551·521·1 (548·1)

TOTAL RADIATION FROM SUN AND SKY ON A HORIZONTAL SURFACE IN RELATION TO CLOUD TYPE AT MADRAS

From a study of the hourly cloud and radiation data for Blue Hill Observatory (Lat. 42°13′N, Long. 71°7′ W, elevation 195 metres), Haurwitz (1945, 1946, 1948) has derived a relation between Q, the total radiation from sun and sky in gm calories per cm^2 of horizontal surface per hour and m, the optical air mass, under conditions of clear sky and of sky overcast with different cloud types. The relation is of the type $Q=(a/m)\, e^{-bm}$, a and b being constants for different sky conditions. He has given the least square values of the constants a and b. The relation between total radiation from sun and sky and optical air mass under different sky conditions can be made use of for obtaining approximately the values of radiation when solarimeter data are not available. In the present note, it is proposed to obtain the least square constants a and b for Madras (Lat. 13·0°N, Long. 80·2°E, elevation 15 m a.s. l.) under conditions of clear sky and of sky overcast with each of the types, Cirrus, Cirrostratus and Altostratus.

Data and Tabulation—At Madras airport, half-hourly current weather messages are issued during the period 0000 to 1400 GMT. Half-hourly cloud observations extracted from the current weather observations taken

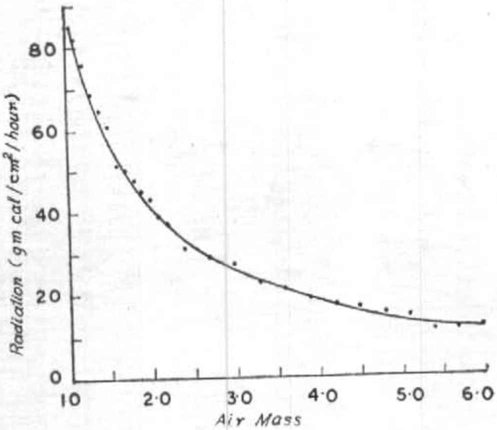

Fig. 1(a). Least square curve for radiation through clear sky

(The dots represent the mean values of radiation)

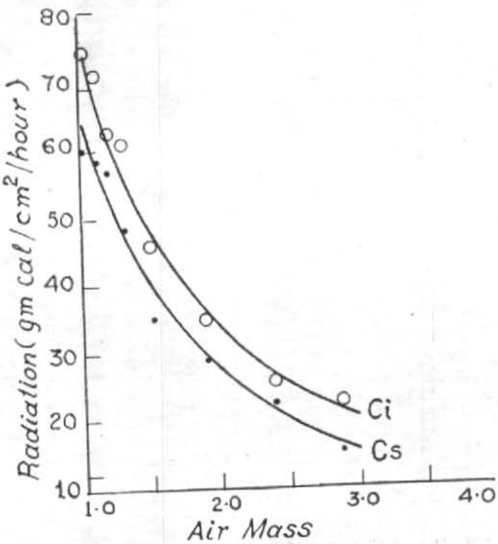

Fig. 1(b). Least square curves for radiation through Cirrus (Ci) and Cirrostratus (Cs) clouds

(The dots represent mean values of radiation through Cirrostratus and circles through Cirrus)

during the 3-year period, 1 October 1957 to 30 September 1960, were considered for the present study. The hourly and 15-minute radiation values obtained from the records of Moll-Gorczynski solarimeter during the same period formed the radiation data for the study.

Periods of time were selected when sky was clear and when sky was overcast with the same type of cloud. For each hour of clear sky and of sky overcast with one type of cloud, sun's zenith angle at Madras at the mid-point of the hour was obtained from the curves given by Ganguly (1954). From the mean zenith angle for the hour optical air mass was obtained, using Smithsonian Meteorological Tables (1958). For each hour the total radiation from sun and sky was tabulated. Suitable intervals of optical air mass were selected and values of radiation falling in each interval were grouped together and mean radiation was obtained for each optical air mass interval.

Variations in optical air mass (which may be upto ± 3 per cent) on account of variation of the solar distance from the mean distance and also the effect of turbidity of air were not taken into consideration since the variations in radiation caused by these factors are much smaller than the variations in radiation caused by differences in the opacity of the same cloud type and the variations in radiation observed in one and the same optical air mass interval.

