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Global radiation derived from sunshine data

G. V. KUMAR and B. MANIKIAM*

Regional Meteorological Centre, Madras

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सार — धूप या मेघ आँकड़ों से माध्य दैनिक विश्व सौर विकिरण की संगणना के लिए विगत वर्षों में कुछ आनुभविक सूत्रों का उपयोग किया गया है। सौर विकिरण को मापने वाले उपकरण, प्रयुक्त विधि पर निर्भर रहते हुए या तो प्रत्यक्ष विकिरण अथवा विसरित विकिरण को मापते हैं। मापित धूप के घंटों और प्राप्त प्रत्यक्ष सौर विकिरण में सहसंबंध स्थापित किया जा सकता है। दिल्ली के लिए एक वर्ष (1971) के आंकड़ों का प्रयोग करके एक आनुभविक सूत्र को अपनाया गया है और उसका परीक्षण किया गया है। यह देखा गया है कि सहसंबंध अप्रैल माह के अतिरिक्त अन्य महीनों में ऊँचा था।

ABSTRACT. Some empirical formulae have been attempted in the past to compute mean daily global solar radiation from sunshine or cloud data. The instruments measuring solar radiation, depending on the method used measure either direct or diffuse radiation. It is possible to correlate the sunshine hours measured and the direct solar radiation received. An empirical formula has been attempted and tested using one year (1971) data for Delhi. The correlation is found to be high except in the month of April.

1. Introduction

Since the network of radiation stations with accurate measuring instruments in most countries is sparsely distributed, many authors have, in the past, attempted to derive the mean daily global solar radiation from sunshine or cloud data by using empirical relation. The Angstrom formulae (1924) :

$$Q = Q_0\,(a^1 + b^1\, n/N)$$

$$\text{or } Q = Q_A\,(a + b\, n/N) \tag{1}$$

have been used by various authors, where Q_A is the daily total of extraterrestrial solar radiation on a horizontal surface and Q_0 is the daily total of global solar radiation on a cloudless day, a^1, b^1, a and b are regression constants, n is the actual hours of sunshine and N is the duration of the day or the maximum possible hours of sunshine.

Mani *et al.* (1967) worked out global radiation by using :

$$Q = Q_0\,[1 - (1 - K_2)\, h] \tag{2}$$

where h is the mean cloud amount in tenths and K_2 a coefficient indicating the effect of clouds on radiation. Jeevanandam (1971) has deduced another formula, taking the humidity factor also into consideration.

Berliand (1961) has given a relation :

$$Q_s = Q_0\,[1 - a\,(-\, bc^2)\,] \tag{3}$$

where, Q_0 is the total incoming solar radiation under cloudless condition, a and b are empirical coefficients and c is the cloud cover in decimals.

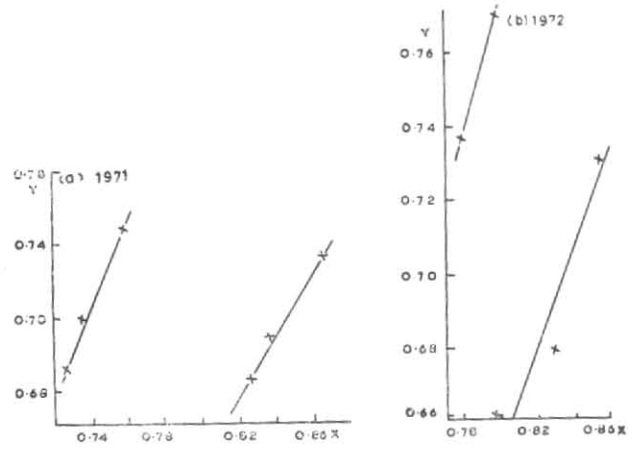
It can be seen from the above formulae that these can be applied for cloudy weather conditions as well as clear sky days. The main aim of this paper is to study the relationship between the bright sunshine values (hours) and the global and direct solar radiation.

