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Global Solar Radiation in Awka, South East, Nigeria Using Weather Station

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ABSTRACT

This paper mainly evaluated the global solar radiation of Awka in Anambra State, Nigeria using the Davis Vantage Pro 2 weather station mounted at Nnamdi Azikiwe University, Awka. The daily sunshine hour were measured for five years (2009 – 2013) from which the monthly mean values were determined. The correlation used was based on the Angstron model for the estimation of the global solar radiation on monthly mean sunshine hour. The values of solar radiation for Awka town vary from the range of 14.78203$Jm^{-2}day^{-1}$ to 22.81541$Jm^{-2}day^{-1}$ under the period of study with the mean value of 21.053767$Jm^{-2}day^{-1}$. This value can be utilized in the design and performance estimation of solar energy systems, which is gaining significant attention in Nigeria in particular and the world at large.

Keywords: *Solar radiation, Davis Vantage Pro 2-weather station, Angstron Model, Daily sunshine hours*

1. INTRODUCTION

Amongst the numerous sources of renewable energy, solar energy occupies a very important place. The South East part of Nigeria is blessed with abundant amount of sunshine required as alternative source of electricity. Unfortunately, the solar radiation measurements are not easily available due to lack of the measuring instruments in most developing countries. It is pertinent, therefore to consider methods of estimating the global solar radiation based on the readily available meteorological parameters. Very many models have been proposed over the years for the prediction of the quantity of global solar radiation in some cities in Nigeria with the aid of several meteorological data, [1-6]. Solar radiation data is considered as an essential requirement to conduct feasibility. The knowledge of the global solar radiation over a long period is also useful not only to the locality where the radiation data was collected, but for the wider environs.

This paper, used the Angstron model for the estimation of the global solar radiation in Awka, Anambra State, Nigeria on the basis of the available climatic parameters of sunshine hour.

2. METHODOLOGY

Angstrom developed the most convenient and widely used correlation for predicting solar radiation and Prescott later modified it. The Angstron formular is given by [7].

$$\frac{\bar{H}}{\bar{H}_o} = a + b\frac{\bar{S}}{\bar{S}_o} \qquad (1)$$

Where

$\bar{H}$ ($Jm^{-2}day^{-1}$) is the monthly mean daily global solar radiation on horizontal surface, $\bar{S}$ (Hours)is the monthly mean daily bright sunshine hours, $\bar{S}_o$ (Hours) is the maximum possible monthly mean daily sunshine hour, $\bar{H}_o$ ($Jm^{-2}day^{-1}$) is the monthly mean extraterrestrial solar radiation on horizontal surface and a and b are regression constants given by the equations [7].

$$a = -0.110 + 0.235\cos\phi + 0.323\left(\frac{\bar{S}}{\bar{S}_o}\right) \qquad (2)$$

$$b = 1.449 - 0.553\cos\phi + 0.094\left(\frac{\bar{S}}{\bar{S}_o}\right) \qquad (3)$$

The monthly mean daily extra terrestrial irradiation $\bar{H}_o$ and monthly mean day length S_o can be derived from the following formulae:

$$\bar{H}_o = \frac{24\times3600}{\pi} I_{sc}\left[1 + 0.033\cos\left(360\frac{n}{365}\right)\right]\left[\sin L\sin\delta\left(\frac{\pi w_s}{180}\right) + \cos\phi\cos\delta\sin w_s\right] \qquad (4)$$

$$\bar{S}_o = \frac{2}{15}\cos^{-1}(-\tan\phi\tan\delta) \qquad (5)$$

Where ϕ is the latitude, δ is the angle of declination which is approximately given as

$$\delta = 23.45\sin\left(360.\frac{284+n}{365}\right) \qquad (6)$$

n in eqn (6) called the Julian day is the day of the year from January 1 to December 31.

3. RESULTS AND ANALYSIS

The monthly mean daily data for sunshine hours were obtained from the Davis Vantage Pro II Weather Station mounted at Nnamdi Azikiwe University, Awka by the researcher. The data obtained converged a period of five years (2009 – 2013) for Awka, Nigeria located on latitude 6º06` and longitude 7º0` The relevant meteorological and solar radiation data calculated using equations (1) to (6) presented the whole period are shown in Tables 1 to 6.

