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Study of Ionospheric Slab Thickness behaviour over Rome

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ABSTRACT

The object of the present study is to analyze the characteristic variations of the ionospheric slab thickness at Rome (41°N, 12°E, LT= (UT+1h), DIP=57.4° N) for the period of August, 2011 to July, 2012. The work deals with diurnal, seasonal, solar and magnetic activity variations of slab thickness. We have observed that the seasonal mean value of slab thickness is higher during summer months than equinox and winter months. The mean diurnal night-time values of slab thickness equal to the day-time values during winter (night-to-day ratio between 1.01), while for summer months night-time value is lower than the day-time value (night-to-day ratio of 0.65). The positive significant correlation between slab thickness and F10.7 solar flux for winter months and summer months has been observed, while negative significant correlation between these two parameters has been observed for equinox months. The negative significant correlation between slab thickness and Ap has been observed for equinox months. The results have been compared with the earlier ones and discussed in terms of possible source mechanism responsible for the variation of slab thickness at mid-latitude region.

KEYWORDS: F2 layer critical frequency (foF2); F2-layer electron density (NmF2); Slab thickness (τ); Solar Flux.

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1. INTRODUCTION

In the Earth's environment the ionosphere plays a vital role due to strong coupling processes to region below and above. The photochemical processes that govern the production and decay of the ionospheric plasma are reasonably well understood. The F2 layer critical frequency (foF2) is one of the ionospheric parameters observed regularly by several observatories and it allows us to examine the relation of F2 layer with the solar activity indices.

The ionospheric slab thickness (τ) is defined as the ratio of the Total Electron Content (TEC) to the maximum ionospheric F2-layer electron density (NmF2), or in terms of the F2 critical frequency (foF2). Besides, from the point of view of satellite to ground radio communication, the equivalent slab thickness is a very useful parameter since it contains all the new information obtainable from TEC measurements, which is not readily available in foF2[1]. From the previous studies it is proved that the slab thickness is subjected to substantial diurnal, annual, latitudinal and storm-time variations, and is influenced by solar and geomagnetic activity. Although the irregular behaviour of τ has been studied to some extent by many authors, more investigations are needed in order to better understand day-to-day and storm-time changes [(2-12 and references therein).]

The increase in slabthickness value at post-sunset hours under varying solar activity conditions at low latitude is due to the secondary fountain effect caused by the post-sunset occurrence of a strong eastward electric field existing over the equatorial latitudes[13-15]. At mid latitudes[16] it may also be associated with the nighttime enhancement events in total electron content, which is mainly due to the field aligned plasma flow from the proton sphere to the ionosphere [11,17and references therein].

[6]studied the slab thickness data obtained from March 1977 to February 1982 to analyze the diurnal, seasonal, and solar cycle variations at Lunping Observatory and found that the diurnal variation showed an unusually large peak that appeared in pre-sunrise hours, especially during winter time. [18] during there study explains the occurrence of pre-sunrise peak τ values as due to the collapse of the bottom side of the F layer. The whole phenomenon is suggested to be primarily due to the electrodynamics of the equatorial F-region during the pre-sunrise hours.

[7] studied the equivalent slab thickness of the ionosphere at 15 stations in middle and low latitudes to determine its dependence on solar cycle and location. They observed that the slab thickness varies approximately linearly with the 12-month smoothed values of the 10.7-cm solar radio flux. In mid latitudes at midnight of winter season the slab thickness is essentially independent of the flux, whereas in summer and equinox the midnight thickness increases with increase of solar flux. The noon thickness increases with increase of solar flux in all seasons.

[11]studied τ during the solar maximum (1981) and minimum (1985) phases of an intense, the 21st, solar cycle. They also found that for magnetically quiet days of solar maximum, the increased

ionization of NmF2 and TEC during the daytime is accompanied by an increased slab thickness of the ionosphere compared to the night-time for non-auroral latitudes, however the reverse is found to be true during the solar minimum compensating TEC against a weak nighttime ionization of NmF2.

