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Variations in radiation, total ozone and illumination during the solar eclipse of 20 May 1966 at New Delhi

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ABSTRACT. A study has been made of the variations of solar and atmospheric radiation, total ozone content during the solar eclipse on 20 May 1966 with the help of available instruments at Radiation Laboratory, New Delhi. Variations in the values of the natural illumination derived from measurements of solar radiation on this day have also been studied and discussed.

1. Introduction

The solar eclipse of 20 May 1966 provided the opportunity to watch, observe and analyse the various aspects of meteorological interest at New Delhi. Special observations, apart from the routine observations, were carried out on the eclipse day and also on a day before and after it at an interval of 15 minutes for comparative study purpose. An Angstrom Pyrheliometer was put into operation for taking sets of observations at an interval of 15-min while the continuous records of a Pyranometer and a net Pyrradiometer designed by Funk (1959) were evaluated for the timings of the special observations. A similar arrangement was made to take special ozone obseruations at all the ozone stations in India.

2. Eclipse data

The various circumstances of the annular solar eclipse of 20 May 1966 are given in Table 1 for all the stations where special observations were taken for this study. These timings were taken from the *Indian Ephemeris and Nautical Almanac* (India met. Dep. 1966). Fig. 1 shows the four photographs of the various phases of the solar eclipse as seen over the National Physical Laboratory in New Delhi. The photographs were taken at 1538 IST (just before the eclipse); at 1545 IST (after the start of the eclipse); at 1649 IST (at maximum phase of the eclipse); and at 1740 IST (before the end of the eclipse). The percentage cut off of the sun's disc covered by the moon at 1545, 1649 and 1740 IST are found to be 1·5, 37·3 and 5·5 respectively.

3. Analysis of data and discussion

3·1. *Variations in radiation*—The data collected for this study consists of direct solar radiation, global radiation, diffuse radiation and net radiation (radiation balance). Fig. 2 shows the variations of these quantities. For comparison, the data for a day before and after the day of eclipse were considered to give a plot of normal curves as shown in the figures. The meteorological conditions on these three days, *viz.*, 19, 20 and 21 May 1966 were more or less the same, but for some variations in the thickness of dust haze. The effect of the eclipse which has a maximum phase at 1649 IST at New Delhi on the radiation intensities is clearly seen in the figure. It can also be seen that there is slight time lag in the decrement or increment at the times of start, maximum phase and end of the eclipse shown by arrows M and E respectively. A similar lag is found by other workers. As to the reason for this time lag, conflicting reports are existing in the literature (Miyake, Sekihara and Kawamura 1949; Ushiyama, Narita, Suzuki and Suzuki 1949; Abbot 1958; Prruitt *et al.* 1965). One school opines that this may be due to lagging after the first and last contacts in the field of the instruments of the intersection of the lunar penumbra with optically important higher atmosphere.

Table 2 gives the percentage reductions of direct solar, global, diffuse and net radiation at the time of maximum phase of the eclipse. As indicated earlier the maximum percentage cut off of the sun's disc area was 37·3 and the corresponding percentage reduction in the various components of radiation intensity can be examined from this table. The percentage reduction in the direct solar radiation is 30·2 which is not the same as the percentage reduction of the area of the sun's disc unlike that reported by Padmanabhamurty and Rakshit (1966).

3·2. *Variations in total ozone*—A programme to take special observations of total ozone was also spread over a day before and after the day of the eclipse for comparative study at all the

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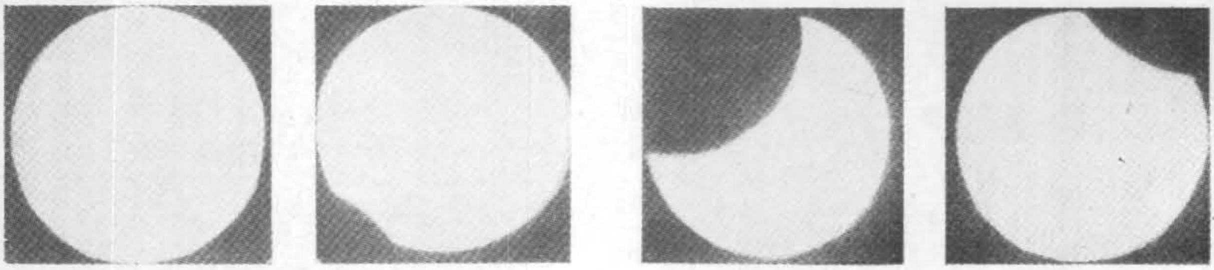


