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Statistical Evaluation of Some Models to Estimate Instantaneous Total Insolation on Horizontal Surfaces within Suez Gulf Region

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ABSTRACT

It is important for many solar energy systems to estimate and predict the instant or daily mean direct and diffuse irradiation on horizontal or tilted surfaces at any known location. One of the targets of the present article is to perform a simple statistical evaluation of 7 model results. These models are employed to estimate and predict the solar radiation on different surfaces and locations. They are fed with local measured data. The results of the evaluation would help to recommend one or more models for the considered region (latitude: 29° N; longitude: 33° E). Statistical indicators, such as Mean Bias Error (*MBE*), Root Mean Square Error (*RMSE*) and Mean Relative Percentage Error (*MPE*) are used in this comparison. The considered models are ASHREA, ATWATER&BALL, BIRD, DAVIES&HAY, HOYT, LACIS&HANSEN and SPECTRAL2. The obtained results have shown that, BIRD and DAVIES&HAY models could be recommended for estimating both the instantaneous hourly direct and diffuse radiation on horizontal surfaces for the considered region. And, ASHREA, SPECTRAL2 and ATWATER&BALL are occupied the second rank. Models such as HOYT and LACIS&HANSEN would not recommend for the considered region. Also, a new correlation is developed by which the total insolation could be predicted.

KEYWORDS: Instantaneous Solar radiation; Solar radiation models; Statistical analysis.

1. INTRODUCTION

Egypt is considered one of the high insolation countries of the world. The sunshine hours are estimated to be 3600 hours/year [1]. Therefore utilization of solar energy in Egypt as an alternative and renewable energy must be strongly taken into consideration in the future, especially, when new communities are established in the desert and remote areas [2]. To determine the feasibility of building solar energy system, it is necessary to know how much solar radiation would be available. At present there are many available models to predict the irradiation; however, these are constructed for specific regions. Hence suitable models for prediction of the irradiation in the different regions in Egypt should be selected. Solar radiation data are not easily available for many locations. Most of the solar energy applications require the estimation of the amount of insolation received on an inclined plane. Hence the quantity of diffuse radiation incident on a horizontal surface would be needed for this estimation [3]. It would not be enough for the scientists or engineers in this location to depend on the measured data only but it would be important to use a useful theoretical model which could estimate and predict the solar radiation. In the absence of measured data, theoretical models may be used to calculate the solar radiation. To estimate the theoretical solar radiation on the horizontal surfaces at Suez-Gulf region, seven models are chosen to evaluate the theoretical results. They are ASHREA [4], AWATER&BALL, DAVIS&HAY, HOYT, LACIS&HANSEN, BIRD and SIMPLE SPECTRAL2 models. All these models are used in the theoretical calculation of total irradiation (i.e,.. direct and diffuse) [5]. The main objective of this work is to evaluate statistically these seven models and compare its results with the local measured data. The data used in this comparison are measured by a pyranometer, which is calibrated to give an estimated error equals to $\pm 4\%$ at a location within the Suez Gulf region (latitude: 29^o N; longitude: 33^o E). The accuracy of these models is determined in terms of *MBE*, *RMSE* and *MPE* tests by statistically comparing the calculated and measured values. Based on the results of this comparison, a model is recommended for this region for each of the summer and the winter seasons. And a new correlation is developed and suggested to be used in this region.

2. DESCRIPTION OF THE USED MODELS

The following models are considered in the present work:

1- The ASHREA model correlation (#1) calculates direct and diffuse radiation [4].

$$It1 = (G_{bn} \times \cos(z)) + G_d \quad (1)$$

Where G_{bn} is the direct beam component, G_d is the diffuse component, z is the zenith angle and $It1$ is the total or global radiation.

2- AWATER&BALL model (#2) [5].

$$It2 = I_o(\cos(z))(T_M - a_W) \times T_A / (1 - r_g r_s) \quad (2)$$

Where I_o is the extraterrestrial direct normal solar irradiance and is equal to $I_o = I_{sc} \times (1 + 0.033 \times \cos(n/365 \times 189))$, where I_{sc} is the constant solar flux and is equal to 1367 W/m^2[3], n taken as the day in the year, T_M, a_W and T_A are transmission functions, r_g and r_s are the ground and sky albedos, respectively.

3- BIRD correlation (#3) [5].

$$It3 = (I_{d_B} + I_{as_B}) / (I - r_g r_s) \quad (3)$$

I_{d_B} is the direct solar irradiance; I_{as_B} is solar irradiance from atmospheric scattering W/m^2.

4- DAVIS&HAY model (#4) [5].

$$It4 = I_{d_D} + I_{as_D} + I_{G_D} \quad (4)$$

I_{G_D} is the solar irradiance on a horizontal surface from multiple reflections between the ground and sky in W/m^2. I_{d_D} and I_{as_D} are defined in the appendix-A for this model.

5- HOYT model (#5) [5].

$$It5 = I_{d_H} + I_{as_H} + I_{G_H} \quad (5)$$

Where I_{d_H} is the direct solar irradiance in W/m^2, I_{as_H} is solar irradiance from atmospheric scattering W/m^2 and I_{G_H} is the solar irradiance on a horizontal surface from multiple reflections between the ground and sky in W/m^2. The values of I_{d_H}, I_{as_H} and I_{G_H} are defined in the appendix-A.

6- LACIS&HANSEN (#6) [5].

$$It6 = I_o(\cos(z))[(0.647 - r_s' - a_0)/(1 - 0.0685 \times r_g) + 0.353 - a_W] \quad (6)$$

Where r_s', a_o and a_w transmission functions and r_g is the ground albedo and almost equal to 0.2.

7- The seventh one is the SIMPLE SPECTRAL2 model (#7) [6].

$$It7 = H_{o\lambda} D T_{r\lambda} T_{a\lambda} T_{w\lambda} T_{o\lambda} T_{u\lambda} \tag{7}$$

$It7$ is the direct irradiance on a surface normal to the direction of the sun at the ground level and is taken as a function of the transmission parameters [6]. The above mentioned parameters are illustrated in appendix-A, and in the nomenclature. A computer program is developed for the above models to compute the total incidence on the horizontal surface hourly and instantaneously at different Julian days. The models are named numerically in the following sections and in all tables and figures.