[20]Studied the diurnal, seasonal, and solar flux variations in slab thickness (τ) of the ionosphere at Chung-Li ionosonde station (24.9°N, 121°E) during 1996–1999 for different solar phases. They observed that the average daily value is greater during summer months and reverse during equinox months in the equatorial ionization anomaly (EIA) region. Moreover, the τ values are greater during the daytime (0800–1600 LT) and nighttime (2000–0400 LT) for summer and winter, respectively and they also observed that the diurnal variation shows two abnormal peaks that appear during the pre-sunrise and post-sunset hours.

[17] studied the diurnal, monthly, seasonal and latitudinal variations of NmF2 and slab thickness (τ) over six different locations during low to moderate solar activity. They observed that maximum electron density of F2-layer (NmF2) at all the stations more or less show similar nature of variation with higher value during daytime as compares to those of slab thickness.

The object of the present study is to analyze the characteristic variations of the ionospheric slab thickness observed at Rome (41°N, 12°E, DIP=57.4°N). The foF2 and ITEC data have been downloaded from NOAA, Space Weather Prediction Centre for period August, 2011 to July, 2012, were used to analyze the diurnal, seasonal, solar and magnetic activity variations.

2. DATA AND METHOD OF ANALYSIS

The ionosphere slab thickness (τ) is a parameter which provides information about the nature of the distribution of ionization at a specific location and is defined as the ratio of the Ionospheric Total Electron Content (ITEC) measured in TEC units (1TECU = 10^{16} electrons m^{-2}) to the maximum ionospheric electron density in the F-region (NmF2) [7,21]

$$\tau = \text{ITEC} / \text{NmF2} \tag{1}$$

The critical frequency of the F2 layer (foF2) is related to the maximum ionospheric F2-layer electron density (NmF2) by

$$\text{NmF2} = 1.24 \times (\text{foF2})^2 \times 10^{10} \tag{2}$$

Hence, Slab thickness can be expressed in terms of foF2 as

$$\tau = \text{ITEC} / \{1.24 \times (\text{foF2})^2 \times 10^{10}\} \tag{3}$$

Where, ITEC is measured in TECU, foF2 in MHz, NmF2 in m^{-3}.and τ in km.

The foF2 and ITEC data have been downloaded from Space Physics Interactive Data Resource (SPIDR) (http: //ngdc.noaa.gov/) for the period of August 2011 to July 2012 i.e., covering one year of high solar active period. For the analysis, the data has been sorted according to month, NmF2 and slab thickness have been calculated by using equation 2 and 3 and the median value of foF2 and slab thickness was calculated for each hour. The data are classified into 3 seasons namely equinox (March, April, September and October), winter (January, February, November and December) and summer (May, June, July and August). The daytime slab thickness is averaged for 0800 to 1600 LT and night-time slab thickness is averaged for 2000 to 0400 LT. The solar flux (10.7cm) and Ap index data are downloaded from Space Physics Interactive Data Resource (SPIDR) web site (http://spidr.ngdc.noaa.gov/spidr).

3. RESULTS AND DISCUSSION

3.1 Diurnal and Seasonal variation of Slab thickness

Figure 1 shows the diurnal variation of slab thickness with standard deviation bars from August, 2011 to July, 2012 at Rome. From it has been observed that during day hours, the slab thickness ranges from 160 to 286 kilometres for summer months, 153 to 258 kilometres for equinox months and 100 to 198 kilometres for winter months. During nighttime, the slab thickness ranges from 100 to 199 kilometres for summer months, 103 to 188 kilometres for equinox months and 129 to 176 kilometres for winter months. In order to bring out the pre sunrise peak more clearly we have drawn the standard deviation bars for the slab thickness values. The diurnal variation of slab thickness shows abnormal peaks at pre sun rise hours (around 0300 LT – 0600 LT) as reaches maximum up to 320 kilometres for summer months and shows minima in at (around 1900 LT - 2100 LT) sunset hours and soon after the occurrence of the morning peak, the slab thickness decreases to a small value. My result supports the result presented by [7,11,13,17,18,20 ,22, 23]. The morning peak in slab thickness may be attributed to the rapid ionization of the topside ionosphere, which increases the TEC. As a significant portion of electrons in TEC are associated with H+ ions, which have large scale heights. The small decrement in slab thickness after morning peak indicates a rapid production of ionization around the peak of F2-layer (Sethia et al.(1980)). The high value of slab thickness during day time is consistent with electrodynamic drift (fountain effect) and the decrease in slab thickness after 2200 hours may be caused by the movement of the equatorial ionosphere to lower altitudes around this time [17 and references therein]. [17] observed that the peak in slab thickness occurred around 0500 hours and the decrease in slab thickness around 2200 hrs. The decrease in slab thickness may be caused by the movement of the equatorial ionosphere to lower altitudes around that time.

