International Journal of Scientific Research & Engineering Technology (IJSET)
Vol.8 pp. 32-37

Programming interface in Matlab to estimate solar radiation in Algeria: Application to M'sila

Younes Kherbiche #1, Nabila Ihaddadene #2, Razika Ihaddadene #3 *and Marouane Mostefaoui* *

 # Department of Mechanical Engineering,
Med Boudiaf University-BP 166 M'sila 28000, Algeria
** M'sila Weather Station-M'sila-Algeria*
1Kherbiche_younes@hotmail.com 2 MAZ1dz@gmail.com 3 tassekurt1@gmail.com

Abstract– **The solar energy gives life to humans and all living beings on earth. Solar energy is used to produce thermal as well as electrical power. Solar energy and other renewable sources, allow us to meet the demand for energy while providing a cleaner and greener footprint. In this work, we have developed a software using the programming language MATLAB GUIs (also known as graphical user interfaces or UIs) for the estimation of solar radiation for the different types of the sky in Algeria. The software contains a database (latitude, longitude, and altitude) of all the regions of Algeria. The program gives the opportunity to compare the values estimated by the theoretical models (Perrin de Brichambaut, Lui & Jordon, Hay & Davies, Klucher and Reindl) and the values measured by the meteorological station in the region of M'sila. A good agreement was found between the measured and recorded values.**

Keywords- **Solar Radiation, Solar Radiation Models, Matlab GUIs.**

I. INTRODUCTION

The sun is the source of solar energy, which is the largest member of the solar system compared to other members around it. About 74% of the sun's mass is hydrogen, 25% is helium, and 1% is the residue tracing heavier elements. Solar radiation is radiation emitted by the Sun, whereas solar energy is the energy emitted by the Sun in the form of electromagnetic waves [1].

The quantities and types of aerosols in the atmosphere, water vapour, ozone, and other components affect the total quantity and the spectral distribution of the solar radiation incident on a solar collector surface. The wavelength range of solar radiation available in the terrestrial region for the use of solar energy applications is from 0.29 to 2.3 μm. Due to dispersing in the atmosphere, solar radiation has two components (beam and diffuse radiations) in the terrestrial region [2].

The solar radiation data are used in the development, as well as in the evaluation of the performance of solar systems. It is possible to predict the instantaneous changes of diffuse, direct and global irradiation for different inclinations, even if the sky possesses cloudy perturbation.

For this, we developed an interface written and designed in Matlab GUIs which calculated the position parameters and the solar radiation on any surface using different models and for different sky types. We also present some simplified models for the evaluation of solar energy received on a horizontal and inclined planes.

II. THEORETICAL

A. Solar Radiation Energy

- Solar time is the calculation of time passing refers to the position of the sun in the sky, solar time is of two types, namely, apparent solar time and mean solar time (clock time or standard time).The difference in minutes between solar time and standard time is: [3]

$$Solar\ time\ -\ standard\ time\ =\ 4(L_{sm}-L_{loc})+\xi \quad (1)$$

  - ✓ L_{sm} is the standard meridian.
  - ✓ L_{loc} is the longitude of the location
  - ✓ ξ is the equation of time (in minutes),

  Which is given by the expression:

$$\xi = 229.2(0.000075+0.001868\cos B-0.032077\sin B-0.014615\ \cos 2B-0.04089\sin 2B) \quad (2)$$

Where: $$B = (N-1)*360/365 \quad (3)$$

- The hour angle corresponding to 1 h is 15°; Expression for the hour angle is given by:

ISSN 1737-9296

International Journal of Scientific Research & Engineering Technology (IJSET)
Vol.8 pp. 32-37

$$\omega = (ST - 12) * 15° \quad (4)$$

- The declination is calculated by the following relation:

$$\delta = 23.45 \sin[(360/365)(284 + N)] \quad (5)$$

- The angle of incidence (θ_i) can be expressed as:

$$\cos(\theta_i) = (\cos\varphi \cos\beta + \sin\varphi \sin\beta \cos\gamma) \cos\delta \cos\omega + \cos\delta \sin\omega \sin\beta \sin\gamma + \sin\delta (\sin\varphi \cos\beta - \cos\varphi \sin\beta \cos\gamma) \quad (6)$$

