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Comparison of Different Models for Estimation of Global Solar Radiation in Jharkhand (India) Region

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ABSTRACT

In this paper with the help of different empirical models we have estimated the value of monthly average global solar irradiation for Ranchi (23.3500˚N, 85.3300˚E), a tropical location. The values of monthly average global solar radiation are calculated using the regression constants in the models (both linear and quadratic) suggested by: Angstrom-Prescott, Rietveld, Ogleman, Akinoglu, Glover, Gopinathan and Sangeeta *et al.* All the regression models are investigated, validated and compared. On comparison it was observed that the quadratic models are overall more accurate for calculating the Global Solar Radiation for the Jharkhand region, but the Angstrom-Prescott model as well shows better variance for most of the months. The calculated data from these models is compared with the data provided by MNRE [1]. GSR values are important parameters for designing any Solar Power Systems as the whole solar power generation is directly proportional to the amount of global solar radiation. The calculated and measured data are simulated using MATLAB.

Keywords: GSR; Sunshine Duration; Predicted Solar Radiation; Daily Global Radiation; Jharkhand

1. Introduction

Solar energy technologies offer a clean, renewable and domestic energy source and are essential components of a sustainable energy future. The amount of global solar radiation and its temporal distribution are the primary variable for the use of solar energy. Development of a solar energy research program must always start with a study of solar radiation data at a site or region of interest [1-20]. Unfortunately, the measurement of these parameters is made only in a few meteorological stations, especially in developing countries, for both historical and economical reasons. For places where it is not directly measured, solar radiation can be estimated by using models and empirical correlations. Therefore, there have been numerous investigations on the examination of the relationship between global radiation and sunshine duration for which data are available in a greater number of meteorological stations [2]. However, the computational complexity and associated time and input data requirements discourage many researchers and users from basing their calculations of energy, irradiation on models which have strong links to the fundamental radiative equations rather they are encouraged by simplicity and expediency of calculations using empirically based methods [3]. It can be observed from

Figure 1 shows that the solar energy potential of India is one of the highest in the world as the tropic of cancer passes through it [4]. But the true potential is yet to be utilized because of lack of data. It is worth pointing that

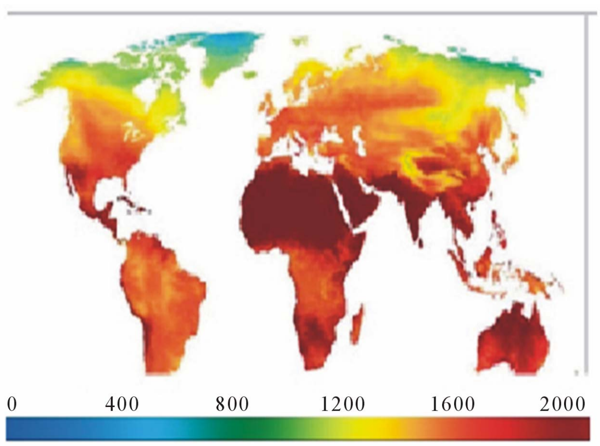

Figure 1. NASA map of world solar energy potential (kW/m^2/year).

regression models are used for prediction or estimation, data description, parameter estimation and control.

2. Model of Analysis (Table 1)

To calculate the monthly mean daily radiation on a horizontal surface in absence of atmosphere H_o a number of approaches had been made here is based on Duffi and Beckman [5]. The value of H_o is thus calculated as shown in Equation (1)

$$H_o = \frac{24}{\pi} I_{SC}\left[1+0.033\cos\left(\frac{360}{365}n\right)\right] \left[\sin\omega_{ss}\cos\phi\cos\delta+\omega_{ss}\sin\phi\sin\delta\right] \quad (1)$$

where $\delta = 23.45\left[\sin\frac{360}{365}(284+n)\right]$

$\cos\omega_{ss} = -\tan\phi\tan\delta$.

