Research Inventy: International Journal of Engineering And Science
Vol.6, Issue 8 (September 2016), PP -01-06
Issn (e): 2278-4721, Issn (p):2319-6483, www.researchinventy.com

Disturbances in Solar Wind Electrons during the Ascending Half of the Solar Cycle 23

Antony Dhivya Tharshini.S[*, 1], Nisha Rani.T[*] & Shanthi.G[*]
[*] *Department of Physics & Research Centre, Women's Christian College, Nagercoil, 629 001, India*

Abstract: *Ulysses achieved a solar orbit with an inclination of 80.20^0, perihelion of 1.34 AU, aphelion of 5.4 AU and a period of 6.2 years. By comparing observations taken over nearly all heliolatitudes and two different intervals covering the same radial distances, we are able to separate the radial and latitudinal variations in the solar wind. This paper describes the detailed results of the studies devoted to the solar activity impact on the Earth's upper atmosphere and ionosphere. The methods used in this study are based on the data driven from the Ulysses spacecraft. The primary objective of the Ulysses solar wind plasma investigation uses SWOOPS (Solar Wind Observations over the Poles of the Sun) instrument to investigate and establish bulk flow parameters and internal state conditions of the solar wind as a function of solar latitude. The electron temperature T_e and the electron density N_e are found to exhibit a sharp enhancement during the ascending half of the solar cycle 23 (1996 – 2004).*
Keywords: *solar wind electrons, solar activity, ionosphere, solar cycle.*

I. INTRODUCTION

The solar wind is generally well characterized by fast and slow regions around solar minimum, with the solar wind confined around the sun's streamer belt and the fast solar wind observed at higher latitudes (McComas et al., 2000). When solar activity increases, the low speed solar wind region extends to higher latitudes. Ulysses observed the solar wind at solar maximum with its second latitudinal polar pass (November 2000 – October 2001). At this time a more complex solar wind structure was found compared to similar bimodal solar wind observed near solar minimum. (Hamzah and Homam., 2015). Electron temperature (T_e) in ionosphere is measured by the heat balance between the photoelectrons, cooling through coulomb collisions with ions, and heat conduction along the magnetic field lines.

Electron density (N_e) is produced by solar EUV (Extreme Ultraviolet Radiation) radiation, since the solar photons have significant energy to ionize the natural atmosphere, Simultaneously photoelectron produced in this ionization process heat the local ambient electrons as well as remote electrons along the magnetic field (Panahi et al., 2013). The determination of the temperature and density structure of the solar corona, both in the regions of closed magnetic field and in the coronal holes, has therefore been of considerable interest for many years (Fludra et al., 1999).

For relation between electron density and electron thermal energy as electron temperature, many studies have shown a negative correlation during daytime and a positive correlation was measured using incoherent scatter radar. Previous studies have concluded that the positive correlation between N_e and T_e accompanies an increase of solar flux. However, a recent study indicates that the positive correlation occurs when N_e is significantly high irrespective of solar flux. The result implies that N_e is an important factor that determines T_e in the topside ionosphere (Panahi et al., 2013; Yoshihiro et al., 2011).

Ulysses is providing an exciting opportunity to explore and characterize the heliospheric medium from the ecliptic plane to above the solar poles at distances from the Sun extending from 1AU to 5AU. Observations made on the way out to Jupiter are extending our knowledge of the interplanetary medium in the ecliptic plane, gained from the pioneer and voyager flights, while observations made after Ulysses encounters Jupiter and journeys over the solar poles will be unique (Bame et al., 1992).The ionospheric electron density variation under different conditions has a very vital role to play in understanding the lower as well as the upper atmosphere. The ionosphere is strongly coupled to other regions like the magnetosphere and interplanetary space, whose states affect activities on earth (Namgaladze et al., 2003). Signals transmitted for communication and navigational purposes from satellite must definitely pass through the ionosphere, which acts as a perturbing medium on satellite based navigation systems (Okeke Francisca et al 2009).

