

Effect of seismic activities on ion temperature in the F₂ region of the ionosphere

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RESUMEN

En este artículo se analizan anomalías ionosféricas relacionadas con eventos sísmicos. Se utilizaron los datos de temperatura ionosférica registrados por RPA del satélite hindú SROSS-C2 para el periodo de enero de 1995 a diciembre de 1996. Para definir las anomalías de la temperatura iónica de la ionosfera asociadas con la preparación, ocurrencia y relajación de los eventos sísmicos se utilizaron los datos de estos eventos registrados por el USGS para la región de interés. Los datos de temperatura iónica fueron analizados de manera que las anomalías debidas a otros fenómenos no enmascararan aquellas relacionadas con los eventos sísmicos. La propagación del campo eléctrico vertical sismogénico hacia la ionosfera induce el calentamiento joulico que podría causar el incremento de la temperatura iónica

ABSTRACT

Ionospheric anomalies related to the seismic events have been analyzed in the present paper. The ionospheric ion temperature data recorded by RPA payload aboard the Indian SROSS-C2 satellite are used for the period from January 1995 to December 1996. Earthquake events recorded in the region of interest by USGS were used to define the ionospheric ion temperature anomalies associated with the earthquake preparation, occurrence and relaxation. Ionospheric ion temperature data were analyzed in such a way that the anomalies due to other phenomena will not be masked over the temperature anomalies due to earthquakes. Ion temperature

enhancements in the ionosphere were observed during earthquake events and few pre-post days to the events. The seismogenic vertical electric field propagation up to ionospheric height induces the Joule heating that may cause the ion temperature enhancement.

Key words: Ion temperature; F₂ region; seismic activity; joule heating.

1. Introduction

The ionospheric temperatures and density are influenced by phenomena occurring above and below it such as solar flare, geomagnetic storm, thunderstorms, lightning/ sprites, etc. An extensive review of the effect on the ionosphere due to phenomena occurring below it is given by Kazimirovsky *et al.* (2003). The effect of solar flares, thunderstorms and lightning/ sprites on the ion temperature have been studied using the data recorded by RPA payload aboard the Indian SROSS-C2 satellite over Indian region by Sharma *et al.* (2004a, 2004b, etc.). The diurnal, seasonal and latitudinal variability of the ionospheric temperatures of the topside F region over Indian region during solar minimum year 1995-96 have also been studied (Sharma *et al.*, 2005, etc.).

It has been observed that the electromagnetic flux associated with earthquake activities also affect the ionospheric parameters. However, the thermal fluctuations in the ionosphere related to the prediction of earthquakes and volcanic eruptions remain largely an unsolved problem. Disastrous earthquakes, which occur 100 to 200 times per year, are extremely hazardous for the inhabitants of our planet. The first publications dealing with ionospheric parameter variations as seismic precursors were the Antselevich (1971) study the variations of *foE* parameter before the Tashkent earthquake 1966, and the Datchenko *et al.* (1972) study of ionospheric electron variations before the same Tashkent earthquake. The anomalous ionospheric electron density associated with the Tashkent earthquake was attributed to the redistribution of electric charge with the earth-atmosphere system. These effects are generally small in size and nearly masked by other ionospheric disturbances. Their small magnitude diminishes their capability to become a real seismic precursor.

The ionospheric anomalies due to the seismic activity appearing few hours or days before have been studied (Koshevaya *et al.*, 1997; Zaslavski *et al.*, 1998; Liu 2000, 2004; Silina *et al.*, 2001; Pulinets, 1998a, 2004; Pulinets *et al.*, 2003a, etc.). Pulinets (1998b) shows that the seismogenic vertical electric field from the epicenter zone penetrates into the ionosphere and creates irregularities. Temporal and spatial variations in the ionospheric parameters as precursors before strong earthquakes have been studied by Pulinets, S. A. and A. D. Legen'ka (2003b). Zaslavski *et al.* (1998) concluded that in some cases the electron density in the F region increases in the localized epicenter zone whereas in other cases it has decreased.

In the present paper ionospheric temperature data have been analyzed to study the anomalous behaviour of ion temperature in the F₂ region of the ionosphere above the epicenter zone of seismic events over India. The ion temperature data recorded by RPA payload aboard the Indian SROSS-C2 satellite during the period from January 1995 to December 1996 were used for this purpose. The earthquake data were obtained from the USGS website. The ion temperature data were carefully analyzed to avoid masking by other possible anomalies.

