ANALYSIS OF PERIODIC INFLUENCE OF SOLAR ACTIVITY ON WINDSPEED FOR WIND ENERGY APPRAISAL IN SOME CITIES IN NIGERIA

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ABSTRACT

In this study, the effects of solar activity on wind speed in some cities in Nigeria were investigated by examining the Periodicity of the mean monthly values of wind speed and solar index using the Spectral Analysis Method (SAM). Results revealed that the dominant periodicity that appeared with the analysis shows some similarities between periodicity of the windspeed data set and that of solar activity.The modal periodicities associated with solar activity areidentified at all the seven meteorological stations. In some stations the associations are influenced by local effects like vegetationdifferences, proximity to the oceans and topography.Impact of solar activity forcing is more pronounced on wind speed at the northern part of the country because it exhibited higher variability in its periods.

Keywords: *Solar Activity, periodicity, Wind speed and Wind Energy*

INTRODUCTION

Both long-term and short-term variations in solar activity are hypothesized to affect global climate [1]. But, it has proven extremely challenging to quantify the link between solar variation and Climate [2]. Measurements from the SORCE's Spectral Irradiance Monitor revealed that solar ultraviolent variability produces colder winters in the US and Southern Europe and warmer winters in Canada and Northern Europe [1,3].

Winds are horizontal movements of air that take place in response to pressure differences in the atmosphere.The greater the difference between pressure in two regions, the faster the air between them will move. Allpressure differences between places on the earth’s surfaces can be traced, directly or indirectly, totemperature differences. If one region is warmer than its surroundings, the air above it is heatedand expands. The hot air rises, leaving behind a low pressure zone into which cool air from the highpressure neighborhood flows. The horizontal flow toward the heated region at low altitudes is

balanced by ahorizontal flow outward of air that has risen, which cools and sinks to replace the air that has moved inward.In this way convection cells convert temperatures differences into pressure differencesand therefore causes winds to occur. On a large scale, the differences between the solar heating of theequatorial and Polar Regions are what power the general circulation of the lower atmosphere. Therefore, wecan say that the sun (solar energy) is the ultimate cause of wind [4, 2]. The complexity of Wind speed variation and the future potential of Wind Energy in Nigeria make the understanding and evaluation of Wind speedparameters and processes that forces them imperative, so that more scientific and technological innovations can be carried out to identify areas with high Wind Energy Potential for Sustainable Power Generation in Nigeria. It will also assist the government in getting an alternative to centralized power plants; Wind Energy can also help to produce a decentralized power supply that will help to reduce the dependence on centralized power supply, especially in the rural areas where the cumulative effect will be seen in better socio-economic activities.

METHODOLOGY

The monthly mean meteorological data for the period of Jan, 1980 to Dec.2010 for wind speed was obtained from the Nigeria Meteorological Agency, Oshodi Lagos. Also for the same period, solar index data was obtained from the archive of NGDC, Boulder, Colorado through their website, (http://www.pmodwrc.ch/pmod.php?topic=tsi/composite/solar). The Solar data span three 11-year solar cycles from 1980 up to 2010.

To investigate the periodicity of the wind speed parameter and the solar index at each station, the Fourier analysis technique ScarglePeriodograms [5] had been applied to the monthly running means of the wind speed parameter and solar indices.

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 often require the use of Fourier Spectra analysis. (6). For an irregular time series, Scargle (5) developed a periodogramm calculated by the following equation:

$$p_x\, v = \frac{1}{2}\left\{\frac{[\sum_{j=i}^{N} X_j cos2\pi v\, t_j - \tau]^2}{\sum_{j=i}^{v} cos^2 2\pi v\, t_j - \tau} + \frac{[\sum_{j=i}^{N} X_j sin2\pi v\, t_j - \tau]^2}{\sum_{j=i}^{v} sin^2 2\pi v\, t_j - \tau}\right\} \qquad (1)$$

Where τ is defined by the relation:

$$tan^4 \pi v\tau = \left(\sum_{j=i}^{N} sin^4 \pi v t_j\right) / \left(\sum_{j=i}^{N} cos^4 \pi v t_j\right) \qquad (2)$$

According to Rabiu *et al*(3)and Ndeda *et al*(7)Fourier transformation can be used to examine periodicity of different kinds of solar events by expressing the signal $g\,(t)$ by a trigonometric Fourier series over any interval duration T_o as:

$$g(t) = a_0 + \sum a_n \cos(nw_o t) + \sum b_n \sin(nw_o t) \qquad (3)$$

Where n=1 to infinity and $w_o = 2\pi/T_O$ and a_o, a_n, b_n are the Fourier Coefficients.

