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Sunrise effect in the *F* region of the ionosphere over Kodaikanal

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ABSTRACT. The sunrise effect in the *F* region of the ionosphere over Kodaikanal has been studied. It is found that the effect occurs about an hour after the moment of sunrise for visible rays in the layer and a few minutes before ground sunrise. This result is compared with those obtained at other places. The delay in the occurrence of the sunrise effect is believed to be due to the absorption of the solar ionizing radiation by the ionospheric layers lying to the east of the observing station.

1. Introduction

It is well known that during the day there are three distinct layers in the ionosphere, the *E*, *F*1 and *F*2 layers. The maximum electron density of the *E* and *F*1 layers follow a regular diurnal and seasonal cycle whereas that of the *F*2 layer is very irregular indicating that it has no close dependence on the sun's zenith angle. At night the *E* layer disappears and the *F*1 and *F*2 layers coalesce to form a single night-time *F* layer. It is known that the initial rise in electron density with sunrise occurs somewhat later than the time at which the sunrise for visible light occurs in the layer. The study of this phenomenon known as the 'Sunrise Effect' is necessary for an undertstanding of the variations in the structure of the layer with time.

The time of the sunrise effect is taken as the time at which the initial rise of ion density occurs in the neighbourhood of the sunrise accompanied by a characteristic change in ion distribution. This phenomenon has been studied by Appleton and Naismith (1935) for Slough, Ghosh (1940) and Baral (1955) for Calcutta, Wells (1949) for Washington and Bhargava (1952) for Kodaikanal. Mitra (1948) has given a brief account of the effect at Calcutta. In this paper an account of the investigation made at Kodaikanal (Lat. 10° 14′N, Long. 77° 28′E, Geomagnetic Lat. 0°·6 N) on the delay in the sunrise effect in the *F* region of the ionosphere is given.

2. Observation of the sunrise effect

With the help of the National Bureau of Standards (U. S. A.) C-3 Type Vertical Sounding Multi-frequency Ionosphere Recorder of the Kodaikanal Observatory, $h'f$ records were obtained at intervals of two minutes for about half an hour centred round the time of initial rise of electron density for four months from December 1957 to March 1958. The $h'f$ records for 82 days were without excessive scatter and showed characteristic sunrise effect. From these records the precise time of the sunrise effect was noted. Also the height of maximum ionization (h_M) at the time of the sunrise effect was computed from the $h'f$ records by the method due to Booker and Seaton (1939) on the assumption of a parabolic layer. The time of sunrise at the level of maximum ionization and the time of ground sunrise for Kodaikanal for all these days were computed using the relations—

$$\cos\theta = \frac{a}{a+H} \qquad \text{and}$$

$$\cos h = \frac{\cos Z \;-\; \sin\phi \sin\delta}{\cos\phi \;\cos\delta}$$

where θ is the angle of depression of the sun below the horizon, a the radius of the earth,

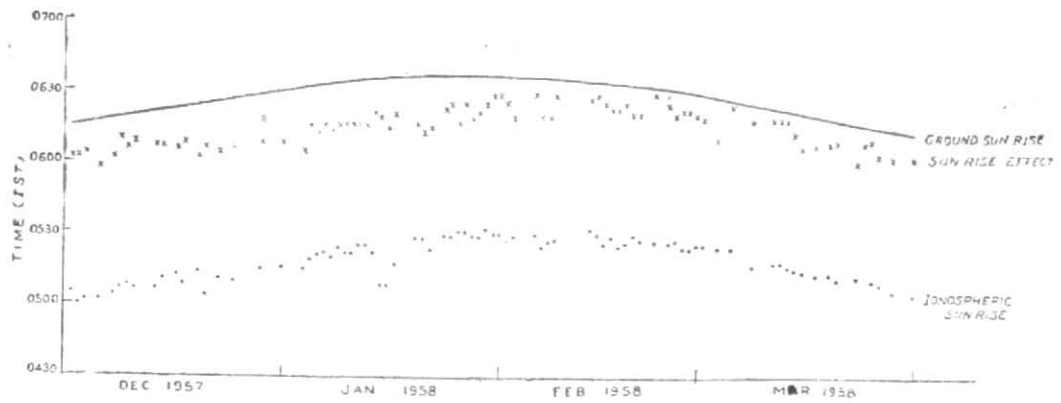

Fig. 1. Times of ground sunrise, sunrise effect and ionospheric sunrise

H the height of the layer, h the hour angle, Z the zenith distance of the sun, δ the solar declination and ϕ the latitude of the place. Corrections for the horizontal refraction and equation of time were also included.

