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Prediction of global solar radiation using relative humidity, maximum temperature and sunshine hours in Uyo, in the Niger Delta Region, Nigeria

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ABSTRACT

In this paper, models are developed with regression equations to predict the monthly global solar radiation future time based on measured air temperature, relative humidity and sunshine hour values between 1991-2007 for Uyo, in Niger Delta Region, Nigeria. Using the Angstrom model as the basis, other regression equations were developed by modifying Angstrom equation. The value of correlation coefficient (r) and value of the mean bias error (MBE), mean square error (RMSE) and mean percentage error root (MPE) were determined for the equation. The equation with the highest value of correlation coefficient (r) and at least values of RMSE, MBE and MPE is given as $\frac{\overline{Hp}}{\overline{Ho}} = 1.387 + 1.592\frac{\overline{S}}{\overline{S}_0} - 0.045\overline{T}m + 0.004\frac{\overline{R}}{100}$. *The results obtained show a remarkable agreement between the measured and the predicted values using different models. The developed model can be used for the prediction of global solar radiation on horizontal surfaces for Uyo in Niger Delta*

Keywords: Global solar radiation, sunshine hour, relative humidity, correlation coefficient, Uyo.

INTRODUCTION

Solar radiation is the most important parameter in the design and evaluation of solar energy devices. An accurate knowledge of solar radiation distribution at a particular geographical location is of vital importance for surveys in agronomy, hydrology, ecology and sizing of the photovoltaic or thermal solar systems and estimates of their performances. Unfortunately, many developing nations' solar radiation measurements data are not easily available; therefore it is rather important to elaborate methods to estimate the solar radiation on the basis of more readily meteorological data. Over the years, many models have been proposed to predict the amount of solar radiation using various parameters [3-27]. Some works used the sunshine duration [7, 9, 17-25]. Some used mean daytime cloud cover or relative humidity and maximum and minimum temperature [20-21], while others still used the number of rainy days, sunshine hours and a factor that depends on latitude and altitude.

The global solar radiation on horizontal surface at the location of interest is the most critical input parameter employed in the design and prediction of the performance of solar energy device. The best way of knowing the amount of solar radiation at a site is to install a pyranometer at many locations in a given region and look after their day to day maintenance and recording. But it is cost effective. With this situation, most researchers within Nigeria use available theoretical values of meteorological data to compute average irradiance of solar radiation for different locations within the country. They lack standard measured data obtained from reliable measuring instrument suitable for their local environment and therefore resort to theoretical prediction using different models for the global daily sunshine radiation [1-8,13, 24-28].

Without the sun's radiant energy, the earth would gradually cool, in time becoming ice. [12] observed that the network of stations measuring solar radiation data is sparse in many countries. In Nigeria, only few stations have been measuring the daily solar radiation consistently. It is therefore, necessary to appreciate radiation from commonly available climate parameter such as sunshine hours, relative humidity, maximum and minimum temperature, cloud cover and geographical locations.

Nigeria is located between latitude of 10^o North and longitude of 8^o East and is one of the countries with high isolation. It is situated in the region which is generally referred to as the solar radiation belt. There is an average range of hours of sunshine in Nigeria of between 3.0 hours per day in July and August and 6.7 hours per day in February. The climate is most favourable for solar energy utilization, but the distribution of the solar radiation is not well known.

Accurate modeling depends on the quality and quantity of the measured data used and is a better tool for predicting the global solar radiation of location where measurements are not available. The main objective of this study is to develop an equation that correlates monthly daily global solar radiation on horizontal surface for Uyo, Niger Delta Region.

2.0 THEORETICAL BACKGROUND

The most widely and convenient by used correlation for predicting solar radiation was developed by Angstrom and later modified by Prescott. The expression is given by (27)

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

$\overline{H}$ = The monthly mean daily global radiation on a horizontal surface

$\overline{H}_o$ = The monthly mean daily extraterrestrial radiation on a horizontal surface

$\overline{S}_o$ = The monthly mean daily maximum number of hours of possible sunshine

$\overline{S}$ = The monthly mean daily number of hours of possible sunshine

The regression coefficients (a) and (b) have been obtained from the relationship given by [4].

$$a = \frac{\sum \frac{\overline{H}}{\overline{H}_o} \sum\left(\frac{\overline{S}}{\overline{S}_o}\right)^2 - \sum \frac{\overline{S}}{\overline{S}_o} \sum \frac{\overline{S}}{\overline{S}_o}\frac{\overline{H}}{\overline{H}_o}}{M\sum\left(\frac{\overline{S}}{\overline{S}_o}\right)^2 - \left(\sum \frac{\overline{S}}{\overline{S}_o}\right)^2} \qquad (2)$$

$$b = \frac{M\sum \frac{\overline{S}}{\overline{S}_o}\frac{\overline{H}}{\overline{H}_o} - \sum \frac{\overline{S}}{\overline{S}_o} \sum \frac{\overline{H}}{\overline{H}_o}}{M\sum\left(\frac{\overline{S}}{\overline{S}_o}\right)^2 - \left(\sum \frac{\overline{S}}{\overline{S}_o}\right)^2} \qquad (3)$$

The extraterrestrial solar radiation on the horizontal surface can be calculated from the following equation[4].

$$\overline{H}_o = \frac{24\times 3600}{\pi} I_{SC}\left[1 + 0.033\cos\left(360\frac{\overline{D}}{365}\right)\right]\cos\phi\cos\delta\sin\omega_s + \omega_s\sin\phi\sin\delta \qquad (4)$$

The value of 1367Wm^{-2} has been recommended for solar constant I_{SC}. The hour angle ω_s is given as

$$\omega_s = \cos^{-1}(-\tan\phi\tan\delta) \quad (5)$$

The solar declination δ is given as

$$\delta = 23.45\sin\left(360\frac{284+\overline{D}}{365}\right) \quad (6)$$

The day length S_o is the number of hours of sunshine or darkness within the 24hours in a given day and is given as:

$$S_o = \frac{2}{15}\cos^{-1}(-\tan\phi\tan\delta =)\frac{2}{15}\omega_s \quad (7)$$

$\overline{D}$ is the day number and ϕ is the latitude of the location

Modifications in the Angstrom-type regression equation have been made by various authors to further predict more accurately monthly average daily global radiation on a horizontal surface. In this paper the modified models used are expressed in equations (8, 9 and 10) below.

