Indian Region Topside Ionospheric Ion Density at Solar Minimum and Maximum Due to Diurnal and Seasonal Variation

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Abstract

This paper present, an in situ measurement of ion and electron parameters of ionosphere F2 region made by dispersed Retarding Potential Analyzers (RPAs) payload on-board the Indian satellite SROSS-C2 over Indian region (65–95LE and 5–35LN) for more than half of 23rd solar cycle are inspected to scrutinize the ion density (n_i) at normal altitude of 500 km (altitude range 500 100 km). The data-set is investigated for the diurnal and seasonal behaviour of n_i and its dependence on solar activity by equating the consequences for solar minima (1995, $F_{10:7}^{0}95$ ¼ 77) and solar maxima (2000, $F_{10:7}^{0}00$ ¼ 178) years. n_i is found to reveal the anticipated diurnal behaviour with day minimum in pre-sunrise hrs and maximum at local noon or afternoon. This trend is not affected by seasons or solar activity. Nevertheless for dissimilar seasons, n_i augments with solar activity and further interestingly, night time values of n_i are found to be pretentious by superior magnitude as equated to daytime analogous values.

1. Introduction

With the increasing dependence on transionospheric communication and satellite based navigation systems, there have been concerted efforts by the ionospheric research community to understand the temporal and spatial variability of the ionospheric electron content so as to develop a prognostic capability on the various ionospheric parameters that affect the radio wave propagation through the ionosphere. In this context the global positioning systems (GPS) provide accurate information at various points above the ground, in terms of total electron content (TEC) and ionospheric irregularities. However, in practice, the utility of the system suffers because of various uncertainties in the evaluation of electron content and hence no measurement is absolute. [1] In evaluating the TEC along the raypath, integration in the form of refractive index is carried out along the geometric path and not along the true path. The importance of the difference between the true path and geometric path becomes obvious if the height variations of electron density, especially its temporal and spatial variations are considered.[2] From a modeling study of the difference between the length of the true propagation path and geometric propagation path of radio waves transmitted by GPS signals, [3] reported that the difference increases with increasing zenith angle at both the frequencies in all directions of propagation and is greater in high solar activity than in low solar activity. Considering the ionospheric effect, spatial changes in electron density, as a function of latitude and longitude as well as altitude, can cause largest errors in positioning. Vertical content (VTEC) is an important indicator for the overall ionization of the ionosphere. To a first-order approximation, the slant TEC is obtained from the GPS measurements. The projection from slant to vertical gives the VTEC and therefore is a crucial process, which enhances strongly the usefulness of the observations [4]. For this conversion a mean ionospheric pierce point altitude is assumed, which is considered as the centroid of ionization mass distribution. It was demonstrated that instead of using a fixed pierce point altitude, an iterative procedure that allows the use of latitudinal dependant mean ionospheric height may be preferred and the most important region in which the iterative procedure should be applied is the low-latitude region, especially in the vicinity of the equatorial anomaly crest. A change in ionospheric height changes the latitude profile of TEC in two ways: (1) by changing the projection factors and (2) by shifting the ionospheric pierce point, which is the intersection point of the line of sight with the ionospheric shell. An increase in ionospheric height decreases the zenith angle and therefore increases the VTEC. The vertical distribution of electron density along the ray path includes electron density distribution in the lower ionosphere (D and E regions), the F region ionosphere (both bottom side and topside), and the protonosphere. If protonosphere is neglected, the errors could be as large as 10– 30%, which are more acute at solar maximum [5]. The equatorial ionosphere is characterized by different typical features like the Appleton ionization anomaly and the postsunset plasma drifts driven by F region polarization fields that are poorly represented in the models particularly in the Indian sector. Therefore assumption of the vertical distribution of ionization based on these models leads to significant errors in the computations. They reported that horizontal gradients can act in such a way that even the occultation inversion results loose close relation to the midpoint profile. Strong variations of height profile with latitude and longitude only appear in locations surrounding the equatorial anomaly. Two of the major problems that limit the accuracy of GPS-derived TEC are the bias errors and effective plasmaspheric altitude, which is popularly referred to as the ionospheric pierce point (IPP) altitude. The altitude problem is more acute at the equatorial and subtropical latitudes as the basic assumption that the ionosphere and protonosphere (collectively called plasmasphere) are spatially uniform is not always valid. The highest TEC values occur in the equatorial anomaly latitudes and hence these regions have the largest ionospheric range delay values for any space-based augmentation system [6]. The day-to-day and seasonal variability of the location of the anomaly crest and the altitude at which plasma transport takes place is large, leading to uncertainties in the prediction of range and timing errors. Another obvious limitation in making corrections for accurate positioning from vertical TEC values at the ionospheric grid points is due to the commonly used assumption of a thin ionospheric shell at a fixed average height in the conversion from slant to vertical TEC. The day-to-day variability in the anomaly causes significant variations in the altitude-latitude structure of the ionization anomaly, thereby changing the centroid of ionization mass distribution from location to location. Thus the assumption of 350/400 km as the mean altitude of IPP for GPS TEC evaluation is ambiguous at these latitudes, demanding a comprehensive investigation of the altitude structure of the ionospheric F region over low and equatorial latitudes. In this paper we report the results of investigations carried out on the variability of the ionization density distribution below and above the F layer peak using the in situ data from SROSS C_2 satellite. Also the ground-based ionosonde data is used in conjunction with the international reference ionosphere (IRI) model-derived values to assess the variation of the centroid of ionization distribution in the equatorial and low-latitude sector. The study clearly demonstrates the limitation of the median models in predicting the ionospheric altitude structure in the Indian low-latitude sector for GPS applications. Keeping these limitations in mind, a qualitative study has been carried out on the variation of the IPP altitude calculated and the results are discussed in light of the current understanding on the equatorial and low-latitude ionosphere. The study brings out that though the equatorial and low-latitude ionosphere is a very dynamic system, during the low solar activity periods conversion of slant to vertical TEC with a time-varying IPP altitude is a possibility and enhances the utility of the GPS-derived TEC data in satellite-based augmentation systems.

