SPACE WEATHER STUDIES OF IONOSPHERIC SCINTILLATIONS AT LOW LATITUDE

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ABSTRACT

Space weather refers to the conditions on the sun and the solar wind, magnetosphere, ionosphere and thermosphere that can influence the performance and reliability of space-borne and ground technological systems and can endanger human life or health. In this paper VHF amplitude scintillation recorded during the period 1991 to 1999 at low latitude Varanasi (geomag. lat. 14^0 55´ N; long. 154^0 E) are analysed to study the behaviour of ionospheric irregularities during active solar periods and magnetic storms. It is observed that scintillation activity increases with the increase in solar activity. The role of magnetic activity shows suppressions of scintillation on disturbed days. Dst index has been used to study the effect of geomagnetic storm on the scintillation activity.

1. INTRODUCTION

Space weather begins at the sun´s surface, which is the source of radiative and particle energy impacting our Earth. The solar activity changes the radiative and particle output of the sun, producing corresponding changes in the near-earth space environment as well as the Earth´s surface. Changes in the radiative output from the sun directly alter the state of the upper atmosphere and ionization of the atoms and molecules. The Earth´s ionized upper atmosphere often becomes turbulent and develops electron density irregularities. These irregularities scatter radio waves from satellites in the frequency range of 100 MHz - 4 GHz [1]. In the presence of a relative motion between the satellite, the ionosphere and the receiver, the received signal exhibits temporal fluctuations of amplitude and phase, called scintillations. Amplitude scintillations cause signals to fade below the average level. When the depth of the fading exceeds the fade margin of a receiver, the signal becomes buried in noise and signal loss and cycle slips are encountered. Phase scintillation may cause loss of phase lock in GPS receivers [2]. Overall, in the presence of scintillations, the performance of communication and navigation systems is degraded. Hence in order to provide support to operational communication and navigation systems, the magnitudes of amplitude and phase scintillations and the temporal structures of scintillations need to be specified.

Mainly two areas of the globe particularly troubled by scintillation are sub-auroral to polar latitude and a belt surrounding the geomagnetic equator. Scintillations are most severe in the equatorial region, where they often occur after sunset, and attain maximum intensity around the peaks of the Appleton anomaly (15^0 N and S of magnetic equator) [3]. The electron density irregularities associated with scintillation are generated in the bottom side of post sunset F-region over the magnetic equator by the Rayleigh-Taylor instability mechanism and then rise up and align along magnetic field lines propagating to higher latitude [4]. The irregularities while diffusing along field lines break into small patches which are observed in the form of scintillations with small patch duration at low latitudes [5]. With increasing interest in understanding the behaviour of ionospheric irregularities near the magnetic equator some excellent efforts have been made to examine the solar and magnetic activity control over the occurrence of scintillation associated with ionospheric irregularities [6-10]. A good overview of scintillations at high and low latitude are recently given by Basu et al. [11]. In this study, we present some results of 244 MHz amplitude scintillation measurement during the period Jan., 1991 to Dec., 1993 and April 1998 to Dec., 1999 at low latitude station Varanasi (geomag. lat 14^0 55´ N; long. 154^0 E). The effect of magnetic storm is also presented using Dst index.

2. RESULTS AND DISCUSSIONS

The amplitude scintillations having peak to peak variations greater than 1 dB were considered in the present analysis using nocturnal scintillation data. It is observed that scintillation occurs in small patches at Varanasi with patch duration usually < 30 minutes [12]. Considering sunspot number as the measure of solar activity, the month-to-month variation of mean percentage occurrence of scintillations and sunspot numbers for the years 1991-1993 and 1998-1999 are presented in Fig.1. During equinox and winter months scintillation activity increases with the increase in sunspot numbers but during summer, no significant change is observed. Similar results were reported by Kumar and Gwal [9] for other low latitude station Bhopal. They concluded that the characteristics of scintillation during equinox and winter months are similar to those of equatorial stations whereas those

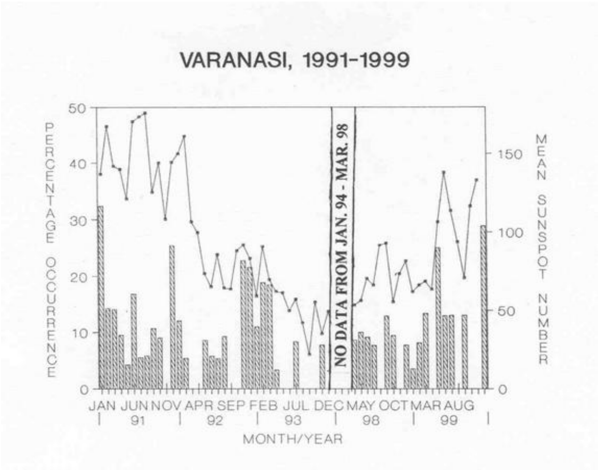

Fig. 1. The month-to-month variation of mean percentage occurrence of scintillations and sunspot numbers for years 1991-1999.

of summer months are similar to mid-latitude scintillations.

