

Daylight illumination from radiometric studies made at Pune

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सार — भारत में विकिरण केन्द्रों के संजाल दिवालीक प्रदीप्ति का वास्तविक मापन नहीं कर रहे हैं। यह दिवालीक प्रदीप्ति विद्युत चुम्बकीय वर्गक्रम के दिखाई देने वाले भाग की विकिरण-ऊर्जा है तथा इससे ही दृश्य संवेदना पैदा होती है। ड्रमंड और अंगस्ट्रॉम द्वारा सुविचारित विधियों द्वारा भूमण्डलीय विकिरण मापों से दिवालीक प्रदीप्ति मापी गई है। यह मापन कार्य 1974 में पुणे में 300-400 तथा 710-2700 माक्रोमीटर की वर्णक्रमीय दूरियों में किया गया और संबंधित आंकड़े प्रस्तुत किए गए हैं। पुणे के लिए प्रमुख घटक, ज्योति दक्षता भी तैयार की गई है। इसके परिणामों पर विचार-विमर्श किया गया है।

ABSTRACT. Actual measurements of daylight illumination—the radiant energy in the visible part of electromagnetic spectrum causing the sensation of sight are not being made in the network of radiation stations in India. Following the method discussed by Drummond and Angstrom, daylight illuminations have been derived from the global radiation measurements made at Pune during 1974 in the spectral ranges 300-400 nm and 710-2700 nm and the data presented. The important factor, luminous efficiency has also been worked out for Pune. The results are discussed.

1. Introduction

Radiation in the visible region of the electromagnetic spectrum is often evaluated with respect to the illumination it produces. Illumination is defined as the luminous flux falling on a unit surface and expressed in lux. Though radiation measurements are being made at a number of places on a regular basis, the same cannot be said to be true of daylight illumination. Information on daylight illumination is of great interest to architects, illumination engineers and agricultural scientists.

2. Computation of daylight illumination

Daylight illumination is not directly measured at any of the radiation stations in India. In the absence of the direct measurements, computation of daylight illumination, from solar radiation measurements, is desirable. But this computation will depend upon such factors as latitude, dust and water vapour concentrations of the lower atmosphere and the optical air mass in the relative path length of the solar beam through the atmospheric column.

Thomas *et al.* (1972) have studied the variations in the direct fluxes illumination field derived from the spectral measurements of direct solar radiation. But these values correspond to the energy at normal incidence only and at specified timings only. Drummond

and Angstrom (1971) have derived a relationship between the global solar radiation in the entire solar radiation spectrum and in that part of spectrum transmitted by a standard RG8 filter (transmission range: 710-2700 nm) and daylight illumination given by:

$$L = 150 F (1 + 0.102 m)$$

where, L is the daylight illumination in kilolux (klx) due to global radiation flux F at $\lambda < 710$ nm expressed in $\text{cal cm}^{-2} \text{min}^{-1}$ and m is the absolute optical air mass. When F is expressed in S.I. units of energy (W/m^2), the equation becomes $L = 0.2151 F (1 + 0.102 m)$. The authors found that the derived values gave an average error of only 1 per cent.

Global solar radiation measurements were made at Central Radiation Laboratory, Pune during 1974 both in the entire solar radiation range (300-400 nm) and in the RG8 part of the spectrum (710-2700 nm) by using two different pyranometers exposed side by side. The pyranometers and the RG8 hemispherical dome were periodically calibrated with reference to the standards maintained at the laboratory. The quantity of daylight illumination expressed in kilolux—hour (klx-h) has been worked out on the basis of the above expression for L . A comparison with the Weston illuminometer (useful for low intensities) showed that the computed values were within 5 per cent from the measured values for reasonably good

