American Journal of Renewable and Sustainable Energy
Vol. 3, No. 2, 2017, pp. 8-14
http://www.aiscience.org/journal/ajrse
ISSN: 2381-7437 (Print); ISSN: 2381-7445 (Online)

Estimation of Global Solar Radiation Using Sunshine and Temperature Based Models for Oko Town in Anambra State, Nigeria

H. O. Nnabuenyi[1, *], L. N. Okoli[2], F. C. Nwosu[3], G. Ibe[1]

[1]Department of Science Laboratory, Federal Polytechniques, Oko, Anambra State, Nigeria
[2]Department of Industrial Physics, Legacy University Okija, Ihiala, Nigeria
[3]Department of Electrical/ Electronics Engineering, Federal Polytechniques, Oko, Anambra State, Nigeria

Abstract

This study used monthly mean daily values of global solar radiation, sunshine duration, maximum temperature, minimum temperature, average temperature of Oko, Nigeria with latitude and longitude (6.05 °N and 7.05 °E) gotten from the archive National Aeronautic Space Administration (NASA). These data were used to develop empirical correlation equations for the estimation of global solar radiation at the site mentioned above. This research presents the comparison between the observed and the predicted values under different geographical and varied meteorological conditions. The comparisons are made using standard statistical tests, namely mean bias error (MBE), root mean square error (RMSE), mean percentage error (MPE) and coefficient of residual mass (CRM). From the result of the statistical analysis, the sunshine and temperature based models proposed for Oko town correlate well with the measured value of the global solar radiation from NASA.

Keywords

Solar Energy, Relative Sunshine Duration, Temperature, Clearness Index, Regression Constants

Received: June 9, 2016 / Accepted: July 1, 2016 / Published online: August 8, 2017

@ 2017 The Authors. Published by American Institute of Science. This Open Access article is under the CC BY license.
http://creativecommons.org/licenses/by/4.0/

1. Introduction

Energy which is the ability or capacity to do work is accepted as a phenomenon that has great link with environmental, social and economic dimensions of sustainable development. The demand of energy, the consumption of fossil fuels and pollution level are increasing with an alarming rate worldwide. With the high demand for this commodity, various stakeholders have now become aware of the urgent need for management of resources and energy conversion activities. The energy consumed in the household sector is perhaps the single largest consumer of energy in the nation's economy in developing countries of the world and Nigeria in particular.

With the rapid depletion of fossil fuel reserves around the world due to high demand, it is feared that the world will soon run out of its nonrenewable energy resources which present the huge amount of energy use in the world. This is a matter of concern for the developing countries like Nigeria and others whose economy heavily depends on imported petroleum products. Under these circumstances it is highly desirable that alternate energy resources should be utilized with maximum conversion efficiency to cope with the increasing energy demand. Among the non-conventional energy resources, solar energy, wind energy and biomass has emerged as most prospective option for the future [1]. This aggressive consumption rate of fossil fuels has created unacceptable environmental problems such as greenhouse effects, which may lead to disastrous climatic consequences.

* Corresponding author
E-mail address: helenpaul4ever@yahoo.com (H. O. Nnabuenyi)

Thus, renewable and clean energy such as that obtained by using solar cells is required to maintain the quality of human life as well as the environment [2].

The utilization of solar energy, like any other natural resources, requires detailed information on availability of the amount of total solar radiation striking the earth surface. This total amount of solar radiation incidents on the earth surface is called global solar radiation. Global solar radiation data are necessary at various steps of the design, engineering, simulation and performance evaluation of any project involving solar energy. Solar radiation provides the energy for photosynthesis and transpiration of crops and is one of the meteorological factors determining potential yields. Crop growth models, which have been developed since the 1960s, have been regarded as important tools of interdisciplinary research and have since been used in a number of areas such as the assessment of agriculture potential of a given region in the field of crop yield forecasting or as a climate change impact assessment tool [3]. Actually, the mapping of the solar radiant energy on the earth's surface is a requirement not only in the studies of climate change, environmental pollution but also in agriculture, hydrology, food industry and non-conventional energy development programs [4].

