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Day to day variability in the critical frequency of F_2 layer over the anomaly crest region, Ahmedabad

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ABSTRACT
Day to day variability in the critical frequency of F-layer (f_oF_2) over Ahmedabad is examined. Hourly data for the months of January, March and July for the year 1969 are analysed to study the variability. Daily variations on different days of the month, normalized deviations from mean and the standard deviations at each hour are studied. The deviations are up to ± 40% during night hours and up to ± 20% during day hours. While the variability during day hours is mainly because of the variability in the electric field (electrojet strength) that gives rise to vertical drift and subsequent ionization anomaly, the variability during night hours is also contributed by the variability in thermospheric neutral winds and temperature. f_oF_2 data at selected hours for Thumba, during the months of March and April 1967 and for Kodaikanal during months of August and October of 1972 and February, March of 1973, both located close to the dip equator also show variability of up to ± 30% at midnight and ± 15% at midday.

INTRODUCTION

Equatorial/low latitude ionosphere has several characteristic features like the Equatorial Electrojet, Equatorial Sporadic-E, Equatorial Anomaly and Equatorial Spread-F. Orthogonal configuration of the northward magnetic field and zonal electric fields of dynamo origin gives rise to these special characteristics of the ionosphere at low and equatorial latitudes. Several reviews cover the different aspects of the ionosphere at equatorial and low latitudes [Rastogi et al. 1972, Kelley and McClure 1981, Raghavarao et al. 1988, Rastogi 1989, Rastogi 1990, Rastogi et al. 1999]. It is well known that the electrodynamics plays an important role in the equatorial/low latitude ionosphere.

The E-region close to the dip equator is marked by intense daytime eastward current flows in the E-region of ionosphere in a narrow band of latitudes (± 3^o) centered over the dip equator and named 'Equatorial Electrojet' by Chapman [1951]. The intense currents are because of the enhanced conductivity due to the vertical polarization field close to dip equator. On occasions westward current flows during daytime due to the electric field reversals, known as counter electrojet [Gouin 1962]. Rastogi et al. [1971] showed that during the counter electrojet event equatorial type of sporadic-E disappears and the electric field reveres to westward as measured from the spaced receiver drift measurements from Thumba near the magnetic equator. Based on the geomagnetic field measurements in the electrojet regions in India and at other longitudes, the occurrence of counter electrojet has been studied in detail [Rastogi 1974].

Associated with equatorial electrojet is the strong sporadic-E of transparent type, resulting from the scattering of radio waves from plasma density fluctuations. Such fluctuations in plasma density arise due to the plasma instabilities that operate in the electrojet region like the two-stream instability and the cross-field instability mechanisms. Matsushita [11] found that the top frequency of Es-q is correlated with electrojet strength. During daytime counter electrojet events, when electric field reverses, equatorial type of sporadic-E also disappears. Ionosonde data have been used extensively to study the occurrence features of the disappearance of equatorial E_s. Away from magnetic equator sporadic-E is of flat type or blanketing type. Thin layers due to Ion convergence give rise to this type of sporadic-E.

The F-region at low latitudes is known to be anomalous with the maximum ionization density around ± 20^o magnetic latitude rather than at equator. This feature is also known as Equatorial Ionization Anomaly (EIA) or Appleton Anomaly [Appleton 1946, Rastogi 1959, Sharma and Raghavarao 1987]. This abnormal ionization distribution with latitude arises because the zonal electric fields map into F-region along the highly conducting geomagnetic field lines and give rise to the vertical plasma drift. Vertical transport of plasma (ExB) from equatorial region followed by diffusion along geomagnetic field lines gives rise to peaks at latitudes of ± 20° magnetic latitudes. In the daily variation of f_oF_2 at low latitudes this is seen as midday bite out.

Equatorial anomaly is related to electrojet strength (electric field) and suppressed during periods of counter electrojet. f_oF_2 near magnetic equator is negatively correlated and near anomaly peak positively correlated with the electrojet strength. Strength of anomaly is also correlated with electrojet strength.

