Global Scientific JOURNALS

GSJ: Volume 9, Issue 10, October 2021, Online: ISSN 2320-9186
www.globalscientificjournal.com

Study of the Best Regions of Solar Radiation in Egypt

M. Abdelmonem , G. Said

M. Abdelmonem, Lecturer, Physics Department, Future High Institute of Engineering in Fayoum, Ph:+201002450052. E-mail: man9max@gmail.com
G. Said, Prof. of Applied Solid State Physics, Faculty of Science, Fayoum University, Ph:+201002317643. E-mail: gamalsaid_eg@yahoo.com

Abstract - The aim of this work is studying and predicting solar radiation in various regions in Egypt along full year and from this study we could obtain the best regions which have high mean solar radiation and be best for solar energy projects. We predict the daily and monthly averages of instant solar radiation Rpr(W/m^2) by using the recorded data temperature Tm in 2012 in nine different sites in Egypt; Fayoum, Marsa-Alam, El-Arish, Aswan, Cairo, Luxor, Marsa-Matruh, Taba and Asyut. These places were selected as a wide distribution in order to cover most different regions in Egypt. Also, the daily global solar radiation RG is estimated for each region. The predicted solar radiation Rpr is calculated by using the corresponding measured temperature Tm in various months. Also, a FORTRAN computational language has been employed to achieve all the required calculations.

Keywords - Predicting solar radiation, daily and monthly averages, different regions in Egypt.

1-Introduction

As Egypt is a part of the best region of the solar radiation and it has a high solar availability and as the solar power is renewable and clean so the sun is the most rewarding source of energy in Egypt. Study of the solar radiation is important for determining the best regions for solar power projects. In this work we predict the solar radiation by using the average of the measured

temperatures during the day time in some selected regions in Egypt; Fayoum, Marsa Alam, El Arish, Aswan, Cairo, Luxor, Marsa Matruh, Taba and Asyut. The used mathematical model and the estimating of the solar radiation in these regions have been discussed, Abdelmonem et. al [1-2].

2-Reviewing similar studies

In a review of the recent similar works, Omran [3] presented an analysis of the solar radiation over Egypt, the analysis consisted of daily sunshine duration and hourly global and diffuse radiation on a horizontal surface in the regions; Cairo, Matruh and Aswan. Moreover Trabea and Shaltout [4] studied the correlation of global solar radiation with meteorological parameters over Egypt, where mean daily maximum temperature, mean daily relative humidity, mean daily sea level pressure, mean daily vapor pressure, and hours of bright sunshine are presented. Batlles et al. [5] presented an empirical modeling of hourly direct irradiance by means of hourly global irradiance, The data set used comprises 25000 hourly values of global and diffuse irradiance in six Spanish locations with different climatic conditions. Togrul et al. [6] estimated the monthly global solar radiation from sunshine duration measurement in Elazigg.

Shaltout et al. [7] presented a study of the solar radiation over Menia, Egypt. Measurements were taken using the Eppley pyranometer to measure the global solar radiation. Iziomon and Mayer [8] studied the performance of solar radiation models in two sites are located at Bremgarten within the Upper Rhine lowland area and at Feldberg on the mountain top of the Black forest in south-west Germany.

In 2002, Paltineanu et al. [9] demonstrated the correlation between sunshine duration and global solar radiation in south-eastern Romania, they used daily data of 30 years period (1971-2000) on sunshine duration and global solar radiation from the Constanta weather station and they calculated the coefficients a and b from Angstrom's equation in this time period. Also, Saylan et al. [10] studied the solar energy potential for heating and cooling systems in big cities of Turkey; Istanbul, Ankara and Izmir. The estimations were achieved for different seasons using hourly solar radiation measurements. Morover, Ferenc et al. [11] studied the changes in solar radiation energy and the relations to monthly average temperature. The analysis of the changes of monthly values of solar radiation energy including global radiation and radiation energy reaching flat surfaces was also presented.

In 2004, Podesta et al. [12] estimated the daily solar radiation in the Argentine, where two scenarios were considered; the sunshine duration data are available for a given location or only by the daily temperature, and its minimum and maximum. Also, Almorox and Hontoria [13] presented a global solar radiation estimation using sunshine duration in Spain. Several equations were employed to estimate global solar radiation from sunshine hours for 16 meteorological stations in Spain, by only using the relative duration of sunshine. These equations included the original Angstrom-Prescott linear regression and modified functions (quadratic, third degree, logarithmic and exponential functions). Estimated values were compared with measured values in terms of the coefficient of determination, standard error of the estimate and mean absolute error. Meanwhile, El-Metwally [14] executed simple new methods to estimate global solar radiation based on meteorological data in Egypt. The methods used ground-based measurements of maximum and minimum temperature, daily mean of cloud cover and extraterrestrial global radiation. The verage of root mean square differences (RMSD) for a comparison between observed and estimated global radiation for all locations tested was around 10% for the new methods and 13% for Supit-Van Kappel method. On the other hand, Zhang et al. [15] studied the analysis of 40 year records of solar radiation data in Shanghai, Nanjing and Hangzhou in Eastern China.

In 2005, El-Metwally [16] studied sunshine and global solar radiation estimation at different sites in Egypt. A simple non-linear method was proposed for estimating relative sunshine duration based on monthly mean daily maximum and minimum air temperatures and cloud cover fraction at six sites in Egypt. While, Trnka et al. [17] studied the global solar radiation in central European lowlands estimated by various empirical formulae.

In 2006, Menges et al. [18] presented an evaluation of global solar radiation models for Konya-Turkey. This study reviewed the global solar radiation models available in order to evaluate the applicability of 50 models for computing the monthly average daily global radiation on a horizontal surface. While, Spokas and Forcella [19] studied the estimating hourly incoming solar radiation from limited meteorological data. Two major properties that determine weed seed germination are soil temperature and moisture content. Incident radiation is the primary variable controlling energy input to the soil system and thereby influences both moisture and temperature profiles. Also, Robaa [20] studied the solar radiation climate at Cairo urban area, Egypt and its environs.

In 2007, Elminir [21] explained an experimental and theoretical investigation of diffuse solar radiation for some Egyptian sites, statistical analysis of hourly, daily and monthly correlations was carried out, using a 5 years data archive (1999–2003) of hourly global and diffuse solar irradiances obtained at five selected meteorological stations over greater Egypt area. Meanwhile, Rahoma and Hassan [22] obtained a typical annual time function by the application of a calculation procedure based on Fourier analysis on global solar radiation data extended to nine years from June 1991 to August 1999 at Helwan - Egypt.

In 2008, Jamil Ahmad and Tiwari [23] predicted the hourly solar radiation received during the average day of each month for different solar energy applications, particularly in design methods. Also, Jamil Ahmad and Tiwari [24] estimated the hourly global solar radiation for the composite climate of New Delhi using regression analysis and they gave a comparison between estimated and measured values showing that the constants derived for New Delhi provide good estimates of the hourly global radiation except for the morning and evening hours. Also, Castellvi [25] evaluated three practical methods for estimating daily solar radiation in dry climates in Spain. Meanwhile, Chineke [26] studied equations for estimating the global solar radiation in data sparse regions. The global solar radiation was thus estimated for three sites, Owerri, Umudike and Ilorin located in different climate zones in Nigeria and West Africa.

In 2009, Jamil Ahmad and Tiwari [27] had given a development of a new model to evaluate the hourly solar radiation for composite climate of New Delhi. The root mean square error (RMSE) and mean bias error (MBE) have been used to show the accuracy of the new model. Also, Kassem et al. [28] used a development of neural network model to estimate hourly total and diffuse solar radiation on horizontal surface at Alexandria -Egypt. On the other hand, Augustine and Nnabuchi [29] presented a relationship between global solar radiation and sunshine hours for Calabar, Port Harcourt and Enugu in Nigeria. Moreover, Togrul [30] estimated the values of the solar radiation from Angstrom's coefficients by using geographical and meteorological data in Bishkek, Kyrgyzstan. Also, Prieto et al. [31] studied the correlation between global solar irradiation and air temperature in Asturias – Spain. However, Bajpai and Singh [32] tried to estimate the instant solar radiation by using the instant temperature. This has been made to correlate the recorded instant temperature and corresponding instant solar radiation of different days in a hot season of Lucknow, India. And, Liu et al. [33] evaluated the temperature-based global solar radiation models in China .

