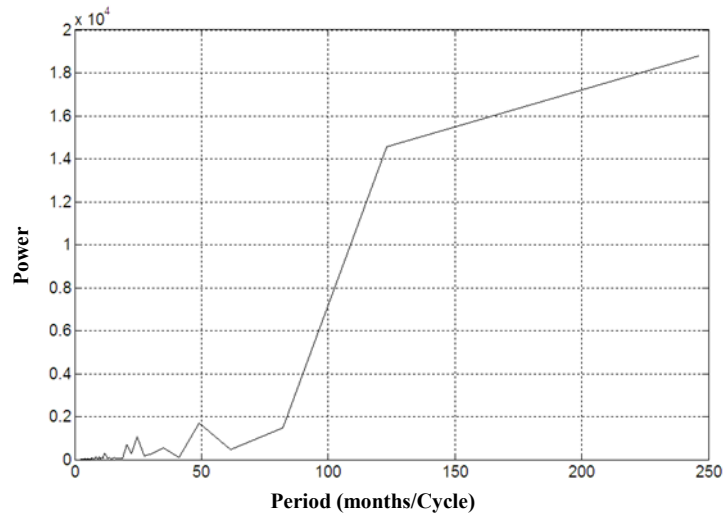


Fig. 5: Periodogram of Sunshine Duration at Kericho KER. (The peaks indicate the periods)

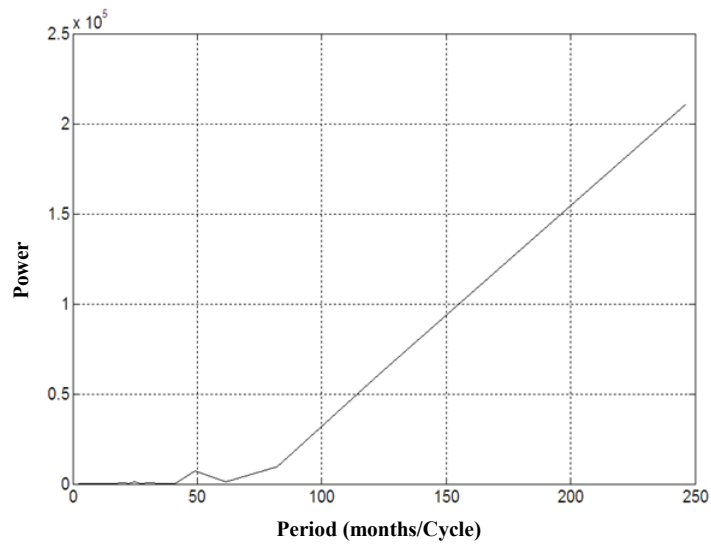
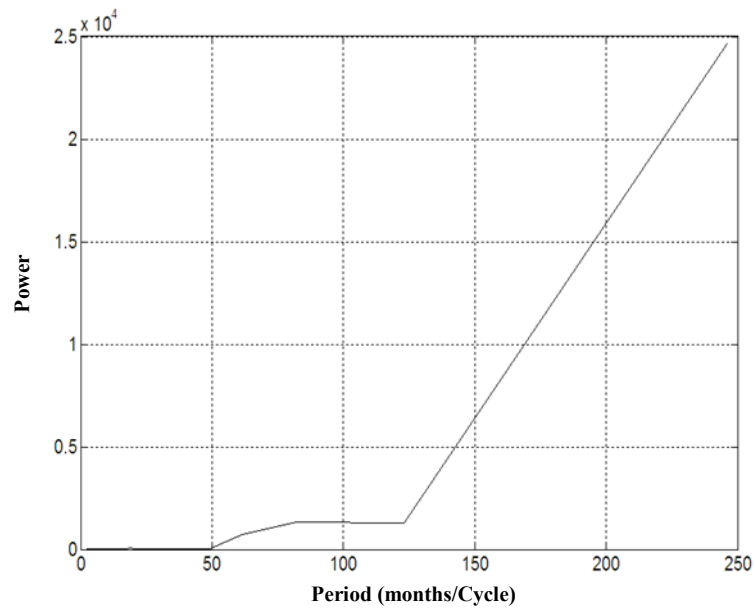
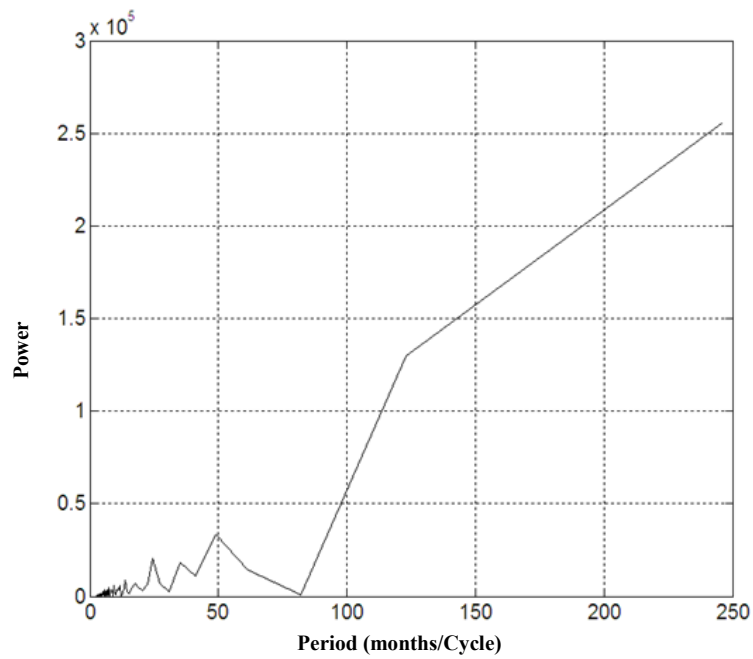


