Ionospheric Measurements during the Total Solar Eclipse of 11 August 1999

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ABSTRACT

A number of radio experiments were conducted from Ahmedabad (23° N, 73°E) to study the ionospheric effects of the total solar eclipse of 11 August 1999. Rapid radio soundings from the ionosonde, Riometer and Oblique incidence field strength measurements along three paths were made. Reduction of 20% was noticed both in f_{min} and in the F_1 layer critical frequency. The signal strengths of the oblique incidence paths also point to eclipse associated decrease in ionization in the D and lower E-region. The Riometer recordings also show higher signal during eclipse day.

INTRODUCTION

Total solar eclipse provides unique opportunity to study several atmospheric processes. Ionospheric effects of the solar eclipse have been studied for many events and decreases in the ionization of different layers (E, F_1 and F_2) in the ionosphere have been reported from radio sounding data. Effects in the D-region ionization have been studied from ionospheric absorption data or field strength measurements. Rishbeth [1] has described the eclipse effects in ionospheric E and F-regions on theoretical considerations. Regular radio soundings are made over Ahmedabad since 1953 and solar eclipse effects have been studied for the events of 30 June 1954 (maximum obscuration of 93 % at 1859h), 14 December 1955 (47 % at 1210h), 16 February 1980 (75 % at 1510h) and 24 October 1995 (83 % at 0800h). Chandra et al [2] has summarized the observed effects from these events. The study for the last two events is based on the true height analysis of rapid ionograms [2,3].

The path of totality for the solar eclipse of 11 August 1999 was about 100 km south of Ahmedabad and the maximum obscuration was 99.4% at 1801h (75° EMT) with first contact at 1656h and fourth contact (end) at 1859h. A number of radio experiments were conducted from Ahmedabad (23° N, 73° E). Physical Research Laboratory (PRL) operates a digital KEL ionosonde at Ahmedabad and rapid radio soundings (every 2 minutes) were made both on the eclipse day and control days (10 and 12 August 1999). A Riometer operating at 30 MHz was set up by the Indian Institute of Geomagnetism (IIG) at the Thaltej campus of PRL, located few km from the main campus and operated during the period 7-13 August. Field strength measurements were made along the three oblique incidence paths of Colombo-Ahmedabad (11905 KHz), Bombay-Ahmedabad (558 KHz) and Rajkot-Ahmedabad (810 KHz) by the Physics Department, Gujarat University, Ahmedabad during the eclipse day and control days. The results of the different experiments are presented here.

ECLIPSE GEOMETRY

The path of the totality along with the magnitude of the solar eclipse in India is shown in Fig. 1.

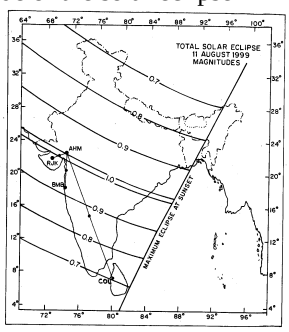

Figure 1. Path of totality over India and the maximum obscuration as seen during the solar eclipse of 11 August 1999

The path of totality was about 100 km south of Ahmedabad. The maximum obscuration was 99.4 % at 1801h with first contact (start) at 1656h and fourth contact (end) at 1859h. The obscuration of 99.4 % is much higher than for the earlier

events of February 1980 (75 %) and October 1995 (83 %). However the event occurred late in the evening. The locations of the transmitters for field strength measurements with mid point of ray path are also shown in the figure.

RESULTS

The period of observations is geomagnetically quiet with normal geomagnetic variations recorded at the Alibag observatory of IIG. The variations of the parameters f_{min} and the critical frequencies f_oE and f_oF_1 are shown in Fig. 2 both for eclipse day and control days (there was no significant change in f_oF_2).

