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Advances in Space Research xxx (2016) xxx–xxx

ADVANCES IN SPACE RESEARCH (a COSPAR publication)

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Ion density variation at upper ionosphere during thunderstorm

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Received 2 May 2016; received in revised form 21 October 2016; accepted 26 November 2016

Abstract

Ionosphere is found to be affected by phenomenon taking place above and below it. Troposphere incidents of thunderstorm and lightning, influence ionospheric temperatures and ion density, from D region to a region of high altitude. Low latitude upper ionosphere in the altitude range of 425–625 km over Indian subcontinent is studied for ion density variation during the event of active thunderstorm. Study is done with the help of ionospheric data obtained from in situ measurements made by Indian satellite SROSS C2, and thunderstorm and other related data obtained from Indian Meteorological Department. Ion density in this region found to show a regular fall from 5 to 65% during the event of thunderstorm over normal day values but consistent heating of ions takes place. O^+ being the main part of the composition of ionosphere at this altitude so total ion density variation show a similar trend as that of O^+ ion, while other ions like O_2^+, He^+ and H^+ do not follow any regular trend with the activity of thunderstorm.

Keywords: Thunderstorm; Ionospheric ion density; VLF radiations; SROSS C2

1. Introduction

Lower ionosphere show remarkable perturbations with the phenomenal changes associated with thunderstorm because of lower ionosphere coupling with lightning energy. Lightning generates a wide variety of electromagnetic radiations ranging from a very high (30–300 MHz) to a very low frequency band (3–30 Hz). ELF/VLF radiations have been found to be main perturbation agents, in lower as well as upper ionosphere region during the event of thunderstorm and lightening, by many researchers (Colman and Starks, 2013; Inan et al., 1993; Němec et al., 2010). In situ observation by DEMETER (Detection of Electromagnetic Emission Transmitted from Earthquake Regions) satellite of ionospheric perturbations generated by ground based VLF transmitter (21° 47′S, 114° 09′E) revealed deviations in electron and ion densities along with their temperature enhancement, and this effect extend up to satellite altitude of 700 km (Parrot et al., 2007). An intense lightning stroke is associated with other related phenomenon above the thunder clouds, collectively called as TLEs (transient luminous events). There are several types of TLEs including sprites (most common), blue jets, gigantic jets, blue starters, and ELVESs ((Emission of Light and Very Low Frequency). These TLEs invade ionosphere to different extent and create their signatures in one or another way (Pasko et al., 1997; Soula et al., 2009). Heating and ionization of lower nighttime ionosphere (90–95 km) by lightning was reported by Inan et al. (1991). Electrons, heated by a factor of 100–500 were producing secondary ionization at this altitude which further leads to charge density enhancement. Rodger et al.

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http://dx.doi.org/10.1016/j.asr.2016.11.039
0273-1177/

Table 1
Thunderstorm events recorded by IMD during the period of 1995–1998.

S. no.	Date of event	Time and duration of thunderstorm	Geographic location of thunderstorm
1	11 January 1995	06:31–09:30 UT (3 h)	23.16° N, 77.36° E, Bhopal
2	28 April 1995	09:31–12:30 UT (3 h)	08.29° N, 76.59° E, Trivandrum
3	29 August 1995	06:31–09:30 UT (3 h)	23.16° N, 77.36° E, Bhopal
4	27 June 1997	01:01–04:00 UT (3 h)	08.29° N, 76.59° E, Trivandrum
5	10 December 1997	03:31–06:30 UT (3 h)	23.16° N, 77.36° E, Bhopal
6	15 August 1998	09:31–12:30 UT (3 h)	15.30° N, 73.55° E, Panji

(2001) with their simulation studies examined lower ionospheric modifications during nighttime lightning discharge and found that such events can lead to 100% or even greater enhancement in electron density at altitude of ~90 km. The study pointed the possibility of region of electron density with significant decrease also. Sharma et al. (2003) gave a report about temperature anomalies associated with active thunderstorm at F2 region in the altitude range of around 400–600 km. The report illustrates the sustained heating of electron and ion but to a smaller extent as compared to that at lower ionosphere. Parrot et al. (2013) used dataset obtained from DEMETER to show the ion density perturbations at upper ionosphere of satellite altitude, 650–700 km. The study group, identified intense lightning event associated with sprite and other TLEs and reported an enhancement in ion density by up to 133% during nighttime especially effected by O^+ ion density. They attributed the perturbations to energetic particle precipitation during long duration intense thunderstorm activity subsequently followed by strong whistlers.

In the present study, the low latitude upper ionosphere has been explored for ion density variation with respect to thunderstorm and lightning. Ionospheric data is obtained from measurements made by Indian satellite SROSS C2.

2. Instrumentation and data analysis

Indian satellite SROSS C2, the 4th and most advance satellite of Stretched Rohini Satellite Series (SROSS), was launched on 4 May 1994 by Indian Space Research Organisation (ISRO) in an elliptical orbit. An aeronomy payload of two separate Retarding Potential Analysers (RPA) for, in situ measurement of electron and ion plasma parameters at equatorial and low latitude ionosphere in altitude range of 420–620 km over Indian subcontinent region, were onboard the satellite. The satellite was active for more than half of 23rd solar cycle, covering from minima to maxima (2001). SROSS C2 yielded data about electron and ion

Table 2
Ion density and ion temperature measurements for thunderstorm event and normal days recorded during the period of 1995–1998.

Date of event	Geographic location of the event	Ion temp, K		O^+ Ion density m^{-3}		O_2^+ Ion density m^{-3}		H^+ Ion density m^{-3}		He^+ Ion density m^{-3}		Total Ion density m^{-3}	
		Normal	Event	Normal	Event	Normal	Event	Normal	Event	Normal	Event	Normal	Event
11 January 1995	Bhopal, 23.16° N, 77.36° E	911	1029	5.62E+11	1.90E+11	1.15E+09	4.97E+08	2.85E+09	2.82E+09	3.70E+09	8.99E+08	5.70E+11	1.94E+11
28 April 1995	Trivandrum, 08.29° N, 76.59° E	1155	1320	1.47E+11	1.40E+11	2.06E+08	1.07E+08	4.64E+09	9.56E+09	3.88E+09	2.61E+08	1.56E+11	1.50E+11
29 August 1995	Bhopal, 23.16° N, 77.36° E	1322	1384	1.17E+11	1.05E+11	4.51E+08	5.50E+08	1.11E+10	1.56E+10	8.15E+09	6.09E+09	1.39E+11	1.28E+11
27 June 1997	Trivandrum, 08.29° N, 76.59° E	990	1140	1.55E+11	6.31E+10	3.03E+08	8.35E+07	2.65E+08	3.70E+08	2.78E+08	2.93E+09	1.56E+11	6.65E+10
10 December 1997	Bhopal, 23.16° N, 77.36° E	1772	2130	4.78E+10	2.49E+10	3.42E+08	7.02E+08	3.91E+09	2.80E+09	5.04E+09	5.62E+09	5.71E+10	3.40E+10
15 August 1998	Panji, 15.30° N, 73.55° E	1185	1366	3.73E+11	1.83E+11	1.46E+09	7.63E+08	9.19E+08	6.36E+07	2.47E+09	7.00E+07	3.77E+11	1.84E+11