In 2010, Jamil Ahmad and Tiwari [34] gave a comprehensive review for the global solar radiation models available in the literature and it was shown that there are several formulae which relate global radiation to other climatic parameters such as sunshine hours, relative humidity and maximum temperature. Also, Muzathik et al. [35] estimated hourly global solar radiation on a horizontal plane and they found that the Collares-Pereira and Rabl model performed better than the other models. Moreover, El-Sebaii et al. [36] studied the global, direct and diffuse solar radiation on horizontal and tilted surfaces in Jeddah, Saudi Arabia. While, Okundamiya and Nzeako [37] employed an empirical model for estimating global solar radiation on horizontal surfaces for selected cities in the six geopolitical zones in Nigeria. And, Liu et al. [38] studied the choice of the Angstrom–Prescott coefficients to confirm if the time-dependent ones are better than the fixed ones in modeling global solar irradiance using data from 20 sites of temperate climate in China.

In 2011, Jamil Ahmad and Tiwari [39] presented the solar radiation models for predicting the average daily and hourly global radiation beam radiation and diffuse radiation on horizontal surface. Also, Tahas et al. [40] evaluated global solar radiation and temperature trends in the Cluj-Napoca – Romania. In the meantime, Ibrahim et al. [41] estimated the solar irradiance on inclined surfaces facing south in Tanta, Egypt. While, Muzathik et al. [42] demonstrated the global solar irradiation on horizontal and inclined surfaces based on the horizontal measurements in Malaysia. Moreover, Al Riza et al. [43] presented hourly solar radiation estimation methods using ambient temperature and relative humidity data using measured data in Universiti Teknologi PETRONAS, Bandar Sri Iskandar, Perak, Malaysia. And, Veeraboina et al. [44] estimated the annual solar radiation from measured temperatures by using temperature-based (TB) approach in different cities in India. However, El Shazly et al. [45] estimated the global and diffuse solar radiation using the sunshine duration at Qena – Egypt.

In 2012, Elom and Nnamdi [46] studied the measurement of global solar radiation and average temperature during the period of eleven years (1996 to 2006) at Onitsha - Nigeria. While, Ituen et al. [47] predicted the global solar radiation using relative humidity, maximum temperature and sunshine hours in Uyo, in the Niger Delta Region, Nigeria. However, Korachagaon and Bapat [48] collected data such as global solar radiation, air temperature, relative humidity, wind and moisture from 875 stations around the globe and these data used to develop the formula for estimating the monthly average daily global radiation on a horizontal surface. On the other hand, Rahimi et al. [49] used a calibration of Angstrom’s equation for estimating solar radiation using meta-heuristic harmony search algorithm (Case study: Mashhad-East of Iran). And, Ulfat et al. [50] estimated the global and diffuse solar radiation in Islamabad -Pakistan. Also, Liu et al. [68] gave assessing models for parameters of the Angstrom–Prescott formula in China.

In 2013, Jemaa et al. [51] estimated monthly and annual average global solar radiation using three simple methods (Linear model, Quadratic model and Cubic model) in Troyes-Barberey City - France. Besharat et al. [52] evaluated the monthly average daily global solar radiation on a horizontal surface in Yazd city - Iran. Suehrcke et al. [53] studied the relationship between sunshine duration and solar radiation received on the earth’s surface by using instantaneous solar radiation measurements from Australia and Germany. On top, Pan et al. [54] estimated the daily global solar radiation spatial distribution from diurnal temperature ranges over the Tibetan Plateau in China. And, Irwan et al. [55] studied the solar characteristic using Hargreaves statistical analysis model for predicting the solar radiation in Kelantan – Malaysia.

In 2014, Soubdhan et al [56] used a statistical and dynamical analysis of time dependent global solar radiation sequences in Guadeloupe (F.W.I.) located in the East part of the lesser Antilles. Also, El Mghouchi et al. [57] proposed a new model used to predict the direct, diffuse and global solar flues for clear skies, by making the comparison between the numerical simulation of this model and the climatology measured data of Energetic Laboratory Station, Faculty of Science of Tetouan City in Northern Morocco. Morover, Kadirgama et al. [58] have attempted to develop a model that can be used to predict hourly total and solar radiation on the horizontal surface using the artificial neural networks method. While, Waewsak et al. [59] presented an estimation of monthly mean daily global solar radiation over Bangkok, Thailand using artificial neural networks. On top, Lopez and Batlles [60] presented a new accurate parametric model to estimate global solar radiation under cloudless conditions. The evaluation of the model performance has been carried out using ground measurements obtained in twelve radiometric stations located in the north face of a town located in the South East of Spain. In the meantime, Kim et al. [61] presented an evaluation of meteorological base models for estimating hourly global solar radiation in Texas. However, Ouali and Alkama [62] discussed a model of global solar radiation based on meteorological data in Bejaia city, Algeria. Also, Padovana et al. [63] described a study of different estimation procedures for the assessment of the direct normal irradiance, using experimental data with a time scale of 1 min, taken at two different latitudes.

In 2015, Eissa et al. [64] treated Mc-Clear approach which is a fast model based on a radiative transfer solver, to estimate the surface down-welling solar irradiances for cloud-free instances. Here, they presented a validation of the model for the specific climate of the United Arab Emirates. Also, Shukla et al. [65] presented a comparison of different empirical models used for the estimation of solar radiation on tilted surface, three isotropic and same number of anisotropic sky models were employed by using average monthly mean value of solar radiation on daily basis for local climatic condition at Bhopal located in central region of India.

3- Location Coordinate

The location coordinates of the meteorological stations of the selected regions are listed in Table1.

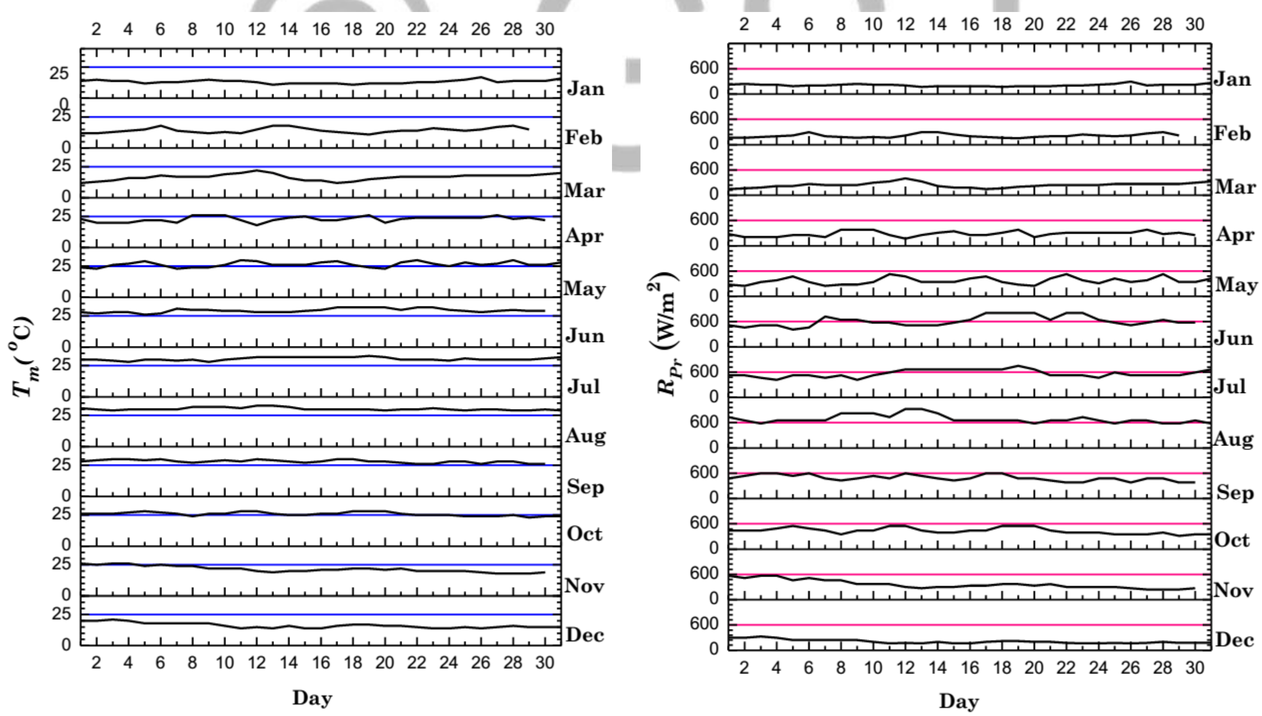
Table 1: The location coordinates of the meteorological stations of the selected regions.

