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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, analysedfor identificationof the behaviour of its wind using several statisticsprobability 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

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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 Ikogosi 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 Ikogosi 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 Ikogosi 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.

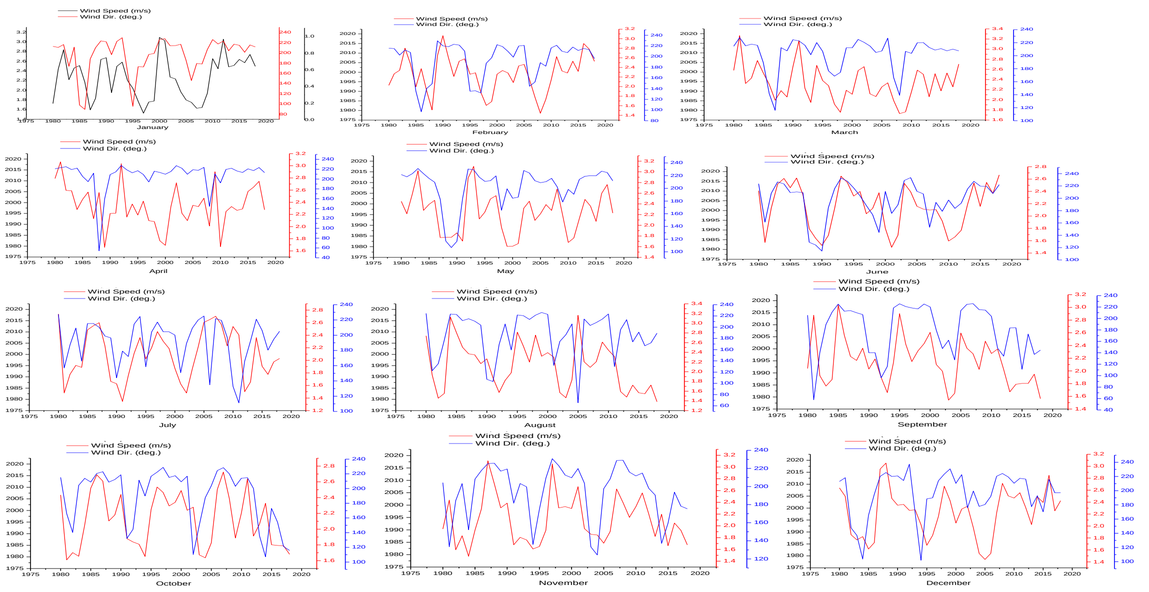

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Figure 1: Multidecadal Wind Pattern in Ikogosi

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.