Low latitudes are also marked with high incidence of spread-F (spreading of echo trace in ionograms) during nighttime [Booker and Wells 1938, Rastogi and Kulkarni 1969, Chandra and Rastogi 1972a,b, Sastri et al. 1979] . Equatorial spread-F (ESF) is associated with the post-sunset uplift of the F-region. Plasma density irregularities covering a wide range of scale sizes, extending from hundreds of km to a fraction of a meter are associated with the phenomenon of ESF [Ossakow 1981]. Plasma density structures also give rise to intense scintillations of radio waves propagating through the ionosphere [Basu and Basu 1985]. During magnetically disturbed periods incidence of equatorial spread-F is generally inhibited though some of the magnetic storm days are marked with intense spread-F. Phase of the Dst determines if the ESF is inhibited, developed in pre-sunrise hours or unaffected.

Ionospheric Variability

The ionosphere exhibits both temporal and spatial (latitudinal) variations. The regular variations like the daily, seasonal and solar cycle variations are fairly well understood. However in addition to these regular variations there are large day to day variations both on geomagnetic quiet as well as on geomagnetic active days. Variability in the neutral winds that give rise to the electric field of the dynamo region is considered the prime factor for this variability at low latitudes. Day to day variability in electrojet is well correlated with the ionospheric drifts near magnetic equator [Chandra et al. 1971]. Ionospheric drifts or VHF radar drift measurements show large variability. Variability in f_oF_2/TEC is of the order of 50% at low latitudes. During counter electrojet (CEJ) events transparent or the equatorial type of sporadic-E disappears. For stronger counter electrojet events anomaly also disappears. The day to day variability of the ESF is an important aspect to understand the onset conditions [Raghavarao et al. 1988, Alex et al. 1989, Vyas and Chandra 1991].

In the anomaly crest region variability in F-layer peak height and ionization is also due to variability in thermospheric neutral winds/temperature [Sridharan et al. 1994, Gurubaran and Sridharan 1993, Gurubaran et al. 1995].

During geomagnetic storms effects could be due to changes in the electric field (disturbance dynamo or those communicated from high latitudes) or due to changes in thermospheric neutral composition, winds and temperature. Ionospheric drifts near magnetic equator show decrease with magnetic activity. In case geomagnetic storms are associated with the reversal of electric field then disappearance of q type of E_s and absence of anomaly are also noted. Changes in the pre-reversal enhancement of electric field affect the post-sunset rise of the F-layer, development of anomaly and the subsequent onset of ESF.

Long series of ionospheric data obtained from regular radio soundings of ionosphere all over the globe provide valuable database for studying the climatology of ionosphere during different geophysical conditions. While the features like daily, seasonal, solar cycle and latitudinal variations are understood but the day-to-day variability, both on geomagnetic quiet and disturbed days, is yet to be completely understood. Space weather effects and pre-seismic ionospheric anomalies are some of the topics of recent interest. It is important to know about the variability of ionosphere both on geomagnetic quiet and disturbed conditions for better distinction between regular and episodic variations in the ionosphere over low latitudes.

With this aim hourly values of the critical frequency of F_2 layer (f_oF_2) over Ahmedabad, situated near the anomaly crest are analyzed to estimate the variability.

RESULTS

Deviations in f_oF_2 and the standard deviations at different hours are computed for different seasons and different solar activity years. Preliminary results on the variability of F-region over Ahmedabad are presented. Fig.1a shows the daily variations of f_oF_2 over Ahmedabad on different days for the month of March 1969. The daily variation of f_oF_2 shows minimum at 06h and maximum at 15h with wide range of day to day fluctuations. The values of f_oF_2 range from about 7 MHz to 15 MHz at midnight and from about 15 MHz to 17 MHz at midday. Thus the variability is

