Empirical Models for the Correlation of Metrological Data for Tikrit-TuzKhurmato and Kirkuk-IRAQ

Fayadh M. Abed Al-Dulaimy **Ghazi-Yousif Mohammed Al-Shahery**
Asst.Prof. **Lecture**
Mechanical Engineering Department- University of Tikrit

Abstract
Measurements of metrological data of maximum, minimum ambient temperature, humidity and sunshine duration for a period of 23 years during the period of 1977-2000, at Tikrit (34. 35°N, 43.37°E), TuzKurmato (34.88°N, 44.64°E), and Kirkuk (35.30°N, 44. 21°E) were used to establish an Angstrom type correlation equations for direct global solar radiation. The diffuse radiation was estimated by using Klien and Page Models. This calculation appears to be sufficient to discriminate each station from the others due to it's local characteristic of the sites. The overall results shown for TuzKurmato, the received radiation on the plane surface is higher than Tikrit and Kirkuk while the diffuse radiation reversely behaved as for Tiktit is the highest. The developed model can be used for estimating global solar radiation on horizontal surfaces. The monthly average total solar radiation was estimated. The value of correlation coefficient (r) and value of Root Mean Square Error (RMSE), Mean Bias Error (MBE) and Mean Percentage Error (MPE) were determined for each equation

Key words: Solar global radiation, Hargreaves equation, temperature, relative sunshine duration

نموذج رياضي تصحيحي لمعطيات الظروف الميترولوجيا لمناطق تكريت،طوز خورماتو وكركوك العراق.

الخلاصة
في هذا البحث تم بناء نموذج معادلات انكستروم للاشعاع الشمسي المباشر باستخدام المعطيات للظروف الجوية المقاسة (درجة الحرارة القصوى والدنيا،فترة الاشعاع الشمسي بين الشروق والغروب والرطوبة النسبية، للفترة من عام 1977 لغاية عام 2000 لمدن تكريت(34.35°N, 43.37°E) وطوز خورماتو (34.88°N, 44. 64°E) ومدينة كركوك, (35.30°N, 44.21°E) اما الاشعاع غير المباشر (الانتشاري) فقد تم تخمينه من خلال معادلة كلاين وبيج. ومن الحسابات يتبين ان التمييز واضح لكل محطة للخصائص المميزة لكل منطقة. النتائج بينت ان كمية الاشعاع الشمسي المباشر لمدينة طوزخورماتو اعلى من مدينة تكريت وكركوك بينما الاشعاع المنتشر لمدينة تكريت الاعلى بالمقارنة مع كمية الاشعاع الشمسي المنتشر لمدينتي طوزخورماتو وكركوك. ايضا الموديلات المستنبطة من

البحث من الممكن الاستفادة منها في تحديد الاشعاع الشمسي الكلي في الدراسات المستقبلية من دون الحاجة الى اجراء قياسات عملية. لتحديد مدة دقة ووثوقية النتائج وبالاعتماد على الطرق الاحصائية تم حساب نسبة الاخطاء القياسية وتبين ان النتائج ضمن الحد المسموح به.

الكلمات الدالة: الاشعاع الشمسي، معادلة هاركريفز، درجة الحرارة، الفترة المشمسة النسبية

Introduction

In any solar energy conversion system, the knowledge of global solar radiation is extremely important for the optimal design and the prediction of the system performance. The best way of knowing the amount of global solar radiation at a site is to install pyranometers at many locations in the given region and look after their day-to day maintenance and recording, which is a very costly exercise. The alternative approach is to correlate the global solar radiation with the meteorological parameters at the place where the data is collected. The resultant correlation may then be used for locations of similar meteorological and geographical characteristics at which solar data are not available.

Several researchers have determined the applicability of the Angstrom type regression model for estimating global solar irradiance Akpabio et al.[1], Ahmad and Ulfat [2], Udo [3], El –Sebaii and Trabea[4], Falayi and Rabiu[5], Serm and Korntip [6], Skeiker[7].

The duration of the solar radiation, which is the most important data for the meteorological model, has been studied in the present work for Tikrit, TuzKurmato and Kirkuk city, located in the mid-north of iraq as shown in Figure.1. Tikrit City sited on the west bank of the River Tigris as far as the westward is the western desert up to the Border with Syria, while Kirkuk located in a savanna type surrounding climate east north surrounded by a hilly and a mountains formation. But Tuzkhurmato surrounded by two mountains from the east and the south of the city. The climatically conditions of Kirkuk and TuzKhurmato have less dusty days due to the mountains barriers of Hamreen mountain. Kirkuk and TuzKhurmato are located far away of water mass..

There are two ways in obtaining solar radiation data at ground level: by measurement and by modeling. As far as this investigation concern we found only measurement at these stations limited to the sunshine duration, weather measurement temperature of it is maximum and minimum and humidity.

A modeling that can be useful in the estimation of solar radiation on the flat surface of the ground level and further modeling for the diffuse radiation as well. The Global solar radiation in Iraq is not measured at the three stations namely Tikrit, and the two other stations mainly TuzKhurmato and Kirkuk. As well as the diffuse solar radiation are not observed experimentally in any Meteorological station in the country. Therefore, it is rather important to develop a method to estimate the global and diffuse solar radiation using climatologically parameters. Several empirical formulas have been developed to calculate the global solar radiation using various parameters. These parameters includes i) The sunshine hours [8-10] ii) the relative humidity and sunshine hours, the declination angle and the latitude[11]. The number of rainy days, sunshine hours latitude and locations[12], sunshine duration, relative humidity maximum temperature, latitude, altitude and location[13]. The linear regression model used in correlating and measured global solar radiation data. The clearness index (H / H_0) with relative sunshine duration $\left(S / S_{max}\right)$is given by Angstrom[8] and later modified by Page [14].

