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The Effect of Meteorological Parameters on Solar Radiation in Babylon

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Abstract
Meteorological parameters like monthly mean global solar radiation, monthly average daily sunshine duration, monthly average of the daily temperature, monthly average of the daily relative humidity, difference of maximum to minimum daily temperature and difference of maximum to minimum daily relative humidity was measure from the meteorological station of the (University of Babylon/College of Education for Pure Sciences /Department of Physics) during the period from August 2012 to June 2013.

Eight model's were developed for the location of the station to predict the calculated monthly mean global solar radiation and compare it with the observed value.

A good argument with model five where the value of the mean bias error (MBE) is (0.1852) , t-statistic was the smallest at (0.121) , correlation coefficient (r) value of (0.9125) and the correlation determination (R^2) with the value of (0.8325).

Introduction
The middle east is a great source of solar energy that has not yet been fully exploited the lack of proper meteorological stations specialized for solar radiation has made it hard to study this great amount of energy source in such regions .

The earliest model used to estimate global radiation from relative sunshine duration only has been developed by (Angstrom,1924), and was modified to a more convenient form by (Prescott,1940) , through the following relation ;

$$\frac{H}{H_\circ} = a + b\frac{S}{S_{max}} \qquad (1)$$

where $\left(\frac{H}{H_\circ}\right)$ clearness index , $\left(\frac{S}{S_{max}}\right)$ relative sunshine duration , (a , b) regression coefficient that are variable from one location to another and from one model to another (Akpabio and Etuk , 2003).

This model has been developed by many researchers such as (Medugu and Yakubu , 2011);(Paulescu *et.al.* , 2006) to suit the theoretical measurement of the monthly mean horizontal daily total terrestrial solar radiation (H) , according to the environmental of deferent place's and country's , although the model is considered by several researchers such as (Falayi and Rabiu, 2005);(Skeiker, 2006);(Okundamiya and Nzeako , 2011) to be regression model.

Other model has been developed to calculate monthly daily global solar radiation on horizontal surface with metrological data with one or more combinations of weather parameters as the number of parameters increased ,the correlation becomes a multiple linear regression with the form (Toğrul , 2009);(Abdulazeez , 2011) ;

$$y = a + bx_1 + cx_2 + dx_3 + \cdots\cdots \qquad (2)$$

where $\left(y = \frac{H}{H_\circ}\right)$, $(x_1, x_2, x_3, ...)$ are deferent metrological parameters.

The objective of the present study is to use different models depending on the number of parameters introduced in each model to calculate monthly daily global solar radiation on horizontal surface (H_{cal}) in (MJ / m^2) and mach it with the observed monthly daily global solar radiation on horizontal surface (H_{obs}) in (MJ / m^2) taken from the metrological station located in (Babylon University / College of Science / Department of Physics) for one year .

Observed data
The data for the monthly mean horizontal daily total terrestrial solar radiation (H_{obs}) , monthly average daily

sunshine duration (S) , monthly average of the daily temperature (T_{av} ^{o}C) , monthly average of the daily relative humidity ($R.H._{av}$%) , difference of maximum to minimum daily temperature (T_{max}- T_{min}) ^{o}C , difference of maximum to minimum daily relative humidity ($R.H._{max}$- $R.H._{min}$) %, were obtained from the meteorological station at the (Altitude 28m) , (Latitude 32° 23' 43.68" N) , (Longitude 44° 24' 05.23" E) from the first of June 2009 to the first of June 2010 and monthly horizontal total extraterrestrial solar radiation (H_O) in (MJ / m²) can be calculated using the relation from (Duffie and Beckman , 1994) ;

$$H_{\circ} = \frac{24 * 3600}{\pi} * G_{sc}(1 + 0.033 * \cos\frac{360 * n'}{365}) * (\cos\phi\cos\delta\sin\omega_s + \frac{\pi * \omega_s}{180}\sin\phi\sin\delta) \qquad (3)$$

Where G_{sc} = solar constant = 1367 Watt/m² , n' = mean day of each month ,

ϕ = Latitude of the station ,

δ = Sun Declination angel $= 23.45\sin(360\frac{284 + n'}{365})$ (4)

ω_s = Sun set hour angle for typical day $= \cos^{-1}(-\tan\phi\tan\delta)$ (5)

, and S_{max} = Number of hours of insulation $= \frac{2}{15}\cos^{-1}(-\tan\phi\tan\delta)$ (6)

and the results are shown in Table (1).

Table (1) Meteorological data from the Meteorological station of (Babylon University / College of Education for pure Science / Department of Physics) from August 2012 to June 2013.

Monthly	S/S_{max}	H_{obs}/H_O	^{o}C T_{av}	$R.H._{av}$%	($R.H._{max}$- $R.H._{min}$)%	^{o}C (T_{max}- T_{min})
JAN.	0.6487	0.5256	13	54	79	31.5
FEB.	0.6851	0.4509	17	44	65	20.25
MAR.	0.5299	0.3224	20.5	49	81	26.5
APR.	0.4901	0.2753	26	49	84	23.5
MAY.	0.4782	0.2493	29	41	71	24
AUG.	0.7198	0.2565	34.5	36	36	21.5
SEP.	0.5588	0.3297	32	40	44	21.5
OCT.	0.7489	0.4120	28	50	75	20.5
NOV.	0.5731	0.5192	17.5	55	80	24
DEC.	0.5897	0.5371	14	63	73	17.5

The models used

Eight models have been built in the present work as shown in Table (2) , the **first model** , includes one parameter , relative sunshine duration and its effect on the clearness index .