3. STATISTICAL INDICATORS OF GOODNESS OF FIT

Three statistical tests; Mean Bias Error (*MBE*), Root Mean Square Error (*RMSE*) and Mean Relative Percentage Error (*MPE*) are used to evaluate the considered models. The mean bias error is defined by [7] as:

$$MBE = \sum_{j=1}^{N} \frac{Is_{j,calc} - Is_{j,meas}}{N} \tag{8}$$

Where $Is_{j,calc}$ and $Is_{j,meas}$ are the calculated and measured instantaneous values of solar radiation on the horizontal plates, respectively. *N* is the numbers of considered day light hours. The lowest values of *MBE* are always the desired ones. So, the nearest values to the zero level are remarkable. The root mean square error is defined by [7] as:

$$RMSE = \left\{ \sum_{j=1}^{N} \frac{(Is_{j,calc} - Is_{j,meas})^2}{N} \right\}^{1/2} \tag{9}$$

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 and measured values. However, some large errors in the sum can produce a significant increase in *RMSE* [3,7]. The mean relative percentage error may be also applied for estimating the error as follows [8]:

$$MPE = \left[\sum_{j=1}^{N} \frac{(Is_{j,meas} - Is_{j,calc})}{Is_{j,meas}} \times 100 \right] / N \tag{10}$$

For the above three indicators, the lowest error values (nearest to the zero level) are remarkable for the considered models.

4. DATA USED

The hourly mean total radiation values are estimated, using the above models for one location in Suez Gulf region, especially, the area of Suez. The estimated data are compared graphically and statistically with the measured data reported by several investigators for the same location through a time span from 1998 to 2005[9, 10, and 11]. A sample of these data is illustrated in Table 1. The measured data are taken by a high sensitive digital pyranometer. Most solar radiation models rely on measured data for their development or validation, and often the uncertainty or accuracy of that measured data are unknown [12]. The used pyranometer in this work is calibrated to give a scale of error less than about $\pm 4\%$.

Table 1. Sample of the Hourly Average Measured Data Recorded on Different Julian Days Between 1998 and 2005.

Year/day	**Measured values obtained instantaneously in W/m^2**							
1998/21	281	422	500	545	510	426	298	140
1999/265	468	599	730	790	710	660	563	488
2000/203	660	800	881	930	882	781	694	542
2001/234	600	750	833	885	811	705	580	480
2002/320	331	430	482	490	444	361	240	111
2003/274	544	662	721	735	691	543	463	384
2004/281	506	637	690	710	640	528	396	212
2005/160	500	622	712	741	706	623	544	467
Time in hrs	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**

5. RESULTS AND ANALYSIS

Figs 1 to 8 show the deviation between the measured and calculated solar radiation values. A large deviation means that there is no matching between the estimated and these measured data. Fig. 1-a shows the solar radiation for the considered models at the location on 21st of January, 1998. From this figure, it could be seen that the measured data at this day are very close to models 4, 3 and 7. However, model 5 and 6 show large differences. Figs. 1-b,c,d show the statistical indicators analysis *MBE*, *RMSE* and *MPE* respectively. The three statistical indicators give lowest values for models 4 and 3. Fig. 2-a shows the data that are measured at a warm condition on the Julian day 265 in 1999. These data show that model 4 curve matches extremely well. The results of models 3, 1 and 7 are apparent to become closer to the measured data on that day. Models 2, 5 and 6 are far matching with the measured data on the same day. The statistical indicators in Figs. 2-b,c,d are seen to be very close to zero level for models 4, 7 and 3 respectively. Fig. 3 shows the solar radiation data obtained on Julian day 203 in 2000. The measured data in Fig. 3-a are very close to models 2, 3 and 7, respectively. However, models 5 and 6 give poor results on the same day. Fig. 3-b shows that the values of the *MBE* are very close to models 2, 3 and 7 respectively. Also the same conclusion can be derived from Figs. 3-c,d. Figs. 4-a,b,c,d represent the solar radiation curves on Julian day 234 in 2001. The figures show that the measured data are very close to models 3, 2 and 7 respectively. Models 5 and 6 are not match with the measured data on this day. Models 1 and 4 to some extent come next best. Figs. 5-a,b,c,d show the results on Julian day 320 in year 2002 in which models 7 and 4 are considered little bit matching with the measured data. Models 3 and 2 come next best. Figs. 6-a,b,c,d show the same comparison on Julian day 274 in year 2003. The results show that; models 3 and 2 are very close to the measured data. However, models 5, 1, and 6 are not matching with the measured results. Figs. 7-a,b,c,d illustrate the comparison between the model results on Julian day 281 in year 2004. These results show that they are in agreement with models 3 and 4. Model 7 comes next best in the same Julian day. Figs. 8-a,b,c,d show the results on Julian day 160 in year 2005. The measured results are very close to models 4 and 3 respectively. However, models 5 and 6 are not in match with the measured results. A similar analysis is performed for a large amount of measured data along the considered time span (1998-2005) [9-11].