- ✓ β surface tilt angle from horizon,°
- ✓ h the height of the sun
- ✓ γ surface azimuth angle, °

For a horizontal plane facing due south:

$$\sin(h) = \cos(\theta_z) = \cos\varphi \cos\delta \cos\omega + \sin\delta \sin\varphi \quad (7)$$

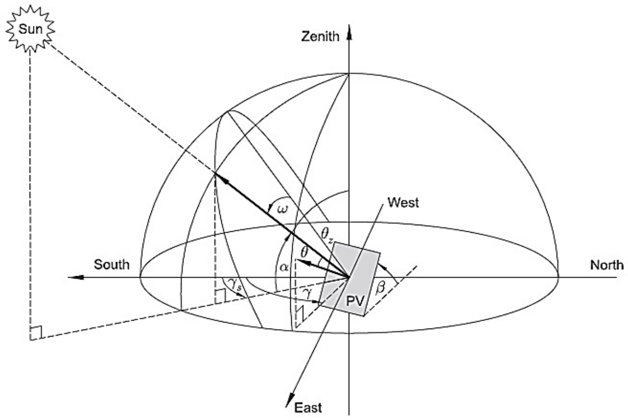


Fig. 1 View of various Sun–Earth angles on an inclined surface. [4]

- The solar intensity on a plane perpendicular to the direction of solar radiation is given by:

$$I_{ext} = I_{SC}\,[1 + 0.033 \cos(360N/365)] \quad (8)$$

- The solar radiation (I_0) incident on a horizontal plane in the extra-terrestrial the atmosphere in W/m^2:

$$I_0 = I_{SC}\,[1 + 0.033 \cos(360N/365)] \cos\theta_z \quad (9)$$

Where (I_{SC}) is the solar constant, the value of solar constant is 1367 W/m^2, for the N the day of the year.

B. Solar radiation models

1) *The isotropic sky model is a simple model when the diffuse radiation is uniformly distributed over the sky dome and this reflection spreads over the ground. [5] :*

$$I_G = I_{dir} R_b + I_{dif}\left(\frac{1+\cos\beta}{2}\right) + (I_{dir} + I_{dif})\rho\left(\frac{1-\cos\beta}{2}\right);$$

Correction factor for beam radiation $R_b = \frac{\cos\theta_i}{\cos\theta_z}$ (10)

2) *Klucher found that the isotopic model gave good results for overcast skies but reduces irradiance under clear and partly overcast conditions, the total irradiation on a tilted plane shown in Eq. (11)*. [6]:

$$I_G = I_{dir} R_b + I_{dif}\left(\frac{1+\cos\beta}{2}\right)\left[1 + k \sin^3\frac{\beta}{2}\right][1 + k \cos^2\theta \sin^3\theta_z] + (I_{dir} + I_{dif})\rho\left(\frac{1-\cos\beta}{2}\right);\ k = 1 - \left[\frac{I_{dir}}{((I_{dir}+I_{dif}))}\right]^2 \quad (11)$$

3) *In the Hay–Davies model, diffuse radiation from the sky is composed of an isotropic and circumsolar component and horizon brightening is not taken into account. [7]*:

$$I_G = (I_{dir} + I_{dif}\,\tau) R_b + I_{dif}(1-\tau)\left(\frac{1+\cos\beta}{2}\right) + (I_{dir} + I_{dif}) * \rho\left(\frac{1-\cos\beta}{2}\right);\ \tau = \left(\frac{I_{on}}{I_{ext}}\right) \quad (12)$$

