Correlation of Monthly Average Daily Global Solar Radiation with Cloudiness for Karachi, Pakistan

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Abstract: For developing countries like Pakistan, the paucity of reliable solar radiation data necessitates the development of empirical models. To develop such a model one could use various parameters. In this study, linear regression models are developed to estimate the monthly average daily global radiation using cloudiness data for Karachi, Pakistan for the period of 20 years (1990-2010). The results showed that the models could estimate global radiation within acceptable error.

Key Words: Global Solar Radiation, Regression, Cloudiness.

1. INTRODUCTION

The preliminary requirement for efficient utilization of solar energy is the information of solar radiation for a significantly prolonged span of time. For developing countries the main issue in this context is the lack of such data. For instance in Pakistan there are only five stations where the daily global solar radiation is being recorded. Therefore, it is necessary to develop methods to estimate the solar radiation on the basis of other meteorological parameters such as sunshine duration, cloud cover, relative humidity, and minimum and maximum temperatures [1-7].

Several attempts have been made to correlate the average daily global solar radiation incident on the horizontal surface over selected stations of Pakistan with the hours of sunshine [8-10]. However no attempt has been made so far to show a relationship between the other climatological parameters and the global solar radiation. In this paper we have proposed two polynomials for the evaluation of the mean monthly daily global solar radiation at Karachi, Pakistan from available data of cloudiness. Cloudiness is a frequently measured parameter and more than fifty meteorological stations of Pakistan record it on daily basis. The basic idea underlined in suggesting the models is the use of such models for most of the southern coastal areas of Pakistan, which possess similar climatic conditions as Karachi. The study is thus quite significant as one could use it to assess the feasibility of utilizing solar radiation in areas lacking in the solar radiation data but do record cloud cover.

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2. DATA EVALUATION

Beside the bright sunshine hours, cloudiness is a commonly measured parameter. The cloudiness data for around 50 stations of Pakistan for a considerably long period is available. Despite the fact that many researchers have attempted to correlate the mean monthly global solar radiation over horizontal surface with the cloudiness [11,12], no such study has been done so far for any location in Pakistan. This study is thus unique in a way, as the means of observations for cloudiness data taken at three specific timings have been employed in this study for Karachi, Pakistan. Along with the cloudiness C (in oktas) we have employed the ratio of monthly average daily global solar radiation (H) to the monthly average daily extraterrestrial solar radiation (H_0) on a horizontal surface as the other input parameter for developing the correlations. H_0 can be calculated from geographical information of a particular station **[**13**]**. The values of H/H_0 and the values C for Karachi for all the months of the year have been listed in Table **1**.

The present analysis is based upon measurements recorded by the Pakistan Meteorological Department at Karachi Airport station during the time interval between April 1990 and April 2010. To appraise the effectiveness of the proposed polynomials we have made an assessment on the basis of mean percentage error (MPE), mean bias error (MBE), root mean square error (RMSE) and the correlation coefficients (r).

3. RESULTS AND DISCUSSION

In the attempt to find the best correlations between H/H_0 and C we use regression analysis and find the following equations: -

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Table 1. Input Parameters

Month	H/H_0	C
January	0.662	0.296
February	0.641	0.247
March	0.641	0.201
April	0.608	0.226
May	0.715	0.377
June	0.569	0.433
July	0.486	0.628
August	0.470	0.611
September	0.577	0.401
October	0.655	0.122
November	0.669	0.117
December	0.662	0.207

Eq.1 (2nd order):

$$H = (-0.9413C^2 + 0.3552C + 0.6226)H_0$$

Eq.2 (3rd order):

$$H = (-1.3940C^3 + 0.5954C^2 - 0.1353C + 0.6666)H_0$$

It is important to mention that the calculated values of H from the proposed models are in fine agreement with the measured values for all the months of the year (see Fig. **1**). Table **2** further elaborates the fact where the results of the error analysis have been highlighted. A little overestimation for some months of the year motivates further improvement in the suggested models [14].

Table 2. Results of Error Analysis

Model	MPE	MBE	RMSE	r
Eq.1	0.003	0.842	1.173	0.917
Eq. 2	0.003	0.838	1.172	0.915

The error in approximating the global solar radiation using both the models does not go beyond a reasonable limit. The value of MPE is quite close to the ideal value (i.e., zero). It must also be noticed that the predictive potential of both quadratic and cubic equations is essentially same. Due to this sole reason we have drawn just one curve for the estimated values of H (using Eq. 2). The low values of MPE, MBE, and RMSE show the suitability of the models. Our reported values of correlation coefficients for the models based on sunshine hours [8] are also quite close to the value reported here.

It must be mentioned that we also fit the data with first order regression (results not shown here) and found that estimates are a bit poor.

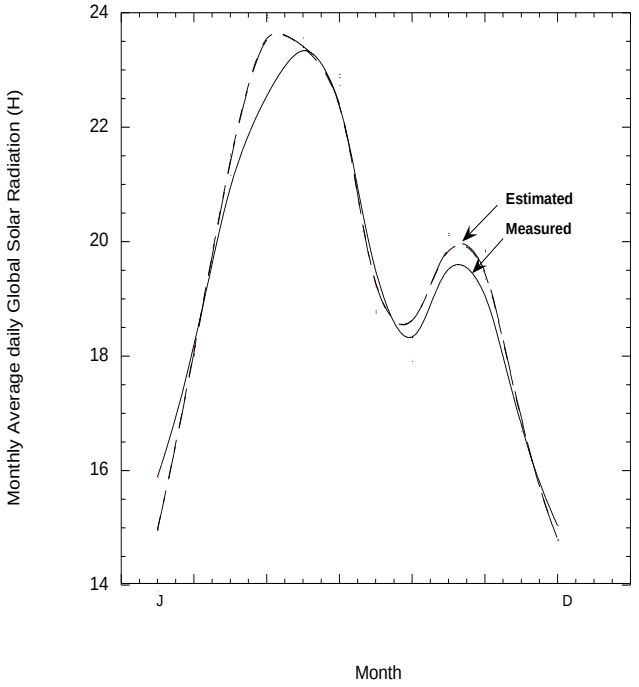

Fig. (1). Monthly distribution of H.

4.CONCLUSION

We have made an attempt to find correlations between the average daily global solar radiation over horizontal surface (H) and cloudiness (C) for Karachi, Pakistan. Two polynomials, one quadratic and the other cubic in C have been suggested. The proposed models can be used for precise prediction of daily global solar-radiation, which assists in making inferences regarding the performances of systems for practical utilization of solar energy. The models have been based on the data for a period of 20 years and have been tested statistically using conventional methods. It has been observed that the statistical indicators for the models such as mean percentage error, mean bias error, root-mean-square error and correlation coefficient are at adequate levels. The values predicted by the models suggested here are in good agreement with both the measured data and the data available in the literature. It is obvious that the empirical models based on the cloudiness are quite capable for estimating the global solar radiation. Moreover as cloudiness is a commonly measured parameter, we recommend the models for predicting H at any location having similar climatological conditions.

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NOMENCLATURE

H = Monthly average daily global solar radiation on horizontal surface

H_0 = Extra terrestrial solar radiation

n = Monthly average daily sunshine hours

N = Monthly average day length

C = Monthly average cloudiness

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