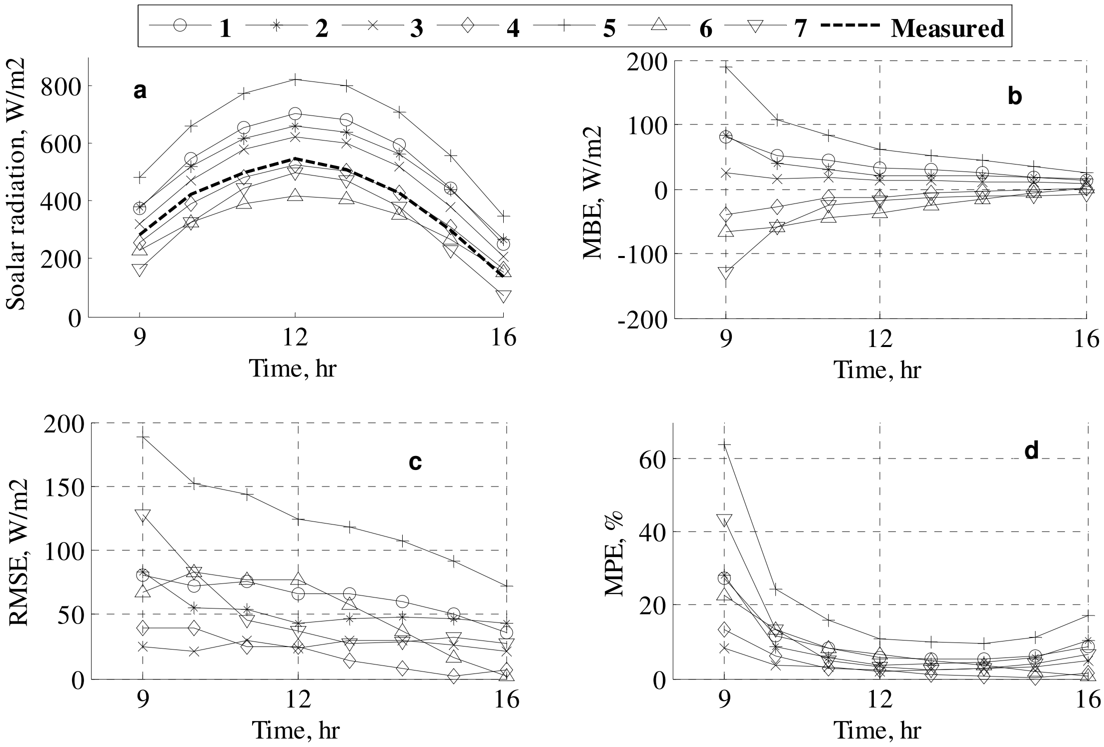

Figure 1. Solar radiation data measured on Julian day 21st, 1998, compared with different models results and its statistical analysis.

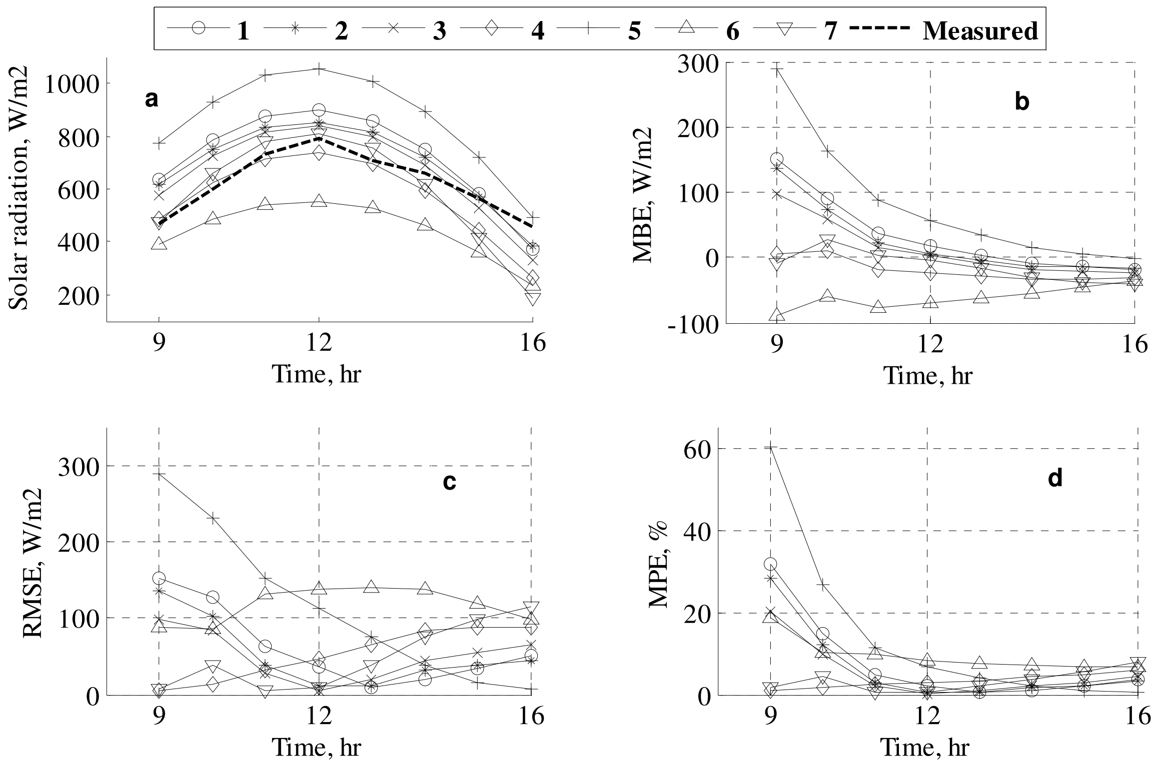

Figure 2. Solar radiation data measured on Julian day 265 in 1999 compared with different models results and its statistical analysis.

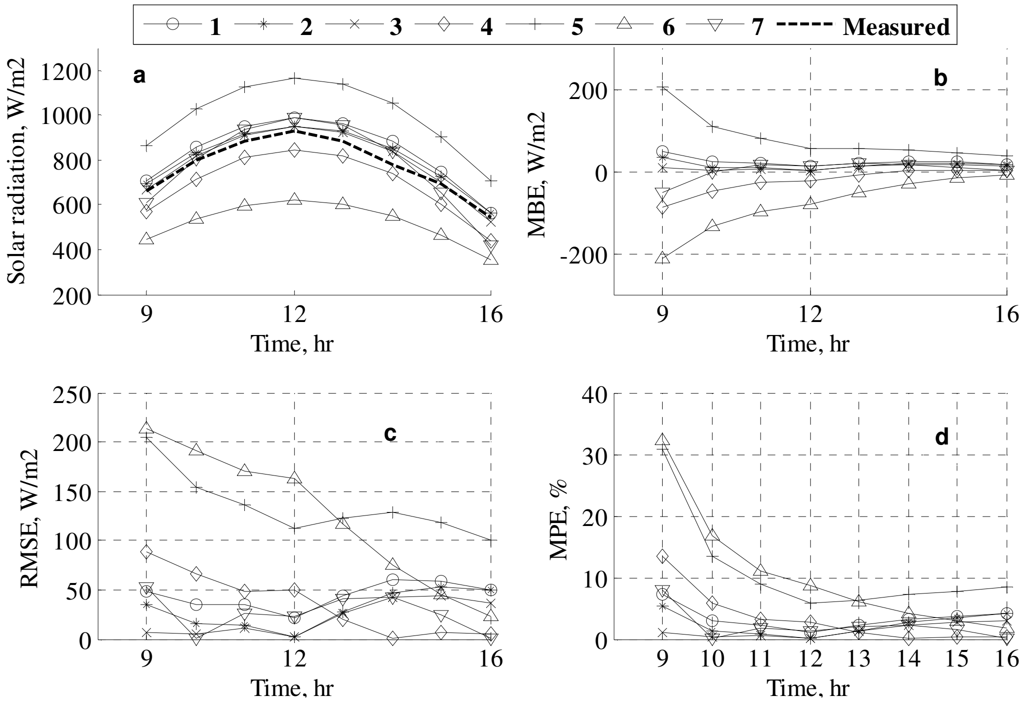

Figure 3. Solar radiation data measured on Julian day 203 in 2000 compared with different models results and its statistical analysis.