Sufficient number of observations for different air mass intervals were available only for clear sky and for overcast sky with each of the cloud types, Cirrus, Cirrostratus and Altostratus. Radiation through other types of clouds could not, therefore, be studied. Optical air mass intervals with less than five observations were not considered.

Least Square Curves—Mean value of radiation was calculated for each optical air mass interval and it was considered to be representative of the mean optical air mass of the interval. From the set of these mean values of radiation at different optical air masses least square curves representing the relations between radiation and optical air mass were obtained for clear sky and for sky overcast with Cirrus, Cirrostratus and Altostratus. The curves are shown in Figs. 1(a), 1 (b) and 1 (c) with points representing the actual

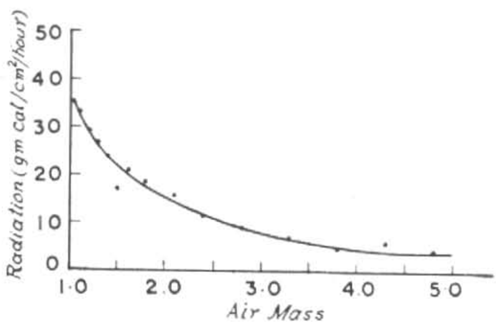

Fig. 1(c). Least square curves for radiation through Altostratus clouds
(The dots represent mean values of radiation)

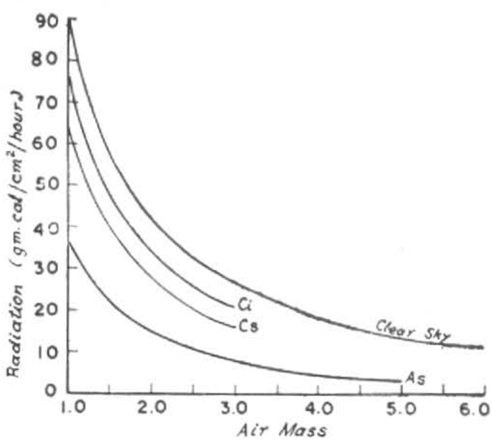

Fig. 2. Least square curves for radiation

TABLE 1

Least square values of constants a and b

Station		Clear sky	Cirrus	Cirro-stratus	Alto-stratus
Madras	a	94·6	86·5	75·0	42·8
	b	0·061	0·118	0·152	0·186
Blue Hill Observatory	a	94·4	82·2	87·1	39·0
(by Haurwitz)	b	0·059	0·079	0·148	0·063

TABLE 2

Percentage of clear sky radiation transmitted through different cloud types

Air mass	Cloud type		
	Cirrus	Cirro-stratus	Alto-stratus
1·0	87	73	40
1·5	84	69	38
2·0	82	66	35
2·5	79	63	33
3·0	77	60	31
3·5			29
4·0			27
4·5			26
5·0			24

values of radiation at different optical air masses. Fig. 2 represents all the curves without the individual points.

The least square values of the constants a and b in the relation $Q = (a/m)e^{-bm}$ are given in Table 1. In the same table are given the values obtained by Haurwitz (*loc. cit.*) for Blue Hill Observatory. It may be seen that the values of constants a and b for radiation through clear sky at Madras agree very well with those for Blue Hill. There is also a good agreement in respect of value of b for Cirrostratus at these places. The constants for other clouds are different at these two places, the difference being well-marked in respect of b for Altostratus. Presumably, as mentioned by Haurwitz (*loc. cit.*) the differences are due to differences in the transparency of the various cloud types under different climatic conditions. The cloud conditions at Blue Hill are representative of those in temperate latitudes, while those at Madras are representative of those within the tropics. Cloud parameters for the same type of cloud are likely to be appreciably different under the temperate and tropical climates.

Percentage of clear sky radiation transmitted through different cloud types—The radiation through clear sky is given by $Q_0 = (94 \cdot 6/m) \times e^{-0 \cdot 061m}$ while that through overcast sky is $Q = (a/m)e^{-bm}$ where a and b are the least square constants for the particular type of cloud. Hence he percentage of clear sky radiation transmitted through a particular type of cloud is, $(100/94 \cdot 6)\ a\ e^{+(0.061-b)m}$. This would depend on optical air mass, unless the value of b for a particular type of cloud is equal to that for clear sky, *viz.*, 0·061. The values of percentage radiation through different types of clouds are given in Table 2. It is seen from this table that the percentage of clear sky radiation transmitted through Cirrus is about 80 per cent, through Cirrostratus about 65 per cent and through Altostratus about 33 per cent.

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