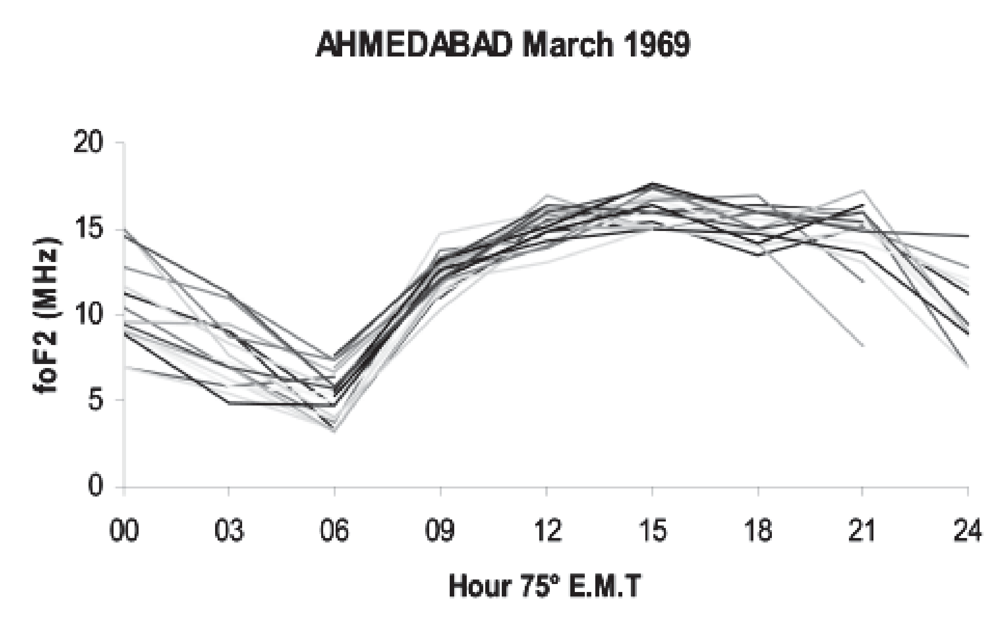


Figure 1a. Daily variations of the critical frequency of F-layer (f_oF_2) over Ahmedabad for each day of the month of March 1969.

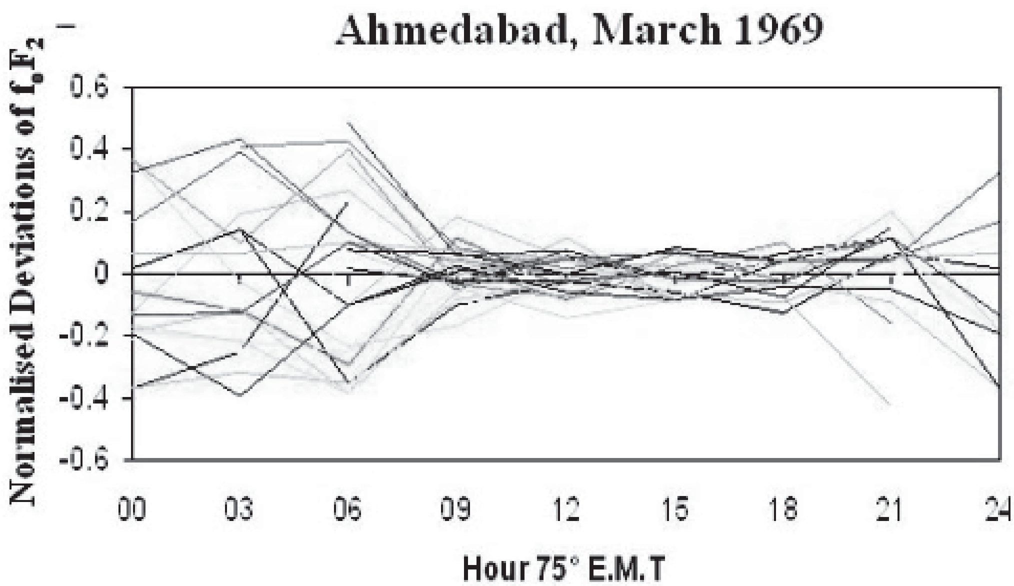
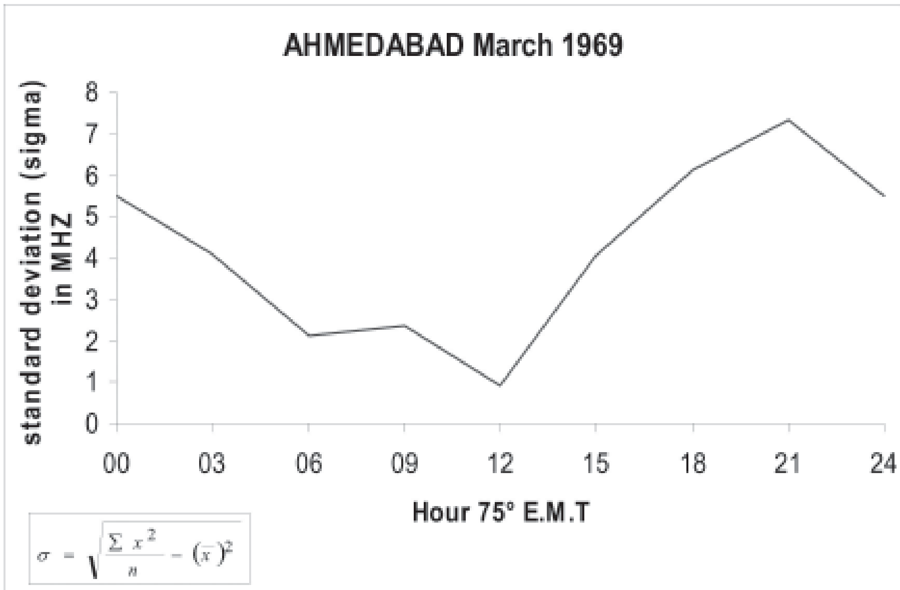


