A new solar radiation models for IRAN

Shahram Javadi
Islamic AZAD University
Central Tehran Branch
IRAN
sh.javadi@iauctb.ac.ir

Sam Moini
Islamic AZAD University
Central Tehran Branch
IRAN

Abstract
The availability of observed solar radiation measurements has proven to be spatially and temporally inadequate for many applications, leading to research focused on the estimation of solar radiation. Various methods have established empirical relationships between measured solar radiation and more commonly observed meteorological and astronomical variables. Sunshine hours are the only long term, reliable and available measured information that can be used to reach highly accurate estimates of solar radiation values on the Earth surface. In this paper the sunshine duration is used to estimate monthly average daily solar radiation on a horizontal surface, it can be used to predict solar radiation in different climatic region of Iran. According to the Kopen classification of climate and considering the sunshine hours five climatic regions are identified for Iran. One of the best models that used sunshine duration to estimate monthly average daily solar radiation on a horizontal surface is the Angström model. Angström coefficients depend on geographical and meteorological parameters, The correlation equations developed are employed to calculate the monthly average daily global solar radiation for various location of Iran, By using the pyranometric stations solar radiation data(H) and the daily sunshine hours (n) will be measured sunshine recorders which were achieved by IRIMO and by calculating N,H0 from Angström equations and utilizing SPSS software ,a regression relation for this five region of Iran has been obtained.

Keywords: solar radiation, model, climate, solar atlas

1. Introduction
Solar irradiation is dependent on different causes including astronomical and meteorological factors. The most reliable way to measure the solar irradiation is installing Pyranometers in stations to record global solar irradiation data amount of solar radiation that reaching the earth surface depends on climatic location of the place. In the absence of a measuring instrument, accurate and reliable solar radiation data is not available. Also error in measurement of this instrument may be as high as 30% even for the averages of the readings and it might be far better to use the sunshine based estimation empirical models instead of using the records of this instrument which is very costly exercise.
Iran has various climates and is located in a region where the potential of global solar irradiation is considerably high. In the construction and validation of all types of models and/or correlations accurate Long term and spatially wide range surface data is needed.
In practical studies it is not possible to consider all the factors and therefore effective models for its prediction use a few numbers of factors are presented. Many researchers derived their models by using sunshine hours, relative humidity, latitude, air temperature of location of interest. Sabbagh [1] estimated the daily solar radiation at various places, by using sunshine hours, Maximum air temperature, latitude and relative humidity. Paltridge and Proctor [2] employed day length cloud fraction and latitude in a model to determine direct and diffuse daily solar radiation at the Earth surface. Daneshyar's [3] model is using the meteorological data of Tehran and Paltridge method to estimate daily total solar radiation for Tehran, (Iran). Samimi

[4] worked on the formula which was suggested by Meinel and Meinel [5] and corrected the coefficients of it by considering the Earth-Sun distance, cloud fraction, Sunshine hours and altitude of the place and used it for various cities of Iran, Yaghoubi and Sabazevari [6] estimated monthly clearness index for Shiraz,(Iran)by using sunshine hours , Jafarpour and Yaghoubi [7] used four different models in order to estimate monthly and annual radiation for Shiraz,(Iran). Sabziparvar [8] used sunshine duration, cloud cover, relative humidity and average of maximum temperature as the input of several radiation models, the monthly average daily solar radiation on horizontal surface in various cities of Iran, Ashjaee [9] worked on tow radiation models of Daneshyar and Bird and Hulstrom to predict daily solar energy for a few specific location of Iran.

Other studies used sunshine hours to estimate surface global solar radiation for different place in the world such as Al-Mohammad [10] Almorox [11] and zhou [12]. The first of such empirical models takes into consideration only the sunshine duration measurements for the solar irradiation estimation. Sunshine hours are the only long term, reliable and readily available measured information that can be used to reach highly accurate estimates of solar irradiation values on the Earth surface.

Controversially, long term records of bright sunshine hours are relatively accurate as the most common instrument used is very simple and quite free of human interfere to run. It is Campbell-Stokes type sunshine recorders. The sum for all the hours within a day gives the value of the daily bright sunshine hours [13].

The objectives of the presented study are:

1) Work on relationship between the global solar radiation and bright sun shine hours,

2) Calculate the Angstrom correlations for various places of Iran by using the climate classification and Angstrom empirical formula.

