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Sunrise effect on ionospheric temperature as measured by SROSS-C2 satellite

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Abstract

The ionospheric electron and ion temperatures are known to be dependent on the position of Sun with respect to Earth. The Retarding Potential Analyzer (RPA) experiment flown aboard Indian SROSS-C2 satellite has yielded valuable data on ionospheric temperatures and composition. The data collected during the period from 1995 to 1998 for two different locations (Bhopal and Chennai) over India have been analyzed.

The night time electron temperature (Te) varies from 745 to 915°K and rises sharply at sunrise 3334 to 4231°K and then falls off slowly becoming minimum after the sunset at Bhopal. Whereas at Chennai the nighttime Te varies from 754 to 883°K and rise sharply at sunrise from 3495 to 5763°K. The nighttime ion temperature (Ti) varies from 618 to 832°K at Bhopal and it also increases at sunrise from 1270 to 2860°K. At Chennai the nighttime Ti varies from 626 to 776°K and increases at sunrise from 1760 to 2930°K. These enhancements of electron and ion temperatures have been found for both stations. However, due to latitude effect the minor difference is observed in Te and Ti behavior at above two stations.

INTRODUCTION

At sunrise, photoelectron production begins in the ionosphere through the ionization of neutral particles. As the photoelectrons share their high energy with the ambient electrons, the electron temperature (Te) increases. This increase is rapid in the early morning hours due to the low electron density. As more and more electrons are produced as sunrise progress, the share of energy for each electron decreases. Thus, the Te after reaching a maximum decreases and attains a steady state value as the day progress. The electron and ion temperature variations in the Earth's ionosphere have been studied extensively through ground-based and in situ observations (Farley et al. 1967; Evans 1973; Hanson, Nagy & Moffett 1973; Oyama & Hirao 1975; Tithe ridge 1976; Brace & Theis 1978; Oyama, Hirao & Yasuhara 1985; Su et al. 1995; Watanabe, Oyama & Abdu 1995; Bhuyan et al. 2000; Sharma et al. 2002 and others) and through theoretical calculations (Dalgarno et al. 1963; Geisler & Bowhill 1965; Banks & Nagy 1970, Mayr et al. 1972; Bailey et al. 1975 and others). The purpose of the present paper is to study the electron and ion temperature variations in the ionosphere at low latitude F_2 region (425-625km) over India for the period from 1995 to 1998. For this purpose, we have used the Stretched Rohini Series Satellite (SROSS-C2) data. The SROSS-C2 was launched by ISRO on May 4, 1994 to study the ionospheric composition and temperature anomalies. The SROSS-C2 is a spin-stabilized satellite with its spin axis perpendicular to its longitudinal axis. Orbital inclination of the satellite is 46° with the equatorial plane. The spin rate of the satellite is about 5 revolutions per minute (rpm).

Data Analysis

The data obtained using RPA payload aboard SROSS-C2 satellite for the period from January 1995 to December 1998 have been analyzed to study the behavior of ionospheric temperatures (Te and Ti). The data were obtained for ten different locations: Aurangabad (19.53° N, 75.23° E), Bhopal (23.16° N, 77.36° E), Chennai (13.04° N, 80.17° E), Cochin (09.58° N, 76.17° E), Indore (22.44° N, 75.50° E), Nagpur (21.09° N, 79.09° E), Panji (15.30° N, 73.55° E), Pune (18.31° N, 73.55° E), Trivandrum (08.29° N, 76.59° E) and Varanasi (25.20° N, 83.00° E). These stations were chosen for the maximum number of passes of satellite SROSS-C2 over India in the altitude range 425-625 km. The electron and ion temperatures have been obtained at fixed locations with ± 1° variation in longitude and latitude. In the present paper we have analyzed the temperature variation data for two stations data: Bhopal (23.16° N, 77.36° E) and Chennai (13.04° N, 80.17° E) in details.