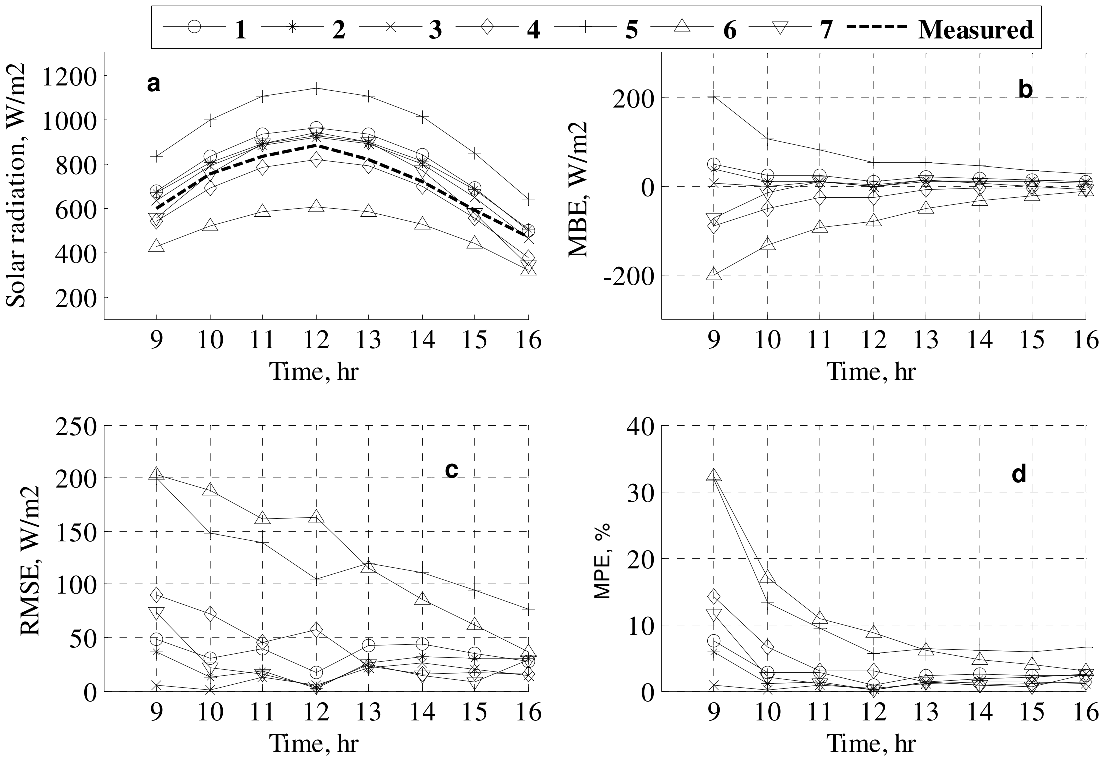

Figure 4. Solar radiation data measured on Julian day 234 in 2001 compared with different models results and its statistical analysis.

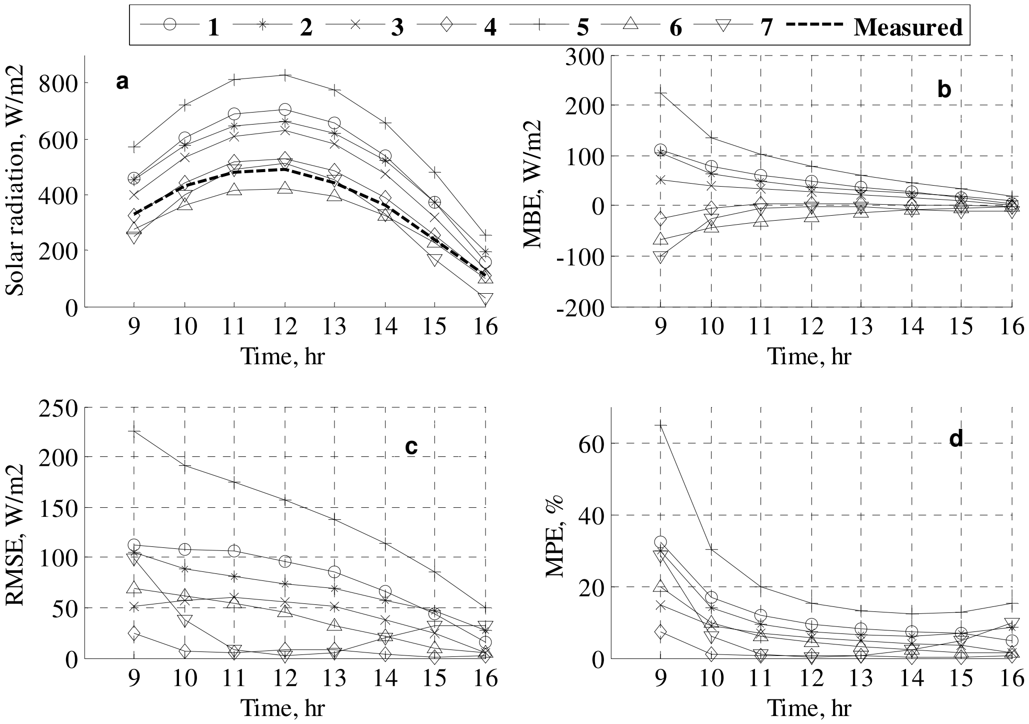

Figure 5. Solar radiation data measured on Julian day 320 in 2002 compared with different models results and its statistical analysis.