2. Ionospheric Empirical and Physical Models

Modeling of the ionosphere is a process, which leads to a generalized and quantitative description of spatial and temporal variations of ionospheric parameters. These include the electron density, ion composition, ion and electron temperatures, and bulk motion of ion drift [7]. Since the ionospheric parameters change with altitude depending on the geomagnetic and geographic coordinates, a central task during modeling is accounting of dependencies of the ionospheric parameters on location, altitude, time, as well as solar and magnetic activity. The ionospheric models can be divided into three groups: empirical, semi-empirical, and physical.

1) Empirical (also known as statistical) ionospheric models are created by assimilation of a large number of observations from different locations and represent a description of the physical-chemical characteristics of the space environment.
2) Semi-empirical models (or hybrid models) are a combination of empirical and theoretical models (in other words, the method calculation of parameters, characteristics and properties of the ionosphere are based on experimental data).
3) Physical models are based on systems of momentum, continuity, energy equations etc., which describe the totality of chemical transformations of the charged particles, their interaction with particles of the neutral atmosphere, the electric and magnetic fields. The solution of these equations determines the state of the ionosphere for predetermined conditions. The implementation of such models requires significant computational resource.

The basic models of the ionosphere which provide information about high altitude variations of the ions investigated in this work are IRI (International Reference Ionosphere) [8], SAMI2 (SAMI2 is Another Model of the Ionosphere), SAMI3 (SAMI3 is Also a Model of the Ionosphere) [9].