The Retarding Potential Analyzer (RPA) payload consists of two sensors viz., electron and ion sensors and associated electronics (Garg & Das 1995). The electron and ion RPAs are used for insitu measurements of ionospheric electron and ion parameters. In addition a spherical Langmuir probe is included and is used as potential probe for estimating the variation of spacecraft potential during spinning of the satellite. The electron and ion sensors both have planar geometry and consist of multigrid Faraday cups with a collector electrode. The different grids in the sensor are designated as the Entrance grid, the Retarding grid, the Suppressor grid and the Screen grid. These grids are made of gold plated tungsten wire mesh having 90 to

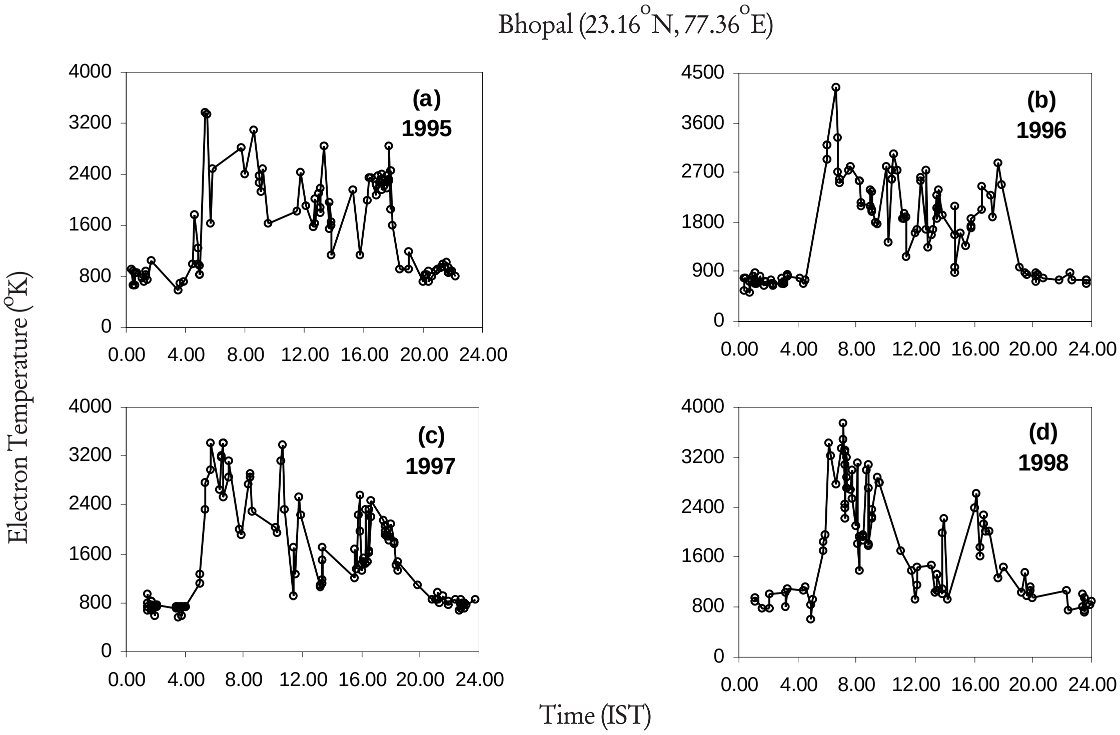

Figure 1. Variation of *Te* at Bhopal form 1995 to 1998.

