Methods for Computing Global Solar Radiation

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Abstract - *In this paper two models for estimating monthly average daily global radiation on a horizontal surface have been applied to four Algerian locations. The first one is an empirical model originally formulated by Barbaro et al.. Some modifications have been suggested. The second one is a regression equation of the Angstrom type. The agreement between the measured and the computed values is remarkable and the models are both recommended for use in any location in Algeria.*

Résumé - *Dans ce papier, deux modèles pour l'estimation de la moyenne mensuelle du rayonnement global sur une surface horizontale ont été appliqués sur quatre sites algériens. Le premier est un modèle empirique formulé par Barbaro et al. Quelques modifications ont été suggérées. Le second est une équation de régression du type d'Angström. L'accord entre les valeurs mesurées et calculées est remarquable et les modèles sont tous deux recommandés pour l'utilisation sur n'importe quel site en Algérie.*

Keywords: Global radiation - Horizontal surface - Sunshine duration.

1. INTRODUCTION

Solar energy occupies one of the most important places among the various possible alternative energy sources. An accurate knowledge of solar radiation distribution at a particular geographical location is of vital importance for the development of many solar energy devices and for estimates of their performances. Unfortunately, for many developing countries solar radiation measurements are not easily available for not being able to afford the measurement equipment and techniques involved. 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 [1-12]. Some works used the sunshine duration [1-8], others used mean daytime cloud cover or relative humidity and maximum and minimum temperature [9-11], while others used the number of rainy days, sunshine hours and a factor that depends on latitude and altitude [12].

Algeria is a high insolation country. The number of sunshine hours amounts almost 3300 h/year. The climate is most favourable for solar energy utilisation, but the distribution of the solar radiation is not well known. The importance of this work lies on the fundamental need of knowledge of the global solar radiation data in the country.

In this paper, two models have been tested. The first one is an empirical method originally formulated by Barbaro et al. [5] and modified by the authors to make it fit Algerian locations. The model only requires the duration of sunshine and the noon height of the sun on the 15th of the month. Barbaro et al. proposed the following relation:

$$G_m = K\,(n_m)^{1.24}\,(h)^{-0.19} + 10550\,(\sin h)^{2.1} + 300\,(\sin h)^3 \quad (1)$$

Where G_m is the monthly global radiation (cal. cm^{-2}); n_m is the monthly average daily number of bright sunshine (hours) and h the noon height of the sun on the 15th day of the month. K a climatic parameter. The second model is a regression equation of the Angström type [2-4].

2. CALCULATION PROCEDURE

In the present work, data of monthly mean of daily global solar radiation and sunshine duration from four Algerian meteorological stations (Algiers, Oran, Beni Abbès and Tamanrasset) are used [4]. The geographical location of stations are presented in Table 1. The duration of records of sunshine duration is 25 years and of global solar radiation is approximately 10 years. Measurements of global solar radiation were performed with Robitzsh and Kipp-Zonen pyranometers. For the recording of sunshine duration, Campbell-stokes heliographs are used.

Using the first model the monthly average of daily global radiation on a horizontal surface is obtained by changing n_m to the daily value, S, and dividing the constants by 30 days of the month and introducing an appropriate parameter (K).

$$G = [K(s)^{1.21} + 10880/30(\sin h)^{1.91} + 10(\sin h)^3]/24 \quad (2)$$

where G is the computed daily global radiation ($MJ.m^{-2}.day^{-1}$), s is the monthly average daily bright sunshine hours and h is the noon solar altitude on the 15th of the month (degrees). K is a zone parameter that depends on the climate.

Table 1: Geographical location of stations.

Station	Latitude (deg.) (N)	Altitude (m)	Longitude (degree)
Algiers	36.43	25	3.15 E
Oran	35.38	99	0.37 W
Béni Abbès	30.13	498	2.16 W
Tamanrasset	22.47	1378	5.31 E

The second model tested is a linear regression equation of Angström's type:

$$G/G_0 = a + b(S/S_0) \quad (3)$$

Where G is the monthly average daily global radiation on a horizontal surface ($MJ.m^{-2}\ day^{-1}$), G_0 is the monthly average daily extraterrestrial radiation on a horizontal surface ($MJ.m^{-2}.d^{-1}$), S is the monthly average daily number of hours of bright sunshine, S_0 is the monthly average daily maximum number of hours of possible sunshine and a and b are regression constants.

The four meteorological stations are divided into three zones according to the relative duration of sunshine.

- Mediterranean climate for Algiers and Oran.
- Sahara climate for Béni Abbès.
- Tamanrasset which is influenced by the African tropical climate.

The relative percentage error is defined as follows:

$$e_i = (G_{i,m} - G_{i,c})(100/G_{i,m}) \quad (4)$$

$G_{i,m}$ and $G_{i,c}$ are the i-th measured and computed values of global radiation.

