The Vector dynamics of Ikogosi Wind Speed/direction relative to Climate Change

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Abstract. This study appraises anticipated vicissitudes to surface wind characteristics from 1980-2018 in Ikogosi South-Western Nigeria. Changes in wind speeds at regional and global levels are signals of global warming. A concern about climate change has been a major driving force for the speedy expansion experienced in wind energy projects. Yearly investigation of wind speed disguises seasonal variation in predictive planning. At times, these changes fluctuate across seasons in some zones. The Inter-governmental Panel on Climate Change (IPCC) gave a proponent for long-term changes in the large-scale atmospheric circulation. In effect, observed changes such as poleward shifts and reinforcement of westerly winds will likely be promoted. Projected changes to annual wind speed display altitudinal variability compared to seasonal and annual mean wind speed. An evaluation of wind changes at specific locations is therefore necessary for site-specific application. This paper presents experience at Ikogosi warm spring site with varying return periods, analysed for identification of the behaviour of its wind using several statistics/probability distribution. Average wind speed of 2.2 m/s in Ikogosi certainly portends a future for hydro-electricity alternative in Nigeria.

Keywords: Climate change, Wind speed, Energy crises, Global warming

1. Introduction

Wind is a life-threatening variable of climate, it assists in the transport of pollutants, momentum, heat and humidity in-between the Earth’s atmosphere and Earth’s surface [1]. Consequently, wind affects evaporation rates in vegetation and is determined by climatic atmospheric circulation, associated with variability due to natural and anthropogenic forcing [2]. Thus, changes in surface wind speed and direction have crucial implications on wind energy production, air pollutants, water cycle components, fire storms, desert and semi-desert environments [3–5]. Furthermore, surface wind fluctuations directly influence agriculture, buildings, and infrastructure [6]. In spite of these implications, rather limited studies have attended to the projected changes in wind characteristics relative to temperature and precipitation [7]. A lot more studies have been directed to investigating the effect of decreasing/increasing changes near surface wind speed relative to altitudes [8]. Quite a lot of these
studies reported decreasing trends over low elevations. Intense cyclonic motion is a system of wide-ranging atmospheric circulation in mid-latitudes. The most powerful cyclones are responsible for several hydrometeorological irregularities that causes loss of lives, property and casualties [9-10]. It has been established that high wind speeds from non-tornadic storms are about the highest ranking destructive natural dangers across the Earth [11]. The damage to structures becomes appreciable when wind gusts assume a proportion greater than the breaking limit. Thus, data on wind gusts is vital for determination of appropriate wind loads for infrastructural design ideals and encryptions, which helps in averting risks and damage to lives [12]. In addition, potential changes to future wind regimes, severity and frequency of future wind gust events portend that comparatively small projections in the annual mean wind speed values may be a façade for a strong seasonal signal [13]. Although there are several ambiguities inherent in the nature of wind, several statistical techniques were employed in this current work to adapt the study area of Ikokosi to industries such as energy, commerce, transportation, agriculture and communities to consider climate change in revising engineering infrastructure design standards, developing adaptation strategies/policies and reducing the associated risks.

2. Study Location

Climatological data of Ikokosi South-Western Nigeria is plotted, wind speed against wind direction for nearly four decades. The source of the data is MERRE, in order to obtain adequate illustration, Origin software was used for the plots. The relationship was further examined with different statistical measures to validate the data and elicit output functions that could be use in future climatic models. R squared values reflects the measure of deviation between the two parameters, Analysis of variance classified the months into two characteristic groups, which aided the final analysis.

3. Results and Discussion

3.1. Wind speed vs direction graphs

The wind speed and direction in Ikokosi show a great deal of congruence as displayed in Figure 1 for all the months of the year during the entire period of this study. The mean wind speed is about 2.2 m/s, which is above the minimum required wind speed for small wind turbine propulsion. When this type of turbines generate power, the range is about 12.6 kph with a cut-out at 3.5 kph.
Figure 1: Multidecadal Wind Pattern in Ikogosi

3.2 Regression Curve fitting of Ikogosi

In spite of the low wind speed, the regression curves present an exponential growth or logarithmic decay trends over protracted periods of time. This portends a significant build-up of wind speed predominantly in future, giving rise to larger wind energy crop projection as illustrated in Figure 2. The line of best fit shows perfect harmony with all the points further corroborating the validity of data used.