The objective of the present study is to present an analyze for the global solar radiation and sunshine duration data recorded at the three cities (Tikrit, TuzKurmato and Kirkuk), and to develop new constants for the first order Angström type correlations.

Methodology

The sunshine duration hours ,max., min. temperature and humidity data (1977 – 2000) for Tikrit (34. 35°N, 43.37°E), TuzKurmato (34.88°N, 44.64°E), and Kirkuk (35.30°N, 44. 21°E), which are the input data for the analysis was collected from the Iraq Meteorological State Agency.

Data Analysis

To develop the model, monthly average of daily global radiation for a given month was calculated from the following equation:

$$\overline{H} = \sum_{j=1}^{NY}\left[\left(\sum_{i=1}^{ND} H_{i,j}\right) / ND\right] / NY \quad \text{.....(1)}$$

Where $\overline{H}$ is the monthly average of daily global radiation, $H_{i,j}$ is the daily global radiation,

ND is the total number of days in the month; NY is the total number of year of data,

i is the index representing a day, j is the index representing a year,

$$H_0 = I_{sc} E_0 \cos\theta_Z \ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

where E_0 is the Extraterrestrial radiation measured on the plane of the nth day of the year, and represented the relative distance between Earth and Sun Duffie and Beckman[15] as follows:

$$E_0 = \left(1 + 0.033 * COS\left(\frac{360n}{365}\right)\right), \qquad (3)$$

I_{sc} =Solar constant=1367 Wm^{-2}, and θ_z = zenith angle of the sun. For a horizontal surface at any time between sunrise and sunset, according to Liu, and Jordan [11] , the cosine of zenith angle can be expressed by:

$$\left.\begin{array}{l} \cos\theta_z = \sin\delta\sin\phi\cos\beta \\ -\sin\delta\cos\phi\sin\beta\cos\gamma \\ +\cos\gamma\cos\phi\cos\beta\cos\omega \\ +\cos\gamma\sin\phi\sin\beta\cos\gamma\cos\omega \\ +\cos\sin\beta\sin\gamma\sin\omega \end{array}\right\} . (4)$$

Considering $\beta = 0$ and $\gamma = 0$, then Eq.4 can be rewritten as:

$$\cos\theta_z = \sin\delta\sin\phi + \cos\phi\cos\omega\cos\delta \text{ .(5)}$$

Combining Eqs.(2) and (5) we have

$$H_0 = I_{sc} E_0 s\left(in\delta\sin\phi + \cos\phi\cos\omega\cos\delta\right)(6)$$

The extraterrestrial daily solar radiation on a horizontal surface can be obtained by integrating eq. (6) over period from sunrise to sunset using $\omega = \omega_s$ we have:

$$\left.\begin{array}{l} H_0 = \dfrac{24*3600}{\pi} * I_{sc} E_0 * \\ \left(\cos\phi\cos\delta\cos\omega_s + \dfrac{2\pi\omega_s}{360}\sin\phi\sin\delta\right) \end{array}\right\} ..(7)$$

if we consider $\cos\theta_s = 0$ and $\omega = \omega_s$.then using equation 5. we have $\omega = Cos^{-1}\left(-\tan\phi\tan\delta\right)$

δ :celestial declination[radians] given as follow:

$$\delta = 23.45^0 \sin\left(360 * \frac{284 + J.}{365}\right) \ldots\ldots..(8)$$

J the Julian day ranging 1 (1 January) and 365 or 366(31 December).

Then the monthly average of daily global radiation $\overline{H}$ was normalized by dividing with the monthly average of daily extraterrestrial radiation $\overline{H}_0$. Therefore, $\left(\overline{H} / \overline{H}_0\right)$ is defined as the ratio of the measured horizontal terrestrial solar radiation ($\overline{H}$), to the calculated horizontal extraterrestrial

solar radiation ($\overline{H}_0$). Where $(\overline{H}/\overline{H}_0)$ is the cleanness index and $(S/S_{\max})$ is the relative sunshine duration. The development of the model as follow:
The most widely used relationship to estimate monthly average daily global radiation on a horizontal surface $\overline{H}$ is that given by Angström[8], Eq. (7). Second and third order Angström type correlations have been also proposed by different authors [4], they concluded that the second and third order Angström type correlations do not significantly improve the accuracy of estimation of the monthly average daily global radiation incident on a horizontal surface.

$$\overline{H} = \overline{H}_0\left(a + b\left(\frac{\overline{S}}{\overline{S}_{\max}}\right)\right) \ldots\ldots\ldots\ldots\ldots\ldots (9)$$

Where a, and b are the regression constants that depend on the location Where $\overline{H}$ is the monthly global solar radiation in MJm^{-2}. The linear regression model used in correlating the measured global solar radiation data ($\overline{H}/\overline{H}_0$) data with relative sunshine duration $(S/S_{\max})$is given by Angstrom [8] and later modified by Page [14]. For the sunshine durations, their monthly average of daily values for a given month was computed by the following equation.