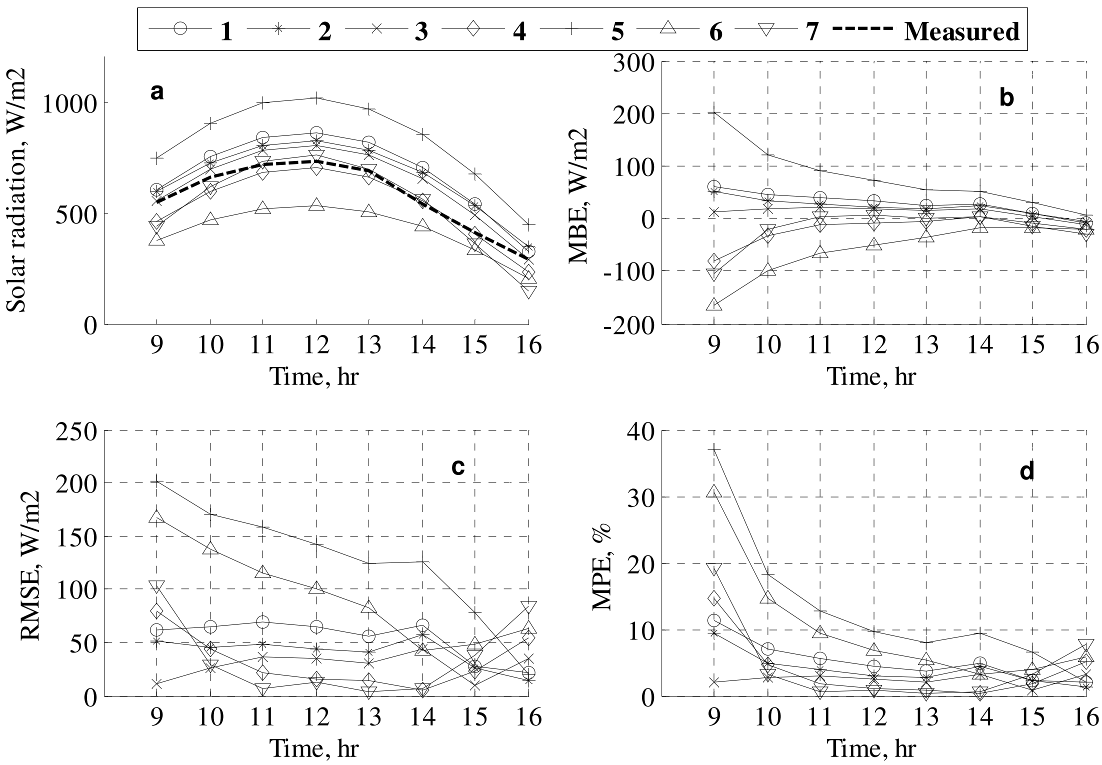

Figure 6. Solar radiation data measured on Julian day 274 in 2003 compared with different models results and its statistical analysis.

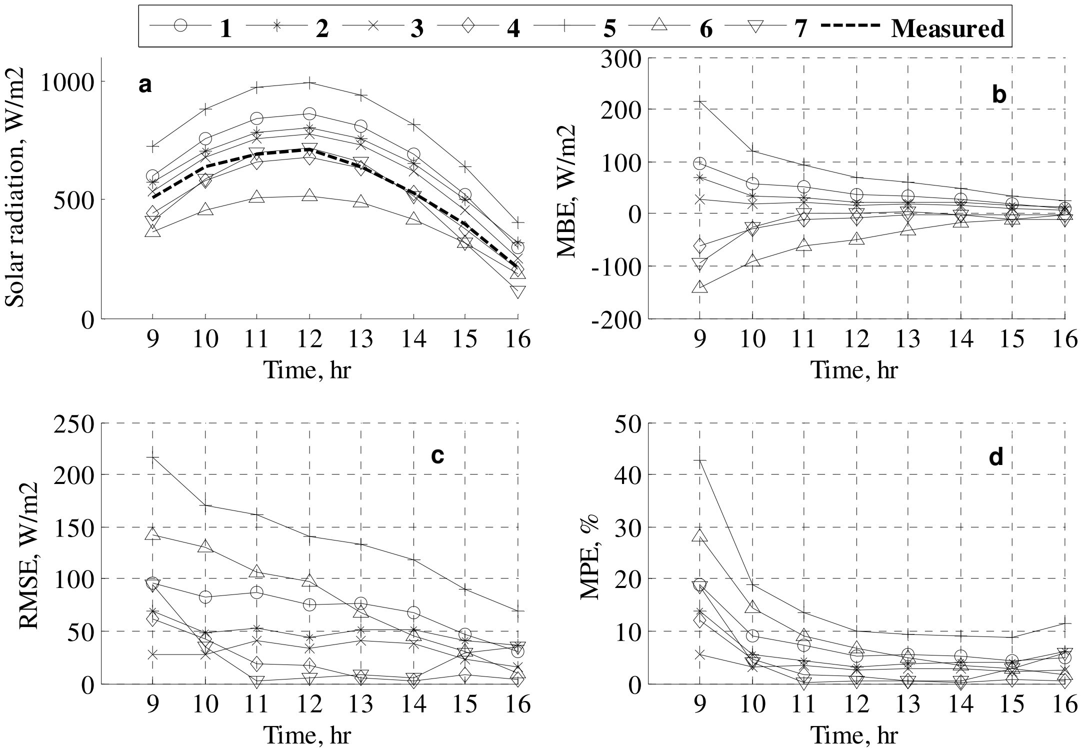

Figure 7. Solar radiation data measured on Julian day 281 in 2004 compared with different models results and its statistical analysis.