2. Algorithm

2.1. Data Gathering

Data were taken from Iran Meteorological Office (IRIMO) [14]. Data were quality controlled by using the statistic SPSS software, and data which were out of the standard deviation were taken out of consideration. The daily sunshine hours (n) were measured by Campbell–Stokes sunshine recorders and the total daily solar radiation were recorded by Kipp and Zonen (CM5) Pyranometers and CC1 integrators for 21 location(table 1).

2.2. Methodology

The first model that used sunshine duration to estimate monthly average daily solar radiation on a horizontal surface is the Angström [15] equation.

$$\frac{\overline{H}}{\overline{H}_{\circ}} = a + b\left(\frac{\overline{n}}{\overline{N}}\right) \quad (1)$$

Where $\overline{H}$ (MJ/m2 day) monthly average daily global solar radiation on a horizontal surface. $H_{\circ}$ is the extra terrestrial daily radiation available outside the atmosphere on a horizontal plane. The monthly average daily extraterrestrial solar radiation on a horizontal surface ($H_{\circ}$) was calculated from the following Klein [16] equation (2)

$$\overline{H}_{\circ} = \frac{24 \times 3600\, G_{sc}}{\pi}\left(1 + 0.033\cos\frac{360\, n}{365}\right) \times \left[\cos\phi\cos\delta\sin\omega_s + \frac{\pi\,\omega_s}{180}\sin\phi\sin\delta\right] \quad (2)$$

Where G_{sc} is the solar constant in energy unit (1373 $\frac{W}{M^2}$ which is calculated in this paper), ϕ is the latitude of the location (degrees), n is the day of the year, δ is the declination angle in degrees (-2.345 $\leq \delta \leq$ 23.45), ω_s is the sunset hour angle in degree. The solar declination and sunset hour angle calculated by the following equation (3), (4)

$$\delta = 23.45\sin\left(360\,\frac{284 + n}{365}\right) \quad (3)$$

$$\omega_s = \cos^{-1}(-\tan\phi\tan\delta) \quad (4)$$

$\overline{n}$ Is the monthly average daily bright sunshine hours. $\overline{N}$ is the maximum possible monthly average daily sunshine hours (the day length) which is calculated by following Cooper's [17] equation (5)

$$N = \frac{2}{15}\omega_S \qquad (5)$$

Many researchers such as: Akinoglu and Ecevit (1989) [18]; Gopinhathan (1988) [19]; Rietvel (1978) [20]; Abdalla and Baghdady (1985) [21] expressed Angström coefficients (a,b) in terms of different geographical and climatic parameters such the latitude, altitude, sunshine fraction, temperature, precipitation.
Parameters a & b, are coefficients of Angstrom equation are calculated for 21 stations of Pyranometers in Iran. (table1)

Table1: Coefficients of Angstrom equation for 21 stations of Pyranometers in Iran

No.	City	a	b
1	BANDARABASS	0.34	0.306
2	JASK	0.404	0.202
3	BUSHEHR	0.359	0.331
4	BIRJAND	0.373	0.351
5	BOJNURD	0.348	0.342
6	RAMSAR	0.404	0.204
7	ZANJAN	0.352	0.372
8	HAMEDAN	0.341	0.37
9	OROOMIEH	0.402	0.305
10	TABRIZ	0.375	0.301
11	TEHRAN	0.346	0.343
12	MASHHAD	0.335	0.332
13	YAZD	0.345	0.398
14	TABASS	0.372	0.35
15	KERMAN	0.322	0.421
16	SHIRAZ	0.317	0.405
17	KERMANSHAH	0.331	0.396
18	KARAJ	0.338	0.256
19	ESFAHAN	0.361	0.35
20	KHORBIABANAK	0.321	0.404
21	ZAHEDAN	0.28	0.433

3. Climate Classification

Climate is derived from the Greek term Klima which means slope that refers to the difference and change of the angular incident of the solar radiation. Dominant weather in a region for a long period is named the climate of that region [22].
According to the Kopen classification of climate which is based upon the rate of temperature and precipitation the same climate are identified and set in one group. Finally considering the climatic similarity and taking account of the sunshine hours, 5 climatic regions are identified. (kopen climatic map).