$$\overline{S} = \sum_{j=1}^{NY}\left[\left(\sum_{i=1}^{ND} S_{i,j}\right)/ND\right]/NY \ldots\ldots (10)$$

Where $\overline{S}$ = monthly average of daily sunshine duration, $S_{i,j}$ = daily sunshine duration Like the case of the global radiation, the monthly average of daily sunshine duration (S) was divided by the monthly average of daily day length ($S_{\max}$). The values of $S_{\max}$ were computed from the following equation [16] as follow:

$$S_{\max} = \tfrac{2}{15} * Cos^{-1}(-\tan\phi \tan\delta) \ldots..(11)$$

Where $S_{\max}$ = monthly average of daily day length, δ = solar declination at the middle of the month, λ = latitude of the station.
Proper computer programs are prepared for the analysis. The monthly mean daily extraterrestrial radiation $\overline{H}_0$ and the maximum possible monthly average daily sunshine duration (S) needed for the calculations are estimated using the standard procedure as discussed later in the analysis.

Global Solar Radiation Estimation

Climatic data like length of day according to sunshine duration in the specific geological area as well as air temperature, humidity, wind speed and sky conditions(clouds, mist, fog, and aerosol) are usually more readily available but sometimes limited metrological is more handy and more accurate readily available for long period of time. The need for radiation data covering entire areas led to the development of radiation models that allow the calculation of radiation parameters within certain margins of error.
Previous modeling efforts of total incoming solar radiation have been conducted. Liu[17]; Monteith[18] used solar radiation form varies as a sine function through the day:

$$R = R_{noon}\sin\left(\frac{t}{D}\right) \quad \ldots\ldots\ldots\ldots\ldots\ldots(12)$$

Where R is the solar radiation at time t, R_{noon} is the solar radiation at solar noon, and D is day length. The major limitation is that the R_{noon} value is still needed. The development of an empirical algorithm for estimating incoming solar radiation using daily maximum and minimum air temperatures was performed by Bristow and Campbell [19]. Their model reduces the total daily solar radiation incident at the top of the atmosphere (R_e) by a correction factor calculated from the temperature extremes and is given by:

$$R = R_e\left[A\left(1 - e^{-B(\Delta T)^C}\right)\right] \quad \ldots\ldots\ldots(13)$$

where *A*, *B*, and *C are* empirical coefficients unique to each location and ΔT is the difference between $T_{\max}$ and $T_{\min}$. McVicar and Jupp [20] gave an estimation for Bristow and Campbell model involved a large amount of meteorological data (including solar radiation) which requires calibrations for the various parameters of the model, it's calculations are numerically complex.

Hargreaves and Samani[21] estimated another model of daily total radiation formulated: as

$$H = H_0 * K_R * \sqrt{T_{MAX} - T_{MIN}} \quad \ldots(14)$$

They observed that total solar radiation was related directly to the square root of the differences between daily temperature extremes ($T_{\max}$ and $T_{\min}$) as well as geographical information. Where H_0 is the extraterrestrial radiation in $\left(MJm^{-2}day^{-1}\right)$ which is calculated from geometric relationships, $T_{\max}$ is maximum air temperature (C^0); $T_{\min}$ is minimum air temperature (C^0); and K_R is an adjustment coefficient ($0.16 - 0.19C^{-0.5}$).The correction factor (K_R) is empirical and is determined by the geographical location with recommended values of 0.16 for sites away from water bodies (interior) and 0.19 for locations near water bodies (coastal)[21].

Chiemeka[22] used the Hargreaves equation to estimate the global solar radiation at Nigeria based on the available climate parameters of measured maximum and minimum temperature and the computed values of the extraterrestrial solar radiation and maximum day light duration are used also this being taken care of in the present model of calculation.

Sunshine Duration

Sunshine hour (SH) is a widely-available climatic variable measured at many meteorological stations. The amount of SH is expressed in fractions of an hour over a 60-min interval. It is logical to take SH = 0 for an overcast sky and SH greater than 1 is considered for a non overcastted sky. If a part of the surface is in the shadow, it receives lesser energy than sunny areas. That is why shadow determination is always an important part of the model. The sky is usually not completely clear, so meteorological parameters had to be integrated into the model**.** The measurement of sunshine duration in any of these region has been taken extended more than 10 years which is a minimum required for this model [23]. Therefore, it is better to use surface data of higher quality.

Estimation of Diffuse solar radiation

Since diffuse solar radiation are not observed experimentally in any Meteorological station. It becomes very important method to estimate the diffuse solar radiation using climatologically parameters. Ahmed M. A. et al.[24] used Angstrom formula and Page Model[14] for prediction global and diffuse radiation.

The diffuse solar radiation H_d can be estimated by an empirical formula which correlates the diffuse solar radiation component H_d to the daily total radiation H. The correlation equation which is widely used is developed by Page [14].

$$H_d = H\left(1.00 - 1.13\frac{H}{H_0}\right) \ldots\ldots\ldots\ldots(15)$$

Where H_d is the monthly mean of the daily Diffuse solar radiation and KT

$=H/H_0$ is the clearness index. The most commonly used correlation is due to Liu and Jordan [11] and developed by Klein [25] and is of the form:

$$H_d = H\left(1.390 - 4.027H\frac{H}{H_0} + 5.53*\left(\frac{H}{H_0}\right)^2 - 3.108\left(\frac{H}{H_0}\right)^3\right) \quad (16)$$

This model is used in the present calculations.