Region	Latitude (Degree)	Longitude (Degree)
Fayoum	29.308	30.84
Marsa-Alam	25.56	34.58
El-Arish	31.07	33.84
Aswan	23.96	32.82
Cairo	30.11	31.41
Luxor	25.67	32.71
Marsa-Matruh	31.33	27.22
Taba	29.35	34.46
Asyut	27.04	31.01

3- Experiment and Result

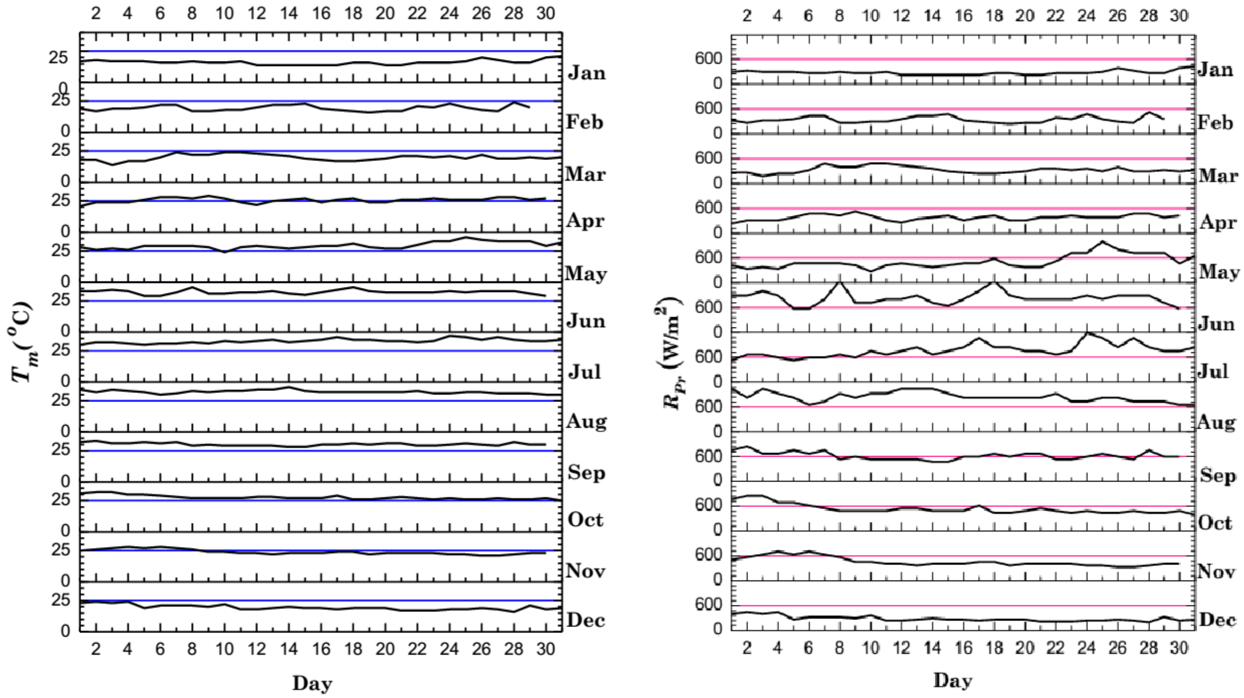
3.1 -The daily averages of the solar radiation

Figs 1 to 9 show the variation of daily averages of the measured temperature and the solar radiations in all months of 2012 in the nine selected regions.



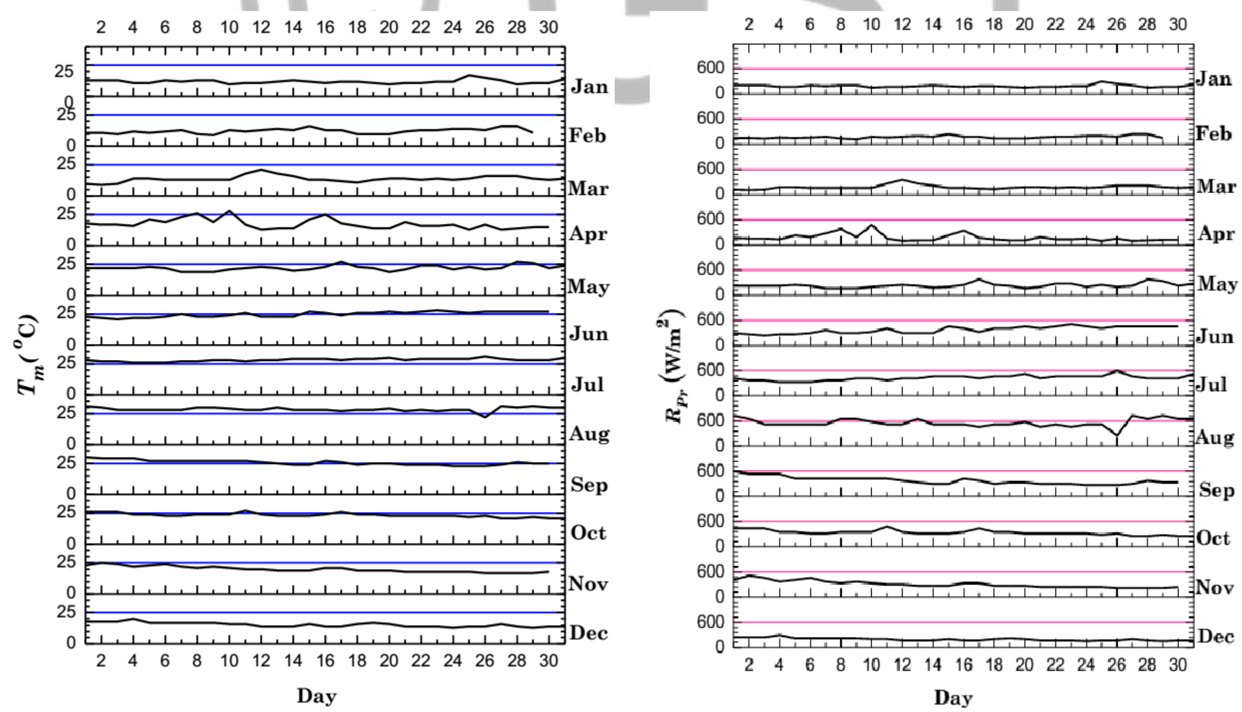
(a) (b)

Fig.1: (a)Daily averages of the measured temperature (b) Daily averages of the predicted solar radiation, Fayoum, 2012.



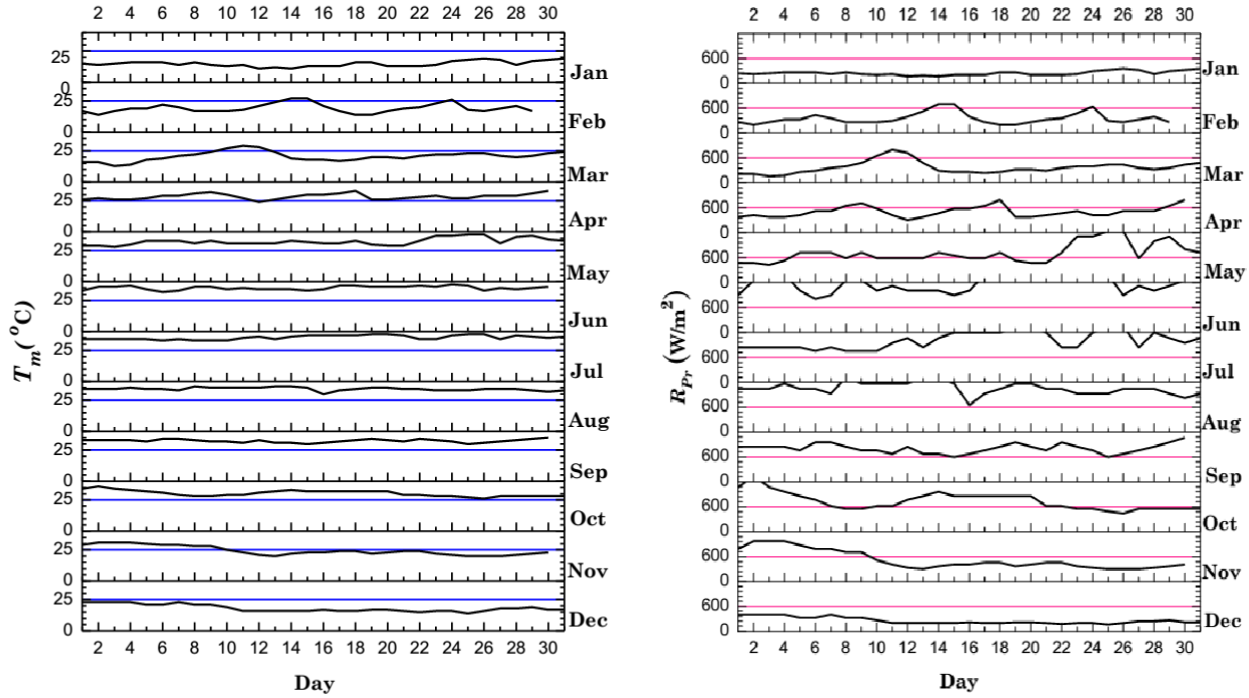
(a) (b)

Fig.2: (a) Daily averages of the measured temperature (b) Daily averages of the predicted solar radiation, Marsa-Alam, 2012.