The effect of magnetic activity was examined by comparing scintillation occurrence on five international most quiet (Q) days and disturbed (D) days in each months. The seasonal and average annual variation of scintillation occurrence (%) on Q and D-days are shown in Fig. 2. During disturbed days scintillations are inhibited in the pre-midnight period in the winter and equinox seasons, while during summer the trend is reversed. The annual variation shows clear suppressions of scintillation on D-days. Similar control of magnetic activity was also reported at the other low latitude stations [8, 9].

The role of magnetic storm on the occurrence of VHF scintillation at Varanasi is examined by using the Dst and Kp indices during selected magnetic storms. A total of 50 geomagnetic storms during the whole observation period of scintillations are selected and association of scintillation with storms are examined. We have categorized these results in three categories, as Aarons [13] hypothesized three basic effects of the ring current in the generation or inhibition of F-layer irregularities during magnetic storms.

Category-I: If the large excurtion of Dst occurs in the midnight to post-midnight period, the layer height rises and then falls and irregularities are generated.

Category-II: If the minimum excursion of Dst takes place during daytime hours and well before sunset, the normal height rise of the F-layer is disturbed and irregularities are inhibited during that night.

Category-III: If the large excurtion of Dst takes place after sunset and before midnight, the F-layer height rise is not disturbed and irregularities are formed on undisturbed night.

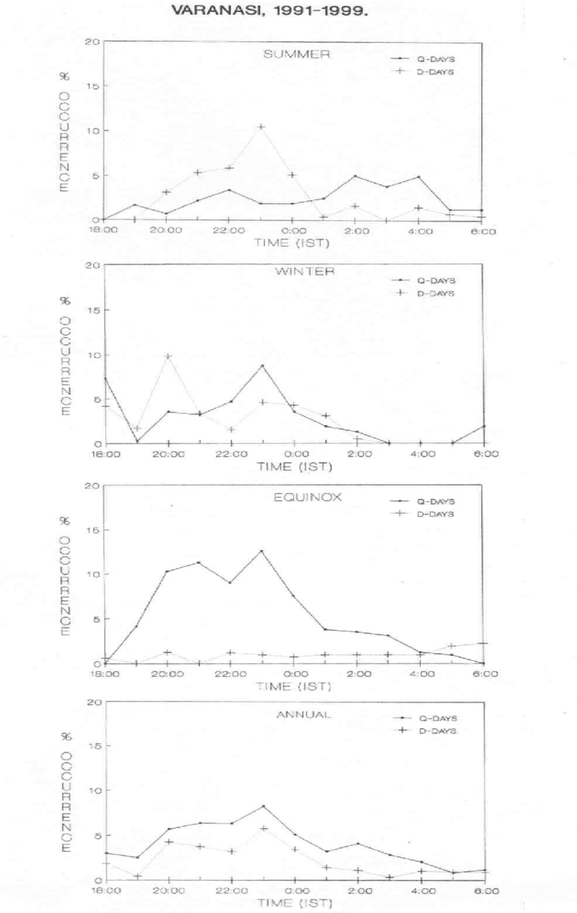

Fig. 2. The seasonal and average annual variation of percentage occurrence of scintillation on magnetic Q and D-days.

Fig. 3 presents a typical example of category-I scintillation activity during post-midnight hours along with Dst and Kp variations in two middle panels. Top panel shows the ionospheric F-layer height variation and the bottom panel contains scintillation index in dB. The figure shows a moderate magnetic storm for the period Dec 29-31, 1998. Dst value shows minima at 0030 hrs LT and 0430 hrs LT with –53 nT and –52 nT on 30th Dec. The Kp value shows a maximum of 5_0 at 0230 hrs LT on 30th Dec. in the post-midnight period. The storm disturbs the height rise of F-layer and creates the irregularities. Intense scintillation occurred during morning hours to daytime with fast fading rate, which lies during recovery phase of the storm. Thus, we can correlate the rise and fall of F-layer with F-region irregularities.