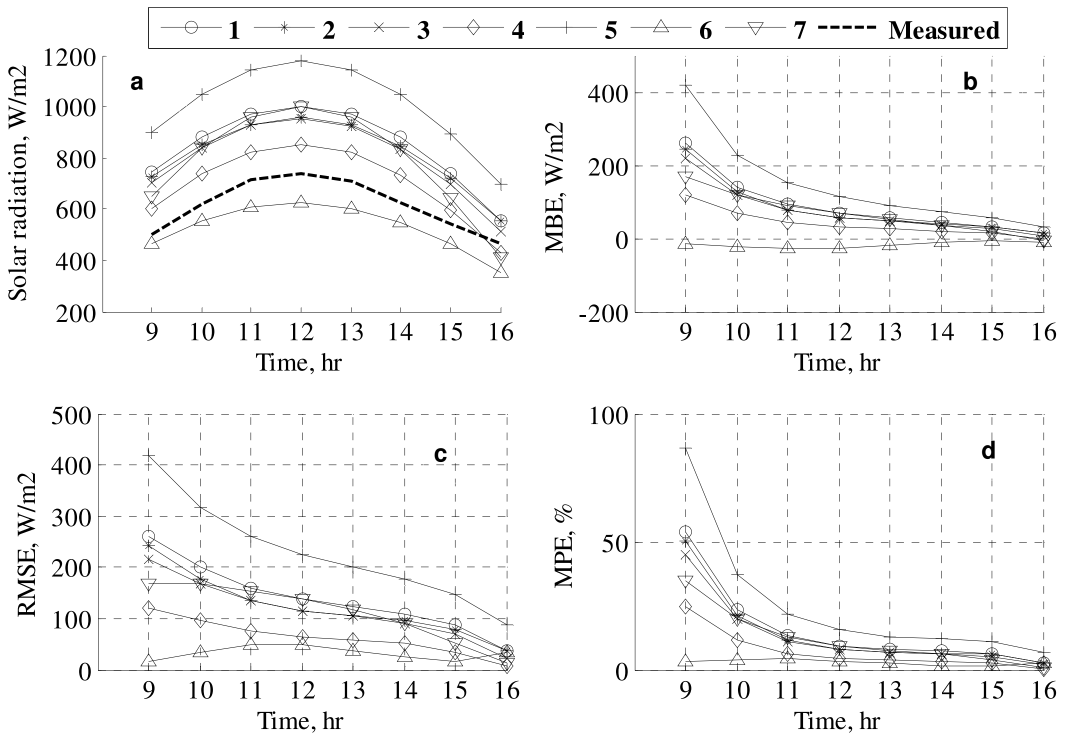

Figure 8. Solar radiation data measured on Julian day 160 in 2005 compared with different models results and its statistical analysis.

It can be concluded from the previous analysis that BIRD (#3) and DAVIES&HAY (#4) models are generally yield the best results in comparison with the measured data. The average values for the *MBE*, *RMSE* and *MPE* for each model are illustrated in Tables 2 to 4. For the *MBE*, Table 2 shows that models 3 and 4 provide lowest values in W/m^2. The lowest values are remarkable on Julian days 234/2001, 274/2003 and 281/2004 for model 3 and on 21/1998, 320/2002 and 160/2005 for model 4. The average values for all models in Table 2 show that the lowest values go to models 3 and 4 by 16.3 and 22 W/m^2 respectively. For the *RMSE*, Table 3 shows that models 3 and 4 give the same indication as presented in Table 2. The lowest of the average values for all seasons in the *RMSE* table go to models 3 and 4 by 29 and 37 W/m^2 respectively. For *MPE*%, Table 4 shows that models 3 and 4 give the lowest average values as 3.4% and 3.7% respectively. However, model 5 gives average results which are deviated approximately by 15%. Models 2, 7 and 1 come next best as 5.37%, 5.4% and 6.8%, respectively. From Tables 2, 3 and 4, globally, models 3 and 4 both are yield the best results. Models 2 and 1 come next as illustrated with the different types of three the error percentages. But model 2 is considered to be applicable only to extremely clear atmospheric conditions like model 1, with an atmospheric turbidity ranges between 0.1-0.5 (μm) wavelengths [5]. Although, this model is extremely simple but does not have a good method for treating the aerosol transmittance [5]. Models 3 and 7 give good results in the summer season, since they can estimate all the transmission parameters. Model 4 provides good agreement with the measured data, especially, in winter but also does not have a good method for treating the aerosol transmittance. Models 5 and 6 give unacceptable results since the errors would be very large. And when recalculating the transmittance and absorptance parameters at modified air mass values, this model will be relatively difficult to be used [5].

Table 2. The Average *MBE* Errors for the Seven Models on Eight Different Julian Days for One Location (W/m^2).

Season	**Win**	**Spr**	**Sum**	**Sum**	**Aut**	**Aut**	**Aut**	**Spr**	**Average**
Model	**21/1998**	**265/1999**	**203/2000**	**234/2001**	**320/2002**	**274/2003**	**281/2004**	**160/2005**	
1.ASHREA	37.33	35.91	7.16	17.57	29.57	27.65	32.04	72.229	34.7
2.ATWATER&BALL	31.54	26.63	-0.874	10.21	41.5	12.25	19.12	62.889	25.7
3.BIRD	13.09	16.41	-6.84	2.86	25.26	1.25	7.37	57.409	16.3
4.DAVIES&HAY	-12.36	-15.49	-40.42	-30.64	-2.36	-30.83	-24.38	23.747	22
5.HOYT	75.73	84.37	63.45	72.39	87.36	68.53	73.72	127.98	81.4
6.LACIS&HANSEN	-31.18	-58.93	-96.34	-81.73	-24.54	-69.87	-60.56	-34.09	56.9
7.SPECTRAL2	-34.68	-10.23	-14.34	-11.62	-20.57	-29.77	-26.52	52.189	25

Note: The shaded cells tend to the lowest values, Win: winter, Spr: spring, Sum: summer, Aut: autumn.

Table 3. The Average *RMSE* Errors for the Seven Models at Eight Different Julian Days for One Location (W/m^2).

Season	**Win**	**Spr**	**Sum**	**Sum**	**Aut**	**Aut**	**Aut**	**Spr**	**Average**
Model	**21/1998**	**265/1999**	**203/2000**	**234/2001**	**320/2002**	**274/2003**	**281/2004**	**160/2005**	
1.ASHREA	63.62	60.23	12.74	30.01	49.12	51.66	55.04	112.42	58
2.ATWATER&BALL	52.54	44.41	5.65	17.46	68.69	26.4	34.34	96.977	43.3
3.BIRD	24.41	37.23	12.39	10.93	42.85	17.41	15.42	88.647	29
4.DAVIES&HAY	19.48	36.54	64.38	47.89	7.47	47.64	34.92	40.03	37
5.HOYT	122.71	126.27	102.68	118.5	142.02	111.5	122.12	202.5	130
6.LACIS&HANSEN	52.83	106.65	156.37	132.77	37.51	111.31	93.46	60.293	93
7.SPECTRAL2	51.46	34.54	27.76	26.14	29.14	44.45	37.81	89.326	41

Note: The shaded cells tend to the lowest values, Win: winter, Spr: spring, Sum: summer, Aut: autumn.

Table 4. The Average *MPE%* Errors for the Seven Models at Eight Different Julian Days for One Location.