As the solar radiation passes through the atmosphere, it undergoes absorption and scattering by various constituents of the atmosphere. The amount of solar radiation finally reaching the surface of earth depends quite significantly on the concentration of airborne particulate matter, gaseous pollutants and water (vapour, liquid or solid) in the sky, which can further attenuate the solar energy and change the diffuse and direct radiation ratio. The global solar radiation can be divided into two components: diffuse solar radiation, which results from scattering caused by gases in the Earth's atmosphere, dispersed water droplets and particulates; and direct solar radiation, which have not been scattered. Global solar radiation is the algebraic sum of the two components. Solar radiation incident on the earth's surface in the visible and near - infrared wavelength range 0.3 µm – 2.0 µm is measured on the ground by means of Pyranometer. But unfortunately, solar radiation measurements are not readily available in many developing countries due to non-availability or inadequate provision of this measurement instrument. It is important therefore, to consider methods of estimating the global solar radiation based on the readily available meteorological parameters.

This global solar radiation varies from latitude to latitude. Thus, a solar radiation measurement parameter is obtained and defined as the ratio of the actual number of hours of sunshine received at a site to the day length. The ratio is known as fraction of sunshine hours (n/N). It is found to vary daily and seasonality [5]. The amount of global solar radiation H_0 is the extraterrestrial radiation which is found at the top of the atmosphere of the site. Similarly H_m is measured global solar radiation which is the fraction of the extraterrestrial radiation at the ground surface after scattering, reflection and absorption in the atmosphere. The ratio of H_m/H_0 is a possible measure of the transparency of the atmosphere to the solar radiation. It is also called clearness index or coefficient of transmission [6].

Several models have been proposed to estimate global solar radiation. [7] presents a linear regression model used in correlating the global solar radiation data with relative sunshine duration, which is a modified Angstrom type model [8]. [9] studied the correlation between the measurements of global solar radiation and the meteorological parameters using solar radiation, mean daily maximum temperature, mean daily relative humidity, mean daily sea level pressure, mean daily vapour pressure, and hours of bright sunshine data obtained from different parts of Egypt. [10] has demonstrated the predictive ability of the Angstrom type model, correlating the global solar radiation to relative sunshine duration in a simple linear regression form. [11] developed a quadratic relation for Calabar, Port Harcout and Enugu. A predicting model which uses only maximum ambient temperature has been developed for Nsukka [12]. However, no previous study of this nature has been conducted in Oko, Anambra State.

Input parameters used in the estimation of the global solar radiation include, sunshine duration, mean temperature, soil temperature, relative humidity, number of rainy days, altitude, latitude, total precipitable water, albedo, atmospheric pressure, cloudiness and evaporation. The most commonly used parameter for estimating global solar radiation is sunshine hours which can be easily and reliably measured. Accurate estimation depends on the quality and quantity of the measured data used.

This paper focuses on the use of climate data such as sunshine hours, minimum, maximum and average temperature from the archives of National Aeronautics and Space Administration (NASA) for a period of 16 years (2000 – 2015) to generate sunshine and temperature based empirical equations for calculating the global solar radiation in Oko, Anambra State, Nigeria. The solar data obtained from these correlations will be tested for errors using; Mean Bias Error (MBE), Root Mean Square Error (RMSE) and Mean Percentage Error (MPE)

2. Material and Method

Oko is an Igbo speaking town in south eastern Nigeria. It is one of the major towns that make up the geopolitical area called Orumba North Local Government Area of Anambra

State. It geographical coordinates are $6^{\circ}3'0''N(6.05^{\circ}N)$ and $7^{\circ}06'0''E(7.05^{\circ}E)$. Oko is regarded as citadel of learning due the presence of Federal Polytechnique in the town. The town is known for agriculture due to the good climatic conditions it enjoys throughout the seasons. The meteorological data of Oko which are to be used for this study were gotten from the archives of National Aeronautic and Space Administration for period of 15 years (2000 – 2014). The meteorological data retrieved include; monthly mean global solar radiation ($\bar{H}_m$) incident on earth surface, monthly mean extraterrestrial global solar radiation ($\bar{H}_0$), monthly mean daily sunshine duration ($\bar{N}$) and the monthly mean minimum, maximum and average temperature (T_{min}, T_{max}, and T_{av}) and other meteorological data.

