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Sunshine and cloudiness over India

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ABSTRACT. The relationship between sunshine and cloudiness has been studied, by utilising sunshine and cloudiness data for period 1953-1965 in respect of 20 stations covering the Indian latitudes. Regression analysis has been carried out and regression constants have been derived. The total of 2995 samples from all the stations for the 12 months of the year has yielded as high a correlation factor as 0·87.

The estimated values of bright hours of sunshine agree very fovourably with those actually observed. The cloud observations can thus be reliably utilised to supplement the instrumental measurements of sunshine to provide sufficient data for the study of climatology of duration of bright sunshine over India.

1. Introduction

The registration of duration of bright sunshine in hours has been receiving considerable attention particularly in the arid and semi-arid regions of the world for many years, because the sunshine provides the more readily accessible source of cheap energy. Large areas of the globe especially the whole of the ocean areas have only sparse network for recording duration of bright sunshine. On the other hand, observations of cloud amount are available for almost all the land and the ocean areas and, therefore, the cloud observations can be used to supplement the instrumental measurements of sunshine.

In India, even though the network of recording bright hours of sunshine with Campbell Stokes sunshine recorders consists of about 100 stations (61 Agrimet. stations and 39 India Meteorological Observatory stations), it is still considered that this network is not adequate to provide the climatology of duration of bright sunshine. In India there are about 480 stations taking daily cloud observations at 0830 and 1730 IST and it is, therefore, possible to estimate sunshine from cloudiness. This paper is a preliminary study directed towards the construction of conversion formula.

It is generally known that the duration of sunshine is negatively associated with cloudiness. Bilham (1938) has remarked that the relationship between sunshine and cloudiness is not so simple and direct as may appear. Assuming conditions along the path of the sun as random samples valid for the entire visible sky, Conrad and Pollak (1950) have shown that the number of hours of available sunshine SS can be obtained as —

$$SS = H\,(1-C) \qquad (1)$$

where, H is the duration from sunrise to sunset and and C is the fraction of sky covered. They have shown that the monthly values derived as above differ from the actual by less than 10 per cent. Jagannathan *et al.* (1967) have estimated —

$$SS' = H\,(1-C') \qquad (2)$$

for all the observatory stations in India, where $C' = (N' + N'')/2$ (C' = average amount of all clouds, N' and N'' are average cloud amounts in tenths of sky at 0800 and 1700 IST respectively).

A comparison of measurements of bright sunshine expressed as percentages of possible duration (time between sunrise and sunset) with estimates of cloud amounts brings out two interesting features illustrated by data for New Delhi, given in Table 1.

In the first place, it is seen that sum of percentages of SS and cloudiness is greater than 100 for some months. If a sunshine recorder is considered as a perfect inverse recorder of cloud, and if it is able to burn the card from the instant of sunrise to the instant of sunset and if there is no diurnal variation of cloud*, then $(S+C)$ per cent should be 100. In the second place, it is seen that sum of the percentages of SS and cloudiness is less than 100 for some months. When the sun is very low it fails to burn the card.

Brooks (1929) has derived —

$$S = (100 - C)\,(1 + t_c - a'w) \qquad (3)$$

(where t_c is the amount of thin cloud, a' = constant and w is the fractional duration of low sun). Rao *et al.* (1966) have studied the relationship between sunshine and cloudiness over Bombay for the rainy months, May to November. They have shown that there is negative association for all the months. The C.Cs are nearly 0·9 which are highly significant even at 1 per cent level of significance. Rao *et al.* (1971) have derived the relationship between sunshine (n/N) and cloudiness $(1-m)$

*There is certain amount of cloud too thin to prevent the SS from burning the card.