2.1 Empirical Model of Ionosphere IRI

Empirical models play an important role in all regions of the Sun-Earth environment. They provide an opportunity for easy access to a "compressed form" of empirical data for a certain parameter based on all compiled data sources that exist for this parameter. One of the most important data sources for the IRI model is a global network of ionosondes, which monitor the state of the ionosphere since the 1930-ies. In addition to ionosondes, there are other sources of data for the development of the IRI model such as incoherent scatter radars, rockets, and satellites. The advantage of this model is that it provides estimates of the altitude profiles ionospheric parameters such as electron density, electron and ion temperatures, ion composition (O^+, H^+, N^+, He^+, $O2^+$, NO^+ and Cluster ions) for the altitude range 50 − 2000 km. These parameters are given as functions of date, season, year, location, time of day (LT or UT), and required range of heights with random step [8s].

Ion composition

Ion composition has always been the most uncertain part of IRI due to scarcity of data (in particular well-calibrated global measurements of ion composition) and discrepancies between ground-based and satellite observations. The earliest version of the IRI was based on the work of [10] in the lower ionosphere and [10] in the upper ionosphere. At the same time, IRI has used results of satellite measurements (Electron-2, Electron-4, S3-1) and rocket observations for the topside ionosphere. The model of [10]s has provided estimates of the ion composition (O^+, H^+, N^+, He^+, $O2^+$, NO^+ and Cluster ions) as a function of solar zenith angle, latitude, season and solar activity. A new version of the ion composition model of the upper ionosphere is TTS (the abbreviation consists of the first letters of surnames model developers. This model uses the best global coverage that is provided by the measurements of satellite mass spectrometers (Intercosmos – 24 and Atmospheric Explorer - C, - E). TTS consists of sub models for individual range of altitudes and seasons. The data were grouped by season (90-day periods those are symmetric according to equinoxes and solstices that provides coverage over all values of the local time) and for the following altitude ranges: 350 ± 40 km 550 ± 50 km, 850 ± 90 km, 1400 ± 150 km and 2000 ±300 km. Significant progress of the latest version of IRI-2012 (in contrast to the previous IRI - 2007) was an improvement of ion composition using tested data about photochemistry in the lower ionosphere which is provided by the physical model FLIP (Field Line Interhemispheric Plasma) sfor computation the concentrations of main ions in this region [8]s.

2.2 Physical Model of Ionosphere

The physical (or theoretical) models are based on physical conservation laws and are intended for study and understanding of physical processes occurring in the ionosphere. SAMI3 is a three-dimensional global ionospheric model based on two- dimensional model SAMI2. This models calculate the plasma dynamics and changes of the chemical composition for seven ion species (H^+, He^+, N^+, O^+, NO^+, $N2^+$ and $O2^+$) in the low and middle latitude ionosphere in the altitude range 85 km to 20000 km by solving the ion momentum and continuity equations [9]. The energy equations are solved for H^+, He^+, and O^+ and electrons. In addition, the E x B drift of plasma motion is included for both zonal electric fields (vertical drifts) and meridional electric fields (zonal drifts). The neutral composition and temperature for SAMI3 are provided by NRLMSISE-00 model and the neutral winds are obtained from the Horizontal Wind Model (HWM) [9]. The input parameters to these models are the value F10.7 (daily and 3 months average) index; AP index and E x B drift velocity. The output parameters are ion densities, ion temperature, ion velocity and electron temperature.

Advantages and disadvantages of theoretical modeling the ion composition

The advantage of theoretical approach in the modeling of the ionosphere is that physical model allows modeling of all required ionospheric parameters with any desired spatial and temporal resolution. Further, there is a fundamental opportunity to take into account the specific helio-geophysical conditions for a certain time in contrast to empirical approach where the monthly averaged conditions are described. However, at the same time, there are many difficulties associated with limiting of our understanding of the physics as such and the computational simplifications. This imposes restrictions on the accuracy of the modeled parameters. Thus, theoretical models represent a very successful basis for describing the state of the ionosphere under different geophysical conditions and, in consequence, for one of the main tasks of the ionospheric service — ionospheric prediction. In practice, theoretical models are still too complex and bulky for operative work with applied problems.[10]s