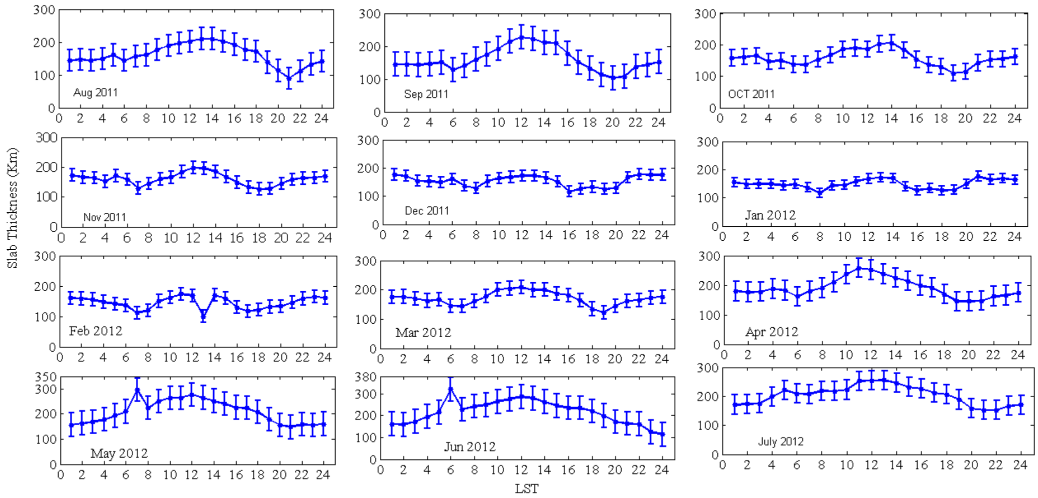

Figure 1: Diurnal profile of monthly mean values of seasonal for each month with standard deviation bar from August, 2011 – July, 2012.

The average daytime (0800-1600LT) and night-time (2000-0400LT) values of slab thickness for summer months, equinox months and winter months during the period under investigation are shown in Table 1. The average day-time value of slab thickness has been observed greater as compared to night time value for summer months followed by equinox months while it is reverse in case of winter months.

Average Slab Thickness (km)								
Summer Months			Winter Months			Equinox Months		
Month	Day time	Night time	Month	Day time	Night time	Month	Day time	Night time
August, 2011	193	130	November, 2011	172	162	March, 2012	191	167
May, 2012	251	160	December, 2011	154	164	April, 2012	225	168
June, 2012	260	158	January, 2012	148	158	September, 2011	198	136
July, 2012	236	169	February, 2012	148	154	October, 2011	165	151

Table 1: Average slab thickness for daytime (0800 - 1600 LT) and night-time (2000-0400 LT).

Figure 2 represents the seasonal mean variation of slab thickness (with standard deviation bars) with respect to local time for the winter months, equinox months and summer months during August, 2011- July, 2012. Form figure it has been observed that the mean value of slab thickness is higher during summer months followed by equinox and winter months for a mid latitude station. Our study confirms the results reported by [24,11,17]. As according to [11] the slab thickness variation at mid latitude during solar maximum having the daytime mean values are higher as compared to the night-time mean values in the different seasons. [17] observed that at mid-latitude location Athens, the variation of slab thickness is maximum during the summer months and the slab thickness is high during daytime hours.

