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Strength of the equatorial electrojet and geomagnetic activity control on VHF scintillations at the Indian longitudinal zone

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Amplitude scintillations on 244 MHz radio signals transmitted from geo-stationary satellite, FLEETSAT (73°E), were continuously recorded at a network extending from Ujjain (situated north of anomaly crest region) to the equatorial station, Trivandrum, by the Indian Institute of Geomagnetism, Mumbai. Parameters of geomagnetic activity like *K*-Alibag, A_p and electrojet strength are used to study the association of the amplitude scintillation recordings at the equatorial station, Trivandrum (dip 1° N) and at Mumbai (dip 26° N), a station south of the anomaly crest region during the high solar activity period 1989-1991. It is observed that an increase in geomagnetic activity (*K*-Alibag or A_p) suppresses the occurrence of scintillation activity at both the stations, whereas the electrojet strength is found to have no association on the occurrence of scintillations. A total of 77 storms occurring during this period are classified into three types according to Aarons criterion. The time of the maximum intensity of ring current appears to play a role directly or indirectly in establishing the conditions necessary for the equatorial F-layer irregularity generation and inhibition which, in turn, manifests itself in scintillation activity. However, there is about 30-40 % of scintillation activity unaccounted by the magnetospheric electric field alone.

1 Introduction

Fluctuations in electron density in various spatial scale sizes, known as ionospheric irregularities, may be produced by turbulence, plasma instabilities, incoming particle streams, gravity waves or other physical processes. These fluctuations, usually present in the post-sunset equatorial F-region, are responsible for the spreading of echoes in ionograms[1], a phenomenon known as equatorial spread-F (ESF) and for the scintillations caused in trans-ionospheric radio propagation. With the advent of satellites, radio beacon has been used extensively to study ionospheric irregularities through the scintillation effect.

Various geomagnetic indices like AE, K_p and D_{st} have been used to study the effect of geomagnetic activity on the generation of ionospheric irregularities producing VHF scintillations. Early investigations into the relationships between spread-F occurrence and geomagnetic activity have indicated, in general, a positive correlation at the high latitudes and a negative one at the equatorial latitudes[2-4]. More detailed analyses for equatorial-belt stations have confirmed that the correlation is predominantly negative. However, at certain times (particularly, in the pre-sunrise period), the correlation can be positive[5,6]. In midlatitude regions it has been known for some time[7,8] that statistically the occurrence of spread-F is found to be delayed by several days following enhanced geomagnetic activity. While scintillation is not universally accepted as equivalent to spread-F (Ref. 9), the two phenomena are obviously related and frequently compared. Rastogi[10] has shown that the F-region irregularities can exist hours after the sunrise when both the F1, F2 and E-layers are fully developed. Vyas and Chandra[11], using scintillation and ionosonde data from March 1991-January 1992 at Ahmedabad, have observed that there is a marked reduction in the occurrence frequency of scintillations on magnetically disturbed days during pre-midnight period. Good agreement has, however, been noted between the occurrence of spread-F and scintillations during equinoxes and winter months, though there are significant differences during summer months.

Nambothiri *et al.*[12] have used a daily value of A_p for grouping storms. The necessary conditions for inhibition of irregularities and generation of irregularities during magnetic storms can be stated for certain states of ionosphere. For inhibition of irregularities, Koster[13] has indicated that there were times during large magnetic disturbances near sunspot maximum when irregularities were 'suppressed'. The forcing factors in the inhibition or generation of irregularities appear to be primarily the height of the F2 layer with the possible addition of the pre-reversal drift velocity, the rate of fall of the layer and the rate of change of density with height. Clemensha and Wright[14] compared the height of F2 layer with scintillations and found no case where scintillations commenced until the height began to fall. In addition, during magnetically disturbed days they[14] found the sunset rise to be considerably reduced. In a study by Jayachandran *et al.*[15], it was concluded that it is not possible to define precise altitudes and vertical velocities at which instabilities would be generated. Many studies of the correlation of altitude with F-layer irregularities at the equator have verified the inability to set a distinctive sunset height for irregularities to develop. In the post-sunset period the equatorial F-region rises to higher altitudes, where ion-neutral collision frequency is quite small, thereby creating conditions favourable for Rayleigh-Taylor (R-T) instability. However, during magnetically disturbed days, the sunset-post sunset height rise is inhibited [15,16].

The equatorial electrojet is primarily caused by the eastward electric field (**E**) which interacts with horizontal magnetic field (**B**) and exerts $\mathbf{E}\times\mathbf{B}$ force on the plasma. In the F-region as well as in topside ionosphere, the electron and ion gyrofrequencies are greater than their respective collisional frequencies with the neutral particles, with the result that electrons and ions drift together with Hall drift velocity $(\mathbf{E}\times\mathbf{B})/\mathbf{B}^2$. The plasma thus rises up along with the associated irregularities, if any, over the magnetic equator and subsequently diffuse these irregularities down the magnetic field lines to the F-region of higher latitudes by some instantaneous mechanism, thereby causing the post-sunset scintillations in the low latitude belt. So, we expect that changes in the equatorial electrojet currents may influence the occurrence of low latitude scintillations.