Figure 1b. Daily variations of the normalised deviations from mean of the critical frequency of F-layer (f_oF_2) over Ahmedabad for each day of the month of March 1969.

much more during nighttime than during day hours. This is clearly seen in Fig.1b where the normalized deviations in f_oF_2 are plotted for each hour of March 1969. The normalized deviations range between ± 0.4 from 00h to 06h and then decrease slowly to ± 0.1 at 09h. The deviations remain of this order till about 21h and later increase slowly to ± 0.4 around midnight. Thus the normalized deviations are much larger during night than during day time. The standard deviation at each hour for March 1969 is plotted in Fig.1c. The value of standard deviation is 5.5 MHz at midnight, decreases steadily to about 2 MHz at 06h and remains at this value till 09h. It decreases to a value of 1 MHz at midday and thereafter increases



$$\sigma = \sqrt{\frac{\Sigma x^2}{n} - (\bar{x})^2}$$

Figure 1c. Daily variation of the standard deviation of the critical frequency of F-layer (f_oF_2) over Ahmedabad for the month of March 1969.

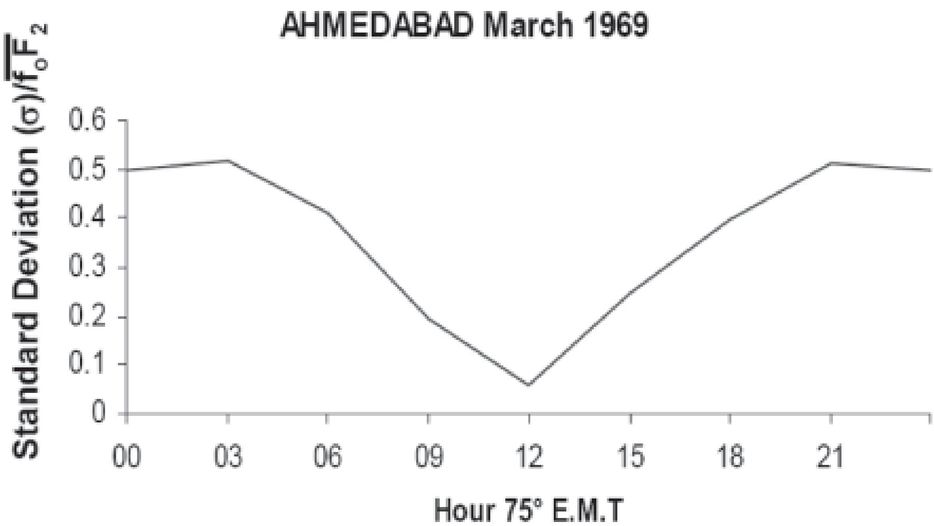


Figure 1d. Daily variation of the normalized standard deviation of the critical frequency of F-layer (f_oF_2) over Ahmedabad for the month of March 1969.