Ionosphere is the upper layer of the Earth atmosphere which has a great impact on signal from telecommunication system. It consists of free electrons and ions that are mostly concentrated in the F-region and produced mainly by solar radiation (Wasiu Akande Ahmed et al., 2016). The plasmaspheric electron temperature is an important indicator of the thermal balance between the topside ionosphere and the plasmasphere, and is a useful parameter with which to determine the thermal coupling between them (Denton et al., 1999). The elementary mechanisms that play an important role in the electron temperature (T_e) variation with solar flux seem to be broadly understood. Recently, interest in the electron temperature (T_e) behaviour at high latitudes has been renewed with the measurements of extremely high electron temperatures ($T_e > 5000$ K) at altitudes below 500 km (Xuemin Zhang et al., 2013). These temperatures and temperature gradients were measured with the radar in the vicinity of both the late morning and early afternoon convection reversals. Very high electron temperatures ($T_e \sim 4000 – 6000$ K) were also measured near 500 km in red aurora (Schunk et al., 1986; Truhlik et al., 2012).

The temperature overshoot occurs because the heating rate is approximately linear in the electron density while the cooling rate is quadratic in the electron density. The electron heating depends on the electron density, because the primary heat source for the thermal electrons is by collision with the photoelectrons that are generated by the photo ionization of the neural gases (Stolle et al., 2011; Schunk et al., 1986). The results shows the comparison of measured and modelled electron densities and electron temperatures for magnetically quiet and moderate solar activity conditions at locations close to the geomagnetic equator and equatorial anomaly crests along 201^0 geomagnetic meridian (Bhuyan et al., 2008)

II. DATA DESCRIPTION

In the life time, Ulysses completed three polar pass around the Sun (1992-2008) in a roughly polar orbit (Bame et al., 1992; Brahmanandam et al., 2011). The orbit perihelion (aphelion) is located in the solar equatorial plane at the distance of about 1.3 AU. Ulysses was constantly in the solar wind during the solar minimum. The data submitted to the National Space Science Data Center (NSSDC) for the electron analyzer has been used for the analysis. The first step in the electron data reduction process is determination of the bulk, scalar spacecraft potential (Yiding Chen et al., 2008; Guidoni et al., 2015). Ulysses data are indeed unique since the spacecraft was mainly measuring fast solar wind originating from the large polar coronal holes .Ulysses solar wind data are provided by the Ulysses final archieve [http://ufa.esac.esa.int] .

The SWOOPS Instrument:

Ulysses achieved a solar orbit with an inclination of 80.20^0, perihelion of 1.34 AU, aphelion of 5.4 AU, and a period of 6.2 years. In route to solar polar orbit, it made a close flyby of Jupiter and made measurements of solar system's largest planet. The SWOOPS electron spectrometer is a 120^o spherical section electrostatic analyzer which measures the 3 dimensional velocity space distributions of solar wind electrons. In its normal solar wind mode, the instrumental energy range is 1.6 to 862 ev in the spacecraft frame. The approach to the SWOOPS design was to attempt to strike a balance between the conflicting requirements so as to optimize the overall plasma science yield from the mission and support other Ulysses investigations while staying within the available mission resources. Solar wind electron measurements are made with a spherical section electrostatic analyzer (Hamidi et al., 2016). Electrons that pass through the entrance aperture with proper angles are selected in energy with appropriate voltages applied across the curved plates. These distributions are, of course from in-ecliptic measurements, but high speed solar wind is emphasized since it is expected that at high latitudes the flow will be somewhat similar to high speed flows observed in the ecliptic plane (Frederic Ouattara et al., 2012).

III. RESULTS AND DISCUSSION

3.1. Solar activity variations of N_e and T_e :

In order to investigate the solar activity variations effect on the parameters are observed using SWOOPS instrument and presented from height 900 km to 2000 km within the polar pass latitude as 80.2^0S – 80.2^0N. It must be proved that obviously the electron temperature (T_e) does not remain same throughout the solar activity, which means both for solar activity minimum and maximum. Most often, a beamed, unidirectional heat flux component is also present in the distributions, carrying energy from the hot corona out into the colder interplanetary space along the interplanetary magnetic field. Sometimes, the heat flux is observed to be counter – streaming, or bidirectional. At other times, the heat flux electrons disappear from the distributions, suggesting field merging and disconnection sunward of the spacecraft (Karine Issautier et al., 1998; Fahmi et al., 2016). These heat flux features contribute important information on the global magnetic topology of the interplanetary magnetic field on the nature of the interplanetary solar wind and on its source.

