 Ionospheric Effects of the Total Solar Eclipse of 16 Feb. 1980 Observed over Ahmedabad

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Ionosonde observations and Faraday rotation measurements were made at Ahmedabad to study the ionospheric effects of the total solar eclipse of 16 Feb. 1980. Data on the eclipse day and control day (mean for 17-19 Feb. 1980) are presented in a comparative way. Decrease in the critical frequencies of E-, F1- and F2-layers, viz. \( f_{OE} \), \( f_{OF1} \) and \( f_{OF2} \) and in the minimum frequency \( f_{\min} \) detected by the ionosonde, associated with the eclipse are noted. True height analysis of the quarter hourly ionograms shows decreases in the electron densities at various heights, the effects being gradually delayed at higher altitudes. Increase in the height of maximum F2-layer ionization \( (h_F2) \) and in the semi-thickness of the F2-layer \( (\Delta h_F) \) are noted. A decrease in the total electron content (TEC) derived from the recordings of Faraday rotation at Ahmedabad is found during solar eclipse. No evidence of gravity waves, generated due to the eclipse and propagating in the ionosphere, could be detected from the continuous recording of \( f_{OF2} \) or TEC.

1. Introduction
A variety of experiments, both ground-based and rocket-borne, were conducted at a number of places in India by the Solar and Planetary Physics Group of the Physical Research Laboratory, Ahmedabad, to study the ionospheric and other effects of the total solar eclipse of 16 Feb. 1980. The details of the various experiments were compiled in a report earlier1. The major highlights of the ionospheric effects as detected by the ground-based experiments have been reported by Chandra et al2. In this paper the features of the ionosphere over Ahmedabad as revealed by the ionosonde observations and Faraday rotation measurements using 136 MHz radio beacon on board the geostationary satellite ETS-II are reported. The automatic ionosonde C4 at Ahmedabad operates quarter hourly as a routine; however, on the eclipse day and on the following day it was operated continuously during 1200-1800 hrs (75° EMT). The sweep time of the ionosonde is 2 min and hence it was possible to study the eclipse effects by means of operations with a time resolution of 2 min. The Faraday rotation measurements are made continuously on a paper chart recorder and the data have been scaled quarter hourly for this study.

2. Geometry of the Eclipse
The eclipse of the 16 Feb. 1980 was seen as a total solar eclipse over a belt of 120 km width passing through Gadag in the Western part of India to Rangapur and then to Puri in Eastern part. This is shown in Fig. 1. The circles represent locations where the Physical Research Laboratory had conducted experiments on its own or in collaboration with other institutions. Completely filled circles denote the totality of the eclipse observed on that location while the partially filled circles denote roughly the amount of totality at that location. The times marked for the locations in the totality zone represent the time (75° EMT) of the second contact for that location. The details were taken from the report by Subrahmanyam and Sreedhar Rao3.

3. Effects on Basic Ionospheric Parameters
To have a quick look on the behaviour of basic
ionospheric parameters, f-plots have been prepared for the eclipse day (16 Feb. 1980) from the quarter hourly ionogram scaling. These give the variations with time of the critical frequencies of E-, F1- and F2-layers ($f_0E$, $f_0F1$ and $f_0F2$) and of the minimum frequency, $f_{\text{min}}$, recorded by the ionosonde. These are shown in Fig. 2. For comparison, the mean variations for the three days (17-19 Feb.) are also shown in Fig. 2. Normally $f_0E$ shows a flat midday peak with maximum value of 3.6 MHz. On eclipse day, however, there is a gradual decrease of $f_0E$ from 1345 hrs and this drop continues till 1530 hrs when $f_0E$ drops down to 2.7 MHz. The $f_0E$ value increases again afterwards. The presence of Es did not permit scaling of $f_0E$ beyond 1600 hrs; hence this is not shown in Fig. 2. The drop from 3.5 to 2.7 MHz comes out to about 40% in terms of electron density. The time of the dip in $f_0E$ matches closely with the time of the maximum phase of the eclipse. Similarly, the decrease in $f_{\text{min}}$ associated with the eclipse on 16 February is noted.

The critical frequency of the F1-layer ($f_0F1$) is hard to identify at low latitudes during the high sunspot years. However, during the eclipse period clear cusp of F1-layer was present and the variation of $f_0F1$ for eclipse day is shown in Fig. 2. A dip around the maximum phase of the eclipse is clear and matches closely in time.