3. RESULTS AND DISCUSSION

Using eq. (2), the monthly average daily global radiation values were calculated and appropriate zone parameters determined, $K = 14.1$ (Algiers and Oran), $K = 14.6$ (Béni Abbès) and $K = 17.3$ (Tamanrasset). The best estimates of global radiation were obtained for Béni Abbès and Tamanrasset. The maximum absolute errors are 8.17 per cent for Béni Abbès, 7.98 per cent for Tamanrasset and 10.55 per cent for Algiers and Oran.

Using eq. (3), the following correlations were obtained:

$$G/G_0 = 0.309 + 0.368(S/S_0) \quad \text{Algiers and Oran} \quad (5)$$

$$G/G_0 = 0.367 + 0.367(S/S_0) \quad \text{Béni Abbès} \quad (6)$$

$$G/G_0 = 0.233 + 0.591(S/S_0) \quad \text{Tamanrasset} \quad (7)$$

It is observed from the results that the maximum percentage error between the measured and predicted values of global radiation are 10.93 per cent for Algiers and Oran, 6.55 per cent for Béni Abbès and 8.88 per cent for Tamanrasset. The statistical indicators of accuracy are presented in Table 3.

The variation of the daily global radiation measured and computed are represented in Figures (1-4). The peak solar insolation occurs in the cases of Algiers, Oran and Béni Abbès in June, July and for Tamanrasset in May-July, the solar radiation fluctuates from 22.21 $MJ.m^{-2}.\ day^{-1}$ to 29.37 $MJ.m^{-2}.day^{-1}$ for all the stations.

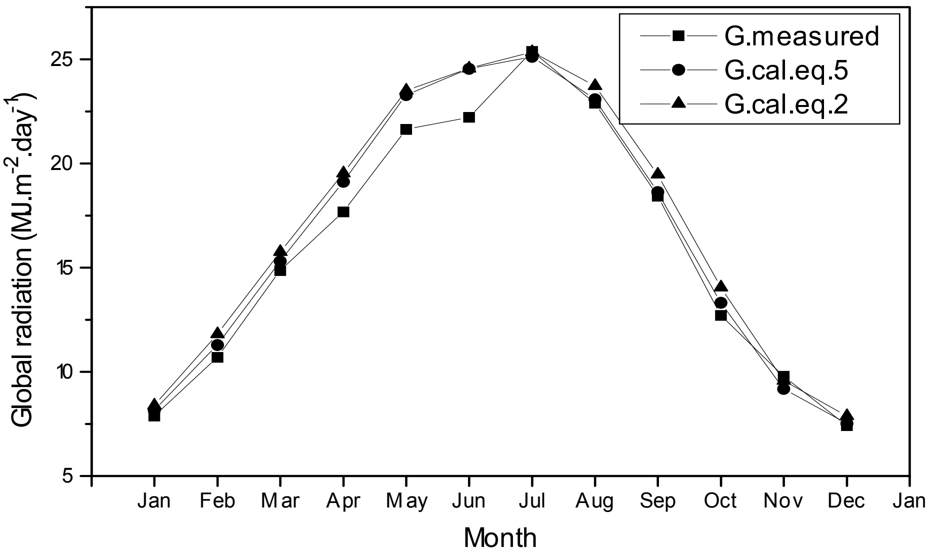

Fig. 1: The measured and calculated values of global solar radiation (Algiers)

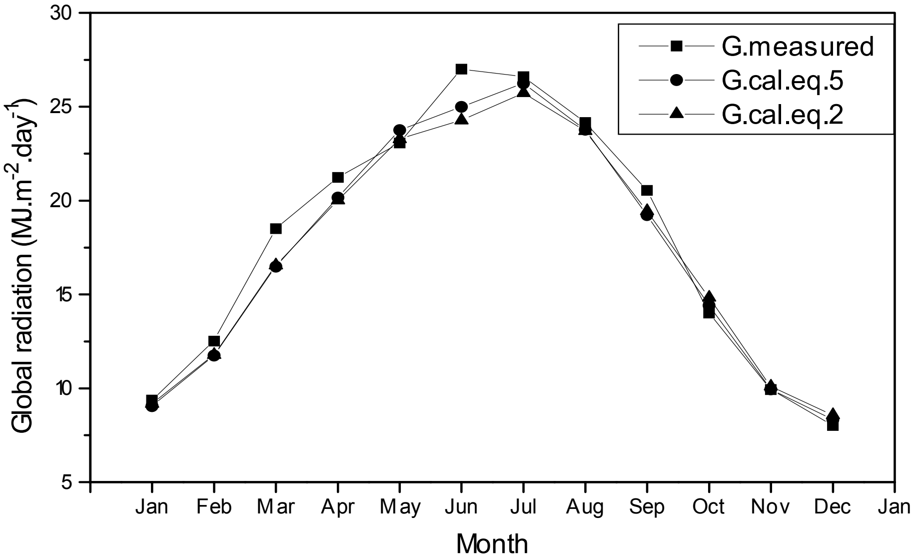

Fig. 2: The measured and calculated values of global solar radiation (Oran)