Advantages and disadvantages of satellite methods of observations

From the works of *Truhlik*, *Triskova*, and *Smilauer*, where comparison between IRI model estimates and results of various experimental observations were made, it is worth to mention that the IRI provides estimates only for an averaged and “smoothed ionosphere”. As a result, the accuracy of estimated concentrations values is low. This, in my opinion, is a considerable disadvantage for the real understanding of day-to-day variations, which control the behavior of the ionosphere for the region of interest. The ionosphere undergoes very complex spatial and temporal variations, which depend on effects of solar activity, electric and magnetic fields, thermosphere circulation, and meteorological formations in the lower and middle atmosphere. In the consequence of this, formation mechanisms of the ionosphere at various heights are different, and even such an important parameter as the electron density can vary in different regions of the ionosphere. Since in the IRI model the required for estimations data are grouped within 90 days, it is natural that for such period the state of geo-space and in particular the ionosphere varies even for quiet helio-geophysical condition. Thus, model estimates often have discrepancy with experimental results into several times. Kharkiv incoherent scatter radar is able to provide continuous experimental data on the ion composition for mid-latitude region of the topside ionosphere. Therefore, important stage of this work is comparison of IS radar data with estimates of IRI and SAMI3 models for clarification, correction, and obtaining reliable results in the future.

3. Radiowave Propagation via Ionosphere

When electromagnetic signals travel in a media, they interact with objects. Due to this interaction radio signals can change their direction as they reflected, refracted or diffracted. The ionosphere is an important region for radio communications. The ionosphere is a region of the upper atmosphere with is large concentrations of free ions and electrons, which affect the radio waves and radio communications. The ionosphere affects the signals on the short wave radio bands where it reflects the signals which were heard over vast distances. Radio stations have long used the properties of the ionosphere to enable them to provide worldwide radio communications coverage. The ionosphere is a continually changing area. It is obviously affected by radiation from the Sun, and this changes as a result aspects including of the time of day, the geographical area of the world, and the state of the Sun. As a result radio communications using the ionosphere change from one day to the next and even one hour to the next. Predicting how what radio communications will be possible and radio signals may propagate is of great interest to a variety of radio communications users ranging from broadcasters to radio amateurs and two way radio communications systems users to those with maritime mobile radio communications systems and many more.

Radio waves are affected by the phenomena of reflection, refraction, diffraction, absorption, polarization and scattering when traveling through the ionosphere as similar to the form of electromagnetic radiation, like lighting waves. Radio propagation is the behaviour of radio waves when they are transmitted, or propagated from one point on the earth to another, or into various parts of the atmosphere. When the radio waves are transmitted from the surface of the Earth, they are reflected back from the ionosphere and able to reach the transmitter. So the ionosphere has practical importance because, among other functions, it influences radio propagation to distant places on the earth. Radio wave was being used on a daily basis for broadcasting as well as for two-way radio communication systems. Radio waves, microwaves, infrared and visible light can be used for communication system. For instance, radio waves are used to transmit television and radio programs, while the microwaves are used to transmit satellite television and for mobile phones. Additionally, infrared wave can be used to transmit information from remote controls. The radio wave propagation is affected by many factors such as by the daily changes of water vapour in the troposphere and ionization in the upper atmosphere, due to the Sun. Understanding the effects of varying conditions on radio propagation has many practical applications, from choosing frequencies for international shortwave broadcasters, to designing reliable mobile telephones systems, or radio navigation, to operation of radar systems.