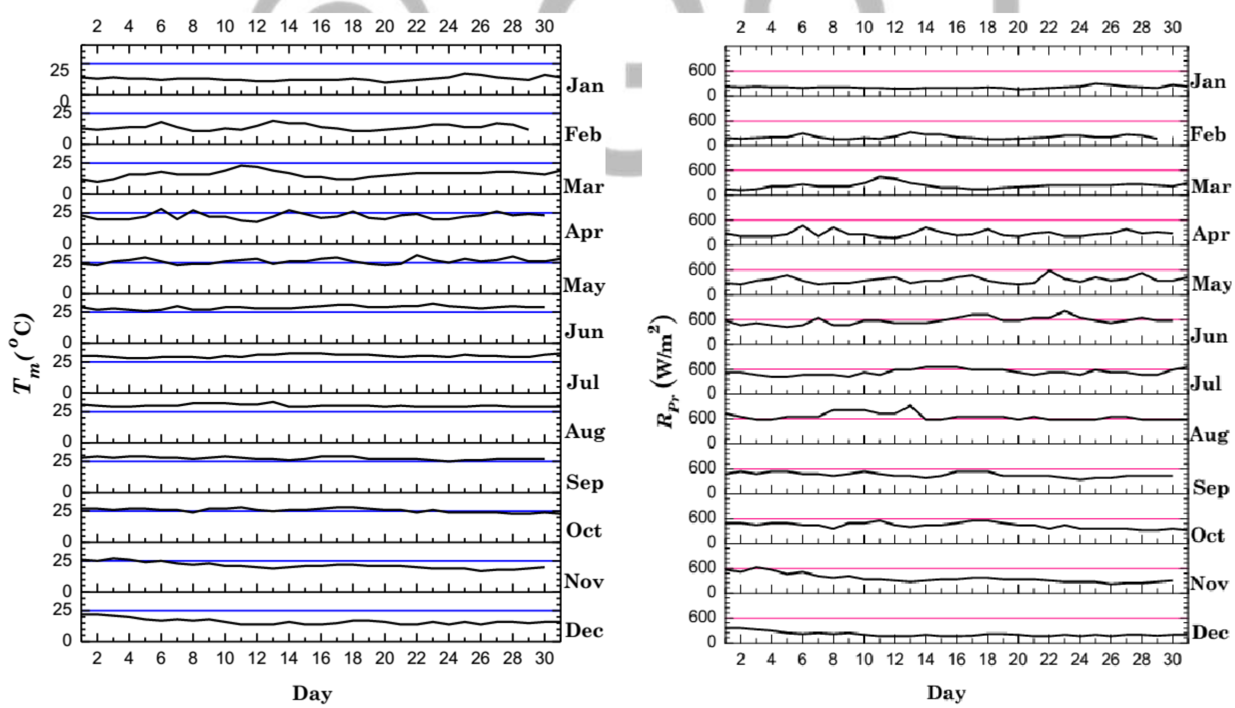
(a) (b)

Fig.3: (a) Daily averages of the measured temperature (b) Daily averages of the predicted solar radiation, El-Arish, 2012.



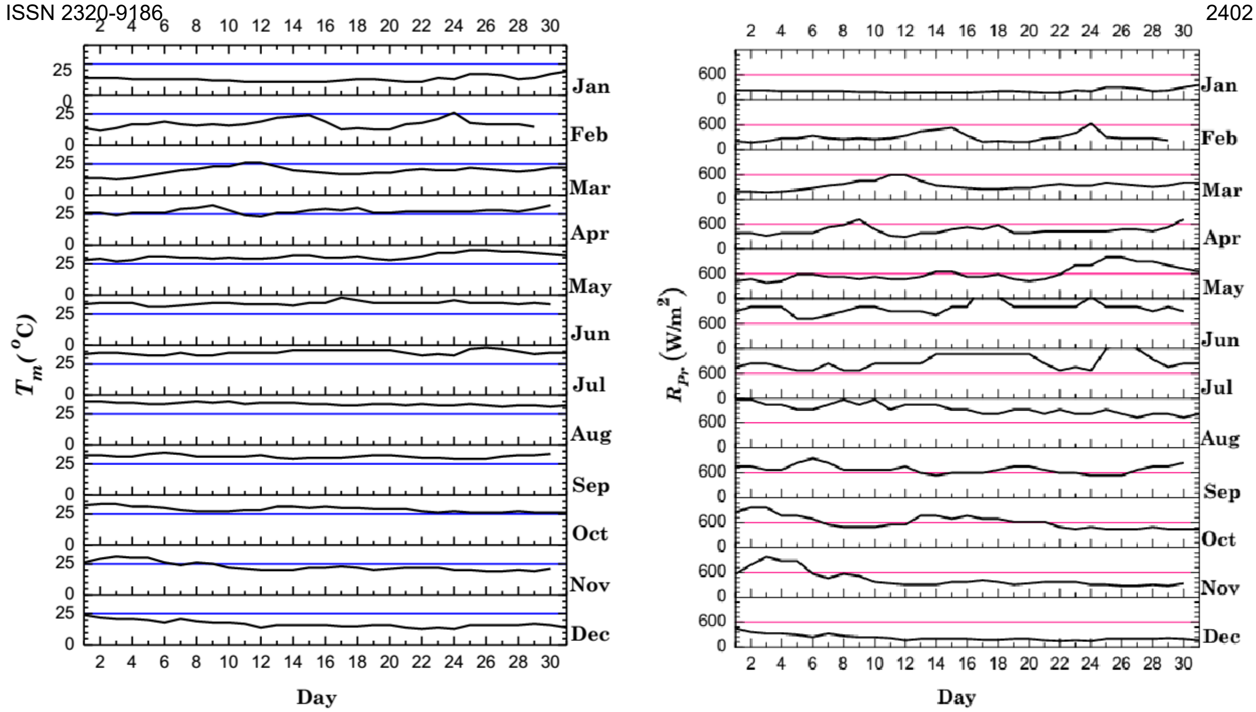
(a) (b)

Fig.4: (a) Daily averages of the measured temperature (b) Daily averages of the predicted solar radiation, Aswan, 2012.



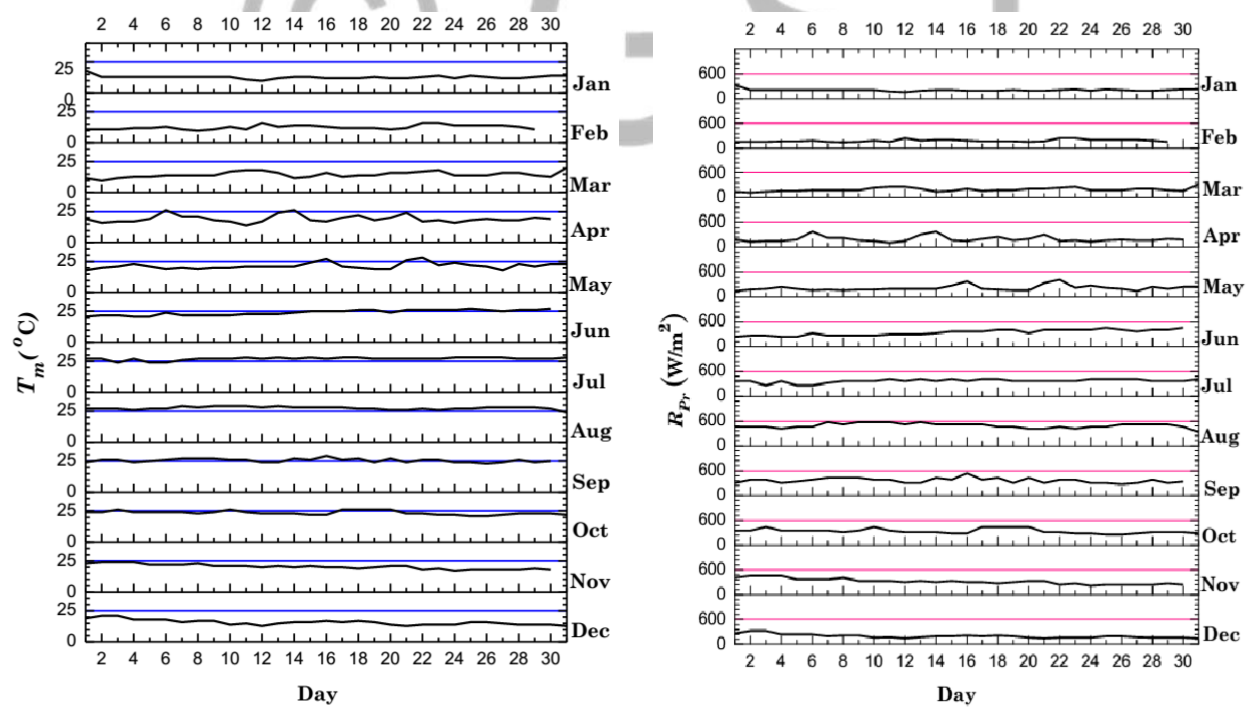
(a) (b)

Fig.5: (a) Daily averages of the measured temperature (b) Daily averages of the predicted solar radiation, Cairo, 2012.