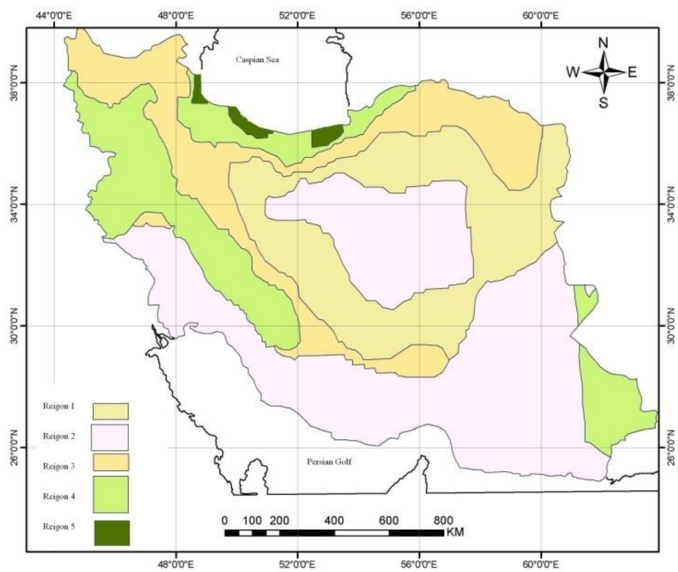

Figure (1): Climate Classification for IRAN

4. Result

By using the pyranometric stations solar radiation data (H) and the daily sunshine hours (n) were measured sunshine recorders which were achieved by IRIMO and by calculating N, H0 from equations (2) and (5) and utilizing SPSS software, a regression relation for this five region has obtained (Table 2) the graph of total solar radiation (TSR) according to sunshine hours for these five climate are as follow (Figure2-6).

Table 2

climate	Relationship
1	$\frac{H}{H_\circ} = 0.352 + 0.373(\frac{n}{N})$
2	$\frac{H}{H_\circ} = 0.317 + 0.386(\frac{n}{N})$
3	$\frac{H}{H_\circ} = 0.343 + 0.347(\frac{n}{N})$
4	$\frac{H}{H_\circ} = 0.360 + 0.359(\frac{n}{N})$
5	$\frac{H}{H_\circ} = 0.404 + 0.204(\frac{n}{N})$