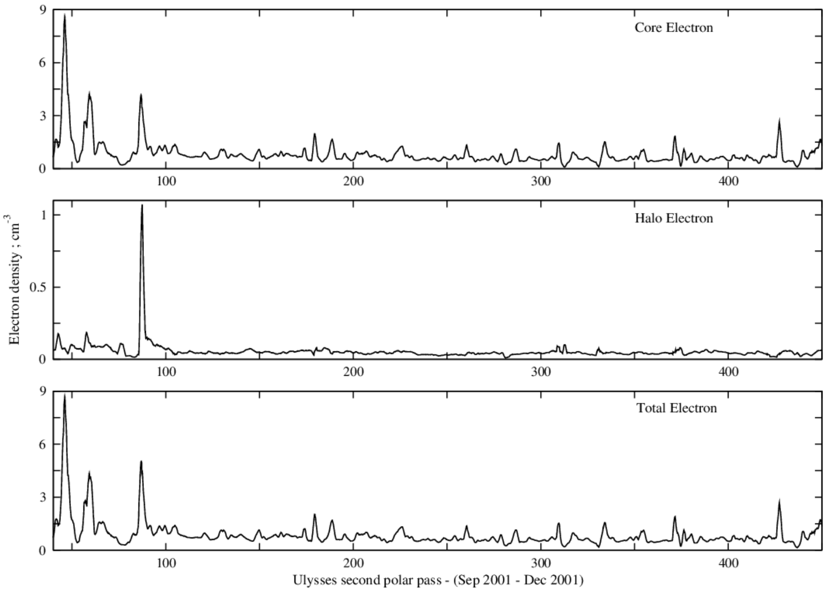

Figure 1 – variation of electron density (N_e) for the Ulysses second polar pass from September 2001 to December 2001 in the ascending half of the solar cycle 23, shows sharp peaks with the polar pass latitude > 70 N.

Figure (1) shows the directly increasing daily average mean values of the solar activity respectively as a function of electron density (N_e) concentration during the descending phase of year 2001. The N_e and T_e data in the figure (1 & 2) is measured by the Ulysses spacecraft; the peaks presented below reveal a positive correlation between them for high values of N_e, where high values of N_e with high T_e are most abundant in all seasons and all levels of solar activity. Interestingly, in all month except with a small difference in September and December, minimum value of T_e corresponds to maximum value of N_e. To investigate the annual variation of N_e and T_e, it should be noted that obviously the electron temperature didn't keep the same for both solar activity minimum and maximum. The peak electron density varies throughout the year as $1x10^5$ cm^{-3} and the temperature below $3x10^5$ (K). The beginning of second polar pass the electron density maximum (1.37342 cm^{-3}) is comparatively less than the maximum of electron temperature ($1.6x10^5$ K). One of the features which are seasonal variation is a typical phenomenon during summer and winter. The effect of winter anomaly is large during solar maximum and small during solar minimum. According to this interpretation when N_e is sufficiently high, the differences in the temperature of electrons during the solar activity is high.

