

## EFFECT OF LIGHTNING ON IONOSPHERIC TEMPERATURES

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**ABSTRACT:** It has been realized in recent years that the ionospheric temperature and ion density may be influenced by lightning. The ionospheric ion densities ( $O^+$ ,  $O_2^+$ ,  $H^+$  and  $He^+$ ) and electron and ion temperatures were measured by the RPA payload aboard the Indian SROSS-C2 satellite. The data at low latitudes falling in the Indian subcontinent in the height range 425 – 625 km for the period 1995–1998 were chosen for this study. Thunderstorms are the main source of lightning (Gupta, 1999; Inan *et al.*, 1991; Otsuyama, 1999). The data on thunderstorm activity for the same period was obtained from India Meteorological Department (IMD). For our analysis the measurements over Bhopal, Panji and Trivandrum were chosen for which the data on thunderstorm activity is also available. Comparison has also been made with IRI model (Bilitza, 1990). It has been found that the electron temperature was enhanced during thunderstorms activity by 1.4 to 2.3 times over the quiet days. A similar enhancement has been found to be 1.2 to 1.7 times in the ion temperature. In all the events the ion density of above ions were found to be unaffected by the thunderstorms activity. It has been argued that the agencies like run-away electrons, UHF emissions from lightning and lightning sprites (Taranenko *et al.*, 1992; Yukhimuk *et al.* 1999; Bell *et al.*, 1995) may cause the increase of ionospheric temperatures.

### INTRODUCTION

It is believed that the space weather changes influence some of the tropospheric parameters and create disturbances in communication and navigation (Schunk and Sojka, 1996). On the other hand, the tropospheric disturbances are known to influence the ionospheric (Rai, 1974; Taranenko *et al.*, 1993; Yukhimuk *et al.*, 1999; Singh *et al.*, 2001 and others) phenomena. The purpose of this paper is to see the influence of thunderstorms on ionospheric electron and ion temperatures ( $T_e$  and  $T_i$ ). The data was obtained by RPA payload aboard Indian SROSS-C2 satellite. The SROSS-C2 satellite was launched by ISRO on May 4, 1994 to study the ionospheric composition and temperature anomalies. It has yielded valuable data on electron and ion temperatures ( $T_e$  and  $T_i$ ) and ion composition over low latitude locations in the altitude range 425-625 km.

### EXPERIMENTAL DATA AND DATA ANALYSIS

The data collected during the period from 1995-98 has been analyzed for anomalous variations in topside plasma temperatures. The data on thunderstorm activity for the same period was obtained from India Meteorological Department (IMD). Comparison has also been made with IRI model (Bilitza, 1990).

It is a difficult task to study the ionospheric temperature using the satellite data in respect of thunderstorm activity because very rarely passes of satellite match the thunderstorm activity at the meteorological stations. Therefore, we have analyzed the data for ten stations during the period 1995 to 1998 over India. However, only three events have been found which correspond to thunderstorm activity over Bhopal, Panji and Trivandrum. Data for electron and ion temperature were obtained and the analysis was done for these locations for the altitude range 425-625 km. The vertical profile of electron and ion temperature has been obtained at fixed locations with  $\pm 1^\circ$  variation in longitude and latitude. The IRI-95 model data were down loaded from the Internet.

### RESULTS AND DISCUSSION

During the period of our observations one event each was found which correspond to Bhopal, Trivandrum and Panji. For the above events  $T_e$  was increased 1.2 to 2.7 times during the thunderstorms activity from the quiet days and  $T_i$  increased 1.2 to 2.4 times for the same period. Figs. 1 (a), 2 (a) and 3 (a) show the variation of  $T_e$  at Bhopal, Trivandrum and Panji respectively. The variation of  $T_i$  has been shown in Figs. 1 (b), 2 (b) and 3 (b) for the same period and location respectively. On December 10, 1997, (Fig. 1a) there was a severe thunderstorm. The preceding day (December 9, 1997) and the succeeding days (December 11, and 30, 1998) were quiet. On the preceding day the  $T_e$  at Bhopal was about 2300°K. It was less by about 1000°K compared to the active thunderstorm day (December 10, 1997) and in succeeding days the  $T_e$  also decreased and attained a value of about 1700°K. Thus during the thunderstorm the  $T_e$  increases 1.4 to 2.3 times from the quiet days. The increase in  $T_i$  at the same location and time varied from 1.2 to 1.6 times (Fig. 1b) during the active thunderstorms day. In preceding and succeeding days the IRI model shows good agreement with the experimental observations. In each figure the horizontal axis

gives the local time (LT) in hours at which the satellite passed over the given meteorological station. In Fig. 1(b) the date December 11, 1997 is absent because of the ion temperature was not recorded on that day.