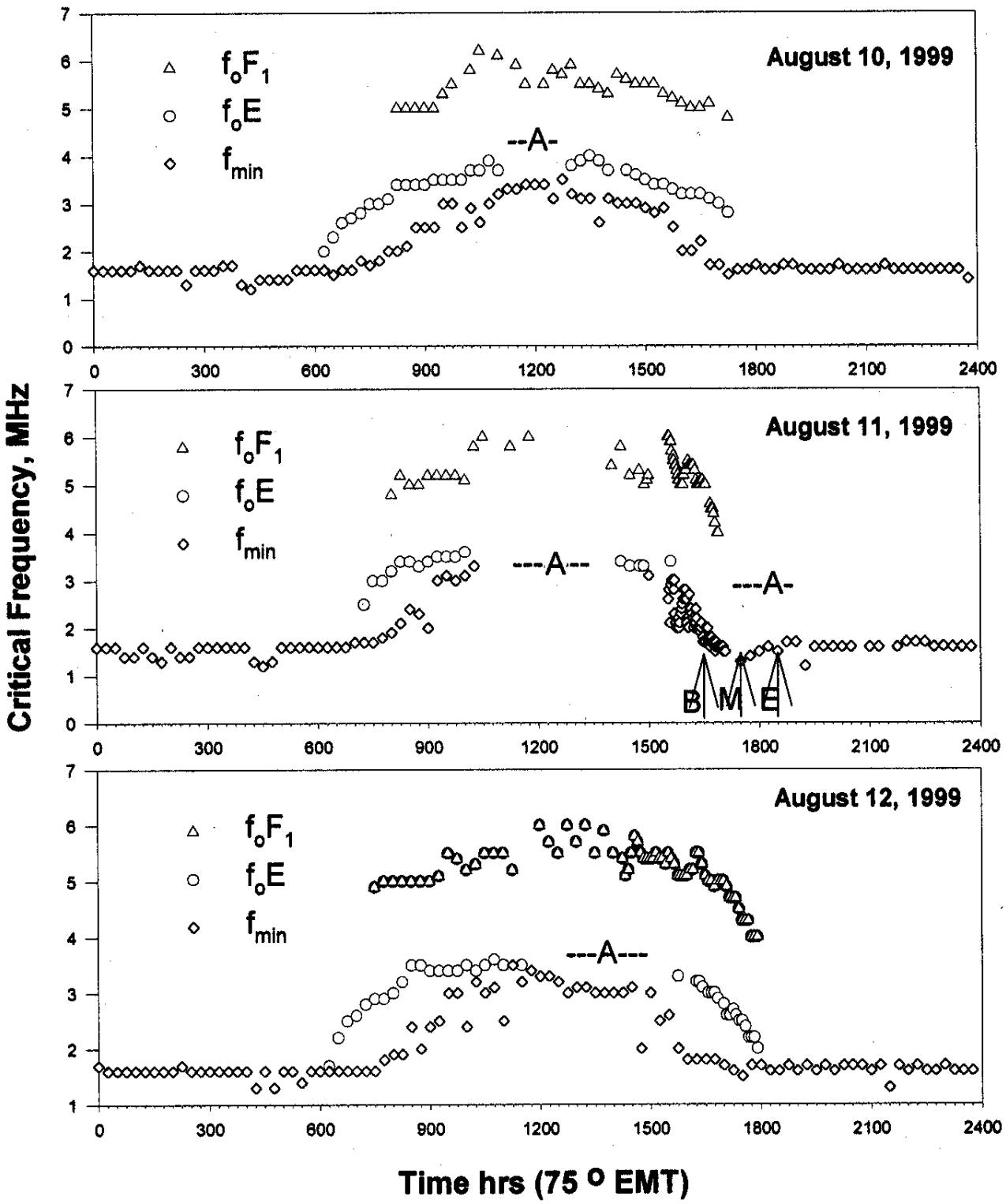

Figure 2. Daily variation of f_{min}, f_oE and f_of_1 on the eclipse day (11 August 1999) and on the control days (10,12 August 1999)

