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Revised solar maps of Algeria based on sunshine duration

M.R. Yaiche [a], A. Bouhanik [a], S.M.A. Bekkouche [b,*], A. Malek [a], T. Benouaz [c]

[a] Centre de Developement des Energies Renouvelable, CDER, Route de l'observatoire, Bouzaréah, 16340 Algiers, Algeria
[b] Unité de Recherche Appliquée en Energies Renouvelables, URAER, Centre de Développement des Energies Renouvelables, CDER, 47133 Ghardaïa, Algeria
[c] University of Tlemcen, Laboratory of Automatic, BP. 119, R.p. 13000 Tlemcen, Algeria

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ABSTRACT

Solar irradiation data is generally required in modelling a system's thermal performance, and evaluation of long-term effects of climatological changes. In Algeria, measurements of solar irradiation have been carried out for a few locations because the measuring instruments are expensive to purchase and install. The only alternative to obtain solar irradiation data is to estimate it by use of an appropriate solar irradiation model.

The present study attempted to draw global solar irradiation maps for Algeria, witch are generated for all types of sky. The incident solar radiation on a horizontal surface, on a surface tilted at the latitude angle and for a vertical plane facing east, south, west, south-east, south-west was determined using numerical models. To obtain a solar radiation map of a certain zone it is necessary to know the solar radiation of a huge number of sites spread wide across the zone.

The comparison between the measured and the computed values is satisfactory; the relative error is less than 7%. The results allow to view information about 48 provinces of Algeria, and are presented in the form of an annual solar radiation map. The solar maps developed in this paper provide information about the levels of total solar radiation which can be used as a database for future investments in the solar sector in Algeria.

1. Introduction

Solar irradiation research is a field of rising interest due to its many applications. Solar radiation is received as heat and light, it can be converted to useful thermal energy or for production of electricity either through solar photovoltaic route or through solar thermal route. However, solar resource assessment is a recurrent problematic faced by all the actors of the solar industry, either photovoltaic or thermal solar. Solar radiation data and its compound play very important role in designing, sizing and performance of energy and renewable energy systems. The difficulties associated with the use of cloud cover for the estimation of total solar radiation have been pointed out [1].

In the literature, several models for estimating and modelling of global solar radiation have been developed. In [2], many studies have been performed using an artificial neural network [1], correlation between global irradiation and sunshine duration is given by Benghanem et al. It should be noted that the sunshine duration play very important role for obtaining high accurate results. Paulescu et al. [3] proposed an innovative two-state model: if the sun is shining, the solar irradiance is estimated with an empirical model fitted on historical data; if the sun is covered, the clear sky solar irradiance is adjusted according to the cloud transmittance. They found that compared to the forecasts in the clearness index approach, the two-state model forecast is more accurate to within 20%.

Generally, the cloudy sky model underestimates the measured values. Its performance is (marginally) good enough for point cloudiness $C = 0–1$. The performance is good for skies with few clouds ($C < 0.3$), good enough for skies with medium amount of clouds ($C = 0.3–0.7$) and poor on very cloudy and overcast skies [4]. On the other hand, general regression type of neural network was used by Celik and Muneer [5] for the conversion of solar irradiation from horizontal to tilted and tested against the measured solar irradiation on a tilted surface as one of the firs. Research for estimating global solar radiation from the duration of sunshine was initiated by Angstrom in the 1920s [6]. Yorukoglu and Celik [7] have estimate the global solar radiation from sunshine duration using five different models (linear, quadratic, cubic, logarithmic and exponential), which are the most common models used in the literature, based on 6 years long measured hourly global solar radiation data.

* Corresponding author.
E-mail address: smabekkouche@yahoo.fr (S.M.A. Bekkouche).

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Table 1
Cloudiness factor corresponding to the different types of skies.

N^{br} of OCTAS n	m	p	Type of sky	N_i	N_d
0	0	/	Completely clear sky	1	1
0/1	1	/	Clear sky	0.9792	1.0208
0/1	2	/		0.9583	1.0417
0/1	3	/		0.9375	1.0625
0/1	4	/		0.9167	1.0833
0/1	5	/	Partly cloudy sky	0.8958	1.1042
1	0	/	Partly cloudy sky	0.8750	1.1429
1/2	1	/	Partly cloudy sky	0.8542	1.1637
1/2	2	/		0.8333	1.1845
1/2	3	/		0.8125	1.2054
1/2	4	/		0.7917	1.2262
1/2	5	/		0.7708	1.2470
2	0	/		0.7500	1.3333
2/3	1	/	Partly cloudy sky	0.7292	1.3542
2/3	2	/		0.7083	1.3750
2/3	3	/		0.6875	1.3958
2/3	4	/		0.6667	1.4167
2/3	5	/		0.6458	1.4375
3	0	/	Partly cloudy sky	0.6250	1.6000
3/4	1	/	Partly cloudy sky	0.6042	1.6208
3/4	2	/		0.5833	1.6417
3/4	3	/		0.5625	1.6625
3/4	4	/		0.5417	1.6833
3/4	5	/		0.5208	1.7042
4	0	/	Moderately cloudy sky	0.5000	2.0000
4/5	/	1	Moderately cloudy sky	0.4792	2.0208
4/5	/	2	Cloudy sky	0.4583	2.0417
4/5	/	3		0.4375	2.0625
4/5	/	4		0.4167	2.0833
4/5	/	5		0.3958	2.1042
5	/	6	Cloudy sky	0.3750	2.1250
5/6	/	7	Cloudy sky	0.3542	2.1458
5/6	/	8		0.3333	2.1667
5/6	/	9		0.3125	2.1875
5/6	/	10		0.2917	2.2083
5/6	/	11		0.2708	2.2292
6	/	12	Cloudy sky	0.2500	2.2500
6/7	/	13	Cloudy sky	0.2292	2.2708
6/7	/	14		0.2083	2.2917
6/7	/	15		0.1875	2.3125
6/7	/	16		0.1667	2.3333
6/7	/	17		0.1458	2.3542
7	/	18	Very cloudy sky	0.1250	2.3750
7/8	/	19	Very cloudy sky	0.1042	2.3958
7/8	/	20		0.0833	2.4167
7/8	/	21		0.0625	2.4375
7/8	/	22		0.0417	2.4583
7/8	/	23		0.0208	2.4792
8	/	24	Covered sky	0	2.5

