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NEW ESTIMATES OF MEAN DAILY DIFFUSE SOLAR RADIATION IN THAILAND

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Abstract

Values of the mean daily diffuse solar radiation at four locations in Thailand calculated season by season from a simulation model for solar radiation in SE Asia have been compared with rough estimates obtained from correlations between global solar radiation and duration of sunshine. The simulation model gives slightly higher values, which range from 6.6 to 11.2 MJ/m^2 per day.

Introduction

The separation of global solar radiation estimates into their direct and diffuse components is needed for deducing the radiation falling on tilted surfaces, and for predicting the performance of focussing solar collectors. Early estimates of diffuse solar radiation in Thailand were based on correlations between measurements of global solar radiation and the duration of sunshine. They were necessarily speculative and were not checked against observations.

In this paper we present new estimates of diffuse solar radiation in Thailand by an improved method based upon observations of the proportion of diffuse radiation in the total under specified conditions. We still have no reliable measurements at hand to check our results. However, diffuse solar radiation in Thailand is now being monitored by several institutions, and it is to be hoped that the results of these measurements will be published in due course.

Methods

The correlation between daily total global solar radiation H_d and daily duration of sunshine S is

$$H_d/H_c = a + bS/S_m,$$

where H_c is the daily total global solar radiation under a clear sky, S_m is the maximum daily duration of sunshine recordable, and a and b are regression parameters. The parameter a represents the fraction of global solar radiation that is not proportional to the amount of direct sunlight. Therefore aH_c was used as a rough measure of the daily total diffuse solar radiation in the old estimates [1].

The new estimates of daily total diffuse solar radiation presented in this paper were calculated using a computerized model for simulating solar radiation in Thailand. Full details of the model are available in a special report.[2]

The method of calculation was based on the following considerations. Let α be the altitude of the sun ; let k be the ratio of the actual global solar irradiance G to the global solar irradiance G_c from a clear sky defined thus

$$k = G/G_c ;$$

and let r be the ratio of the diffuse solar irradiance D to the global solar irradiance G defined thus

$$r = D/G.$$

Then correlations by Bugler[3] allow one to estimate r from a and k with an accuracy of about ± 0.1. If, now, the statistical distribution of the values of k at a particular location in a particular period of the year is known, one may derive from Bugler's correlations the statistical distribution of the values of D, from which the mean daily total diffuse solar radiation can be calculated. All the parameters required for this method are contained in the computerized model mentioned above.

The proceedure for estimating the mean daily total diffuse solar radiation at a particular location in a particular period of the year consists of the following steps.

First we calculate the solar altitude a each hour of the day from 6 a.m. to 6 p.m. apparent solar time in the middle of the period using the location latitude, the solar declination, and the solar hour angles. Next we calculate the global solar irradiance G_c and the direct solar irradiance I_c (perpendicular to the beam) under a clear sky for each hour from α, with a small correction for the date. From these quantities we obtain for each hour the diffuse solar irradiance D_c under a clear sky given by

$$D_c = G_c - I_c \sin \alpha$$

and the ratio

$$r_c = D_c/G_c ,$$

which depends only on a. We now let the ratio k_h of the actual global solar irradiance G_h for a particular hour to the global solar irradiance G_c under a clear sky defined by

$$k_h = G_h/G_c$$

assume the eleven possible values 0.0, 0.1, ..., 0.9, 1.0. Then for each value of k_h we estimate the diffuse solar irradiance D_h (k_h) in accordance with the correlations of Bugler, which are summarized in the empirical equation

$$D_h(k_h) = [1 - (0.733k_h^2 + 0.267k_h^4)(1 - r_c)]\, k_h G_c.$$

Next, we take the probabilities P(k) of the occurrence of the ratios k for the particular location and period (which are known from solar climate studies) and calculate the mean value $\overline{D}_h$ of the diffuse solar irradiance by means of the equation

$$\overline{D}_h = \Sigma P(k_h)\, D(k_h),$$

where the summation is for $k_h = 0.0, 0.1, \ldots, 0.9, 1.0$. This calculation is repeated for each hour to give thirteen values of $\overline{D}_h$ whose sum multiplied by one hour gives the required mean dialy diffuse solar radiation for the particular location and period of the year.

Results and Discussion

Table 1 shows the mean dialy total global solar radiation $\overline{H}_c$ under a clear sky at four stations in eight $1\frac{1}{2}$ - month periods, and Table 2 shows the corresponding estimates of mean daily total global solar radiation $\overline{H}_d$ as affected by the incidence of cloud.

Values of $a\overline{H}_c$ representing the mean daily total diffuse solar radiation estimated from the correlations between solar radiation and duration of sunshine are given in Table 3. They suggest that on the average about 48% of the global solar radiation is diffuse.

The new estimates of mean daily total diffuse solar radiation obtained by the second method described earlier are shown in Table 4. They are almost all higher than those in Table 3, and indicate that on the average about 56% of the global solar radiation is diffuse.

