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Estimation of the Global Solar Radiation in Okura Kogi State Using Angstrom-Prescott Model

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Abstract
This research is aimed at estimating Global Solar radiation data in Okura Kogi State using the sunshine hour data obtained from Anyigba. Angstrom Prescott model was used to estimate the global solar radiation for Anyigba using the latitude of the area which is 7.4809 and the sunshine hour, after which the Global Solar radiation data in Okura, Kogi State (Latitude 7.4146) was estimated The Angstrom-Prescott model for Okura was found to be $\overline{H_O}$= (0.2324+0.6655(S/s_0). Where the regression coefficient **a** and **b** were found to be 0.2324 and 0.6655 respectively. The result was validated using a 6years global solar radiation data between years 2011 to 2016, obtained from the weather station of National Airspace Research and Development Agency (NASRDA) located in the campus of Kogi State University Anyigba

Keywords: Global Solar Radiation, Extraterrestrial Solar Radiation, Clear Sky index

Introduction
The importance of global solar radiation cannot be over emphasized, global solar radiation is important for agriculture and photovoltaic energy system design. Solar radiation serve is the fundamental for most physical biological and chemical processes on earth (Anjorin *et al*, 2014) [2]. The sun melt snows and is needed for photosynthesis of plants, evapotranspiration, and crop growth, hydrological simulation (Meza F. And Varas E., 2000) [5]. Solar radiation data is principal to photovoltaic energy design. A photovoltaic module is an environmentally sealed collection of cells which convert sunlight directly to electricity (Wansah, J.F. *et al*, 2014). Quit a number of researches have been conducted on acquiring solar energy data either from location with solar energy measuring equipment of regions without measuring equipment data. This might either involve direct measurement or the use of models. Most of the models used correlates global radiation of different cities and towns (Innocent A.J., *et al*, 2015) [4]. Burari *et al* (2001), proposed a model for the estimation of global solar radiation in Bauchi and found the regression coefficient a and b to be 0.24 and 0.46 respectively. Akpo and Etuk (2003) established the relationship between global solar radiation and sunshine duration for Onne, and found the regression coefficient a and b to be 0.23 and 0.38 respectively. Musa *et al* (2012) [6] estimated the global solar radiation in Maiduguri Nigeria, using Angstrom model. In all literatures available, none was found in respect to the global solar radiation in Okura Kogi State.

Aim and Objectives
Aim of this study is to evaluate the solar radiation in Okura Kogi state, using Angstrom-Prescott Model. The objectives of the study are as follows:
1. To obtain the solar radiation data from the Centre for Atmospheric Research.
2. To determine the regression coefficient of Angstrom Prescott model for both Anyigba and Okura
3. To evaluate RMSE and the MBE between the measured solar radiation data and the estimated global solar radiation.
4. Estimate the global solar radiation in Okura using the sunshine hour for Anyigba.

Scope of the studies
This research estimates the global solar radiation in Okura in Kogi State, Okura in located in Dekina Local government in Kogi East of Kogi State with location between (7.4809ºN and 6.9ºE), Okura house the Nigeria Navy Secondary School. Six (6) years solar radiation data (2011-2016) would be used for this research. The availability of solar radiation will be analyzed using Angstrom-Prescott Model. This research focuses on global solar radiation in Okura and environs.

Materials and Method
Angstrom–Prescott Model
This research uses Angstrom Prescott to estimate the global solar radiation which was first proposed 1924, using a linear relationship between the ratio of average daily global radiation to the corresponding value on a completely clear day ($\frac{H}{Hc}$) at a given location and the ratio of average daily sunshine duration to the maximum possible sunshine duration given as(Abdu and Ayodele);

$$\frac{H}{Ho} = a+b\left(\frac{S}{So}\right) \quad (2)$$

$$a = -0.110 + 0.235\cos\varphi + 0.323\left(\frac{S}{So}\right) \quad (3)$$

$$b = 1.449 - 0.553\varphi - 0.694\left(\frac{S}{So}\right) \quad (4)$$

(a and b are the regression coefficient)

Ho is the monthly average daily extraterrestrial radiation; the values of the monthly average daily extraterrestrial irradiation (H_o) can be calculated from the equation given below as

$$H_o=\frac{24}{\pi}I_{sc}[1+0.033\cos(\frac{360n}{365})]\ [\cos\varphi\cos\delta\sin\omega_s+\frac{\pi}{180}\omega_s\sin\varphi\sin\delta] \qquad (5)$$