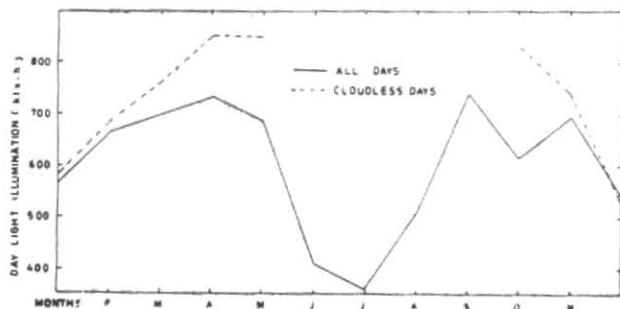
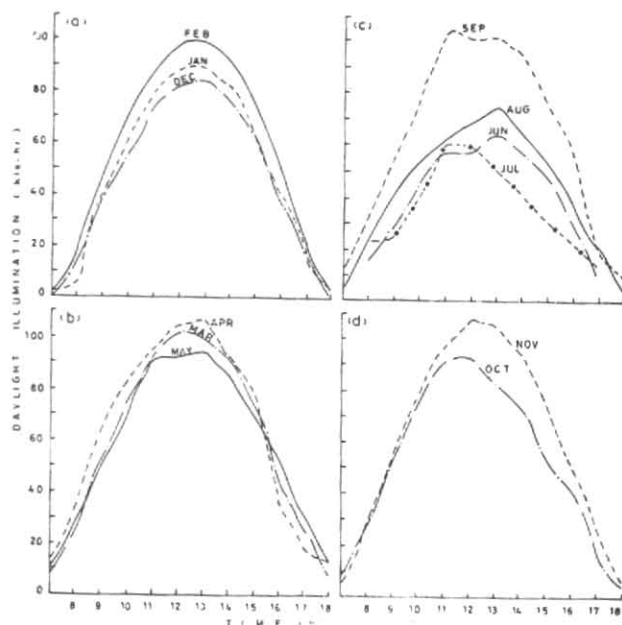


Fig. 1. Monthly variation of daylight illumination at Pune



Figs. 2. (a-d). Diurnal variation of daylight illumination — all days

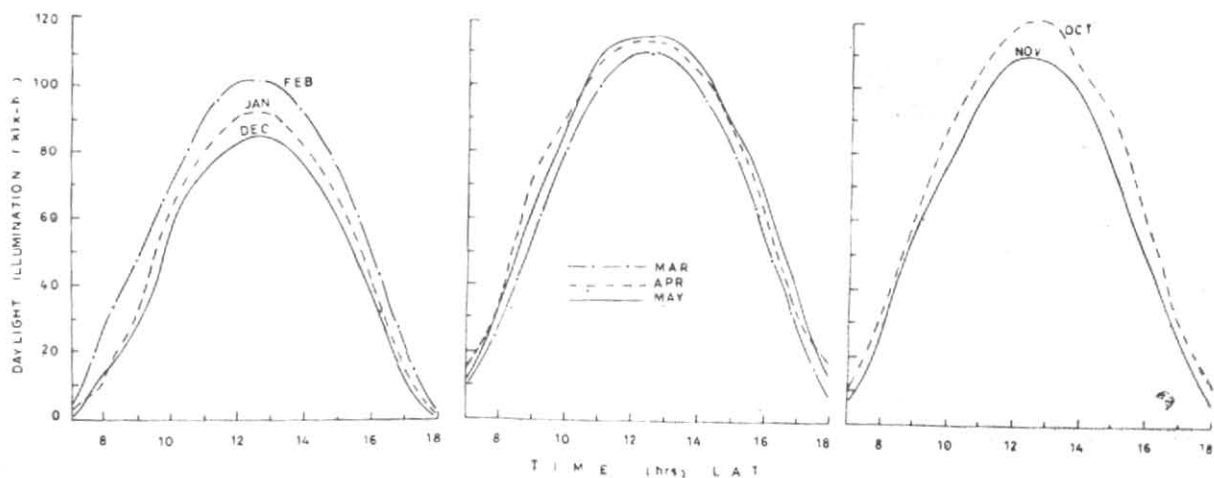


Fig. 3. Diurnal variation of daylight illumination — cloudless days

illuminations and that for very low intensities obtainable at the twilight hours, the agreement was far from satisfactory. This must be mainly due to the large differences in the sensitivities of thermopile pyranometers and the photoelectric illuminometer. The data obtained are discussed in the following paragraphs.

3. Discussion of data

3.1. Monthly variations

3.1.1. The variation of daily values of daylight illumination from month to month is given in Fig. 1. The illumination increases from 565 klx-h in January to 734 klx-h in April mostly due to the increasing intensity of solar radiation and increasing dust-load of the atmosphere. The illumination decreases thereafter in May, due to the increasing clouding of the

skies in May and the skylight component also probably decreases due to the rain out of dust particles by the thunderstorm activities. With the onset of monsoon in June the skies are generally covered with the low clouds (duration of sunshine is less than 60 per cent). The daylight illumination drops down very sharply by about 40 per cent. The lowest value of 364 klx-h is recorded in July. The daylight illumination reaches a secondary maximum in September and the values steadily decrease thereafter.

