EFFECT OF ANNULAR SOLAR ECLIPSE OF 19TH APRIL, 1958 (AT SUNRISE) ON THE F_2 LAYER OF THE IONOSPHERE

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(*Received, October* 30, 1959)

ABSTRACT. The paper describes the effect of the annual Solar Eclipse of 19th April, 1958 on the ionisation density of the F_2 layer over Trivandrum, Tiruchirapalli and Madras (South India) The eclipse occurred near sunrise at all the three places and its magnitude at maximum phase was 75 to 83%. Analysis of $(foF_2)^2$ values during control period and eclipse day showed a marked decrease in the ionisation density with the progress of the eclipse at all the three places. Theoretical considerations of the effect of an eclipse at sunrise on the ionisation density of the F_2 layer are discussed which have also led to the determination of the value of attachment co-efficient at 350 km. as approximately 10^{-5} sec^{-1} over Trivandrum.

INTRODUCTION

It is well known that an eclipse of the sun produces a decrease in the ionisation density in the E and F_1 layers. But such an effect is not so clearly marked in the F_2 layer, nor it is expected to be so from theoretical considerations. However, when the eclipse occurs around ground sunrise at any particular location, interesting results can be obtained of its optical effect on the F_2 layer. The annular solar eclipse of 19th April, 1958 occurred near sunrise in the south of India and special investigations of the ionosphere were carried out at Trivandrum, Tiruchirapalli and Madras Stations of All India Radio. The present paper deals with these observations. The circumstances of the eclipse are shown in Table I below.

It would be noted from Table I that the eclipse occurred very near to ground sunrise at all the three locations. Ionospheric observations have also shown interesting results

EXPERIMENTAL PROCEDURE

The equipment for ionospheric observations at all the three places are exactly identical. The pulse transmitter is manually operated and is capable of sweeping through a frequency range of 1.5 to 18 Mc/s. The radiated power is of the order of one kilowatt. The echoes are received in a receiver modified for pulse reception and displayed on a cathode ray oscillograph in the usual way. A height calibrator provides height marks at intervals of 40 or 20 km. A suppressor unit has been provided to suppress the strong ground pulse for facilitating the measurement of E layer characteristics. The transmitting and the receiving aerials are conventional inverted deltas oriented at right angles to each other.

The effect on the F_2 layer of the solar eclipse of 19th April 1958 was investigated in the following way. The control period was taken as 8 days each preceding and following the eclipse day. The half hourly measurements of layer heights and critical frequencies of E and F_2 layers for this period were utilised as control observations. On the eclipse day itself, measurements were taken once every 15 minutes. (The accuracy in height measurements was ± 20 or ± 10 km and critical frequency ± 0.1 Mc/s). Measurements on E layer were vitiated by the appearance of Es and those on the F_2 layer will only be discussed.

TABLE I

Circumstances of the eclipse of 19th April '58.

	Trivandrum (8°29'N, 76°57'E)	Tiruchirapalli (10°49'N, 78°42'E)	Madras (13°05'N, 80°17'E)
Eclipse begins	0604 IST	0606 IST	0609 IST
Eclipse maximum	0711 ,,	0714 ,,	0718 ,,
Eclipse ends	0829 ,,	0834 ,,	0838 ,,
Ground sunrise	0612 ,,	0603 ,,	0555 ,,
Magnitude	83%	79%	75%

(IST = GMT+5½ hours).

RESULTLS

The average behaviour of the F_2 layer is determined from the observations during the control days (± 8 days centred on the eclipse day) and compared with those on the eclipse day. The layer heights did not show any significant behaviour and therefore, only f_0 F_2 values will be considered.

(*a*) *Trivandrum*

Figure 1 shows the variation of $(foF_2)^2$ from 0430 to 0930 IST on the control days and on the eclipse day. The eclipse and sunrise timings are indicated in the figure. It would be seen from this figure that there was a steady and rapid increase in ionisation from about 0530 to 0830 IST during the control period. This type of rapid increase in early morning is well known at equatorial latitudes and is also regularly observed at all the three stations. The day-to-day variation is only in the level of ionisation. On the eclipse day, the initial level of ionisation