2.1. Angstrom-Prescott Model

Among the different empirical models, the most popular is the regression equation of the Angstrom [6,7] type. The regression constant *a* and *b* depend on *φ* (latitude) and seasonal variation.

$$\frac{H_g}{H_o} = a + b(s) \quad (2)$$

2.2. Rietveld Model

Rietveld [8] examined several published values of a and b and noted that *a* is related linearly and *b* hyperbolically to the mean value of *S* such that this equation is believed to be applicable anywhere in the world and yields superior results for cloudy conditions, for $S < 0.4$.

$$\frac{H_g}{H_o} = 0.18 + 0.62(s) \quad (3)$$

2.3. Ogleman Model

Ogleman [9] *et al.* proposed the use of a correlation which relates the global solar radiation to *S* in a quadratic form as

$$\frac{H_g}{H_o} = 0195 + 0.675(s) - 0.142(s)^2 \quad (4)$$

2.4. Akinoglu Model

Akinoglu and Ecevit [10] suggested a quadratic correlation between the ratio of H_g/H_o and *S* to estimate the values of global solar radiation for 58 locations displaced in several countries. This equation, whose coefficients have the same values, respectively for all tested locations is

$$\frac{H_g}{H_o} = 0.29\cos\phi + 0.52(s) \quad (5)$$

2.5. Glover Model

Glover and McCulloch [11] attempted to introduce latitude dependency to one of the Angstrom-Prescott coefficients and presented the following

$$\frac{H_g}{H_o} = 0.29\cos\phi + 0.52(s) \quad (6)$$

2.6. Gopinathan Model

Gopinathan [12] proposed *a* and *b* are related to three parameters, the latitude, the elevation and the sunshine hours.

$$a = -0.309 + 0.539\cos\phi - 0.0693h + 0.290(s)$$
$$b = 1.527 - 1.027\cos\phi + 0.0926h - 0.359(s) \quad (7)$$
$$\frac{H_g}{H_o} = 0.32 + 0.42(s)$$

2.7. Sangeeta *et al.* Model

In this model *a* and *b* are related to the parameters, the latitude and the sunshine hours.

$$a = -0.110 + 0.235\cos\phi + 0.323(s)$$
$$b = 1.449 - 0.553\cos\phi - 0.694(s) \quad (8)$$
$$\frac{H_g}{H_o} = 0.29 + 0.52(s)$$

3. Comparison of Models

The various models discussed above are used to calculate the extra-terrestrial radiation and the Global Solar Radiation. The calculated values are show in **Table 2**. In **Figure 2** and **Table 3**, the comparison of different linear models with measured data provided by MNRE for Ranchi for the year 2008 is shown. In **Figure 3**, the comparison of quadratic models with measured data is shown. In **Figure 4**, the variation of H_g (GSR) in all proposed models is compared and it is observed that the quadratic models have more accuracy than the linear models with the exception of Angstrom-Prescott and Riveted for the months of June-October.

4. Conclusion

When all the values of H_g for different linear models are compared in **Figure 2**, it is seen that the Angstrom-Prescott model shows more accuracy than rest of the linear models, while quadratic models are compared in **Figure 3**; it is observed that Ogleman and Akinoglu models have shown more accuracy with respect to other linear

Table 1. Regression models.

Model No.	Regression Equation	Model Type	Author
1	$H_g/H_o = a + b(S)$	Linear	Angstrom-Prescott
2	$H_g/H_o = 0.18 + 0.62(S)$	Linear	Rietveld
3	$H_g/H_o = 0.145 + 0.845(S) - 0.280(S)^2$	Quadratic	Ogleman
4	$H_g/H_o = 0.145 + 0.845(S) - 0.280(S)^2$	Quadratic	Akinoglu
5	$H_g/H_o = 0.29\cos\varphi + 0.52(S)$	Linear	Glover
6	$H_g/H_o = 0.32 + 0.42(S)$	Linear	Gopinathan
7	$H_g/H_o = 0.29 + 0.52(S)$	Linear	Sangeeta *et al.*

Table 2. Calculated values of basic parameters for the city Ranchi.

Month	Ñ (in hours)	n (no. of day starting from 1st January)	δ (in degrees)	ω_s (in radians)	ω_s (in degrees)	N (in hours)
January	8.7	16	−210761	1.403259	80.36844	10.71579
February	8.8	45	−13.5783	1.466101	83.96758	11.19568
March	8.6	75	−2.36253	1.552944	88.94131	11.85884
April	9.3	105	9.469933	1.643031	94.10085	12.54678
May	8.7	136	19.06845	1.720925	98.56203	13.1416
June	4.9	166	23.32178	1.758439	100.7106	13.42807
July	4.2	197	21.32284	1.740509	99.68363	13.29115
August	4	228	13.39006	1.67398	95.87333	12.78311
September	5.1	259	1.731019	1.583873	90.71267	12.09502
October	6.6	289	−10.0464	1.494067	85.56924	11.40923
November	8.2	320	−19.4304	1.417565	81.18776	10.82504
December	8.6	350	−23.3795	1.382628	79.18681	10.55824