Glover and McCulloch include the effect of the latitude of location and is given as:

$$\frac{\overline{H}}{\overline{H}_o} = 0.29\cos\theta + 0.52\left(\frac{\overline{S}}{\overline{S}_o}\right) \quad (8)$$

where θ *is the latitude*

Turton's model developed average regression constants for humid tropical countries as:

$$\frac{\overline{H}}{\overline{H}_o} = 0.30 + 0.540\left(\frac{\overline{S}}{\overline{S}_o}\right) \quad (9)$$

[4] have developed a model for estimating global solar radiation for the rainforest climate zone of southern Nigeria. This model is expressed as:

$$\frac{\overline{H}}{\overline{H}_o} = 0.23 + 0.52\left(\frac{\overline{S}}{\overline{S}_o}\right) \quad (10)$$

MATERIALS AND METHODS

The monthly mean daily data for sunshine hours, relative humidity, maximum temperature and the solar radiation data for Uyo were collected from the Archives of the Nigerian Meteorological Agency, Federal Ministry of Aviation, Oshodi, Lagos. The data obtained covered a period of seventeen years (1991-2007) for Uyo at Latitude 5.03^o and longitude 7.93^o. The monthly averages data processed in preparation for the correlation are presented in Table(1, 2 & 3).

To develop the model, the global solar radiation data for Uyo measured in millimeters using Gun-Bellani Distillate were converted to (MJm^{-2}day^{-1}), proposed by [24]. The first correlation proposed for estimating the monthly mean daily global solar radiation on a horizontal surface $(\overline{H})$ Angstrom correlation has been put in a convenient form by Prescott (1940) as:

$$\frac{\overline{H}}{\overline{H}_o} = a + b\left(\frac{\overline{n}}{\overline{N}}\right) \tag{11}$$

[4] has put the Prescott correlation as

$$\frac{\overline{H}_m}{\overline{H}_o} = 0.23 + 0.52\left(\frac{\overline{S}}{\overline{S}_o}\right) \tag{12}$$

Where $\overline{H}_m$ the global is mean solar radiation (measured) and other symbols retain their meaning.

According to [7], the monthly mean daily solar radiation reaching a horizontal surface on the earth $\overline{H}_m$ is related to the maximum temperature $\overline{T}_m$ as:

$$\frac{\overline{H}_m}{\overline{H}_o} = a + b\overline{T}_m \tag{13}$$

Where $\overline{T}_m$ is the monthly mean daily maximum temperature. Other symbols retain their usual meaning.

Also, [8,24], correlated solar radiation with relative humidity using the relation:

$$\frac{\overline{H}_m}{\overline{H}_o} = a + b\frac{\overline{R}}{100} \tag{14}$$

3.1 Analysis of Data

3.1.1 *Correlation Between Solar Radiation, Relative Humdity, Maximum Temperature And Sunshine Hour*

The sunshine data is related to solar radiation, linear regression and correlation analysis of the parameter $\frac{\overline{S}}{\overline{S}_o}$ was employed to predict the global solar radiation [4]. Also, linear regression and correlation analysis of the parameter $\frac{R}{100}$ was employed using [8] to estimate the global solar radiation. Finally, multiple linear regression and correlation analysis of the parameters $\left[\frac{\overline{S}}{\overline{S}_o}, \frac{\overline{R}}{100}, \overline{T}_m\right]$ was carried out using SPSS computer software program.

The accuracy of the estimated values was tested by calculating the mean bias error (MBE), root mean square error (RMSE) and mean percentage error (MPE). The expression for the MBE ($MJm^{-2}day^{-1}$), RMSE ($MJm^{-2}day^{-1}$) and MPE (%) projected by [4] are given by the equations (15, 16 and 17)

$$MBE(\%) = 100\left(\frac{1}{\overline{H}_m}\right)\sum\left(\frac{E_i}{M}\right) \tag{15}$$

$$RMSE(\%) = 100\left(\frac{1}{\overline{H}_m}\right)\sum\left(\frac{E_i}{M}\right)^{0.5} \tag{16}$$

$$MPE = \left[\frac{\sum \left(\overline{H}_m - \overline{H}_p \right)}{\overline{H}_m} \right] / n \qquad (17)$$

Where $\overline{H}_p$ and $\overline{H}_m$ are the ith measured and predicted values respectively and n is the total number of the observation. [17, 26], have recommended that a zero value for MBE is ideal and a low RMSE is desirable. The RMSE test provides information on the short term performance of the study model as it allows a term by term comparison of the actual derivation between the calculated and measured the values. The MPE test gives long term performance of the examined regression equations. Positive values of MPE means overestimation in the calculated values of the global solar radiation, while the negative values give underestimation. A low MPE is desirable [4, 13, 19].

RESULTS

The calculated value for monthly mean sunshine hours, day length, fraction of sunshine hours, global solar radiation, extraterrestrial solar radiation and clearness index for Uyo are presented in table I. The predicted value for maximum temperature, global solar radiation, extraterrestrial solar radiation and clearness index for Uyo are presented in Table II. While the predicted (calculated) value for relative humidity, percentage of relative humidity, global solar radiation, extraterrestrial solar radiation and clearness index for Uyo are presented in Table III. The predicted value for maximum temperature, fraction of sunshine hours, global solar radiation, extraterrestrial solar radiation and clearness index for Uyo are presented in Table IV. The predicted value for value of relative humidity, fraction of sunshine hours, global solar radiation, extraterrestrial solar radiation and clearness index for Uyo are presented in Table V. The predicted value for value of relative humidity, maximum temperature, global solar radiation, extraterrestrial solar radiation and clearness index for Uyo are presented in Table VI. The predicted value for value of relative humidity, maximum temperature, fraction of sunshine hour, global solar radiation, extraterrestrial solar radiation and clearness index for Uyo are presented in Table VII.

Table 1: The Monthly values of Sunshine $\overline{S}$, Day Length $\overline{S}_0$, possible fraction of Sunshine $\frac{\overline{S}}{\overline{S}_0}$, Global Solar Radiation $\overline{Hm}$, Extraterrestrial Solar Radiation $\overline{Ho}$, Predicted Global Solar Radiation $\overline{Hp}$, Clearness index $\overline{K}_T$, Characteristic Day Number N for Equation 18 for Uyo (1991-2007 inclusive).