2. Data selection and analysis

The ion temperature was measured by the Retarded Potential Analyzer (RPA) payload aboard the Indian SROSS-C2 satellite, which was launched by Indian Space Research Organization (ISRO) on May 4, 1994 to study the ionospheric composition and temperature anomalies. A detailed description of RPA payload design, fabrication and characteristics has been given by Garg and Das (1995). Two years (from January 1995 to December 1996) data collected by SROSS-C2 satellite using RPA payload were used to analyze the anomalous variations in the ion temperature due to earthquake events in the altitude range from 425 to 625 km above the epicenter zone. The earthquake data and related details for the same period were obtained from United State Geological Survey (USGS) website.

It is a difficult task to study the ionospheric temperature data in relation to the earthquake events because very rarely passes of satellite match the epicenter zone. The first task is to select the satellite data recorded in the epicenter zone of the seismic events selected for the period from January 1995 to December 1996. The recorded average ion temperature during seismic activity has been compared with average normal days ion temperature. The ion temperature data were analyzed in such a way that the perturbation due to diurnal, seasonal, latitudinal, longitudinal and altitude effects are negligible. The average of normal days ion temperature was calculated for a month, which includes 20 days pre- and post- earthquake events leaving the 10 days of events duration. Pre- and post- event 5 days data are affected by the earthquake preparation, occurrence and relaxation process. One season data has been included for each event, so that the possibility of a seasonal effect has been ruled out. A 5° window zone in the ionosphere above epicenter has been selected for each event to avoid the latitudinal and longitudinal effects. To calculate the normal day ion temperature, only event hourly data have been used to avoid any masking due to diurnal effect. All data were recorded at an average altitude of 500 km, and the temperature anomalies due to altitude variation of recorded point are negligible. The maximum error in the temperature data recorded by the SROSS-C2 satellite is ± 50 K in the temperature range 500 K to 5000 K (Garg and Das, 1995; Sharma *et al.*, 2004a).

The solar flare data obtained from National Geophysical Data Center (NGDC), Boulder, Colorado (USA) and the thunderstorms/ lightning activity data from India Meteorological Department (IMD) Pune, have been used to verify that the earthquake events are free from solar flares and thunderstorms/ lightning activities.

3. Results and discussion

The comparisons of ion temperature during the earthquake day along with the normal days are shown in Figures 1 and 2. On March 12, 1995; an earthquake of magnitude of 4.7 with an epicenter location (17.74°N and 73.77°E) has been recorded. Figure 1(a) shows that the average ion temperature was enhanced by 1.2 times during the earthquake over the normal days average ion temperature. A similar enhancement in the ion temperature has been estimated from the Figures 1 (b, c) during the earthquake events on October 21, 1995 and December 09, 1995 with magnitude of 4.9 and 4.8 recorded at two different locations (31.43°N , 78.96°E ; 15.44°N , 88.43°E) respectively.

