Study of the ionospheric slab thickness during one year of low solar activity

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Abstract

This paper present a study of the ionospheric slab thickness in the Brazilian sector during one year of low solar activity. The ionospheric slab thickness (τ) is an important parameter which provides information on the density profile of the ionosphere. The ionospheric slab thickness is defined as a ratio of the total electron content (TEC) to the F-region peak electron density (N_mF_2). Values of TEC and N_mF_2 were obtained at the equatorial station of Palmas ~~-~~and in the low-latitude station of São José dos Campos from March 2009 to February 2010. The τ presented diurnal~~,~~ and seasonal variability for the different latitude zones. The night time slab thickness is lower compared to the daytime for both latitude and also in all seasonal periods.

Introduction

The ionospheric slab thickness is defined as the ratio of the total electron content (TEC) to the F-region peak electron density (NmF2). It is capable of addressing many ionospheric phenomena and has been studied over the last five decades (e.g Bhonsle et al., 1965; Kersley and Hajeb Hosseinieh, 1976; Huang, 1983; Bhuyan and Tyagi, 1985; Davies and Liu, 1991; Minakoshi and Nishimuta , 1994; Gulyaeva, 1997 (Jayachandran et al, 2004). A study of this parameter at any location provides information about the nature of the distribution of ionization at those locations. Slab thickness is a significant parameter since it contains information regarding the neutral temperature and, for an assumed electron density profile, it can be related directly to the scale height of the ionizable constituents (Titheridge, 1973).

A detailed research of this parameter for low latitudes (e.g Bhuyan et al., 1986; Rao et al., 1988; Davies and Liu, 1991) and mid latitudes (e.g Bhonsle et al., 1965; Titheridge, 1973; McNamara and Smith, 1982) are available in the literature. However, studies related to the high-latitude variations of τ are rare (e.g Buonsanto et al., 1979; Jayachandran et al., 2004).

Several slab thickness phenomena has been reported by many investigators for low and mid latitudes due the occurrence of a pre-sunrise and post-sunset peak in τ. Minakoshi and Nishimuta (1994) reported that for Japanese low and mid-latitudes, a large peak in slab thickness appears during the solar minimum and disappears as the sunspot number ascends. According to Titheridge (1973), pre-sunrise peak in τ is due to the downward movement of the ionosphere when neutral winds that maintained the ionosphere decrease or reverse. The early morning peaks in τ may also appear due the fact that sunrise is earlier at heights above F2-layer causing some production at the topside, tending to give TEC a lead over NmF2 which is still decaying.

The post sunset increase in the τ values observed during the different seasons under varying solar activity conditions for low latitude could be explained as being due to the secondary fountain effect caused by the post-sunset occurrence of a strong eastward electric field existing over the equatorial latitudes (Modi and Iyer, 1989; Balan and Baley, 1995).

Data and method of analysis

The total electron content (TEC) data were derived from the dual frequency (L1=1575,42 MHz and L2=1227.60 MHz) GPS receivers installed in the Brazilian stations of Palmas (10.12º S, 48.21º O, 7.73º S dip lat) - an equatorial station - and São José dos Campos (23.07º S, 45.52º O, 19.61º S dip lat), a low latitude station located under the southern crest of the Equatorial Ionization Anomaly (EIA). The data were collected during for the low solar activity period from March 2009 to February 2010. The months of March-April, September-October; from May to August; and from November to February are, respectively, taken as equinox, winter and summer seasons. Simultaneous NmF2 data obtained from the CADI Ionosonde located at the above two stations were used in the present study. These ionosondes are operated in the frequency range from1 to 20 MHz with 600 W of transmitting power. They probe the ionosphere at regular intervals by the pulse-echo technique at vertical incidence and plot the relationship between the virtual height-at the frequency of reflection. TEC and NmF2 data is used for computing the slab thickness using the relation

$$\tau = \frac{TEC}{NmF2} \quad (km)$$

Results and Discussion

Variation of Total Electron Content (TEC)

The monthly mean diurnal variation plots of TEC over the two different stations of Palmas and São José dos Campos for each season are presented in Fig.1 and Fig.2, respectively.

