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Article

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Updating Algerian solar atlas using MEERA-2 data source

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Abstract

According to its geographical location, Algeria holds one of the highest solar potential in the Mediterranean basin, as indicated in many studies. Unfortunately, an important lack of data of the solar global radiation is observed. With a huge area of 2 381 741 km², it is necessary to have numerous stations performing radiation measurement in order to quantify in an objective way the solar potential. Previously, several studies have been conducted dealing with solar potential evaluation. In this study, an update of the Algerian solar atlas is presented. Thus, a solar mapping on the national territory was carried out based this time on data measured over a period of almost 37 years. In fact MEERA-2 "The Modern-Era Retrospective Analysis for Research and Applications, Version 2, NASA", were used in this study.

Therefore, solar maps for solar radiation on different tilting planes were plotted thanks to the use of SURFER[®] software, through Kriging interpolation method. Furthermore, measured data for five (05) locations across the country were used in order to make comparison to those given by MERRA-2.

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Keywords: Solar radiation; MEERA-2 data; Solar atlas; SURFER[®] software; Kriging interpolation method

1. Introduction

Knowledge of the potential solar of the region is crucial for sizing different solar systems before their installation at a particular location. Furthermore, in order to assess solar potential, it is necessary to have a large network of stations ensuring measurement of solar radiation. Moreover, this assessment must take into account the daily and seasonal variations, solar radiation and load profile. Solar potential in Algeria is considerable as indicated in previous studies, [1–10].

The country is moving smoothly toward the production of its electricity from renewable. Indeed, many solar plants were installed in the country recently [11]. Furthermore, 22 000 MW are planned to be installed by 2030, with 13 575 MW of capacity for solar photovoltaic (PV). Therefore, a reliable assessment must be carried out before achieving any solar plant.

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Nomenclature

D_h^{day}	Daily diffuse irradiation
I_h^{day}	Daily horizontal direct irradiation
G_h^{day}	Daily global irradiation on titled plane
n	Cloud index
ρ	Surface albedo
$\omega_{.s}$	Hour angle of the sunset on the tilted plane
ω_s	True hour angle of the sunset.
G_est	Monthly measured global solar irradiation by MERRA-2
G_meas	Monthly measured global solar irradiation by ONM
e_r	Yearly relative error

In order to make a reliable assessment, trusted data must be used in order to quantify in credible way, solar potential where a PV or a Concentrated Solar Power (CSP) system are intended to be installed.

Solar atlases based on statistical approach were established by [12,13].

Our contribution deals with the presentation of the new Algerian solar atlas. Thus, a solar mapping on the national territory was carried out based this time on hourly data measured over a period of almost 37 years. In fact MEERA-2, “The Modern-Era Retrospective Analysis for Research and Applications, Version 2, NASA”, [14], were used in this work. They are hourly type data, obtained from recordings where a pyranometer is installed and satellite measurements combined with data from radiative transfer models where measurements are not available (inaccessible locations, no radiometric stations). They are available on a geographic resolution of 0.5 degrees (eq.50 km) covering the whole globe.

2. Methodology adopted

The methodology developed, is presented in the following diagram (Fig. 1).

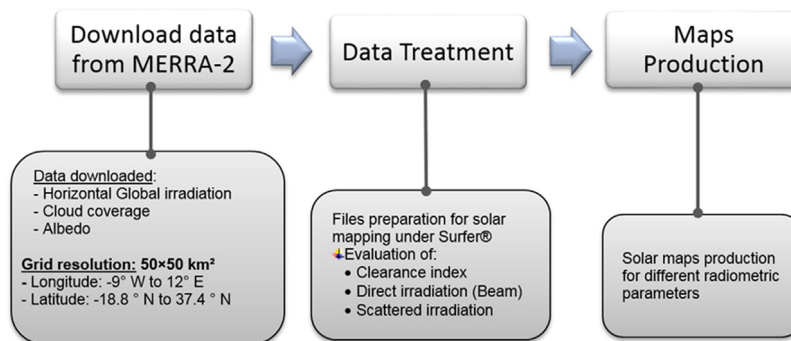


Fig. 1. Synoptic diagram for the different process.

Three major processes are necessary in order to establish the solar atlas, which are:

2.1. Downloading data from MERRA-2 database

The first step in our work consist of downloading data from MERRA-2 database. They can be downloaded free of charge. The downloaded components are the global irradiation under clear sky and the real irradiation. The data are given at each point of grid with a resolution of $50 \times 50 \text{ km}^2$. In our case, we have considered a domain, which starts from 9°W to 12°E, for the longitude, and from 18.8°N to 37.4°N for the latitude.