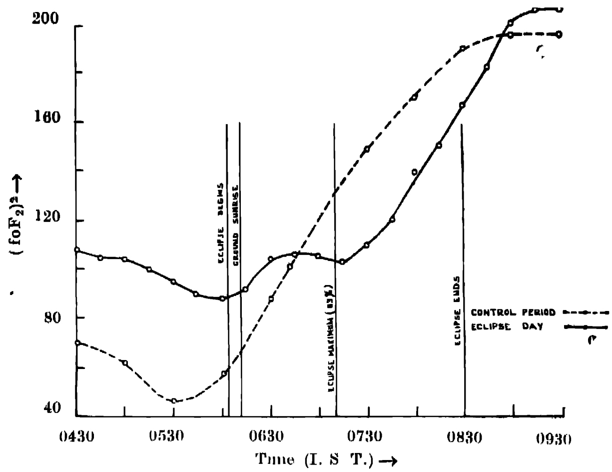

Fig 1 Variation of ion density, Trivandrum

was itself high as would be seen from figure 1. At about 0600 IST, the ionisation density started increasing and followed its usual trend upto about 0630 IST Thereafter, it remained more or less stationary as the eclipse progressed. It showed a slight decrease at 0715 IST Thus, the usually observed rapid rise in the ionisation density was arrested with the obscuration of the solar disc. During the recovery period i.e after the maximum of the eclipse, there was a rapid increase in ionisation density to reach the normal level by about 0900 IST. It may be noted that the decrease in ionisation density near the maximum of the eclipse, as compared to the level on control days, is quite considerable.

(*b*) *Tiruchirapalli*

Figure 2 shows the variation of $(foF_2)^2$ for Tiruchirapalli. The eclipse timings were a few minutes later than those at Trivandrum. The same trend, as observed in the case of Trivandrum, is also apparent here; the initial level of ionisation was high on the eclipse day, it remained practically constant from 0645 to 0745 IST, a small decrease at 0800 IST and thereafter a rapid rise to a constant level at 0845 IST. During the control period, there was a steady but rapid increase in ionisation density from 0600 to 0830 IST which is, however, a regular feature at this station. The minimum in ionisation density occurred about 45 minutes after the eclipse maximum. Here also, the decrease in the ionisation density with the onset and progress of eclipse was quite considerable.

(c) ***Madras***

Figure 3 shows the variation of $(foF_2)^2$ for Madras and the same trend in the behaviour of the ionisation density was observed as was in the case of Trivandrum and Tiruchirapalli. On the eclipse day, the values of foF_2 at 0430,

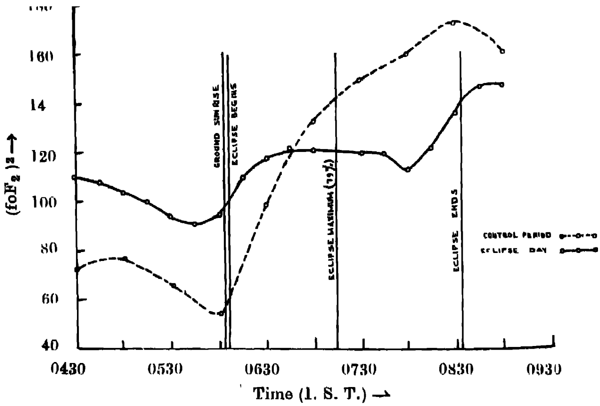

Fig. 2. Variation of ion density, Tiruchirapalli.

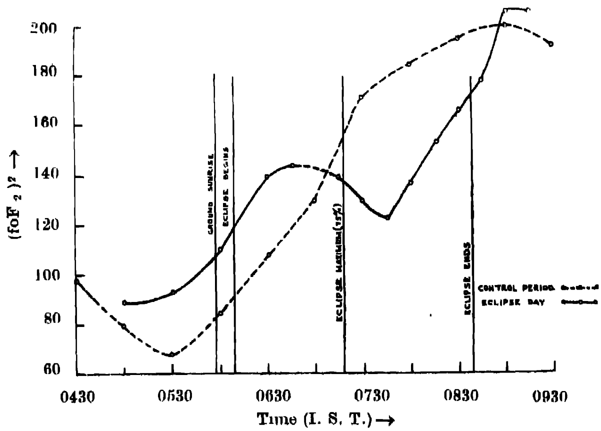

Fig. 2 Variation of ion density, Madras.

0445, 0515, 0545 and 0615 IST were doubtful and have been excluded from the mean curve. During the control period, the ionisation density increased rapidly from 0530 to 0900 IST. On the eclipse day, the increase was maintained till

0645 and then the ionisation decreased gradually to reach a minimum at 0745 IST. Thereafter, the increase was rapid till a constant level was reached at 0900 IST. The minimum in the ionisation density was quite considerable and was displaced from the eclipse maximum by about 27 minutes.