Figure 2: Regression curve of Ikogosi wind speed and direction

3.3 Use of Statistical Analysis in Interpretation of Ikogosi wind speed-direction

The validity of the data used is proven by the measure of deviation from the mean in the values plotted. adjusted $R^2$, the value of the standard error is very minimal at B2 relative to B1. The adjusted R squared is generally higher for wind speed compared to direction, this is probably due to the fundamental nature of wind energy. A congruency in the value is illustrated by the value of unity, which is constant for all the months of the year. This ascertains that the meteorological data values are accurate and reliable as shown in Table 1.
Table 1: Statistical Evaluation of Ikogosi wind speed-direction

|           | Intercept | B1 | B2 | Statistics |
|-----------|-----------|----|----|------------|
| Wind Speed| 4637.4219 | -4.64379 | 2.405 | 0.00116 | 0.05425E-4 | 0.0063 |
| Wind Dir. | 13565.02616| -135.30401 | 200.01713 | 0.03429 | 0.05503 | 0.02146 |
| February  | -2.9127E-12 | 5.0096E-12 | 1 | 7.8565E-19 | 1.25227E-18 | 1 |
| Wind Speed| 3910.0565 | -3.91174 | 2.09549 | 9.7889E-4 | 5.2439E-4 | 0.04065 |
| Wind Dir. | 18976.37956 | -189.49051 | 193.46972 | 0.0478 | 0.04839 | 0.01437 |
| March     | -2.9127E-12 | 5.0096E-12 | 1 | 7.8565E-19 | 1.25227E-18 | 1 |
| Wind Speed| 4611.08319 | -4.00374 | 1.80403 | 0.00115 | 4.5122E-4 | 0.15929 |
| Wind Dir. | 110713.81983 | -110.73431 | 147.17572 | 0.02774 | 0.03638 | 0.03359 |
| April     | -2.9127E-12 | 5.0096E-12 | 1 | 7.8565E-19 | 1.25227E-18 | 1 |
| Wind Speed| 5349.51579 | 1734.77338 | 5.24593 | 1.73519 | 0.00134 | 4.3413E-4 | 0.03176 |
| Wind Dir. | 102232.3953 | 17239.47609 | -192.5331 | 172.49054 | 0.02574 | 0.04314 | 0.02069 |
| May       | -2.9127E-12 | 5.0096E-12 | 1 | 7.8565E-19 | 1.25227E-18 | 1 |
| Wind Speed| 3792.87219 | -3.791 | 2.18181 | 9.4798E-4 | 5.4981E-4 | 0.02751 |
| Wind Dir. | 263167.60012 | -263.60544 | 168.56554 | 0.00605 | 0.04243 | 0.02654 |
| June      | -2.9127E-12 | 5.0096E-12 | 1 | 7.8565E-19 | 1.25227E-18 | 1 |
| Wind Speed| 3073.31657 | 2041.14734 | -3.07528 | 2.04221 | 7.5847E-4 | 5.1080E-4 | 0.00593 |
| Wind Dir. | 238966.48105 | -239.32147 | 172.83047 | 0.00597 | 0.04324 | 0.02263 |
| July      | -2.9127E-12 | 5.0096E-12 | 1 | 7.8565E-19 | 1.25227E-18 | 1 |
| Wind Speed| -1114.58178 | 2297.90279 | 1.42924 | 2.2811 | -2.8564E-4 | 5.7905E-4 | -0.0467 |
| Wind Dir. | 3538.34752 | 16325.03142 | -3.11677 | 159.4135 | 7.2169E-4 | 0.04237 | -0.0657 |
| August    | -2.9127E-12 | 5.0096E-12 | 1 | 7.8565E-19 | 1.25227E-18 | 1 |
| Wind Speed| 4617.99258 | 2670.52604 | 4.53672 | 2.57187 | -0.00116 | 6.4328E-4 | 0.13757 |
| Wind Dir. | 103918.37426 | 23344.03185 | 104.13179 | 233.571 | -0.02094 | 0.05842 | -0.04972 |
| September | -2.9127E-12 | 5.0096E-12 | 1 | 7.8565E-19 | 1.25227E-18 | 1 |
| Wind Speed| 2819.45714 | 1981.2044 | 2.83329 | 1.98224 | -7.1121E-4 | 4.9680E-4 | 0.09971 |
| Wind Dir. | -501550.05004 | 240476.72545 | 502.23312 | 240.50237 | -0.12569 | 0.05618 | 0.06351 |