Months	$\overline{S}$ (hrs)	$\overline{S}_0$ (hrs)	$\frac{\overline{S}}{\overline{S}_0}$	$\overline{Hm}$ (MJm^{-2}day^{-1})	$\overline{Ho}$ (MJm^{-2}day^{-1})	$\overline{K}_T = \frac{\overline{Hm}}{\overline{Ho}}$	$\overline{Hp}$	$\overline{D}$
JAN	4.06	11.74	0.3458	14.23	33.79	0.3978	14.91	17
FEB	4.29	11.83	0.3626	16.27	36.05	0.4513	16.26	45
MAR	3.56	11.96	0.2977	14.49	38.02	0.3811	15.71	74
APR	3.89	12.11	0.3212	14.95	37.49	0.3988	16	105
MAY	3.58	12.22	0.293	14.84	36.41	0.4076	14.93	135
JUN	2.84	12.29	0.2311	13.55	35.32	0.3836	13.22	161
JUL	1.91	11.74	0.1627	12.22	35.59	0.3434	11.89	199
AUG	1.79	12.11	0.1478	10.67	37.06	0.2879	12.06	239
SEP	2.59	12.01	0.2157	14.27	37.23	0.3833	13.6	261
OCT	2.84	11.86	0.2395	14.67	36.11	0.4063	13.7	292
NOV	3.79	11.75	0.3226	16.41	34.31	0.4783	14.67	322
DEC	3.73	11.61	0.3213	15.31	33.4	0.4584	14.26	347

Table II: The Monthly Mean Daily Maximum Temperature (T_m), Global Solar Radiation $\overline{Hm}$, Extraterrestrial Solar Radiation $\overline{Ho}$, Predicted Global Solar Radiation $\overline{Hp}$ and Clearness index $\overline{K}_T$, Characteristic Day Number $\overline{D}$ for Equation 19 for Uyo (1991-2007 inclusive).

Month	T_m 0^0C	$\overline{Hm}$ (MJm^{-2}day^{-1})	$\overline{Ho}$ (MJm^{-2}day^{-1})	$\overline{K}_T = \frac{\overline{Hm}}{\overline{Ho}}$	$\overline{Hp}$	$\overline{D}$
JAN	33.20	33.2	14.23	33.79	0.3978	14.69
FEB	33.40	33.4	16.27	36.05	0.4513	15.83
MAR	33.15	33.15	14.49	38.02	0.3811	16.5
APR	32.56	32.56	14.95	37.49	0.3988	15.83
MAY	31.69	31.69	14.84	36.41	0.4076	15.83
JUN	30.57	30.57	13.55	35.32	0.3836	13.51
JUL	28.96	28.96	12.22	35.59	0.3434	12.46
AUG	28.93	28.93	10.67	37.06	0.2879	12.96
SEP	24.53	24.53	14.27	37.23	0.3833	13.46
OCT	30.46	30.46	14.67	36.11	0.4063	13.73
NOV	31.71	31.71	16.41	34.31	0.4783	13.9
DEC	32.25	32.25	15.31	33.4	0.4584	13.89

Table III: The Monthly Mean Daily Relative Humidity $\overline{R}$, the Fraction Percentage of Relative Humidity $\frac{\overline{R}}{100}$, Global Solar Radiation $\overline{Hm}$, Extraterrestrial Solar Radiation $\overline{Ho}$, Predicted Global Solar Radiation $\overline{Hp}$ and Clearness index $\overline{K}_T$ for Equation 20 for Uyo (1991-2007 inclusive).

Month	$\overline{R}$	$\frac{\overline{R}}{100}$	$\overline{Hm}$ (MJm^{-2}day^{-1})	$\overline{Ho}$ (MJm^{-2}day^{-1})	$\overline{K}_T = \frac{\overline{Hm}}{\overline{Ho}}$	$\overline{Hp}$ (MJm^{-2}day^{-1})
JAN	50.1	0.501	14.23	33.79	0.3978	15.16
FEB	49.94	0.4994	16.27	36.05	0.4513	16.19
MAR	61.78	0.6178	14.49	38.02	0.3811	15.82
APR	68.78	0.6878	14.95	37.49	0.3988	14.86
MAY	73.44	0.7344	14.84	36.41	0.4076	13.96
JUN	76.22	0.7622	13.55	35.32	0.3836	13.27
JUL	81.33	0.8133	12.22	35.59	0.3434	12.86
AUG	81.56	0.8156	10.67	37.06	0.2879	13.36
SEP	79.89	0.7989	14.27	37.23	0.3833	13.6
OCT	75.33	0.7533	14.67	36.11	0.4063	13.65
NOV	65.72	0.6572	16.41	34.31	0.4783	13.9
DEC	55.72	0.5572	15.31	33.4	0.4584	14.46

Table VIII summaries various regression analysis, obtained from the application of equation (11) to the monthly mean value for the three variables on the study area. It is obvious that the correlation coefficient r, coefficient of determination R^2, MBE (MJm^{-2}day^{-1}), RMSE (MJm^{-2}day^{-1}) and MPE (%) vary from one variable to another variable.

One variable correlation

The correlation of coefficient of 0.811 exists between the clearness index and fraction of sunshine hour also coefficient of determination of 0.657 implies 65.7% of clearness index can be accounted using fraction of sunshine hour. The result of Table I using the clearness index and fraction of sunshine data for Uyo shows that $a = 0.239$ and $b = 0.239$. Hence, the monthly mean daily solar radiation on a horizontal surface for any month of the year can be predicted using equation 18

$$\frac{\overline{Hp}}{\overline{Ho}} = 0.239 + 0.585\frac{\overline{S}}{\overline{S}_0} \tag{18}$$

Where $\overline{H}_p$ the predicted global solar radiation and other symbols retain their usual meaning.

Table 1V: The Monthly Mean Daily Maximum Temperature (T_m), Possible Fraction of Sunshine $\frac{\overline{S}}{\overline{S}_0}$, Global Solar Radiation $\overline{Hm}$, Extraterrestrial Solar Radiation $\overline{Ho}$, Predicted Global Solar Radiation $\overline{Hp}$ and Clearness index $\overline{K}_T$, for Equation 21 for Uyo (1991-2007 inclusive).

Month	T_m 0^0C	$\frac{\overline{S}}{\overline{S}_0}$	$\overline{Hm}$ ($MJm^{-2}day^{-1}$)	$\overline{Ho}$ ($MJm^{-2}day^{-1}$)	$\overline{K}_T = \frac{\overline{Hm}}{\overline{Ho}}$	$\overline{Hp}$
JAN	33.20	0.3458	14.23	33.79	0.3978	14.91
FEB	33.40	0.3626	16.27	36.05	0.4513	16.26
MAR	33.15	0.2977	14.49	38.02	0.3811	15.71
APR	32.56	0.3212	14.95	37.49	0.3988	16
MAY	31.69	0.293	14.84	36.41	0.4076	14.93
JUN	30.57	0.2311	13.55	35.32	0.3836	13.22
JUL	28.96	0.1627	12.22	35.59	0.3434	11.89
AUG	28.93	0.1478	10.67	37.06	0.2879	12.06
SEP	24.53	0.2157	14.27	37.23	0.3833	13.6
OCT	30.46	0.2395	14.67	36.11	0.4063	13.7
NOV	31.71	0.3226	16.41	34.31	0.4783	14.67
DEC	32.25	0.3213	15.31	33.4	0.4584	14.26

Table V: The Fraction Percentage of Relative Humidity $\frac{\overline{R}}{100}$, Possible Fraction of Sunshine $\frac{\overline{S}}{\overline{S}_0}$, Global Solar Radiation $\overline{Hm}$, Extraterrestrial Solar Radiation $\overline{Ho}$, Predicted Global Solar Radiation $\overline{Hp}$ and Clearness index $\overline{K}_T$, for Equation 22 for Uyo (1991-2007 inclusive).