Moreover, radio wave propagation is also affected by several other factors determined by its path from point to point. This path can be direct line of sight path or an over-the-horizon path added by refraction in the ionosphere, which is a region between approximately 50 and 600 km. In addition, factors influencing ionospheric radio signal propagation can include inonospheric variability such as sporadic-E, Spread-F and ionospheric layer tilts, and solar activities such as solar flares, geomagnetic storms, and solar proton events and so on. Radio waves of different frequencies propagate in different modes. At extra low frequencies (ELF) and very low frequencies have very much larger wavelength than the separation between the earth's surface and the D-layer of the ionosphere. Consequently, electromagnetic waves can propagate in this region as a waveguide. Actually, for frequencies below 20 kHz, the wave propagates as a single waveguide mode with a horizontal magnetic field and vertical electric field. The interaction of radio waves with the ionize regions of the atmosphere makes radio propagation more complex to predict and analyse than in free space. Radio wave propagation through the ionosphere, especially during the disturbed ionospheric conditions also referred to as ionospheric irregularities, is more complex to predict and analyse than in free space. Ionospheric radio wave propagation has a strong association to space weather. A sudden ionospheric disturbance or shortwave fadeout is observed when the X-ray associated with a solar flare ionizes the D-region ionosphere. Consequently, enhanced ionization in that region increases the absorption of radio signals passing through it. During the active solar period, such as strongest solar X-ray flares complete absorption of virtually all ions spherically propagated radio signals in the sunlit hemisphere can occur. These solar flares can disrupt HF radio propagation, which disturb GPS (Global Position System) accuracy. Since radio wave propagation is not fully predictable, such services as emergency locator transmitter in flight communication for long distant such as with ocean crossing aircraft, and television broadcasting have been moved to communications satellites. A satellite link, through expensive, can offer highly predictable and stable line of sight coverage of a given area.

4. Instrumentation and data

Ionosphere composition and temperature data were derived from RPA payload measurements aboard Indian satellite SROSS-C2. Some detailed aspects of aeronomy experiments have been discussed by [11]. The SROSS-C2 was launched by Indian Space Research Organization (ISRO) on May 4, 1994 with the help of ASLV-D4 rocket in an elliptical orbit of 938 437 km and 46.3Linclination. After two months of operations, the satellite orbit was trimmed to 630 430 km for making the orbit less elliptical. Two aeronomy pay-loads of RPA, designed at National Physical Laboratory (NPL), New Delhi were onboard the satellite SROSS-C2 to make F2 region in situ measurements of electron and ion parameters separately, over Indian region. The satellite provided important data up to July 2001, for more than half of a solar cycle, covering solar minimum (1995) and solar maximum (2000) of 23rd solar cycle. SROSS-C2 was spin-stabilized satellite with spin rate of 5 rpm; octagonal prismoid in shape with body mounted solar panels and payload sensors, mounted over the top deck. The satel-lite moved in cartwheel mode, keeping its spin axis perpen-dicular to the orbital plane. The two RPA sensors consist of four mechanically identical grids viz Entrance grid, Retarding grid, Suppressor grid and Collector grid; and a collector electrode with different grid voltage, suitable for collection of ions and electrons. The electrons and ions, with energy greater than applied voltage on retarding grid, made pass through various grids and finally reach the col-lector electrode and cause collector current. Payload data collection was done at main ground station Banglore (12.5LN, 77.3LE); the other two being Lucknow (26.8LN, 80.8LE) and Mauritius (20LS, 56LE). Data for O+, Oþ2, H+ and He+ ions was derived from ion RPA during the experiment. One of the authors collected satellite data from NPL, New Delhi. F10.7 data was obtained from website of National Geophysical Data Center (NGDC), Boulder, Colorado. Averaged values of F10.7 are used in the current study.

5. Results and Discussion

For the present study, data obtained from Indian satellite SROSS-C2 is segregated into three different seasons viz. equinox (March, April, September, October), summer (May, Jun, July, August) and winter (November, December, January, February). Satellite data is available for O^+, $O^{þ}_2$, H^+ and He^+ions. Here summation of all these ion densities is taken as ionospheric ion density. Ion den-sity for topside ionosphere over Indian region is studied for all three seasons of solar minimum (1995) and solar maximum (2000) of 23rd solar cycle. $O^+$is found to be a major constituent of ionosphere and contributor to n_i during all seasons at the said altitude. They drew the curve of O^+ concentration close to ion density.

Study on different solar activity periods helps us under-stand the effect of solar activity on the ion density of the above said region. Here solar activity is considered w.r.t. $F_{10.7}$ scale. In Figs. 1–3, smoothed and averaged ion density is plotted against local time for equinox, summer and winter of 1995 and 2000.