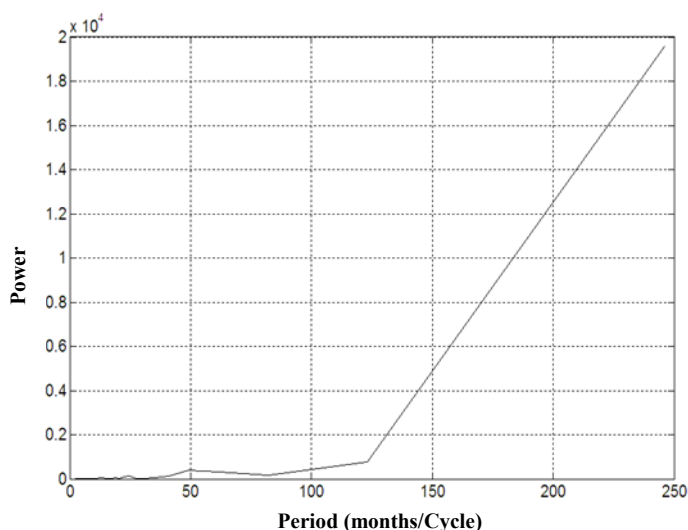
Fig. 6: Periodogram of Solar Radiation Intensity at Kericho KER. (The peaks indicate the periods)