2.2. Data treatment

From the global radiation, the cloud index (n) and the surface albedo (ρ) downloaded from the MERRA2 database; we calculate the diffuse irradiation, the direct irradiation both on horizontal plan and lastly the global irradiation on tilted plane.

Daily diffuse irradiation

$$D_h^{day} = 0.952 \times G_h^{day} \quad \text{if } n \leq 0.13 \tag{1}$$

$$D_h^{day} = (0.868 + 1.335 \times n + 5.78 \times n^2 + 3.72 \times n^3)G_h^{day} \quad \text{if } 0.13 < n \leq 0.80 \tag{2}$$

$$D_h^{day} = 0.141 \quad \text{if } n \geq 0.80 \tag{3}$$

Daily horizontal direct irradiation

$$I_h^{day} = G_h^{day} - D_h^{day} \tag{4}$$

Daily global irradiation on tilted plan

$$G_{tit}^{day} = G_h^{day} R_b + D_h^{day} \times \frac{1 + \cos(\beta)}{2} + I_h^{day} \times \rho \frac{1 - \cos(\beta)}{2} \tag{5}$$

$$R_b = \frac{\cos(\varphi - \beta) \cos(\delta) \sin(\omega'_s) + \pi/180 \omega'_s \sin(\varphi - \beta) \sin(\delta)}{\cos(\varphi) \cos(\delta) \sin(\omega_s) + \pi/180 \omega_s \sin(\varphi) \sin(\delta)} \tag{6}$$

2.3. Map production

All maps are produced through Surfer® software. Using Surfer® software, with the Kriging method, different maps were produced in order to represent the Algerian solar potential.

Monthly and yearly maps were established.

3. Solar atlas

In our study, most radiometric parameters were considered including solar irradiation at different titles, albedo, and cloud coverage. Maps representing the main radiometric parameters are given below.

3.1. Map analysis

The maps (Figs. 2, 3, 4, 5, 6) represent the normal of global, diffuse and direct solar irradiation.

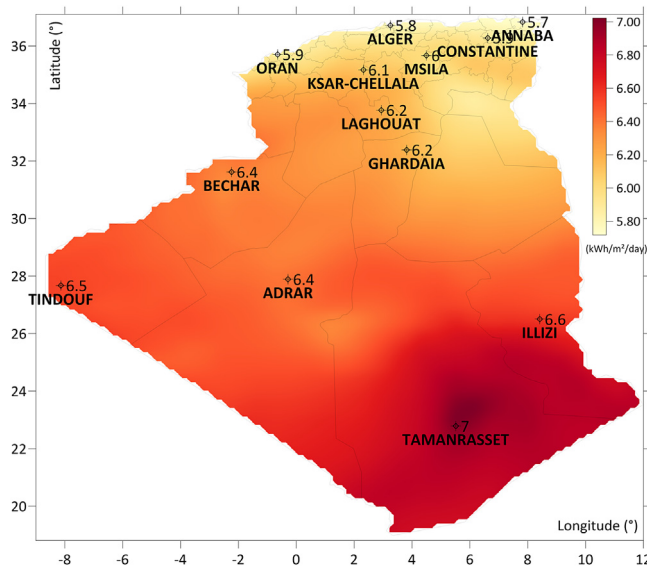


Fig. 2. Clear sky global irradiation map.

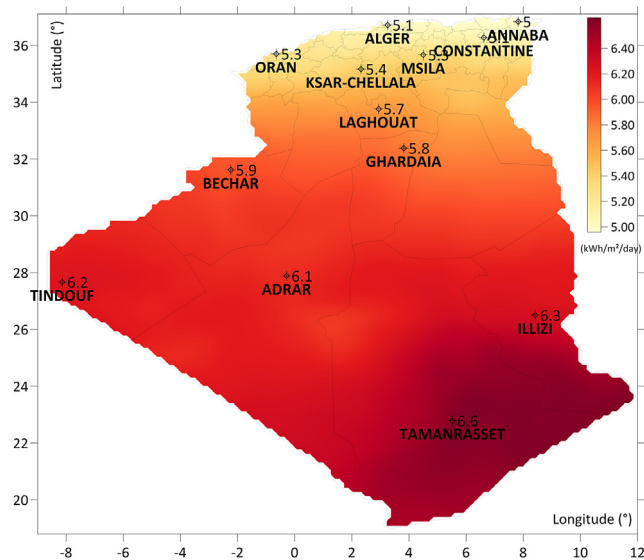


Fig. 3. Global horizontal irradiation map.