4) *The Reindl model also accounts for horizon brightening and employs the same definition of the anisotropy index τ as described in Eq.(12), The total irradiance on a tilted surface can then be calculated using Eq. (13)*:

$$I_G = (I_{dir} + I_{dif}\,\tau) R_b + I_{dif}(1-\tau)\left(\frac{1+\cos\beta}{2}\right)\left[1 + \sqrt{\frac{I_{dif}}{((I_{dir}+I_{dif}))}}\sin^3\frac{\beta}{2}\right] + (I_{dir} + I_{dif})\rho\left(\frac{1-\cos\beta}{2}\right) \quad (13)$$

- ✓ I_{dir} Direct-normal component of solar irradiance on the horizontal surface, W/m^2
- ✓ I_{dif} Global diffuse horizontal solar irradiance, W/m^2
- ✓ I_{on} Direct-normal solar irradiance, W/m^2
- ✓ I_{ext} Direct extraterrestrial normal irradiance, W/m^2

5) *The Perrin de Brichambaut model have proposed another correlation to predict direct normal irradiance in the terrestrial region, which is given by: [8]*:

$$I_{on} = I_{ext} \cos\theta_i\, e^{\left(-T_L * \left(0.9 + \frac{9.4}{(0.89)^Z}\cos\theta_z\right)^{-1}\right)} \quad (14)$$

- T_L is the Linke turbidity factor, which is given by the expression: $T_L = \Psi + X + \Upsilon$ (15)
- Ψ is the turbidity corresponding to the absorption by the gases of the atmosphere

ISSN 1737-9296

$$\Psi = (0.89)^{z} \quad (16)$$

- X is the turbidity relative to diffusion by aerosols

$$X = (0.9 + 0.4\,A) * (0.63)^{z} \quad (17)$$

- Υ is the turbidity due to gas absorption, by water vapor, which is given by the expression:

$$\Upsilon = 2.4 - 0.9\sin(\varphi) + 0.1(2 + \sin(\varphi))A - 0.2Z - (1.22 + 0.14\,A)(1 - \cos\theta_z) \quad (18)$$

- A is the factor as a function of the geo-astronomical

$$A = \sin((360/365)(N - 121)) \quad (19)$$

The model estimates the 02 components of the global solar radiation on a horizontal plane as follows:

$$I_{dir} = \mathrm{A} * \sin(h) * e^{(-1*(B*\sin(h+C))^{-1})} \quad (20)$$

$$I_{dif} = \mathrm{D} * (\sin(h))^{0.4} \quad (21)$$

Sky condition	A	B	C	D
Normal Conditions Of Clear Sky	1230	3.8	1	125
Clear Sky polluted	1260	2.3	3	166.6
Clear Sky	1210	6	1	93.75
Very Clear Sky	1300	6	2	87
Average Sky	1230	4	2	125
Polluted Sky	1200	5	2	187

Tableau 1. The values of the constants A, B, C and D in terms of the nature of the Sky. [9]

III. SOFTWARE OVERVIEW

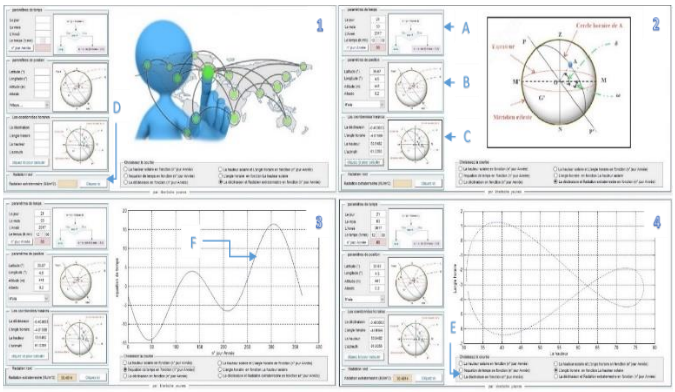
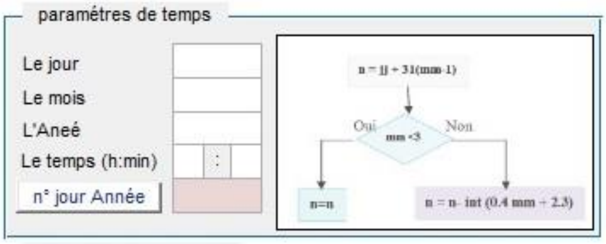
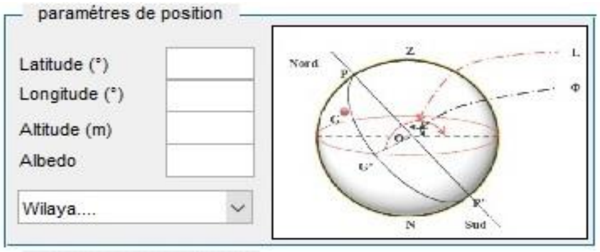