Table 1: Monthly mean values of daily solar radiation and the required meteorological parameters for Awka in the year 2009

Month	$\bar{S}$	$\overline{S_o}$	$\bar{S}/\overline{S_o}$	a	b	$\overline{H_o}$	$\bar{H}$
JAN	8.0000	11.0254	0.72560	0.251817	0.276185	34.31022	22.32060
FEB	8.0000	10.8473	0.73751	0.252560	0.271155	34.31321	22.35066
MAR	8.0000	11.0410	0.72457	0.251725	0.277090	34.31014	22.31726
APR	8.0000	11.0265	0.72552	0.251421	0.277701	34.31464	22.31427
MAY	6.3000	10.7753	0.58467	0.251210	0.358625	34.31316	21.11500
JUN	6.0000	10.7464	0.55833	0.275311	0.401761	34.31120	20.43755
JUL	6.0000	11.0133	0.54382	0.206721	0.403017	34.31301	20.41003
AUG	6.0000	11.0272	0.54411	0.206103	0.403374	34.31065	20.40113
SEP	6.0000	11.0581	0.54259	0.205605	0.404102	34.31551	20.40052
OCT	6.0000	11.0100	0.54496	0.206212	0.402602	34.31100	20.41250
NOV	6.0000	10.8458	0.55332	0.206711	0.401536	34.31564	20.44066
DEC	6.0000	11.0026	0.54531	0.20654...	0.403143	34.31020	20.41075

Table 2: Monthly mean values of daily solar radiation and the required meteorological parameters for Awka in the year 2010

Month	$\bar{S}$	$\overline{S_o}$	$\bar{S}/\overline{S_o}$	a	b	$\overline{H_o}$	$\bar{H}$
JAN	8.0000	11.0254	0.72560	0.251817	0.276185	34.31022	22.32060
FEB	8.0000	10.8473	0.73751	0.252560	0.271155	34.31321	22.35066
MAR	8.0000	11.0410	0.72457	0.251725	0.277090	34.31014	22.31726
APR	8.0000	11.0265	0.72552	0.251421	0.27770l	34.31464	22.31427
MAY	6.4000	10.7753	0.58467	0.251210	0.368625	34.31316	21.11500
JUN	6.0000	11.7464	0.55833	0.275311	0.401761	34.31120	20.43755
JUL	6.0000	11.0133	0.54382	0.206721	0.403017	34.31301	20.41003
AUG	6.0000	11.0272	0.54411	0.206103	0.403374	34.31065	20.40113
SEP	6.0000	11.0581	0.54259	0.205605	0.404102	34.31551	20.40052
OCT	6.0000	11.0100	0.54496	0.206212	0.402602	34.31100	20.41250
NOV	6.0000	10.8456	0.55332	0.206711	0.401536	34.31564	20.44066
DEC	7.5000	11.0026	0.68166	0.246521	0.314207	34.31020	22.20125

Table 3: Monthly mean values of daily solar radiation and the required meteorological parameters for Awka in the year 2011

Month	$\bar{S}$	$\overline{S_o}$	$\bar{S}/\overline{S_o}$	a	b	$\overline{H_o}$	$\bar{H}$
JAN	8.5000	11.0254	0.77095	0.270633	0.235757	34.31022	22.65090
FEB	8.1000	10.8489	0.74662	0.257930	0.259618	34.31321	22.45915
MAR	8.2000	11.0573	0.74159	0.262815	0.253263	34.31095	22.53443
APR	6.6000	11.0334	0.59818	0.219097	0.347152	34.31455	21.32678
MAY	6.2000	10.7927	0.57446	0.250921	0.369245	34.31304	21.10231
JUN	6.6000	11.7568	0.56138	0.296718	0.355766	34.31045	21.36686
JUL	6.2000	10.9977	0.56375	0.223130	0.368118	34.31466	21.14907
AUG	4.2000	11.0102	0.38146	0.168692	0.483756	34.31037	18.21051
SEP	5.6000	11.0610	0.50628	0.200194	0.415728	34.31617	20.12661
OCT	7.8000	11.0273	0.70734	0.257009	0.293459	34.31078	22.25764
NOV	9.4000	11.8597	0.86560	0.300838	0.199295	34.31460	22.81541
DEC	8.4000	11.4091	0.73630	0.282390	0.237140	33.09710	22.11103

Table 4: Monthly mean values of daily solar radiation and the required meteorological parameters for Awka in the year 2012