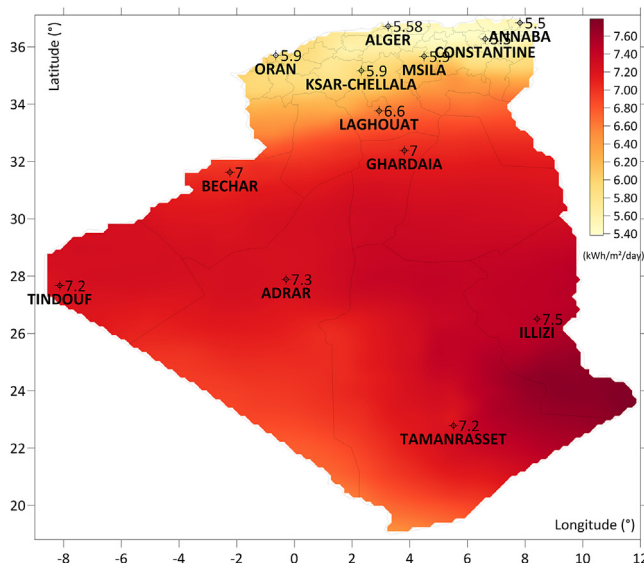


Fig. 4. Direct irradiation (beam) map.

The analysis of these figures shows an increasing solar potential toward the south of Algeria. Extreme values are recorded on the Hoggar and Tassili whose altitude reaches 3000 m with a very clear atmosphere, which reduces the absorption of solar radiation by aerosols. Analysis of diffuse irradiation map (Fig. 5) again shows slightly higher values on the Hoggar and Tassili and northern regions compared to regions of the Sahara. This difference is explained by the presence of clouds during the summer by the weather disturbances recovered from the tropical regions of the Hoggar and Tassili and weather disturbances from the Mediterranean to the northern regions of Algeria. This presence of clouds increases the diffuse component of solar radiation by clouds. Concerning the Sahara in which records low values of diffuse radiation is explained by the fact of the absence of clouds throughout the year on these areas, which increases the direct component and the decreases of diffuse component.

This study also shows that the analysis of global irradiance maps on a sloping scale at the seasonal scale for an optimal inclination of the gain in solar energy is more interesting in winter than in summer, especially in the

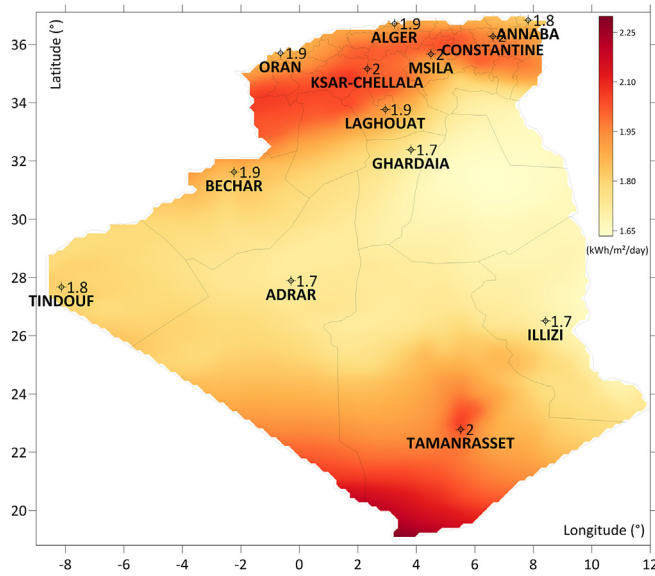


Fig. 5. Scattered irradiation on horizontal plan map.

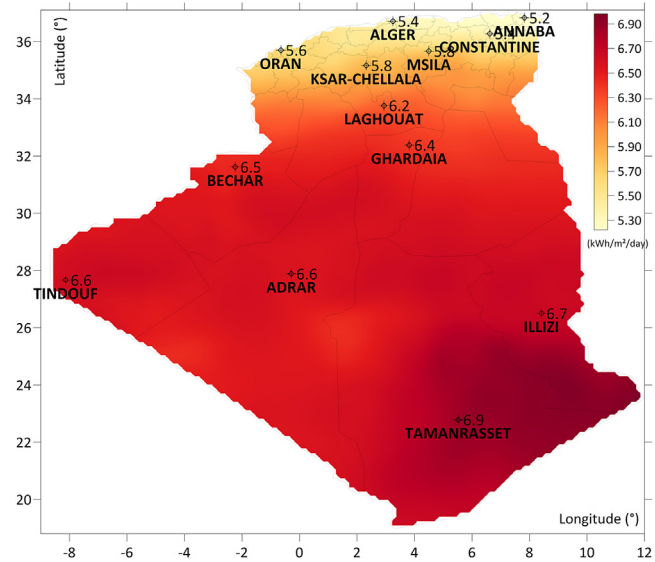


Fig. 6. Global irradiation on optimal slope map.

northern regions of Algeria. At the level of the year, the gain (Fig. 7) is 15% for more northern latitudes and becomes insignificant further down south.