Statistical Calculations

The values of the monthly average daily global radiation H and the average number of hours of sunshine were obtained from daily measurements covering a period of 23 years. The method of least squares was used to obtain the constants a and b as follows Almorax et. at [26].

$$a = \frac{\sum_{i=1}^{M}\frac{\bar{H}}{H_0}\sum_{i=1}^{M}\left(\frac{\bar{S}}{S_{\max}}\right)^2 - \sum_{i=1}^{M}\frac{\bar{S}}{S_0}\sum_{i=1}^{M}\frac{\bar{S}}{S_{\max}}\frac{\bar{H}}{H_0}}{M\sum_{i=1}^{M}\left(\frac{\bar{S}}{S_{\max}}\right)^2 - \left(\sum_{i=1}^{M}\frac{\bar{S}}{S_{\max}}\right)^2}, \ldots(17)$$

$$b = \frac{M\sum_{i=1}^{M}\frac{\bar{S}}{S_{\max}}\frac{\bar{H}}{H_0} - \sum_{i=1}^{M}\frac{\bar{H}}{H_0}\sum_{i=1}^{M}\frac{\bar{S}}{S_{\max}}}{M\sum_{i=1}^{M}\left(\frac{\bar{S}}{S_{\max}}\right)^2 - \left(\sum_{i=1}^{M}\frac{\bar{S}}{S_{\max}}\right)^2}, (18)$$

Where M is the number of data points.

The accuracy of the estimated values was tested by calculating the Mean Bias Error (MBE), the Root Mean Square Bias Error (RMSE), and the Mean Percentage Error (MPE). The expressions for the MBE ($MJ.m^{-2}day^{-1}$), RMSE ($MJ.m^{-2}day^{-1}$), and MPE (%) is stated by (El– Sebaii A. Trabea)[4] and Correlation Co-efficient as follows:

$$\left.\begin{aligned} RMSE &= \left(\left[\sum\left(\bar{H}_{cal.} - \bar{H}_{obs.}\right)^2\right]/M\right)^{1/2}, \\ MBE &= \left[\sum\left(\bar{H}_{cal.} - \bar{H}_{obs.}\right)\right]/M, \\ MPE &= \left[\sum\left(\frac{\bar{H}_{obs.} - \bar{H}_{cal}}{\bar{H}_{obs.}}\times 100\right)\right]/M \end{aligned}\right\}.(19)$$

$$r = \frac{N\sum\left(\frac{\bar{H}}{\bar{H}_0}\right)\left(\frac{\bar{S}}{\bar{S}_{\max}}\right) - \left(\sum\frac{\bar{H}}{\bar{H}_0}\right)\left(\sum\frac{\bar{S}}{\bar{S}_{\max}}\right)}{\sqrt{\left(\left[N\sum\left(\frac{\bar{S}}{\bar{S}_{\max}}\right)^2\right] - \left(\sum\left(\frac{\bar{S}}{\bar{S}_{\max}}\right)\right)^2\right)\left(\left[N\sum\left(\frac{\bar{H}}{\bar{H}_0}\right)^2 - \left(\sum\left(\frac{\bar{H}}{\bar{H}_0}\right)\right)^2\right]\right)}} \quad \ldots..(20)$$

Results and Discussion

For this study a choice being made for three sites. These sites are differing in climatologically differences mainly in geographical position and weather patterns effected by it's surrounding. For Tikrit City is mostly effected by the wind pattern, which is blowing from the north western and for few weeks of the year changes it is direction from the south which bring high humidity and dust in summer and rainy days in winter. In Tuzkhurmato city the wind pattern is the same with fewer extremes in dust storm having a clearer sky; moreover enhanced radiation from the surrounding mountain. For Kirkuk region the wind pattern is the same but having longer wet days in winter and surrounding by the savanna planes which is enhanced the humidity but due it is heavy oil field in the north and east hill side of the city the effect of the aerosol and carbon dust from the surrounding oil filed burning effect the quality of the global solar radiation.

The calculations give a clear picture of the climatologically effects on these sites. Where Tuzkhurmato is received the highest solar radiation values, while to a lesser extent in Kirkuk due to the reason mentioned. The lowest is in Tikrit due to dusty weather which is affected by the western planes of the desert with less humidity.

The analysis of the measured and calculated of global solar radiation shows that for all locations in concern, the maximum values of global solar radiation are observed in June while the minimum values are appeared in December as shown in Figures 2, 3 and 4.