2.1. Sunshine Based Model

The first correlation proposed for estimating the monthly mean daily global solar radiation on a horizontal surface using the sunshine duration and clear sky radiation (H_c) data was due to Angstrom [8].

$$\frac{H}{H_c} = a + b\left(\frac{n}{N}\right) \quad (1)$$

Because there may be problems in calculating clear sky radiation accurately, by replacing clear sky radiation with extraterrestrial radiation (H_o), the Angstrom correlation was put in more convenient form by Prescott [13]. [14] and others have modified the method using the value of the extraterrestrial radiation H_0 on a horizontal surface rather than the clear day radiation H_c [15].

$$\frac{\bar{H}}{\bar{H}_0} = a + b\left(\frac{\bar{n}}{\bar{N}}\right) \quad (2)$$

Where H is the monthly average daily global radiation on a horizontal surface ($MJ.m^{-2}.day^{-1}$). H_0 is the daily extraterrestrial radiation on a horizontal surface $MJ.m^{-2}.day^{-1}$, n is the monthly average daily hours of bright sunshine, N is the monthly average day length, (a and b) values are known as angstrom empirical constant or regression coefficients. Their values have been obtained from the relationship given by [16] and confirmed by [17] as

$$a = -0.110 + 0.235\cos\emptyset + 0.323\left(\frac{\bar{n}}{\bar{N}}\right) \quad (3)$$

$$b = 1.449 - 0.553\cos\emptyset - 0.694\left(\frac{\bar{n}}{\bar{N}}\right) \quad (4)$$

The monthly average daily extraterrestrial irradiation $\bar{H}_0$ can be calculated from the equation below.

$$\bar{H}_o = \frac{24}{\pi} I_{sc}\left[1 + 0.0333\cos\left(\frac{360D}{365}\right)\right]\left[\cos\emptyset\cos\delta\cos\bar{\omega}_s + \frac{2\pi\bar{\omega}_s}{360}\sin\emptyset\, sin\delta\right]$$

$$\bar{H}_o = \frac{24}{\pi} I_{sc}\, E_0\left[\cos\emptyset\cos\delta\cos\bar{\omega}_s + \frac{2\pi\bar{\omega}_s}{360}\sin\emptyset\, sin\delta\right] \quad (5)$$

Where I_{sc} is the solar constant with numerical value of 1367 Wm^{-2} and can also be expressed in $MJm^{-2}day^{-1}$ in equation (6),

$$I_{sc} = \frac{1367 \times 3600}{1000000}\ MJm^{-2}day^{-1} \quad (6)$$

E_0 is the eccentricity correction factor expressed in equation (7),

$$E_0 = \left[1 + 0.0333\cos\left(\frac{360D}{365}\right)\right] \quad (7)$$

$\emptyset$ is the latitude of the site under study, δ is the solar inclination angle given as

$$\delta = 23.45\sin\left(360\left(\frac{D+284}{365}\right)\right) \quad (8)$$

$\bar{\omega}_s$ is the mean sunrise hour angle for the given month expressed as;

$$\bar{\omega}_s = \cos^{-1}(-tan\emptyset\tan\delta) \quad (9)$$

D in equations (7) and (8) is the characteristic day number for each month: D = 1 on 1st of January and D = 365 on 31st of December. The day length N is the number of hours of sunshine within the 24 hours in a given day. The mean day length $\bar{N}$ is expressed as;

$$\bar{N} = \frac{2}{15}\cos^{-1}(-tan\emptyset\tan\delta) = \frac{2}{15}\bar{\omega}_s \quad (10)$$

2.2. Temperature Based Model

[18] were first to estimate global solar radiation by using the difference in the maximum and minimum temperature given by

$$\frac{\bar{H}}{\bar{H}_0} = K_r(T_{max} - T_{min})^{0.5}. \quad (11)$$

where, $\bar{H}$ is the measured monthly mean global solar radiation in $MJ.m^{-2}.day^{-1}$. $\bar{H}_0$ is the monthly mean extraterrestrial radiation in $MJ.m^{-2}.day^{-1}$. T_{max} is the maximum temperatures measured in °C. T_{min} is the minimum temperatures measured in °C, and K_r is the empirical coefficient which was recommended by [19] to be 0.16 for interior regions and 0.19 for coastal regions. Oko town being an interior region, empirical coefficient of 0.16 is used for the estimation.

