

VLF whistler wave activity and effects of geomagnetic disturbances at low latitudes

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Abstract. The disturbances on the solar surface lead to the enhanced injection of energetic charged particles into the inner magnetosphere, which modifies the electrodynamic features of ionosphere and magnetosphere. The electrodynamic properties control the generation and propagation characteristics of VLF waves. At Varanasi station, which is one of the low latitude stations in India, we have recorded VLF waves from 1990 onwards. The source of VLF wave is natural lightning discharges. Whistler activity varies with latitude having maximum around 50° geomagnetic latitude. The occurrence rate is low at low latitudes and also depends on the solar and geomagnetic conditions. In this paper, we report the results derived from the statistical analysis of whistler waves recorded at Varanasi during the period January 1990 – December 1999. The monthly occurrence rate shows maximum during January to March. Seasonal variations of the occurrence rate are also studied. In order to study the role of geomagnetic disturbances on the occurrence rate, we have used Kp index and its variation. It is observed that the occurrence probability monotonically increases with ΣKp values. Detailed result of occurrence of whistler waves during the main phase and recovery phase of geomagnetic storms is also presented.

Keywords : whistler waves – ducted mode propagation – geomagnetic storms

1. Introduction

Electromagnetic waves in a wide frequency range are radiated due to lightning discharges. The radiated wave energy is maximum in the very low frequency (VLF) range (1-10 kHz)

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and decreases both with the increase and decrease of wave frequency. A part of VLF wave energy propagating along geomagnetic field lines gets dispersed due to interaction with charged particles present in the ambient medium. The wave is known as whistler and may propagate back and forth along the field lines with almost no attenuation or with little attenuation. This is attributed to the trapping of wave energy in the plasma duct aligned along geomagnetic field lines.

Whistler activity varies with latitude having maximum around 50° geomagnetic latitude (Helliwell 1965; Lalmani & Singh 1977). The occurrence rate is low at low latitudes (Singh 1993). The whistler activity depends on the source and conditions conducive to the whistler mode propagation below, through and above the ionosphere. The activity also depends on the solar and geomagnetic conditions. Somayajulu & Tantry (1968) observed enhanced whistler activity during the magnetic storm period and explained it in terms of formation of additional ducts supporting the whistler mode propagation (Singh 1993).

The world-wide varying correlation coefficients (in magnitude and sign) between thunderstorm / lightning and solar activity was first reported by Brooks (1934). The activity and properties of thunderstorm/lightning discharges have good correlation with the relative sunspot number giving the conditions on solar surface.

In this paper we have analyzed the whistlers recorded at Varanasi during the period January 1990–December 1999. The monthly, seasonal and annual variations of occurrence rates have been studied. We have studied the variation of occurrence rate probability with the variation in K_P index. Also the effect of geomagnetic storms on the occurrence rate has been studied.

2. Data analysis

At our low latitude ground station at Varanasi (geomag. lat.= $14^\circ 55'$ N, long. 154° E), we have recorded VLF whistler mode waves from lightning discharges on routine basis using a T-type antenna, pre- and main amplifiers and cassette tape recorder having bandwidth of about 15 kHz. The gain of the amplifier is adjusted (0-40 dB) to avoid overloading of the amplifier at the time of intense VLF wave activity.

In the present paper, we report the statistical analysis of whistler waves recorded at Varanasi during January 1990 to December 1999. The rate of occurrence at low latitude stations is normally quite low, which gets enhanced during magnetic activity periods (Singh 1993; Somayajulu et al. 1972; Ohta et al. 1989; Hayakawa 1991). The occurrence rate of whistler wave varies from month to month having maximum during January to March in any year. Therefore, only three months occurrence rate for the whole period is shown in Fig. 1. The scale on Y-axis clearly shows relatively intense rate during January

Table 1. Occurrence probability of whistlers at different K_P (1990-1999).

ΣK_P	No. of days recording	No. of days with whistler waves	Occurrence probability %	
0-10	174	7	4.02	
10-20	354	28	7.91	
20-30	218	35	16.06	$\Sigma K_P \geq 40$ 28.57
30-40	65	12	18.46	
40-50	15	3	20	
50-60	6	3	50	
Total	832	88	10.58	

to March. It is due to the increase of lightning and thunderstorm activity in the conjugate region of Varanasi.

In order to understand the role of geomagnetic disturbances on the occurrence rate of whistler waves, we have used the variation of K_P index. Further, we have grouped the number of days recordings carried out according to ΣK_P values and identified the days when whistlers were recorded. The probability of occurrence of whistlers is shown in Table 1, which clearly shows that the occurrence probability monotonically increases with ΣK_P values. Similar results were reported by other workers for different stations (Tanaka & Kashiwagi 1968; Hayakawa et al. 1975; Hayakawa et al. 1986).