The metrological data for the three sites of (the average sunshine duration, and the maximum and minimum temperature) are shown in table.1 a, b and c. Also the average observed solar radiation values that obtained from those data is shown in the same tables. Furthermore, in order to relate the observed values of clearness index with sunshine duration, employing these parameters the regression constant "a" and "b" are evaluated Inserting these values in equation (7) the monthly average daily Global solar radiation H is estimated. These parameters are fitted in an empirical equation as follows:

$$H = H_0\left(0.2021 + 0.5589\left(\frac{S}{S_{\max}}\right)\right) \quad ....(21)$$

For Tikrit city,

$$H = H_0\left(0.2693 + 0.5503\left(\frac{S}{S_{\max}}\right)\right) \quad ...(22)$$

for TuzKhurmato city

And $$H = H_0\left(0.2922 + 0.4932\left(\frac{S}{S_{\max}}\right)\right)$$

....(23)

For Kirkuk city

Accordingly the comparison between the observed and estimated values represented in each site as shown in Figures 2. 3 and 4. These model shows that it is quite sensitive to discriminate the amount of sunshine on these sites, however these sites are not far away from each other by not more than 120 km. the general overall distribution of the solar radiation of each site graphs are behaved rather well with that of the observed values.

The other indirect solar radiation namely the solar diffuse predicted by Klien[25] were confirmed well with geological and climatologically effect on these three district. The results of diffuse radiation calculations are presented in Figures 2, 3 and 4. In Tikrit it appears to be below 7% the total radiation due to the fact of dusty weather. While below 6% in TuzKhurmato due to the clearer sky, as far as Kirkuk concern the aerosol effect and carbon particles fume reduce it below 5%. A statistical analysis performed of the results of the calculations the RMSE , MBE and MPE which represent the fundamental measured accuracy are given for tikrit (MBE=0.0231, RMSE=0.3465, and MPE=-0.0437), TuzKhurmato is MBE=-0.0171, RMSE=0.4942, MPE=-0.0626, while Kirkuk is (MBE=-0.1242,RMSE= 0.7051 ,MPE=-0.1074. It is observed from the results that the maximum error obtained for the present model is not less 3% table (4). The test RMSE provides information on the short-term performance of the studied model as it allows a term-by term Comparison of the actual deviation between the calculated value and the measured value. Igbal [15], Almorox[26] and Che et al.[27] have recommended that a Zero value for MBE is ideal and low RMSE is desirable. MPE value provides information on under estimation since it is negative while if it s positive it is overestimation in the calculated value. A low value of MPE is desirable by Akpabio et al [1]. The regression constants (a) and (b) for Tikrit, Tuzkhurmato and Kirkuk were determined by correlating the solar radiation with sunshine duration hours. The results of the regression analysis show that the correlation coefficients are 0.96, 0.92 and 0.95 respectively. The value of correlation shows a clear linear correlation between the sunshine and measured solar radiation.

Conclusions

A model for calculating the monthly average of daily global radiation from the sunshine duration has been developed. The model is expressed as a linear relation between the normalized global radiation and the normalized sunshine duration. The coefficients of the model are stated as functions of the latitude. The performance of the model was investigated. It was found that global radiation calculated from the model is in good agreement with that obtained from the measurement. Therefore, first order or linear correlations between the monthly average daily clearness index and the relative possible sunshine duration for the selected locations have been proposed. It is concluded that the correlation proposed for these site can be used successfully for estimation of *solar radiation* for any location of Iraq with similar meteorological characteristics.

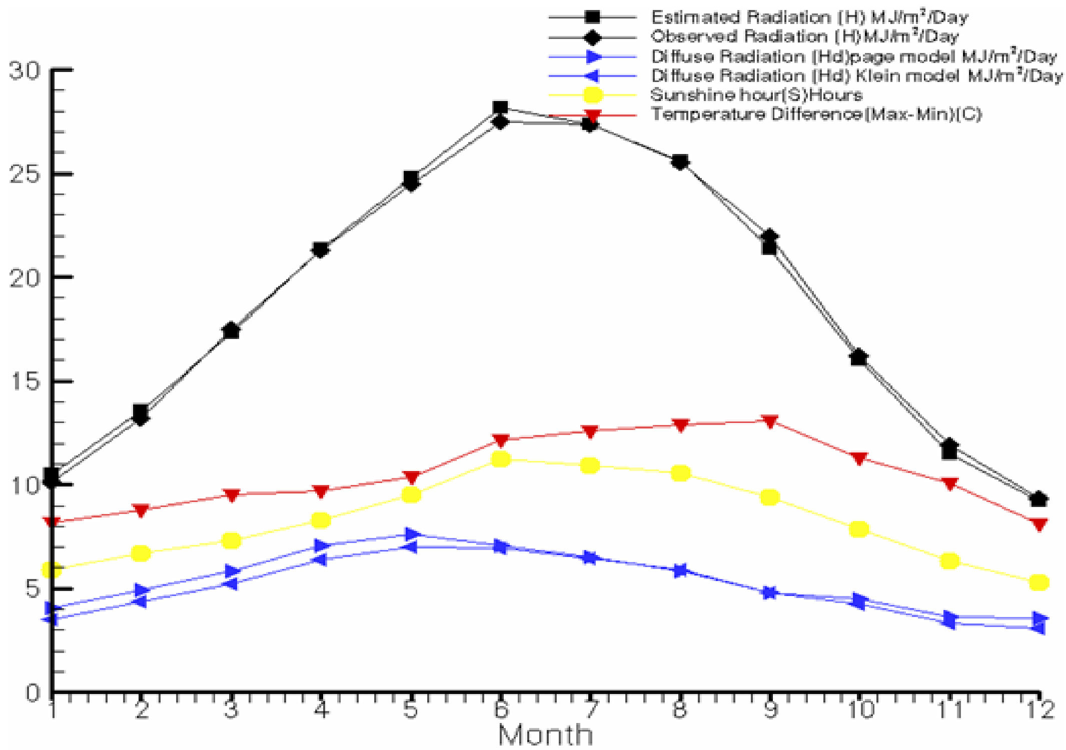
The statistical calculations were found to be adequate to discriminate between the sites, and found to be ranging within 3% which is highly reliable. The global solar radiation intensity values produced by this approach can be used in the designed and estimation of performance of solar applications system which is gaining attention in Iraq.