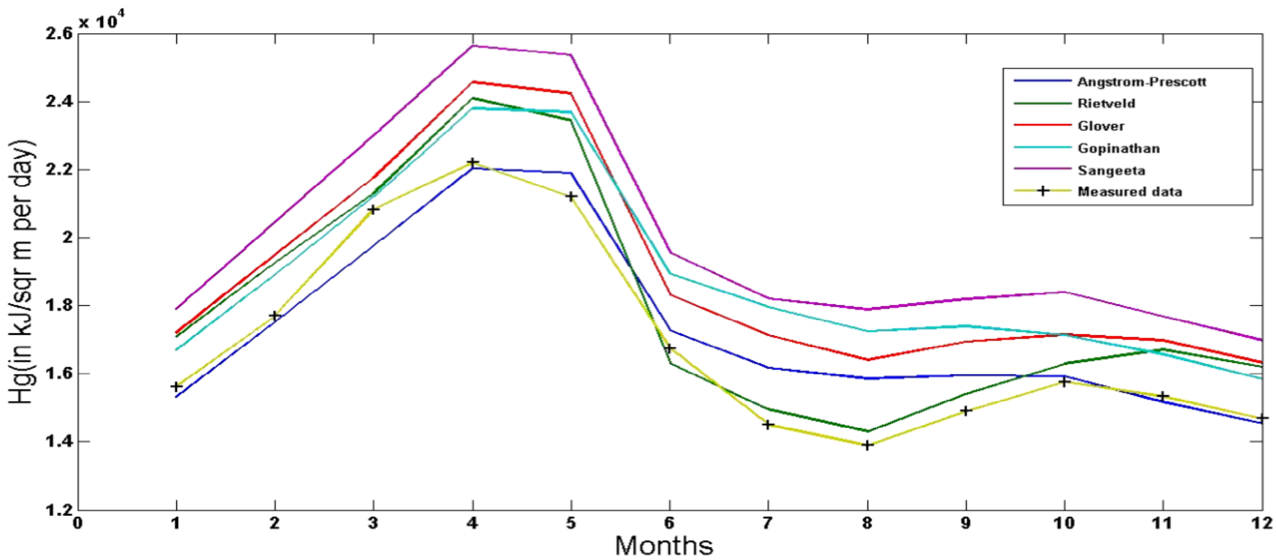

Figure 2. Comparison of different models with measured data.

Table 3. Comparison of different models.

Month	Extra-terrestrial radiation H_o (kJ/m^2-day)	Angstrom-Prescott H_g kJ/m^2-day)	Riveted H_g (kJ/m^2-day)	Ogleman H_g (kJ/m^2-day)	Akinoglu H_g (kJ/m^2-day)	Glover H_g (kJ/m^2-day)	Gopinathan H_g (kJ/m^2-day)	Sangeeta H_g (kJ/m^2-day)	Measured data H_g (kJ/m^2-day)
January	24992.4	15322.24	17079.04	16230.62	16157.06	17204.78	16687.7	17898.63	15,630
February	28890.68	17517.32	19279.64	18427.37	18380.09	19499.74	18917.4	20446.4	17,690
March	33818.71	19769.61	21293.01	20623.62	20647.56	21756.34	21198.41	23012.7	20,820
April	37676.49	22027.4	24096.38	23258.09	23265.21	24552.17	23798.27	25641.1	22,210
May	39683.93	21893.71	23431.46	23001.95	23083.79	24225.86	23688.08	25370.12	21,190
June	40182.93	17285.26	16324.01	16973.43	16718.61	18322.28	18945.03	19573.25	16,750
July	39793.11	16172.86	14959.02	15683.27	15282.95	17132.52	17952.59	18200.31	14,500
August	38247.13	15862.04	14304.66	15004.82	14610.22	16405.52	17240.99	17890.83	13,890
September	34906.92	15955.97	15408.96	15860.79	15761.18	16946.74	17387.2	18180.77	14,900
October	30248.38	15929.34	16293.5	16272.26	16337.64	17151.71	17128.28	18387.75	15,760
November	25722.3	15184.56	16710.55	16072.16	16061.6	16979.85	16569.91	17688.56	15,340
December	23666.03	14532.32	16211.43	15397.03	15323.97	16324.24	15845.4	16977.84	14,680