On the control day of 10 August 1999 f_{min} values are close to 1.6 MHz from 17h to 19h. On the eclipse day f_{min} values is 1.7 MHz at 17h but decreases to 1.3 MHz at 1730h then increases to 1.6 MHz at 18h, a decrease of about 20%. The parameter f_{min} is a measure of the D-region ionization, therefore the decrease indicates a reduction in D-region ionization. The critical frequency of the E-layer was not measurable beyond 16h on the eclipse day due to blanketing sporadic-E. F_1 layer critical frequency was lower on eclipse day than on control days. The f_oF_1 value is 5.0 MHz at 17h both on 10 and 12 August but only 4.0 MHz on 11 August. This amounts to a decrease of 20% in the critical frequency or 36% in the maximum F_1 layer ionization.

The field strengths of the three transmissions are shown in Fig. 3.

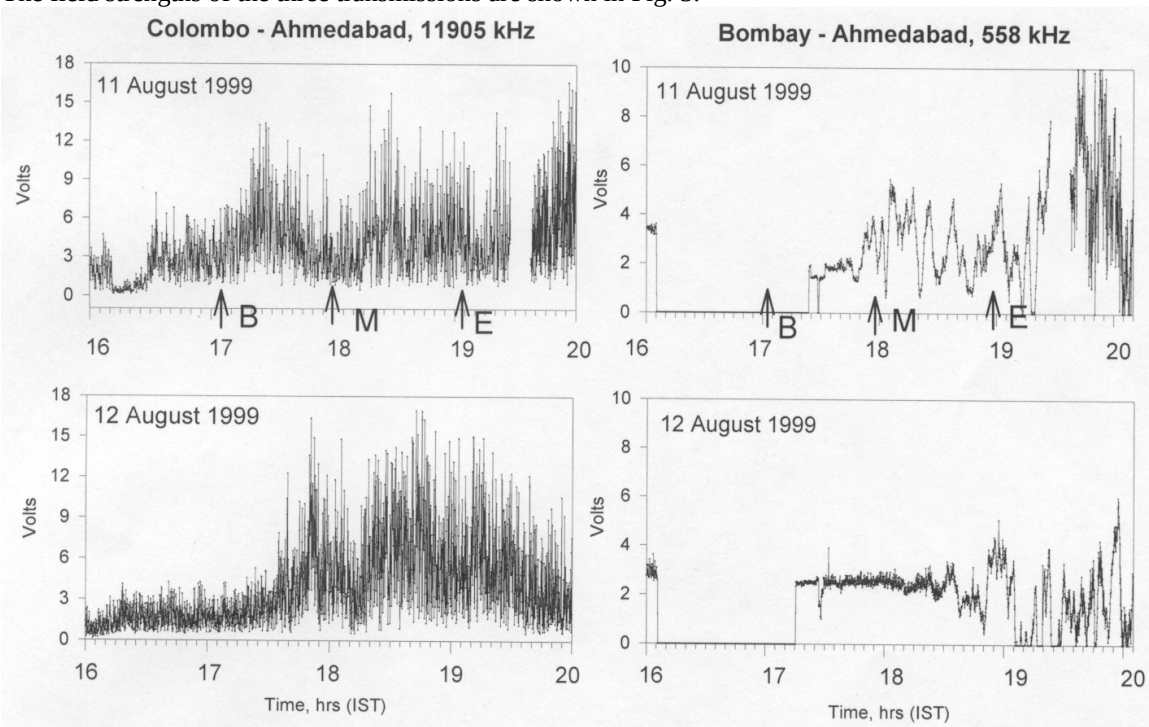

Figure 3. Field strength recordings of 11905 kHz (Colombo-Ahmedabad) and 558 kHz (Bombay-Ahmedabad) during solar eclipse day (11 August 1999) and on control day (12 August 1999).

