Available online at www.sciencedirect.com

ScienceDirect

Advances in Space Research 56 (2015) 2117–2129

ADVANCES IN SPACE RESEARCH (a COSPAR publication)

www.elsevier.com/locate/asr

Electron–ion–neutral temperatures and their ratio comparisons over low latitude ionosphere

Ananna Bardhan [a], D.K. Sharma [b,*], M.S. Khurana [b], M. Aggarwal [c], S. Kumar [a]

[a] Department of Physics, FET, Manav Rachna International University, Faridabad 121001, India
[b] Department of Physics, Manav Rachna University, Faridabad 121001, India
[c] Indian Institute of Geomagnetism, Mumbai 410206, India

Received 5 December 2014; received in revised form 26 August 2015; accepted 28 August 2015
Available online 4 September 2015

Abstract

Annual variations in temperatures of plasma (electron–Te, ion–Ti) using SROSS-C2 satellite and neutral (Tn) using NRLMSIS-00 (neutral atmospheric model); have been investigated and their ratios have been compared over half solar cycle (year 1995–2000, F10.7 ~ 72–190). The region under consideration spans over 5–35°N geog. latitude and 65–95°E geog. longitude in the Indian sector, at an average altitude of 500 km. Te and Ti exhibit similar, while Tn show completely different diurnal features. During nighttime Te, Ti and Tn attain equilibrium with each other, but plasma cools faster than neutrals. Magnitude of Te and Ti reduces, while that of Tn increases with increasing solar activity. Ratio comparisons (Te/Tn, Ti/Tn and Te/Ti) show higher sensitivity of electrons compared to ions and neutrals. Te/Tn, Ti/Tn exhibits linear/direct relationship with solar flux, while Te/Ti doesn't. The deviation of Te, Ti and Tn from equilibrium temperature decreases with increasing solar activity.

Keywords: Plasma temperatures (Te and Ti); Neutral temperature (Tn); Ionospheric temperature ratios (Te/Tn, Ti/Tn and Te/Ti); SROSS-C2 satellite; Neutral atmospheric model – NRLMSIS-00 and low latitude F2 region

1. Introduction

The lower regions of the atmosphere above the Earth's surface have been studied intensively by meteorologists as the seat of weather phenomena. It is comparatively in the recent times that the comprehensive study of upper region atmosphere–ionosphere, has become extremely important, owing to society's technological dependence on satellite communication and navigation. Thus, understanding, forecasting and monitoring changes in ionosphere has become extremely important.

As the Earth is embedded in the outer atmosphere of the Sun, the effects of its radiations affect the thermospheric dynamics of F region ionosphere. Ionospheric parameters modulate with solar cycle, geomagnetic conditions, seasons and local time. Extensive studies using ground and space born facilities have been carried to understand and forecast changes in ionosphere. Greatest bulk of research is concentrated on ion composition and electron densities. Although examples of comprehensive reports on ionospheric temperatures were provided by Balan et al. (1997), Watanabe et al. (1995), Titheridge (1998), Schunk et al. (2003), Bhuyan et al. (2002), Aggarwal et al. (2007), Sharma et al. (2010) and many more, still, studies focused on global distribution of ionospheric temperatures are less rich (Slominska and Rothkaehl, 2013). Ionospheric temperatures in F region are determined by heating, cooling and

* Corresponding author.
E-mail addresses: dksphses@rediffmail.com, jointcoe@mru.edu.in (D.K. Sharma).

http://dx.doi.org/10.1016/j.asr.2015.08.031
0273-1177/

energy flow (Schunk and Nagy, 1978). The solar radiation reaching the earth's atmosphere cause ionization of neutral atoms and produce photoelectrons. The energetic photoelectrons lose their energy by sharing it with the ambient electrons causing a rise in electron temperatures. The increase in electron temperature is higher during early morning as the electron density is low (Sharma et al., 2003). However, as the day progresses, more and more electrons are produced and energy share of each electron decreases. Thus, the electron temperature reaches a maximum in the early morning, decreases and then attains a steady value by the afternoon. The ion temperature also shows similar enhancement during sunrise hour, however, the peak in ion temperature is delayed as compared to electron temperature (Aggarwal et al., 2007; Sharma et al., 2010).