Month	$\bar{S}$	$\overline{S_o}$	$\bar{S}/\overline{S_o}$	a	b	$\overline{H_o}$	$\bar{H}$
JAN	8.2000	11.0254	0.74374	0.259881	0.258859	34.31022	22.48385
FEB	7.6000	10.8473	0.70064	0.244457	0.288566	34.31321	22.15859
MAR	7.4000	11.0736	0.66826	0.238290	0.305956	34.31014	21.97238
APR	6.7000	11.0265	0.60763	0.219217	0.346895	34.31464	21.33145
MAY	5.7000	10.7753	0.52899	0.235058	0.403330	34.31316	20.34488

JUN	5.4000	11.7464	0.45972	0.261817	0.430753	34.31120	19.73364
JUL	6.3000	11.0133	0.57204	0.217482	0.380252	34.31301	20.90926
AUG	5.7000	11.0270	0.51691	0.200729	0.414921	34.31065	20.12953
SEP	7.2000	11.0581	0.65111	0.240486	0.329158	34.31551	21.81714
OCT	7.2000	11.0100	0.65395	0.241203	0.327419	34.31100	21.82200
NOV	7.2000	10.8456	0.66386	0.241796	0.326151	34.31564	21.84445
DEC	3.8000	11.8156	0.32161	0.149650	0.522345	34.31020	17.05733

Table 5: Monthly mean values of daily solar radiation and the required meteorological parameters for Awka in the year 2013

Month	$\bar{S}$	$\overline{S_o}$	$\bar{S}/\overline{S_o}$	a	b	$\overline{H_o}$	$\bar{H}$
JAN	8.4000	11.0254	0.76188	0.265257	0.247308	34.31022	22.57461
FEB	8.0000	10.8473	0.73751	0.249859	0.276959	34.31321	22.29029
MAR	8.0000	11.0736	0.72244	0.249038	0.282864	34.31014	22.25551
APR	6.3000	11.0265	0.57135	0.203115	0.381492	34.31464	20.64540
MAY	3.0000	10.7753	0.27841	0.156988	0.571072	34.31316	14.78203
JUN	5.5000	11.7464	0.46823	0.259119	0.436552	34.31120	19.58193
JUL	4.1000	11.0133	0.37228	0.152912	0.519328	34.31301	17.04450
AUG	4.1000	11.0270	0.37182	0.152358	0.518851	34.31065	17.03464
SEP	4.1000	11.0581	0.37077	0.151943	0.519402	34.31551	17.03212
OCT	4.1000	11.0100	0.37239	0.152379	0.518268	34.31100	17.04768
NOV	4.1000	10.8456	0.37803	0.152734	0.517512	34.31564	17.07800
DEC	4.1000	11.8156	0.34700	0.152341	0.516561	34.31020	17.26362

Table 6: Annual mean global solar radiation and other meteorological parameters for Awka from 2009 – 2013

Year	$\bar{S}$	$\overline{S_o}$	$\bar{S}/\overline{S_o}$	a	b	H_o	$\bar{H}$
2009	6.690	10.951575	0.610859	0.230865	0.357524	34.312382	21.110911
2010	6.825	10.951575	0.622222	0.234326	0.316986	34.312382	21.260036
2011	7.150	11.073292	0.646159	0.249197	0.283547	34.211342	21.509216
2012	6.533	10.951575	0.590705	0.229172	0.361217	34.312382	22.644503
2013	5.317	10.951575	0.479343	0.191504	0.442181	34.312382	21.053765

Graph of the mean monthly global solar radiation $\bar{H}\ (Jm^{-2}day^{-1})$ against month, annual mean global solar radiation against year and the monthly mean sunshine hours $\bar{S}(hr)$ against months are displayed in figures 1, 2, 3 and 4 respectively.