Month	$\frac{\overline{R}}{100}$	$\frac{\overline{S}}{\overline{S}_0}$	$\overline{Hm}$ ($MJm^{-2}day^{-1}$)	$\overline{Ho}$ ($MJm^{-2}day^{-1}$)	$\overline{K}_T = \frac{\overline{Hm}}{\overline{Ho}}$	$\overline{Hp}$
JAN	0.501	0.3458	14.23	33.79	0.3978	14.91
FEB	0.4994	0.3626	16.27	36.05	0.4513	16.26
MAR	0.6178	0.2977	14.49	38.02	0.3811	15.71
APR	0.6878	0.3212	14.95	37.49	0.3988	16
MAY	0.7344	0.293	14.84	36.41	0.4076	14.93
JUN	0.7622	0.2311	13.55	35.32	0.3836	13.22
JUL	0.8133	0.1627	12.22	35.59	0.3434	11.89
AUG	0.8156	0.1478	10.67	37.06	0.2879	12.06
SEP	0.7989	0.2157	14.27	37.23	0.3833	13.6
OCT	0.7533	0.2395	14.67	36.11	0.4063	13.7
NOV	0.6572	0.3226	16.41	34.31	0.4783	14.67
DEC	0.5572	0.3213	15.31	33.4	0.4584	14.26

The correlation of coefficient of 0.641 exists between the clearness index and maximum temperature data also coefficient of determination of 0.411 implies 41.1% of clearness index can be accounted using maximum temperature data. The result of Table II using the clearness index and maximum temperature data for Uyo shows that $a = -0.229$ and $b = 0.020$. Hence, the monthly mean daily solar radiation on a horizontal surface for any month of the year can be predicted using equation 19

$$\frac{\overline{Hp}}{\overline{Ho}} = -0.229 + 0.02T_m \qquad (19)$$

The correlation of coefficient of 0.636 exists between the clearness index and fraction of relative humidity also coefficient of determination of 0.404 implies 40.4% of clearness index can be accounted monthly average daily temperature. The result of Table III using the clearness index and fraction of relative humidity for Uyo shows that

$a = 589$ and $b = -280$. Hence, the monthly mean daily solar radiation on a horizontal surface for any month of the year can be predicted using equation 20

$$\frac{\overline{Hp}}{\overline{Ho}} = -0.589 - 0.280\frac{\overline{R}}{100} \quad (20)$$

Table VI: The Fraction Percentage of Relative Humidity $\frac{\overline{R}}{100}$, The Monthly Mean Daily Maximum Temperature (T_m), Global Solar Radiation $\overline{Hm}$, Extraterrestrial Solar Radiation $\overline{Ho}$, Predicted Global Solar Radiation $\overline{Hp}$ and Clearness index $\overline{K}_T$, for Equation 23 for Uyo (1991-2007 inclusive).

Month	$\frac{\overline{R}}{100}$	T_m ^{0}C	$\frac{\overline{S}}{\overline{S}_0}$	$\overline{Hm}$ (MJm^{-2}day^{-1})	$\overline{Ho}$ (MJm^{-2}day^{-1})	$\overline{Hp}$
JAN	0.501	33.20	0.3458	14.23	33.79	14.91
FEB	0.4994	33.40	0.3626	16.27	36.05	16.26
MAR	0.6178	33.15	0.2977	14.49	38.02	15.71
APR	0.6878	32.56	0.3212	14.95	37.49	16
MAY	0.7344	31.69	0.293	14.84	36.41	14.93
JUN	0.7622	30.57	0.2311	13.55	35.32	13.22
JUL	0.8133	28.96	0.1627	12.22	35.59	11.89
AUG	0.8156	28.93	0.1478	10.67	37.06	12.06
SEP	0.7989	24.53	0.2157	14.27	37.23	13.6
OCT	0.7533	30.46	0.2395	14.67	36.11	13.7
NOV	0.6572	31.71	0.3226	16.41	34.31	14.67
DEC	0.5572	32.25	0.3213	15.31	33.4	14.26

Table VII: The Fraction Percentage of Relative Humidity $\frac{\overline{R}}{100}$, Possible Fraction of Sunshine $\frac{\overline{S}}{\overline{S}_0}$, the Monthly Mean Daily Maximum Temperature (T_m), Global Solar Radiation $\overline{Hm}$, Extraterrestrial Solar Radiation $\overline{Ho}$, Predicted Global Solar Radiation $\overline{Hp}$ and Clearness index $\overline{K}_T$, for Equation 24 for Uyo (1991-2007 inclusive).

Month	$\frac{\overline{R}}{100}$	T_m ^{0}C	$\frac{\overline{S}}{\overline{S}_0}$	$\overline{Hm}$ (MJm^{-2}day^{-1})	$\overline{Ho}$ (MJm^{-2}day^{-1})	$\overline{K}_T = \frac{\overline{Hm}}{\overline{Ho}}$	$\overline{Hp}$
JAN	0.501	33.20	0.3458	14.23	33.79	0.3978	14.91
FEB	0.4994	33.40	0.3626	16.27	36.05	0.4513	16.26
MAR	0.6178	33.15	0.2977	14.49	38.02	0.3811	15.71
APR	0.6878	32.56	0.3212	14.95	37.49	0.3988	16
MAY	0.7344	31.69	0.293	14.84	36.41	0.4076	14.93
JUN	0.7622	30.57	0.2311	13.55	35.32	0.3836	13.22
JUL	0.8133	28.96	0.1627	12.22	35.59	0.3434	11.89
AUG	0.8156	28.93	0.1478	10.67	37.06	0.2879	12.06
SEP	0.7989	24.53	0.2157	14.27	37.23	0.3833	13.6
OCT	0.7533	30.46	0.2395	14.67	36.11	0.4063	13.7
NOV	0.6572	31.71	0.3226	16.41	34.31	0.4783	14.67
DEC	0.5572	32.25	0.3213	15.31	33.4	0.4584	14.26

Two Variable Correlations

The correlation of coefficient of 0.922 exists between the clearness index, fraction of sunshine hour and maximum temperature also coefficient of determination of 0.850 implies 85.0% of clearness index can be accounted fraction of sunshine hour and maximum temperature.