**Fig. 7:** Periodogram of Evaporation at Kericho KER. (The peaks indicate the periods)



**Fig. 8:** Periodogram of Rainfall Intensity at Kericho KER. (The peaks indicate the periods)



**Fig. 9: Periodogram of Average Temperature at Kericho KER. (The peaks indicate the periods)**

**Table 2: Periodicities in months of different climatic parameters at different stations**

Climatic Parameters	NBI	KER	KSM	MSA	GRS	MODE
RH	5, 12, 40.5	50, 86	3, 6, 12, 22, 36, 85	3, 6, 12, 36, 62, 125	3, 6, 12, 41, 82	3, 6, 12
MAT	4, 6, 12.5	50	3, 6, 12, 36	3, 6, 12, 16, 35, 60	3, 6, 12, 18, 27.5, 40, 122	3, 6, 12
MIT	5, 12.5	25, 86	3, 6, 12, 62, 125	6, 11, 12, 17, 22.5, 31, 50, 83	3, 6, 12, 18, 36	6, 12
WIS	7.5, 12	50, 82	6, 12, 21, 31, 61	3, 6, 12, 35, 82.5	3, 6, 12, 22, 28, 62	3, 6, 12
SUD	12, 35	25, 50	1, 6, 12, 20, 25, 35, 85	3, 6, 7, 12, 32, 36, 50	3, 6, 7, 12, 21, 36	6, 12
SRA	6, 12, 50	50	3, 6, 12, 81	3, 6, 12, 50	3, 5, 6, 12, 32, 123	6, 12
EVA	6, 12		6, 12, 22, 35, 82.5	3, 6, 12, 80	3, 6, 12, 50, 82	6, 12
RNF	3, 6, 12	25, 35, 50	3, 6, 17, 20, 40	3, 6, 12	3, 4, 6, 12, 50	3, 6, 12
AVT	3, 6, 7, 12, 25	50	3, 6, 12, 82.5	3, 5, 6, 7, 12, 32, 50, 82.5	2, 3, 7, 37	3, 6, 12

**Table 3: Periodicities of some solar indices and/or solar related activities**

Periodicity	Solar indices/solar related activities with similar periodicity
Semiannual (6 months)	Semiannual effects in atmosphere due to solar activity
Annual (12 months)	Annual effects in the atmosphere due to solar activity
Quasi-biennial (25 months)	Sunspot numbers, Solar radio flux 10.7 cm, Green coronal activity index, Solar neutrino index.
10 to 11 year (About 125 months)	Sunspot numbers, Solar radio flux 10.7 cm, Mg II core-to-wing ratio etc.

some of the variables. The region is characterized by mountainous terrain that is rainy, with colder temperature throughout the year (Ogallo, 1989). The kind of climate in KER that is caused by the attendant orography can be the cause of the observed periods.

The 6-month period is a demonstration of semi-annual effect in the atmosphere, while the 12-month period is a manifestation of the annual effect. The semiannual changes in the atmosphere have been related to solar activity by Russell and McPherron, (1973) and Clua de 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 semiannual, 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.

Quasi-biennial periods of 25 months are also seen in Kericho meteorological station for: MIT, SUD and RNF. Georgieva, *et al.* (2000) have reported that Quasi-biennial oscillation of stratospheric winds (QBO) signals have been identified in a number of geophysical parameters, such as sea level pressure, ozone distribution, Earth's rotation, and that its existence has been shown in solar activity parameters as sunspot numbers, solar radio flux 10.7 cm, green coronal activity and solar neutrino flux.

The 10 to 11 year solar cycle manifests as 125 months periodicity that appears in all the solar indices. The climatic parameters: MAT, SRA, all in GRS show similar periodicity. This is an indication that the semi arid region is prone to

solar signature on these climatic parameters. RH in MSA also shows the same periodicity as the solar parameters. The coastal region of MSA registers the highest humidity levels of all the regions. Since RH depends on evaporation that in turn depends on radiation from the sun, it is therefore true that the unique humidity levels in MSA are due to the solar forcing in this region. We also have periodicity of 125 months occurring in KSM for MIT that corresponds to the 10 to 11 year solar cycle.

## CONCLUSIONS

The modal 6 and 12 months (the semiannual and annual) periodicities observed in all the climatic parameters in NBI, KSM, MSA and GRS are due to solar activity forcing.

The Quasi-biennial periodicities of 25 months/cycle observed in Minimum temperature, Sunshine duration and rainfall in Kericho are due to solar activity whose parameters such as sunspot numbers, solar radio flux 10.7 cm, green coronal activity and solar neutrino flux have also shown Quasi-biennial Oscillation signals.

The 10 to 11 year solar cycle that is evident in all the solar indices, is also observable in MIT and RH for KSM and MSA respectively as 125 months/cycle; it is also close to the 122 and 123 months/cycle for MAT and SRA respectively in GRS. This is a probable evidence of solar control on terrestrial climate.

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