References

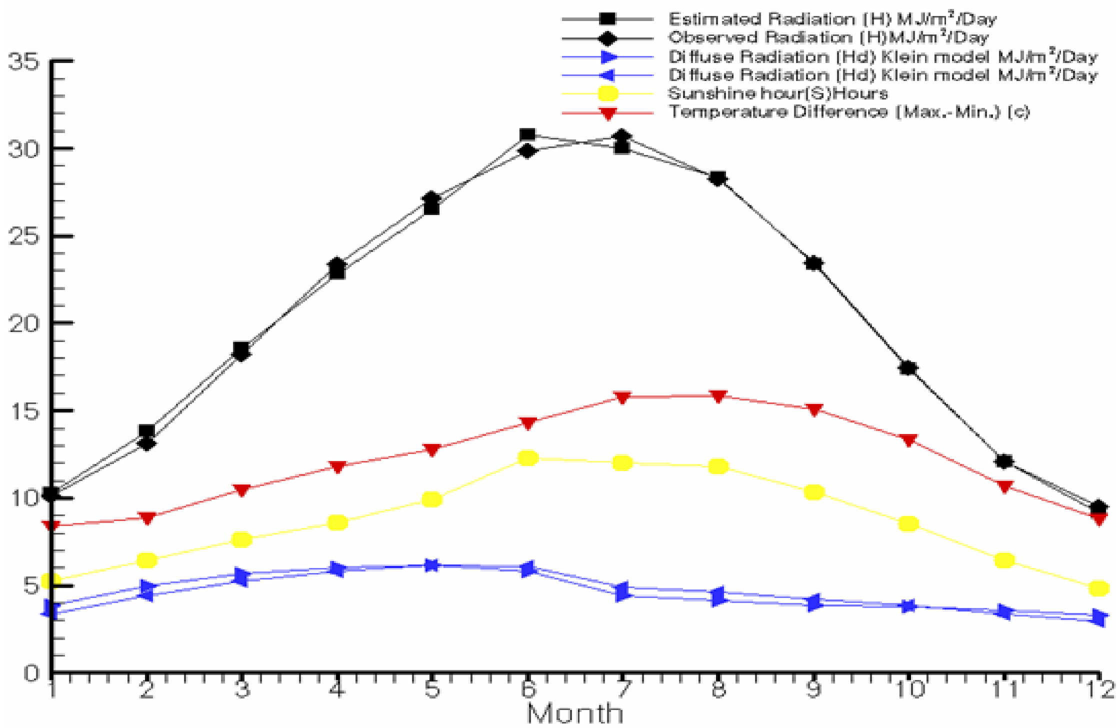
1. L.E. Akpabio,S.O. Udo, S.E. Etuk, Empirical correlation of global solar radiation with Meteorological data for Onne, Nigeria. Turkish J. Physics, 28 (2004) 222-227.
2. F. Ahmad, I. Ulfat, Empirical models for the correlation of monthly average daily solar radiation with hours of sunshine on a horizontal surfaces at Karachi, Pakistan. Turkish J. Physics, 28 (2004) 301-307.
3. S.O. Udo, Contribution to the relationship between solar radiation of sunshine duration to the tropics, A case study of experimental data (2002).
4. A. A. EL.-Sebaii, A. A. Trabea, Estimation of global solar radiation on horizontal surfaces over Egypt, Egypt J. Solids, 28 (2005):163- 175.
5. E.O. Falayi, A.B. Rabiu, Modeling global solar radiation using sunshine duration data. Nig. J. Physics, 17S (2005).: 181-186.
6. J. Serm, T. Korntip, A model for the Estimation of global solar radiation from sunshine duration in Thailand. The joint international conference on Suitable energy and environment (SEE), (2004) pp. 11-14.
7. K. Skeiker, Correlation of global solar radiation with common geographical and meteorological parameters for Damascus province, Syria. Energy conversion and management, 47 (2006) 331-345.
8. A. Angstrom, Solar and terrestrial radiation Q.J.R. Met. Soc. 50(1924) 121-126.
9. J.N. Black, C.W. Bonython, and J.A. Prescett, Solar radiation and duration of Sunshine, Q.J.R Metero. Soc. 80 (1954) 231-235.
10. J. Glover, and F. McCulloch, The empirical relationship between solar radiation and hours of sunshine. Q.J.R. Met. Soc. 84(359) (1958): 56-60.
11. Y.H. Liu, and R.C. Jordan, The inter relationship and characteristic distribution of direct, diffuse and total solar radiation from metrological data. Solar Energy.4 (1960) 1-19.