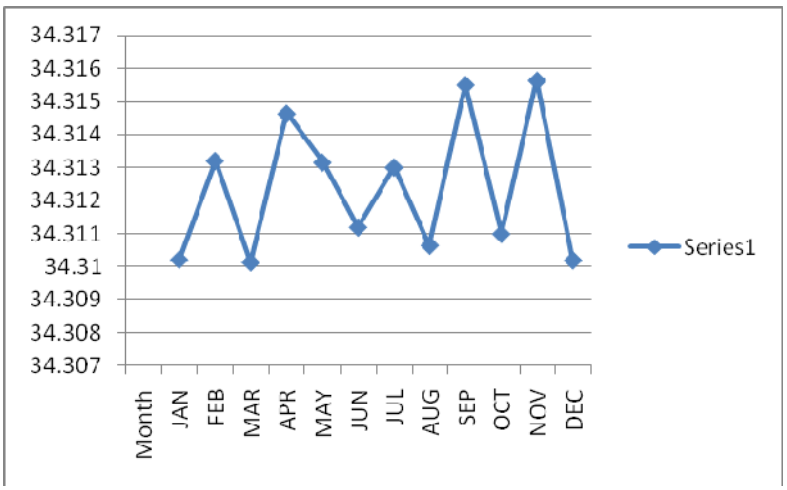


Fig 1: Monthly mean global solar radiation for 2009, 2010, 2012, 2013

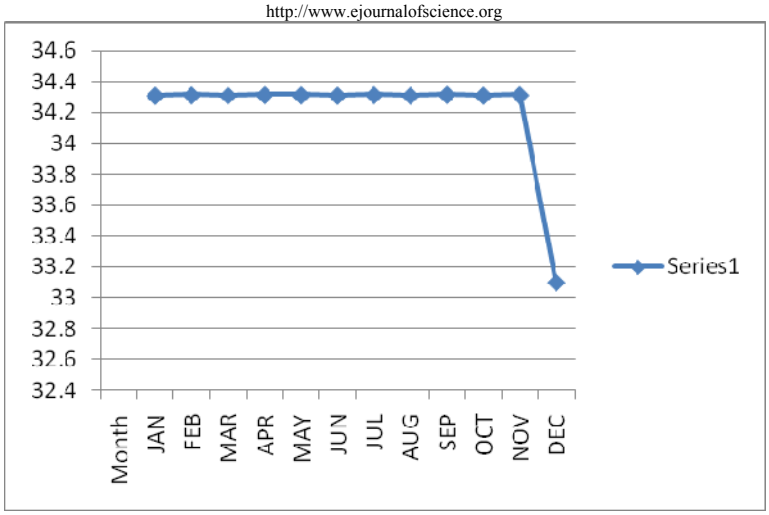


Fig 2: monthly mean global solar radiation for 2011

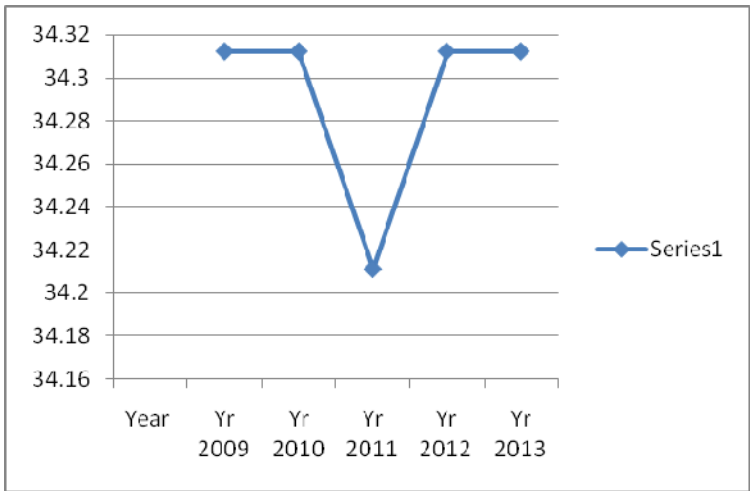
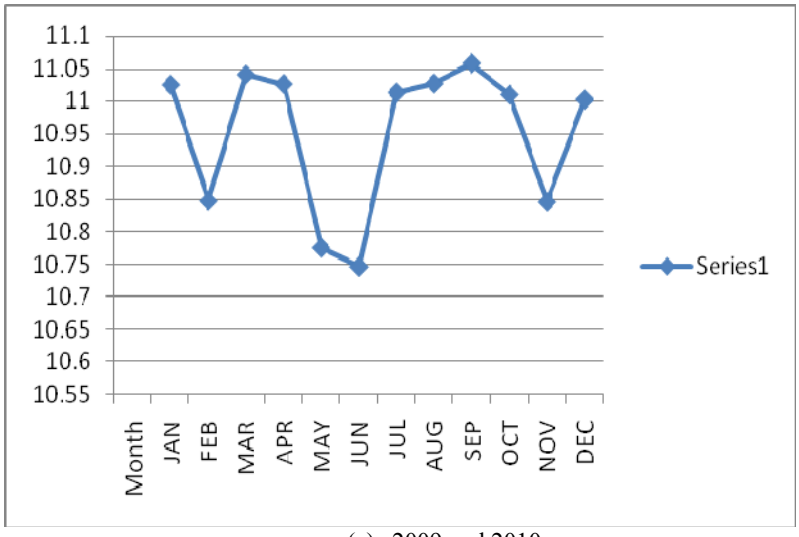
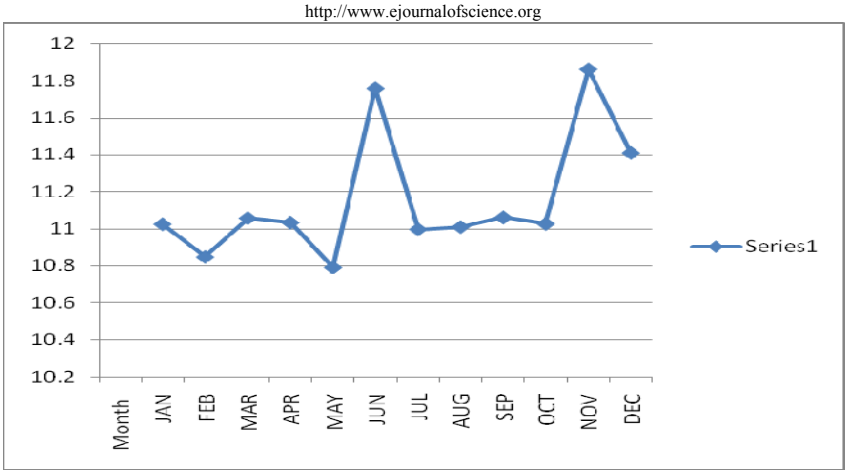