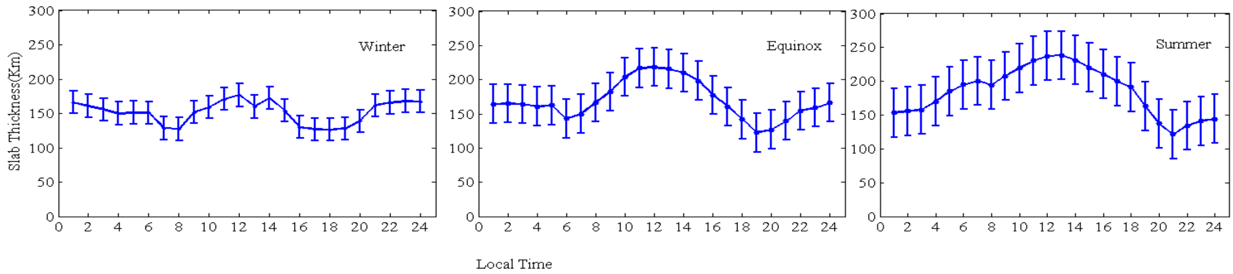

Figure2: Seasonal variation of slab thickness during August, 2011-July, 2012.

3.2 Solar activity variation of Slab thickness

In this section, we have presented the solar activity variations of the slab thickness. The monthly mean value of slab thickness for summer months, winter months and equinox months are plotted against the corresponding F10.7 solar flux value as shown in figure 3 for the period of August, 2011- July, 2012. It was observed that during the period of study, slab thickness ranges between approx.145 to 216 Km and solar flux lies between 101 and 153 solar flux units and the slab thickness increases with increase in solar flux for summer and winter months while it decreases with increase in solar flux value for equinox month. For winter months and summer months positive significant correlation between slab thickness and F10.7 solar flux i.e., r = 0.94 and 0.75 respectively (fig. 3a and 3c), while for equinox months negative significant correlation between the two parameters has been observed i.e., r = -0.88 (fig. 3b). Many authors have reported positive co-relation between slab thickness and F10.7 solar flux for various locations [25-26]. [7]observed that at noontime slab thickness increases with increase of solar flux in all seasons. [11] observed that during solar maximum, there is a linear increase of τ with solar flux for the different seasons of the three latitudes except during the winter season at low-latitude and during the winter and equinox seasons at mid-latitude. Our results supports the result presented by [25,26, 11].

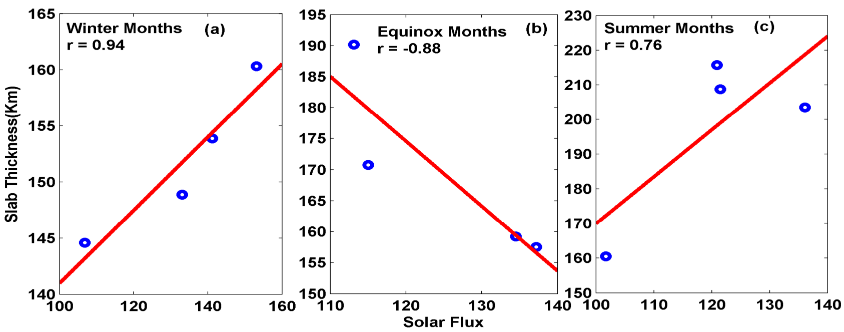

Figure3: Solar activity variation of slab thickness during August, 2011- July, 2012

3.3 Magnetic activity variation of Slab thickness

The monthly mean value of slab thickness was plotted against the corresponding Ap value for summer, equinox and winter months during the period August, 2011- July, 2012 in figure 4. It observed that during the period of study, the slab thickness ranges between 145 and 216 km and Ap lies between 04 and 16 solar flux units. The negative significant correlation between the slab thickness and Ap parameters has been observed i.e., r = -0.83 (fig. 4a) for equinox months but for winter months and summer months slab thickness shows no significant correlation is observed (i.e., r = 0.113 and 0.383; fig. 4b and 4c). Most of the earlier studies of geomagnetic activity dependence on the slab thickness were inconclusive. [13] report no correlation between slab thickness and magnetic activity index Ap for Indian low-latitudes. [5] report a positive correlation between τ and magnetic activity during medium solar activity conditions for the mid-latitude station of Aberystwith (53ºN, 4º W). [11] during their study indicates a positive dependence of slab thickness on magnetic activity for mid-latitude during solar minimum and for high-latitude during solar maximum. In our study we can conclude that magnetic activity has no definite impact on slab thickness same as result presented by [27]. In their study during the solar minimum period of 1975–76 for Indian low-latitudes, they found that increase and decrease in slab thickness occurs with equal frequency, and concluded that magnetic activity has no definite impact on slab thickness.