$$\frac{\overline{Hp}}{\overline{Ho}} = 1.395 - 0.046\overline{T}m + 1.591\frac{\overline{S}}{\overline{S}_0} \qquad (21)$$

The correlation of coefficient of 0.830 exists between the clearness index and fraction of sunshine hour and relation humidity also coefficient of determination of 0.689 implies 68.9% of clearness index can be accounted fraction of sunshine hour and relation humidity.

$$\frac{\overline{Hp}}{\overline{Ho}} = 0.056 + 0.833\frac{\overline{S}}{\overline{S}_0} + 0.170\frac{\overline{R}}{100} \qquad (22)$$

The correlation of coefficient of 0.656 exists between the clearness index and maximum temperature and relation humidity also coefficient of determination of 0.429 implies 42.9% of clearness index can be accounted fraction of sunshine hour and relation humidity.

$$\frac{\overline{Hp}}{\overline{Ho}} = 0.138 + 0.011\overline{T}_m - 0.136\frac{\overline{R}}{100} \qquad (23)$$

Three variable correlation

The correlation of coefficient of 0.921 exists between the clearness index and fraction of sunshine hour, maximum temperature and relation humidity also coefficient of determination of 0.850 implies 85.0% of clearness index can be accounted fraction of sunshine hour, maximum temperature and relation humidity.

$$\frac{\overline{Hp}}{\overline{Ho}} = 1.387 + 1.592\frac{\overline{S}}{\overline{S}_0} - 0.045\overline{T}m + 0.004\frac{\overline{R}}{100} \qquad (24)$$

DISCUSSION

A close examination of Table I shows that the maximum value of the mean daily sunshine hours, and the monthly mean global radiation on horizontal were 4.29 hour and 16.27 $\left(MJm^{-2}day^{-1}\right)$ respectively and occurred in the month of February while the maximum value of the monthly mean daily relative is 68.32%. The maximum value of the mean daily maximum temperature, and the monthly mean global radiation on horizontal were 33.40 Celsius and 16.27 $\left(MJm^{-2}day^{-1}\right)$ respectively and occurred in the month of February. This value is within what is within what is expected of tropical site [9-11]. However, it should be noted that isolation instrument records hour of bright sunshine solar radiation flux density is above the threshold value. Hence, during the month, during the month of Febuary, very high daily mean sunshine hours are obtained because it has high clearness index.

Conversely, the minimum values of the monthly mean daily sunshine hour and monthly mean daily global solar radiation on the horizontal surface occurred in August were 12.11 hours and 10.67 $\left(MJm^{-2}day^{-1}\right)$ respectively. These values were compared with previous work [6,19] and it was characterized by heavy rainfall and percentage of sunshine hours is very low as the sky is mostly heavily overcast [13].

For the correlations involving sunshine hours and solar radiation for Uyo, the values of the regression constants is 0.239 and 0.585 are in close agreement with different research work in Nigeria [4,8,24]. The sum of regression coefficient (a + b) is interpreted as transmissivity of the atmosphere for global solar radiation under perfectly clear sky condition [17]. Similarly, the intercept 'a' is interpreted as the transmissivity of an overcast atmosphere. It is therefore important to examine the regression relation we have developed and compare it with others in terms of the value of the atmospheric transmissivity under skies. The value of Uyo is 0.82, which compares favourably with the value of 0.68-0.85 as clear sky transmissivity of most tropical regions [1-3, 7-8, 24].

In general, the values of the regression coefficients obtained for one variable correlation for Uyo was found to different from the values obtained by[8,14,19 20-25] for the Northern Nigeria. These differences indicate that the regression coefficient associated with meteorological data changes with latitude and atmospheric conditions. The correlation coefficient of 0.811 exists between clearness index and fraction of sunshine hours.

The result of the analysis from equation 18 using the clearness index and fraction of sunshine data for Uyo shows $a = 0.239$ and $b = 0.585$. Therefore, the monthly mean daily solar radiation on the horizontal surface for any month can be predicted from equation (18, 19 and 20). Finally the result also shows that the annual average global solar radiation received in Uyo is 14.32 $\left(MJm^{-2}day^{-1}\right)$.

Table VIII: Equations with Regression and Statistical Indicator for Uyo (1991-2007 inclusive)

Equation	No.	r	R^2	MBE	RMSE	MPE
$\frac{\overline{Hp}}{\overline{Ho}} = 0.239 + 0.585\frac{\overline{S}}{\overline{S}_0}$	18	0.811	0.811	-0.0042	0.0012	0.029
$\frac{\overline{Hp}}{\overline{Ho}} = -0.229 + 0.02T_m$	19	0.641	0.411	-0.0042	0.0012	0.0029
$\frac{\overline{Hp}}{\overline{Ho}} = -0.589 - 0.280\frac{\overline{R}}{100}$	20	0.636	0.404	-0.027	0.0953	0.192
$\frac{\overline{Hp}}{\overline{Ho}} = 1.395 - 0.046\overline{T}m + 1.591\frac{\overline{S}}{\overline{S}_0}$	21	0.921	0.848	-0.0458	0.159	0.32
$\frac{\overline{Hp}}{\overline{Ho}} = 0.056 + 0.833\frac{\overline{S}}{\overline{S}_0} + 0.170\frac{\overline{R}}{100}$	22	0.83	0.689	0.0133	0.146	-0.093
$\frac{\overline{Hp}}{\overline{Ho}} = 0.138 + 0.011\overline{T}_m - 0.136\frac{\overline{R}}{100}$	23	0.656	0.429	-0.0275	0.0953	0.192
$\frac{\overline{Hp}}{\overline{Ho}} = 1.387 + 1.592\frac{\overline{S}}{\overline{S}_0} - 0.045\overline{T}m + 0.004\frac{\overline{R}}{100}$	24	0.922	0.85	0.0225	0.078	-0.157

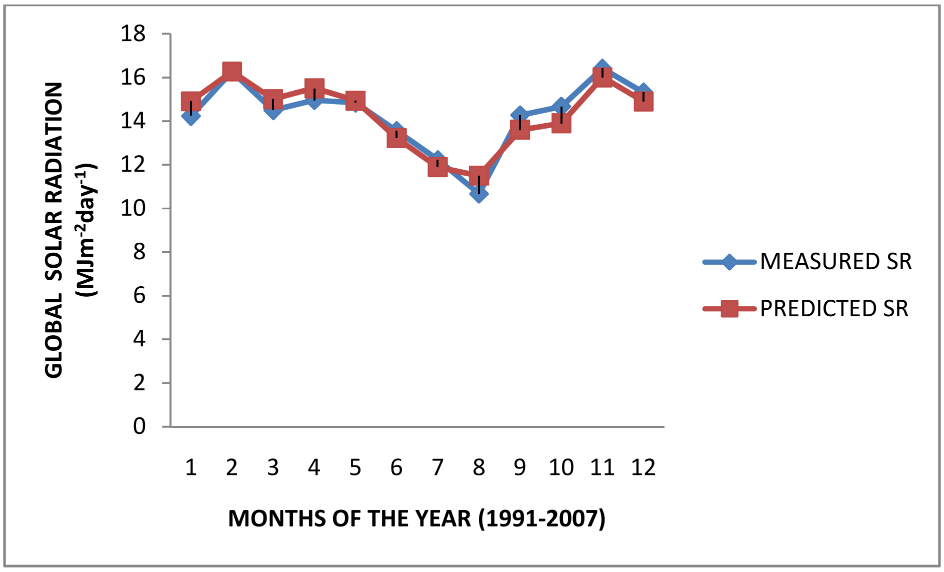

Figure 1: comparison between the measured and predicted Global Solar Radiation for equation 18 (1991-2007).