5.1 Equinox of solar minimum and solar maximum ($F_{10.7}{}^{0}95 = 77$, $F_{10.7}{}^{0}00 = 178$)

Data obtained from Indian SROSS-C2 satellite and fig. 1 clearly shows that early morning hours (3:00–5:00 h LT), before sunrise, show the lowest value of ion density (n_i Þ of the day for both solar minima and maxima equinox. A rising trend in n_i from sunrise is observed, irrespective of solar activity. A broad peak, leading to diurnal maximum has been found at mid-day: 10:00–14:00 h LT for 1995 and 11:00–16:00 h LT for 2000. A downward trend in n_i is observed afterwards, especially in night hours. Overall, different trends of variations of n_i is similar for both solar minima and maxima; however solar maxima shows higher value of n_i than that of solar minima. Solar activity is found to affect n_i directly, but not by equal magnitude throughout the day. Night-time values of n_i for equinox are found to be affected by greater magnitude by solar activity than corresponding daytime values. Night hrs n_i for solar maxima is found to be 2–3 order of magnitude higher than that of solar minima, whereas in peak hrs (12:00–3:00 h LT) it is less than one order of magnitude higher than n_i of ’95. Overall day average values also do not show a great difference. They examined the night time topside helium ion variability with solar cycle over Arecibo, and found that during equinox of low solar flux, He^+ ion number density tends to be quite low, about 10–15% of topside plasma density, at an altitude of around 550–650 km, near O^+- H^+ transition height. How-ever for state of high solar flux He^+ number density can reach up to 60–65% of topside plasma, at an altitude of around 700 km which is below O^+- H^+ transition height. This relative abundance of He^+ at night time topside iono-sphere during high solar flux conditions can be considered as one probable reason for greater night time effect of solar activity. A post sunset (21:00 – 22:00 h LT) diffused peak is visible for the year of solar maxima.

3.2. Summer of solar minimum and solar maximum ($F_{10.7}{}^{0}95 = 77$, $F_{10.7}{}^{0}00 = 180$)

The smoothed averaged data of SROSS-C2 and fig. 2 have recognized the value of n_i to be the lowest at presunrise, early morning hours (3:00–5:00 h LT) for the summer season, irrespective of the solar activity of the year, although magnitude of this value is effected by solar activity. Rising trend of n_i starts from sun rise and attains a broad peak at noon time (10:00–15:00 h LT for ’95 and at 11:00–17:00 h LT for ’00); afterwards a downward trend in n_i is observed. Day time values of n_i are found higher than night time values for any solar year. Ion density dur-ing summer season of solar maximum is 1 order of mag-nitude higher than that of solar minimum.

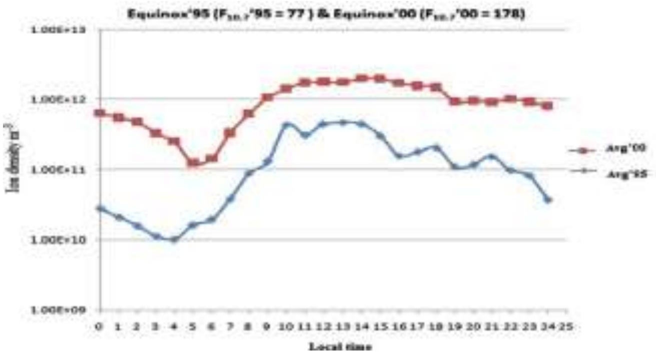

Fig. 1. Ion density of 1995 and 2000 for equinox season.

The day average ion density of 6.6×10^{10} in the year 1995 increased to 8.8×10^{11} in the year 2000. This fact is consistent for day time as well as night time, except late evening hours (20:00 – 21:00 h LT) after local sunset, when it is found to be about 3–4 order of magnitude greater for solar max-imum. A small diffused peak of ion density is also seen dur-ing this postsunset time for high solar flux conditions. They in their studies with SROSS C2 data reported a post sunset enhancement of O^+ ion density and attributed the fact to prereversal enhancement in F region vertical drift due to F region dynamo and meridional winds.