The association of the scintillation activity with the geomagnetic indices on global and regional scales and that of equatorial electrojet strengths are examined in this paper, using two stations in the same longitudinal zone but widely separated in latitudes. Trivandrum, a station being situated very close to the magnetic equator, may be assumed to be the seat of the generation, while Mumbai is a station just south of the anomaly crest region, far from the generation region. The present study also explores one source which directly or indirectly is related to the rise and fall of the F-layer, viz. the time of onset of recovery phase, which is represented by the time of maximum D_{st} excursion rather than the other phases of the geomagnetic storm.

2 Data

Information on the occurrence of scintillation for each of the days at stations Trivandrum (geogr. lat. 8.48°N, long. 76.95°E; dip 1°N) and Mumbai (geogr. lat. 19°N, long. 73°E ; dip 26°N) during the high solar activity interval years 1989-1991 are the source of basic data for studying the association with electrojet strength and indices of geomagnetic activity (*K*-Alibag and A_p index). Also few typical geomagnetic storms during the above years were selected from *Solar Geophysical Data* (*Prompt Report*) and the results on the case studies are presented.

3 Results

3.1 Maximum electrojet strength

The equatorial electrojet currents are responsible for the enhanced daily variation of the *H* component of magnetic field at stations close to the dip equator. The electrojet is basically a daytime phenomenon. Thus, the values of *H* field above the nighttime level represent the strength of electrojet. However, these values contain both S_q and electrojet currents. If, the difference in the diurnal pattern between two stations in the same longitudinal sector such that one is under the influence and the other well outside the electrojet are compared , then the magnetospheric currents can be presumed to be cancelled out and the additional ionospheric contribution due to electrojet can be estimated.

The hourly diurnal inequalities in the horizontal component *H* of the geomagnetic field level over the midnight base level at Alibag (representing the S_q, dip 26°N) are numerically subtracted from similar inequalities at Trivandrum (representing S_q + electrojet) to isolate the strength of the electrojet. Indian Institute of Geomagnetism (IIG), Mumbai, publishes these values in their quarterly publication as prompt report and the same have been used. The maximum noon hourly value designated as that day's electrojet strength and the occurrence of the scintillation on that night are taken as the parameters for examining the association. Scintillation data (both pre-midnight and post-midnight events) are arranged in 14 different groups depending on the range of the strength of the electrojet. Mean percentage occurrences observed at Trivandrum and Mumbai (Bombay) for each of these groups are computed which conclude that the electrojet strength does not have any perceptible association with the scintillation occurrence at both the stations.

The electrojet strength during daytime hours, under favourable conditions, are expected to provide additional 'electric fields' to generate irregularities in the ionosphere mostly during the early evening/nighttime. As such, the occurrence of scintillation activity during post-midnight hours are excluded and the data are regrouped for examination for any possible association with electrojet. The pre-midnight scintillations, with onset times between 2000 and 2300 hrs IST, are classified into similar 14 different ranges of electrojet strengths and the mean scintillation activity for each of these groups is worked out and are shown in Fig. 1. These results have further confirmed the non-association of the electrojet strength during the daytime and the pre-midnight occurrence of scintillation activity at both the stations.

3.2 Association with geomagnetic activity

3.2.1 K-indices—Bartels *et al.*[17] developed *K*-indices to characterize irregular geomagnetic activity originating from the outflow of plasma from the sun. These are the 3-hourly indices having values from 0 to 9 depending on the range of amplitude of *H* component in that particular period. With the easy availability of *K*-indices from several stations distributed over the globe, a truly planetary index, K_p of geomagnetic activity could be derived. The IIG publishes *K*-indices for Alibag station and the same have been used . Depending on the daily *K*-index at Alibag, all the days during 1989-1991 are arranged in 11 different groups. The first group of *K*, ranges from 1 to 12, the second from 13 to 14 and so on, the last eleventh group ranges from 32 to 45. Mean percentage occurrences of scintillation activity at both the stations Trivandrum and Mumbai are computed for each of the *K* groups and are shown as histograms in Fig. 2. The scintillation occurrence at both the stations is inferred to decrease with increase in *K*-index, thus with local geomagnetic activity.