TABLE 1

Sunshine (S) and cloudiness (C) at New Delhi (1951—1965)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
C (per cent)	35	31	30	23	18	33	65	67	37	11	11	27	33
S (Per cent)	73	79	69	73	71	54	47	49	62	79	87	80	67
$S+C$ (per cent)	108	110	99	96	89	87	112	116	99	90	98	107	100

TABLE 2

Mean cloudiness (tenths of sky)—Annual

Station	Cloudiness in tenths of sky (m)	Percentage of sky free from cloud ($1-m$)	Sunshine as % of possible (n/N)
	(a)	(b)	(c)
Adhartal	4·4	56	61
Allahabad	3.9	61	67
Ahmadabad	3·5	65	66
Bombay/Colaba	4·1	59	61
Bhopal	4·0	60	69
Calcutta/Alipore	4·8	52	55
Gwalior	3·6	64	68
Jullunder	3·0	70	69
Jodhpur	3·1	69	67
Jaipur	3·2	68	67
Karjat	4·1	59	59
Madras	5·9	41	62
New Delhi	3·4	66	67
Nagpur	4·8	52	59
Poona	4.4	56	64
Patna	3·6	64	64
Silicoorie	4·9	51	54
Sholapur	4·6	54	62
Srinagar	5·2	48	52
Trivandrum	6·2	38	52

TABLE 3

Station	Regression constants		No. of samples
	a	b	
Ahmadabad	0·23	0·74	156
Allahabad	0·27	0·64	155
Amritsar	0·36	0·46	155
Bangalore	0·27	0·79	156
Baroda	0·21	0·75	156
Bombay	0·15	0·83	152
Calcutta	0·18	0·68	156
Gauhati	0·24	0·68	108
Hyderabad	0·31	0·78	139
Jaipur	0·19	0·73	156
Jodhpur	0·28	0·89	156
Kodaikanal	0·13	0·93	156
Madras	0·38	0·56	156
Nagpur	0·22	0·83	144
New Delhi	0·25	0·60	151
Poona	0·21	0·77	155
Port Blair	0·21	1·08	155
Srinagar	0·15	0·78	133
Tiruchirapalli	0·34	0·73	144
Trivandrum	0·19	0·85	156
All 20 satations	0·26	0·68	2995