12. S.J. Reddy, An empirical method for the estimation of net radiation intensity Solar Energy. 13 (1971) 291-292.
13. J.A. Sabbagh, A.A.M Sayigh, and E.M.A.El-Salam, Estimation of the total solar radiation from meteorological data. Solar Energy.19 (1977): 307-311.
14. J.K. Page, The estimation of monthly mean values of daily short wave radiation on vertical and inclined surface from sunshine records of latitude 40 degree N to 40 degree S. Proc. of UN-Conf. on New Sources of Energy. l:4 paper s/98 (1964). 378
15. Duffie, J.A. and Beckman W.A., Solar *engineering of thermal processes*, 2nd edition. New York: Jon Wiley and Sons Inc., (1991).
16. Iqbal, M., *An Introduction to Solar Radiation*, Academic press, Toronto (1983).
17. D.L. Liu, Incorporating diurnal light variation and canopy light attenuation into analytical equations for calculating daily gross photosynthesis.Ecol. Model. 93 (1996):175–189.
18. J.L. Monteith, Evaporation and the Environment. In the state and movement of water in living organisms. (1965) Pages 205–234 *in* Proceedings of the 19th Symposium, Society for Experimental Biology. Cambridge: Cambridge University Press.
19. K. L. Bristow, and G. S. Campbell. On the relationship between incoming solar radiation and daily maximum and minimum temperature. Agric. For. Meteor. 31(1984) 159–166.
20. T.R. McVicar, and D.L.B. Jupp. Estimating one-time-of-day meteorological data as inputs to thermal remote sensing based energy balance models. Agric. For. Meteor. 96 (1999):219–238.
21. G.H. Hargreaves and Z. A. Samani. Reference crop evapotranspiration from temperature. Appl. Eng. Agric. 1(1985) 96–99.
22. I.U. Chiemeka, Estimation of solar radiation at Uturu, Nigeria, International Journal of Physical Sciences Vol. 3 (5) (2008) pp. 126-130.
23. A. AL-SALAYMEH, modeling of global daily solar radiation on horizontal surfaces for Amman city".*Emirates Journal for Engineering Research, 11 (1) (2006) 49-56* [24]. A. Al-Mohamad, Global, direct and diffuse solar-radiation in Syria. *Appl. Energy*, 79(2), 2004, 191.
24. S.A. Klein, Calculation of monthly average insolation on tilted surface. Solar Energy. 9 (1977) 325.
25. J. Almorox, M. Benito, C. Hontoria, Estimation of monthly Angstrom –Prescott equation coefficients from measured daily data in Toledo, Spain. Renewable Energy Journal, 30 (2005) 931-936.
26. H.Z. Che, G.Y. Shi, X.Y. Zhang ,J.Q. Zhao,Y. Li, Analysis of sky condition Using 40 years Records of Solar radiation data in china. Theoretical and applied climatology. 89 (2007) 83-94.

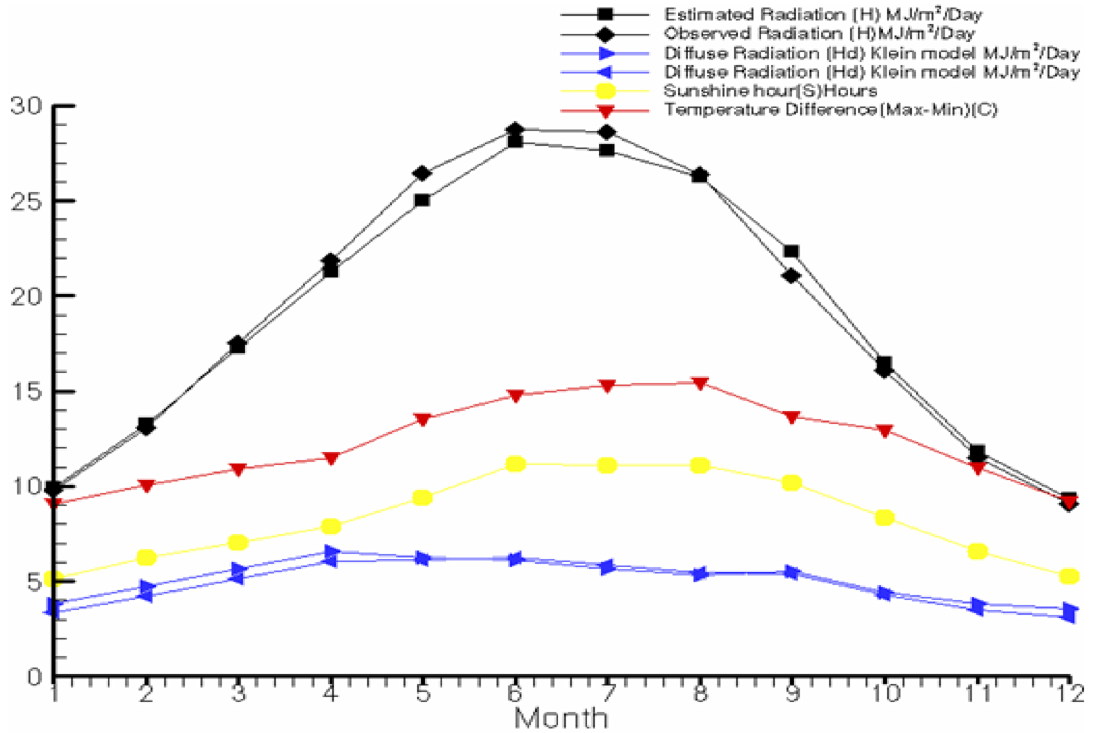
Figure(1) Regional location of Tikrit, TuzKurmato and Kirkuk



Figure(2) Monthly viariation of Temp. Difference, H,S,Hd Page and Klien Models) For Tikrit –Iraq.