3.1.2. The daylight illumination is always more under cloudless sky conditions (Fig. 1). While the values are marginally higher in the winter months due to higher incidence of cloudless sky conditions, they are much higher during the pre-monsoon months and in October. The values on cloudless days are 16

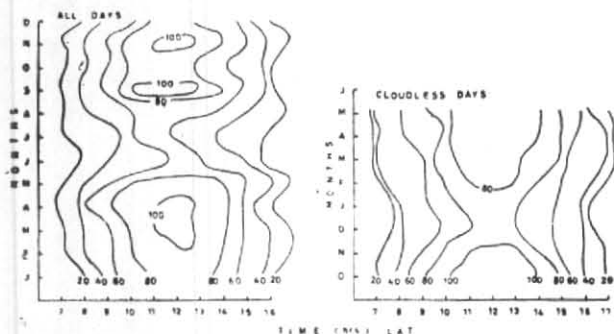


Fig. 4. Isoleths of daylight illumination

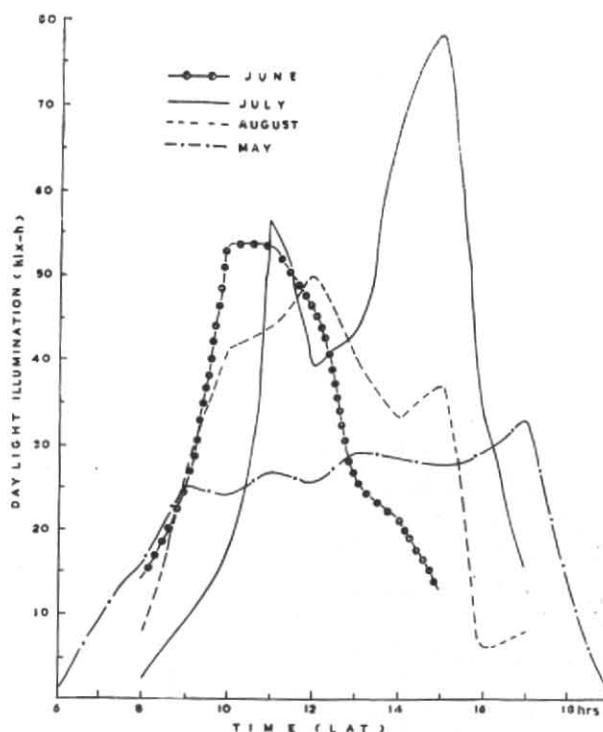


Fig. 5. Daylight illumination under overcast sky condition

TABLE I
Luminous efficiency of daylight (lumens per watt) at Pune

Season	Time (L.A.T.)													Day
	6	7	8	9	10	11	12	13	14	15	16	17	18	
	All days													
Winter		155	86	110	109	109	109	110	111	111	114	128	165	110
Pre-monsoon		148	107	111	108	108	107	108	106	107	99	101	181	108
Monsoon		107	132	114	114	119	114	116	111	111	112	113	157	115
Post monsoon		350	161	137	130	125	121	118	122	118	135	152	320	127
	Cloudless days													
Winter		277	96	105	107	109	109	110	110	111	112	116	283	111
Pre-monsoon		158	115	119	112	113	110	110	111	111	111	113	113	113
Post monsoon		325	155	125	123	123	125	124	123	126	126	147	476	129
	Overcast days													
May	93	152	128	157	177	161	165	174	169	161	169	145	229	186
June	—	—	96	84	116	104	118	106	104	90	—	—	—	100
July	—	—	—	186	130	155	137	174	149	190	152	145	—	152
August	—	—	191	193	199	178	176	170	189	198	87	262	—	181

and 24 per cent higher in April and May than those on all days and again they are higher by 36 per cent in October.