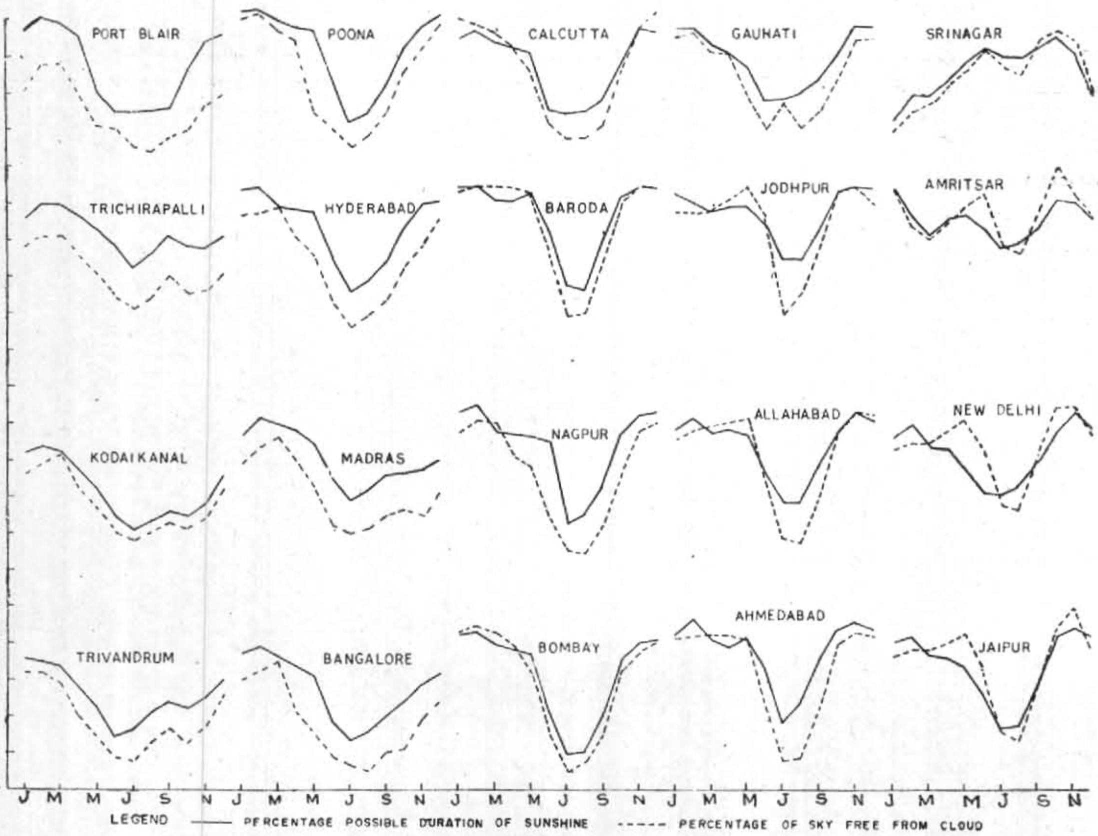

Fig. 1

Percentage of sunshine and cloudiness—Annual variation

from the long sunshine records of Poona from 1933 to 1964 and for the data of all stations combined annual mean values of 57 stations. In spite of some limitations of the data used, the relationship was found to be highly significant.

In the present study the relationship between sunshine (n) expressed as percentage of the possible (N) and percentage of sky-free from cloud ($1-m$) (where m is the mean cloudiness in tenths of sky) has been studied.

2. Data utilised

Monthly means of daily (*i*) duration of sunshine (n) and (*ii*) all cloud amount in oktas converted into tenths of sky (m), based on observations at 0830 and 1730 IST for the period 1953-1965, in respect of 20 stations covering the Indian latitudes, were utilised in the analysis.

3. Analysis of data

3.1. The annual means of daily cloudiness in tenths of sky and percentage of sky-free from cloudiness (100 *minus* mean per cent area of sky covered with cloud, obtained by multiplying the annual mean cloudiness by ten) and annual means of daily per cent of possible hours of sunshine— $100\,(n/N)$ are given in Table 2 for a few stations.

It is seen that the figures in Col. (b) agree closely with figures in Col. (c). There is a fairly good agreement for most of the stations but this is not so with few stations which may be due to the following facts —

(*i*) Sunshine data are obtained from continuous records but cloud data depends on estimates made at 0830 and 1730 IST. The latter may not give accurate means for the state of sky between sunrise and sunset.

(*ii*) Sunshine is intercepted by haze, mist, fog and cloud.

(*iii*) Even on clear days, the sunshine recorded is weak to record sunshine shortly after sunrise and before sunset.

(*iv*) Intermittent sunshine is over recorded.

TABLE 4

Estimated values of duration of bright sunshine in hours as compared with that of actually observed