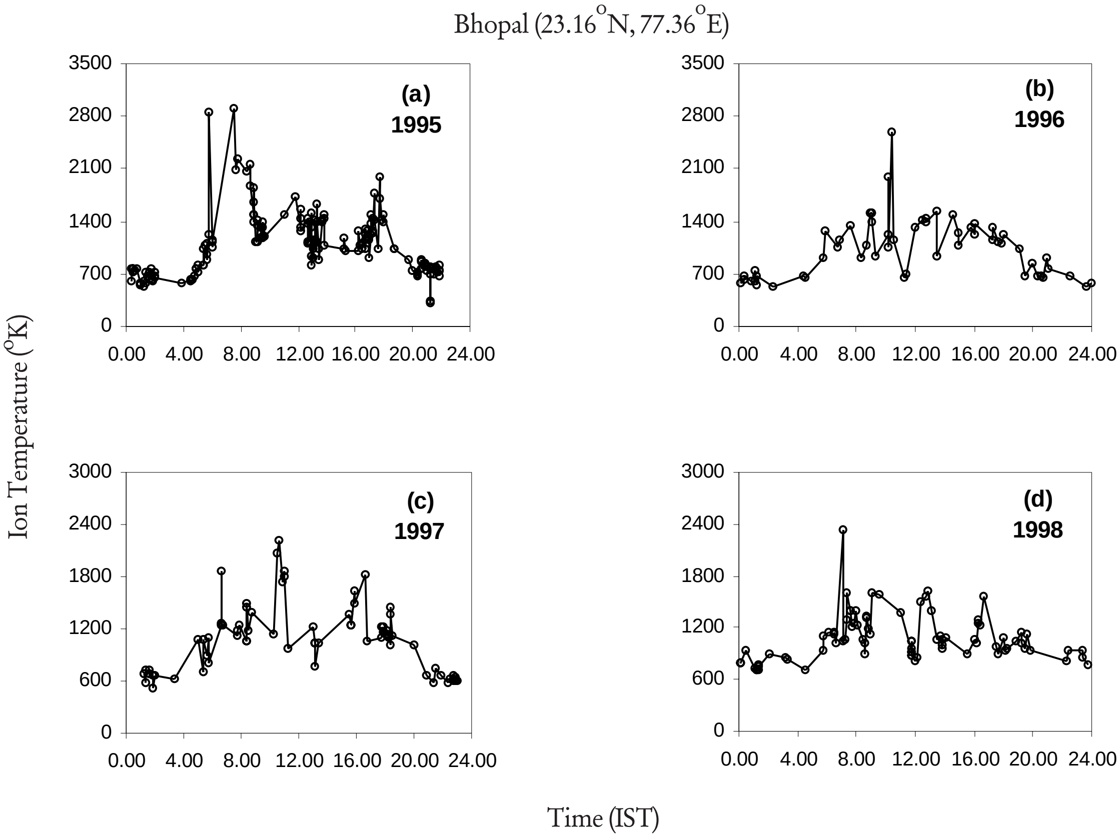

Figure 2. Variation of *Ti* at Bhopal form 1995 to 1998.

Table-1a: Comparison of *Te* at Bhopal and Chennai from 1995 to 1998.

Year	*Bhopal*			*Chennai*		
	Maximum Temp. at Sunrise (°K)	Average Temp. at Daytime (°K)	Average Temp. at Nighttime (°K)	Maximum Temp. at Sunrise (°K)	Average Temp. at Daytime (°K)	Average Temp. at Nighttime (°K)
1995	3334	2089	879	5763	2121	807
1996	4231	2121	745	3495	1618	754
1997	3403	2059	789	4667	1995	777
1998	3438	2114	915	4784	3132	883

Table-1b: Comparison of *Ti* at Bhopal and Chennai from 1995 to 1998.

Year	*Bhopal*			*Chennai*		
	Maximum Temp. at Sunrise (°K)	Average Temp. at Daytime (°K)	Average Temp. at Nighttime (°K)	Maximum Temp. at Sunrise (°K)	Average Temp. at Daytime (°K)	Average Temp. at Nighttime (°K)
1995	2860	1312	702	1890	1099	646
1996	1270	1254	658	1760	1153	626
1997	1870	1278	618	2930	1140	675
1998	2230	1163	832	2400	1247	776

Table-2: After sunrise the decay equation of *Te* and *Ti* at Bhopal and Chennai.

Year	**Electron Temperature**		**Ion Temperature**	
	Bhopal	*Chennai*	*Bhopal*	*Chennai*
	Decay Equation	**Decay Equation**	**Decay Equation**	**Decay Equation**
1995	$Y = 5232.8e^{-0.0759 X}$	$Y = 5812.9e^{-0.0884 X}$	$Y = 1945.5e^{-0.0459 X}$	$Y = 3848.3e^{-0.0740 X}$
1996	$Y = 4853.3e^{-0.0775 X}$	$Y = 4964.8e^{-0.0848 X}$	$Y = 2346.4e^{-0.0576 X}$	$Y = 1636.3e^{-0.0275 X}$
1997	$Y = 4865.1e^{-0.0734 X}$	$Y = 6387.6e^{-0.1018 X}$	$Y = 2492.8e^{-0.0644 X}$	$Y = 2149.3e^{-0.0442 X}$
1998	$Y = 4408.0e^{-0.0704 X}$	$Y = 5576.9e^{-0.0851 X}$	$Y = 2024.8e^{-0.0422 X}$	$Y = 1735.0e^{-0.0293 X}$