Fig. 2 Graphical interface giving: the position of the earth in relation to the sun, the declination of the sun, the number of the day and the month and the equation of the appropriate time.

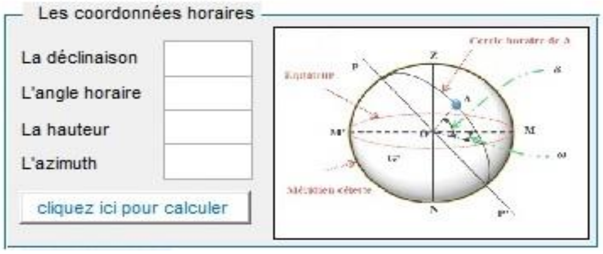
The computational software developed has flexibles graphical interfaces (two graphical interfaces) as illustrated in FIGURE 2 and FIGURE 3. It has graphical interfaces and digital data. The first graphical interface is divided into six panels; A, B, C, D, E and F.



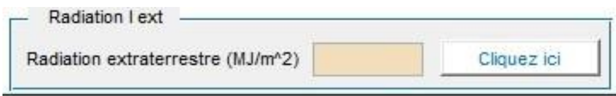
Panel A: this panel contains time parameters as the day, the month, the year, the time as illustrated in FIGURE2.



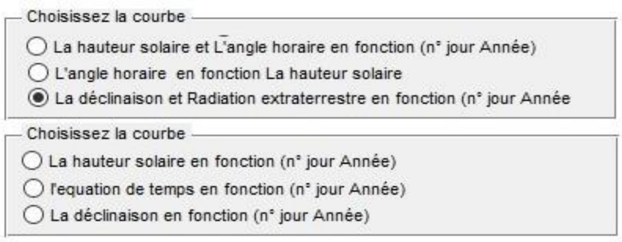
Panel B: this panel covers positional parameters such as latitude, longitude, elevation, albedo and location (Wilayas) as shown in FIGURE2.



Panel C: this panel contains the time coordinates such as declination, height, time angle, azimuth as noted in FIGURE2;



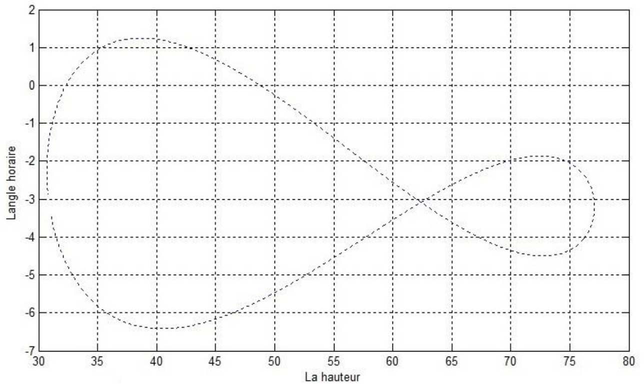
Panel D: this panel calculate direct extraterrestrial normal radiation I_{ext} as illustrated in FIGURE2;



Panel E: this panel is used to select curves (ex: Analma, the time equation, the declination...etc.) as illustrated in FIGURE2;

ISSN 1737-9296

International Journal of Scientific Research & Engineering Technology (IJSET)
Vol.8 pp. 32-37



Panel F: Custom area for displaying curves as illustrated in FIGURE2.