3.2. Diurnal variations of daylight illumination

3.2.1. The diurnal variations of daylight illumination on all days represented in Fig. 2. Fig. 2(a) shows that the December values are consistently the lowest—lower than January and February values, the noon maximum being less than 85 klx. With the season advancing into the pre-monsoon period, the noon maximum also increases to 106 klx. The values in May

(Fig. 2b) are the lowest during this period probably due to more clouding. Like the daily sums, the diurnal variations are lowest during July (Fig. 2c). The values in June, July and August are by far very low compared to those in September. This is due to the lesser clouding in September and to the reduced activity of the monsoon circulation over Pune. Excepting July and September or October the tendency for daylight illumination to reach the maximum is during 1200-1300 hr L.A.T. Again November values are higher than those of October due to the less clouding during November (Fig. 2d).

3.2.2. The diurnal variation of daylight illumination on cloudless days is more symmetric and the maximum is reached by the noon (Fig. 3). As in the previous case, December (Fig. 3a) has the lowest and the noon maximum increases as the sun ascends the sky higher and higher as the season advances into the pre-monsoon season. The striking feature is that the illumination values of May (Fig. 3b) are higher than those of April, until the conditions are as depicted in Fig. 2(b). The highest noon illumination recorded is, however, in October only, the value being 120 klx (Fig. 3c). Again the October values on cloudless days are much higher than the November values unlike the case depicted in (Fig. 2d).

3.2.3. Fig. 4 shows the isopleths of hourly daylight illumination over the year as a whole for all days and for cloudless sky conditions. The isopleths are drawn for every 10 klx-h. The daylight illumination registers more than 100 klx per hour only around 1200 hr during February-April and in September and November. The lowest value of noon maximum is reached in December under all types of sky conditions.

Under the cloudless sky conditions, the isopleths tend to curve inwards at noon in the winter months when the solar radiation is weak and the noon maximum is around 90 klx-h. The 100 klx-h isopleth however covers longer hours during the pre-monsoon and post monsoon months.

3.2.4. The values under overcast sky conditions are given in Fig. 5. The number of days of overcast sky conditions were very few and restricted to the period May to August only. The type of clouding and the extent of clouding were highly variable and hence no steady pattern could be discerned. In July 1974, due to very low stratus clouding the illumination values were very less, the highest being only 53 klx during 10-11 and 11-12 hours LAT. In June the values were more or less uniform due to steady cloud cover.

4. Luminous efficiency of daylight

The evaluation of the ratio of the photometric daylight illumination expressed in lumens/m² and the global solar radiation expressed in watts/m² gives a first approximation to determine the illumination levels at places where the radiation measurements are made.

Thus the following section discusses this ratio which can be termed as luminous efficiency of daylight (expressed in lumens per watt) for different times of the day in different seasons at Pune. The values of luminous efficiency (L.E.) for the four different seasons

under all sky conditions 'all days' and under 'cloudless' sky conditions are given in Table 1.

The highest value of L.E. is recorded during the post monsoon period, the daily average working out to be 127. The monsoon season has a value of 115. The lowest efficiency works out to be during the pre-monsoon period. The L.E. values are slightly higher under cloudless sky conditions. The hourly efficiencies are nearly constant throughout the day between 09 and 15 hr LAT and there is no consistent variation.

The higher values of L.E., it is seen, occur during the periods where the air column is relatively moist. In such cases, the water vapour bands absorb the terrestrial radiation and reduce the radiation in solar radiation wavelength ranges and this naturally would lead to greater L.E. This effect will be manifold for larger values of the optical air masses that are obtained at the times of sunrise or sunset. Over and above this effect of moisture, the effect of attenuation of the solar radiation by the particulate matter — the Rayleigh and Mie scattering effects — also play an important role in finally determining the L.E. values.

5. Conclusion

Illumination for all days increases from January to April. The primary maximum is reached in the month of April and the secondary maximum in September. The lowest illumination is reached in December if the monsoon months are excluded. Illumination is more in cloudless sky conditions and the hourly distribution more symmetrical. It is high in April, May and October when cloudless days are more. The highest illumination at noon is reached in the month of October, being of the order of 120 klx and lowest about 83 klx in December. Post monsoon and pre-monsoon values of illumination are more or less equal under cloudless conditions but there are large differences at all hours between the winter values and other two seasons. Luminous efficiency of daylight is highest when air column is more moist in post monsoon and lowest in pre-monsoon period.

There is need to calculate intensity of illumination for longer periods at selected stations in India so that some normal pattern can be worked out for India as a whole. However, the derived values are not reliable for twilight intensities.

References

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