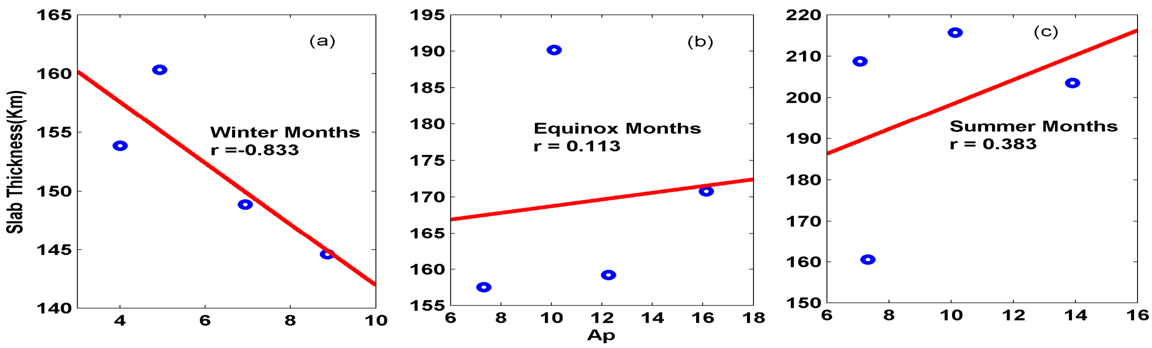

Figure4: Magnetic activity variation of slab thickness during August 2011- July 2012.

Table2 gives the slab thickness ratios of night-to-day mean values for Rome, during the winter, equinox and summer seasons of the solar maximum period August 2011-July, 2012. The night-to-day ratio ranges from 0.65 to 1.01. The slab thickness ratios of night-to-day mean values are higher during winter and equinox as compared to the summer, with values around 1.01, 0.8 and 0.65 respectively. Our result support the result presented by [28]

In this paper an attempt has been made to study slab thickness during the period of study. We observed that the mean value of slab thickness is higher during summer months followed by equinox and winter months. It is found that, the mean daytime values of slab thickness are greater during daytime than those during nighttime for all seasons except winter months.

Time Sector	Slab thickness in Km		
	WNT	EQN	SMR
Day	156	195	235
Night	159	156	154
N/D Ratio	1.01	0.8	0.655

Table 4: Mean daytime (0800–1600 LT), night-time (2000–0400 LT) value and night/day (N/D) ratio of ionospheric slab thickness, in km, for three seasons (WNT – winter, EQN – equinox, SMR – summer) during the period of study

4. CONCLUSIONS

The present study on the diurnal, seasonal solar and magnetic activity variations of ionospheric slab thickness at mid-latitude during the high solar activity period brings out the following important results:

- The mean value of slab thickness is higher during summer months followed by equinox and winter months.
- The positive significant correlation between slab thickness and F10.7 solar flux for winter months and summer months have been observed (i.e., r = 0.94 and 0.75), while negative significant correlation between the two parameters has been observe for equinox months (r = -0.88).
- The negative significant correlation between slab thickness and Ap has been observed for equinox months (r = -0.83) while for winter months and summer months non significant correlation is obtained (i.e., r = 0.113 and 0.383).
- The mean diurnal night-time values of slab thickness equal to the day-time values during winter (night-to-day ratio between 1.01), while for summer months night-time value is lower than the day-time value (night-to-day ratio of 0.65) at Rome.
- The diurnal variation of slab thickness shows abnormal peaks during 0300 LT – 0600 LT, the pre-sunrise hours. Furthermore, the diurnal variation shows minima at around 1900 LT - 2100 LT, during the sunset hours. The pre-sunrise peak in τ is due to the downward movement of the ionosphere and soon after the occurrence of the morning peak, the slab thickness decreases to a small value indicating a rapid production of ionization around the peak of F2-layer.

The ionospheric monitoring capabilities of the slab thickness remain largely unexplored, despite the fact that, operationally, it is a very useful parameter. From this aspect, various possibilities exist for utilising the ionospheric slab thickness modelling/monitoring efforts. In general the continuous monitoring of slab thickness would help in various GNSS applications including improving the integrity and performance of network positioning service and aircraft navigation, efforts should be made to strengthen research on ionospheric parameters and practical application of the derived models/results.

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