The second graphical interface is divided into five panels; G, H, I, J and K as noted:

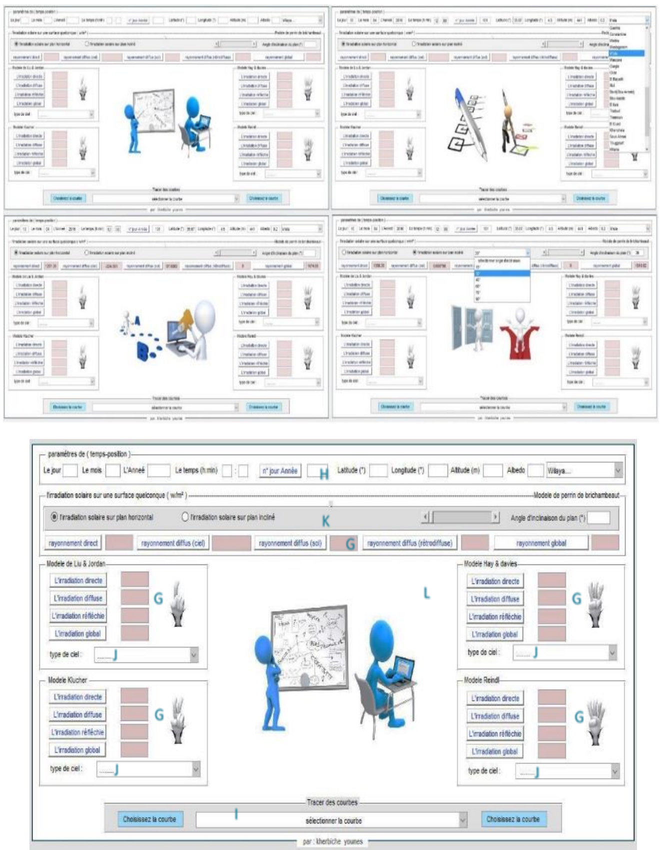
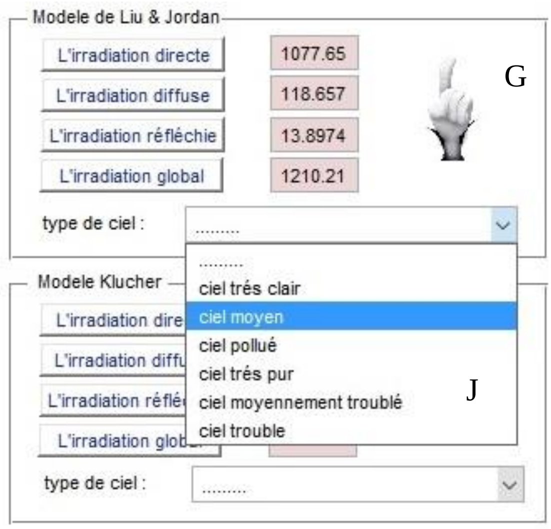


Fig. 3 Interface allowing the daily global, diffuse irradiations and direct timetables, l irradiation measured on any surface and the type of sky and use of several model.

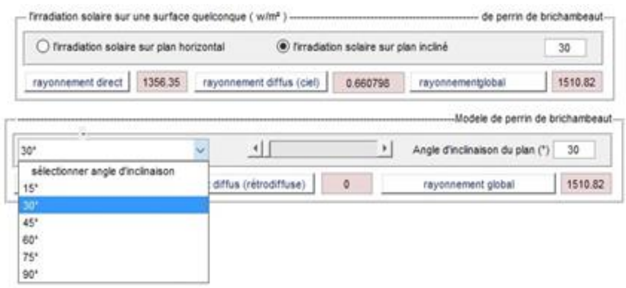
Panel H: this panels contains time-position parameters such as the day, the month, the year, day number, the time , latitude, longitude, elevation and albedo for the chosen location as noted in FIGURE3.;



Panel G: this panel covers solar radiations (direct, diffuse, reflected and global) for each models of the five cited models (Perrin de Brichambaut model, Lui & Jordan model, Klucher model, Hay–Davies model and Reindl model) as shown in FIGURE3.