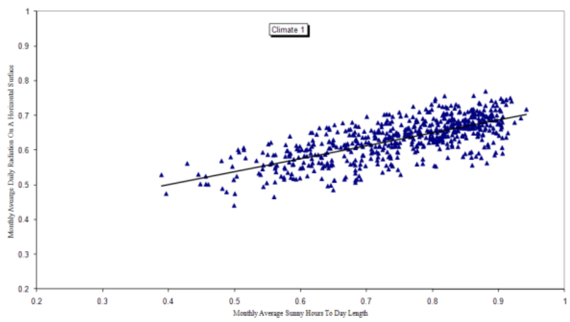

Figure 2

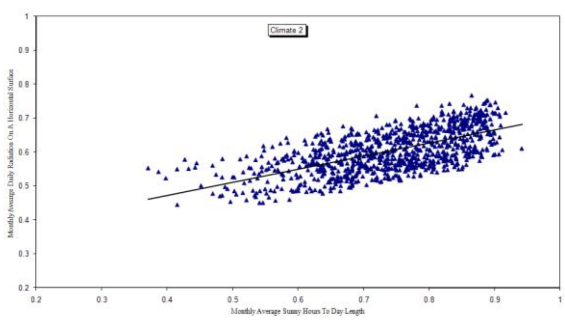

Figure 3

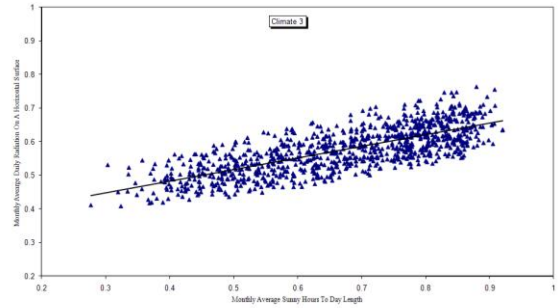

Figure 4

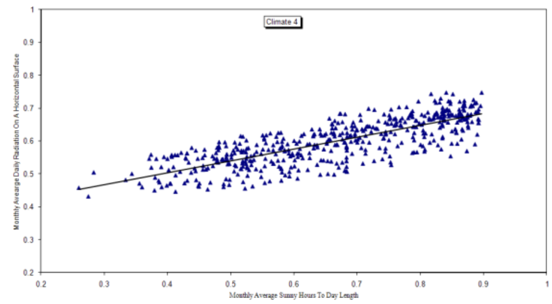

Figure 5

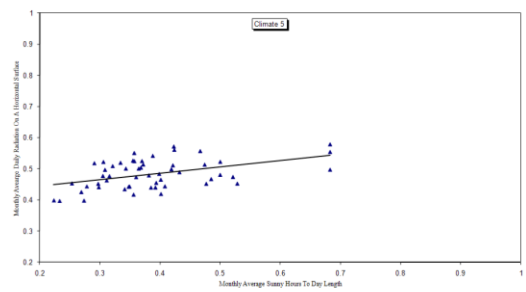

Figure 6

5. Discussion

Considering the sunshine hours which is the important factor for estimating global solar radiation and the fact that Iran is a country in which sunshine hours are sensible therefore the Angesterom model could be the best for estimating the solar radiation. Considering the resultant achieved, Angesterom coefficient for each climate are in a normal state and close to each other (about 0.3) and getting more space between these coefficient amounts implies the special climate of that region as we see the fifth climate which is for the Iran Norton region separation with respect to other climates are completely sensible.

Reference

1] Sabbagh J, Sayigh AAM, Al-Salam EMA. Estimation of the total solar radiation from meteorological data. Sol Energy 1977;19:307–11.

[2] Paltridge GW, Proctor D. Monthly mean solar radiation statistics for Australia. Sol Energy 1976;18:235–43.

[3] Daneshyar M. Solar radiation statistics for Iran. Sol Energy 1978;21:345–9.

[4] Samimi J. Estimation of height-dependent solar irradiation and application to the solar climate of Iran. Sol Energy 1994;52:5401–9.

[5] Meinel, A.B., and Meinel, M.P., (1977), “Applied Solar Energy, An Introduction”, Addison-Wesley Publishing, Company, Tuscon, Arizona.

[6] M. A. Yaghoubi and A. Sabazevari, “Further data on solar radiation in Shiraz, Iran,” *Renewable Energy*, vol. 7, no. 4, pp.

[7] Jafarpur K, Yaghoubi MA. Solar radiation for Shiraz, Iran. Sol Wind Technol 1989;6(2):177–9.

[8] Ali A. Sabziparvar, H. Shetaee, "Estimation of global solar radiation in arid and semi-arid climates of East and West Iran", Energy, Vol. 32, 2007, pp 649–655

[9] Ashjaee M, Roomina MR, Ghafouri-Azar R. Estimating direct, diffuse and global solar radiation for various cities in Iran by two methods and their comparison with the measured data. Sol Energy 1993;50:441–6.

[10] Al-Mohammad A. Global, direct and diffuse solar-radiation in Syria. Appl Energy 2004;79:191–200.

[11] Almorox J, Benito M, Hontoria C. Estimation of monthly Angstrom–Prescott equation coefficients from measured daily data in Toledo, Spain. Renewable Energy 2005;30:931–6.

[12] Zhou J, Yezheng W, Gangm Y. General formula for estimation of monthly average daily global solar radiation in China. Energy Conversion Manage 2005;46:257–68.

[13] Viorel Badescu Modeling Solar Radiation at the Earth's Surface

[14] Islamic Republic of Iran Meteorological Office (IRIMO). Annual year book reports, Data Center, Tehran, Iran, 1988–2000.

[15] A. Angstrom, Solar and terrestrial radiation. *Q.J.R. Meteorol. Soc.* 50, 121 (1924).

[16] S. A. Klien, *Solar Energy*, **19,** (1977), 325.

[17] Cooper PI. The absorption of solar radiation in solar stills. Sol Energy 1969;12(B):333–46.

[18] B.G. Akinoglu and A. *Ecevit,"Constructionofa quadratic model using modified Angstrom coefficients to estimate global solar radiation",* 45, 85 (1990).

[19] GOPINATHAN .K. K,(1988),” A simple method for predicting global solar radiation on a horizontal surface”, Sohw & Wind Teclmolo9) Vol 3. No. 5, pp. 581 583. 1988

[20] M. R. Rietveld, *Agric.Meteoro*., **19,** (1978), 243.

[21] Viorel Badescu Modeling Solar Radiation at the Earth's Surface

[22]Mohamadreza Kavyani,Bohlol Alijani, The Foundations of climatology