The power spectra (periodogram) characteristics of wind speed parameters at various stations were obtained by applying a suitable program in MATLAB. The relationship between the periods and solar activity index were examined and the physical state of the atmosphere responsible for these was evaluated. Also the probable effects of the sun on the wind and wind energy, and the influence of some local effects were determined.

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. Figure1 presents the geographical locations of the Study Sites.

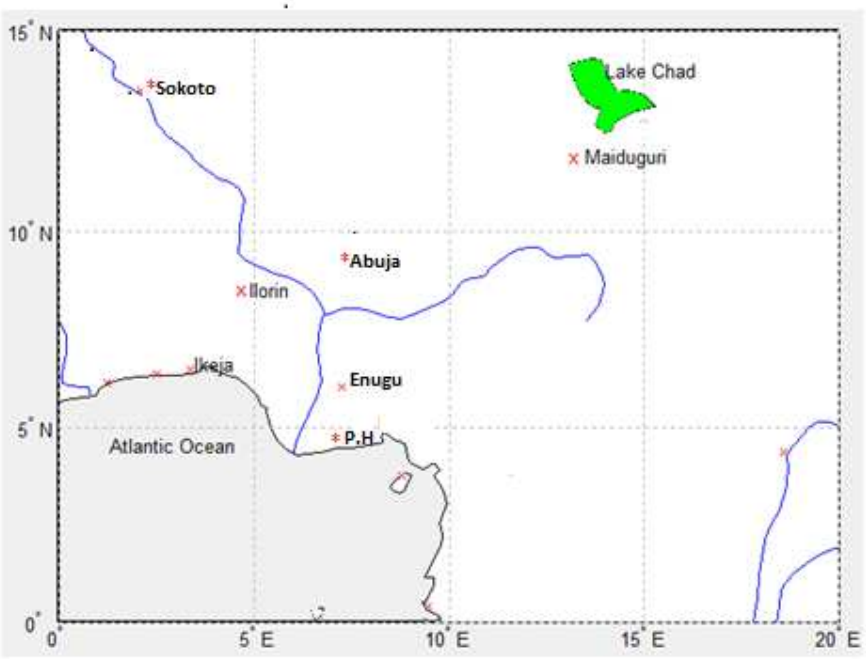


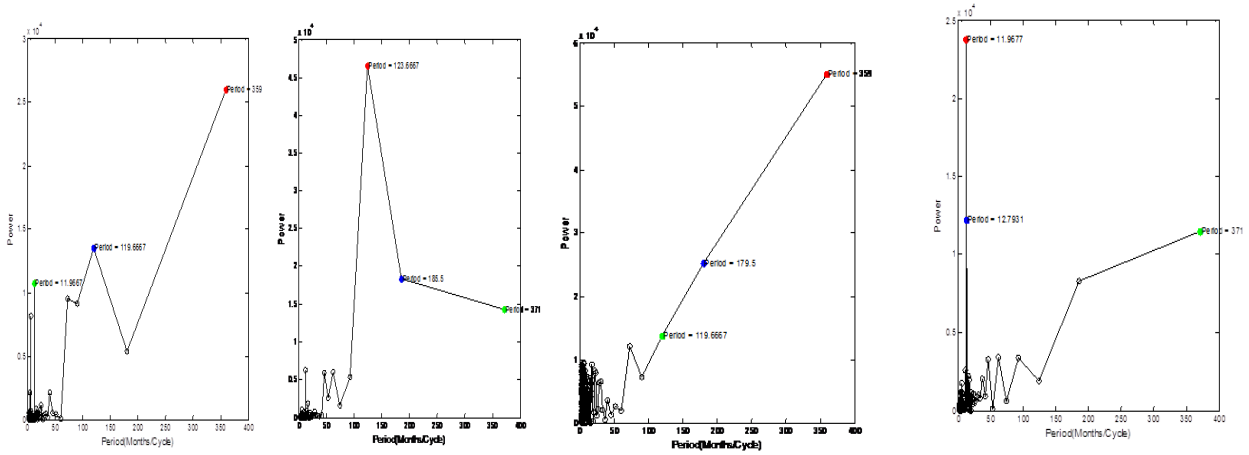
Figure 1: Geographical locations of the Study Sites, in