The discrepancies between the two estimates of the mean daily total diffuse solar radiation average 2.8 MJ/m^2 in March, 1.0 MJ/m^2 in June, and 0.4 MJ/m^2 in December. In spite of these discrepancies it is remarkable how close the two different estimates are. Since the theory underlying the new method of calculation is more sound, we expect the values in Table 4 to be the best currently available estimates of diffuse solar radiation in Thailand—that is until they are replaced by the publication of new values derived from a sufficient volume of reliable measurements.

TABLE 1. MEAN DAILY TOTAL GLOBAL SOLAR RADIATION UNDER A CLEAR SKY ($\overline{H}_c$), MJ/m^2 PER DAY

	Chiang Mai	Khon Kaen	Bangkok	Songkhla
14 Jan - 26 Feb	22.4	23.3	24.2	26.3
27 Feb - 12 Apr	26.9	27.3	27.7	28.3
13 Apr - 28 May	29.7	29.5	29.2	28.3
29 May - 15 Jul	30.0	29.6	29.0	27.6
16 Jul - 31 Aug	29.2	29.1	28.9	28.1
1 Sep - 15 Oct	26.5	26.9	27.3	27.9
16 Oct - 29 Nov	22.2	23.1	24.1	26.1
30 Nov - 13 Jan	19.9	21.0	22.1	24.6

TABLE 2. MEAN DAILY TOTAL GLOBAL SOLAR RADIATION ($\overline{H}_d$), MJ/m^2 PER DAY

	Chiang Mai	Khon Kaen	Bangkok	Songkhla
14 Jan - 26 Feb	16.8	17.2	17.0	17.6
27 Feb - 12 Apr	19.3	18.0	19.7	19.5
13 Apr - 28 May	20.1	19.3	18.0	17.4
29 May - 15 Jul	17.4	17.6	16.8	16.8
16 Jul - 31 Aug	15.9	16.8	15.5	17.2
1 Sep - 15 Oct	17.2	16.3	15.1	15.9
16 Oct - 29 Nov	17.4	17.8	16.3	14.7
30 Nov - 13 Jan	15.9	16.8	16.8	14.9

TABLE 3. MEAN DAILY TOTAL DIFFUSE SOLAR RADIATION ESTIMATED FROM DURATION OF SUNSHINE ($a\overline{H}_c$), MJ/m^2 PER DAY

	Chiang Mai	Khon Kaen	Bangkok	Songkhla
14 Jan - 26 Feb	6.1	6.6	7.1	7.7
27 Feb - 12 Apr	7.3	7.4	7.5	7.7
13 Apr - 28 May	10.1	9.3	8.4	8.1
29 May - 15 Jul	10.5	10.1	9.6	9.1
16 Jul - 31 Aug	10.1	9.9	9.6	9.3
1 Sep - 15 Oct	8.5	8.4	8.4	8.6
16 Oct - 29 Nov	7.3	7.4	7.6	8.2
30 Nov - 13 Jan	6.4	6.8	7.1	7.9

TABLE 4. MEAN DAILY TOTAL DIFFUSE SOLAR RADIATION ESTIMATED BY SIMULATION MODEL, MJ/m^2 PER DAY

	Chiang Mai	Khon Kaen	Bangkok	Songkhla
14 Jan - 26 Feb	7.9	8.5	8.7	9.9
27 Feb - 12 Apr	10.1	10.5	10.0	10.7
13 Apr - 28 May	11.1	11.2	10.8	10.8
29 May - 15 Jul	11.2	11.2	10.7	10.4
16 Jul - 31 Aug	10.7	10.8	10.7	10.6
1 Sep - 15 Oct	9.8	9.8	9.7	10.3
16 Oct - 29 Nov	7.1	7.7	8.4	9.2
30 Nov - 13 Jan	6.6	6.8	7.4	8.9

References

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2. Exell, R.H.B. (1980) *Simulation of Solar Radiation in a Tropical Climate with Data for Thailand.* Research Report No. 115, Asian Institute of Technology, Bangkok.

3. Bugler, J.W. (1977) The determination of hourly insolation on an inclined plane using a diffuse irradiance model based on hourly measured global horizontal insolation. *Solar Energy* **19,** 477 - 491.

บทคัดย่อ

ค่าเฉลี่ยประจำวัน ของรังสีกระจายจากดวงอาทิตย์ในสี่จังหวัดของประเทศไทย ที่คำนวณสำหรับแต่ละฤดู จากแบบจำลองของการแผ่รังสีดวงอาทิตย์ ในเอเซียอาคเนย์ ได้ถูกนำมาเปรียบเทียบกับ ค่าที่ประเมินอย่างคร่าว ๆ จากค่ารังสีดวงอาทิตย์ทั้งหมด ร่วมกับ ระยะเวลาที่มีแสงอาทิตย์. ค่าที่ประเมินจากแบบจำลองคณิตศาสตร์สูงกว่าเล็กน้อย และอยู่ในพิกัดจาก 6.6 ถึง 11.2 เมกะจูลต่อตร.ม.ต่อวัน.