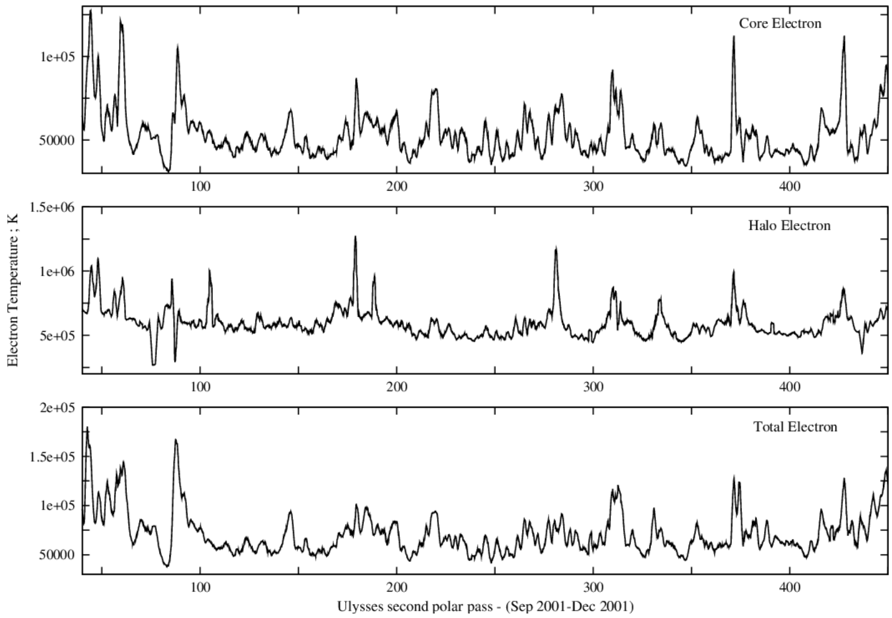

Figure 2 – variation of electron temperature (T_e) for the Ulysses second polar pass from September 2001 to December 2001 in the ascending half of the solar cycle 23, shows sharp peaks with the polar pass latitude > 70 N.

3.2. Analysis of Electron density (N_e):

The study of electron density within 80.2^0N latitude is a model algorithm presented for the time period of 1996-2004. As illustrated in the figures, the electron density variation trends are almost similar in 2002-2004. In these years the electron density N_e increases initially with sharp peaks at $3.8cm^{-3}$, from August to December the solar wind plasma significantly decreases. Absolutely a different pattern of N_e is observed in the year 1996 till August very less variation is been observed the peak reaches $1.4cm^{-3}$. There are similar variations observed in the years 1998-1999 and 2000-2001. In the range of 1100km to 1500km electron density changes are reliable.

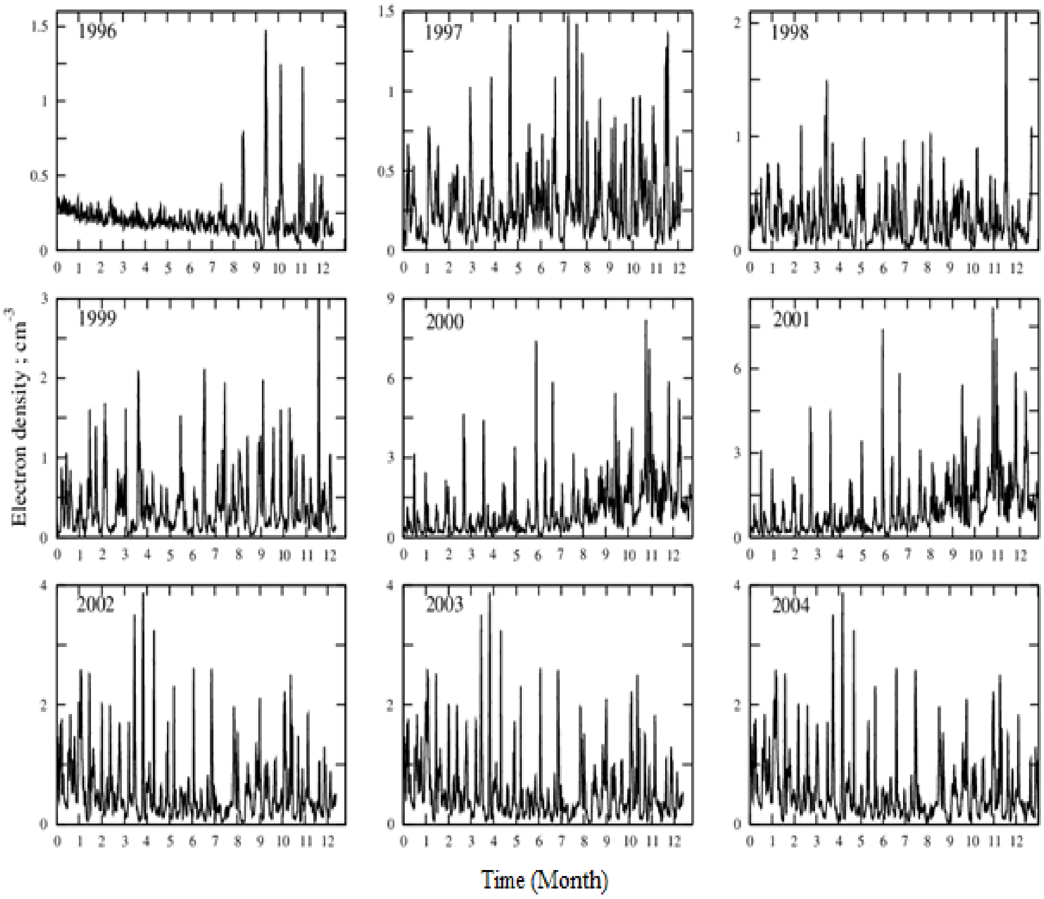

Figure 3 – Annual variation total electron density (N_e) for the year (1996 – 2004) has been plotted for the hourly averaged Ulysses second polar pass