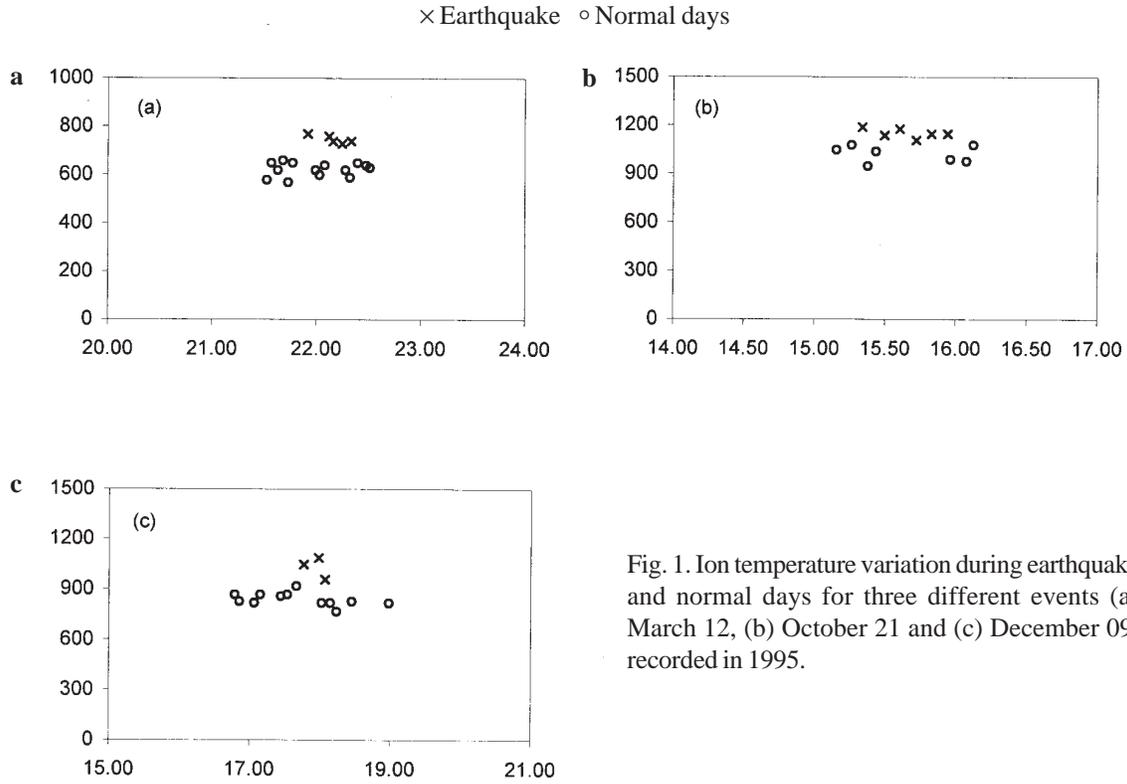


Fig. 1. Ion temperature variation during earthquake and normal days for three different events (a) March 12, (b) October 21 and (c) December 09, recorded in 1995.

Three events were recorded in 1996; on February 12, September 25, and November 10, with magnitudes 4.3, 5.0 and 4.1, respectively. During the event of February 12, 1996 the average ion temperature was enhanced 1.2 times over the normal days average ion temperature as estimated from Figure 2(a). A similar enhancement in ionospheric ion temperature was observed for the events of September 25, 1996 and November 10, 1996. The recorded ion temperature during the events and normal days for these events are shown in Figures 2 (b, c), respectively.

The magnitude, depth and locations of earthquake epicenter events along with the quantitative values of the temperature anomalies during the occurrence of the earthquakes along with the standard error are given in the Table 1.

The above analysis shows that there is a clear enhancement of ionospheric ion temperature recorded during the occurrence of an earthquake. The enhancements were for the average ion temperature to about 1.2 times compared to the average normal days ion temperature. It is worth mentioning here that ion temperature data were analyzed in such a way that the effect of diurnal, seasonal, latitudinal, longitudinal and altitude are insignificant. It has also been verified that the