2.3. Statistical Analysis

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 (%) as stated by [20] are:

$$MBE = \frac{[\sum(H_{ical} - H_{imeas})]}{n} \quad (12)$$

$$RMSE = \left[\frac{\sum(H_{ical} - H_{imeas})^2}{n}\right]^{1/2} \quad (13)$$

$$MPE = \frac{\left[\sum\left(\frac{H_{imeas} - H_{ical}}{H_{imeas}} \times 100\right)\right]}{n}. \quad (14)$$

The Coefficient of Residual Mass (CRM) was calculated according to equation provided by [21]

$$CRM = \frac{\sum(H_{imeas} - H_{ical})}{n\bar{H}_{meas}} \quad (15)$$

Where H_{ical} and H_{imeas} are the ith calculated and measured values of global solar radiation respectively, $\bar{H}_{meas}$ is the mean of the measured global solar radiation and n is the total number of observations. In general, MBE provides information on the long term performance of the models. Positive MBE shows overestimation while a negative MBE indicates underestimation. RMSE provides information on the short term performance of the model. It is always positive and a low value of it is desirable. The demerit of this parameter is that a single value of higher error leads to a higher value of RMSE. MPE test provides information on long – term performance of examined regression. A negative value of MPE indicates the average amount of under estimation while a positive value indicates over estimation. It is recommended that a zero value for MBE is ideal while a low RMSE and low MPE are desirable [22], [23], [24]. CRM equals zero gives a perfect estimation. A positive value of CRM indicates underestimation of the measured values while a negative value indicates overestimation of the measured values. (Bandyopadhyay et al., 2008)

3. Result and Discussion

Table 1. Meteorological Data of Oko Town.

Months	$\bar{H}_0$ (MJm⁻² day⁻¹)	$\bar{H}_{mea}$ (MJm⁻² day⁻¹)	a	b	$\bar{n}$ (hrs)	$\bar{N}$ (hrs)	$\bar{T}_{min}$ (°C)	$\bar{T}_{max}$ (°C)	$\bar{H}_1$ (MJm⁻² day⁻¹)	$\bar{H}_2$ (MJm⁻² day⁻¹)	$\bar{n}/\bar{N}$
JANUARY	33.70	20.42	0.28	0.55	5.91	11.87	21.55	33.65	18.88	18.99	0.50
FEBRUARY	35.70	20.51	0.28	0.57	5.70	11.94	22.52	33.09	19.59	18.81	0.48
MARCH	35.61	20.20	0.27	0.58	5.61	12.14	22.52	33.49	19.24	19.11	0.46
APRIL	37.68	18.99	0.26	0.60	5.27	12.23	23.69	32.61	19.65	18.23	0.43
MAY	36.72	17.88	0.25	0.62	4.97	12.31	23.57	32.05	18.50	17.33	0.40
JUNE	35.88	16.18	0.24	0.65	4.49	12.44	23.02	30.76	17.03	16.17	0.36
JULY	36.11	14.79	0.20	0.73	3.11	12.43	22.28	28.16	13.94	14.18	0.25
AUGUST	36.94	13.98	0.20	0.73	3.08	12.32	21.93	27.08	14.26	13.58	0.25
SEPTEMBER	37.19	14.98	0.21	0.72	3.16	12.14	22.32	27.82	14.69	14.13	0.26
OCTOBER	36.05	16.74	0.25	0.63	4.65	12.02	22.63	30.92	17.76	16.81	0.39
NOVEMBER	34.07	18.82	0.27	0.59	5.23	11.84	22.10	32.86	17.99	18.11	0.44
DECEMBER	32.83	19.81	0.28	0.56	5.80	11.71	20.45	33.67	18.35	19.34	0.50

Table 2. Statistical Error Indicators Values.