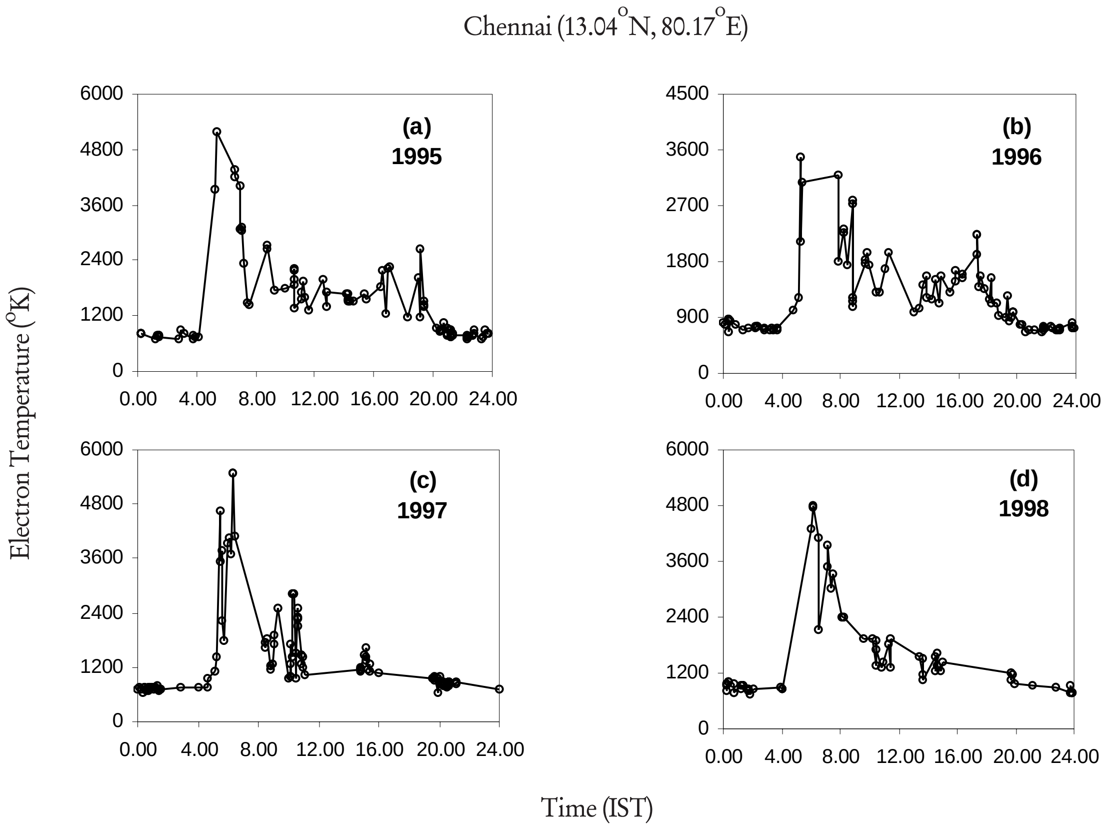

Figure 3. Variation of *Te* at Chennai form 1995 to 1998.