reaching a value of more than 7 MHz at 21h and decreases thereafter to a value of 5.5 MHz at midnight. The standard deviation normalized by f_oF_2 is shown in Fig. 1d. The values range from about 0.50 during 00h to 03h, decrease slowly to a minimum of less than 0.1 at noon and then slow increase to 0.5 at 21h. It remains at same value till midnight.

For studying the variability during different seasons the daily variations of f_oF_2 are examined over different months. Fig. 2a shows the daily variations of f_oF_2 over Ahmedabad for the month of July 1969. The daily variation shows minimum at 06h and broad maximum in the afternoon. The range of the daily variation is less compared to that of March 1969. The values of f_oF_2 range between 5 and 10 MHz at midnight to between 11 and 15 MHz in the afternoon. The

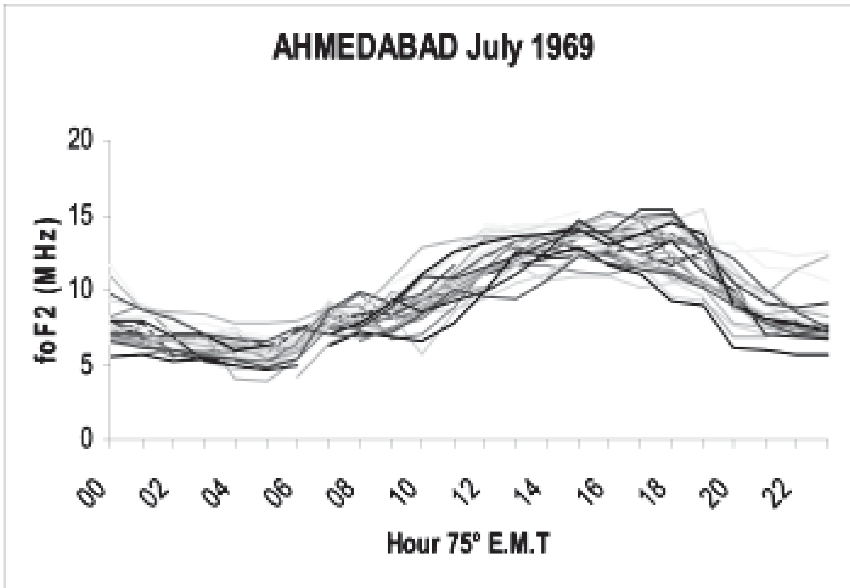


Figure 2a. Daily variations of the critical frequency of F-layer (f_oF_2) over Ahmedabad for each day of the month of July 1969.

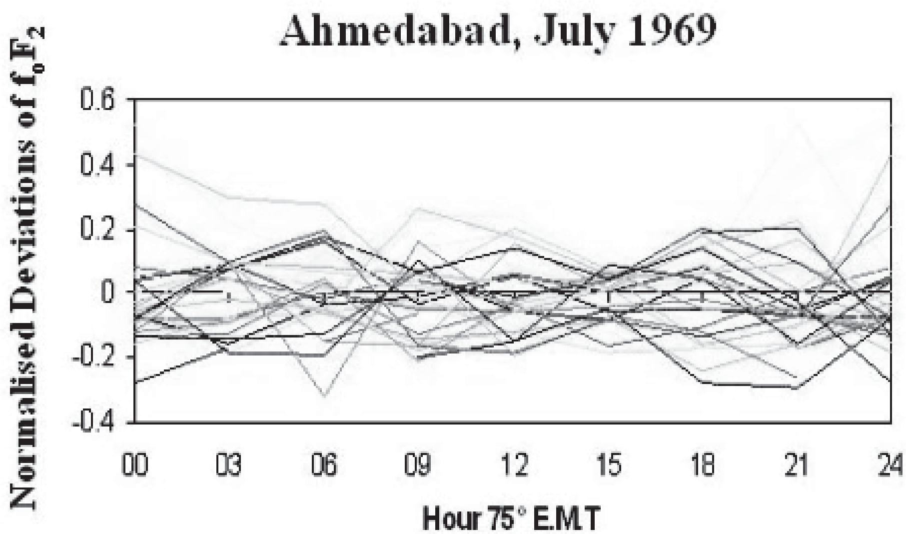


Figure 2b. Daily variations of the normalised deviations from mean of the critical frequency of F-layer (f_oF_2) over Ahmedabad for each day of the month of July 1969.