3. Results and discussion

In Table 1 are given the times of ground sunrise, sunrise effect and ionospheric sunrise, the time delays and the height of maximum ionization at the time of occurrence of sunrise effect. The times of ground sunrise, the sunrise effect and the sunrise in the ionosphere are plotted in Fig. 1.

It will be seen from Table 1 and also Fig. 1 that the sunrise effect in the F region over Kodaikanal occurs a few minutes before ground sunrise and about an hour after the sunrise in that region. This delay of nearly one hour in the sunrise effect in the F region seems to be very nearly constant during the period of observation. Bhargava (1952) has observed that at Kodaikanal the sunrise effect and ground sunrise occurred simultaneously during March, in April the ionospheric effect occurred 2 minutes after ground sunrise and during May, June and July it occurred $3\frac{1}{2}$, 6 and 5 minutes respectively before ground sunrise. The results of these observations made at Kodaikanal may be compared with those obtained at other places.

Appleton and Naismith (1935) have reported for Slough that the early morning minimum of ionisation obtains when the ion production due to the rising sun just balances the effect of recombination and that the ionization minimum occurs at a time approaching to ground sunrise in summer but occurs about one hour earlier than ground sunrise in winter.

Ghosh (1940) has shown from observations carried out at Calcutta that the early morning minimum occurs after sunrise in region F in all seasons.

From recordings of the ionosphere conducted during May and June 1949 at the Derwood Experimental Laboratory, Carnegie Institution of Washington, Wells (1949) has observed that the time of initial sunrise effect followed ground sunrise in all instances.

Ghosh (1940) explains the delay in the occurrence of the sunrise effect (after sunrise in region F) as due to the predominance of the decrease in the density of the layer in the initial stages due to heating by the incidence of solar rays over the increase in density due to detachment of electrons. This explanation is no longer accepted.

Baral (1955) explains the delay times as due to the difference between the night-time and day-time heights of the ionospheric layer. According to him, if the night-time height is greater than the day-time height, the delay

TABLE 1

Date	Time of ground sunrise		Time of sunrise effect		Height of max. ionisation at the time of sunrise effect	Time of ionospheric sunrise		Time difference between ground sunrise and sunrise effect	Time delay of sunrise effect from ionospheric sunrise
	h	m	h	m	(km)	h	m	(min)	(min)
1-12-57	06	15	06	02	310	05	05	13	57
2-12-57	06	15	06	02	360	05	00	13	62
3-12-57	06	16	06	04	350	05	02	12	62
5-12-57	06	17	05	58	360	05	02	19	56
7-12-57	06	18	06	02	345	05	04	16	58
8-12-57	06	18	06	10	325	05	07	8	63
9-12-57	06	19	06	06	320	05	08	13	58
10-12-57	06	19	06	08	330	05	07	11	61
13-12-57	06	21	06	07	340	05	07	14	60
14-12-57	06	21	06	06	320	05	11	15	55
16-12-57	06	22	06	05	300	05	13	17	52
17-12-57	06	23	06	08	340	05	09	15	59
19-12-57	06	24	06	02	310	05	14	22	48
20-12-57	06	24	06	06	400	05	04	18	62
22-12-57	06	25	06	04	350	05	11	21	53
24-12-57	06	26	06	06	335	05	13	20	53
28-12-57	06	28	06	08	335	05	15	20	53
31-12-57	06	30	06	08	340	05	16	22	52
3- 1-58	06	31	06	04	360	05	15	27	49
4- 1-58	06	31	06	15	335	05	19	16	56
5- 1-58	06	32	06	12	320	05	21	20	51
6- 1-58	06	32	06	15	315	05	22	17	53
7- 1-58	06	32	06	13	335	05	20	19	53
8- 1-58	06	33	06	15	300	05	24	18	51
9- 1-58	06	33	06	15	320	05	22	18	53
10- 1-58	06	33	06	15	325	05	22	18	53
11- 1-58	06	34	06	15	300	05	25	19	50
12- 1-58	06	34	06	15	310	05	25	19	50
13- 1-58	06	34	06	20	340	05	22	14	58
14- 1-58	06	34	06	18	480	05	08	16	70
15- 1-58	06	35	06	14	480	05	08	21	66
16- 1-58	06	36	06	20	395	05	17	15	63

TABLE 1 (*contd*)