Panel J: this panel contains the sky type as noted in FIGURE3;

Panel I: this panel is used for selecting curves of solar irradiation as illustrated in FIGURE3;



Panel K: this panel contains the plan type; horizontal or inclined with the inclination angle value as illustrated in FIGURE3;

ISSN 1737-9296

International Journal of Scientific Research & Engineering Technology (IJSET)
Vol.8 pp. 32-37

Panel L: Custom area for displaying curves as illustrated in FIGURE3.

IV. RESULTS AND DISCUSSION

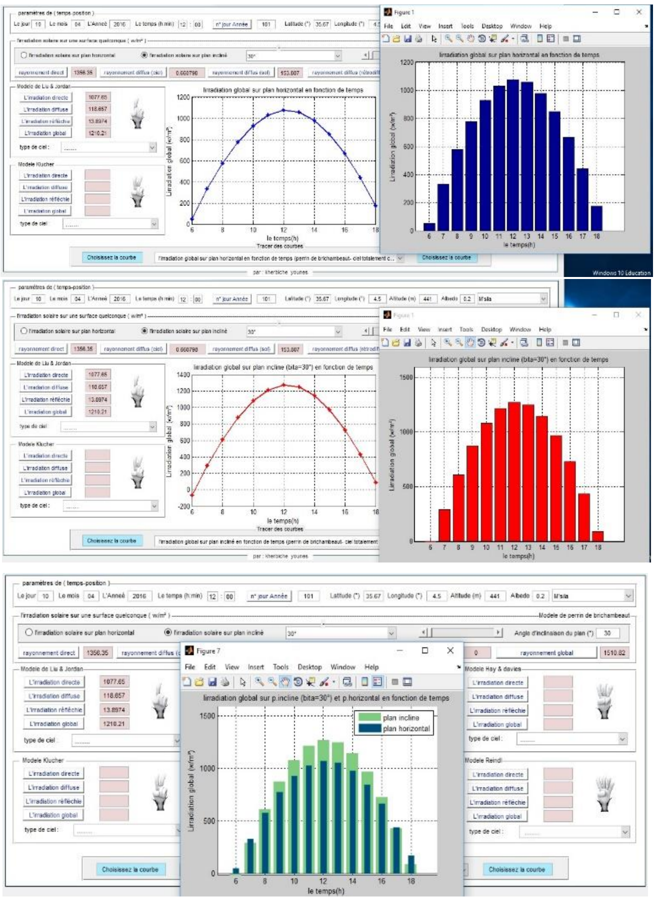


Fig. 4 Graphical interface giving: the solar radiation for the model of "Lui & Jordan" and the type of sky and horizontal surface.

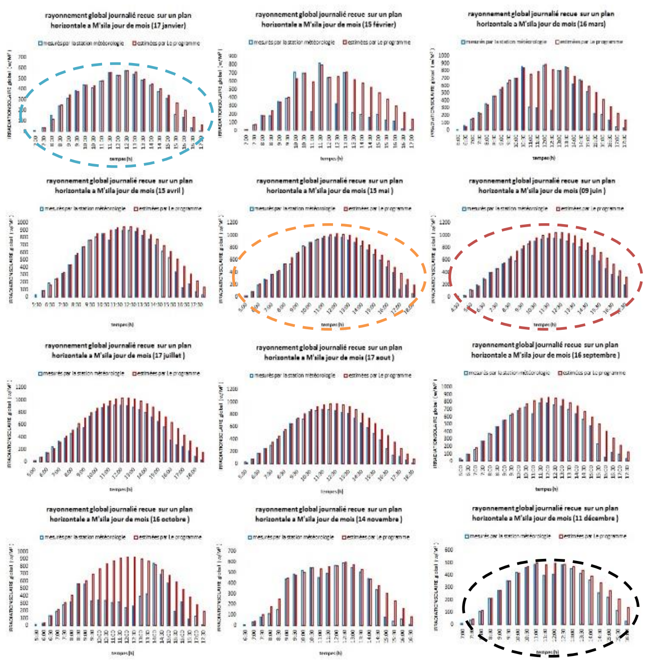
In order to validate our calculation software, a comparison is made between the global solar radiations on a horizontal surface calculated according to Lui and Jordan model and the values noted by M'sila meteorological station for a few days. Four illustrative examples are shown in FIGURE 5 (the days 17/01/2016, 15/05/2016, 09/06/2016) and 11/12/2016).