3. Results and discussions

In Table 1 we have shown that whistler occurrence rate increases with the increase of ΣK_P , this means that an increase in magnetic disturbances is associated with the increased probability of occurrence rate of whistlers. To get an idea about the dependence of whistler activity on the geomagnetic storms and sub-storms, we have analyzed data recorded during geomagnetic storms of different strengths namely strong, moderate and weak storms (Sugiura & Chapman 1960).

Fig. 2 shows a strong magnetic storm during March 21-25, 1991. Dst value decreases sharply and attains the minimum value of -310 nT at 08:30 hrs on March 25, 1991. The K_P value varied between 1_- to 9_- during the storm period. Whistler waves are observed on March 22, during 00:30 – 02:30 hrs and March 25, during 00:26 – 00:50 hrs. The first example corresponds to the initial phase of the storm, whereas the second example relates to the main phase of the storms. Fig. 3 shows a moderate magnetic storm in which Dst value decreased to a minimum value of -65 nT at 17:30 hrs on 28 February, 1993. The K_P value during the storm period varied between 0_+ and 4_+ . Whistler waves are observed on 28 February during the recovery phase of the storm.

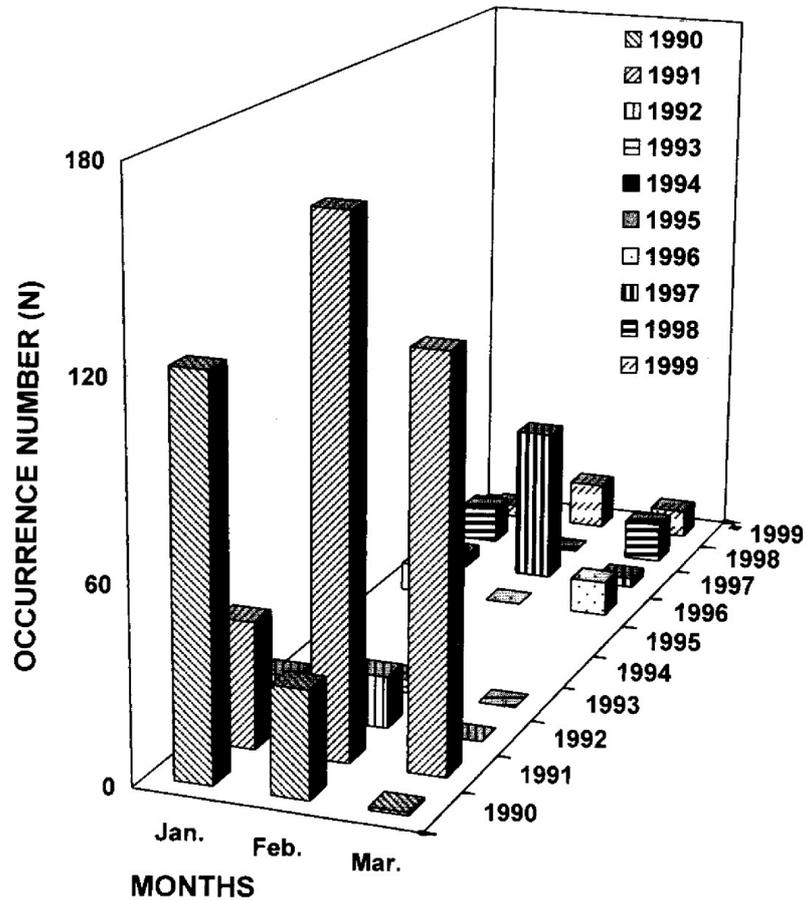


Figure 1. Monthly occurrence rate of whistlers observed at the low latitude station at Varanasi during January to March from 1990–1999.

We have analyzed various examples of magnetic storm periods and we found that whistler waves are usually observed either during the initial phase of the storm or the recovery phase of the storm (Singh et al. 2007). In some cases no whistlers are observed in any phase of the storm. It is also seen that the number of whistler signals go on decreasing as the storm changes from weak to medium and then to strong. The geomagnetic storms change the properties of the ionosphere and magnetosphere and hence propagation conditions of the whistler mode waves are modified.