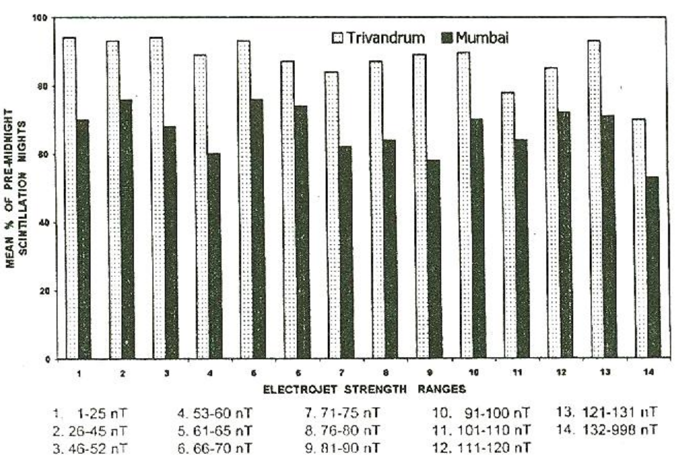

Fig. 1—Histograms showing the electrojet strength association with mean percentage of pre-midnight scintillation nights (onset time between 2000 and 2300 hrs IST) during 1989-1991 at Mumbai and Trivandrum (Electrojet strength during daytime is grouped into 14 ranges)

3.2.2 A_p indices—The A_p indices, for each of the days, are published every month by IAGA in their bulletins. The days during 1989-1991 are divided into 14 different A_p ranges and the mean percentage occurrences in each of the range groups are estimated. In Fig. 3 mean percentage occurrences at both Mumbai and Trivandrum are shown as histograms. It is clear from Fig. 3 that there is a general tendency of decrease in scintillation occurrence with increase in A_p values at both the stations. However, it can be visualized from the results in Fig. 3 that the reduction in the scintillation activity at Trivandrum is not very

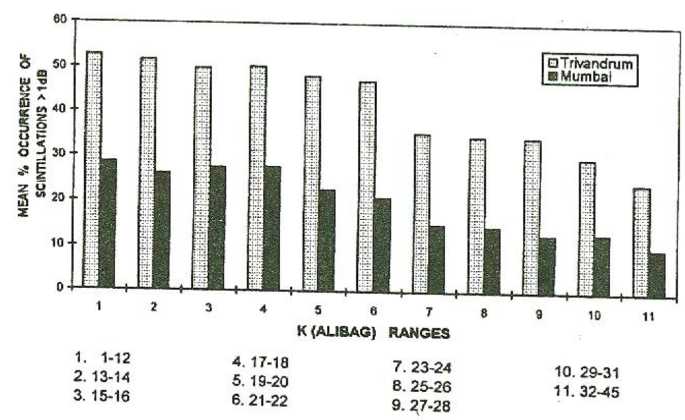

Fig. 2—Histograms showing the *K*-Alibag association with mean percentage occurrence of scintillation during 1989-1991 at Mumbai and Trivandrum (*K*-Alibag is divided into 11 groups.)

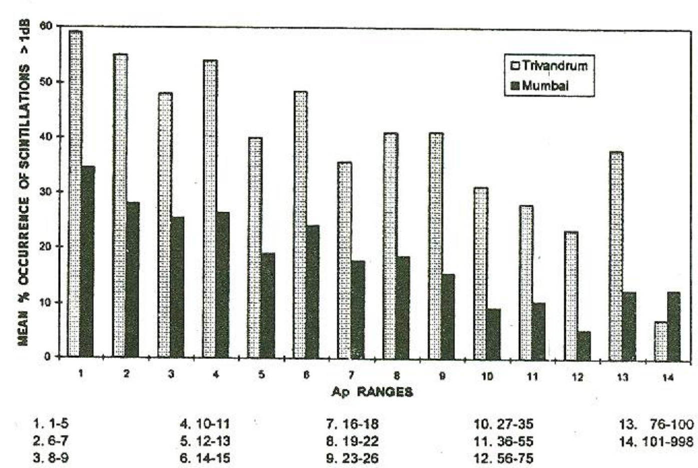

Fig. 3—Histograms showing the A_p-index association with mean percentage occurrence of scintillation during 1989-1991 at Mumbai and Trivandrum (A_p-index is divided into 14 groups)

systematic, though it is apparent that the reduction at Mumbai is systematic. For example, at Trivandrum the average percentage of occurrence of scintillation in A_p groups 1-5 is around 50%, while in the groups 10-14 it is around 26%. Thus, the scintillation occurrences at both the stations have shown reduction with increase in A_p values, although the reduction is much more pronounced near the anomaly crest station, Mumbai.