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Trivandrum	I	6·9	7·0	7·8	6·4	5·6	4·7	4·6	5·3	5·8	5·1	5·7	7·1	6·1
	II	8·3	8·3	8·1	6·7	5·5	3·7	4·0	5·1	5·8	5·2	5·7	7·1	6·0
Kodaikanal	I	7·2	7·7	8·2	6·9	6·1	5·0	4·5	5·0	5·2	4·8	5·1	6·4	6·0
	II	7·3	7·8	7·7	6·7	5·5	3·7	2·6	3·3	3·9	3·5	4·2	5·9	4·9
Tiruchirapalli	I	7·4	7·9	8·2	7·4	6·8	5·8	5·2	5·5	6·5	5·5	5·6	6·2	6·5
	II	8·5	9·8	9·6	9·1	8·2	7·2	5·6	6·4	7·5	6·7	6·3	7·1	7·6
Port Blair	I	6·1	7·4	7·7	6·4	5·2	5·1	4·2	3·8	4·3	4·6	5·5	6·0	5·6
	II	8·6	9·6	9·4	8·7	5·1	3·7	3·9	3·8	3·9	6·1	7·7	8·1	6·5
Bangalore	I	7·5	8·1	8·9	6·7	5·8	4·9	4·3	4·1	4·9	4·7	6·0	6·7	6·1
	II	8·4	9·0	8·9	8·5	7·8	4·8	3·2	3·9	4·9	5·6	6·5	7·3	7·1
Madras	I	7·4	8·3	9·0	8·3	7·2	5·4	5·1	5·1	5·6	5·7	5·3	6·3	6·5
	II	8·3	9·6	9·5	9·3	8·6	6·3	4·8	5·4	6·4	6·3	6·3	6·8	7·3
Hyderabad	I	8·4	8·8	9·5	8·3	7·9	5·6	4·4	4·8	5·2	6·5	7·1	8·2	7·1
	II	9·6	10·2	9·3	9·5	9·6	6·5	4·0	4·7	5·7	7·8	8·8	8·9	7·9
Poona	I	8·8	9·6	9·9	9·5	9·3	6·1	4·3	4·6	5·5	7·1	7·8	8·6	7·6
	II	9·4	9·9	9·6	9·5	9·5	6·3	3·0	3·5	5·6	7·6	8·7	8·9	7·6
Bombay	I	9·4	9·8	10·0	10·0	9·0	6·1	4·3	4·6	5·6	8·0	8·7	9·1	7·9
	II	9·3	9·7	9·5	9·6	9·5	5·6	2·3	2·6	5·2	8·3	9·0	9·0	7·5
Nagpur	I	8·5	9·2	9·6	8·5	8·6	6·2	4·3	4·1	5·2	7·2	8·5	8·7	7·4
	II	8·3	10·1	9·3	9·5	9·6	6·7	3·4	3·7	5·5	8·4	9·4	9·2	7·8
Baroda	I	8·7	9·7	10·2	10·7	10·9	8·3	5·0	5·1	7·0	9·3	9·4	9·2	8·8
	II	9·6	10·1	9·8	10·2	11·1	8·5	4·4	4·1	6·7	9·6	9·0	8·8	9·5
Calcutta	I	8·7	8·8	9·0	8·7	7·9	5·5	4·7	4·6	5·0	7·1	8·6	8·7	7·3
	II	7·5	8·3	8·1	8·3	7·9	4·0	3·7	3·7	4·3	6·2	8·5	7·7	6·5
Ahmadabad	I	8·8	9·1	10·0	10·7	10·7	7·9	4·9	4·8	7·0	9·3	9·2	8·7	8·5
	II	9·5	10·2	9·3	10·0	10·8	8·7	4·5	4·3	6·5	9·5	9·7	9·4	8·7
Allahabad	I	8·0	8·7	9·5	10·0	10·6	7·8	5·1	4·8	6·4	8·7	9·1	8·6	8·2
	II	8·2	9·3	9·1	9·7	9·7	7·1	4·9	4·9	6·9	8·5	9·1	8·4	7·9
Jodhpur	I	8·1	8·6	9·2	10·2	11·5	10·3	5·2	6·0	8·0	9·7	9·3	8·3	8·7
	II	9·0	9·7	9·1	9·9	10·4	9·5	6·6	6·4	8·1	9·9	9·7	9·2	9·0
Gauhati	I	7·7	8·4	8·1	8·5	6·9	5·6	6·5	5·2	5·6	6·6	7·9	7·6	7·1
	II	7·8	8·3	7·8	7·7	7·1	4·9	4·8	5·2	5·6	7·3	8·3	7·9	6·9
Jaipur	I	8·1	9·0	9·4	10·0	11·0	9·6	6·3	5·6	7·9	10·0	10·3	8·5	8·9
	II	8·6	9·4	8·9	9·3	9·2	7·2	4·6	4·6	7·1	9·4	9·7	8·8	8·1
New Delhi	I	7·4	8·0	8·9	9·9	11·1	9·8	6·8	6·2	8·4	9·8	9·2	7·9	8·7
	II	7·9	8·6	8·3	9·1	9·6	7·6	5·8	5·8	7·2	9·1	8·9	7·8	8·0
Amritsar	I	6·9	7·8	8·0	9·5	10·9	12·0	9·1	8·1	9·3	10·6	9·4	7·2	9·0
	II	6·9	7·9	7·5	9·2	10·1	9·3	7·7	7·7	8·1	9·2	8·5	7·1	8·6
Srinagar	I	3·8	4·7	5·7	7·1	8·4	8·8	8·8	7·9	8·7	8·4	7·2	3·7	7·1
	II	2·7	4·2	4·5	6·1	7·7	9·1	8·4	7·8	7·9	7·9	6·3	3·9	6·4

I—Computed mean monthly values of daily duration of bright sunshine in hours using the regression equation $n/N=0\cdot26+0\cdot68\ (1-m)$.