Figure (3) depicts that the density of electron varies gradually with the temperature of electrons but in few cases the manifesto is reversible this may be due to the velocity distribution in the particular medium. As the results the maximum density during the beginning of the year is about 1.373 cm^{-3} which gradually shows the greatest peak during the middle of the year as 2.11018 cm^{-3} and the temperature ranges from $1x10^5$ to $4x10^6$. The above figure shows, that there is no large difference in the total and core density of electrons but the halo density is comparatively less than the core electron density, but it is reversible in the temperature of electron where the halo temperature of electron is higher than the total and the core which says the temperature is more when it reaches the ionosphere.

3.3. Analysis of Electron temperature (T_e):

One of the prime objectives of SWOOPS is to establish a global picture of the internal plasma state of the solar wind. The solar activity has occurred with different temperature throughout the year. Here we discuss about the electron temperature T_e which changes by time during the initial phase of the solar cycle 23. The electron temperature T_e pattern has no similar variations throughout the solar cycle. Figure (4) shows a day average for the Ulysses second polar pass (1996-2004), on which the biggest solar event has observed where initially the T_e has raised above $1.5x10^5$ (K) but the core temperature remains less than $1x10^5$ (k) and then there occur a sudden variation in the last month of the year. Furthermore with the decreasing temperature ranges between $3.2x10^5$K – $1.4x10^5$K.

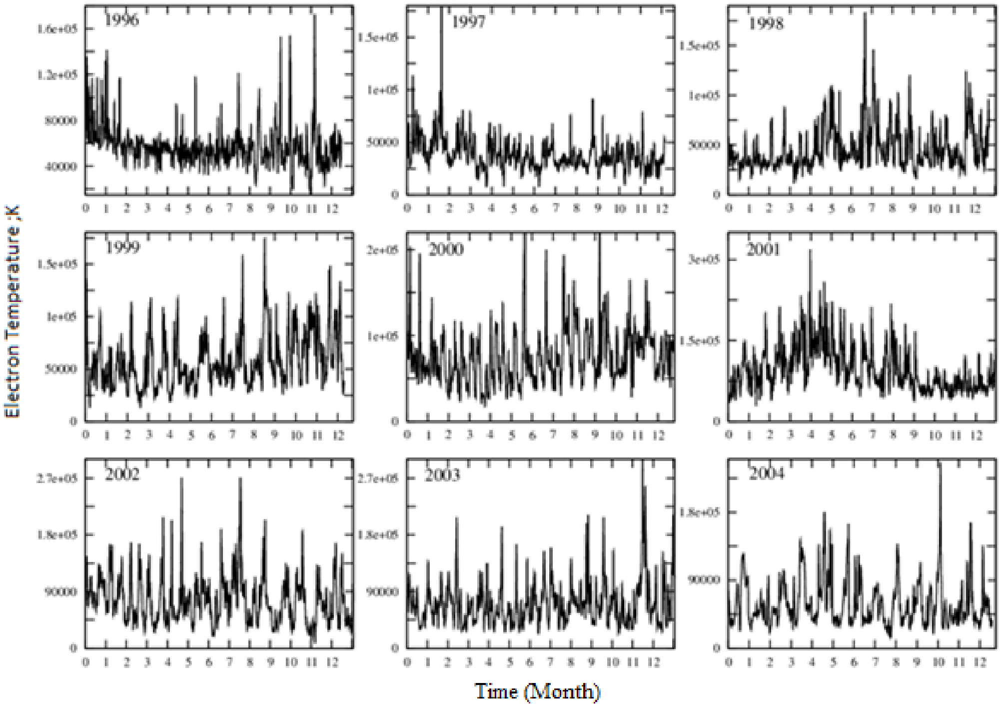

Figure 4 – Annual variation total electron temperature (T_e) for the year (1996 – 2004) has been plotted for the hourly averaged Ulysses second polar pass.