3.2.3 Seasonal associations of indices—In the above grouping of activities, no seasonal sub-divisions were made and the entire period 1989-1991 is considered as a single unit. To understand the seasonal association at the two stations, the percentage occurrences of scintillation activity are divided into the three seasons, namely, *j*, *e* and *d*, and are classified into the same groups as was divided earlier for the entire period in respect of *K*-Alibag and A_p. Histograms are made for each of the seasonal groups separately and are shown in Fig. 4 for both the stations. At Trivandrum, mean percentage of occurrence of scintillation activity is noticed to be

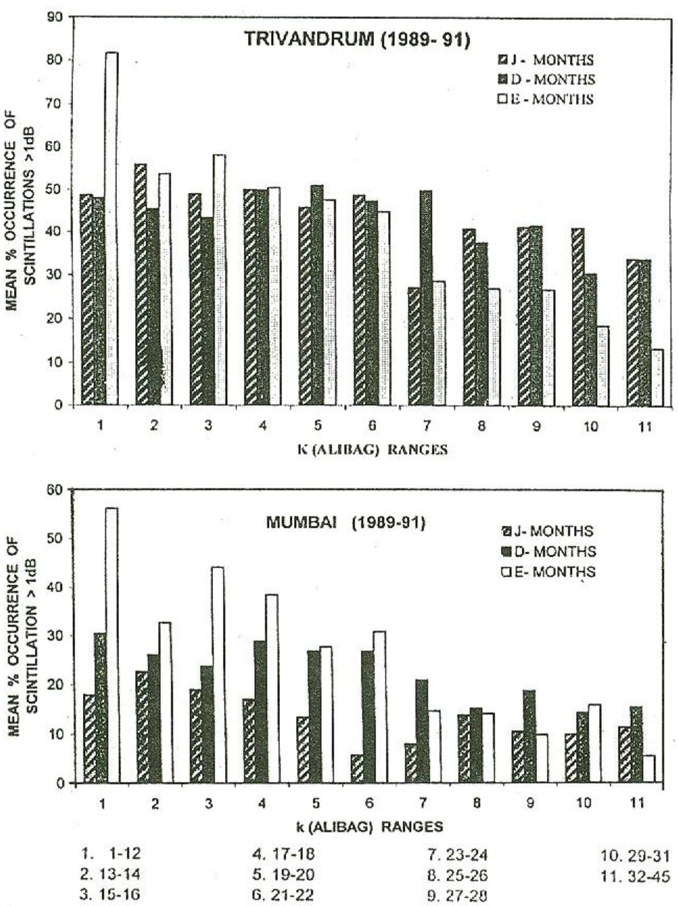

Fig. 4—Histograms showing the seasonal association of scintillation activity with *K*-Alibag at Mumbai and Trivandrum during 1989-1991 (*K*-Alibag ranges are the same as in Fig. 2)

maximum for the lower classified groups (the first four groups) of *K*-Alibag indices, while from fifth group onwards (*K*, 19-20 group), the percentage occurrence for *e*-season is found to decrease with increase in *K*-indices. The percentages of activities are less in the other two seasons for lower classified groups. At Mumbai, for all the *K* ranges, the percentage occurrence during *e*-season is maximum (except 3 cases) when compared with other two seasons. Also, decrease in scintillation activity with increase in *K* is inferred at all the seasons. Similar results at both the stations, Trivandrum and Mumbai, are obtained at all the seasons in A_p sub-divisions according to seasons (not shown here). However, as expected, the percentage occurrence of scintillation is more at the generation region, Trivandrum, than those at Mumbai at all seasons.

To have an idea on percentage occurrence of scintillation activity during quiet and disturbed period, the occurrence of scintillations at both the stations were estimated by taking five International quiet (IQ) and International disturbed (ID) days of the month for each of the years. It is noticed that scintillations of varying duration were present at almost all nights (about 98% of nights) on IQ days, whereas it is at only 69% of nights on ID days at Trivandrum. For quiet period, the mean percentages of the times of occurrence of the activity over 12 hours of the night (between 1800 and 0600 hrs LT) at Trivandrum for the years 1989, 1990 and 1991 are 60%, 55% and 40%, respectively, whereas in respect of Mumbai they are 38%, 31% and 23%. The decrease in the percentage of occurrence is due to the decrease in solar activity from 1989 to 1991. Similarly for disturbed period at Trivandrum the mean percentages are 28%, 34% and 19%, whereas at Mumbai they are 12%, 12% and 10%, respectively, for the above three years.

3.3 Magnetic storms association

There are extensive studies[18,19] indicating the generation of range spread-F and scintillation of radio beacon signals during the post-midnight time period when geomagnetic storms were active. Das Gupta *et al.*[20] reported that post-midnight VHF scintillations are related to the maximum negative excursion of the horizontal intensity of the magnetic field occurring in the 0000-0600 hrs LT interval. This parameter, when considered on global scale, is the global D_{st}. Thus, one can visualize two effects of the maximum ring current excursion of D_{st}:

(i) Post-midnight creation of conditions necessary for the generation of irregularities and

(ii) Absence of an effect if the maximum negative excursion is after sunset and before midnight.