3.4 Analysis of variance (ANOVA) of Ikogosi

The outcome of using ANOVA divides the result into two distinct groups of Pr. > 0.004 and Pr. < 0.91, which satisfies the condition for using the analysis of variance as illustrated in Table 2. A majority of the months of Ikogosi months display Probability < than 0.91, this directly impacts on the future prospects of the wind data. On the one hand, this measures the validity and reliability of MERRE data, while on the other hand, it ranks higher than zero and the largest value is unity. This is a measure of consistency of the wind speed crop, this is relatively high and suggests a good prospect. Directly, small wind turbines would probably give in to medium wind turbines and eventually large sizes of wind turbines would serve some of the energy need in Ikogosi environs. Economically, this would lead to economies of scale, the price of wind turbine would become less as wind energy resource gets popular. Conversely, the effect of various parameters on wind energy production, factors affecting terrain, vegetation, ecological need to be given serious consideration. At higher altitudes, wind speeds increase, this could account for the consistency of Ikogosi wind energy crop over the years. As the only part of the ecosystem actively involved in utilizing and regulating carbondioxide, vegetation must not be the price for development of Ikogosi wind energy project as is the usual norm for most industrial and economic growth. This is therefore crucial in determining the quality of air in the environment and health standard. Therefore, rural and urban planning must integrate forest conservation alongside future energy solution. In fact, cultivating cash tree crops is one area that Nigeria needs to resuscitate as intermediary step to our economic growth. Every part of the ecosystem plays an important role in maintaining equilibrium on our planet, attention should be given to Aves flight trail when installing the wind turbines.
Table 2: Analysis of variance of Ikogosi wind speed-direction

| Month  | Wind Speed | Model 1 | Error 1 | Total 1 | Mean Square 1 | F Value 1 | Prob>F 1 | Model 2 | Error 2 | Total 2 | Mean Square 2 | F Value 2 | Prob>F 2 |
|--------|------------|---------|---------|---------|---------------|-----------|---------|---------|---------|---------|---------------|-----------|---------|
| April  | 4.6995     | 0.0491  | 0.1628  | 0.1628  | 0.0491        | 0.1628    | 0.0491  | 0.1628  | 0.0491  | 0.1628  | 0.0491        | 0.1628    | 0.0491  |
| May    | 4.7402     | 0.0491  | 0.1628  | 0.1628  | 0.0491        | 0.1628    | 0.0491  | 0.1628  | 0.0491  | 0.1628  | 0.0491        | 0.1628    | 0.0491  |
| June   | 4.7402     | 0.0491  | 0.1628  | 0.1628  | 0.0491        | 0.1628    | 0.0491  | 0.1628  | 0.0491  | 0.1628  | 0.0491        | 0.1628    | 0.0491  |
| July   | 4.7402     | 0.0491  | 0.1628  | 0.1628  | 0.0491        | 0.1628    | 0.0491  | 0.1628  | 0.0491  | 0.1628  | 0.0491        | 0.1628    | 0.0491  |
| August | 4.7402     | 0.0491  | 0.1628  | 0.1628  | 0.0491        | 0.1628    | 0.0491  | 0.1628  | 0.0491  | 0.1628  | 0.0491        | 0.1628    | 0.0491  |
| September | 4.7402  | 0.0491  | 0.1628  | 0.1628  | 0.0491        | 0.1628    | 0.0491  | 0.1628  | 0.0491  | 0.1628  | 0.0491        | 0.1628    | 0.0491  |
| October| 4.7402     | 0.0491  | 0.1628  | 0.1628  | 0.0491        | 0.1628    | 0.0491  | 0.1628  | 0.0491  | 0.1628  | 0.0491        | 0.1628    | 0.0491  |
| November| 4.7402    | 0.0491  | 0.1628  | 0.1628  | 0.0491        | 0.1628    | 0.0491  | 0.1628  | 0.0491  | 0.1628  | 0.0491        | 0.1628    | 0.0491  |
| December| 4.7402    | 0.0491  | 0.1628  | 0.1628  | 0.0491        | 0.1628    | 0.0491  | 0.1628  | 0.0491  | 0.1628  | 0.0491        | 0.1628    | 0.0491  |
4. Conclusion and Recommendation

Ikogosi wind speed and direction over decades indicates a steady deposit for inauguration of developing alternate sources to the sole dominance of hydro-electricity on our grid. The outcome of regression analysis extrapolates in future to a possibility of increased wind speeds. However, for sustainability of the present wind energy crop, planting of arable crops should be done in a specified direction to prevent run-off by the warm water spring. Embankment of farmland is advised to take advantage of the mountainous region and guard against surface soil erosion by rainfall and the spring and frequent readings of wind speed-direction, such as three-hourly is encouraged to reveal intrinsic trends that may be concealed. This is in order to have credence for this weather model being used as a fiscal development and planning instrument.

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