DISCUSSION

It is apparent from the variation of $(foF_2)^2$ as shown in figures 1, 2 and 3 that the eclipse did bring down the ionisation density along with the obscuration of the solar disc. It is also noticed that the ionisation density did not vary very appreciably as the solar disc was gradually covered and its minimum did not coincide with the maximum obscuration. But in all the three cases, the increase in ionisation density had been very rapid soon after the maximum of the eclipse. As the eclipse had occurred shortly after sunrise, the difference in the behaviour of the ionisation before and after the maximum of the eclipse can be explained qualitatively in the following way. During the obscuration of the solar disc, though the intensity of the solar radiation was gradually decreasing Cos χ (χ = solar zenith angle) was on the increase. These two effects were apparently balancing each other so as to retain the ionisation density at a fairly constant value. On the other hand, after the maximum of the eclipse, both the intensity of radiation as well as cosχ were increasing with the result that the ionisation density showed a rapid rise.

We have mentioned earlier that the effect of eclipse in the F_2 layer of the ionosphere has not been so regularly observed as in the case with the E and F_1 layers But when the eclipse occurs near ground sunrise the situation is different and a clear effect on the F_2 layer should be observable. Wells (1952) has reported well-marked effects of solar eclipse of September 1, 1951 which occurred near sunrise along the coast of United States.

It is interesting to note that the variation in the ionisation density during the progress of the eclipse, as observed by Wells, is very similar to what has been observed by us and described in this paper. Theoretical interpretation of the effect of eclipse near sunrise is discussed below.

The ionisation density of the F_2 layer at times other than sunrise is not wholly determined by χ but is greatly influenced by large scale movements of electrons. Ratcliffe (1956) has shown that if the electrons in the F_2 layer disappear by attachment process, its co-efficient γ varying with height, being given by

$$\gamma(Z) = 10^{-4} \exp \left[\frac{300 - Z(km)}{50} \right] \sec^{-1} \quad \ldots (1)$$

then the time constant of the electrons at different heights would be 3 hours at 300 km, 7.5 hours at 350 km and 20 hours at 400 km. In the present case, the eclipse lasted for about 2 hours and the layer height was about 350 km. Thus, if the same considerations are to hold good, the effect of the eclipse should be nil.

But the eclipse occurring near sunrise brings about a significant difference. Assuming that the peaks electron production rate is at the height(Z_m) of maximum electron density (N_m) as in a Chapman layer, the variation of N_m with time during solar eclipse is governed by :

$$\frac{dN_m(t)}{dt} = AQ_0 \cos \chi - \gamma(Z_m)N_m(t) \qquad \ldots \quad (2)$$

Where A = fraction of the solar disc exposed,

Q_0 = peak electron production rate when the solar rays are vertical.

The motion of electrons in the F_2 layer represented by a function $M(t)$ gives an additional term $N_m.M(t)$ (Ratcliffe, 1956). But near sunrise, $\frac{dN_m(t)}{dt}$ is large and $\gamma(Z_m)N_m(t)$ and N_m $M(t)$ are small, so that N_m is mostly determined by $AQ_0 \cos \chi$ Thus, when an eclipse occurs near sunrise, its effect should manifest itself in a distinct decrease of the ionisation density in synchronism with the obscuration of the solar disc.

It will be noted from figure 1 that $\frac{dN_m}{dt} \simeq 0$ from 0630 to 0715 IST. From equation (2) we get, for this time interval,

$$AQ_0 \cos \chi = \gamma(Z_m) \, . \, N_m \qquad \ldots \quad (3)$$

Assuming probable values of Q_0, $\gamma(Z_m)$ was found to be of the order of 10^{-5} sec^{-1} when the height of the maximum ionisation density was 350 km. This value of the attachment co-efficient is in good agreement with the same obtained elsewhere.

ACKNOWLEDGMENTS

The work described in this paper forms a part of programme of ionospheric research of Research Department of All India Radio, and also forms a part of the programme of the Indian National Committee for International Geophysical Year. The paper is published by permission of the Chief Engineer, All India Radio.

We are grateful to Mr. P. Ramankutty Nair, Mr. Y.N.G. Rao and Mr. S. S. Kohli, Station Engineers, All India Radio at Trivandrum, Tiruchirapalli and Madras for the supervision and to the CSIR staff at the stations for taking observations. The eclipse parameters have been obtained from the Indian Ephemeris and Nautical Almanac, 1958, published by the Director General of Observatories, New Delhi.

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