In this Section, the association of magnetic storms on the occurrence of scintillations at the two stations is examined . For this, the D_{st} values and planetary magnetic activity indices K_p during selected storms were used, as D_{st} reflects the ring current intensity, whereas K_p indicates the geomagnetic activity in the middle and low latitudes and there is a definite time gap between these two. Aarons[21] hypothesized three basic effects of the ring current in the generation or inhibition of equatorial F-layer irregularities during magnetic storms. He categorized the storms in three different ways as follows:

Category I—If the maximum excursion of D_{st} takes place during daytime hours and well before sunset, the normal height rise of the F-layer is disturbed and irregularities are inhibited that night.

Category II—If the large excursion occurs in the midnight to post-midnight time period, the layer height rises and then falls and creates irregularities.

Category III—If the large excursion of D_{st} takes place after sunset and before midnight, the layer height rise is not disturbed and irregularities form as on an undisturbed night.

Gonzales *et al.*[22] have pointed out that in the equatorial region during the day, local ionospheric currents (the electrojet) and remote currents such as ring current contribute to magnetometer displacement. However, at night where the ionospheric component is practically non-existent, only remote sources contribute to equatorial magnetic field measurements. Therefore, at night ring current is the primary source of magnetic activity. The available model of ring current effects on the generation of equatorial F-layer irregularities in basic form depends on the timing of the maximum negative D_{st} excursion vis-a-vis local time[21].

A total of 77 storms are considered for the period 1989-1991, dividing the storms by the time of maximum excursion of D_{st} (the minimum value of D_{st}) as per the three categories of Aarons. An example of each of the three categories of the storms and associated occurrences or otherwise of scintillation activity at Trivandrum are shown in Figs 5-7 along with the ionospheric F2 height changes at Kodaikanal (dip 4°N).

3.3.1 Storm of category I (28-31 October 1991)—Figure 5 shows severe magnetic storm for period 28-31 Oct. 1991 with D_{st} and K_p values in the two middle panels, whereas top panel shows the ionospheric F-layer height changes at Kodaikanal (dip 4°N) and the bottom panel shows scintillation patch durations. Commencement of magnetic storm occurred at 1054 hrs UT (1624 hrs IST) on 28 October. From about 1200 hrs UT, D_{st} value starts decreasing and attains lowest value of –251 nT at 0800 hrs UT on 29 October with A_p index 128, K_p varying from 5_- to 8_+. Range of horizontal component of magnetic field, H, at Alibag is 333. Top panel shows that during this time normal height rise of F-layer is disturbed and irregularities are inhibited during 29 October night. On 28 Oct. 1991 scintillation onset time is 1901 hrs UT (0031 hrs IST) at Trivandrum during which F-layer height increases rapidly to about 430 km and then decreases to about 260 km.

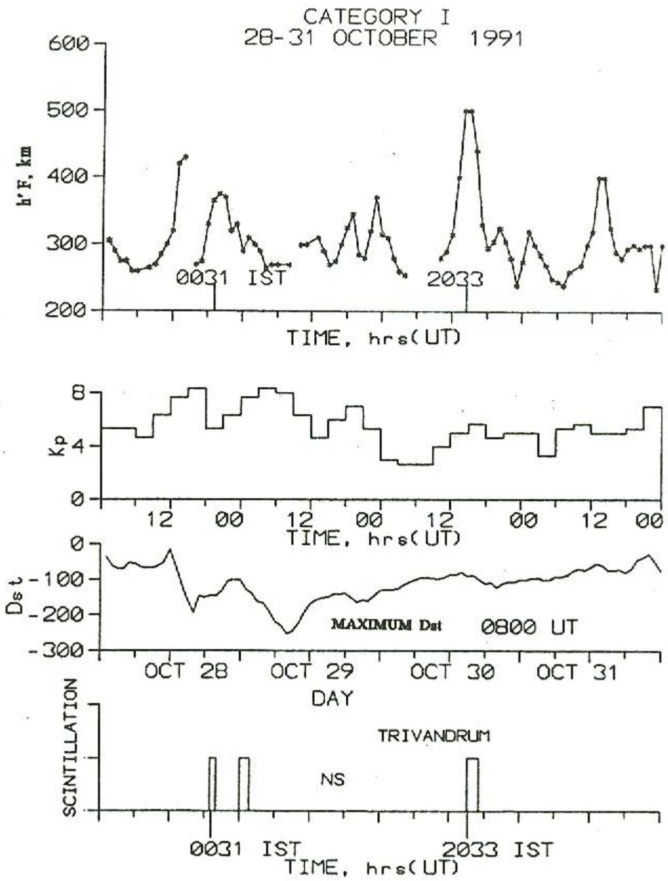

Fig. 5—Example of a magnetic storm that occurred during 28-31 Oct. 1991 which follows Aarons Criterion I [The top panel is ionospheric F-layer height (*h*'F) at Kodaikanal, the two middle panels are K_p and D_{st} and the bottom panel shows occurrence times of scintillation activity at Trivandrum (vertical blocks are patch durations.)]