Models	MBE	RMSE	MPE	R^2	R	CRM
Angstrom	-0.29	0.93	1.33	0.94	0.97	0.016
Hargreaves and Samani	-0.71	0.87	3.85	0.97	0.98	0.040

Table 1 show the average monthly measured and calculated meteorological parameters for Oko in Anambra State, Nigeria within the years 2000 to 2014 (15 years). The two models of sunshine and temperature were used to estimate the global solar radiation on the horizontal surface in Oko for the 15 years using the meteorological parameters given in table 1 above. The statistical error estimations such as RMSE, MPE, MBE and CRM used to test the correlation between the measured global solar radiation and the calculated global solar radiation were summarized in table 2 above. The ideal error value is zero; therefore the accuracy of any model depends on the closeness of its error values to zero. We observed that the values of global solar radiation predicted by the two models are closely related to the measured global solar radiation. This is reflected in table 2 where the MBE and RMSE values are low and coefficient of residual mass (CRM) values are approximately equal to zero. These two models are adequate for estimating global solar radiation at Oko. MPE values of the models show that Hargreaves model is overestimated.

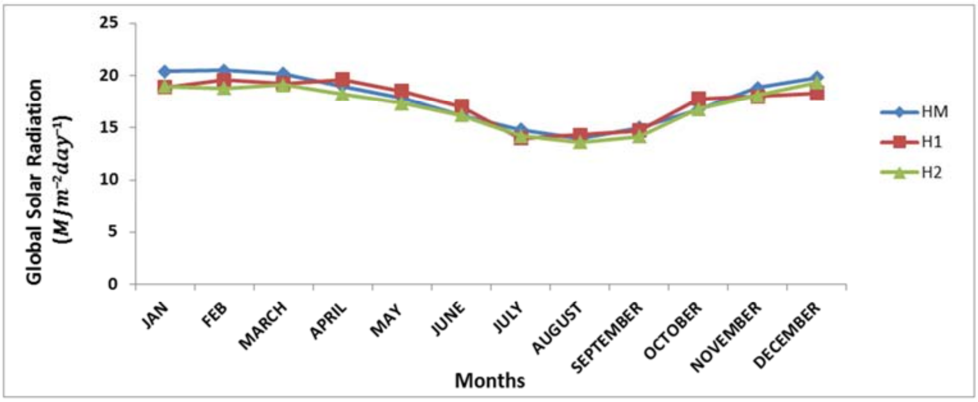

Figure 1. Graph of Global Solar Radiations against Months of the Year from 2000 to 2014.

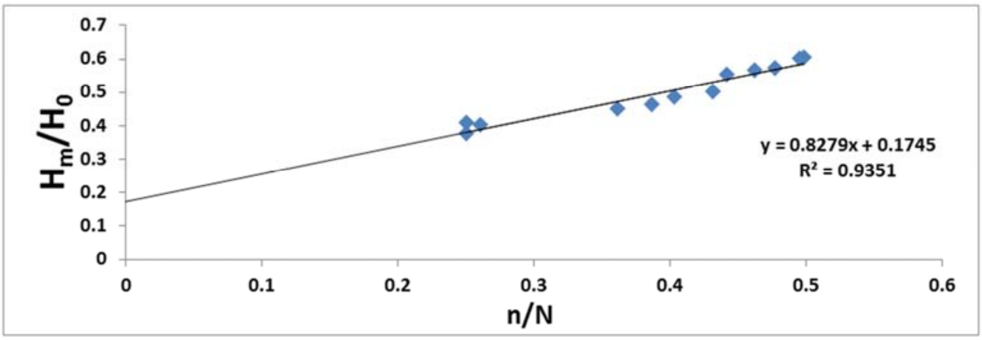

Figure 2. Graph of Clearness Index of Sunshine Based Model against Ratio of Sunshine Hours of Oko for the years (2000 – 2014).