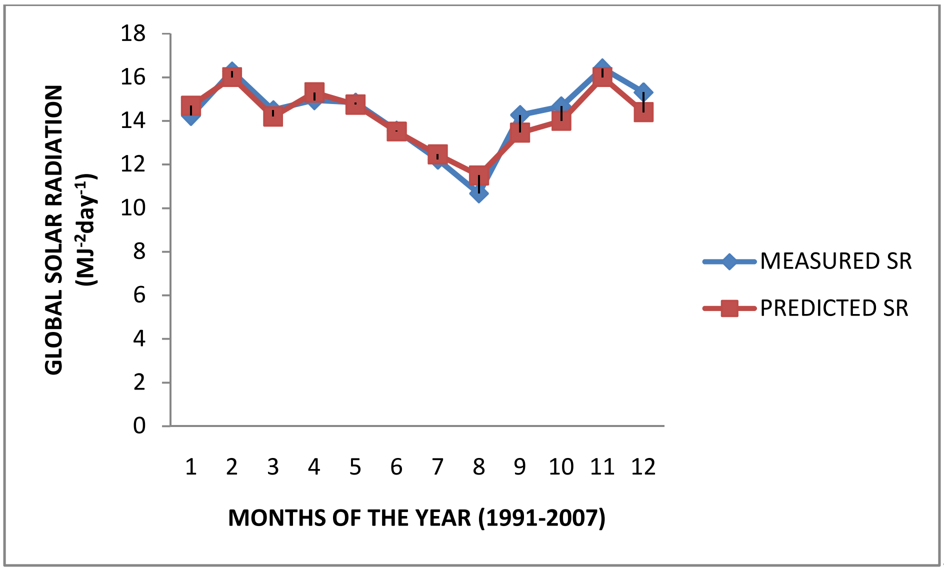

Figure 2: Comparison between the measured and predicted Global Solar Radiation for equation 19 (1991-2007).

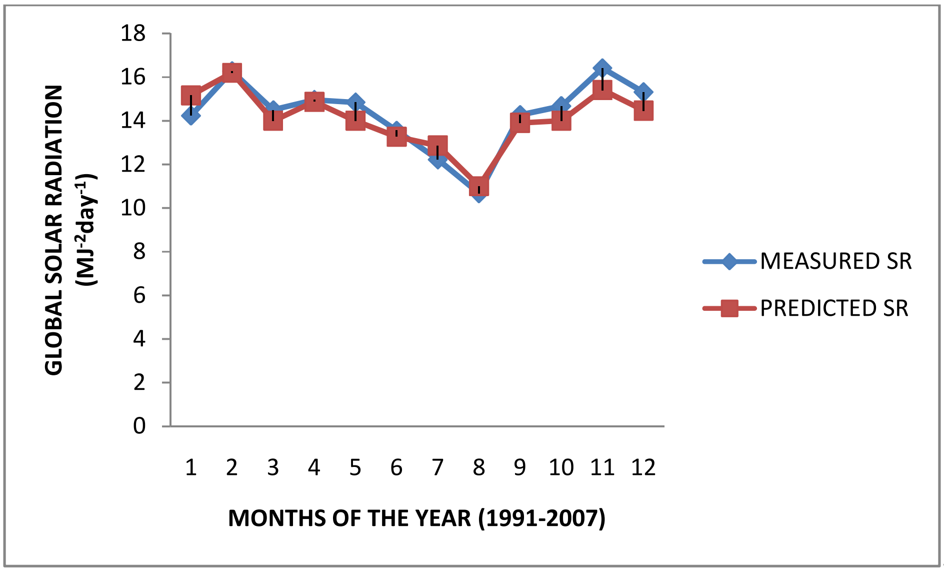

Figure 3: comparison between the measured and predicted Global Solar Radiation for equation 20 (1991-2007).

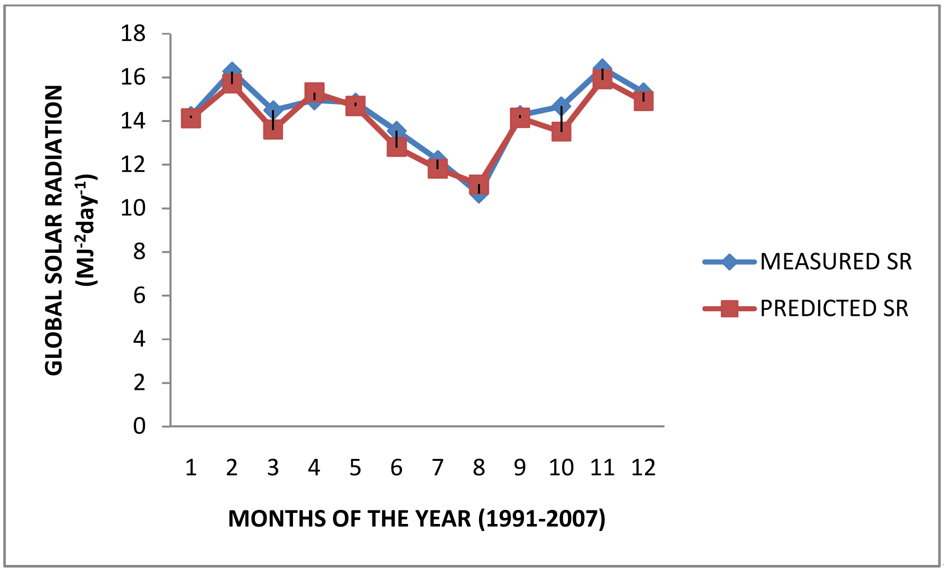

Figure 4: Comparison between the measured and predicted Global Solar Radiation for equation 21 (1991-2007).