The **second model** , uses three parameters , the relative sunshine duration with monthly average of the daily temperature and monthly average of the daily relative humidity and its effect on the clearness index .

The **third** , **fourth** and the **fifth model** like the second uses three parameters but take the inverse for monthly average of the daily temperature in the third , inverse for the monthly average of the daily relative humidity in the fourth and the inverse for both temperature and relative humidity in the fifth with the relative sunshine duration.

The **sixth** and the **seventh models** use four parameters , the relative sunshine duration , with monthly average of the daily temperature and monthly average of the daily relative humidity and the difference between maximum and minimum temperature on the sixth model and the difference between maximum and minimum relative humidity for the seventh model .

The **eighth model** includes five parameters , the relative sunshine duration , monthly average of the daily temperature , monthly average of the daily relative humidity and both the difference between maximum and minimum for temperature and relative humidity, and for each model the regression coefficient is found and inserted in the model equation .

Table (2) The models suggested for the location of the station.

Model Number	Model
1	$H/H_o = 0.0378 + 0.539\ S/S_{max}$
2	$H/H_o = 0.5104+0.674\ S/S_{max} - 0.0133\ T_{av} - 0.00506\ R.H._{av}\%$
3	$H/H_o = -0.2057+0.496\ S/S_{max} - 3.279\ (1/T_{av}) + 0.015\ R.H._{av}\%$
4	$H/H_o = 1.9989 - 1.6309\ S/S_{max} + 0.01516\ T_{av} - 30.5622\ (1/R.H._{av}\%)$
5	$H/H_o = 0.2078 - 0.0236\ S/S_{max} + 5.651\ (1/T_{av}) - 3.7577\ (1/R.H._{av}\%)$
6	$H/H_o = 1.3061 + 0.8740\ S/S_{max} - 0.0211\ T_{av} - 0.00506\ R.H._{av}\% - 0.0268\ (T_{max} - T_{min})$
7	$H/H_o = 0.2160 + 0.5874\ S/S_{max} - 0.0114\ T_{av} + 0.00886\ R.H._{av}\% - 0.0036\ (R.H._{max} - R.H._{min})$
8	$H/H_o = 0.2160 + 0.5874\ S/S_{max} - 0.0114\ T_{av} + 0.00886\ R.H._{av}\% - 0.0268\ (T_{max} - T_{min}) - 0.0036\ (R.H._{max} - R.H._{min})$

Methods of calculating the error in the models

The mean bias error (MBE) , root mean square error (RMSE), and (t-statistic) were used to evaluate the accuracy of each model , **(Mean Bias Error (MJ/m^2))** is defined as;

$$MBE = \frac{1}{n}\sum_{i=1}^{n}(H_{cal} - H_{obs})_i \quad (7)$$

where n is the number of data pairs and $(H_{cal}\text{-}H_{obs})_i$ is the difference (H_{cal}) calculated and (H_{obs}) observed values , this test provides information on the long-term performance , a low (MBE) is desired , a positive value gives the average amount of over-estimation in the calculated value and vice-versa , a drawback of this test is that over-estimation of an individual observation will cancel under-estimation in a separate observation , and **(Root Mean Square Error (MJ/m^2))** is defined as;

$$RMSE = [\frac{1}{n}\sum_{i=1}^{n}(H_{cal} - H_{obs})_i^2]^{1/2} \quad (8)$$

this test provides information on the short-term performance of the correlations by allowing a term by term comparison of the actual deviation between the calculated value and the observed value the smaller the differences , the better the model's performance , however, a few large error in the sum can produce a significant increase in (RMSE) , it is obvious that each test by itself may not be an adequate indicator of a model's performance , It is possible to have a large (RMSE) value and at the same time a small (MBE) (a large scatter about the line of perfect estimation). It is also possible to have a relatively small (RMSE) and a relatively large (MBE) (consistently small over- or under estimation) , although these statistical indictors generally provide a reasonable procedure to compare the models, they do not objectively indicate whether models estimates are statistically significant, i.e., not significantly different from their measured counterparts : **(t-statistic)** is defined as (Walpole and Myers, 1989);

$$t = \left[\frac{(n-1)MBE^2}{RMSE^2 - MBE^2}\right]^{1/2} \quad (9)$$

the statistical indicator allows model's to be compared and at the same time indicates whether or not models estimates are statistically significant at a particular confidence level (Stone, 1993) , it was seen that the statistic used in addition to the (RMSE) and (MBE) gives more reliable and explanatory results (Toğrul, 1998).