normalized deviations of f_oF_2 at each hour for the month of July 1969 are shown in Fig. 2b. The values range between ± 0.3 during night to between ± 0.2 during day hours. The minimum values of ± 0.14 are at 15h. The daily variations of f_oF_2 for the month of January 1969 are shown in Fig.2c. The day to day values range between 3 and 7.5 MHz at midnight and between 8.5 and 15 MHz around midday. The daily variations of normalized deviations of f_oF_2 for the month of January 1969 are shown in Fig.2d. The values range between ± 0.40 during night hours and between ± 0.25 during day hours. Comparing the deviations for the three months of March, July and January, which are representative of the equinox, summer and winter months, it is seen that while the daytime deviations are of same order during different

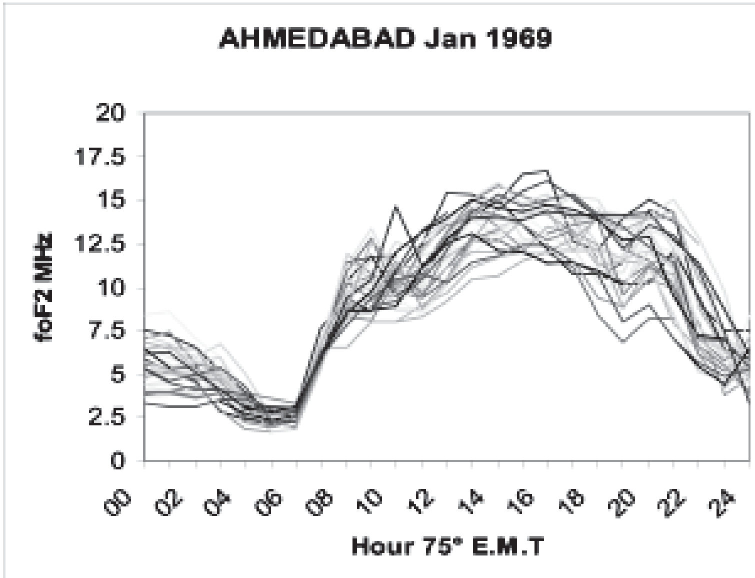


Figure 2c. Daily variations of the critical frequency of F-layer (f_oF_2) over Ahmedabad for each day of the month of January 1969.

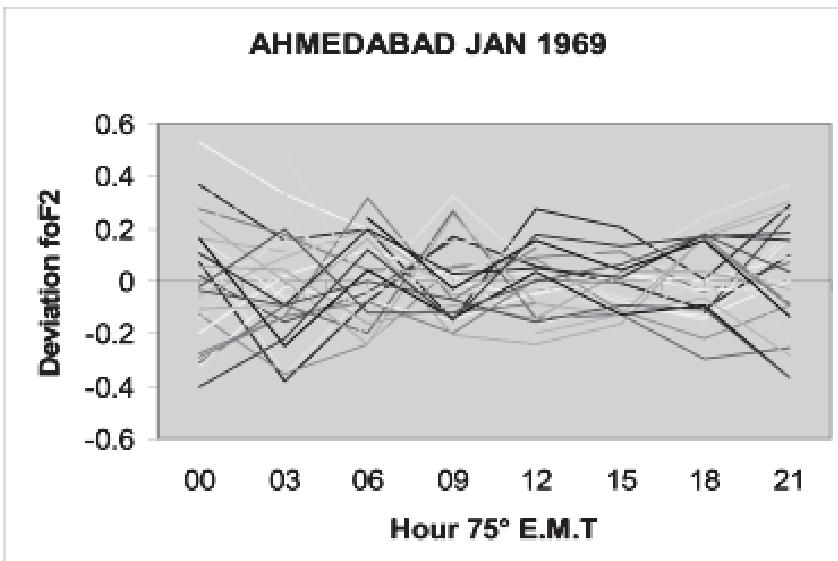


Figure 2d. Daily variations of the normalised deviations from mean of the critical frequency of F-layer (f_oF_2) over Ahmedabad for each day of the month of January 1969.

seasons. The nighttime deviations are least during equinoxes.