Season	Win	Spr	Sum	Sum	Aut	Aut	Aut	Spr	Average
Model	**21/1998**	**265/1999**	**203/2000**	**234/2001**	**320/2002**	**274/2003**	**281/2004**	**160/2005**	
1.ASHREA	9.83	7.03	0.92	2.47	7.52	4.61	5.68	11.744	6.8
2.ATWATER&BALL	8.27	5.54	0.36	1.57	11.02	2.28	3.66	10.302	5.37
3.BIRD	3.49	4.39	1.02	0.719	6.26	1.53	1.33	9.317	3.4
4.DAVIES&HAY	3.57	2.43	5.17	4.24	1.44	5.16	4.16	4.215	3.7
5.HOYT	20.91	14.34	8.04	10.03	22.95	10.687	13.11	20.828	15
6.LACIS&HANSEN	7.72	9.25	12.09	11.12	6.1	11.12	10.07	5.365	9
7.SPECTRAL2	10.14	2.68	2.58	2.67	6.601	5.36	5.204	8.688	5.4

Note: The shaded cells tend to the lowest values, Win: winter, Spr: spring, Sum: summer, Aut: autumn.

Julian day's samples that are presented in the previous figures and tables just an example about the error values of the models at different seasons of the year. For example, Julian day 21/1998 shows the models error status as an example in winter seasons and so on for the all the chosen days. Table 5 shows the error analysis of *MPE%* for winter and summer seasons from 1998 to 2005. The table is based on the results of BIRD and DAVIES&HAY models (The lowest values). Each season is compound from three months. The *MPE%* is estimated three times per month for each season. Table 5 shows that the lowest error values are remarkable for DAVIES&HAY model in winter seasons, and the same is existed for BIRD model during summer seasons. The average error values for each month helping to represent the total average error value for each season (Winter-Summer). For this reason the table shows that the average error values for each model are not exceeding about 2.68% for DAVIES&HAY model (winter) and 2.7% for BIRD model (summer).

Table 5. The *MPE%* Errors for BIRD and DAVIES&HAY in Winter and Summer Seasons from 1998 to 2005.

Season	Year	MPE% values for winter and summer:									Average:
		December			January			February			
Winter for DAVIES& HAY	1998	1.8761	1.5605	1.6548	1.717	3.4	4.1	2.7	2.6	4.4	2.6484
	1999	1.7861	1.6505	1.4558	1.613	3.344	4.102	2.127	1.96	3.4	2.5768
	2000	2.1	1.65	1.48	1.237	3.14	4.4	1.97	2.2206	4.41	2.5842
	2001	1.81	1.05	1.48	1.103	3.25	4.09	2.37	2.36	4.3	2.5905
	2002	1.62	1.209	1.358	1.862	3.31	3.91	2.66	2.97	2.994	2.6468
	2003	1.681	1.55	1.68	1.73	3.24	4.22	2.57	2.106	3.894	2.6124
	2004	1.71	1.605	1.58	1.67	3.41	4.91	2.507	2.76	4.293	2.5937
	2005	2.062	1.305	1.383	1.597	3.33	3.981	2.579	2.496	4.54	2.6876
Summer for BIRD		June			July			August			
	1998	9.3	1.322	1.456	2.402	1.0206	3.1672	1.6317	0.72	2.816	2.6676
	1999	9.26	1.242	1.43	2.418	1.126	3.2	1.17	0.729	2.616	2.382
	2000	9.02	1.2	1.36	2.3102	1.006	3.2	1.7	0.662	2.8	2.512
	2001	10.001	1.2	1.4	2.12	1.01	3.12	1.1637	1.2	2.1	2.4237
	2002	9.42	1.32	1.536	2.42	1.26	3.162	1.31	0.742	2.651	2.4326
	2003	9.13	1.8	1.3	2.3	1.092	3.06	1.53	0.6	2.7	2.519
	2004	9.17	1.129	1.5	2.3	1.1	3.0962	1.737	0.81	2.501	2.7161
	2005	9.4	1.222	1.515	2.302	1.226	3.006	1.83	0.597	3.09	2.5859

6. NEW CORRELATION

It is important to develop a simple, accurate and easy to use correlation for the considered location. For that a statistical linear regression technique is used to predict a new correlation for the estimation of the total insolation on horizontal surfaces. A new correlation S.C.S.G (Solar Correlation in Suez Gulf) is developed as follows;

$$It8 = (A \times I_o \cos(z)) - C_{season} \tag{11}$$

Where *It*8 is the total insolation on horizontal surfaces, *A* is the correlation non-varying constant and always equals to 0.709 for all seasons. C_{season} is the correlation varying constant that changes according to the variation of the seasons. Table 6 shows the different values of the C_{season}.

Table 6. The S.C.S.G Correlation Constants *A* and C_{season} for Different Seasons.

Seasons and Julian days (n):	**Dec, Jan, Feb: (winter)**	**Mar, Apr, May: (spring)**	**Jun, Jul, Aug: (summer)**	**Sep, Oct, Nov: (autumn)**
A:	0.709			
C_{season}:	90.36	84.13	60.031	88.178

Equation (11) is only deduced for the Suez-Gulf region (latitude: 29° N; longitude: 33° E). The new correlation is compared with the most accurate models; BIRD and DAVIES&HAY from the side of *MPE%*. And there is no need to compare between it and the other models. Fig. 9 shows the *MPE%* for models S.C.S.G (*It*8), BIRD (*It*3) and DAVIES&HAY (*It*4) along different Julian days. Fig. 9 shows that on Julian day 21, S.C.S.G (*It8*) and DAVIES&HAY (*It4*) models presented a small deviation of error compared with *It*3. *It*3 gives minimum *MPE%* for Julian days 203/2000, 234/2001, 274/2003, 281/2004 and 171/2005. Table 7 illustrates the *MPE%* for the proposed S.C.S.G model compared with (*It*3) and (*It*4) along different Julian days and seasons. *MPE%* for S.C.S.G model is found to be not exceeding about 4.9% error. However, *MPE%* for BIRD and DAVIES&HAY models is not exceeding about 6.25%, 5.17% respectively. Generally these three models (S.C.S.G, BIRD and DAVIES&HAY) yield the lowest values of *MPE%* error than the other examined models in this article.