IV. CONCLUSION

During the period from 1999-2001, the electron density N_e of solar wind was highest just after solar maximum and decreased by nearly a factor of 2 over the rest of the solar cycle. The sun's approach to solar maximum, coronal structure becomes increasingly complex, and the magnetic field becomes less dipolar. The electron temperature T_e in the second polar pass from September 2000 to January 2001 with the polar pass latitude greater than 70^0N along with the maximum latitude as 80.2^0N polar shows a temperature drop seems to be slightly cooler than the south polar orbit, during this time the temperature ranges from $1.2x10^5$ .We investigated that the integrated N_e decreases with an increase of the integrated T_e along with the average distribution in observed with more number of spikes below $2x10^6$ K. The maximum and minimum phase variations of N_e are possible during every plasma waves with respect to the solar events. The electron temperature increases with increasing solar activity at altitudes above 2000 km. The day-time differences between high and low activity can be as much as 1000 K. Between 1000 km and 2000 km altitude, a reverse variation occurs and T_e is comparatively higher during low solar activity.

REFERENCES

[1]. Bame.S.J; McComas; Barraclough.B.L; Phillips.J.L; Sofaly.K.J; Chavez.J.C; Goldstein.B.E and Sakurai.R.K; (1992) "The Ulysses solar wind plasma experiment " Astronomy and Astrophysics Supplement Series, Vol 92, 237-265.

[2]. Bhuyan.P.K; Borgohain.A; Bhuyan.K; (2008) "Theoretical simulation of electron density and temperature distribution at Indian equatorial and low latitude ionosphere" Advances in Space Research, Vol (41), 587-598.

[3]. Brahmanandam.P.S; Chu.Y.H; Wu.K.H; Hsia.H.P; Su.C.L and Uma.G ;(2011) "vertical and longitudinal electron density structures of equatorial E and F – regions" Annales Geophysicae, Vol29, 81-89.

[4]. Denton .M.H; Bailey.G.J; Su.Y.Z; Oyama.K.I; Abe.T; (1999) "High altitude observations of electron temperature and a possible north – south asymmetry" Journal of Atmospheric and Solar – Terrestrial Physics, vol 61,775 – 788.

[5]. Fahmi.A.Mohammed;(2016) "The relationship between solar indices and electron density of D-Region over Baghdad city during the ascending and the descending phases of solar cycle 23" Iraqi Journal of Science, Vol 57, No 2A, 1031 – 1040.

[6]. Fludra.A; Del Zanna.G; Alexander.D and Bromage.B.J.I; (1999) "Electron density and temperature of the lower solar corona" Journal of Geophysical Research, Vol 104; 9709 – 9720.

[7]. Frederic Ouattara, Doua Allain Gnabahou, and Christine Amory Mazaudier; (2012) "Seasonal, Diurnal and solar cycle variations of electron density at two West Africa equatorial ionization anomaly stations" International Journal of Geophysics, 640463.

[8]. Fujiki.K; Kojima.M; Tokumaru.M; Ohmi.T; Yokobe.A; Hayashi.K; McComas.D.T and Elliott.H.A; (2003) "How did the solar wind structure change around the solar maximum from interplanetary scintillation observation" Annales Geophysicae, Vol 21: 1257 – 1261.

[9]. Guidoni.S.E; McKenzie.D.E; Longcope.D.W; Plowman.J.E and Yoshimura.K ;(2015) "Temperature and electron density diagnostics of a candle flame shaped flare" The Astrophysical Journal, 800:54 (18pp).

[10]. Hamidi.Z.S., Ali.M.O., Shariff.N.N.M., Monstein.C., (2016) "Electron density and drift rate of solar burst type II during 1st June 2015" International letters of Chemistry, Physics and Astronomy, vol63,49-56.

[11]. Hamzah.S.Z.M and Homam.M.J (2015) "The correlation between total electron content variations and solar activity" Asian Research Publishing Network, Vol 10, 9870-9875.

[12]. Karine Issautier., Nicole Meyer-Vernet., Michel Moncuquet and Sang Hoang., (1998) "Solar wind radial and latitudinal structure: Electron density and core temperature from Ulysses thermal noise spectroscopy "Journal of Geophysical Research, vol 103, 1969-1979.