Fig. 4 presents a typical example of category-II scintillation activity when Dst minimum occurs during daytime. This figure presents severe storm of Oct. 28-31, 1991, where Dst - index starts decreasing at about

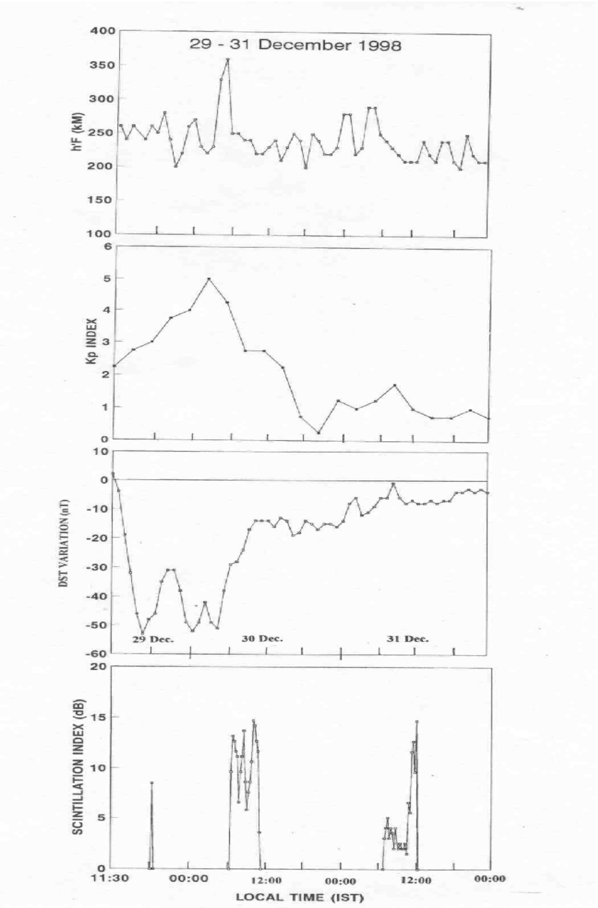

Fig. 3. A typical example of category-I scintillation activity during post-midnight hours along with Dst, Kp and F-layer height variations.

1730 hrs LT on Oct. 28th and attains the lowest value of -251 nT at 1330 hrs LT on Oct. 29th with Kp index varying between 5_0 to 8_+. The F-layer height is disturbed during the magnetic storm period. Weak scintillations are observed on 28th and 29th Oct. before Dst attains its minimum value but no scintillation could be seen on post-midnight of 29th and 30th Oct. This shows that magnetic storm suppresses the scintillation occurrence when Dst minimum occurred during daytime.

Fig. 5 shows a typical example of category-III scintillation activity when Dst minimum occurs during the pre-midnight. The figure shows severe storm of July 12-15, 1991, which attains a minimum Dst value of –185 nT at 2130 hrs LT on 13th July with Kp varying between 5_- to 9_-. At the time of Dst minimum h´F rises rapidly to about 573 km, which is associated with the onset of spread-F in the post sunset period. Weak scintillation (less than 2dB) are observed during 2245-2345 hrs LT on July 13th and between 0100 and 0200 hrs LT on July 14th. No scintillation is observed during the next two days, which shows that storm has suppressed the scintillation occurrence.