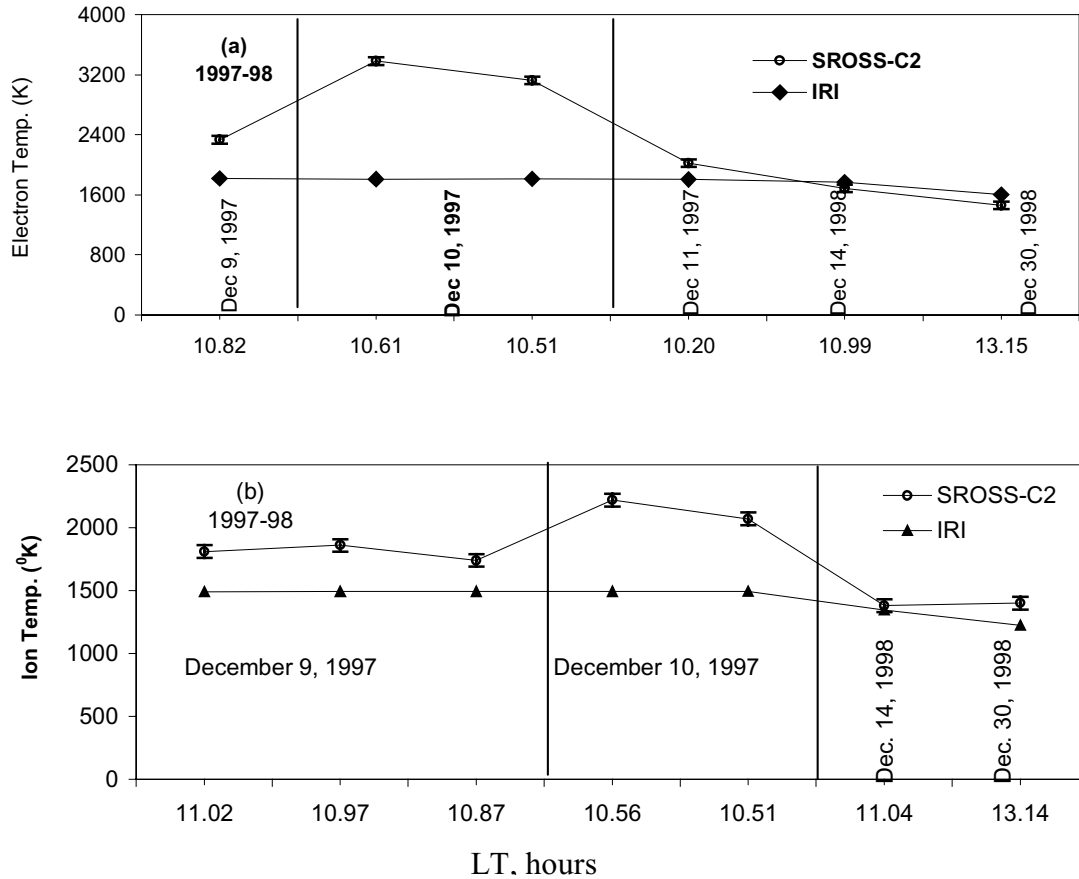
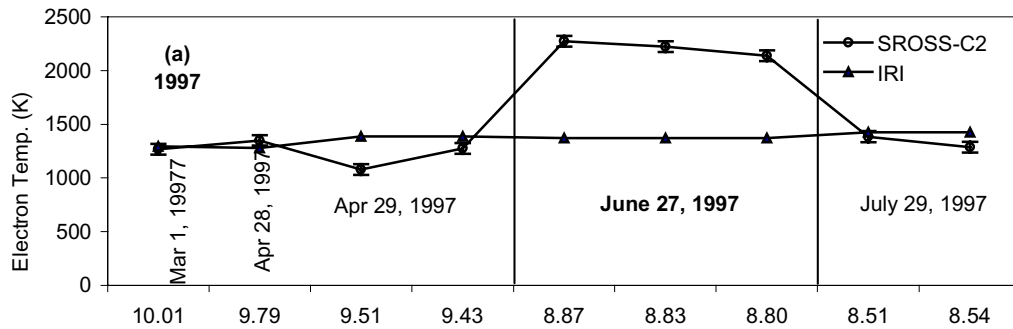


Figure 1. Variation of  $T_e$  and  $T_i$  at Bhopal along with IRI model.

At Trivandrum there was a severe thunderstorm on June 27, 1997.  $T_e$  was increased 1.6 to 2.2 times from the quite days, which is quite similar to the  $T_e$  variation at Bhopal. During the active thunderstorm day the  $T_e$  was about 2300°K and in quite preceding and succeeding days the  $T_e$  came to about 1400°K. At Trivandrum the IRI model has the same behavior as at Bhopal and Panji and shows good agreement with experimental observations for quite days. There is no significant change in  $T_i$  (Fig. 2b).