It is found that all the curves of global solar radiation measured and calculated by the model of Lui and Jordan for the region of M'sila follows the same shape of bell shape. They reach their maximum values between 11:30 and 12:30. As an example for 17/01/2016, the maximum value is recorded at 12: 30 with 573 W/m² for the measured value and 575,09 W/m² for the calculated value. It is also noted that this value varies from one month to the other, which is illustrated in FIGURE 5. The highest values are reached during the summer and lowest values during the winter.

It is also found that Lui and Jordan model is in good agreement with the measured values as illustrated in FIG. 5. It has a coefficient of determination of 0.967 for the 17/01/2016, 0.965 for the 15/05/2016, 0.974 for the 09/06/2016 and 0.942 for the 11/12/2016.

It is noted that the solar radiation values calculated by the Lui and Jordan model are higher than those measured at the meteorological station of M'sila. This difference is usually visible at the end of the day and in the afternoon on 9/06/2016 and 11/12/2016. It is due to the sky state, which is not taken into account in the model of Lui and Jordan, which is taken in the clear sky. This confirms that the Lui and Jordan model is a very good model for estimating global solar radiation on a horizontal surface in the M'sila region.

Therefore, it can be said that our software gives good results in the estimation of global solar radiation on a horizontal surface in M'sila region. We propose to check it for other models (Klucher model, Hay-Davies model, Reindl model and Brichambaut model), to take account the sky condition and to apply it for other regions, which is the subject of another work to confirm its validation.