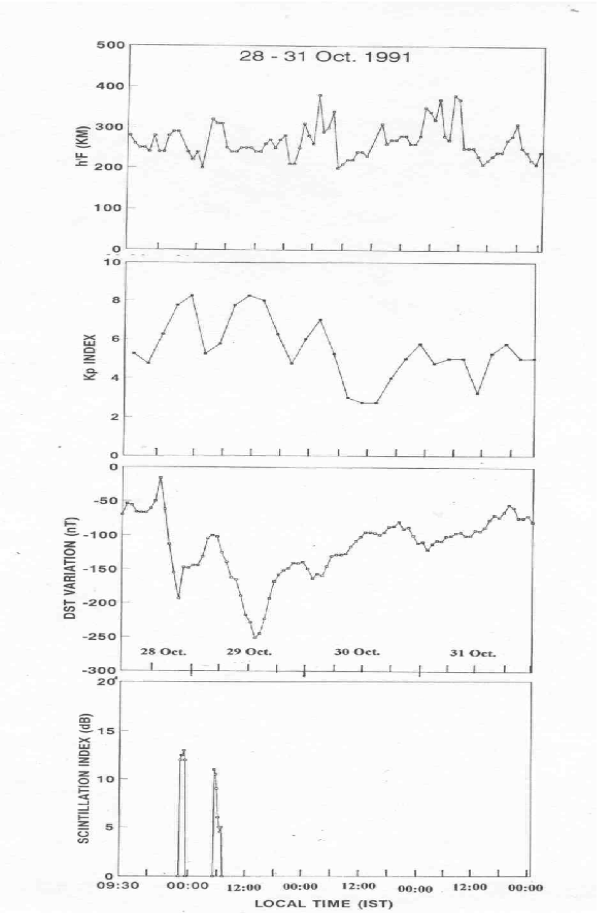

Fig. 4. A typical example of category-II scintillation activity when Dst minimum occurs during daytime along with Dst, Kp and F-layer height variations.

The present study of VHF scintillation at Varanasi, which lie at the outer edge of the equatorial anomaly is important for developing unified model of ionospheric scintillations. The overall features of the irregularities derived from scintillation data at Varanasi is in conformity with the idea that the plasma instabilities produces plasma bubbles in the bottom side of F-layer which lift upward due to E x B force, the electric field E being in the equatorward direction. These plasma bubbles after reaching the apex height in the equatorial plane around post-sunset move either side along the field lines, while moving downward they break into small patches due to non-linear processes [14].

Scintillation occurrence is suppressed during enhanced magnetic activity at low latitude [8]. The inhibition of the occurrence of irregularities at low latitude on geomagnetically disturbed days in the pre-midnight is due to the reduction in the post-sunset rise of F-layer in the equatorial region, presumably due to the disturbance in electric fields opposing the normal ionospheric electric fields. Aarons [13] explained the pattern of inhibition and generation of irregularities during geomagnetic disturbance using the changes in

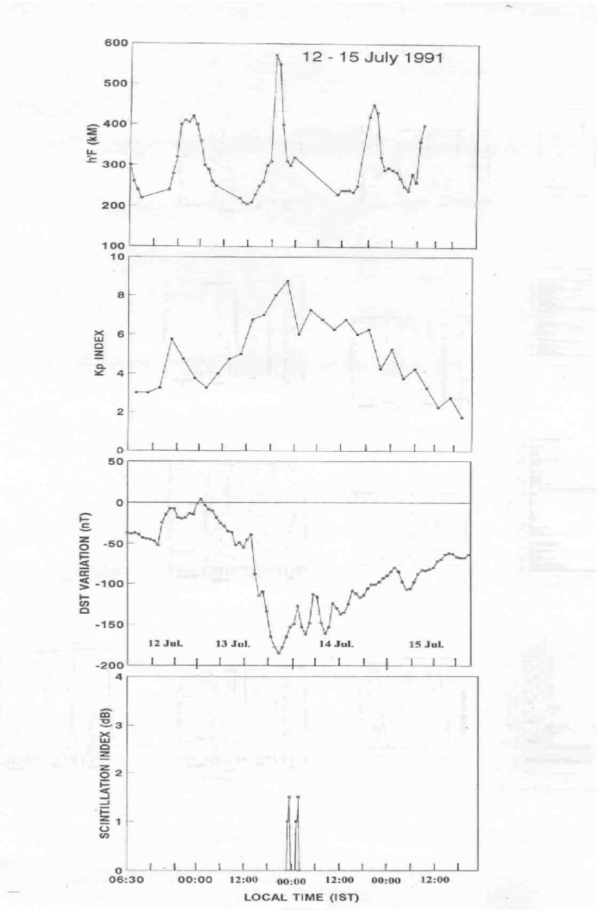

Fig. 5. A typical example of category-III scintillation activity when Dst occurs during the pre-midnight period along with Dst, Kp and F-layer height variations.

ring current. It is known that during pre-sunset period F-layer height normally rises. The negative excursion of ring currents in this time period causes decreasing effect in the local eastward electric field, thus reducing the layer height. As a result, the necessary conditions for the creation of irregularities are hampered. This results in the suppression of irregularities during magnetic active period. The effect of ring current during post-midnight period when electric field is westward and F-layer height is falling, is to create an eastward electric field (momentarily). This short lived eastward electric field rises the F-layer height momentarily and allows the F-layer to fall again, thus creating the irregularities.

Apart from ring current there are several other factors, which control the generation and vertical growth of F-layer irregularities such as ion-neutral collision frequency, partial neutral wind, large scale plasma density gradient, presence of gravity waves etc.

3. ACKNOWLEDGEMENTS

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