2. Relationship between radiation parameter and sunshine hours

In the case of devices using focussed solar beams, it is the direct solar radiation that is to be taken into account whereas the global solar radiation on a horizontal surface is important in the case of flat plate collectors.

The sunshine hours are recorded on the sunshine cards held normal to the incident light by the solid spherical glass sphere acting as a lens. In view of the above, it is possible to correlate the actual bright sunshine hours with the direct solar radiation received on the surface held normal to the incident radiation. It is also clear that on cloudy days or more accurately, when there is a cloud in front of the sun, the direct radiation becomes less or even zero, depending upon the nature and thickness of the cloud, hence it would be appropriate to use the vertical component of the global solar radiation instead of direct solar radiation.

*Presently at ISRO Headquarters, Bangalore-560 009.



Figs. 1 (a & b). Scatter diagram between X and Y for April 1971 and 1972

Therefore, it is possible to correlate these two factors, taking into consideration the values of global radiation which includes all types of radiation (*viz.*, direct component, diffuse radiation etc) and the maximum possible hours of sunshine (duration of the day). The empirical relation can, therefore, be stated as :

$$\frac{\text{Global radiation in vertical plane}}{\text{Global radiation in horizontal plane}} \propto \frac{\text{Actual sunshine hours}}{\text{Max. possible sunshine hours}} \qquad (4)$$

We know that the global radiation and direct radiation are related as :

$$\frac{G_h - D_f}{\sin h} = I \qquad (5)$$

where G_h is global solar radiation, D_f is diffuse solar radiation on horizontal surface, I is direct solar radiation and h is solar elevation.

Eqn. (5) can be rewritten as :

$$\frac{G_h}{I} = \frac{D_f}{I} + \sin h$$

or

$$\frac{G_h}{I \sin h} = \frac{D_f}{I \sin h} + 1$$

$$= \frac{D_f}{G_h - D_f} + 1 \text{ (from Eqn. 5)}$$

$$= \frac{G_h}{G_h - D_f} \qquad (6)$$

The direct radiation becomes zero when thick clouding occurs in front of the sun. Hence, $I \sin h$ can be replaced by a term G_v which is the vertical component of the global solar radiation. Thus, Eqn. (6) becomes :

$$\frac{G_v}{G_h} = \frac{G_h - D_f}{G_h} \qquad (7)$$

Substituting this in Eqn. (4), we have,

$$\frac{G_h - D_f}{G_h} \propto \frac{S_a}{S_p} \qquad (8)$$

where S_a and S_p are actual and possible sunshine hours respectively. Eqn. (8) can be written as :

$$\frac{G_h - D_f}{G_h} = K\frac{S_a}{S_p} + C \qquad (9)$$

where K is the constant of proportionality and C is a constant.

3. Data studied

Radiation data pertaining to the year 1971 for Delhi was utilised for this study. Data for the clear sky days and hazy days in the various months of the year have been used in this study. The data included the maximum possible sunshine hours, for the selected days, which was determined from the Astronomical Ephemeris.

4. Results and discussion

Tables 1 and 2 present the various results obtained from the data of 1971. Data for the months January, April and October are only given in Table 1. The parameters $(G_h - D_f)/G_h = (Y)$ and $[S_a/S_p] = (X)$ were calculated from available data for clear sky days. The difference $X - Y$ is also given. In Table 2, the correlation coefficient of X and Y are given for the different months as also the constant of proportionality K. It can be seen that except for the months of April and October, significant correlation exist between X and Y. As the number of clear days in October is only 3, the correlation coefficient so determined may not be dependable. But for April, as can be seen from the values of $X - Y$ given in Table 1, there exists no correlation. The scatter diagrams between X and Y for the month of April (1971) is given in Fig. 1(a).

In order to understand the lack of correlation in April and October, data for the year 1972 was studied for these months and the results obtained are given in Table 3. It can be seen that there is no correlation between X and Y. Another feature noticed is that from the first half to the second half of the month of April, the difference $X - Y$ exhibits gradual increase (as can be seen from the corresponding scatter diagram (Fig. 1). This type of behaviour may probably be due to the rapid increase in turbidity content in April, that being a summer month. This aspect needs further study. In the month of October also the correlation is poor (0.49 in 1971; 0.59 in 1972).