To study the variability at different solar cycle epochs we have examined data for the month of January 1997 also. Fig. 3a shows the daily variations of f_oF_2 at Ahmedabad during different days of January 1997. The values of f_oF_2 range between 2 and 4 MHz at midnight and between 5 and 11 MHz at midday. The daily variation of the standard deviation is shown in Fig. 3b. The value is about 1 MHz at midnight and decreases till 06h. It increases thereafter reaching a small peak at 09h and than another peak at 18h.

Thus the deviations are more during the night hours than during day hours. This is due to the fact that the daytime values of f_oF_2 at Ahmedabad are mainly controlled by the equatorial electrodynamics and the subsequent development of equatorial ionization anomaly. During nighttime the variability in

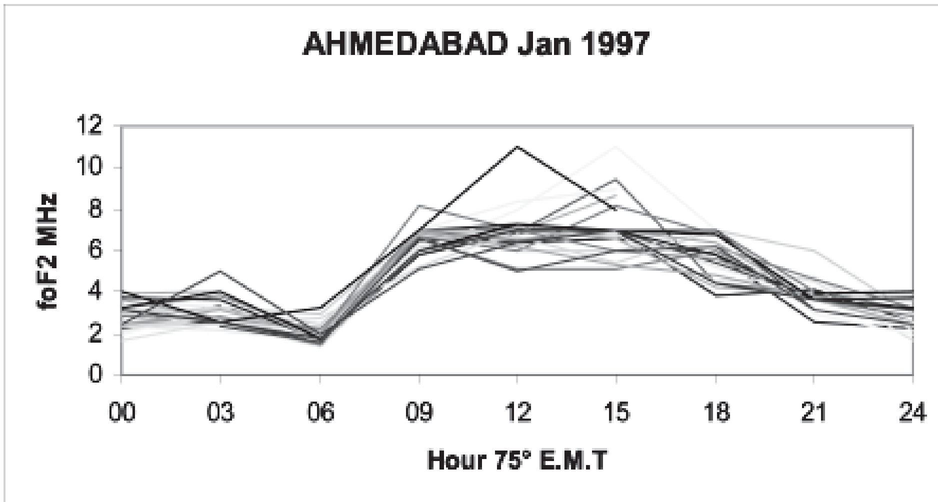


Figure 3a. Daily variations of the critical frequency of F-layer (f_oF_2) over Ahmedabad for each day of the month of January 1997.