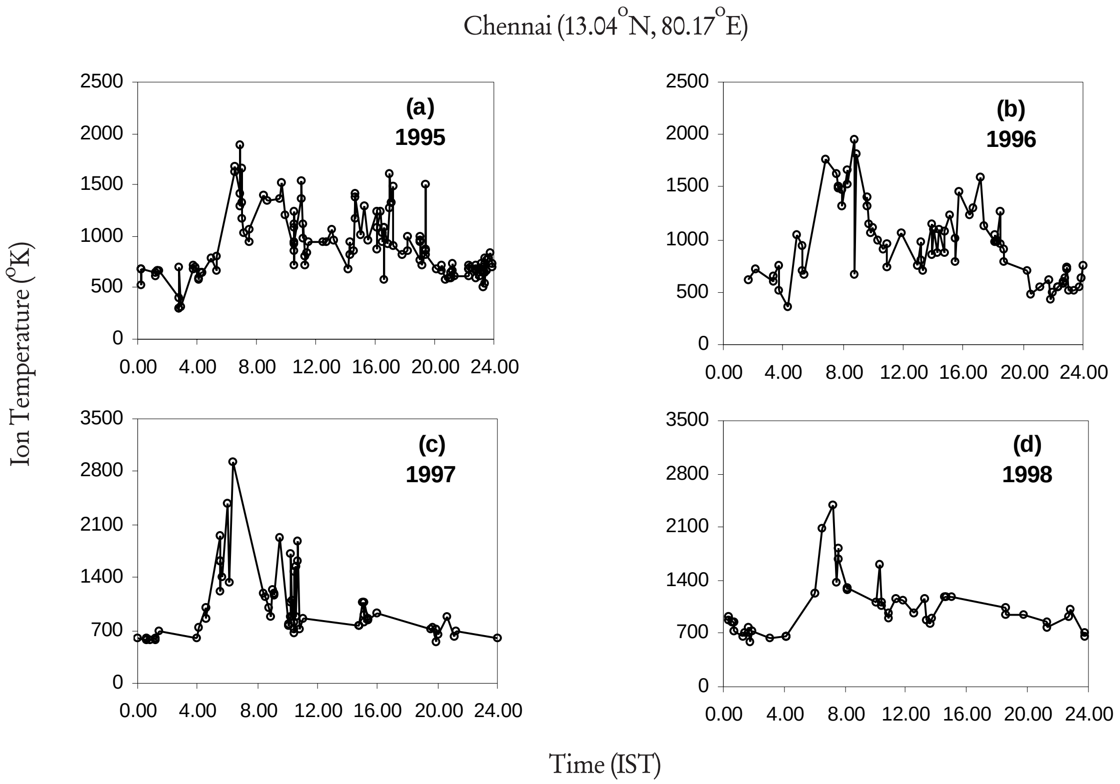

Figure 4. Variation of *Ti* at Chennai form 1995 to 1998.