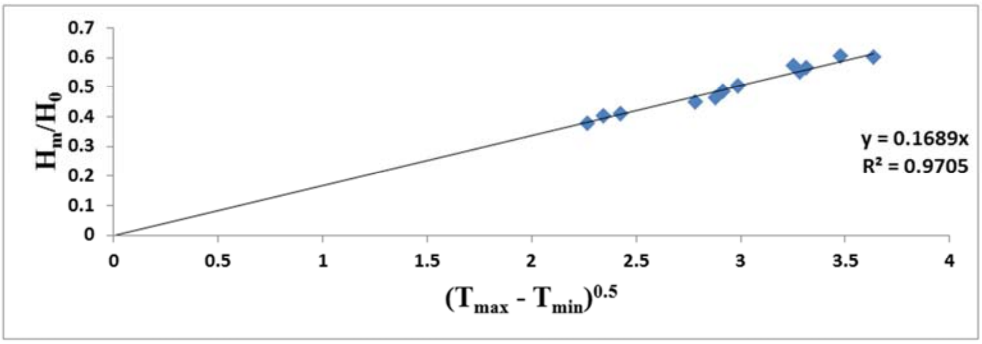

Figure 3. Graph of Clearness Index of Temperature Based Model against Square root of Change in Temperature of Oko for the years (2000 – 2014).

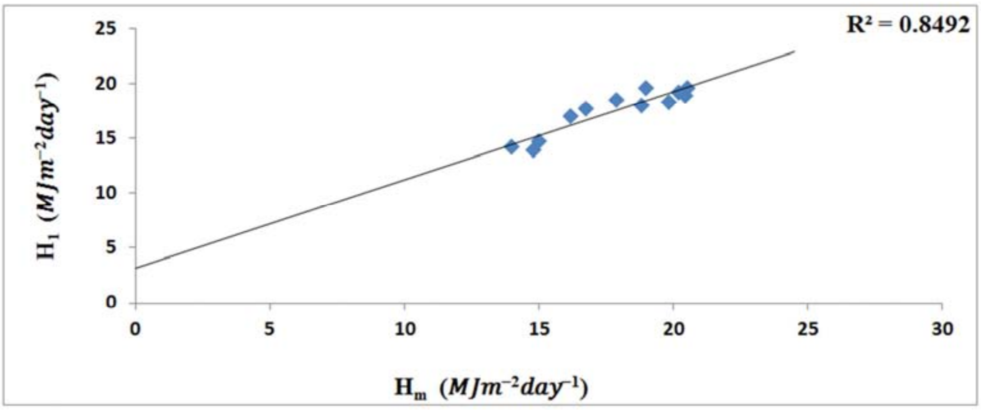

Figure 4. Graph of Sunshine Based Global Solar Radiation against Measured Global Solar Radiation of Oko for the years (2000 – 2014).

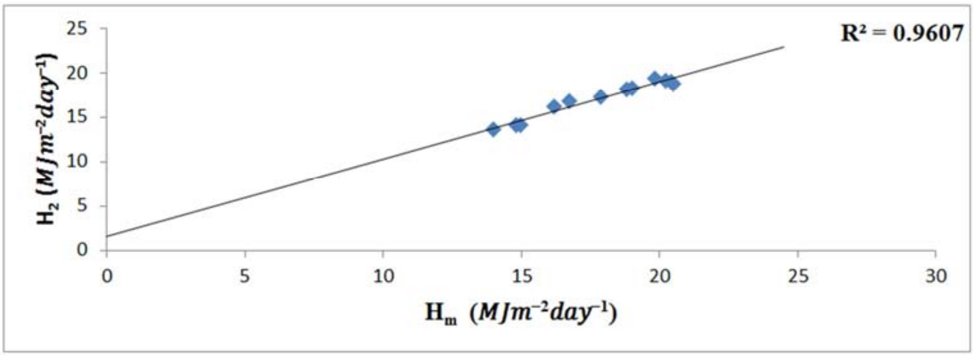

Figure 5. Graph of Temperature Based Global Solar Radiation against Measured Global Solar Radiation of Oko for the years (2000 – 2014).