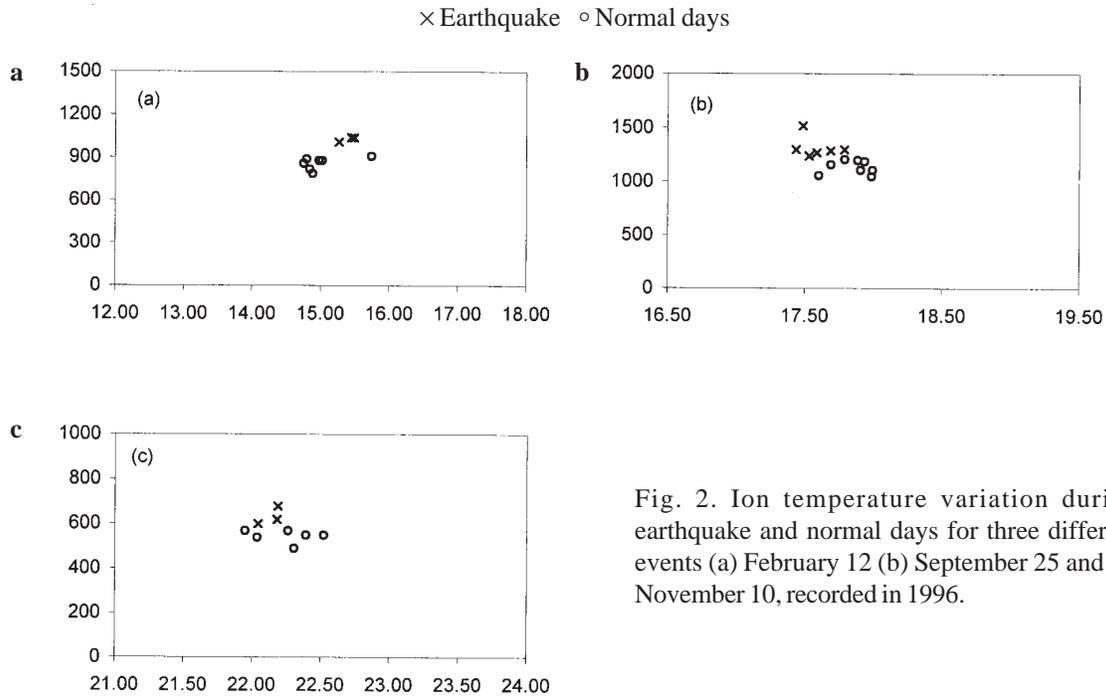


Fig. 2. Ion temperature variation during earthquake and normal days for three different events (a) February 12 (b) September 25 and (c) November 10, recorded in 1996.

temperature perturbations are free from solar flare and thunderstorms/lightning activities. Therefore we may conclude that the temperature anomalies are related to earthquake events only.

Table 1. Comparison of average ion temperatures during the earthquakes, normal and pre-post 5 days.

S. No.	Date of event	Origin time of seismic events (LT)	Location of epicenter	Magnitude	Depth (km)	Ion temperature ($^{\circ}\text{K}$)		
						Average during normal days	Average during earthquakes events	Average pre-post (\pm) days
1.	Mar 12, 95	08:22:54	17.74 $^{\circ}$ N, 73.77 $^{\circ}$ E	4.7	10	623 \pm 28	748 \pm 16	783 \pm 81
2.	Oct 21, 95	19:39:39	31.43 $^{\circ}$ N, 78.96 $^{\circ}$ E	4.9	33	1024 \pm 51	1153 \pm 29	1094 \pm 137
3.	Dec 09, 95	10:04:44	15.44 $^{\circ}$ N, 88.43 $^{\circ}$ E	4.8	10	842 \pm 38	1033 \pm 54	972 \pm 125
4.	Feb 12, 96	20:39:54	22.62 $^{\circ}$ N, 82.89 $^{\circ}$ E	4.3	33	861 \pm 42	1030 \pm 17	989 \pm 158
5.	Sep 25, 96	17:41:17	27.43 $^{\circ}$ N, 88.55 $^{\circ}$ E	5.0	33	1136 \pm 63	1320 \pm 101	1224 \pm 149
6.	Nov 10, 96	09:00:04	18.30 $^{\circ}$ N, 76.69 $^{\circ}$ E	4.1	33	545 \pm 30	633 \pm 42	578 \pm 63

The possible physical mechanism of the enhancement in ionospheric temperatures is discussed by Pulinets (1998b) which is also supported by experimental evidence. The main source of atmospheric-ionospheric coupling over the epicenter zone is emanation of different chemical substances like radon, light gases and submicron aerosols from earth (Alekseev and Alekseeva, 1992). They change the electrodynamic property of atmosphere over the epicenter zone. The vertical atmospheric electric field changes due to an electrode effect near ground layer of atmosphere have been observed by Hoppel, 1967. In the presence of aerosols the electrode effect enhanced the electric field of up to several kV/m (Vershinin *et al.*, 1997; Boyarchuk *et al.*, 1997). These vertical fields penetrate into the ionosphere where, due to the anisotropic conductivity of the ionosphere they transform into horizontal fields (Kim and Hegai, 1994). The Joule heating plays an important role in the enhancement of ionospheric temperature. The seismogenic electric field within the ionosphere is modulated by daily variations of plasmaspheric electric fields that cause the daily variations of the sign of seismo-ionospheric variations (Pulinets *et al.*, 1998c). The detailed theoretical calculations and further experimental observations strengthen the hypothesis of temperature enhancement due to earthquake over the epicenter zone of ionospheric region which may transform into a short term precursor.

4. Conclusions

The SROSS-C2 data have been analysed to study the ionospheric ion temperature anomalies in F₂ region due to earthquake. It has been found that the average ion temperature is enhanced during the occurrence of earthquakes by 1.2 times over the normal day average ion temperature. The seismogenic vertical electric field propagation up to ionospheric height induces Joule heating, which play a significant role in the ion temperature enhancement. The present studies further broaden the scope of earthquake precursor studies using ionospheric temperature anomalies.

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