

ESTIMATING THE REGRESSION COEFFICIENTS IN THE FORMULA RELATING SOLAR RADIATION TO SUNSHINE DURATION AND ITS APPLICABILITY TO INDIAN LOCATIONS

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ABSTRACT

By assuming a quadratic relationship between elevation (h) and the regression coefficients a and b of Angstrom type correlation, a procedure is suggested for estimating the monthly mean daily global radiation for locations in India. Data from six locations, spread all around India, are analysed to obtain the coefficients of the quadratic equation connecting a and b to elevation of the locations above sea level. The procedure for estimating global radiation is tested by calculating monthly mean daily global radiation values for these six locations. The estimated and reported experimental values agree well and the procedure is accurate for any location in India, with altitude less than 600 m.

INTRODUCTION

Data on the monthly averages of the daily total and diffuse solar radiation at a location is of significant use in the design of most solar energy conversion devices. Actual measurements of insolation are only made at a few places because of the cost of the equipment required and the care needed for maintaining it. Attempts have, therefore, been made to develop statistical correlations for estimating insolation from various surface weather observations, most of which are usually made at many locations. Angstrom (1924) suggested the use of per cent possible sunshine hours as a parameter to predict available global radiation on a horizontal surface. Angstrom correlation has been modified by Page (1961).

Lund (1968) correlated nine years of daily insolation observations with measurements of temperature, snow cover, wind, sunshine, sky cover, pressure and precipitation at Blue Hill, Massachusetts. He found that sunshine observations were the best specifiers of insolation in all the months of the year. Sky cover was the second best for most of the months. Norris (1968) reviewed attempts to divide cloud reports into classes of transmissivity for use of prediction. He reported poor correlation and concluded that it is probably impossible to predict solar radiation from such measurements. Bennet (1969) brought out the usefulness of opaque sky cover as an important

$$a = 0.458 - 0.213 h + 0.219 h^2$$

$$b = 9.288 + 0.229 h - 0.236 h^2$$

where the elevation is in kilometres. The geographical location of the six stations along with estimated values of a and b are presented in Table 1. Table 2 gives a comparative study of the experimental and estimated values of monthly mean daily global irradiation on a horizontal surface for the six locations. The global radiation values presented are in $\text{MJ m}^{-2} \text{ day}^{-1}$. The relative percentage errors (e) and S/S_0 ratio are also included in the same table. The quantity $(S/S_0) \times 100$ is often called the percentage of possible sunshine duration. A comparison between the measured and the estimated values shows that there is a remarkable agreement between the two for all the locations during most of the months of the year. The relative percentage error rarely exceeds 10 per cent in most of the cases and the average values are far less than 10 per cent. However, the relative percentage error for July and August are found to be high for most of the locations. It can be seen from Table 2 that the accuracy of the estimated values decrease when the per cent possible sunshine decreases and the relative per cent error can be above 10 per cent when the S/S_0 ratio is below 0.4. It can be established from the results of Table 2 that the error of the estimated values will lie between 10 to 20 per cent if the percentage sunshine duration is below 40 per cent, with the estimated values always being higher than the experimental values.

Table 1. Estimated values of the regression coefficients for the six locations

Location	Latitude in Degrees	Elevation in Metres	a	b
Ahmedabad	23° 2 N	55	0.447	0.300
Bombay	18° 56 N	14	0.455	0.291
Jodhpur	26° 18 N	224	0.421	0.327
Nagpur	21° 09 N	310	0.413	0.336
Poona	18° 32 N	559	0.407	0.342
Trivandrum	8° 29 N	64	0.445	0.302

The suggested procedure can thus be applied to estimate monthly mean daily global radiation for locations in India. The developed equations can be directly employed for estimation purposes, for any month of the year, if the error of the estimated values are allowed to go upto 20 per cent in some cases. However, if more accurate estimations are necessary, the estimated values for the months with per cent possible sunshine duration less than 40 per cent need to be corrected. The correction procedure is very simple as the estimated values are always higher than the experimental values by 10 to 20 per cent. It should also be noted that these correlations are developed from data for six locations, all having the altitude less than 600 m. This procedure should then be expected to hold good for only those stations having

Table 2. Monthly mean daily global radiation on a horizontal surface in M J m⁻² for the six locations.