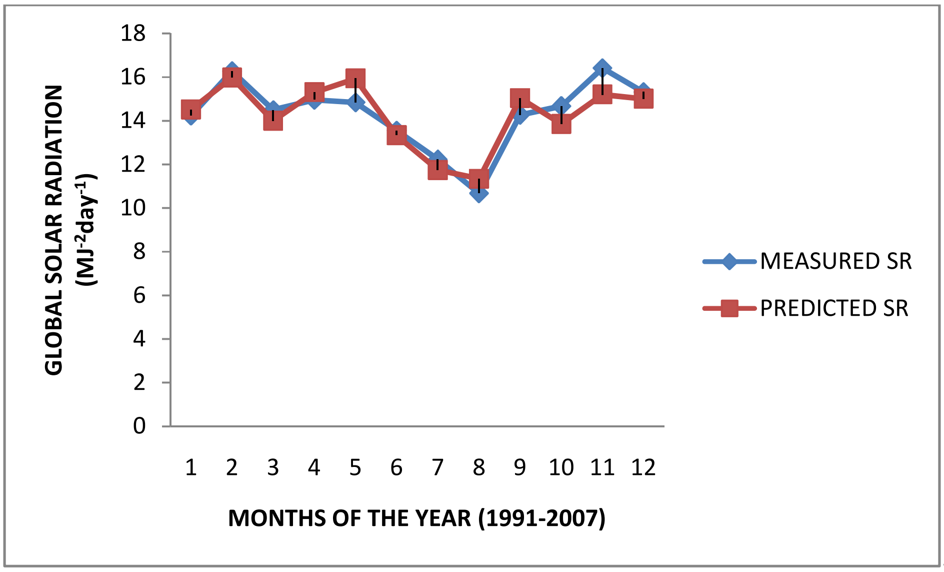

Figure 5: Comparison between the measured and predicted Global Solar Radiation for equation 22 (1991-2007).

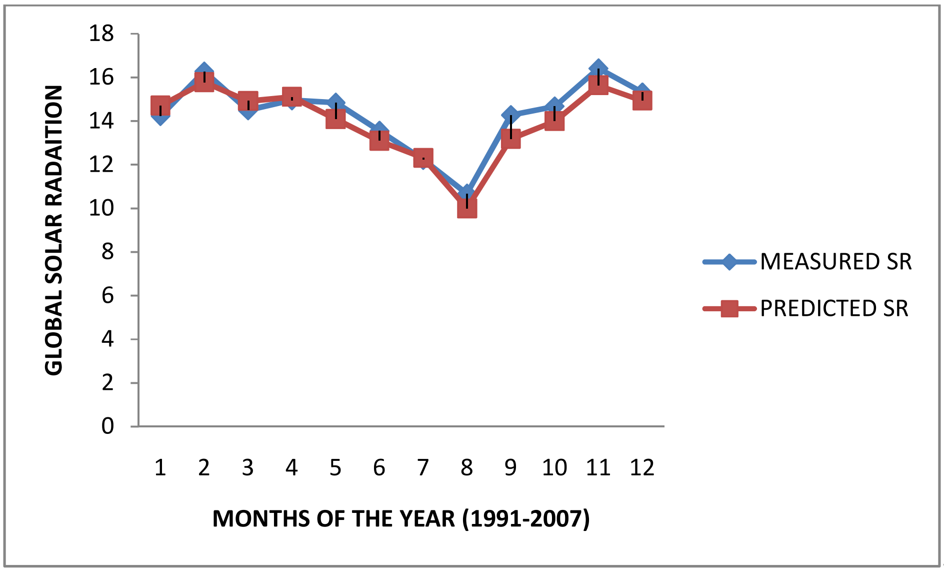

Figure 6: Comparison between the measured and predicted Global Solar Radiation for equation 23 (1991-2007).

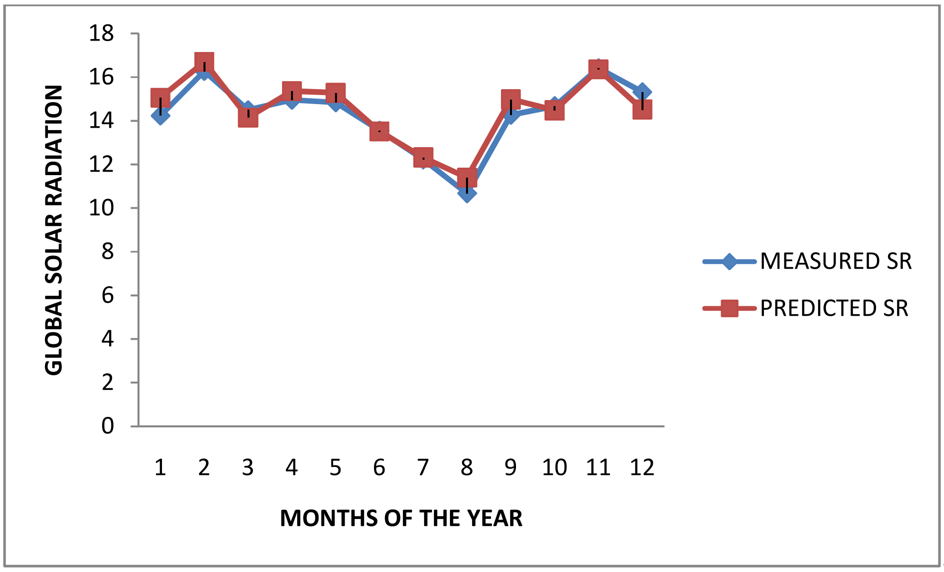

Figure 7:Comparison between the measured and predicted Global Solar Radiation for equation 24 (1991-2007).