II—Monthly means of daily duration of bright sunshine in hours based on actual measurements for available years upto December 1965.

(*v*) All clouds do not intercept sunshine completely when the sky is overcast with thin cirrus cloud and a continuous record may be produced.

(*vi*) Interception of *SS* by fog or haze tends to make percentage of *SS* lower than the percentage of sky-free from cloud and over registration of *SS* during intermittent cloud and transparancy of the cloud have the opposite effect.

To illustrate some of the facts mentioned above, graphs of annual variation of percentage of (*i*) possible duration of sunshine (n/N) and (*ii*) sky-free from cloud ($1—m$) at representative stations are shown in Fig. 1. Percentages of n/N and ($1—m$) are given in full lines and dotted lines respectively for each of the stations. The general similarity between the two graphs are striking. The sunshine percentage generally exceeds the percentage of clear sky and this feature is markedly so during monsoon season. The cloudiness percentage is some what higher than sunshine particularly in the hot weather period at Calcutta, Ahmadabad, Jodhpur, Jaipur and New Delhi, probably due to ioterception by industrial smoke and dust haze. In the extreme north interception of sunshine by fog or mist during winter lowers the sunshine as may be seen in the graphs of Amritsar and Srinagar.

3·2. If the monthly means of daily cloudiness is denoted by m (in tenths of sky) and n and N are the monthly means of actual and maximum possible duration of bright sunshine in hours, the regression analysed is between 100 ($1—m$) and 100 (n/N) and the regression equation is given by —

$$n/N = a + b(1—m) \qquad (4)$$

where a, b are regression constants and r is the correlation factor between the two meteorological parameters, n/N and ($1—m$).

Regression analysis was carried out between monthly mean values of n/N and ($1—m$) for each month of the year for each of the 20 stations and computed values of annual coefficients for each station and combined 20 stations are given in Table 3.

Monthly means have been considered because errors in monthly mean data are less than those for daily observations. The variations from month to month for each station and for each month between stations are rather large, because of small sample sizes from 9 to 13 years. When all the 12 months in the year are considered for each station the sample size ranges between 108 to 156 and the coefficients do not show large variations, *i.e.*, a ranges from 0·13 to 0·38 and b from 0·46 to 1·08. Taking each month of the year for the 20 stations together, the sample size ranges between 243 to 252 and the variation of coefficients between months is also not very large, a ranges from 0·21 to 0·41 and b from 0·41 to 0·77 (data not presented here).

The total of 2995 samples from all the 20 stations for the 12 months of the year is considered, there fore, for deriving the regression equation —

$$n/N = 0\cdot26 + 0\cdot68\,(1—m) \qquad (5)$$

and this equation has been used to estimate sunshine from cloudiness in the present study.

In view of the fact that (*i*) there is good agreement between computed coefficients both between stations using data for all months and between months using data for all stations, (*ii*) the correlation coefficient between the parameters n/N and ($1—m$) based on 2995 samples being as high as 0·87, the general application of the regression equation (5) appears to be justified. Table 4 shows the computed monthly means of duration of bright sunshine in hours using the relationship $n/N = 0\cdot26 + 0\cdot68\ (1—m)$ and monthly means of duration of bright sunshine in hours based on actual measurements for all available years upto December 1965 for different months of the year for 20 stations. It is interesting to note that the estimated values compare very favourable with the actually observed values.

4. Conclusion

Until such time as a long series of sunshine observations are available for a considerably greater number of stations for recording sunshine, the method suggested in this paper may serve as the basis for estimating sunshine from cloudiness and thus cloud observations can be reliably utilised to supplement the instrumental measurements of sunshine to provide sufficient data for the study of climatology of duration of bright sunshine.

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