4. Data validation

A data validation was conducted in order to confirm the quality of MERRA-2 data that we have used in our study. Therefore, a simple comparison was done using yearly measured data provided by the National office of Meteorology (ONM, Algeria), (Fig. 8). In fact, a basic relation allowing the calculation of the relative error was used, the relation is given as follow:

$$e_r (\%) = 100 \times \left| \frac{G_{est} - G_{meas}}{G_{meas}} \right| \tag{7}$$

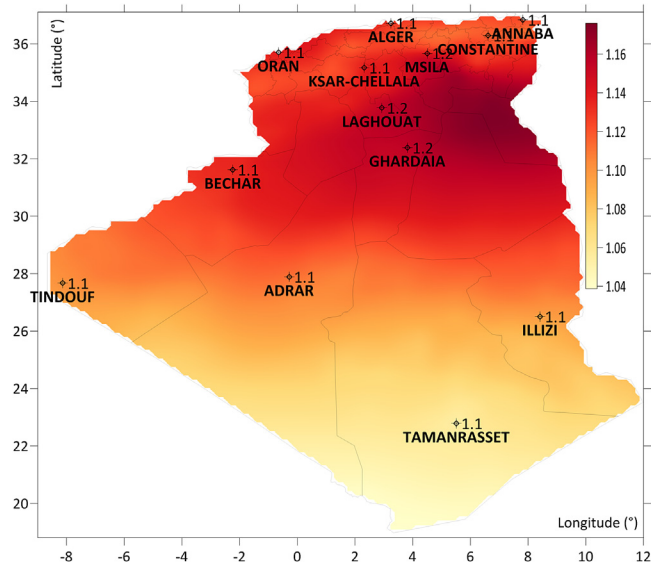


Fig. 7. Overall irradiation gain on optimal slope map.

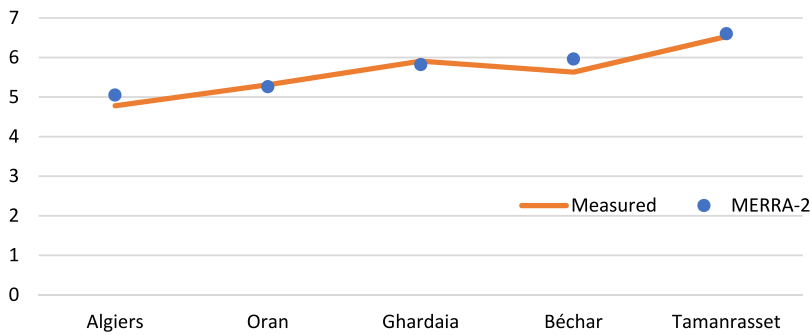


Fig. 8. Measured data Vs MERRA-2.

In Table 1, are presented the results for the relative error comparing measured and those given by MERRA-2, the calculation was performed for only five (05) available sites .

Table 1. Yearly relative error values (%).

	Algiers	Oran	Ghardaia	Béchar	Tamanrasset
e_r (%)	5.6	0.9	1.5	5.9	1.1

We can remark that data provided by MRRA-2 are almost the same for the 5 cases, the maximum error was obtained for the site of Béchar with a weak value approaching 6%. Oran site is still the best for our case, where the error was less than 1%.

5. Conclusion

The new Algerian atlas was presented. A solar mapping was carried out, where most of the radiometric parameters were considered. The study has confirmed that Algeria holds one of the most important solar potential in the region, as indicated by various studies.

The assessment was possible thanks the availability of the MERRA-2 data. A confrontation was made with data measured by the ONM, for only 5 locations due the lack of measured data. An excellent fitting was obtained, which

confirms the credibility of the data we have used in the present study. It should be noted that these data are provided by the NASA Space Agency. However, they allowed us to establish a reliable Algerian solar atlas.

However, this present study helped us to contribute to the assessment of Algerian solar potential. In addition, this work consolidates the studies that preceded it, including the production of solar maps for the country. This contribution can serve as a basis for any solar system installer before investing in PV or (CSP) at any site across the country

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