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Review

Variation of ionospheric electron and ion temperatures during periods of minimum to maximum solar activity by the SROSS-C2 satellite over Indian low and equatorial latitudes

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Abstract

To study the variation of ionospheric electron and ion temperatures with solar activity the data of electron and ion temperatures were recorded with the help of Retarding Potential Analyzer payload aboard Indian SROSS-C2 satellite at an average altitude of ~500 km. The main focuses of the paper is to see the diurnal, seasonal and latitudinal variations of electron and ion temperatures during periods of minimum to maximum solar activity. The ionospheric temperatures in the topside show strong variations with altitude, latitude, season and solar activity. In present study, the temperature variations with latitude, season and solar activity have been studied at an average altitude ~500 km. The peak at sunrise has been observed during all seasons, in both electron and ion temperatures. Further, the ionospheric temperatures vary with latitude in day time. The latitudinal variation is more pronounced for low solar activity than for high solar activity.

Keywords: Electron and ion temperatures; F_2 region; Low latitude; Solar activity; Satellite observation

Contents

1. Introduction

The solar activity has been studied for long by geophysicists and solar physicists with its conspicuous 11 year cycle. The change in ionospheric parameters may affect the radio communication, navigation, exploration of near Earth space electronic system in satellites and spacecraft. For measuring the ionospheric temperatures, the principal instruments are ground-based incoherent scatter radars and satellite in situ probes (Langmuir probe and Retarding Potential Analyzer). Temperature measurements with both techniques began in the early sixties and both techniques have been continuously improved and refined over the past decades. The changes in instrument design and data analysis, however, pose a problem for studies which investigate the long-term trends in parameters measured by these instruments. Namely, part of the changes seen may be due to improved accuracy rather than dependence on solar activity (Bilitza and Hoegy, 1990; Bilitza et al., 2007). Bili-

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tza and Hoegy (1990) have studied that the ion temperature and its dependence on solar activity are determined by the close coupling with the neutrals and their temperatures at low altitudes and with electron at high altitudes. The ionospheric electron gas exhibits a rather complex thermal response pattern to changing solar activity. By using the satellite probe measurement from AE-C and DE-2 they found that the positive correlation between electron temperature and solar activity at high altitudes. Incoherent scatter measurements have shown that the response of electron temperature to changes in solar activity depends on season and is different for day and night (Bilitza and Hoegy, 1990).

Measurement of ionospheric electron and ion temperatures give an insight into the energy balance of the ionosphere–thermosphere regime. Features of electron temperature have been studied using measurements from incoherent scatter radar (McClure, 1969, 1971; Mahajan, 1977; Oliver et al., 1991; Otsuka et al., 1998; Zhang and Holt, 2004; Lei et al., 2007), rocket probes (Oyama et al., 1980, 1996) and satellite based instruments (Brace et al., 1967; Sharma et al., 2003; Rich et al., 2003). Brace and Theis (1981) and Triskova et al. (1996) had empirical models of electron temperature in the ionosphere and lower plasmasphere. Schunk and Nagy (1978) have presented a review article on the electron temperature in F-region of ionosphere. Richards and Torr (1986) and Watanabe et al. (1995) theoretically studied the temperature variations in the ionosphere and plasmasphere. Su et al. (1995), Oyama et al. (1996) and Balan et al. (1996a,b) used Sheffield University Plasmasphere Ionosphere model, SUPIM to investigate the temperature measurements made by Hinotori and Exos D satellites. A Japanese 'Hinotori' satellite which had a nearly circular orbit at ~600 km with an orbital inclination of 30° provided an ideal database for study of the temporal and spatial variations of the electron density and temperature in the topside ionosphere (Watanabe and Oyama, 1996; Oyama et al., 1985; Suhasini et al., 2001; Balan et al., 1997). But the Hinotori data are limited to a period of medium and high solar activity. Watanabe and Oyama (1996) studied the electron temperature observed by the Hinotori satellite in terms of local time, season, latitude magnetic inclination and the solar flux intensity for a 16 month period during 1981–1982. They found that the electron temperature shows a steep rise in the early morning, a decrease after that and again an increase at ~18:00 h LT. Hanson et al. (1973) observed the electron and ion temperatures with the OGO-6 satellite near the magnetic equator above 500 km altitude. They showed that equatorial troughs of electron and ion temperatures occur in the topside ionosphere during nighttime. Plasma cooling was also measured by the ISS-b satellite at ~1100 km altitude (Sagawa et al., 1981).

From last decade ionospheric temperatures and composition anomalies over equatorial and low latitudes have been studied through the completion of many satellite missions like Atmospheric Explorer, Dynamic Explorer, ISIS, AEROS, TAIYO, etc. But the data base, to study these anomalies over the Indian region, is sparse. Another advantage of SROSS-C2 mission is that the orbit is just above the F-region electron density peak and the orbital ellipticity is much less. Many researchers (Bhuyan et al., 2002, 2004, 2006; Aggarwal et al., 2009) have also used the SROSS-C2 satellite data to study the behavior of ionospheric parameters. Bhuyan et al. (2004) studied the diurnal, seasonal and latitudinal variations of the ion temperature using the SROSS-C2 satellite data in the Indian zone equatorial and low latitude ionosphere at an average altitude ~500 km. They found that the pre-sunrise enhancement in the ion temperature in between 4:00 and 6:00 LT and also found that an afternoon enhancement of lower amplitude is also observed in summer season. Aggarwal et al. (2009) have studies of electron and ion temperatures at 500 km altitude during the sunrise using the same satellite data set as that in the present study. They found that in winter the morning overshoot in electron temperature enhances to ~4000 K is observed around 6:00 LT during low solar activity and it was slightly lower during higher solar activity. In summer, it is observed around 5:30 LT, but the rate of electron temperature enhancement is higher during moderate solar activity than low solar activity. During equinox, this phenomena is delayed and is observed around 6:00 LT during all three phases of solar activity.

Present study is different from that of the study of other researcher (Bhuyan et al., 2002, 2004, 2006; Aggarwal et al., 2009) in various aspects using the same satellite data set. Aggarwal et al. (2009) chose the data only for sunrise period for the equatorial region from 10°S to 20°N. However, in the present study we have chosen the satellite data for whole Indian region (from 5°S to 20°N geomagnetic latitude and from 137°E to 168°E geomagnetic longitude) to study the variation of ionospheric electron and ion temperatures during minimum to maximum solar activity. This region was chosen on the basis of maximum passes of SROSS-C2 over India. Bhuyan et al. (2004, 2006) have chosen the same study region as that by Aggarwal et al. (2009) to study the diurnal, seasonal and latitudinal variations of electron and ion temperatures. Bhuyan et al. (2004) have also studied the latitudinal variation during day time for the year from 1994 to 1998. However, in the present study the latitudinal variation has also been studied during the quiet time (nighttime) along with the standard deviation for the year 1995 (solar minimum) to 2000 (solar maximum) for whole Indian region.

The aim of the present study is to study the diurnal, seasonal and latitudinal variations of the ionospheric electron and ion temperatures during the low solar activity period (1995) to high solar activity (2000) using the data recorded by the SROSS-C2 satellite. The ionospheric electron and ion temperatures were measured with the help of Retarding Potential Analyzer (RPA) payload aboard the Stretched Rohini Series Satellite (SROSS-C2), which was launched by Indian Space Research Organization (ISRO) on May