Where:
I_{sc} is the solar constant ($1367Wm^{-2}$),
φ is the latitude of the site,
δ is the solar declination,
ω_s is the mean sunrise hour angle for the given month
n is the number of days of the year starting from first January.
The solar declination (δ) and the mean sunrise hour angle (ω_s) can be calculated by following equations:

$$\delta = 23.45\sin[360/365(284+n)] \qquad (6)$$

H_0 is the extraterrestrial radiation (radiation intensity outside the earth's atmosphere) measured in mega joule per square meter per day ($MJm^{-2}\ day^{-1}$), n is the day of the year i.e. the Julian day calculated every 15^{th} of each month.

$$n = INT\left(\frac{275\times M}{9}\right) - K\times INT\left(\frac{M+9}{12}\right) + D - 30 \qquad (7)$$

Where M is the month number, D is the day of the month, and K=1 for a leap year, K=2 for a common year. INT means taking the integer part of the number (Julian, c.).

$$\omega_s=\cos^{-1}(-\tan\varphi\tan\delta) \qquad (8)$$

The maximum possible sun-shine duration (monthly average day length, S_0) can be computed by using the following equation:

$$S_0=\frac{2}{15}\ \omega s \qquad (9)$$

Results

Table 1: H_0, Represents the extraterrestrial solar radiation for Anyigba, $H_{1,\ Cal}$ represents the calculated solar radiation using Angstrom-Prescott model, K

Months	H_0	$H_{1,\ Cal}$	$K=\frac{\overline{H_0}}{H_0}$	$H_{1,MEASURED}$
January	32.9788	16.7035	0.5065	16.402
February	35.2930	18.08151	0.5123	19.4216
March	37.2209	19.2863	0.5182	20.9286
April	37.7024	21.074	0.5590	22.3609
May	36.8846	15.1306	0.4540	20.8980
June	36.1095	15.1306	0.4190	16.1656
July	36.3333	14.3769	0.3957	15.7878
August	37.1391	12.3134	0.3315	13.6800
September	37.1569	12.5359	0.3374	20.5848
October	35.6608	15.5665	0.4365	17.2066
November	33.3856	16.9097	0.5065	17.5666
December	32.1838	16.6763	0.5182	16.2436

Represents the clear sky index and $h_{1,\ measured}$ represents the measured solar radiation values

Table 2: H_0, Represents the extraterrestrial solar radiation for Okura, $H_{1,\ Cal}$ represents the calculated solar radiation using Angstrom Prescott model, k represents the clear sky index and $H_{1,\ MEASURED}$ represents the measured solar radiation values

Month	H_0	$H_{1,\ Cal}$	$K=\frac{\overline{H_0}}{H_0}$	$H_{1,\ MEASURED}$
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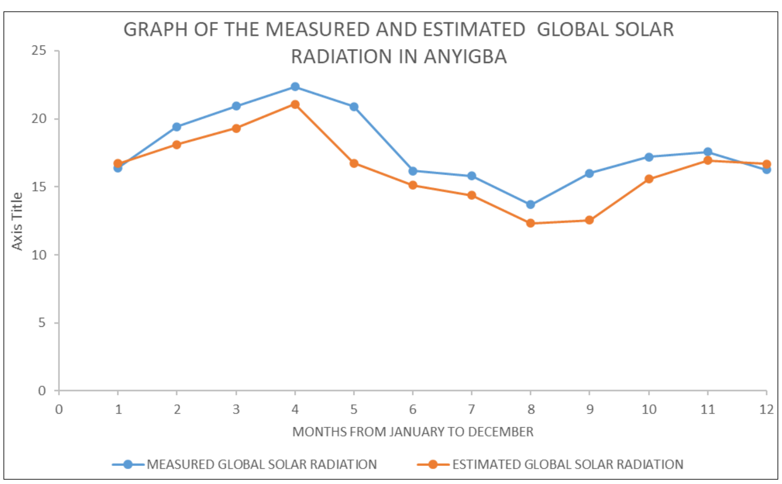

Fig 1: Shows the graph of the estimated and measured global solar radiation for Anyigba