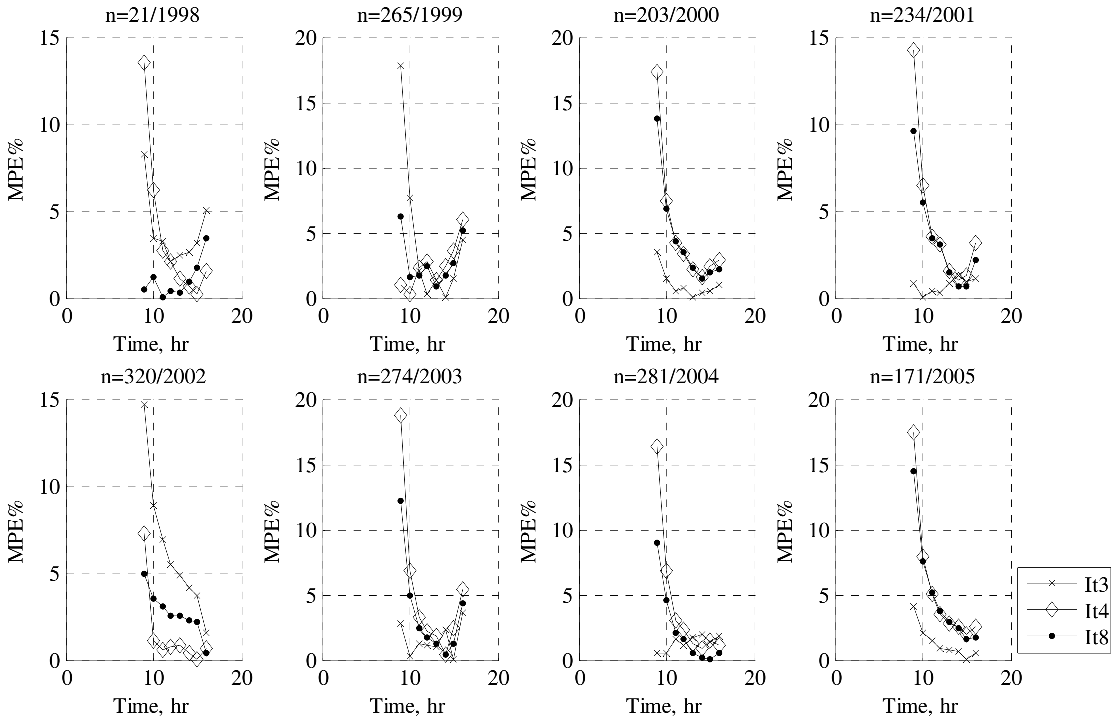

Figure 9. The *MPE%* for models: (*It*3), (*It*4) and (*It*8) along different Julian days.

Table 7. The Average *MPE%* for Equation (11) Compared with BIRD *(It3)*, DAVIES&HAY *(It4)* and S.C.S.G *(It8)* Models Along Different Julian Days.

Season	**Win**	**Spr**	**Sum**	**Sum**	**Aut**	**Aut**	**Aut**	**Sum**
Model	**21/1998**	**265/1999**	**203/2000**	**234/2001**	**320/2002**	**274/2003**	**281/2004**	**171/2005**
BIRD (It3)	3.49	4.39	1.02	0.719	6.26	1.53	1.33	1.3
DAVIES&HAY (It4)	3.57	2.43	5.17	4.24	1.44	5.16	4.16	5.4
S.C.S.G (It8)	2.2428	2.7872	3.7166	2.3521	2.5486	3.8117	2.5848	4.9

Note: The shaded cells tend to the lowest values, Win: winter, Spr: spring, Sum: summer, Aut: autumn.

7. CONCLUSIONS

ASHREA, ATWATER&BALL, BIRD, DAVIES&HAY, HOYT, LACIS&HANSEN and SPECTRAL2, models are presented and used to estimate the instantaneous direct and diffuse insolation on horizontal surfaces at Suez-Gulf area. BIRD and DAVIES&HAY models are most accurate for this area. The lowest hourly *MBE*, *RMSE* and *MPE* are recorded to BIRD and DAVIES&HAY models while the highest deviations are found with HOYT and LACIS&HANSEN models. BIRD model gives superior results in summer; however, DAVIES&HAY gives the same superior results in the winter. ASHREA and SPECTRAL2 models would be the next best ones. HOYT and LACIS&HANSEN models give poor indications about this location compared with the measured data. Also a simple new correlation (S.C.S.G) is developed to predict the total insolation only in the Suez-Gulf region. The new suggested correlation gives an acceptable result compared with BIRD and DAVIES&HAY. S.C.S.G model gives minimum error results in winter seasons against summer. The developed correlation is simple and valid for all seasons at the mentioned location. Generally DAVIES&HAY, BIRD and S.C.S.G models would be recommended to be employed for the calculation of the total solar radiation (direct and diffuse) instantaneously at Suez-Gulf Area.

NOMENCLATURE

a_w	*Water vapor Absorptance*
A	*The apparent solar irradiance at air mass zero (ASHREA model), and equal to 0.69 in (S.C.S.G model)*
C	*Is the diffuse radiation factor (ASHREA)*
C_{season}	*Is the season coefficient (S.C.S.G model)*
G_{bn}	*The global normal beam (ASHREA)*
G_d	*The global diffuse (ASHREA) W/m²*
I_{as}	*Solar irradiance on a horizontal surface from atmospheric scattering(W/m²)*
I_d	*Direct solar irradiance on a horizontal surface (W/m²)*
I_G	*Solar irradiance on a horizontal surface from multiple reflections between the ground and sky (W/m²)*
I_s	*Solar irradiance on a horizontal surface from scattered light (I_{as}+I_G)*
I_T	*Total (global) Solar irradiance on a horizontal surface (W/m²)*
It1,2,3,4,5,6,7,8	*Total (global) Solar irradiance on a horizontal surface for ASHREA, ATWATER&BALL, BIRD, DAVIES&HAY, HOYT, LACIS&HANSEN, SPICTRAL2 and S.C.S.G models respectively (W/m²)*
I_0	*Extraterrestrial Solar irradiance (1367 W/m²)*
MBE	*Mean bias error (W/m²)*

MPE	*Mean percentage error (%)*
n	*Julian day number*
r_g	*Ground albedo*
r_s	*Sky, or atmospheric, albedo*
$r_S^{'}$	*Correlation by LACIS&HANSEN*
RMSE	*Root mean square error (W/m²)*
T_A	*Transmittance of aerosol absorptance and scattering*
T_{AA}	*Transmittance of aerosol absorptance*
T_M	*Global Transmittance of all molecular effects except water vapor for Atwater*
T_{Md}	*Direct transmittance of all molecular effects except water vapor for Atwater*
T_0	*Transmittance of ozone absorptance*
T_R	*Transmittance of Rayleigh scattering*
T_{ws}	*Transmittance of water vapor scattering*
z	*Zenith angle (degree)*
Subscript	
B	*BIRD*
D	*DAVIES&HAY*
H	*HOYT*

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