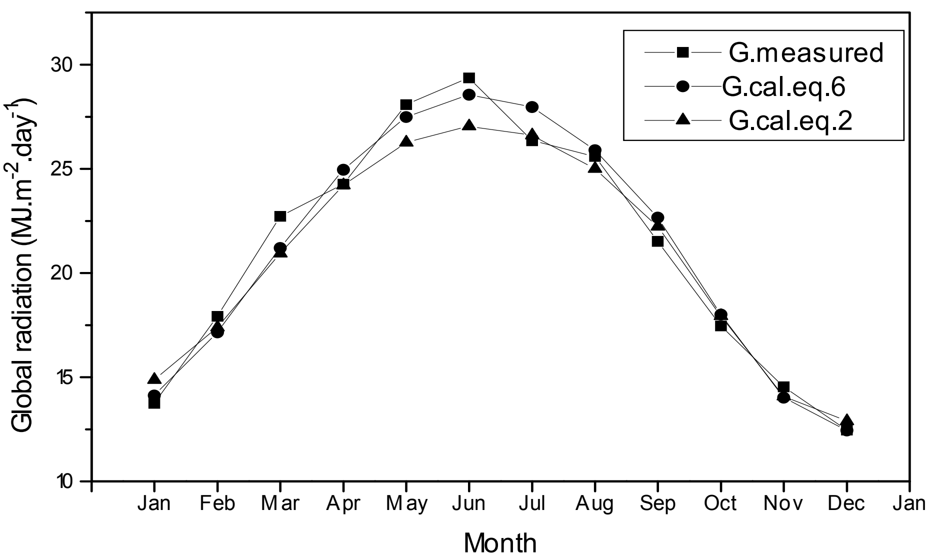

Fig. 3: The measured and calculated values of global solar radiation (Béni Abbès)

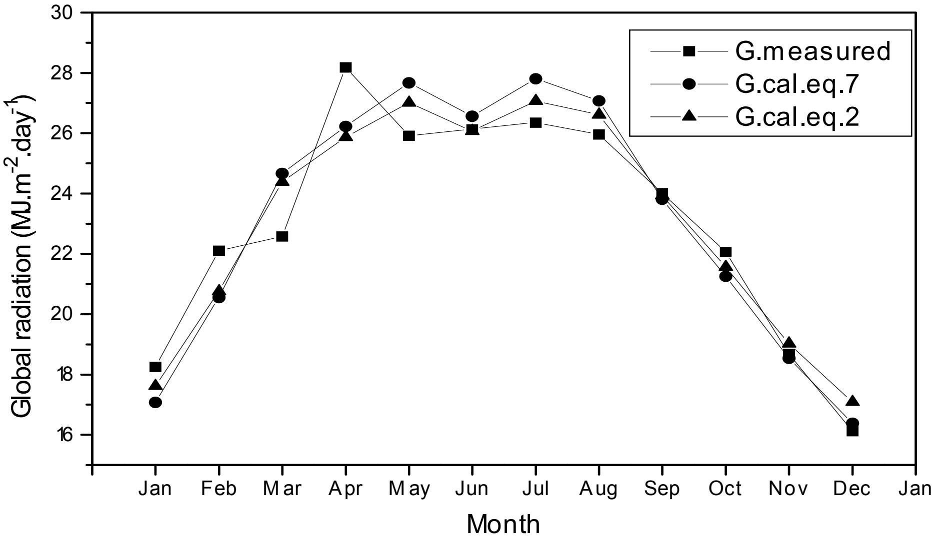

Fig. 4: The measured and calculated values of global solar radiation (Tamanrasset)

4. CONCLUSION

The monthly average daily global radiation incident on a horizontal surface has been estimated using two empirical models. The first one was originally formulated by Barbaro et al. and modified by the authors to make it fit some Algerian meteorological stations. The formula requires only the sunshine duration and the noon solar altitude of the sun. Appropriate zone parameters have been determined, $K = 14.1$ for Algiers and Oran, $K = 14.6$ for Béni Abbès and $K = 17.3$ for Tamanrasset. It is possible to determine other zone parameters by extending this model to other meteorological stations. The second one is a linear regression of the Angstrom type. The values of the constants a and b change from place to place according to the climatic characteristics. The agreement between the measured and the estimated values is remarkable and both models are recommended for use in any location in Algeria or stations with similar climate.

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