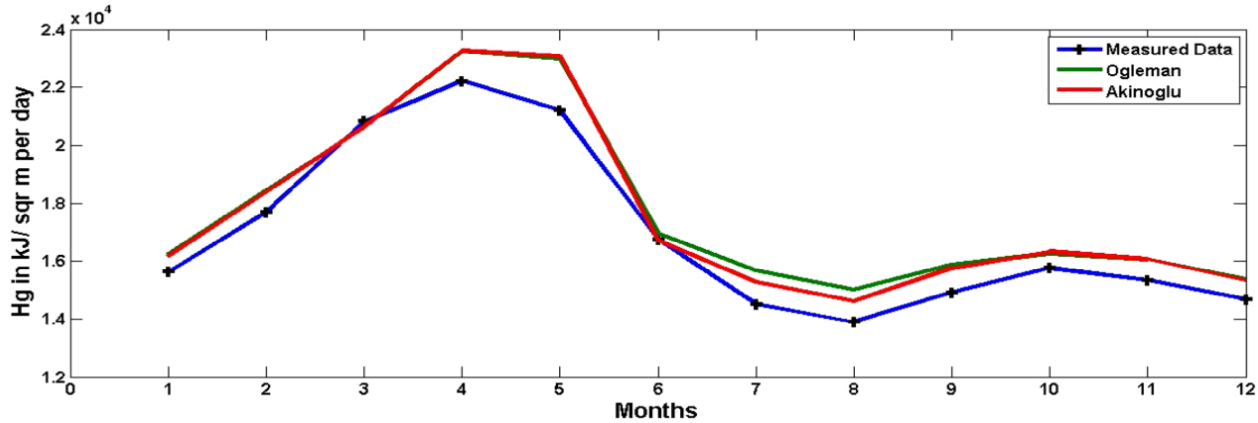

Figure 3. Comparison of quadratic models with measured data.

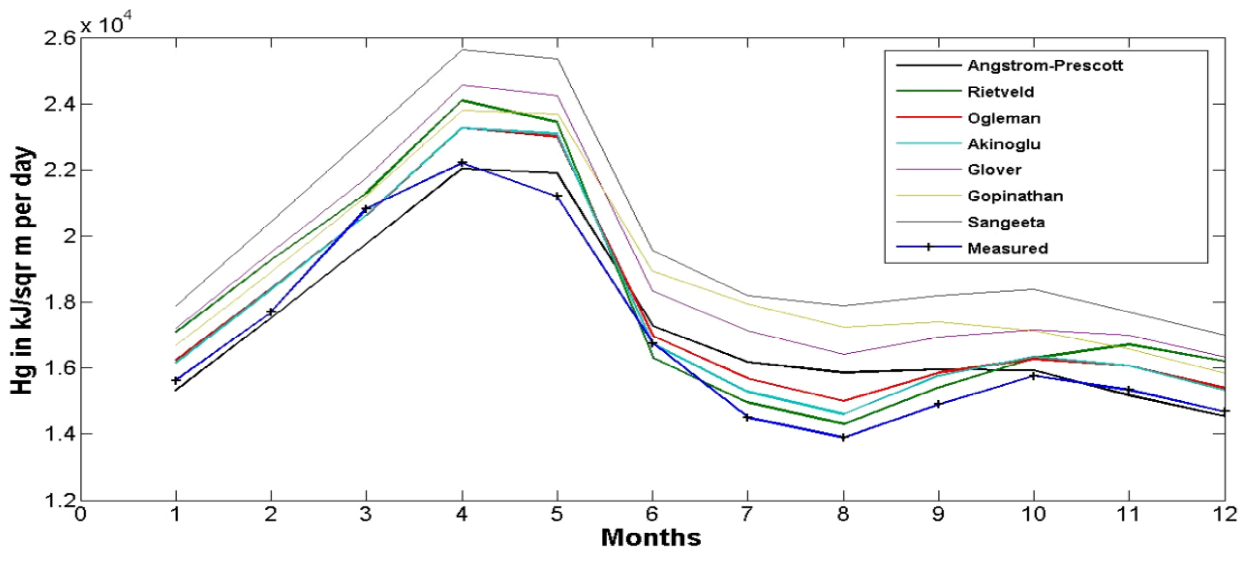

Figure 4. Comparison of all models with measured data.

models. Though it can be seen that Rietveld model show greater accuracy during June-October period *i.e.* during the monsoon. Thus observing all the factors Ogleman, Akinoglu and Angstrom-Prescott models are proposed for measuring the Global Solar Radiation for the Jharkhand region. Thus we can conclude that the quadratic models are more accurate than the linear models for calculating the Global Solar Radiation in Jharkhand region.

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