LOCATION	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
AHMEDABAD	H _E	18.41	21.34	24.27	27.62	28.04	25.53	19.25	16.74	22.60	19.67	15.90
	H _C	17.86	20.83	23.26	25.97	26.83	25.14	21.59	20.12	22.03	21.35	18.89
	e	3.0	2.4	4.2	6.0	4.3	1.5	-12.1	-20.2	2.5	-8.5	-18.8
BOMBAY	S/So	0.89	0.90	0.82	0.83	0.79	0.62	0.34	0.28	0.62	0.86	0.94
	H _E	19.25	21.76	24.27	25.53	26.36	19.25	16.32	15.48	19.25	21.34	20.92
	H _C	18.80	21.30	23.45	25.09	25.76	22.01	20.31	19.31	20.75	20.52	19.75
JODHPUR	e	2.3	2.1	3.4	1.7	2.3	-14.3	-24.4	-24.7	-7.8	3.8	5.6
	S/So	0.81	0.81	0.76	0.73	0.72	0.38	0.24	0.19	0.44	0.65	0.86
	H _E	17.16	20.09	23.44	26.46	28.46	28.46	22.18	20.09	22.60	21.34	18.41
NAGPUR	H _C	16.13	19.15	21.89	24.99	27.32	26.53	20.61	21.22	21.45	20.12	17.35
	e	6.0	4.7	6.6	5.2	4.0	6.7	7.1	-5.6	5.1	5.7	5.8
	S/So	0.84	0.84	0.77	0.78	0.83	0.73	0.48	0.43	0.64	0.84	0.91
POONA	H _E	19.25	21.34	23.85	25.53	26.36	20.09	16.74	15.90	20.09	20.92	20.09
	H _C	18.45	20.68	22.78	24.53	25.30	21.55	19.15	18.58	20.56	20.00	18.96
	e	4.1	3.1	4.5	3.9	4.0	-7.3	-14.4	-16.8	-2.3	4.4	5.6
TRIVANDRUM	S/So	0.88	0.83	0.76	0.72	0.70	0.40	0.23	0.23	0.51	0.69	0.87
	H _E	20.12	23.85	25.77	27.66	27.82	22.22	16.86	16.74	19.83	20.71	19.45
	H _C	19.37	21.92	24.10	25.18	26.06	22.43	19.01	18.86	20.54	20.05	19.62
TRIVANDRUM	e	3.7	8.1	-6.5	9.0	6.3	-0.9	-12.7	-12.7	-3.6	3.2	-0.9
	S/So	0.87	0.89	0.84	0.77	0.78	0.50	0.25	0.27	0.50	0.65	0.85
	H _E	22.17	24.68	24.68	20.92	22.17	16.74	16.74	20.08	20.50	18.41	17.99
TRIVANDRUM	H _C	21.43	22.70	24.06	22.27	22.87	19.46	19.44	21.77	21.65	20.03	19.22
	e	3.3	8.0	2.6	-6.4	-3.2	-16.2	-16.1	-8.4	-5.6	-8.8	-6.8
	S/So	0.72	0.70	0.70	0.50	0.58	0.31	0.30	0.48	0.48	0.42	0.47

elevation in the range 0-600 m. For locations of higher altitude one may have to find out separate values of the coefficients A_0 , A_1 , A_2 and B_0 , B_1 , B_2 .

CONCLUSION

A method is suggested whereby global radiation values can be estimated from sunshine duration and altitude, for locations in India. There is a remarkable agreement between the experimental and estimated values of global radiation from this method. The suggested method gives very accurate estimation of monthly mean daily global radiation if the altitude of the location is in the range 0-600m and the per cent possible sunshine duration is above 40 per cent. However, if the per cent possible sunshine duration for a location or for any month in a given location is less than 40 per cent, the accuracy of the estimated values decreases and a correction should be applied to the estimated data. Further, new set of constants may be necessary for locations of altitude above 600 m.

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