Hayakawa et al. (1986) based on statistical analysis showed that the unstructured emissions are closely associated with geomagnetic storms whereas structured ones are closely associated with substorms. Storm-time chorus is especially important for the

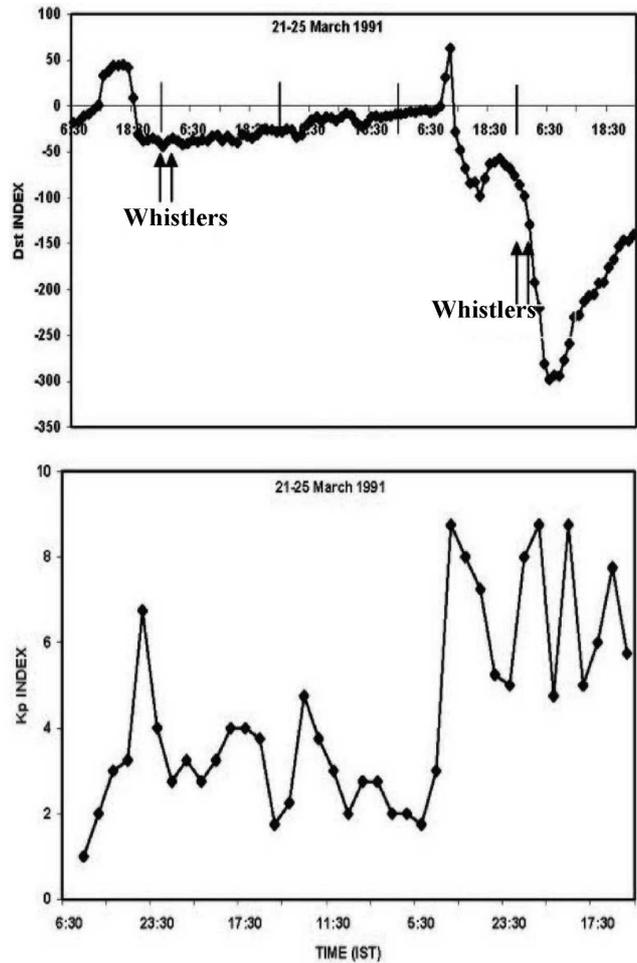


Figure 2. Typical example of whistler observations at Varanasi during strong magnetic storms on March 21-25, 1991.

physics of the Earth’s magnetosphere since it can significantly influence the distribution functions of the energetic electrons in the outer radiation belt (Meredith et al. 2003; Horne et al. 2003; Horne & Thorne 2003).

4. Conclusions

The statistical analysis of whistler waves observed at low latitude ground station Varanasi, India are reported. The whistlers are mostly observed during the night. The occurrence

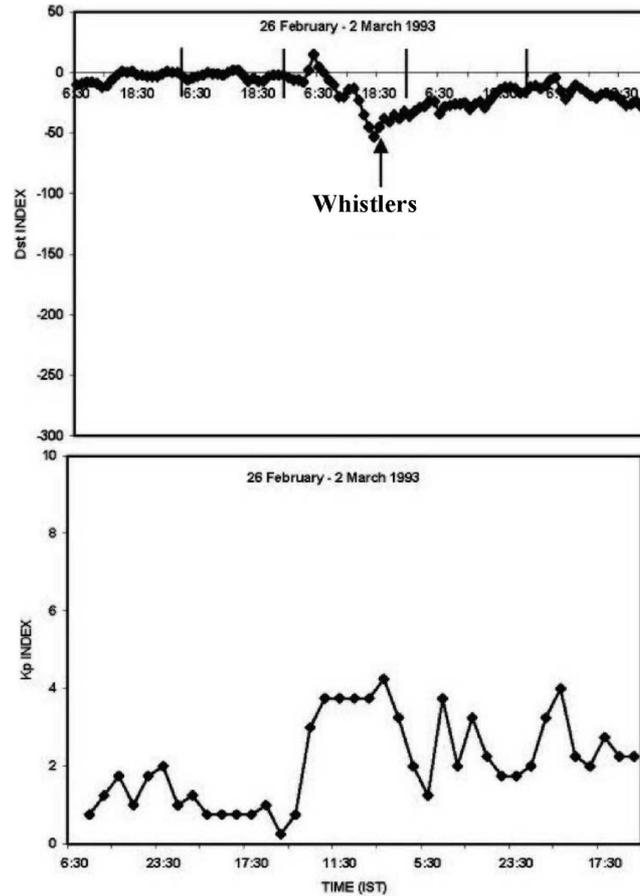


Figure 3. Typical example of whistler observation at Varanasi during moderate storm on 26 February -2 March, 1993.

rate is enhanced during the months of January to March. In general the probability of occurrence rate increases with the increase in geomagnetic activity. But for strong magnetic storms the probability of whistler occurrence rate is less.

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