3.3.2 Storm of category II (11-14 January 1989)—Figure 6 is an example of moderate storm occurring during 11-14 Jan. 1989. Storm commencement time is at 1204 hrs UT on 11 January attaining a maximum

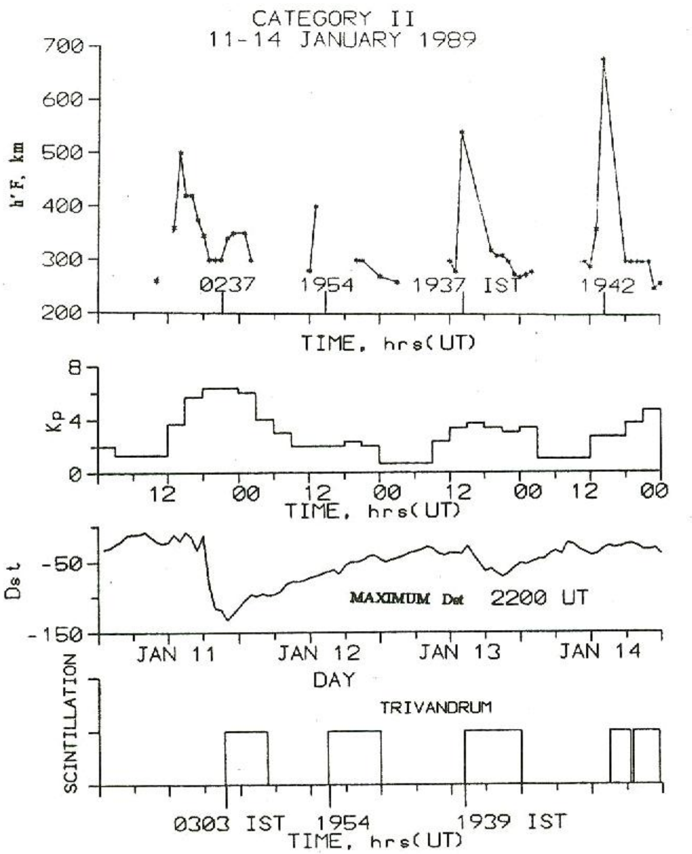

Fig. 6—Example of a magnetic storm that occurred during 11-14 Jan. 1989 which follows Aarons Criterion II [The top panel is ionospheric F-layer height (h'F) at Kodaikanal, the two middle panels are K_p and D_{st} and the bottom panel shows occurrence times of scintillation activity at Trivandrum (vertical blocks are patch durations.)]

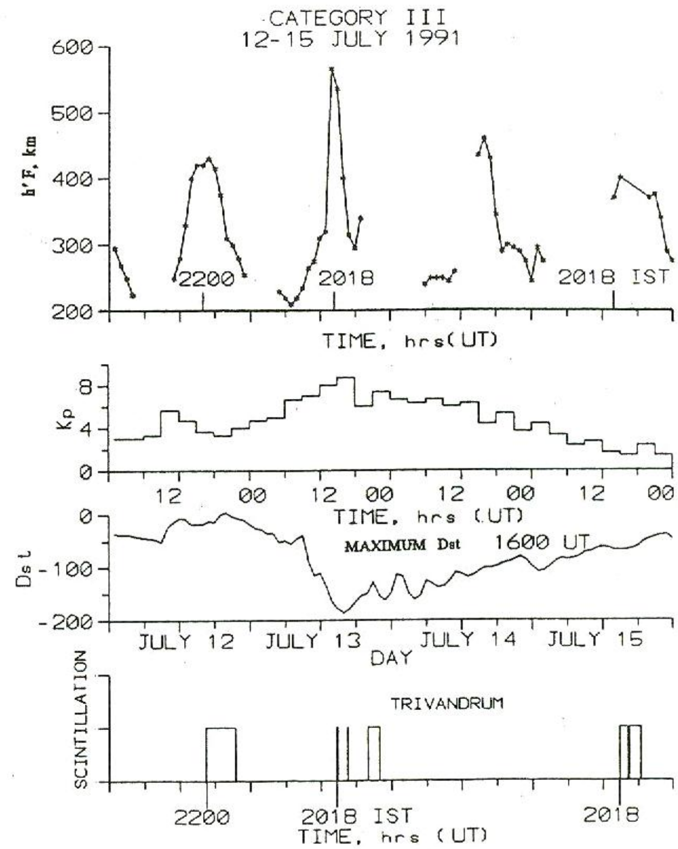

Fig .7—Example of a magnetic storm that occurred during 12-15 July 1991 which follows Aarons Criterion III [The top panel is ionospheric F-layer height (h'F) at Kodaikanal, the two middle panels are K_p and D_{st} and the bottom panel shows occurrence times of scintillation activity at Trivandrum (vertical blocks are patch durations.)]