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

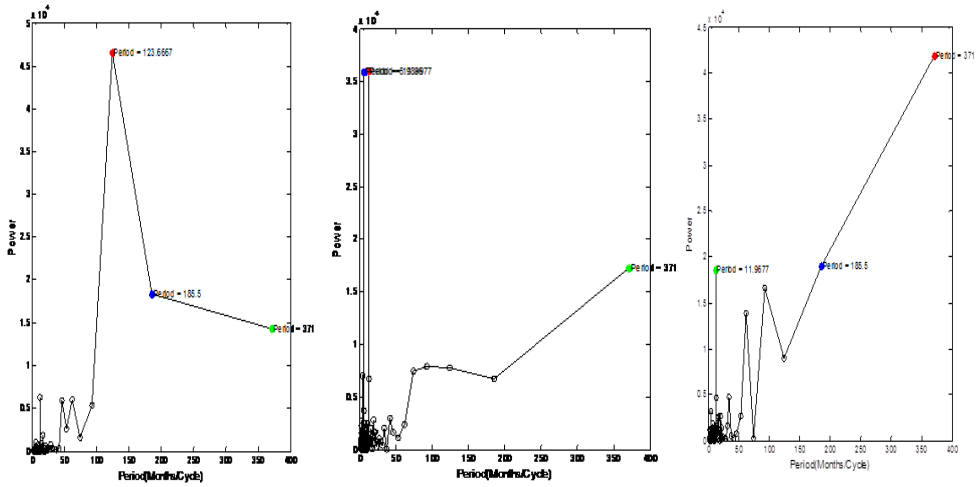
S/N	Stations(site)	Latitude(^{O}N)	Longitude(^{O}E)	Elevation(m asl)
1	Ikeja	06.58	03.33	39.4
2	Port H	04:51	07:21	19.5
3	Enugu	06:28	07:33	141.8
4	Ilorin	08.48	04.58	307.4
5	Abuja	09.15	7.00	343
6	Sokoto	13:01	05:15	350.8
7	Maiduguri	11.85	13.08	353.8

RESULTS AND DISCUSSION

Figure 2 (a-h) depicted the power spectra (periodograms) results of the windspeed and sunspots number data sets at different stations. The figures show similarities in the power spectra in the selected seventerrestrial meteorological stations with slight variations in that of Ilorin and Sokoto due to local effects. The prominent periodicities identified in the periodograms for windspeed and sunspots number in the various stations are indicated in Table 2. It could be observed from Table 2that the wind speed variables consistently demonstrate modal periodicities of either 12, 124 or 371 months/cycle across the stations. This may be considered as an evidence of solar control on windspeed and wind energy potential in the three considered stations.



2 (a)IKEJA 2(b)PORT H 2(c)ENUGU 2(d)ILORIN



2(e)ABUJA 2 (f)SOKOTO 2 (g) MAIDUGURI

Figures 2(a - g);Spectral Analysis of wind speed at Ikeja,PH, Enugu,Ilorin,Abuja,Sokoto, and Maiduguri and the corresponding Sunspots number from 1980 to 2010 respectively.

Table 2: Periodicities in months/cycles for Windspeed at all the stations.

SYNOPTIC STATIONS	WINDSPEED
Ikeja	74, 124,371
Port Harcourt	12,124,371
Enugu	124,186,371
Ilorin	12 , 13, 371
Abuja	124,186,371
Sokoto	6,12,371
Maiduguri	12, 186, 371
Sunspots Number	93,124,371
MODE	12,124,371

Conclusion

This work shows the effect of sunspots number an indicator of the solar activity on wind speed characteristics at Ikeja, Port-Harcourt,Enugu, Ilorin,Abuja,Sokoto and Maiduguri in Nigeria. The prominent periodicities identified in the analysis suggest a connection between solar activity and the wind speed parameter at the selected stations and therefore deserved further consideration for wind energy potential in Nigeria. The dominant periodicity that appeared with the analysis show some similarities between periodicity of the wind speed data set and that of solar activity. The detected Sun-weather relation was influenced at some locations by local effects such as vegetation differences. Impact of solar activity forcing is more pronounced on wind speed at the northern part of the country because it exhibited higher variability in its periods. These results suggest a connection between solar activity, Wind speed and Wind Energy Potentials in Nigeria. It can also be ascertained from the seeming trends in the wind speed – sunspot numbers profiles. This may be considered for wind energy appraisal in the considered stations in Nigeria.

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