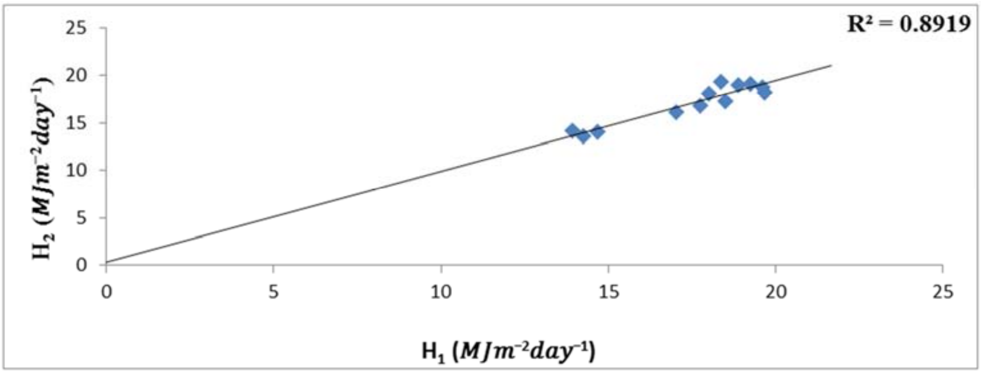

Figure 6. Graph of Temperature Based Global Solar Radiation against Sunshine Based Global Solar Radiation of Oko for the years (2000 – 2014).

Figure 1 shows the plot of measured and calculated monthly mean global solar radiation using the Angstrom – page sunshine model and Hargreaves / Samani temperature based model. We observed that the results from the predicting models show a good agreement with the measured values. The peak values of the global solar radiation are in the first four months of the years before dropping to it minima at August which is due to peak of rainy season.

Fig. 2 and Fig. 3 above show the graph of clearness index of sunshine based model and temperature based model against the ratio of sunshine hours and square root of change in temperature of Oko for the years (2000 – 2014). The values of coefficient of determination R^2 and coefficient of correlation R show that clearness index shows good correlation with the ratio of sunshine hours and change in temperature.

Fig. 4 and Fig. 5 show the correlation between the calculated sunshine based global solar radiation and temperature based global solar radiation against measured global solar radiation. The values of the R and R^2 for in Fig. 4 and Fig. 5 show that the measured global solar radiation and estimated global solar radiation for the two models are close.

Fig. 6 shows the correlation between the values of the solar radiation of the two models used for the estimation of global solar radiation at Oko. This result shows that both models can be used to estimated global solar radiation at Oko due to the closeness of the values which was confirmed by near unity of the R and R^2.

4. Conclusion

In line with world concern about the economic importance of global solar radiation as an alternative renewable energy, the models for estimating monthly global solar radiation of Oko town in Anambra State, Nigeria have been developed. These models are based on sunshine and temperature according to Angstrom – page sunshine model and Hargreaves – Samani temperature model. The model equations developed for Oko town using these two models are

$$\frac{H_m}{H_0} = 0.17 + 0.83\left(\frac{n}{N}\right) \quad (16)$$

$$\frac{H_m}{H_0} = 0.17\,(T_{max} - T_{min})^{0.5} \quad (17)$$

Our equations for the estimation of global solar radiation are comparable with other equations obtained for cities with similar meteorological data. The estimated global solar radiation data and its correlation will provide a useful source of information to designers of renewable energy, air conditioning systems and other solar energy related systems at Oko town, Anambra State, Nigeria. It could also enrich the National Energy data bank of the nation.

References

[1] Banjade D., Poudyal K. N., Daponte P., Rapuano S. and Vito L. di, (2010), Estimation of Global Solar Radiation using Empirical Models at Benevento, Italy, National Seminar on Power and Communication Sectors Development (PCSD), Kathmandu, Nepal, 41-44.

[2] Mandalia H. C., Jain V. K. and Pattanaik B. N., (2012), Application of Super-molecules in solar energy conversion, A Review, Res. J. Chem. Sci., 2(1), 89-102.

[3] Falayi, E. O. and Rabiu, A. B., (2011), Estimation of Global Solar Radiation using Cloud Cover and Surface Temperature in some Selected Cities in Nigeria, Archives of Physics Research, 2 (3), pp. 99–109.

[4] Iqbal M., (1983), An introduction to solar radiation, Academic Press New York.

[5] Shears R. D., Flocchini R. G. and Hatfield J. L., (1981), Technical note on correlation of total, diffuse and direct solar radiation with percentage of possible sunshine for Davis, Journal of Solar Energy, 27(4), 357-360.