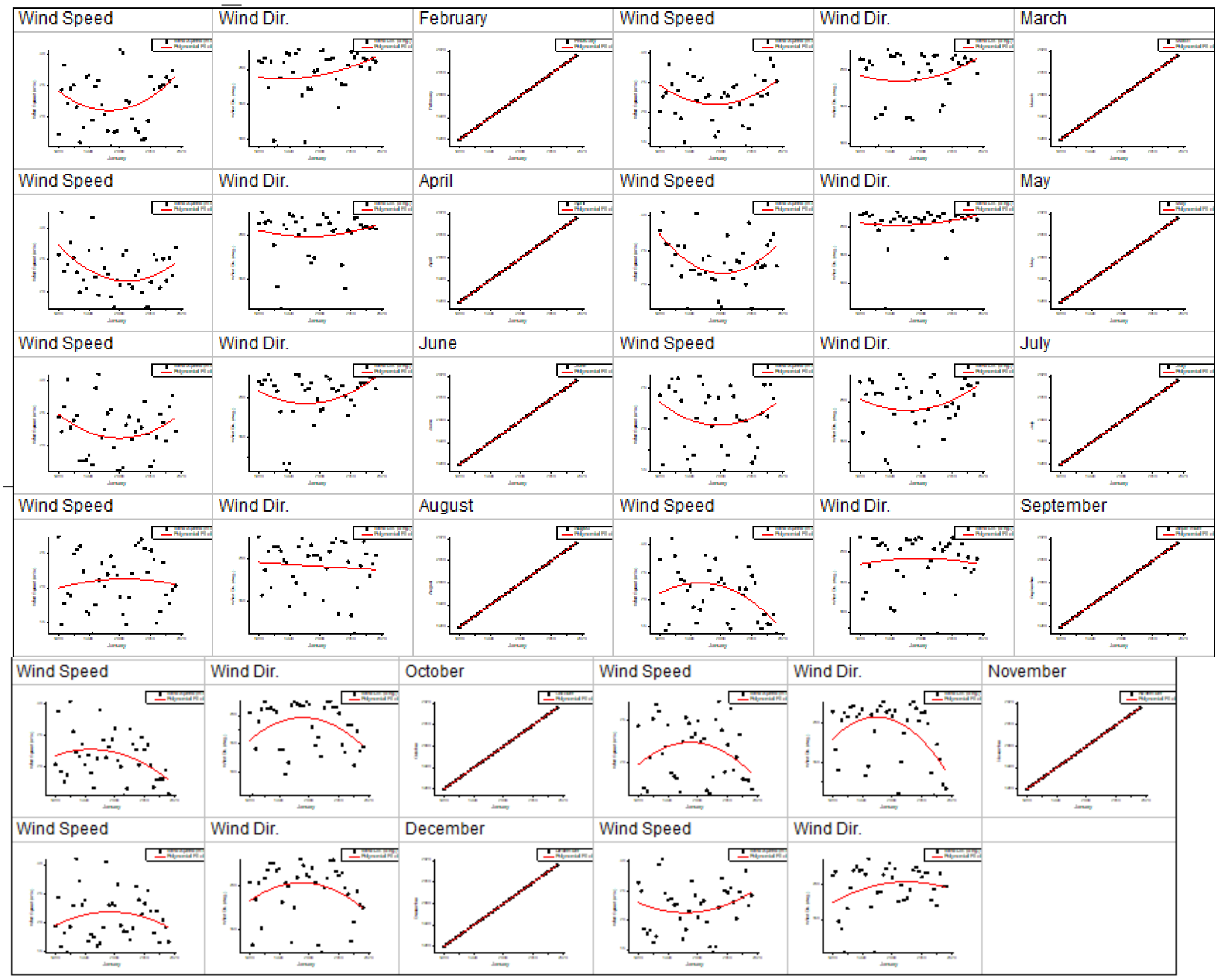

Figure 2: Regression curve of Ikogosi wind speed and direction

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
	Value	Standard Error	Value	Standard Error	Value	Standard Error	Adj. R-Square
Wind Speed	4637.47219	2419.23457	-4.64379	2.4205	0.00116	6.05425E-4	0.0663
Wind Dir.	135654.02616	199912.68553	-136.30401	200.01713	0.03429	0.05003	0.02146
February	-2.91271E-12	5.00398E-12	1	5.0066E-15	-7.85654E-19	1.25227E-18	1
Wind Speed	3910.0585	2095.39891	-3.91174	2.09649	9.78891E-4	5.24384E-4	0.04065
Wind Dir.	189976.37965	193368.68716	-190.49501	193.46972	0.0478	0.04839	0.01437
March	-2.91271E-12	5.00398E-12	1	5.0066E-15	-7.85654E-19	1.25227E-18	1
Wind Speed	4611.08319	1803.08764	-4.60374	1.80403	0.00115	4.51232E-4	0.15929
Wind Dir.	110713.81983	147098.8678	-110.73431	147.17572	0.02774	0.03681	-0.03359
April	-2.91271E-12	5.00398E-12	1	5.0066E-15	-7.85654E-19	1.25227E-18	1
Wind Speed	5349.51579	1734.77398	-5.34593	1.73568	0.00134	4.34136E-4	0.18012
Wind Dir.	102329.3663	172390.47609	-102.5331	172.48054	0.02574	0.04314	-0.02608
May	-2.91271E-12	5.00398E-12	1	5.0066E-15	-7.85654E-19	1.25227E-18	1
Wind Speed	3792.67219	2185.02041	-3.791	2.18616	9.47858E-4	5.46812E-4	0.02751
Wind Dir.	263187.60012	169566.85861	-263.60544	169.65545	0.06605	0.04243	0.04264
June	-2.91271E-12	5.00398E-12	1	5.0066E-15	-7.85654E-19	1.25227E-18	1
Wind Speed	3073.31667	2041.14734	-3.07258	2.04221	7.68473E-4	5.10807E-4	0.00693
Wind Dir.	238966.46105	172790.19099	-239.32147	172.88047	0.05997	0.04324	0.02263
July	-2.91271E-12	5.00398E-12	1	5.0066E-15	-7.85654E-19	1.25227E-18	1
Wind Speed	-1141.58178	2279.90729	1.14294	2.2811	-2.8554E-4	5.70558E-4	-0.04667
Wind Dir.	3538.34752	169325.03142	-3.11677	169.4135	7.21693E-4	0.04237	-0.04697
August	-2.91271E-12	5.00398E-12	1	5.0066E-15	-7.85654E-19	1.25227E-18	1
Wind Speed	-4617.98261	2570.52504	4.63672	2.57187	-0.00116	6.43287E-4	0.13757
Wind Dir.	-103918.37426	233449.03185	104.13719	233.571	-0.02604	0.05842	-0.04972
September	-2.91271E-12	5.00398E-12	1	5.0066E-15	-7.85654E-19	1.25227E-18	1
Wind Speed	-2819.48714	1981.20144	2.83329	1.98224	-7.11219E-4	4.95805E-4	0.09971
Wind Dir.	-501505.09004	240476.72545	502.23312	240.60237	-0.12569	0.06018	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