Figure(3) Monthly viariation of Temp. Difference, H,S,Hd Page and Klien Models) For TuzKhurmato-Iraq



Figure(4) Monthly viariation of Temp. Difference, H,S,Hd Page and Klien Models) For Kirkuk-Iraq

Table (1a): Comparison between measured Metrological data estimated values for Tikrit for a period of 23 years

Month	*Mean sunshine* (hours) n	Max day length(N) (hours)	$\left(\frac{\bar{S}}{\bar{S}_{max}}\right)$	H_0	$MJm^{-1}day^{-1}$ Measured	calculated	$K_T=\left(\bar{H}/\bar{H}_0\right)$	Tmax. (c)	Tmin. (c)
Jan	5.879	9.982	0.589	18.54	10.14	10.471	0.56	14.56	6.03
FEB	6.682	10.75	0.622	23.29	13.67	12.848	0.58	17.04	8.97
MAR	7.332	11.78	0.622	29.77	17.58	17.034	0.58	21.49	11.13
APR	8.303	12.88	0.645	35.94	21.16	20.930	0.59	28.51	18.91
MAY	9.555	13.70	0.690	39.95	24.80	24.496	0.62	34.10	24.29
JUNE	11.235	14.28	0.788	41.51	28.47	27.350	0.68	40.29	28.88
JULY	10.947	14.06	0.779	40.66	27.90	27.694	0.67	43.25	30.21
AUG	10.575	13.27	0.797	37.41	25.53	24.824	0.68	42.17	29.82
SEP	9.370	12.20	0.770	31.90	21.61	20.370	0.67	39.71	26.27
OCT	7.825	11.10	0.710	25.26	16.66	15.709	0.63	31.54	20.58
NOV	6.400	10.17	0.629	19.64	11.18	10.637	0.58	22.14	12.09
DEC	5.255	9.735	0.546	17.05	9.38	8.969	0.54	15.53	7.35

Table (1b): Comparison between measured Metrological data estimated values for

Month	*Mean sunshine* (hours) n	Max day length(N) (hours)	$\left(\frac{\bar{S}}{\bar{S}_{max}}\right)$	H_0	$MJm^{-1}day^{-1}$ Measured	calculated	$K_T=\left(\bar{H}/\bar{H}_0\right)$	Tmax. (c)	Tmin. (c)
JAN	5.230	9.936	0.53	18.32	10.10	10.241	0.56	13.05	4.63
FEB	6.430	10.72	0.60	23.10	13.08	13.844	0.60	14.52	5.63
MAR	7.630	11.78	0.65	29.62	18.21	18.539	0.63	18.90	8.43
APR	8.590	12.90	0.67	35.87	23.38	22.804	0.64	25.77	14.00
MAY	9.900	13.83	0.72	39.94	27.11	26.487	0.66	32.98	20.22
JUNE	12.26	14.31	0.86	41.54	29.86	30.773	0.74	38.42	24.10
JULY	11.98	14.09	0.85	40.66	30.71	29.979	0.74	41.70	25.90
AUG	11.80	13.29	0.89	37.36	28.26	28.320	0.76	41.55	25.70
SEP	10.33	12.21	0.85	31.78	23.45	23.365	0.74	37.52	22.43
OCT	8.540	11.08	0.77	25.08	17.40	17.394	0.69	31.03	17.70
NOV	6.460	10.15	0.64	19.44	12.07	12.044	0.62	21.37	10.68
DEC	4.830	9.684	0.50	16.84	9.51	9.154	0.54	14.73	5.90

Table (1c): Comparison between measured Metrological data estimated values for Kirkuk for a period of 23 years

Month	Mean sunshine (hours) n	Max day length(N) (hours)	$\left(\frac{\bar{S}}{\bar{S}_{max}}\right)$	H_0	$MJm^{-1}day^{-1}$ Measured	calculated	$K_T = \left(\bar{H}/\bar{H}_0\right)$	Tmax. (c)	Tmin. (c)
JAN	5.160	9.891	0.52	17.98	10.29	10.425	0.58	13.84	4.76
FEB	6.252	10.69	0.58	22.79	13.71	13.960	0.61	15.80	5.78
MAR	7.008	11.77	0.59	29.39	18.42	18.169	0.62	19.70	8.82
APR	7.892	12.92	0.61	35.75	23.03	22.391	0.63	25.70	14.20
MAY	9.364	13.87	0.68	39.92	27.93	26.342	0.66	33.82	20.26
JUNE	11.16	14.36	0.78	41.57	30.35	29.647	0.71	39.87	25.02
JULY	11.09	14.14	0.80	40.67	30.23	29.166	0.72	43.46	28.17
AUG	11.09	13.32	0.840	37.28	27.79	27.671	0.74	42.79	27.39
SEP	10.19	12.21	0.844	31.59	22.18	23.478	0.74	37.42	23.76
OCT	8.320	11.06	0.744	24.80	16.93	17.361	0.70	31.37	18.46
NOV	6.608	10.11	0.642	19.10	12.03	12.393	0.65	22.29	11.30
DEC	5.280	9.633	0.551	16.49	9.52	9.787	0.59	15.76	6.53