[6] Babatunde E. B. and Aro T. O., (1990), Characteristics variation of total solar radiation at a llorin, Nigerian Journal of Solar Energy, 9, 157-173.

[7] Page, J. K., (1964), The estimation of monthly mean valuesof daily total short – wave radiation on vertical and inclined surfaces from sunshine records. Proceeding of the UN Conference on New Sources of Energy, page 98.

[8] Angstrom, A., (1924), Solar and Terrestrial Radiation, J. Meteor. Soc., 50: 121-126.

[9] Trabea, A. A. and Shaltout M. A., (2000), Correlation of global solar-radiation with meteorological parameters over Egypt. Renew. Energ., 21: 297-308.

[10] Falayi, E. O. and A. B. Rabiu, (2005), Modelling global solar radiation using sunshine duration data. Nigeria Journal of Physics, Vol. 17, pp. 181-186.

[11] Augustine C. and Nnabuchi M. N. (2009), "Relationship Between Global Solar Radiation and sunshine hours for Calabar, Port Harcourt and Enugu, Nigeria", International Journal of Physical Sciences, 4(4), pp. 182-188.

[12] Awachie, I. R. N and Okeke, C. E. (1990). New empirical solar model and its use in predicting global solar irradiation. *Nigerian J. Solar Energy*, 9, 143-156.

[13] Prescott, J. A., (1940), Evaporation from a Water Surface in Relation to Solar Radiation. Trans Roy Soc Aust 64, 114–48.

[14] Page, J. K., (1961), The Estimation of Monthly Mean Values of Daily Total Short Wave Radiation on Vertical and Inclined Surface from Sunshine Records for Latitude 40 °N – 40 °S, Proceedings of UN Conference on New Sources of Energy, 4(598), 378–390.

[15] Duffie, J. A. and Beckman, W. A (2006). Solar Engineering of Thermal Processes, 3rd Edn., John Wiley and Sons, New York.

[16] Tiwari, G. N and Sange eta, S. S (1977), Solar Thermal Engineering System, Narosa Publishing House, New Delhi, India.

[17] Frere E. T., (1980), Estimation and prediction of global solar radiation over Greece, Solar Energy, 24: 63-70.

[18] Hargreaves, G. H. and Samani Z. A. (1982), Estimating Potential Evapotranspiration. Journal of Irrig. and Drain Engr., ASCE, 108(IR3): 223-230.

[19] Hargreaves, G. H. (1994), Simplified coefficients for estimating monthly solar radiation in North America and Europe." Departmental Paper, Dept. of Biol. And Irrig. Engrg., Utah State University, Logan, Utah.

[20] El – Sebaii A. A. and Trabea A. A., (2005), Estimation of Global Solar Radiation on Horizontal Surface over Egypt, Egypt Journals of Solids, Vol. 28, N0. 1, pp. 163–175.

[21] Ezekoye B. A., Ezekoye V. A., Ike P. O., and Nwanya A. C., (2011), Estimating Monthly Solar Radiation of Nsukka Using Some Temperature Based Radiation Models, Nigeria Journal of Solar Energy, Vol. 22, pp. 67–70.

[22] Akpabio, L. E. and Etuk, S. E. (2003), Relationship Between Global Solar Radiation and Sunshine Duration for Onne, Nigeria. Turk J. Phys, 27: 161–167.

[23] Almorox, J., Benito, M. and Hontoria, C. (2005), Estimating of Monthly Angstrom-Prescott equation Coefficients from measured daily data in Toledo, Spain. Ren. Energy J. 30: 931 - 936.

[24] Che, H. Z., Shi, G. Y., Zhang, X. Y., Zhao, J. Q. and Li Y. (2007), Analysis of Sky Condition using 40 years records of solar radiation data in China, Theor. Appl. Climatol., 89: 83–94.

[25] Bandyopadhyay A., Bhadra A., Raghuwanshi N. S., and Singh R., (2008), Estimation of Monthly Solar Radiation from Measured Air Temperature Extremes, Agricultural and forest meteorology, Vol. 148 (Issues 11), pp. 1707–1718.