No eclipse (1538 IST) 1545 IST 1649 IST 1740 IST

Fig. 1. Solar eclipse of 20 May 1966 at New Delhi

TABLE 1

Station	Co-ordinates		Circumstances of the eclipse								
	Lat. N	Long. E	Starting time		Max. phase		Time of end		Time of sunset		Max. portion eclipsed
			h	*m*	*h*	*m*	*h*	*m*	*h*	*m*	
Kodaikanal	10°14′	77°28′	15	39·0	16	49·1	17	50·1	18	15·0	0·479
New Delhi	28°35′	77°12′	15	39·0	16	49·1	17	50·1	19	07·2	0·479
Srinagar	34°05′	74°50′	15	25·6	16	42·8	17	51·2	18	58·0	0·631
Varanasi	25°18′	83°01′	15	53·4	16	56·4	17	52·0	18	37·8	0·421
Dum Dum	22°39′	88°27′	16	03·9	17	01·1	17	52·4	18	11·3	0·383

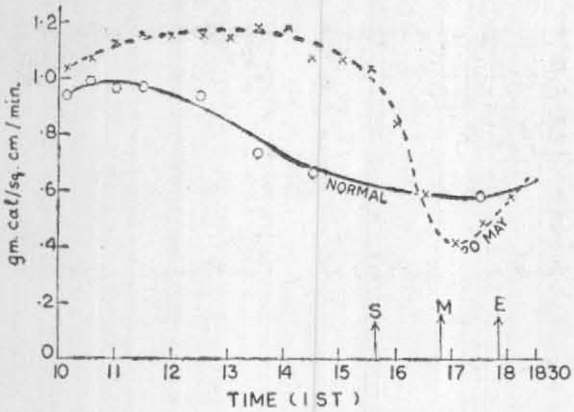
Time in IST

TABLE 2

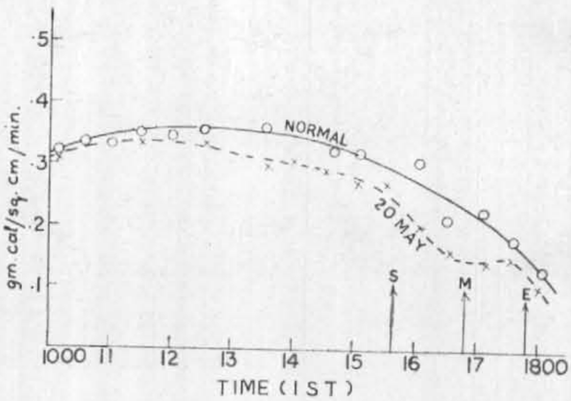
Radiation measurements during the period of eclipse at New Delhi

Instrument used and mode of measurement	Radiation intensity (gm. cal/cm² /min) at			Max. reduction (per cent)
	Start	Max. phase	End	
Pyrheliometer (Direct Solar radiation)	·996 (·610)	·412 (·590)	·510 (·598)	30·2
Pyranometer (Global radiation)	·850 (·985)	·304 (·635)	·225 (·325)	52·1
Pyranometer (Diffuse radiation)	·245 (·292)	·146 (·232)	·128 (·157)	37·1
Funk net Pyrradiometer (Radiation Balance)	·335 (·409)	·110 (·184)	·003 (·016)	40·2

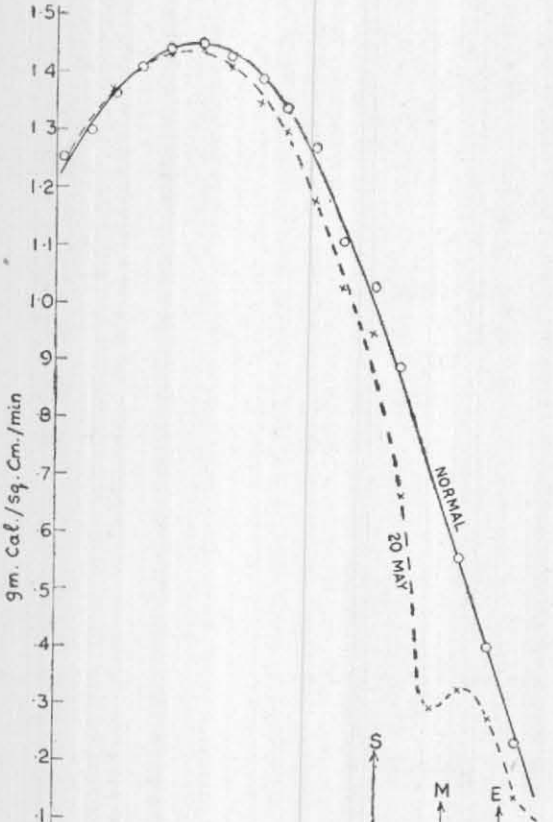
Values picked up from normal curves are given in brackets