[13]. Lalitha.T.Alexander (2014) "Features of the diurnal variation of electron and ion temperatures in the low latitude upper ionosphere" International Journal of applied Science and Technology, Vol 4, No 2.

[14]. McComas.D.J; Barraclough.B.L; Funsten.H.O; Gosling.J.T; Santiago-Munoz.E; Skoug.R.M; Goldstein.B.E; Neugebauer.M; Riley.P and Balogh.A (2000) "Solar wind observations over Ulysses first full polar orbit" Journal of Geophysical Research, Vol 105, 10,419-10,433.

[15]. McComas.D.J; Elliott.H.A; Schwadron.N.A; Gosling.J.T; Skoug.R.M and Goldstein.B.E (2003) "The three-dimensional solar wind around solar maximum" Geophysical Research Letters, Vol 30, No 10, 1517.

[16]. Minakshi Chamua (2016) "Temporal and Latitudinal variation of electron density during the ascending half of the solar cycle 23 in the topside F-region of the Indian low and equatorial latitudes" International Journal of Advanced Research, Vol 4, 1747-1762.

[17]. Namgaladze.A.N; Evstafiev.O.V; Khudukon.B.Z and Namgaladze.A.A (2003) "Model interpretation of the ionospheric F-region electron density structures observed by ground based satellite tomography at sub auroral and auroral latitudes in Russia in January-May 1999" Annales Geophysicae, Vol 21, 1005-1016.

[18]. Okeke Francisca Nneka; Onwuneme.S.Ebere and Hanson Esther Akpan (2009) "Investigation of electron density variation in some regions of the ionosphere at Nsukka, Nigeria" International Journal of Library and Information Science, Vol 1(2)pp,012-016.

[19]. Oladipo.O.A; Adeniyi.J.O; Radicella.S.M; Adimula.I.A (2011) "Variability of the ionospheric electron density at fixed heights and validation of IRI-2007 profiles prediction at Ilorin" Advances in Space Research, Vol 47, 496-505.

[20]. Panahi.Z; Emami.Z; Shafigh.S; Kuhi.R (2013) "Simulation models of electron density and temperature variations in the topside ionosphere plasma" Life Science Journal" Vol10: 133-137.

[21]. Schunk.R.W; Sojka.J.J and Bowline.M.D ;(1986) "Theoretical study of the electron temperature in the high latitude ionosphere for solar maximum and winter conditions" Journal of Geophysical Research, Vol 91, 12041-12054.

[22]. Sofiane Bourouaine; Eckart Marsch and Fritz.M.Neubauer; (2010) "correlations between the proton temperature anisotropy and transverse high-frequency waves in the solar wind" Geophysical Research Letters, Vol 37, L14104.

[23]. Stolle; Claudia; Liu.H;Truhlik.V;Luehr.H; Richards.P.G; (2011) "Solar flux variation of the electron temperature morning overshoot in the equatorial F region" Journal of Geophysical Research, Vol 116, A04308.

[24]. Truhlik.V; Bilitza.D; Triskova.L (2012) "A new global empirical model of the electron temperature with the inclusion of the solar activity variations for IRI" Earth Planets Space, 64, 531-543.

[25]. Wasiu Akande Ahmed; Ganiyu Ishola Agbaje; Sikiru Yommy Ayeiola; Bola.O.Balogun; Ngbede Joshua Ada Echoda; Yakubu Abdullahi Onimago; Taiwo Olunuga; (2016)" Determination of total electron content at equatorial region – Thailand using radio occulation technique" Atmospheric and Climate Sciences, Vol 6, 319-328.

[26]. Xuemin Zhang; Jiadong Qian and Xuhui Shen; (2013) "Solar cycle variation of the electron density in the topside ionosphere at local night time observed by DEMETER during 2006-2008" Journal of Geophysical Research: Space Physics, JAO19463.

[27]. Yiding Chen; Libo Liu and Huijun Le; (2008) "Solar activity variations of night time ionospheric peak electron density" Journal of Geophysical Research Vol 113, A11306.

[28]. Yoshihiro Kakinami; Shigeto Watanabe; Jann-Yenq Liu and Nanan Balan; (2011) "Correlation between electron density and temperature in the topside ionosphere" Journal of Geophysical Research, Vol 116, A12331.