		DF	Sum of Squares	Mean Square	F Value	Prob>F
Wind Speed	Model	2	0.86035	0.43018	2.34912	0.10992
	Error	36	6.59242	0.18312		
	Total	38	7.45278			
Wind Dir.	Model	2	3543.0325	1771.51625	1.4167	0.25571
	Error	36	45016.30478	1250.45291		
	Total	38	48559.33728			
February	Model	2	4940	2470	3.15267E33	0
	Error	36	2.82046E-29	7.83462E-31		
	Total	38	4940			
Wind Speed	Model	2	0.49597	0.24799	1.80512	0.17902
	Error	36	4.94564	0.13738		
	Total	38	5.44161			
Wind Dir.	Model	2	2988.12859	1494.0643	1.27706	0.29119
	Error	36	42117.38835	1169.92745		
	Total	38	45105.51694			
March	Model	2	4940	2470	3.15267E33	0
	Error	36	2.82046E-29	7.83462E-31		
	Total	38	4940			
Wind Speed	Model	2	0.93585	0.46793	4.59998	0.01663
	Error	36	3.66204	0.10172		
	Total	38	4.59789			
Wind Dir.	Model	2	517.94431	258.97216	0.38251	0.68488
	Error	36	24372.93308	677.02592		
	Total	38	24890.87739			
April	Model	2	4940	2470	3.15267E33	0
	Error	36	2.82046E-29	7.83462E-31		
	Total	38	4940			
Wind Speed	Model	2	0.97438	0.48719	5.17401	0.01059
	Error	36	3.38981	0.09416		
	Total	38	4.36419			
Wind Dir.	Model	2	961.47566	480.73783	0.51701	0.60066
	Error	36	33474.62141	929.85059		
	Total	38	34436.09708			
May	Model	2	4940	2470	3.15267E33	0
	Error	36	2.82046E-29	7.83462E-31		
	Total	38	4940			
Wind Speed	Model	2	0.45935	0.22967	1.53749	0.2287
	Error	36	5.37774	0.14938		
	Total	38	5.83709			
Wind Dir.	Model	2	3321.82426	1660.91213	1.8462	0.17247
	Error	36	32387.02712	899.63964		
	Total	38	35708.85137			
June	Model	2	4940	2470	3.15267E33	0
	Error	36	2.82046E-29	7.83462E-31		
	Total	38	4940			
Wind Speed	Model	2	0.29529	0.14764	1.13261	0.3334
	Error	36	4.69286	0.13036		
	Total	38	4.98815			
Wind Dir.	Model	2	2690.07818	1345.03909	1.43983	0.25029
	Error	36	33630.03391	934.16761		
	Total	38	36320.11209			
July	Model	2	4940	2470	3.15267E33	0
	Error	36	2.82046E-29	7.83462E-31		
	Total	38	4940			
Wind Speed	Model	2	0.04971	0.02486	0.15284	0.85882
	Error	36	5.85495	0.16264		
	Total	38	5.90467			
Wind Dir.	Model	2	264.86704	132.43352	0.14763	0.86327
	Error	36	32294.7157	897.07544		
	Total	38	32559.58274			
August	Model	2	4940	2470	3.15267E33	0
	Error	36	2.82046E-29	7.83462E-31		
	Total	38	4940			
Wind Speed	Model	2	1.66669	0.83335	4.03084	0.02632
	Error	36	7.44274	0.20674		
	Total	38	9.10943			
Wind Dir.	Model	2	341.45618	170.72809	0.10012	0.90498
	Error	36	61386.55906	1705.1822		
	Total	38	61728.01524			
September	Model	2	4940	2470	3.15267E33	0
	Error	36	2.82046E-29	7.83462E-31		
	Total	38	4940			
Wind Speed	Model	2	0.76249	0.38124	3.10426	0.05705
	Error	36	4.42126	0.12281		
	Total	38	5.18375			
Wind Dir.	Model	2	8281.67136	4140.83568	2.28852	0.11598
	Error	36	65138.12226	1809.39229		
	Total	38	73419.79363			
October	Model	2	4940	2470	3.15267E33	0
	Error	36	2.82046E-29	7.83462E-31		
	Total	38	4940			
Wind Speed	Model	2	0.41407	0.20703	1.7674	0.18527
	Error	36	4.21706	0.11714		
	Total	38	4.63113			
Wind Dir.	Model	2	14033.84401	7016.92201	6.19009	0.00489
	Error	36	40808.62815	1133.573		
	Total	38	54842.47216			
November	Model	2	4940	2470	3.15267E33	0
	Error	36	2.82046E-29	7.83462E-31		
	Total	38	4940			
Wind Speed	Model	2	0.24083	0.12041	0.73811	0.48511
	Error	36	5.87298	0.16314		
	Total	38	6.1138			
Wind Dir.	Model	2	2529.91437	1264.95718	1.41053	0.25718
	Error	36	32284.73138	896.79809		
	Total	38	34814.64574			
December	Model	2	4940	2470	3.15267E33	0
	Error	36	2.82046E-29	7.83462E-31		
	Total	38	4940			
Wind Speed	Model	2	0.35391	0.17695	1.10357	0.34264
	Error	36	5.77251	0.16035		
	Total	38	6.12642			
Wind Dir.	Model	2	2728.00149	1364.00075	1.35166	0.27163
	Error	36	36328.61694	1009.12825		
	Total	38	39056.61844			

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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 toreveal 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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