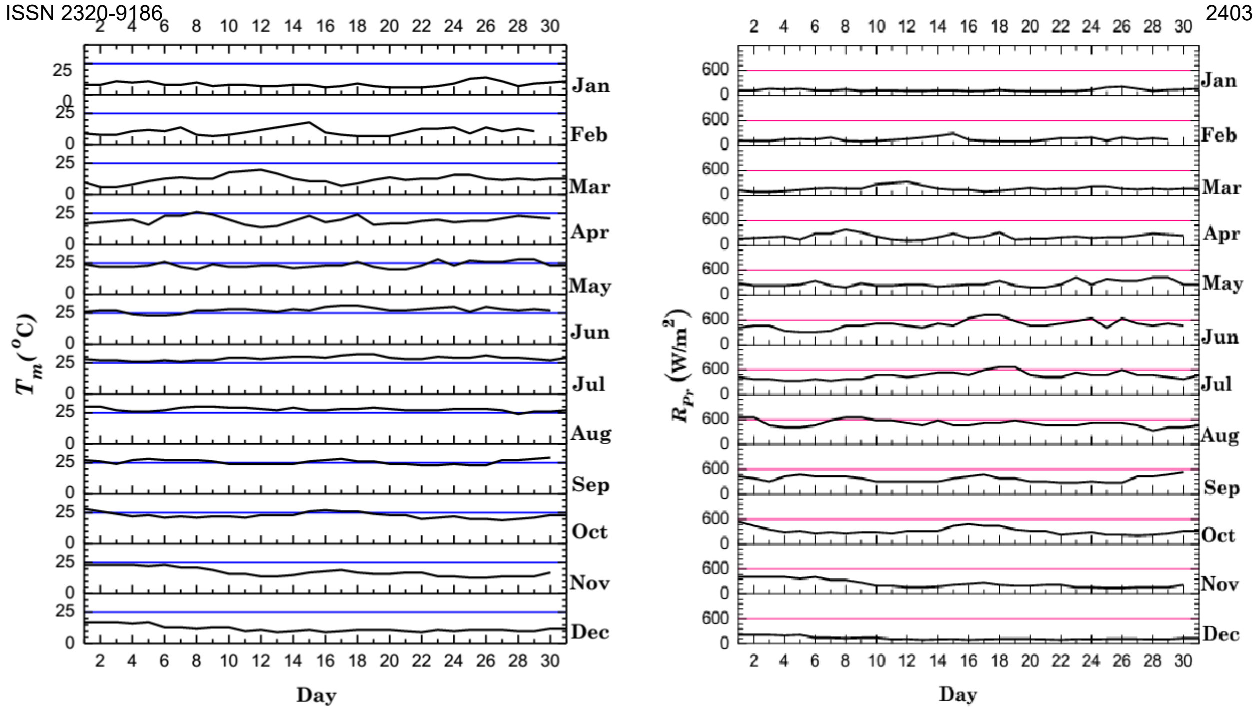
(a) (b)

Fig.6: (a) Daily averages of the measured temperature (b) Daily averages of the predicted solar radiation, Luxor, 2012.



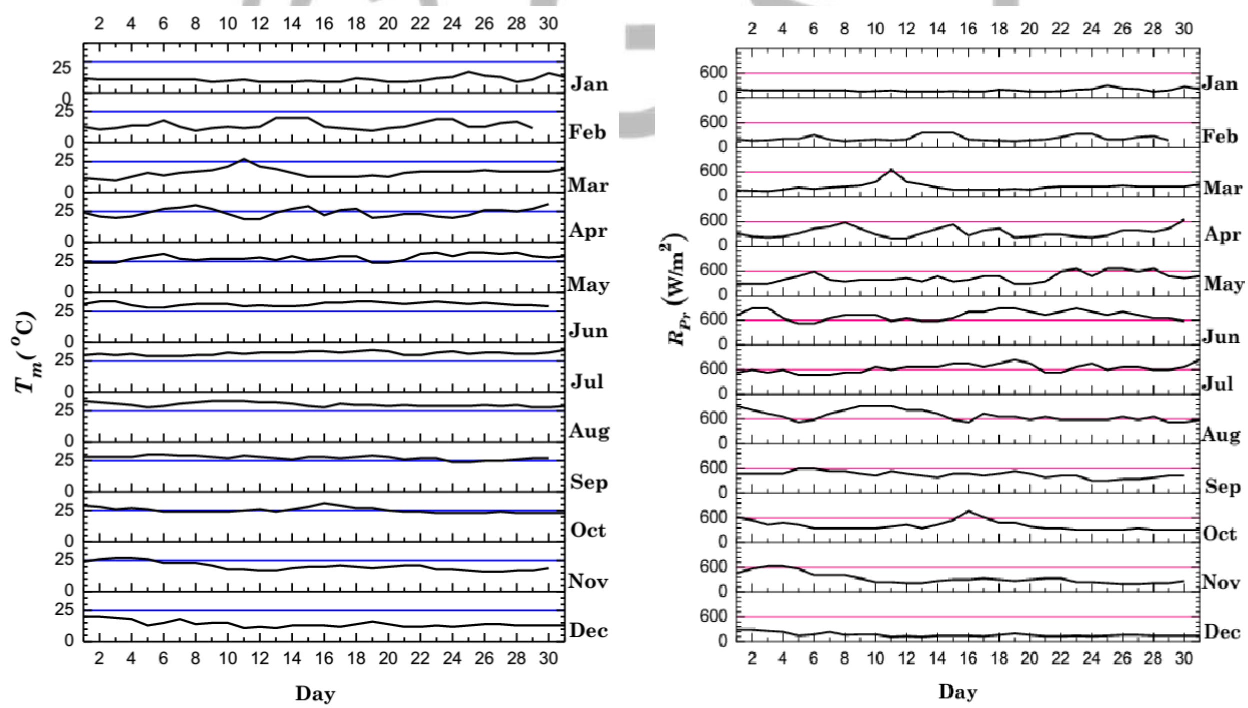
(a) (b)

Fig.7: (a) Daily averages of the measured temperature (b) Daily averages of the predicted solar radiation, Marsa-Matruh, 2012.



(a) (b)

Fig.8: (a) Daily averages of the measured temperature (b) Daily averages of the predicted solar radiation, Taba, 2012.



(a) (b)

Fig.9: (a) Daily averages of the measured temperature, (b) Daily averages of the predicted solar radiation, Asyut, 2012.

3.2 The Monthly averages of the solar radiation

The monthly average of instant solar radiation Rpr (W/m^2) by using the monthly average of instant temperature Tm (K) during 2012 in the nine selected places in Egypt could be predicted. The monthly averages of temperature of the selected regions were calculated and listed in Table 2 and hence the monthly averages of the solar radiation of the selected regions can be obtained as it is shown in Table 3.

Table 2: Monthly averages of the measured temperature Tm, 2012.

T_m (K)									
Month	Fayoum	Marsa-Alam	El-Arish	Aswan	Cairo	Luxor	Marsa-Matruh	Taba	Asyut
Jan	285.92	289.26	285.06	287.87	285.87	286.19	285.84	281.42	284.07
Feb	288.13	292.38	285.35	292.28	287.02	290.32	285.66	283.79	287.17
Mar	289.78	292.84	286.81	293.65	289.21	292.52	287.68	285.61	289.09
Apr	298.35	298.77	290.51	301.44	296.07	300.27	292.14	292.57	297.11
May	300.22	302.42	295.19	305.42	299.16	304.04	294.48	296.45	300.94
Jun	302.47	305.22	297.94	308.14	301.83	306.71	297.13	300.33	303.87
Jul	304.12	306.01	301.19	308.42	303.02	307.29	300.01	301.58	304.42
Aug	303.17	305.21	301.52	307.55	302.96	306.09	300.42	300.71	303.23
Sep	302.07	303.21	298.77	305.47	300.47	304.07	298.47	298.57	300.37
Oct	299.04	300.62	296.49	303.26	298.68	301.65	296.52	295.74	298.16
Nov	295.32	296.84	292.97	297.43	294.34	295.81	293.42	290.43	293.31
Dec	289.29	292.48	288.48	291.16	289.26	289.91	288.84	284.87	287.13

Table 3: Monthly averages of the solar radiation R_{pr} , 2012.