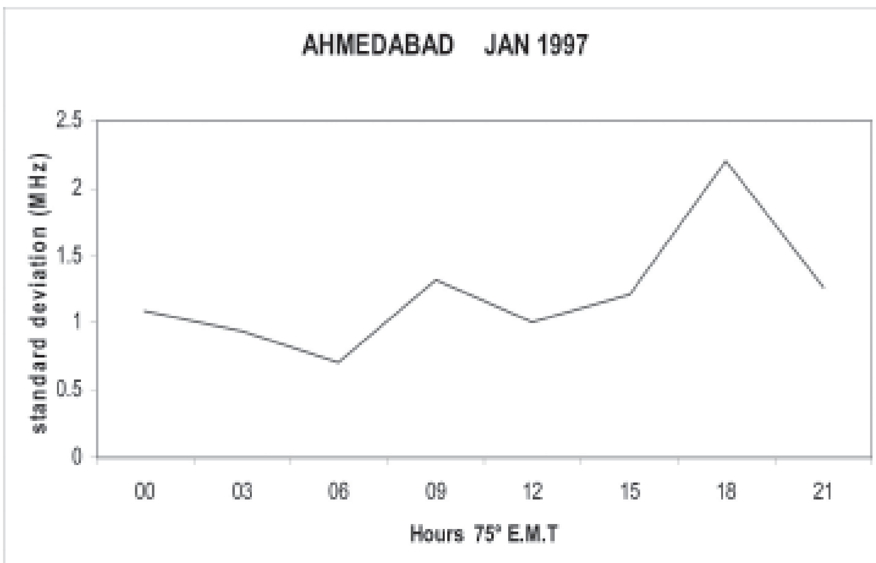


Figure 3b. Daily variation of the standard deviation of the critical frequency of F-layer (f_oF_2) over Ahmedabad for the month of January 1997.

thermospheric neutral winds and temperature also contribute in the variability of f_oF_2 at a location in the anomaly crest region. Detailed analysis covering different solar cycle epochs and different geomagnetic activity is in progress.

To have a comparative feel of the variability at a location near dip equator we have examined the f_oF_2 data at Thumba for the months of March and April 1967. The mean, maximum and minimum values of f_oF_2 at few hours (00, 06, 12, 18 h) are collected in Table 1. The variability is around ± 30% at midnight and ± 15% at midday. Similar examination of data at Kodaikanal for the months of August and October of 1972 and February and March of 1973 are made and the results are collected in Table 2. The variability are again similar to that at Thumba.

Table 1. Maximum and Minimum f_0F_2 (MHz) and deviations at Thumba

March 1967

Hour 75° EMT	Mean	Max	Deviation of Max in %	Min	Deviation of Min in %
06	6.1	8.5	39	4.5	26
12	10.3	12.4	20	9.4	9
18	10.5	13.4	28	8.2	22
00	9.0	10.5	17	5.2	42

April 1967

Hour 75° EMT	Mean	Max	Deviation of Max in %	Min	Deviation of Min in %
06	7.2	9.4	30	6.0	17
12	10.3	11.8	15	9.0	13
18	12.0	13.8	15	10.4	13
00	10.7	12.6	18	7.6	30

Table 2. Maximum and Minimum f_0F_2 (MHz) and deviations at Kodaikanal

August 1972

Hour 75° EMT	Mean	Max	Deviation of Max in %	Min	Deviation of Min in %
06	5.9 7.4		25	5.0	15
12	9.0	12.0	33	7.6	15
18	10.4	13.2	27	8.6	17
00	8.8 9.4		7	4.4	50

October 1972

Hour 75° EMT	Mean	Max	Deviation of Max in %	Min	Deviation of Min in %
06	6.6	7.2	10	5.8	8
12	10.0	11.4	14	8.6	14
18	11.0	13.6	24	9.4	15
00	10.0	11.4	14	8.8	12

February 1973

Hour 75° EMT	Mean	Max	Deviation of Max in %	Min	Deviation of Min in %
06	6.8	7.2	6	5.8	15
12	8.5	11.5	35	7.6	10
18	9.2	11.6	27	6.4	30
00	8.6 9.0		5	6.8	21

March 1973

Hour 75° EMT	Mean	Max	Deviation of Max in %	Min	Deviation of Min in %
06	3.8	4.4	16	3.2	16
12 8.8		10.8	23	8.2	7
18	10.2	12.4	21	8.6	15
00 8.7		10.0	15	7.0	19

SUMMARY AND CONCLUSION

The critical frequency of the F_2 layer, f_oF_2 over Ahmedabad is examined to study the day to day variability. Deviations from mean and standard deviations are computed for January, March and July 1969 and for January 1997. Normalised deviations range from 0.4 during night to 0.2 during day for the year 1969. The higher values during nighttime seem to be due to the variability in the thermospheric neutral temperature and winds. Data of the months of March, April 1967 for Thumba located at dip equator are also examined for 00, 06, 12 and 18h. The variability is up to 0.3 at midnight and 0.15 at midday. It is planned to study the day to day variability during different months and solar activity years for both quiet and disturbed days. The day to day variability in the equatorial electrojet strength will also be examined.

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