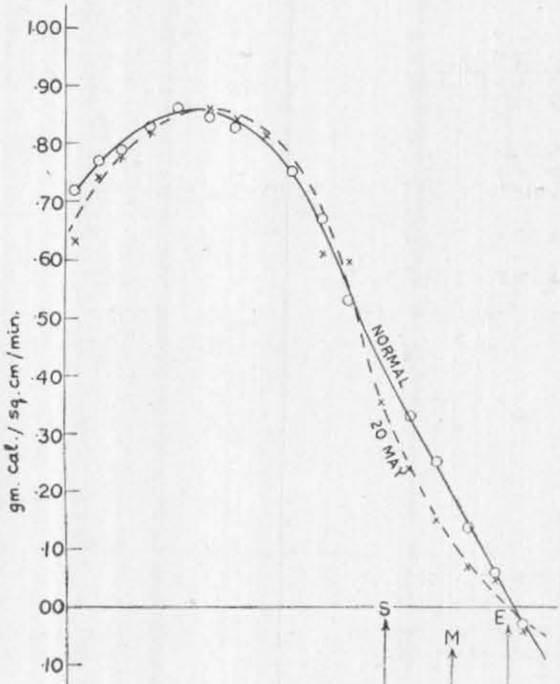
(a) Direct Solar Radiation



(c) Diffuse Radiation



(b) Global Radiation



(d) Radiation Balance

Fig. 2. Radiation measurements at New Delhi

ozone observatories in India. Due to cloudy conditions no observations could be taken at Dum Dum and only a few observations could be taken at Varanasi, Kodaikanal and Srinagar. Inspite of slight dust haze in the atmosphere the ozone observations were taken at New Delhi. Fig. 3 (a) shows a plot of total ozone on the eclipse day (20 May 1966) and mean curve for 19 and 21 May 1966. Contrary to the findings of Padmanabhamurty *et al.*, no definite increase in the total ozone during the eclipse could be established although there appears to be an increasing tendency

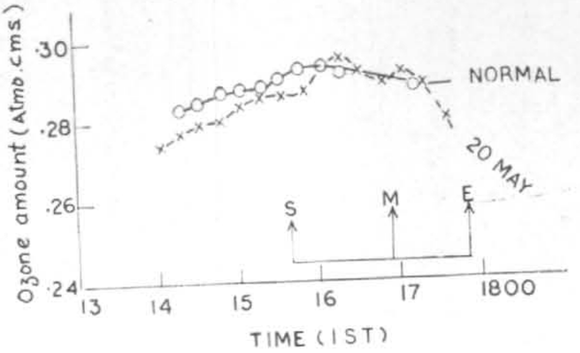


Fig. 3(a). Total Ozone at New Delhi

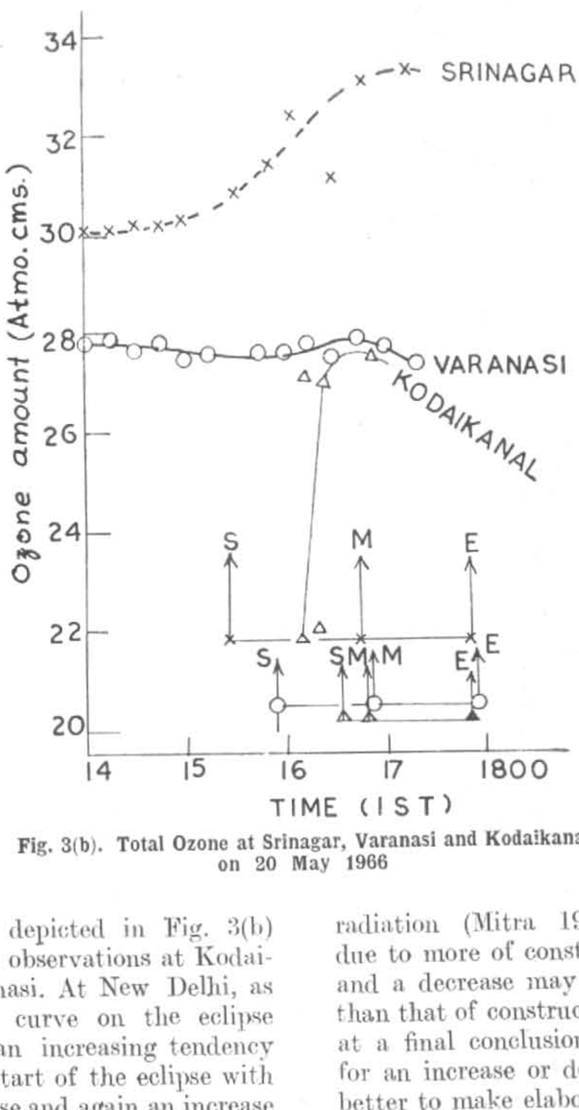


Fig. 3(b). Total Ozone at Srinagar, Varanasi and Kodaikanal on 20 May 1966

in the ozone amount as depicted in Fig. 3(b) based on the few available observations at Kodaikanal Srinagar and Varanasi. At New Delhi, as shown in Fig. 3(a) the curve on the eclipse day depicts that there is an increasing tendency in the total ozone at the start of the eclipse with a fall at the maximum phase and again an increase at the end of the eclipse. This pattern is interesting. The increase or decrease of ozone value with the inclination of the incident radiation depends upon the relative intensities of construction and destruction of ozone by the same solar radiation (Mitra 1952). The increase may be due to more of construction than of destruction and a decrease may be due to more of destruction than that of construction of total ozone. To arrive at a final conclusion to assign any such reason for an increase or decrease in ozone it would be better to make elaborate arrangements to observe and study at a number of stations on such occasion in future.