R_{pr} (W/m^2)									
Month	Fayoum	Marsa-Alam	El-Arish	Aswan	Cairo	Luxor	Marsa-Matruh	Taba	Asyut
Jan	202.67	276.49	187.09	242.96	201.73	207.82	201.16	133.36	170.63
Feb	224.64	314.08	160.21	311.08	187.99	257.85	165.04	137.98	190.71
Mar	238.70	279.29	154.21	302.48	195.33	270.62	168.01	137.01	193.03
Apr	308.67	374.68	158.71	494.61	282.95	437.94	188.02	196.62	315.27
May	420.54	533.28	245.58	735.68	375.93	634.47	227.57	281.12	455.01
Jun	575.39	707.55	316.51	976.98	486.49	834.18	289.42	412.18	609.5
Jul	600.67	749.32	426.34	993.41	528.13	870.38	371.36	446.27	622.13
Aug	618.08	727.24	474.88	952.91	560.81	805.04	418.22	432.47	578.57
Sep	541.47	617.04	371.96	798.38	451.51	680.61	359.45	363.57	446.38
Oct	443.83	528.91	334.42	709.01	426.44	592.97	335.53	307.71	402.53
Nov	385.77	391.59	259.32	416.98	300.05	350.91	272.05	197.86	268.88
Dec	204.09	282.72	188.01	247.11	203.57	217.53	195.04	130.09	163.82

Figs. 10 and 11 show the monthly averages of instant temperature Tm(K) and instant solar radiation R_{pr} (W/m^2) respectively versus the months in the selected regions in Egypt.

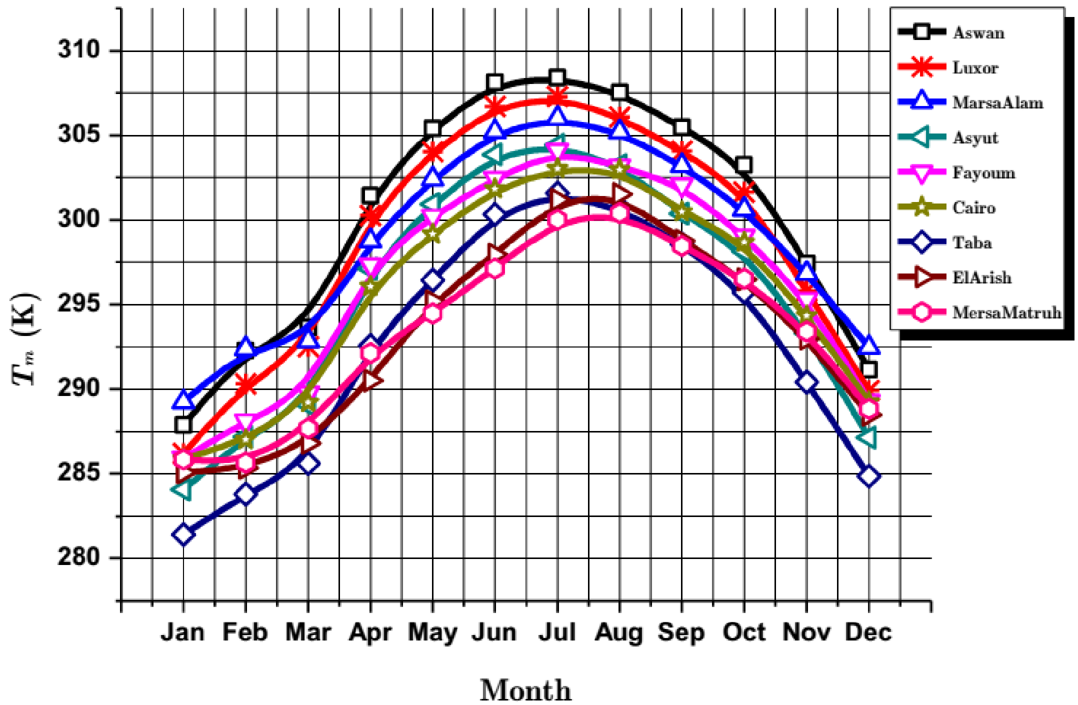


Fig. 10: Monthly averages of T_m(K) of the selected regions in Egypt during 2012.

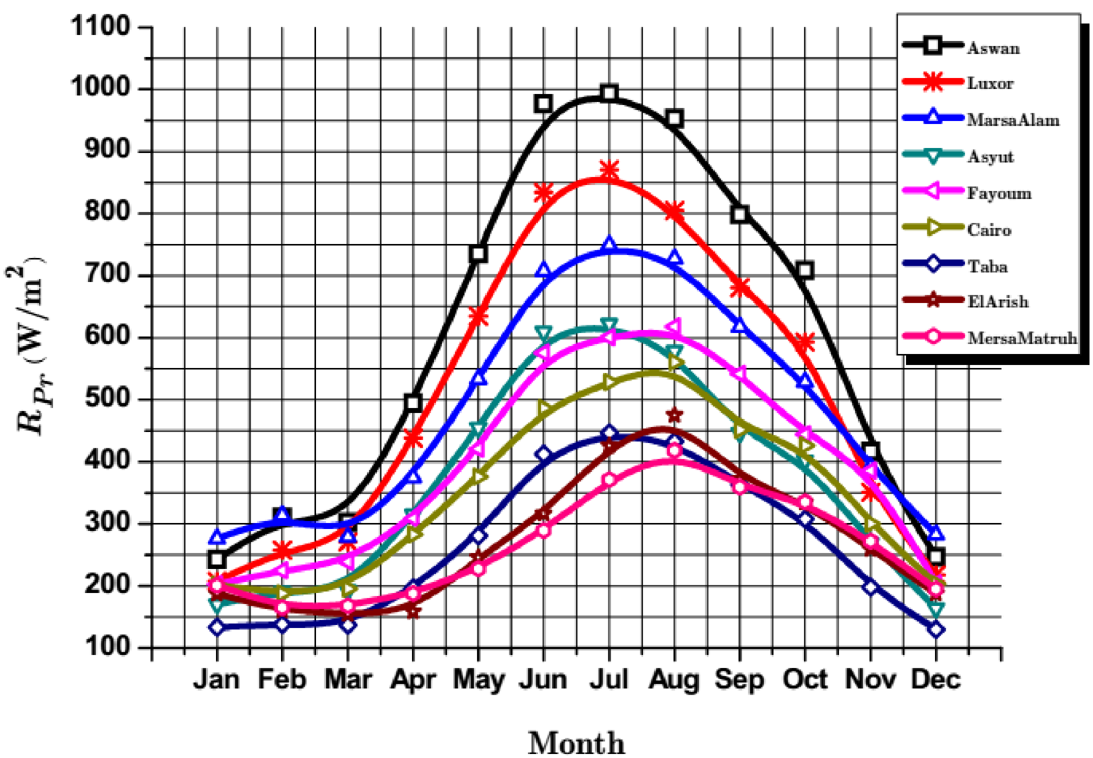


Fig. 11: Monthly averages of R_{pr} (W/m^2) of the selected regions in Egypt during 2012.

3.3 Estimation of the global solar radiation

The daily global solar radiation RG is determined using the total average of instant solar radiation and the average of the day length DL and it is shown in table 4.

Table 4: The Daily average of solar radiation Rav, the average day length time DL and daily global solar radiation RG of the different regions.

	Fayoum	Marsa Alam	El Arish	Aswan	Cairo	Luxor	Marsa Matruh	Taba	Asyut
Rav (W/m2)	440.8	466.2	356.6	501.7	408.6	484.9	349.8	393.6	426.2
DL (h)	12.4	12.4	12.3	12.8	12.4	12.7	12.3	12.2	12.5
RG MJ/m2/day	19.68	20.81	15.79	23.12	18.24	22.17	15.49	17.43	19.18

4 -Discussion

The study and prediction of the solar radiation in the selected regions in Egypt, nine regions (Fayoum, Marsa-Alam, El-Arish, Aswan, Cairo, Luxor, Marsa-Matruh, Taba and Asyut) have been evaluated. The temperature data were obtained from record data on international website (http://www.wunderground.com), These temperatures were measured in the meteorological stations located in these regions. Using the daytime averages of the temperature in whole year of 2012 and FORTRAN program we calculated the daily average of the solar radiations in these regions.