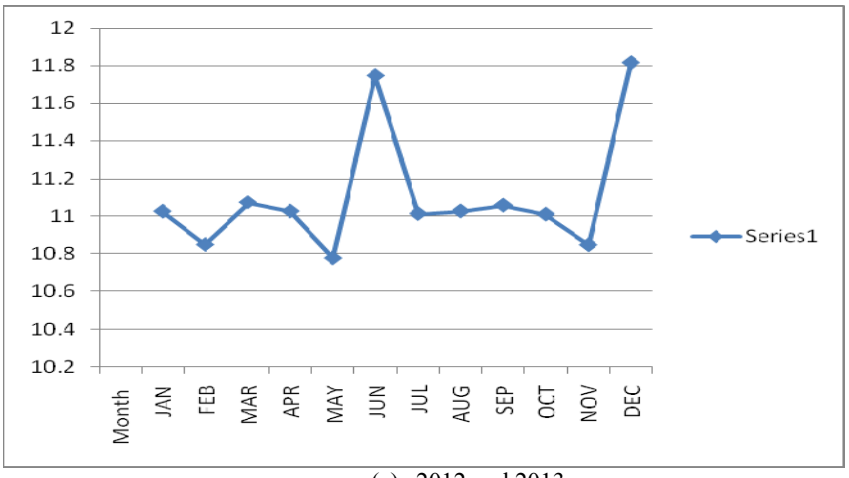
Fig 3: Annually mean global solar radiation against year for Awka from 2009 – 2013



(a) 2009 and 2010



(b) 2011



(c) 2012 and 2013

Fig 4 (a, b, c): Monthly mean sunshine hours against months for Awka 2009 – 2013

From Table 6 and fig. 2, it is observed that the monthly global solar radiation is not uniform throughout the period of study. Peak radiation is observed in the months of February, March and April with values of 22.470112 $Jm^{-2}day^{-1}$ 22.32187$Jm^{-2}day^{-1}$ and 22.279368$Jm^{-2}day^{-1}$ respectively.

On the other hand, the months of June, July and August recorded last amount of solar radiation average values of 10.984578$Jm^{-2}day^{-1}$, 19.235388$Jm^{-2}day^{-1}$ and 19.956318$Jm^{-2}day^{-1}$ respectively. This is as a result of the peak period of rainy season resulting in dark cloud cover in Awka. Generally higher value of global solar radiation is obtained in dry season than wet season. The value of global solar radiation for Awka town over the period of study is estimated to 19.80428$Jm^{-2}day^{-1}$ using the Angstron model.

4. CONCLUSION

Clearly the results from this paper indicate the main significance of developing empirical models for estimating global radiation on horizontal surfaces reaching the earth for a particular geographical location. The Angstron model can also be applied to other cities for the prediction of global solar radiation. The intensity of global solar radiation predicted in this research can be utilized in design, analysis and performance estimation of solar energy systems, which is gaining significant attention in Nigeria.

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