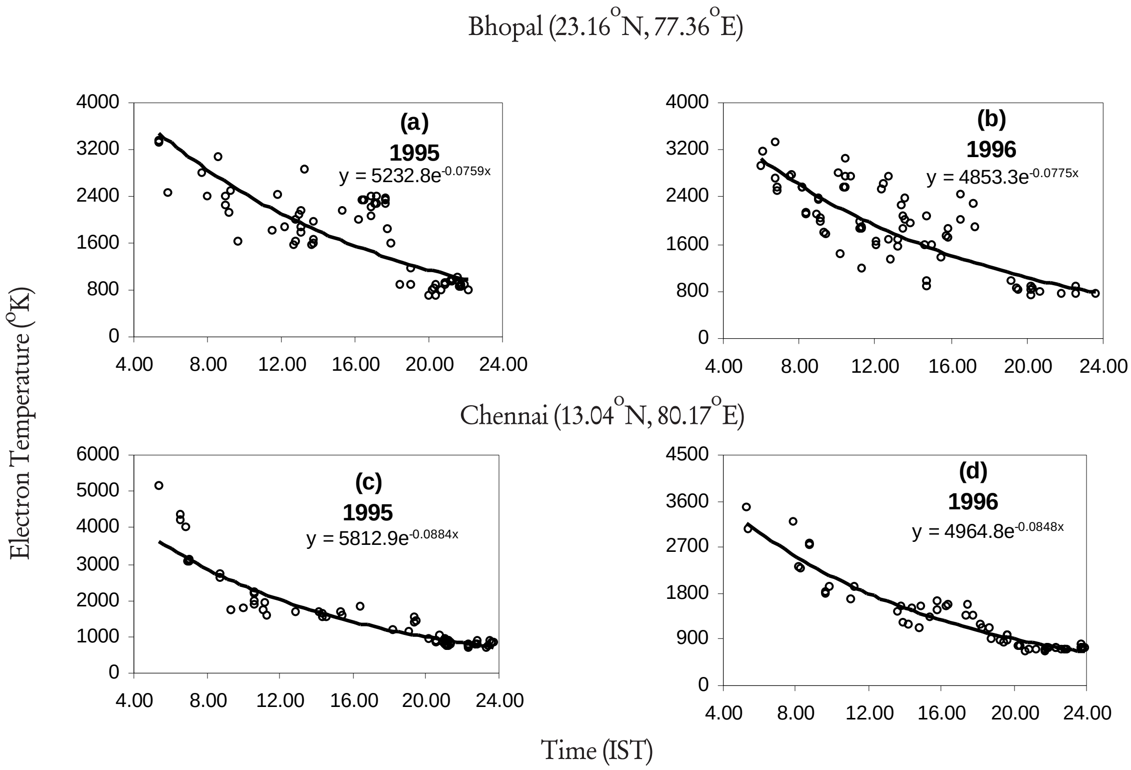

Figure 5. After sunrise the exponential decay of *Te* at Bhopal and Chennai.

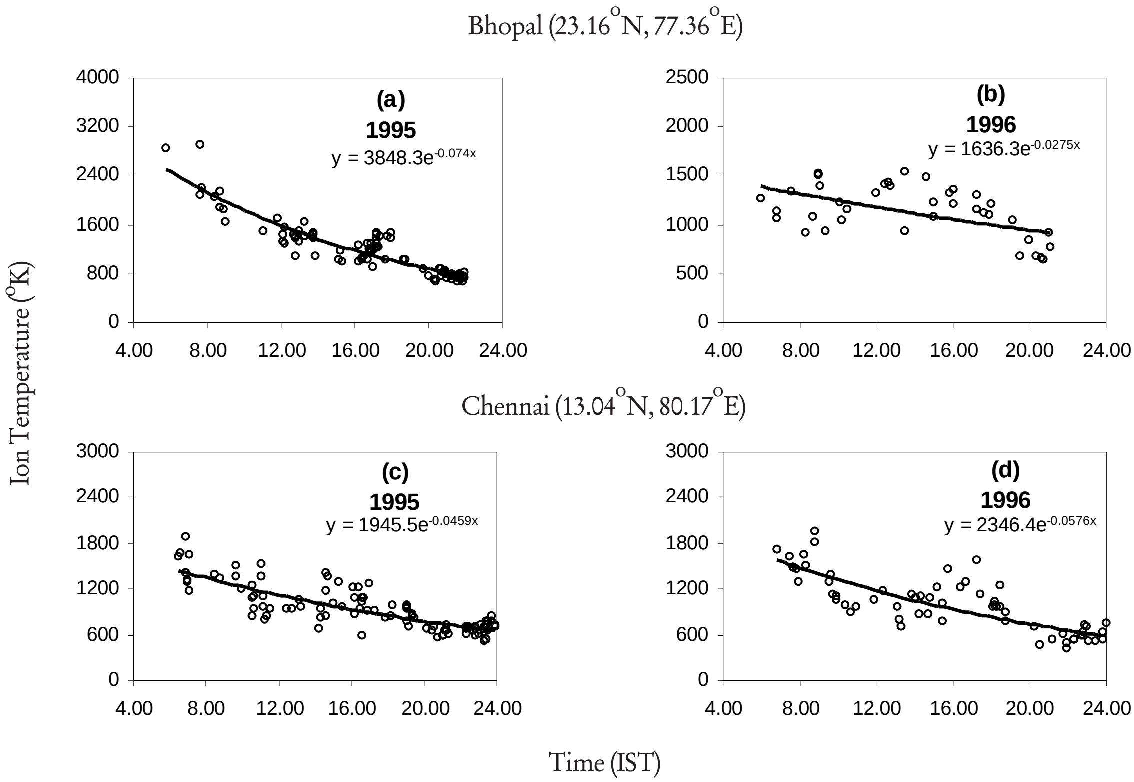

Figure 6. After sunrise the exponential decay of *Ti* at Bhopal and Chennai.

95% optical transparency. The two sensors are mechanically identical but have different grid voltages suitable for collection of electrons and ions respectively. The charged particles whose energies are greater than the applied voltage (Garg & Das 1995) on the retarding grid pass through various grids and finally reach collector electrode to cause the sensor current. This current is measured by a linear auto-gain ranging electrometer. The raw data in the form of LOTUS file are obtained from Indian Space Research Organization (ISRO).