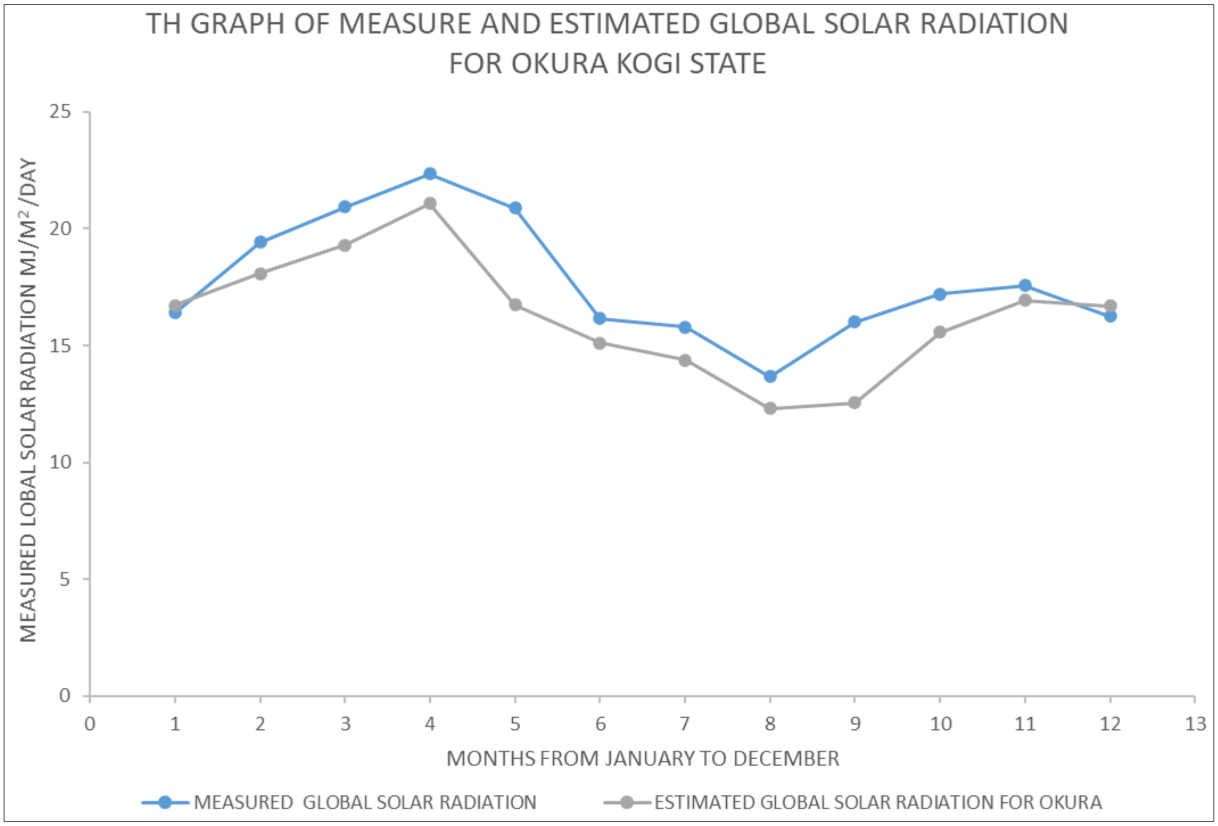

Fig 2: Shows the graph of the estimated and measured global solar radiation for OKURA

Discussion

Computation of the horizontal global solar Radiation for Okura using the mean monthly sunshine hour (S) and the latitude of the location (Latitude 7.4146). From table 1, which show the estimated global solar radiation for Anyigba (H_{Cal}) and the measured global solar radiation ($H_{Measured}$). The measured global solar radiation was obtained from the weather station of National Airspace Research and Development Agency (NASRDA) located in the campus of Kogi State University Anyigba. The measured global solar radiation was used to validate the Angstrom Prescott model for Anyigba, haven shown a good agreement between the measure and estimated global solar radiation, Angstrom-Prescott model was used to obtain the global solar radiation for Okura. The extraterrestrial solar radiation was represented with (H_0) and k represent the clear sky index. Table 2 shows the Angstrom-Prescott parameters for Okura Kogi State, The month of April is the month with the highest global solar radiation which correspond with the highest clear sky index value, while the month of August has the lowest global solar radiation, which correspond with the month with the lowest clear sky index, this is as a result of high rainfall and cloudy weather of the month. The pattern of the global solar radiation for Okura was presented in the graph titled figure 2.

Conclusion

The result obtained shows the regression coefficient (a and b) for Okura Kogi State,whic was found to be 0.2324 and 0.6655 respectively. The Angstrom-Prescott model for Okura was found to be $\overline{H_O}$= (0.2324+0.6656(S/S_0)). The graph in figure 2. Shows that Angstrom-Prescott model is suitable to estimate the global solar radiation in Okura Kogi State. The average monthly solar radiation for Okura was obtained to be 16.2876 MJ/Day/m^2 with a RMSE of 2.442 MJ/Day/m^2 and MBE of 1.91103 MJ/Day/m^2 which is within acceptable range.

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