ISSN 1737-9296

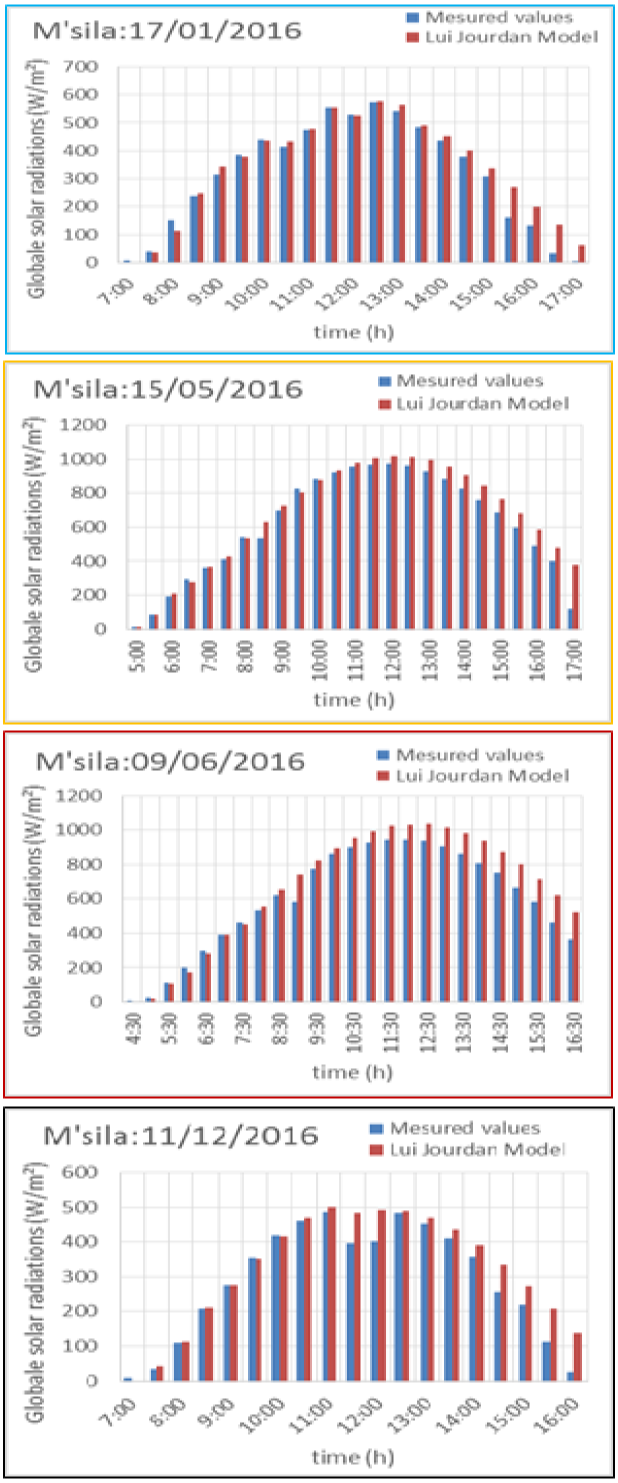


Fig. 5 Compare the values estimated by the theoretical models (program) and the values measured by the metrological station in the region of m'sila (the typical days).

V. CONCLUSIONS

In this work, a solar calculation software was developed using MATLAB. This software can calculate the solar radiation components (diffuse, direct, and comprehensive reflichi) using five models; Lui and Jordan model, Klucher model, Hay-Davies model, Reindl model and Brichambaut model. The validation of our software was carried out by comparing global solar radiation according to Lui and Jordon model and the global solar radiation recorded by the meteorological station of M'sila region. The results show a good agreement between them which confirms the validation of our calculation software.

REFERENCES

[1] Dorota Chwieduk D.Sc., Ph.D. M.Sc., Solar Energy in Buildings. Optimizing Thermal Balance for Efficient Heating and Cooling-Elsevier Inc., Academic Press, London (2014).

[2] T. Stoffel, "Terms and Definitions," Solar Energy Forecasting and Resource Assessment, edited by J. Kleissl, 2013, pp. 12–15.

[3] G. N. Tiwari, Arvind Tiwari, Shyam, Handbook of Solar Energy_ Theory, Analysis and Applications-Springer Singapore (2016).

[4] M. Despotovic, V.Nedic, Comparison of optimum tilt angles of solar collectors determined at yearly, seasonal and monthly levels, Energy Conversion and Management 97, 123-124 (2015).

[5] K. Kerkouche 1, F. Cherfa, A. Hadj Arab, S. Bouchakour, K. Abdeladim et K. Bergheul, Evaluation de l'irradiation solaire globale sur une surface inclinée selon différents modèles pour le site de Bouzaréah, Revue des Energies Renouvelables Vol. 16 N°2 (2013) 269 – 284.

[6] K.N. Shukla, Saroj Rangnekar, K. Sudhakar, Comparative study of isotropic and anisotropic sky models to estimate solar radiation incident on tilted surface: A case study for Bhopal, India, Energy Reports 1 (2015) 96–103.

[7] P.G. Loutzenhiser, H. Manz , C. Felsmann , P.A. Strachan ,T. Frank a, G.M. Maxwell, Empirical validation of models to compute solar irradiance on inclined surfaces for building energy simulation, Solar Energy 81, 254–267 (2007).

[8] Ali Mohammad Nooriana, Isaac Moradib, Gholam Ali Kamalia, Evaluation of 12 models to estimate hourly diffuse irradiation on inclined surfaces, Renewable Energy 33 (2008) 1406–1412.

[9] Mokhtar Ghodbane, Boussad Boumeddane, Estimating solar radiation according to semi empirical approach of PERRIN DE BRICHAMBAUT: application on several areas with different climate in Algeria, International Journal of Energetica (IJECA), Volume 1. Issue 1. 2016.

ISSN 1737-9296