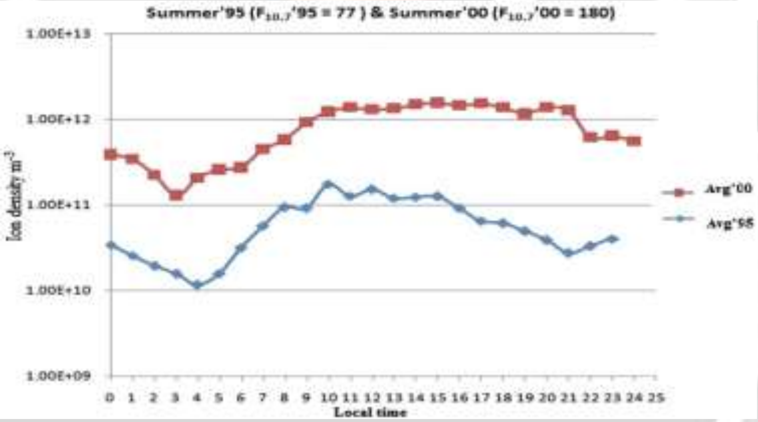

Fig. 2. Ion density of 1995 and 2000 for Summer.

Fig. 3. Ion density of 1995 and 2000 for Winter.

3.3. Winter of solar minimum and solar maximum ($F_{10.7}{}^{0}95 = 77$, $F_{10.7}{}^{0}00 = 175$)

The fig. 3 and measured data of RPA payload aboard SROSS-C2 identify the early morning hrs (4:00–6:00 h LT) as the hrs of diurnal minimum of n_i during winter sea-son of a solar year, irrespective of solar activity. With the sun rise, enhancement in the value of n_i takes place with different magnitude for solar minimum and solar maxi-mum. A broad peak leading to diurnal maxima has been obtained at noon or afternoon hours (12:00–16:00 h LT for n_i ’95 and at 13:00–17:00 h LT for n_i’00). A small but sharp peak is also found for n_i of high solar activity condition after local sunset (21:00–22:00 h LT), followed by the downward trend. Night hrs n_i for the year 2000 is found to be 2–4 order of magnitude greater than that of ’95, whereas in peak hrs (12:00–3:00 h LT), it is 5-fold higher than n_i of ’95. This leads to the fact that night time ion density of winter season is more affected by solar activity than corresponding daytime values. This fact cannot be attributed solely to solar activity of that particular period; some other related or independent dynamic and physical phenomena are also involved.

4. Conclusion

Using the data from Indian SROSS-C2 satellite during solar minimum (1995) and maximum (2000) in the topside ionosphere F-region over Indian region the Diurnal and seasonal dissimilarities of ionospheric ion density have been considered. In this research study, we exposes that the ion density is the lowermost at quick morning hours formerly local sunrise, of all seasons and demonstrates dissimilarities during daytime for mutual solar mini-mum and maximum. A comprehensive peak is observed at mid-day, irrespective of season and solar activity, however, the time and magnitude of this peak differs with season and solar activity. Peak of diurnal maximum is perceived late by 2h. In winter season, when linked with summer. Equinox season illustrates greater value of n_i as associated to other seasons for both solar years, even though summer nights of solar minimum have slightly higher ion density than equinox nights. Day average ion density of equinox is institute to be 1.5–2 folds higher than that of summer season and marginally higher than that of winter season, for both solar years (1995 and 2000). Night time ion densities are enriched by a superior magnitude by solar motion. The element may be attributed to a blend of factors like trans-portation of ions and plasma drift etc. A secondary topmost of ion density in wholly seasons (more sharp during winter) is perceived as a specific feature of high solar flux condition. In the present study, the effect of solar activity is studied over diurnal and seasonal variations, although n_i is also exaggerated by several other known and unknown factors.

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