The daily global solar radiations of the different regions were predicted by using the daily averages of the solar radiation and the daily averages of day length time. The predicted global solar radiation in Fayoum; 19.68 MJ/m^2/day, Marsa-Alam; 20.81 MJ/m^2/day, El-Arish; 15.79 MJ/m^2/day, Aswan; 23.12 MJ/m^2/day, Cairo; 18.24 MJ/m^2/day, Louxor; 22.17 MJ/m^2/day, Marsa-Matruh; 15.49 MJ/m^2/day, Taba; 17.43 MJ/m^2/day, Asyut; 19.18 MJ/m^2/day. In a similar previous work, Omran [3] estimated the average daily global solar radiation for Marsa-Matruh, Cairo and Aswan, respectively are 19.4, 18.67, and 21.78 MJ/m^2/day, and he obtained that the large values of hourly global solar radiation has a maximum of eight hours per day in both June and July, all over the country.

Robaa [20] estimated the daily global solar radiation in Cairo 18.57 MJ/m^2/day. Trabea and Shaltout [4] obtained that the maximum values of the global solar radiation in Egypt appear in June, while the minimum values are in December, and the average daily global solar radiation on horizontal surface at Aswan is 22.76 MJ/m^2/day, at Kharga is 22.11 MJ/m^2/day, at Cairo is 19 MJ/m^2/day, at Marsa-Matruh is 18.93 MJ/m^2/day and at Al-Arish is 19.75 MJ/m^2/day. Also, it was shown that the values of global solar radiation at Aswan and Kharga (south Egypt) are higher than they are in Cairo (middle Egypt), Marsa-Matruh and Al-Arish (northern Egypt). El-Metwally [14] estimated the daily global solar radiations in some regions in Egypt, in Marsa-Matruh 19.3 MJ/m^2/day, Rafah 17.8 MJ/m^2/day, Bahtim 18.9 MJ/m^2/day, Asyut 21.6 MJ/m^2/day, Kharga 22.0 MJ/m^2/day, and in Aswan 22.8 MJ/m^2/day. As example on the international regions, Zhang et. al [15] estimated the average value of the daily global solar radiation in China, in Shanghai 12.5 MJ/m^2/day, in Nanjing 12.42 MJ/m^2/day and in Hangzhou 11.37MJ/m^2/day. Further studies predicted solar radiation using meteorological data and empirical formula were shown by I. Korachagaon and V. Bapat, H. Yıldırım and others, Z. Tahir and M. Asim and C. Louis and R. Gambol [66–69] .

5-Conclusions

From figs 1 to 11 and tables 3 and 4 we can notice that the best months of the solar radiation are June, July and August which are the summer months. Moreover, it is clear that Aswan has the best solar availability. In conclusion, the regions Fayoum, Marsa-Alam, El-Arish, Cairo, Luxor, Marsa-Matruh, Taba and Asyut have also high solar availability and they could be used for the solar power projects either for energy production or desalination covering different areas of Egypt.

6-References

[1]. M. Abdelmonem, N. Yasein , H. Hassan and G. Said. The statistical analysis between instant solar radiation and instant temperature and predicting the solar radiation over different places in Egypt. J. Basic Sci. Appl. Res, vol, 1, pp. 5-22, 2015.

[2]. M. Abdelmonem, N. Yasein , H. Hassan and G. Said. The statistical analysis between instant solar radiation and instant temperature in Fayoum Governorate -Egypt. Journal of American Science, vol. 9, pp. 557- 567, 2013.

[3]. M. Omran. Analysis of solar radiation over Egypt. Theoretical and Applied Climatology **67** (2000) 225 –240.

[4]. A. Trabea and M. Mosalam Shaltout. Correlation of global solar radiation with meteorological parameters over Egypt. Renewable Energy **21** (2000) 297-308.

[5]. F. Batlles, M. Rubio, J. Tovar, F. Olmo and L. Alados-Arboledas. Empirical modeling of hourly direct irradiance by means of hourly global irradiance. Energy **25** (2000) 675–688.

[6]. I. Togrul, H. Togrul and D. Evin. Estimation of monthly global solar radiation from sunshine duration measurement in Elazigg. Renewable Energy **19** (2000) 587–95.

[7]. M. Shaltout, A. Hassan, A. Fathy. Study of the solar radiation over Menia. Renewable Energy **23** (2001) 621–639.

[8]. M. Iziomon, H. Mayer. Performance of solar radiation models - a case study. Agricultural and Forest Meteorology **110** (2001) 1–11.

[9]. C. Paltineanu, I. Mihailescu, V. Torica, and A. Albu. Correlation between sunshine duration and global solar radiation in south-eastern Romania. International Agrophysics **16** (2002) 139-145.

[10]. L. Saylan, O. Sen, H. Toros and A. Arısoy. Solar energy potential for heating and cooling systems in big cities of Turkey. Energy Conversion and Management **43** (2002) 1829–1837.

[11]. K. Ferenc, B. Jozsef and V. Marianna. Changes in solar radiation energy and its relation to monthly average temperature. Acta Mont anisti ca Slovaca **3** (2002) 164-166.

[12]. G. Podesta, L. Nunez, C.Villanueva and M. Skansi. Estimating daily solar radiation in the Argentine Pampas. Agricultural and Forest Meteorology **123** (2004) 41-53.

[13]. J. Almorox and C. Hontoria. Global solar radiation estimation using sunshine duration in Spain. Energy Conversion and Management **45** (2004) 1529–1535.

[14]. M. El-Metwally. Simple new methods to estimate global solar radiation based on meteorological data in Egypt. Atmospheric Research **69** (2004) 217–239.

[15]. Y. Zhang, B. Qin, W. Chen. Analysis of 40 year records of solar radiation data in Shanghai, Nanjing and Hangzhou in Eastern China. Theoretical and Applied Climatology **78** (2004) 217– 227.

[16]. M. El-Metwally. Sunshine and global solar radiation estimation at different sites in Egypt. Atmospheric and Solar-Terrestrial Physics **67** (2005) 1331–1342.

[17]. M. Trnka, Z. Zalud, J. Eitzinger and M. Dubrovsky. Global solar radiation in Central European lowlands estimated by various empirical formulae. Agricultural and Forest Meteorology **131** (2005) 54–76.

[18]. H. Menges, C. Ertekin and M. Sonmete. Evaluation of global solar radiation models for Konya-Turkey. Energy Conversion and Management **47** (2006) 3149–3173.

[19]. K. Spokas and F. Forcella. Estimating hourly incoming solar radiation from limited meteorological data. Weed Science **54** (2006) 182–189.

[20]. S. Robaa. Study of solar radiation climate at Cairo urban area, Egypt and its environs . International journal of Climatology **26** (2006) 1913 – 1928.

[21]. H. Elminir. Experimental and theoretical investigation of diffuse solar radiation: Data and models quality tested for Egyptian sites. Energy **32** (2007) 73 – 82.

[22]. U. Rahoma and A. Hassan. Fourier transforms investigation of global solar radiation at true noon: in the desert climatology. American Journal of Applied Sciences **4** (2007) 902-907.

[23]. M. Jamil Ahmad and G.N. Tiwari. Study of models for predicting the mean hourly global radiation from daily summations. Open Environmental Journal **2** (2008) 6-14.

[24]. M. Jamil Ahmad and G.N. Tiwari, Estimation of hourly global solar radiation for composite climate. Open Environmental Journal, **2** (2008) 34-38.

[25]. F. Castellvi. Evaluation of three practical methods for estimating daily solar radiation in dry climates. The Open Atmospheric Science Journal **2** (2008) 185-191.

[26]. T. Chineke. Equations for estimating global solar radiation in data sparse regions. Renewable Energy **33** (2008) 827–831.

[27]. M. Jamil Ahmad and G.N. Tiwari, Evaluation an d comparison of hourly solar radiation models. International Journal of Energy Research, **33** (2009) 538-552.

[28]. A. Kassem, A. Aboukarima, N. El-Ashmawy. Development of neural network model to estimate hourly total and diffuse solar radiation on horizontal surface at Alexandria city (Egypt). Journal of Applied Sciences Research **5** (2009) 2006-2015.

[29]. C. Augustine and M. Nnabuchi. Relationship between global solar radiation and sunshine hours for Calabar, Port Harcourt and Enugu Nigeria. International Journal of Physical Sciences **4** (2009) 182-188.