3·3. *Variations in illumination*—Angstrom and Drummond (1963) have shown how the natural illumination due to direct solar radiation may be

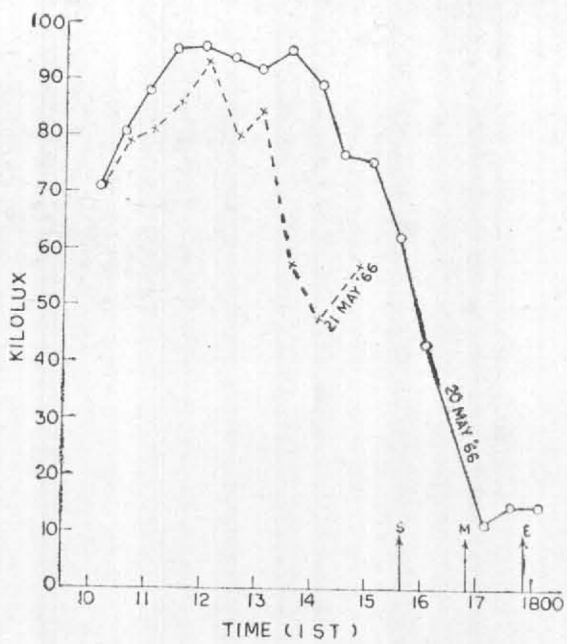


Fig. 4. Horizontal Illumination at New Delhi

derived from measurements of solar radiation at normal incidence combined with measurements obtained with the aid of meteorological standard filters, OG_1, RG_2 and RG_8. They defined a quantity corresponding to different values —

$$\rho = \int_0^\infty \phi(\lambda)F(\lambda)d\lambda \, / \int_0^{\lambda m} F(\lambda)\, d\lambda$$

of air mass and turbidity and with an upper wave length limit λ_m. The function $F(\lambda)$ denotes the solar radiation at a given time with respect to solar height, air mass and turbidity; while the function $\phi(\lambda)$ denotes the relative spectral luminous responsivity of the human eye, according to the data adopted by the International Commission on Illumination. In general it was found that the ratio ρ is a simple function of true air mass (m) and turbidity (β) through the following equations :

$$OG_1 : \rho = 0{\cdot}58 \;\; (1 + 0{\cdot}235m + 1{\cdot}19m\beta)$$

$$RG_2 : \rho = 0{\cdot}39 \;\; (1 + 0{\cdot}073m + 0{\cdot}305m\beta)$$

$$RG_8 : \rho = 0{\cdot}315\, (1 + 0{\cdot}032m)$$

In the case of the Schott filter RG_8 the value is free from dependence on β. Moreover, the illumination refers to the wave-length range $.35\mu$ to $\cdot 75\ \mu$ and since the difference between the direct solar radiation measured without filter and with filter RG_8 very nearly relates to the last equation (RG_8), it gives a direct evaluation of the above range. ρ values were calculated by using the last equation (RG_8). It gives a direct evaluation of the illumination which is sufficiently accurate for most practical purpose.

If we denote $w = \int_\lambda^{\lambda m} F(\lambda)\, d\lambda$

then $\rho \times w = \int_0^\infty \phi(\lambda) F(\lambda)\, d\lambda \approx E$

where E stands for illumination. But the above integral has to be multiplied by 475 in order to give illumination in Kilolux. For further details the *Smithsonian Tables* (1963) and the paper by Angstrom and Drummond (1963) may be consulted.

The illumination E (in Kilolux) on a horizontal surface is thus given by the formula $E = 475\, \rho w$ where w is the radiation amount received on a horizontal surface which was derived from the measure of solar radiation at normal incidence. The values of w and ρ were calculated from the solar radiation data obtained on the eclipse day and a day after it. The variations in the illumination are shown in Fig. 4. The plot of the few available values of 21st are fairly in agreement with the plot for the time before the start of the eclipse of 20 May 1966. The effect of the solar eclipse at the start, at maximum phase and at the end is clearly shown by the curve of the eclipse day. This curve has similar trend as shown by the radiation measurements discussed earlier justifiying the validity of the formula used.

4. Acknowledgement

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