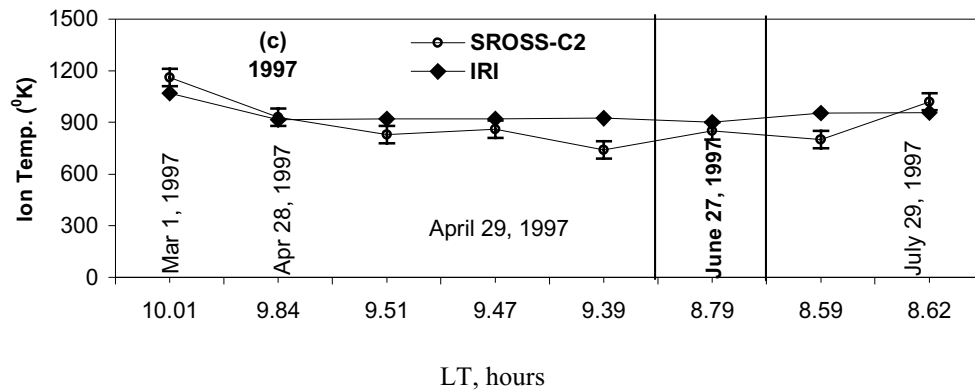


Figure 2. Variation of  $T_e$  and  $T_i$  at Trivandrum along with IRI model.

Fig. 3 (a, b) shows the variation in  $T_e$  and  $T_i$  at Panji. At Panji a severe thunderstorm was present on two consecutive days (August 15, and 16, 1998). During the thunderstorms the  $T_e$  reaches upto about  $2300^\circ\text{K}$ , which shows the increase in the range from 1.6 to 1.8 times compared to the quite days. During quite days the  $T_e$  was about  $1400^\circ\text{K}$ . The IRI model shows the good agreement with quite day measurements. The enhancement in variation of  $T_i$  (Fig. 3b) at the same location during the active thunderstorms day was in the range from 1.2 to 1.7 times as compared the normal days, which is similar to that of Bhopal.

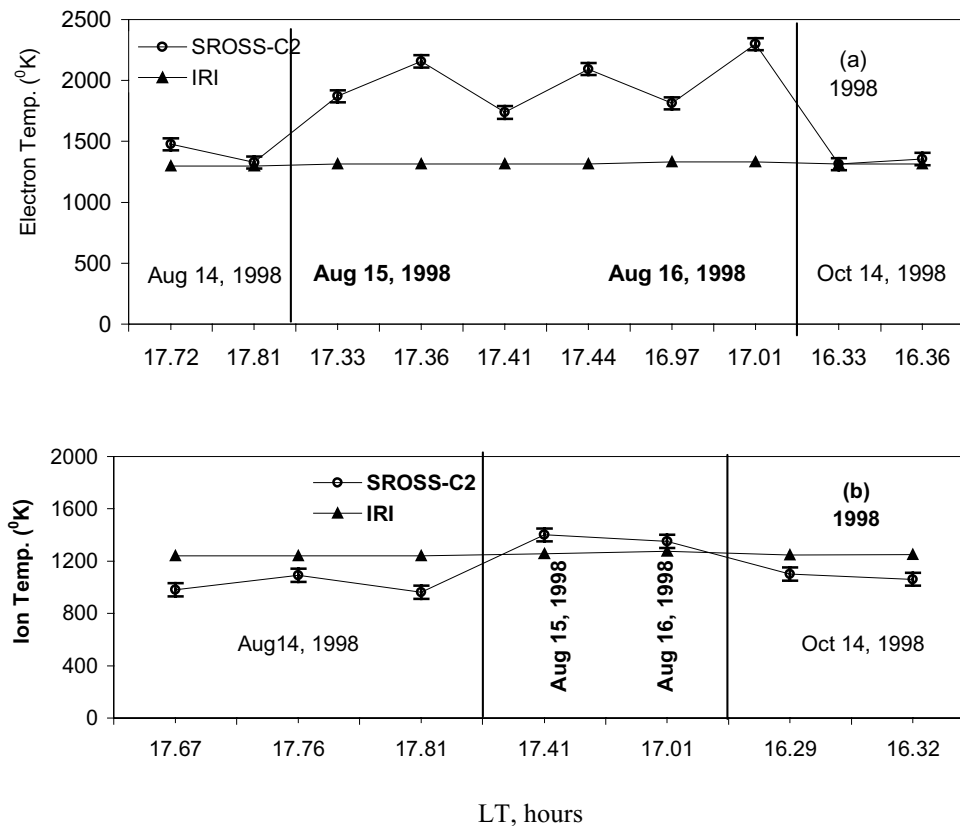


Figure 3. Variation of  $T_e$  and  $T_i$  at Panji along with IRI model.

These enhancements in ionospheric electron and ion temperatures have been attributed to different kind of lightning activity during a thunderstorm such as Red sprites, blue jets, blue starters and elves above an active thunderstorm (Lyons, 1994; Sentman and Wescott, 1993; Inan et al., 1995; Taranenko, 1993). Thunderstorms are the

main source of lightning discharges. During lightning discharge the energized charged particles beam is set up which is known to radiate wide spectrum (Singh et al., 2001) electromagnetic waves, optical emissions, X-rays and gamma rays. In the production of these radiations the run-away electrons may play a significant role in troposphere-ionosphere interaction via these radiations.

## CONCLUSION

The present study reveals that the electron temperature was enhanced during thunderstorms activity by 1.4 to 2.3 times over the quiet days. A similar enhancement has been found to be 1.2 to 1.7 times in the ion temperature. However, the ion density of above ions were found to be unaffected by the thunderstorm activity. The IRI-95 model shows a good agreement with quiet days measurement of electron and ion temperatures.

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