[30]. I. Togrul. Estimation of solar radiation from Angstrom's coefficients by using geographical and meteorological data in Bishkek, Kyrgyzstan, Thermal Science and Technology **29** (2009) 99-108.

[31]. J. Prieto, J. Martinez-Garcia and D. Garcia. Correlation between global solar irradiation and air temperature in Asturias – Spain. Solar Energy **83** (2009) 1076 - 1085.

[32]. U. Bajpai and K. Singh. Estimation of instant solar radiation by using of instant temperature. Acta Montanistica Slovaca **1** (2009) 189-196.

[33]. X. Liu, X. Mei, Y. Li, Q. Wang and J. Jensen . Evaluation of temperature-based global solar radiation models in China. Agricultural and Forest Meteorology **149** (2009) 1433-46.

[34]. M. Jamil Ahmad and G.N. Tiwari. Solar radia tion models: review. International Journal of Energy and Environment, **3** (2010) 513-532.

[35]. A. Muzathik, W. M. Nik, K. Samo, and M. Z. Ibrahim. Hourly global solar radiation estimates on a horizontal plane. Journal of Physical Science **21** (2010) 51–66

[36]. A. El-Sebaii, F. Al-Hazmi, A. Al-Ghamdi and S. Yaghmour. Global, direct and diffuse solar radiation on horizontal and tilted surfaces in Jeddah, Saudi Arabia. Applied Energy **87** (2010) 568–576.

[37]. M. Okundamiya and A. Nzeako. Empirical model for estimating global solar radiation on horizontal surfaces for selected cities in the six geopolitical zones in Nigeria. Research Journal of Applied Sciences, Engineering and Technology **2** (2010) 805-812.

[38]. X. Liu, X. Mei, Y. Li, J. Porter, Q. Wang and Y. Zhang. Choice of the Angstrom–Prescott coefficients: Are time-dependent ones better than fixed ones in modeling global solar irradiance?. Energy Conversion and Management **51** (2010) 2565–2574.

[39]. M. Jamil Ahmad and G.N. Tiwari. Solar radiation models- A review. International Journal of Energy Research **4** (2011) 271-290.

[40]. S. Tahas, D. Ristoiu and C. Cosma. Trends of the global solar radiation and air temperature. Romania Journal Physics **56** (2011) 784–789.

[41]. A. Ibrahim, A. El-Sebaii, M. Ramadan and S. El-Broullesy. Estimation of solar irradiance on inclined surfaces facing south in Tanta, Egypt. International Journal of Renewable Energy Research. **1** (2011) 18-25.

[42]. A. Muzathik, M. Ibrahim, K. Samo and W. Nik. Estimation of global solar irradiation on horizontal and inclined surfaces based on the horizontal measurements. Energy **36** (2011) 812-818.

[43]. D. Al Riza, S. Gilani and M. Aris. Hourly solar radiation estimation using ambient temperature and relative humidity data. International Journal of Environmental Science and Development **2** (2011) 188-193.

[44]. P. Veeraboina, G. Yesuratnam and L. Sundar. Estimation of annual solar radiation from measured temperatures by using temperature-based (TB) approach in different cities in India. Sustainable Cities and Society **1** (2011) 187 - 94.

[45]. S. El Shazly , A. Hassan, K. Kassem, M. Adam and Z. Ahmed. Estimating global and diffuse solar radiation from sunshine duration at Qena – Egypt. Canadian Journal on Computing in Mathematics, Natural Sciences, Engineering and Medicine **2** (2011) 237-261.

[46]. E. Elom and N. Nnamdi. Solar radiation in Onitsha: A correlation with average temperature. Scholarly Journal of Biotechnology **1** (2012) 101-107.

[47]. E. Ituen, N. Esen, S. Nwokolo. and E. Udo. Prediction of global solar radiation using relative humidity, maximum temperature and sunshine hours in Uyo, in the Niger Delta Region, Nigeria. Advances in Applied Science Research **3** (2012) 1923-1937.

[48]. I. Korachagaon and V. Bapat. General formula for the estimation of global solar radiation on earth's surface around the globe. Renewable Energy **41** (2012) 394 - 400.

[49]. I. Rahimi, B. Bakhtiari, K. Qaderi and M. Aghababaie. Calibration of Angstrom's equation for estimating solar radiation using meta-heuristic harmony search algorithm (Case study: Mashhad-East of Iran). Energy Procedia **18** (2012) 644 - 51.

[50]. I. Ulfat, F. Javed, F. A. Abbasi, F. Kanwal, A. Usman, M. Jahangir and F. Ahmed. Estimation of solar energy potential for Islamabad, Pakistan. Energy Procedia **18** (2012) 1496 – 1500.

[51]. X. Liu, Y. Xu, X. Zhong, W. Zhang, J. Porter and W. Liu. Assessing models for parameters of the Angstrom–Prescott formula in China. Applied Energy **96** (2012) 327-38.

[52]. A. Jemaa, S. Rafa, N. Essounbouli, A. Hamzaoui, F. Hnaien and F. Yalaoui. Estimation of global solar radiation using three simple methods. Energy Procedia **42** (2013) 406 – 415.

[53]. F. Besharat, A. Dehghan and A. Faghih. Empirical models for estimating global solar radiation: A review and case study. Renewable and Sustainable Energy Reviews **21** (2013) 798 - 821.

[54]. H. Suehrcke, R. Bowden and K. Hollands. Relationship between sunshine duration and solar radiation. Solar Energy **92** (2013) 160-71.

[55]. T. Pan, S. Wu, E. Dai and Y. Liu. Estimating the daily global solar radiation spatial distribution from diurnal temperature ranges over the Tibetan Plateau in China. Applied Energy **107** (2013) 384-93.

[56]. Y. Irwan, I. Daut, I. Safwati, M. Irwanto, N. Gomesh and M. Fitra. An estimation of solar characteristic in Kelantan using Hargreaves model. Energy Procedia **36** (2013) 473 – 478.

[57]. T. Soubdhan, M. Abadi and R. Emilionc. Time Dependent Classification of Solar Radiation Sequences Using Best Information Criterion. Energy Procedia **57**(2014) 1309 -1316

[58]. Y. El Mghouchi, A. El Bouardi, Z. Choulli and T. Ajzoul. New model to estimate and evaluate the solar radiation. International Journal of Sustainable Built Environment 3 (2014), 225–234.

[59]. K. Kadirgama, A. K. Amirruddin and R.A.Bakar. Estimation Of Solar Radiation By Artificial Networks: East Coast Malaysia. Energy Procedia **52** (2014) 383 – 388.

[60]. J. Waewsak, C. Chancham, M. Mani and Y. Gagnon. Estimation of Monthly Mean Daily Global Solar Radiation over Bangkok, Thailand using Artificial Neural Networks. Energy Procedia **57** (2014) 1160 – 1168.

[61]. G. Lopez and F. J. Batlles. Estimating solar radiation from MODIS data. Energy Procedia 49 (2014) 2362 – 2369.

[62]. K. H. Kim, J. Baltazar and J. S. Haberl. Evaluation of Meteorological Base Models for Estimating Hourly Global Solar Radiation in Texas. Energy Procedia **57** (2014) 1189 – 1198.

[63]. K. Ouali and R. Alkama. A new Model of global solar radiation based on meteorological data in Bejaia City (Algeria). Energy Procedia **50** (2014) 670 – 676 .

[64]. A. Padovana, D. Delcol, V. Sabatelli and D. Marano. DNI estimation procedures for the assessment of solar radiation availability in concentrating systems. Energy Procedia **57** (2014) 1140 – 1149.

[65]. Y. Eissa, S. Munawwar, A. Oumbe, P. Blanc, H. Ghedira, L. Wald, H. Bru and D. Goffe. Validating surface downwelling solar irradiances estimated by the McClear model under cloud-free skies in the United Arab Emirates. Solar Energy **114** (2015) 17–31.

[66]. I. Korachagaon and V. Bapat. General formula for the estimation of global solar radiation on earth's surface around the globe. Renewable Energy **41** (2012) 394–400.

[67]. H. Yıldırım, O celik, A. Teke and B. Barutcu. Estimating daily Global solar radiation with graphical user interface in Eastern Mediterranean region of Turkey. Renewable andSustainable Energy Reviews **82** (2018) 1528–1537.

[68]. Z. Tahir and M. Asim. Surface measured solar radiation data and solar energy resource assessment of Pakistan. Renewable and Sustainable Energy Reviews **81** (2018) 2839–2861.

[69]. C. Louis and R. Gambol. Estimation of Global Solar Radiation from Meteorological Parameter in Peninsular Malaysia. Eureca **14** (2014).