5. Conclusion

An empirical formula has been derived between radiation parameters (G_h, D_f) and the sunshine hours. This has been verified for the year 1971 for clear sky days. Very good correlation exist between the two parameters $(G_h - D_f)/G_h$ and S_a/S_p except in the months of April and October. Thus, for clear sky days, an empirical formula can be proposed as :

$$\frac{G_h - D_f}{G_h} = K\left(\frac{S_a}{S_p}\right)$$

where $K = 0.865$. C being small may be neglected.

TABLE 1

Radiation data for New Delhi, 1971

Date (1971)	Global solar radiation (G_h) (kWh/m²)	Diffuse radiation D_f (kWh/m²)	$\frac{G_h - D_f}{G_h}$ (=Y)	S_a	S_p	$\frac{S_a}{S_p}$ (=X)	Difference (X—Y)
Jan							
1	4.41	0.90	0.7959	9.4	10.3	0.9126	0.1167
3	4.18	1.05	0.7488	9.1	10.3	0.8835	0.1347
5	4.12	0.99	0.7597	9.3	10.4	0.8942	0.1345
17	4.35	1.07	0.7540	9.3	10.5	0.8857	0.1317
23	4.51	1.00	0.7783	9.6	10.6	0.9057	0.1274
30	4.94	1.01	0.7955	10.0	10.8	0.9259	0.1304
31	4.95	1.01	0.7960	10.0	10.8	0.9259	0.1299
Apr							
1	6.77	1.70	0.7489	9.4	12.4	0.7581	0.0092
2	6.65	1.99	0.7008	9.2	12.5	0.7360	0.0352
3	6.80	2.24	0.6706	9.1	12.5	0.7280	0.0574
7	7.28	1.48	0.7967	9.2	12.6	0.7302	0.0665
24	7.30	2.51	0.6562	10.8	13.1	0.8244	0.1682
26	7.09	2.22	0.6869	11.0	13.1	0.8397	0.1528
27	7.23	1.95	0.7303	11.4	13.1	0.8702	0.1399
Oct							
10	5.54	1.65	0.7022	9.0	11.7	0.7692	0.0670
29	4.78	1.12	0.7657	9.7	11.1	0.8739	0.1082
30	4.76	1.16	0.7563	9.7	11.1	0.8739	0.1176

TABLE 2

Correlation coefficient from 1971 data for New Delhi

	No. of clear sky days	Correlation coefficient	Constant of proportionality K
January	7	0.89	0.857
February	10	0.79	0.885
March	8	0.84	0.967
April	7	No correlation	—
May	4	0.83	0.756
September	5	0.97	0.861
October	3	0.49	0.883
November	11	0.93	0.855
December	9	0.88	0.854
Mean K			0.865

TABLE 3

Radiation data for New Delhi — April and October 1972

Date (1972)	G_h (kWh/m²)	D_f (kWh/m²)	$\frac{G_h - D_f}{G_h}$ (=Y)	S_a	S_p	$\frac{S_a}{S_p}$ (=X)	X—Y
Apr							
6	7.09	1.86	0.738	9.8	12.6	0.778	0.040
12	7.33	1.69	0.769	10.2	12.8	0.797	0.028
13	7.14	1.93	0.730	10.9	12.8	0.851	0.121
14	6.93	2.22	0.680	10.6	12.8	0.823	0.148
15	6.79	2.30	0.661	10.3	12.9	0.798	0.137
Oct							
1	5.92	1.38	0.767	9.4	11.9	0.790	0.023
9	5.69	1.43	0.749	9.3	11.7	0.795	0.046
10	5.83	1.40	0.760	9.5	11.7	0.812	0.052
11	5.76	1.37	0.762	9.5	11.6	0.819	0.057
12	5.65	1.41	0.750	9.1	11.6	0.784	0.034

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