The daily variation of $f_0F2$ at Ahmedabad shows a well defined peak centred around 1400-1500 hrs as seen for 17-19 February when the peak value is about 16 MHz. The daily variation of $f_0F2$ on 16 February, however, does not show an afternoon peak, but short period fluctuations are noticed. It must be noted that a magnetic storm was recorded on 14 February and the unusual daily variation on 16 February could be the effect of storm conditions. A decrease in $f_0F2$ is, however, clearly seen associated with the eclipse. This is clearer in Fig. 3 where $f_0F2$ on 16 February is plotted during 1300-1700 hrs for every 2 min scalings. Values of $f_0F2$ show a slow decrease from 1300 to 1700 hrs when it drops from 14.5 to 13.5 MHz. But during 1530-1545 hrs there is an indication of a drop in $f_0F2$. The exact time of this minimum in $f_0F2$ could not be estimated due to the rather poor quality of ionograms during 1536-1541 hrs. However, from the slopes one can infer the minimum in $f_0F2$ at around 1540 hrs which is about 30 min after the maximum phase of the eclipse.

The variations in the minimum virtual height of F-layer ($h'F$) and the height of maximum ionization, $h_pF2$, derived as the virtual height at 0.834 of $f_0F2$, are shown in Fig. 4. There is no eclipse associated change in $h'F$ on 16 February. However, an increase in $h_pF2$ associated with the eclipse is suggested.
4. Effects in Electron Density Distribution with Height

To examine the eclipse effects in the ionization at different real heights, quarter hourly ionograms on the two days have been reduced for true height analysis using Budden's matrix method. The time variations of the electron densities at fixed real heights starting from 160 km up to $N_{\text{max}}$ level during the interval 1300-1700 hrs are shown in Fig. 5. On 16 February (Fig. 5), in addition to the smooth diurnal decrease, there was a sharp decrease in electron densities at all heights associated with the eclipse. This decrease was seen first at 1445 hrs at lower altitudes and gradually delayed to 1515 hrs at higher altitudes (around 400 km). The minimum in electron density shown by the dotted curve (Fig. 5) was seen at 1515 hrs for 160 km and gradually delayed to about 1550 hrs for higher altitudes. Thus there was a delay of about 40 min near $F_2$-region peak around 350-400 km.

The electron density distributions with height for a few selected times on 16 February are shown in Fig. 6. For comparison, a few profiles for 17 February are also shown in the same figure with dotted lines. The electron densities above the $N_{\text{max}}$ level have been obtained by extrapolation using an exponential decrease. It is interesting to note that the distributions at 1515 and 1530 hrs on 16 February show higher values of $h_{\text{max}}F_2$ and the semi-thickness of $F_2$-layer, $y_m$, than those on 17 February. Thus the eclipse effects include the thickening of the $F_2$-layer as well as a raise in the $F_2$-layer itself.

5. Effect in TEC and Slab Thickness

Continuous recording of the Faraday rotation measurements were made at Ahmedabad using the radio beacon at 136 MHz on board the geostationary satellite ETS-II. Quarter hourly values of the Faraday rotation angle have been converted into total electron content (TEC) using 350 km as mean field height. The variation of TEC on 16 February is shown in Fig. 7. As pointed out earlier, due to the prevailing storm condition, TEC does not show a smooth variation with afternoon peak. There are fluctuations with a periodicity of a few hours. Nevertheless the dip in TEC at around 1530 hrs is associated with the eclipse. The change works out to 10%, roughly. No evidence of
eclipse-induced gravity wave effects in TEC is noted. For comparison, variation of $N_m F2$ on this day is also shown (Fig. 7) along with the slab thickness (TEC/ $N_m F2$). The $N_m$ shows much sharper decrease than does the TEC, which is probably because TEC is an integrated effect. Sharp increase in the slab thickness is seen around 1530 hrs which is also associated with the eclipse.

6. Discussion
Ionosonde and Faraday rotation observations to study the ionospheric effects were conducted during the total solar eclipse of Mar. 1970 and annular eclipse of Sep. 1969 in United States. These observations of middle latitude stations showed decreases (around 20%) in the critical frequencies, $f_0E$ and $f_0F1$. The phase lag between the times of the eclipse maximum and electron density minimum increased with height to about 15-20 min and then remained constant around F2 peak. Increase in $h_m F2$ was also noted. Decrease in TEC amounted to about 30% in both of the eclipses and with time delay of about 30-50 min. Short period fluctuations due to eclipse induced gravity waves were not found in any of the TEC records.

The observations at a low latitude station, Ahmedabad, are similar in most respects except that the decrease in TEC is considerably smaller in magnitude. Much higher values of the thickness of the F2-layer and of $h_m F2$ could possibly be the reason for smaller effects contributed at higher altitudes.

References
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