Results and Discussion

The yearly data for Te recorded at Bhopal and Chennai from 1995 to 1998 are shown in Fig.1 (a, b, c and d) and Fig.3 (a, b, c and d) respectively. The sunrise time varies between 5:00 to 7:00 IST depending upon the season. During this time we have observed a sharp increases in Te at both stations. The maximum Te at Bhopal reaches up to 3334°K in 1995, 4231°K in 1996, 3403°K in 1997 and 3438°K in 1998 during sunrise hours. Whereas at Chennai in 1995 maximum Te goes up to 5763°K, 3495°K in 1996, 4667°K in 1997 and 4784°K in 1998. At Chennai double peak is observed in 1997 (Fig. 3c). The cause for the appearance of the second peak is not understood. The nighttime average Te varies from 745 to 915°K at Bhopal and from 754 to 883°K at Chennai during 1995 to 1998. Table 1a shows the details of Te variations over these stations from 1995 to 1998.

The spatial and temporal variations of the electron temperature at equatorial anomaly latitudes has been studied by Su et al. (1996) using the Hinotori satellite at about 600km. They have observed similar morning rise in Te. Thus the results obtained from SROSS-C2 satellite data are consistent with the Japanese satellite Hinotori (Su et al. 1996) data.

Oyama et al. (1996a) have studied the morning overshoot of Te by the downward plasma drift in the equatorial topside ionosphere and found that the rapid increase in electron temperature in the early morning period is the well known Te phenomenon called 'morning overshoot'. Oyama et al. (1996b) have also studied the season, local time and longitude variations of the electron temperature at the height of about 600km in the low latitude region. They found that an electron temperature enhancement occurs in the morning period (between 5:00 to 8:00 LT). The peak value is highest at the magnetic equator and reaches about 5000°K for the high solar activity. Our study also pertains to low latitude and observed that the highest peak of Te is about 5763°K at Chennai in 1995 (Fig.3a). It is similar to the value reported for equatorial region by Oyama et al. (1996b).

The yearly data for Ti recorded at Bhopal and Chennai from 1995 to 1998 are shown in Fig. 2 (a, b, c and d) and Fig.4 (a, b, c and d) respectively. The Ti also shows the similar behavior at these stations. However, the change in Ti is relatively less than Te. During the time of sunrise we have observed a sharp increases in Ti at both stations. The maximum Ti at Bhopal reaches up to 2860°K in 1995, 1270°K in 1996, 1870°K in 1997 and 2230°K in 1998 during sunrise hours. Whereas at Chennai in 1995 maximum Ti is 1890°K, 1760°K in 1996, 2930°K in 1997 and 2400°K in 1998. The nighttime average Ti varies from 618 to 832°K at Bhopal and from 626 to 776°K at Chennai during 1995 to 1998. Table.1b shows the details of Ti variations over these stations from 1995 to 1998.

The Te and Ti decrease almost exponentially after reaching the maximum value at both stations. The exponential decay in Te at Bhopal is shown in Fig.5 (a and b) and at Chennai in Fig. 5 (c and d) respectively for the year 1995 to 1996. The Ti decay at Bhopal is shown in Fig.6 (a and b) and at Chennai in Fig.6 (c and d) during the year of 1995 and 1996 after the sunrise hours. Similar exponential decay has also been observed for the year 1997 and 1998. The generalized decay equation can be written as:

$$Y = Ae^{-BX}$$

Where A and B are two arbitrary constant, the value of A and B are shown in Table.2 for both stations Bhopal and Chennai during 1995 to 1998. The valve of A varies from 4000 to 6500 for Te and from 1500 to 4000 for Ti. The value of B for Te varies from 0.07 to 0.10 and from 0.02 to 0.07 for Ti for both the stations.

CONCLUSIONS

The variation of Te and Ti over two Indian stations (Bhopal and Chennai) during the solar minimum (1994) to solar maximum (2000) has been studied using SROSS-C2 satellite data. Due to latitude effect the maximum Te at Chennai is higher than Bhopal. Generally the behavior of ionospheric temperatures and morning overshoot are in consistent with other similar observation using the data from different satellites.

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