The smaller the value of t, the better is the model's performance to determine whether model estimates are statistically significant, one simply has to determine a critical t value obtainable from standard statistical tables, i.e., α / 2 t at the α level of significance and (n-1) degrees of- freedom , For the model's estimates to be judged statistically significant at the (1-α) confidence level, the calculated t value must be less than the critical t value.

Results

A comparison between the calculated clearness index (H_{cal}/H_o) from the theoretical model and the observed clearness index (H_{obs}/H_o) are introduced for all the models as shown in Fig. (1) and Fig. (2) .

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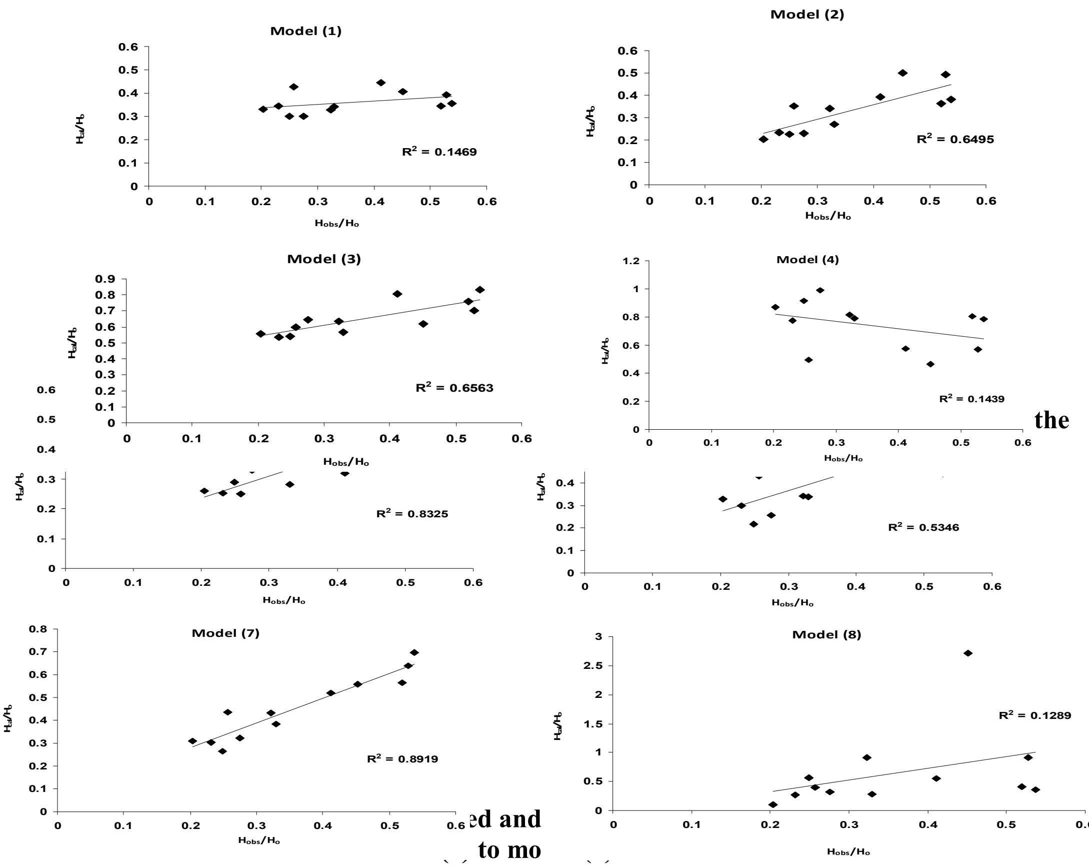

to determine the correlation determination (R^2) , correlation coefficient (r) , and from equations (7-9) , (MBE) in (MJ/m^2) , (RMSE) in (MJ/m^2) and (t-statistic) are presented in Table (3) , the figures (1) & (2) and table (3) show :

- The correlation coefficient (r) for model (5) at value (0.9124) and model (7) at value (0.9444) are the highest among all the models .
- The correlation determination (R^2) has a value of (0.8325) for model (5) and (0.8919) for model (7) which are also the highest.
- As for the short-term performance is not good , for all the model's the (RMSE) has a positive but large values.

Table (3) The results of regression and statistical analyses of the models .

Model Number	r	R^2	MBE *10^6	RMSE*10^6	t-statistic
1	0.3832	0.1469	0.8602	3.258353	0.273
2	0.8059	0.6495	-0.5210	1.823179	0.298
3	0.8101	0.6563	9.3081	10.117026	2.348
4	0.3793	0.1439	13.3604	16.896973	1.291
5	0.9124	0.8325	0.1852	1.541006	0.121
6	0.7311	0.5346	1.9192	3.528084	0.648
7	0.9444	0.8919	2.7530	3.163733	1.766
8	0.3590	0.1289	8.0415	17.908681	0.502

- while in the long-term performance the (MBE) for model (5) with the value of (0.1852) is better than all the other seven models.

- t-statistic gives model (5) the smallest value (0.121) from all other model's and this indicates that the performance of the model is better than the others.

Conclusion

The results presented in figures (1) & (2) and table (3) show that the performance of model (5) is better then the other models , and can be employed for estimation of global solar radiation for the location of the station and for other locations that has the same geographical coordinates.

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