Date	Time of ground sunrise		Time of sunrise effect		Height of max. ionization at the time of sunrise effect	Time of ionospheric sunrise		Time difference between ground sunrise and sunrise effect	Time delay of sunrise effect from ionospheric sunrise
	h	m	h	m	(km)	h	m	(min)	(min)
19-1-58	06	36	06	16	300	05	28	20	48
20-1-58	06	36	06	12	300	05	28	24	44
21-1-58	06	36	06	14	345	05	23	22	51
23-1-58	06	36	06	22	300	05	29	14	53
24-1-58	06	36	06	24	300	05	29	12	55
25-1-58	06	36	06	16	285	05	31	20	45
26-1-58	06	36	06	24	285	05	31	12	53
27-1-58	06	36	06	18	300	05	29	18	49
28-1-58	06	36	06	20	300	05	29	16	51
29-1-58	06	36	06	24	280	05	32	12	52
30-1-58	06	36	06	28	300	05	30	8	58
31-1-58	06	36	06	28	300	05	30	8	58
1-2-58	06	36	06	24	320	05	27	12	57
2-2-58	06	36	06	18	310	05	29	18	49
5-2-58	06	36	06	28	300	05	30	8	58
6-2-58	06	36	06	18	340	05	25	18	53
7-2-58	06	35	06	18	320	05	27	17	51
8-2-58	06	35	06	28	310	05	28	7	60
13-2-58	06	34	06	26	270	05	32	8	54
14-2-58	06	34	06	28	290	05	30	6	58
15-2-58	06	34	06	24	325	05	26	10	58
16-2-58	06	33	06	22	290	05	29	11	53
17-2-58	06	33	06	22	330	05	25	11	57
18-2-58	06	33	06	24	320	05	26	9	58
19-2-58	06	32	06	20	280	05	30	12	50
20-2-58	06	32	06	20	290	05	28	12	52
22-2-58	06	31	06	29	300	05	27	2	62
24-2-58	06	31	06	24	290	05	27	7	57
25-2-58	06	30	06	20	300	05	28	10	52
26-2-58	06	30	06	22	300	05	25	8	57
27-2-58	06	29	06	22	300	05	25	7	57
28-2-58	06	29	06	20	290	05	26	9	54

TABLE 1 (*contd*)

Date	Time of ground sunrise		Time of sunrise effect		Height of max. ionization at the time of sunrise effect	Time of ionospheric sunrise		Time difference between ground sunrise and sunrise effect	Time delay of sunrise effect from ionospheric sunrise
	h	m	h	m	(km)	h	m	(min)	(min)
1-3-58	06	28	06	18	285	05	26	10	52
3-3-58	06	27	06	10	285	05	25	17	45
5-3-58	06	26	06	24	280	05	25	2	59
8-3-58	06	25	06	18	340	05	17	7	61
11-3-58	06	23	06	18	300	05	19	5	59
12-3-58	06	23	06	19	300	05	19	4	60
13-3-58	06	22	06	18	310	05	17	4	61
14-3-58	06	22	06	12	320	05	16	10	56
15-3-58	06	21	06	06	320	05	15	15	51
17-3-58	06	20	06	07	320	05	14	13	53
19-3-58	06	19	06	08	310	05	14	11	54
20-3-58	06	18	06	09	320	05	12	9	57
23-3-58	06	16	06	00	300	05	13	16	47
24-3-58	06	16	06	08	260	05	17	8	51
25-3-58	06	15	06	10	300	05	11	5	59
26-3-58	06	15	06	04	310	05	10	11	54
28-3-58	06	14	06	02	320	05	07	12	55
31-3-58	06	12	06	02	320	05	05	10	57

in the sunrise effect will be such that the effect will occur before ground sunrise but after sunrise in the region and if the daytime height is greater than the night-time height the sunrise effect in the region will occur after ground sunrise.

From the maximum electron density-time curves drawn for Kodaikanal it is observed that there is no appreciable change in the slope of the curves, *i.e.*, in the value of dN_m/dt at the time of sunrise for visible rays in the *F* region of the ionosphere. The slope changes just a few minutes before ground sunrise indicating a rise in the electron density. From this it follows that over Kodaikanal when the sunrise for visible rays occurs in the *F* region the rays pass through the ionospheric layers lying to the east of this place which absorb the solar ionizing radiation to such an extent that practically no ionization at the height of the *F* layer is caused. But just before ground sunrise the solar rays strike the *F* region almost horizontally without passing through any absorbing layer and so the solar ionizing radiation is strong enough to cause ionization and produce electrons. Thus it is the absorption of the solar ionizing radiation by the ionospheric layers lying to the east of the place that is responsible for the delay of about an hour in the occurrence of the sunrise

effect after the sunrise for visible rays takes place in the F region.

It is also found from the maximum electron density-time curves that increase in N_m at ground sunrise is rapid. A similar rapid increase in electron density at dawn in low latitudes had been noticed by Martyn (1955) who explained it on the basis of the horizontal drift of ionisation.

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