D_{st} value of –132 nT at 2200 hrs UT (0330 hrs IST), i.e. after midnight. The A_p index is 37 on 11 January and K_p index varies from 1_+ to 6_+. Top panel shows height variation during the storm period. On 11 January after maximum D_{st} excursion at 2200 hrs UT, i.e. after local midnight, layer height rises up to 350 km and then falls and creates irregularities. On 12 January strong scintillation starts around 0303 hrs IST at Trivandrum, i.e. after midnight and continues in post-sunrise up to 1000 hrs IST, thus follows Aarons II criterion. Similarly on 12, 13 and 14 January nights, post-sunset steep height rises are noticed up to 400 km, 520 km and 680 km, respectively, and strong scintillations are observed on all these days.

3.3.3 Storm of category III (12-15 July 1991)— Storm occurring during 12-15 July 1991 shown in Fig. 7 is an example of severe storm. Commencement time is 0925 hrs UT on 12 July and attains a maximum D_{st} value of –185 nT at 1600 hrs UT on 13 July with A_p value of 134 and K_p varies from 5_- to 9_-. At the time of maximum D_{st} excursion height rises rapidly to about 573 km which is associated with the onset of spread-F in the post-sunset period. Similarly on 12, 14 and 15 July post-sunset height rises of 420 km, 450 km and 400 km, respectively, are seen and strong scintillations are observed on the 3 nights except on 14 July 1991.

Statistical classification of all the 77 storms at both Trivandrum and Mumbai during 1989-1991 are made as per the time of occurrence of maximum D_{st} value (or maximum intensity of ring current). The results of such classification on the percentage of storms satisfying three Aarons criteria in generation or inhibition of scintillation activity are given in Table 1. Scintillation is present during 32 storms at Trivandrum and 25 storms at Mumbai. The maximum percentage satisfying the Aarons criterion when large excursion of D_{st} occurs during midnight to post-midnight, is observed to be marginally higher at 71% when compared to the other 2 categories in the Indian region during high solar activity period. However, it is intriguing why the percentage is not high during the

Table 1—Classification of geomagnetic storms satisfying Aarons criteria for the years 1989-1991

Storm Type	No. of SC storms	Storms satisfying Aarons criteria for		
		Mumbai		Trivandrum
		1989		
I	15	8	No Scnt.	9
II	7	6	Scnt. Present	6
III	11	8	No effect	9
		1990		
I	10	7		5
II	3	3		3
III	5	3		2
		1991		
I	12	7		7
II	7	3		3
III	7	2		3
		Total for years 1989-1991		
I	37	22 (60%)		21 (57%)
II	17	12 (71%)		12 (71%)
III	23	13 (57%)		14 (61%)

other two categories? Pathak *et al.*[23] have also studied different storms during 1988-1990 and observed the effect on scintillations (at Trivandrum, Mumbai and Rajkot) and their dependence on Aarons criteria. They have concluded the satisfaction of Aarons criteria in the generation of irregularities responsible for scintillation activity.

The larger percentage of association of only 71% during the Aarons criterion of maximum ring current intensity in the specific times (*category II*) is noticed, but nearly 40% of cases is not satisfying the generation and inhibition of scintillation activity in the other two *categories I* and *III*. These associations have to be further probed with larger data base along with the other probable causes of generation of irregularities. This aspect has to be understood in the generation/inhibition of the local 'electric fields' not related with the ring current in the ionospheric irregularities responsible for the equatorial and low latitude scintillations.

4 Discussion

It is well established that the plasma instabilities generated in the form of plasma bubbles over magnetic equator initially at the bottomside of the F-layer during nighttime develop into scintillations and spread-F producing irregularities in the equatorial and low latitude F-region. Under the influence of eastward electric fields the plasma bubbles rise non-linearly in the F-layer as a result of $\mathbf{E}\times\mathbf{B}$ motion producing plasma irregularities along the magnetic field lines in a wide spectrum of scale sizes on either side of magnetic equator extending up to 20° and more[24,25].

In our study, it is observed that the electrojet strength during daytime has no perceptible effect on the generation of the nighttime scintillation activity. Also when the scintillation activity is classified into pre- and post-midnight intervals, no association is found between pre-midnight activity and the strength of the electrojet. It is well known that the E-region electric fields are transferred to F-region of the ionosphere at the equator, which, interacting with the horizontal component of the earth's magnetic field, sets up an upward $\mathbf{E}\times\mathbf{B}$ drift of the plasma. Thus, latitudinal extent of the plasma distribution in the ionospheric F-layer is affected by the strength of the electrojet. Rastogi and Woodman[18] have shown that the reversal of the F-region electric field to an eastward direction during anytime of the night is followed by the generation of the equatorial type of spread-F and hence scintillation activity. Though it is not possible to establish a relation between directional change of the electric field and electrojet strength from this study, it appears that larger strengths of the electrojet during daytime may not have direct association in the generation of the irregularities during nighttime. However, Loknadham and Reddy[26] have shown that scintillation activity is well correlated with electrojet strength using nighttime scintillation data recorded at Hyderabad on 136.1 MHz.