The morphology and dynamics of equatorial ionosphere is notably different from that of mid and high latitude. In low latitudes, magnetic field lines become nearly horizontal with insignificant vertical component, giving birth to a different dynamics. Equatorial/low latitudes exhibit unique features such as equatorial electrojet, vertical $E \times B$ drift, etc. The region under consideration for present study is over Indian subcontinent (low latitude). Electron and ion temperatures in the upper ionosphere over the Indian subcontinent have been studied in detail by various researchers based on the SROSS C2 satellite data (Bhuyan et al., 2002, 2004, 2006; Aggarwal et al., 2007, 2009). The studies are based on diurnal, seasonal and latitudinal variations of ionospheric parameters. Bhuyan et al. (2002) have studied the diurnal and seasonal variation of electron and ion temperatures along with electron density during 1995–96. Both the electron and ion temperature show an enhancement during sunrise hours, although; the ion temperatures were found to be less than electron temperatures in all seasons and latitudes under study. Nayar et al. (2004) have used the same satellite data to make a direct comparison of electron and ion temperatures at the low-latitude topside ionosphere. They observe d that electron and ion temperatures exhibit similar diurnal features with morning and evening enhancements. Characteristics of these enhancements were found to evolve with season, altitude, latitude and solar activity. Aggarwal et al. (2009) have studied electron and ion temperatures at 500 km altitude during the sunrise. They studied the solar dependence of the electron and ion temperatures during early morning hours and observed seasonal variations in the temperature with the varying solar activity. Sharma et al. (2010) made a similar study using the SROSS C2 electron and ion temperature data to study the diurnal, seasonal and latitudinal variations of electron and ion temperatures, during periods of minimum to maximum solar activity. Sharma et al. (2005) also made a study of the seasonal variation of electron and ion temperature ratios for the period 1995–1999 for low solar activity period (1995–1997; $F10.7 < 50$) and high solar activity period (1998–1999; $F10.7 > 50$).

Present work analyses the diurnal variability of plasma temperatures (Te and Ti) obtained from SROSS-C2 satellite according to latitude and different seasons – summer (May, June, July, August), winter (November, December, January, February) and equinox (March, April, September, October) with varying solar activity. For the first time, the present study brings out comparison of diurnal behaviour of neutral temperatures with electron and ion temperatures during half solar cycle (1995–2000) over low latitude region (Indian subcontinent). We have used the SROSS-C2 satellite data and Neutral model NRLMSIS-00 to study the annual hourly variation of electron, ion and neutral temperature ratios with varying solar activity. Current study is different from earlier studies as it provides a detailed investigation of electron ion temperature ratios for each year from 1995 to 2000 i.e. half of the solar cycle, instead of binning them into low and high solar activity periods (Sharma et al., 2005) or low, moderate and high activity periods (Aggarwal et al., 2009). Also the study is not confined to specific hours of a day and has been carried for both morning and quiet hours. We believe that detailed treatment of the Te, Ti and Tn ratios would give a better understanding of the variation of ionospheric temperature ratios with the varying solar activity and help in improving the existing ionospheric models.

2. Data used

2.1. SROSS-C2 data

To investigate the diurnal behaviour of Te, Ti and ratios of Te and Ti over half solar cycle (1995–2000), data of ionospheric temperatures from RPA (Retarding Potential Analyser), aboard SROSS-C2 satellite, have been used. The region considered for present study spans over the Indian subcontinent/ low latitude (5–35°N geog. Lat., 65–95°E geog. Long.) at an average altitude of ~500 km/F2 region.

The detail description of SROSS-C2 mission and the procedure for retrieval of plasma parameters have been given by Garg and Das (1995). The ionospheric parameters (Te, Ti, $O+$ and $H+$) are obtained using a Retarded Potential Analyser (RPA) payload aboard the SROSS-C2 satellite, which was launched by Indian Space Research Organization (ISRO) on May 4, 1994 around 420×620 km altitude. The RPA payload consisted of two sensors, (i.e. electron and ion sensors) and associated electronics (Garg and Das, 1995). In addition, a spherical Langmuir probe was included which acted as a probe to estimate the spacecraft potential as the satellite spin. The electron and ion sensors had a planar geometry and consisted of multi-grid Faraday cups with a collector electrode. The mechanically identical sensors were mounted on the top deck; and move in the cartwheel mode perpendicular to the spin axis of the spacecraft. Both sensors had different grid voltages which was suitable for the collection of