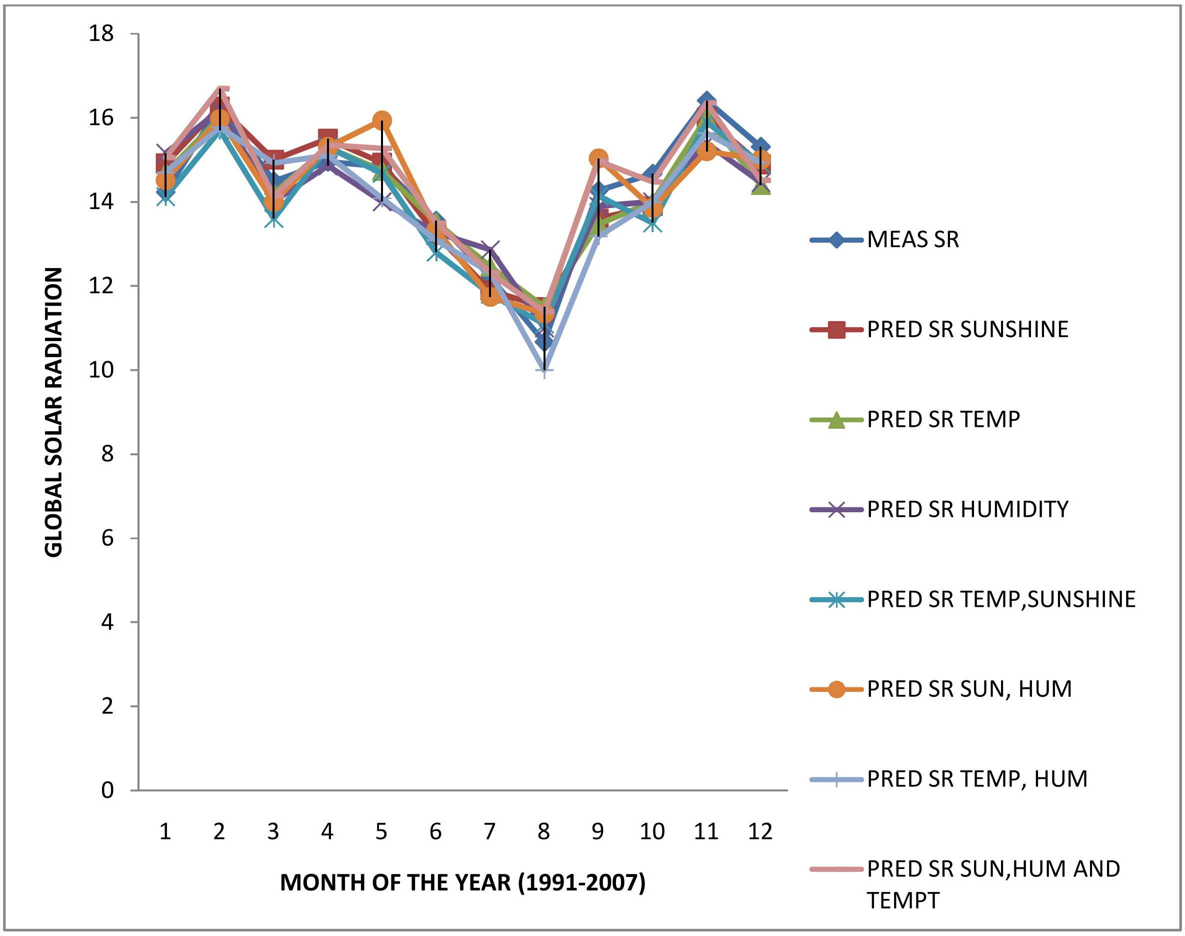

Figure 8: comparison between the measured and predicted Global Solar Radiation for equations 18-24 (1991-2007).

CONCLUSION

In view of the worldwide concern about the economic importance of global solar radiation as an alternative renewable energy, the monthly global solar radiation using relative humidity, sunshine hour and maximum temperature have been employed in this study to develop correlation equations.

Three variables have been developed with different types of equations obtained. From the results when considering statistical indicators that are MBE, RMSE and MPE. This equation could be employed in the prediction of global solar radiation of location with similar latitude and other geographical information as in Uyo, Niger Delta Region.

Again the correlation with the smallest value of RMSE is given by equation (24). The global solar radiation intensity values produced by this approach can be used in the designed and prediction of performance of solar applications system which is gaining attention in Nigeria.

REFERENCES

[1] Adnam Sozen and Erol Areaklioglu (**2005**): *Journal of Applied Energy* 82: 345-350.
[2] Ahmet Aksakal and Shafiqur Rehman (**1999**): *Journal of Renewable Energy* 17: 461- 467.
[3] Akpabio L.E., Udo S.O. Etuk S.E. (**2004**): *Turkish Journal Physics*. 28: 222-227
[4] Akpabio L.E., Etuk S.E., (**2002**): *Turkish Journal. Physics*. 27:161-167.
[5] Angstrom A.S., (**1924**). Solar and terrestrial radiation Meteorological Society 50:121-126.
[6] Ali, A. Sabziparvar and H. Shetaee. (**2007**): *Journal of Renewable Energy* 32, 649.

[7] Augustine C.and Nnabuchi M.N., (**2009**):.*International of Journal Physical Science*. Vol 3(5),182-188.
[8] Burari and Sambo, (**2001**): *Nigeria Journal. Renewable Energy* 9:34-36.
[9] Canada J. (**1988**): *International Journal of ambient energy* 4: 197-203
[10] Canada J. (**1988**): *Solar and wind technology*. 5: 591-597.
[11] Canada J. (**1992**): *J. Renewable energy 3: 212-219.*
[12] Chiemeka I.U., (**2008**): *International Journal of Physical Sciences*. 3(5): 126-130.
[13] Chegaar M. and Chibani A. (**2001**): J. *Energy conversion and management* 42: 961-967.
[14] Duffie J. A. and Beckman W. A. (**1994**): Solar Engineering of thermal processes. John Willey Published New York, U.S.A. P. 234-367.
[15] Falayi E.O. and Rabiu A.B. (**2005**): *Nigeria journal of Physics*. 17: 181-186.
[16] Folayan C.O., (**1988**): *Journal. Solar Energy* 8(3) :1-10.
[17] Gueymard C. (**1993**): *J. Solar energy* 51: 131-139.
[18] Hussain, M. Rahman, L and Rahman, M.M. (**1999**): *Renewable Energy*. 18pp.263 – 275
[19] Halouani N. (**1993**):*Journal of Solar energy* 50: 239-247.
[20] Kamal S. (**2006**): *Energy Conversion and Management* 4: 328-331.
[21] Medugu and Yabubu (**2011**): *Journal of Applied Science Research* 2(2):414-421.
[22] Ododo J.C. (**1997**): *Energy conversion and Management* 38, 1807.
[23] Ododo J.C. (**1995**): *Renewable energy* 6: 751
[24] Iheonu, E. E., (**2001**): *Nigerian Journal of Solar Energy*. 9:12 – 15.
[25] Sabbagh J. A., Sayigh A.A. M. and El-Salam E. M.A. (**1977**): *Solar Energy*. 19, 307.
[26] Sambo A.S., (**1985**): *Nigeria Journal Solar Energy* 8(1): 59-65
[27] Ibrahim S.M.A., (**1985**): *Nigerian Solar Energy* 35(2):185-188.
[28] Iqbal M, (**1983**): An introduction to solar radiation. Academy Press. New York. P. 6-51.
[29] Tiwari R. F. and Sangeeta T.H. (**1997***)*: *Solar energy* 24(6): 89-95.
[30] Trabea, A. and Mosalam, M. A. (**2000**): *Renewable Energy*, 21, 297.