Several studies have shown that in the equatorial and low latitudes the phenomenon of spread-F and scintillations occur in the evening hours following a steep rise in *h*'F during post-sunset period (1900-2000 hrs LT) which is associated with the enhancement in the eastward electric field[27] . Normally, quiet time electric fields in the equatorial ionosphere generated by the dynamo action of neutral winds are directed eastward during the day and westward during the night with a pre-reversal enhancement in the eastward electric field around sunset time[27,28].

Chandra and Rastogi[29] have studied the effect of magnetic activity on scintillation at Thumba and arrived at the conclusion that the scintillation activity decreases with increase in magnetic activity . For African zone, both spread-F (Ref. 30) and scintillation index[13,31] were found to decrease with magnetic activity. Bandyopadhyay and Aarons[9] have not found any clear relationship between scintillation and magnetic activity at Huancayo. However, Rastogi *et al.*[32] and Pathan *et al.*[33] observed very strong negative correlation between scintillation occurrence and magnetic activity in the Indian sector. Rastogi *et al.*[32] computed percentage occurrence of scintillations at Trivandrum and Huancayo during geo-magnetically quiet and disturbed periods for different seasons of years of low and high sunspots and concluded that magnetic activity tends to reduce the occurrence of scintillations more significantly in the Indian than in American sector. Pathak *et al.*[23] grouped scintillation data, from Rajkot during 1987-1991, into International quiet (IQ) and International disturbed (ID) days separately and concluded that scintillation activity is suppressed on the disturbed days for the most part of the night. According to them, suppression is quiet significant during the high solar activity years. Chandra *et al.*[34] discussed the characteristics of magnetic storm-induced F-region scintillations extending into daytime in the Indian longitude.

In this paper, the scintillation activity both at Mumbai and Trivandrum have been categorized with local geomagnetic activity (*K*-indices at Alibag) and the planetary geomagnetic activity, A_p. There is a clear suggestion of scintillation activity being suppressed with increase in the levels of geomagnetic activity. Also, when the scintillation activity is divided into different seasons, the activity at all seasons is found to decrease uniformly with increase in magnetic activity. This result indicates that the magnetospheric electric fields are shielded by the changes developed in the ring current from being penetrated into the ionospheric levels under specific conditions, and thus inhibit the necessary conditions resulting in the scintillation activity. Pattern of inhibition and generation during geomagnetic disturbance was explained by Aarons[21] . The predominant low in the ever present ring current is westward, which is responsible for the depression in D_{st}. Equatorial eastward electric fields produce an upward vertical drift during the day. In the pre-sunset period the F-layer height normally rises. Ring current negative excursions in this time period directly or indirectly have the effect of decreasing the local eastward electric field, thus reducing the layer height and possibly the downward velocity of F-layer in the post-sunset generation period. This result spoils or de-stabilizes the necessary conditions for the creation of irregularities. At night, zonal westward electric fields produce a downward vertical drift. However, the effect of the ring current in the midnight and post-midnight period when layer height is normally falling and electric field is westward, is to create momentarily an eastward electric field and raise the layer height; the change is relatively short-lived and the layer height then falls, creating the irregularities. For the growth of irregularities under magnetically disturbed conditions, a reversal of the normal nighttime downward drift of the F-layer to upward direction is required.

There are several other factors that control the plasma bubble generation and its subsequent vertical growth. The linear growth rate of the plasma bubble and associated irregularities is inversely proportional to the ion-neutral collision frequency and, consequently, when F-layer is high, the growth rate will also be high[35] because of reduced ion drag at higher altitudes. In addition, the vertical growth rate and, hence, its latitudinal spread depends on the rate of rise of the F-layer during pre-sunset hours. Anderson and Haerendel[36] have shown that the bubble growth rates are, in general, always small (large) when F-region ambient electric field or the $\mathbf{E}\times\mathbf{B}$ vertical drift velocity is small (large). Dabas and Reddy[37] showed that vertical growth rate (or the latitudinal extent) of the plasma bubble and associated irregularities is higher whenever the F-layer vertical velocity ($dh'F/dt$) is high. This implies its dependence on the $\mathbf{E}\times\mathbf{B}$ drift speed due to background eastward electric field.

From the present study, it appears that the magnetospheric electric field changes related to ring current intensification may not be solely responsible for the generation/inhibition of equatorial ionospheric irregularities during nighttime.

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