The signal strength of the Colombo-Ahmedabad path increased rapidly initially with the start of the eclipse and later decreased till the maximum of the eclipse. The initial increase is due to the decrease in the ionization in the D and lower E regions while the decrease later is due to the excessive deviative absorption because of the wave penetrating to E-region. The field strength measurements of Bombay-Ahmedabad path show fadings in the nighttime due to the sky wave also reaching after sun set. On eclipse day the fading started about an hour earlier. The Riometer signal strength recordings are shown in Fig. 4.

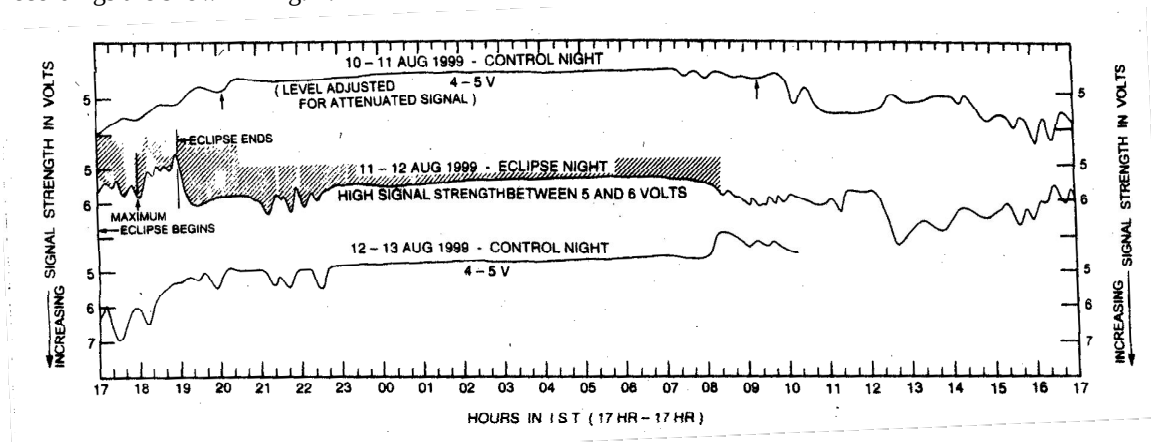

Figure 4. Riometer signal strength recordings on eclipse day (11 August 1999) and control days.

The signal strength decreases slowly from 17h to about 20-21h both on 10 and 12 August. However on eclipse day increase is noticed between 1730 to 18h. Higher signal is also seen on the eclipse night.

DISCUSSION

Field strength measurements of 15.07 MHz transmission from BBC (London) were made at Ahmedabad for the solar eclipse of 30 June 1954. An increase in the field strength was observed following the solar eclipse and the time of maximum field strength matched with the time corresponding to the maximum phase of the eclipse at the midpoint of the transmission path [4]. For the solar eclipse of 16 February 1980 field strength (11.8 MHz) measurements for the Colombo-Ahmedabad path showed an increase of about 23db above the normal value during the totality [5]. Multi-frequency absorption measurements at Ahmedabad showed decreases of 40-45% in absorption [6]. Phase and field measurements at VLF (16 KHz, Rugby) and HF (10 MHz ATA, New Delhi) and field strength at LF (164 KHz, Tashkent) were also made at Kavalur in India during this event [7]. For the VLF transmission there was an increase in phase with maximum phase anomaly at the eclipse maximum. This is due to the increase in the VLF reflection height because of the decrease in the D-region ionization. The amplitudes of the LF and HF signals also increased during the same time because of the lower absorption due to the decrease in D-region ionization. For the solar eclipse of 24 October 1995 measurements of absorption at 2.5 and 2.8 MHz at Ahmedabad showed decrease associated with eclipse [8] and the field strength for Colombo-Ahmedabad path (11.8 MHz) also showed an increase [9]. Ionspheric absorption measurements at 2.5 MHz at Delhi also showed minimum in absorption during the eclipse [10]. Thus the ionosonde, LF/HF field strength and Riometer measurements show eclipse associated decrease of ionization in in ionospheric D, E and F_1 regions.

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