Suehrcke et al. [8] examine the relationship between sunshine duration and solar radiation received on the earth's surface. Furthermore, Ledanoi and Priero [9] have proposed a revised solar map, based on the latest average irradiation of 37 cities and hours of bright sunshine in 40 other Venezuelan places published by the Venezuelan Air Force, has been plotted. Our objective is in the same context; the results obtained enable a study of the best place and times for future developments of solar energy applications and are a contribution to the knowledge of the solar climatology of the country. There are other works which are related to the creation and updating of solar maps by different methods. Monthly mean global radiation for 24 Jordanian locations have been computed and analysed by Alsaad [10]. The results for all stations are presented in the form of monthly global radiation table and annual solar radiation map and the reported results can be used with a monthly error less than 20% and an average error ranging from 2% to 5%. The Mubiru and Banda [11] study attempted to draw global solar irradiation maps for Uganda. Global solar irradiation values were estimated for eight out of twelve stations using an artificial neural networks model proposed for Uganda. Measured values of monthly average daily global solar irradiation were used for the remaining four stations and then, the values for the twelve stations were utilised for the interpolation using moving average method. The result is a set of twelve global solar irradiation maps for Uganda with relative errors in the range of 8–16%. On the other hand, the solar map of Algeria has been elaborated and witnesses to the high solar potential of the country. All the Sahara desert of Algeria is the suitable areas for constructing solar thermal system. Messen has drawn descriptive maps of the solar field in Algeria from the computed solar radiations for the 42 stations. The study shows that the annual average solar radiation is more marked by the astronomical factors whereas the monthly radiation is rather dependent on meteorological phenomena. A descriptive cartography of the radiation in Algeria has established [12]. The methodology used by Mefti et al. [13] consists of successive transformations of solar data, respectively, based on the exponential probability distribution of daily sunshine duration, Angstroom equation, beta probability distribution of hourly global solar radiation flux, polynomial correlations of hourly direct and diffuse radiation with global solar radiation and the Klucher model. Indeed, Almorox and Hontoria [14] validate several expression models for the prediction of monthly average daily global radiation on a horizontal surface from sunshine hours and to select the most adequate model.

This paper presents the results of solar radiation predicted using the sunshine hours (duration). The developed solar maps provide information about the of the total solar radiation levels which can be used as a database for future investments in the solar sector in Algeria. We use the theoretical approach of Perrin Brichambaut [15] which is valid only for a completely clear sky. It allows us to calculate the solar radiation incident on a horizontal plane. We are interested in determining the cloud cover (also

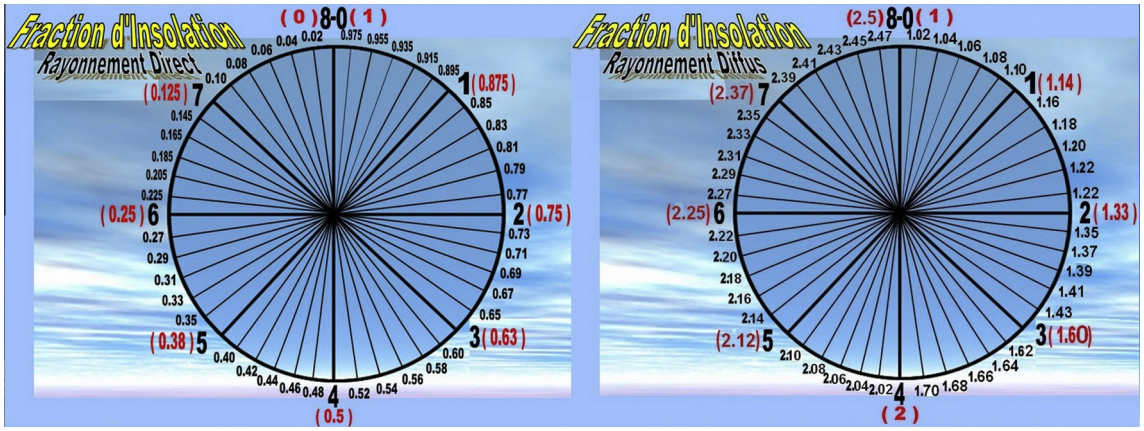

Fig. 1. Representation of cloudiness divided into eight equal parts and division of 1 octa into six parts: left the direct solar radiation, right for the diffuse solar radiation.