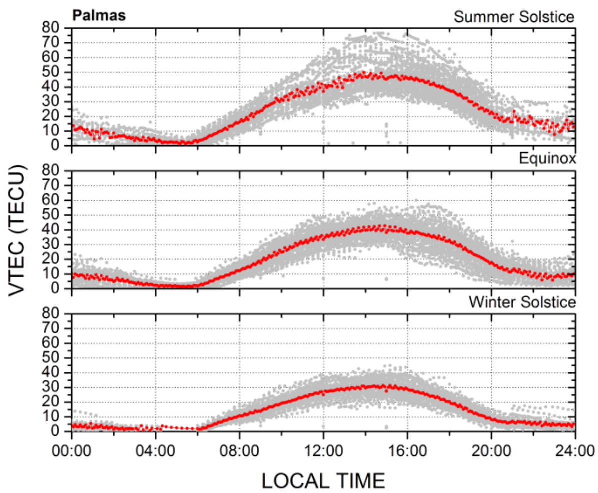

Fig.1 – TEC behavior at Palmas during the three seasonal periods

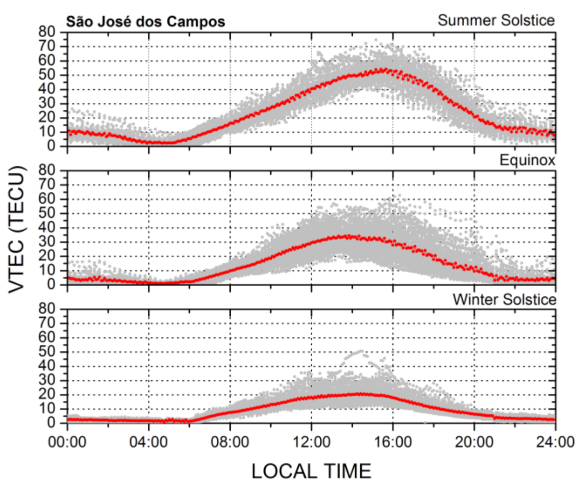

Fig.2 – TEC behavior at São José dos Campos during the three seasonal periods

It is readily seen from these figures that the diurnal variation of TEC over both stations shows a sharp minimum about 2-5 TECU around from 04:00 to 06:00 local time and a broad maximum of TEC varying from 20 to 75 TECU between 15:00-16:00 local time in all the three different seasons. Night-time maintenance of ionization is observed over Palmas particularly during summer and equinoxes with TEC varying up to 10 TECU.

The results also reveal that during the summer and the equinoctial periods, the measured values of TEC in both stations are higher compared to those observed during the winter solstice months. The observed differences is seasonal periods are related to the elevation of the sun's zenith angle ($\cos\chi$) and changes in the neutral atmosphere (Davies, 1990).

The day-to-day variability in the day maximum values of TEC over the low latitude station, São José dos Campos is significantly low compared to that at the Palmas station, except during the equinox due São José dos Campos be located at the equatorial anomaly region.

Variation of peak electron density of the F2 layer (N_mF_2)

The monthly mean diurnal variation plots of N_mF_2 over the two different stations of Palmas and São José dos Campos, for each season, are presented in Fig.3 and Fig.4, respectively.

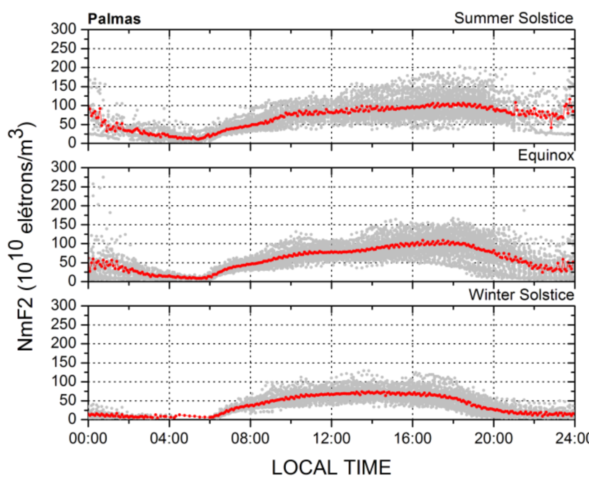

Fig.3 – NmF2 behavior at Palmas during the three seasonal periods

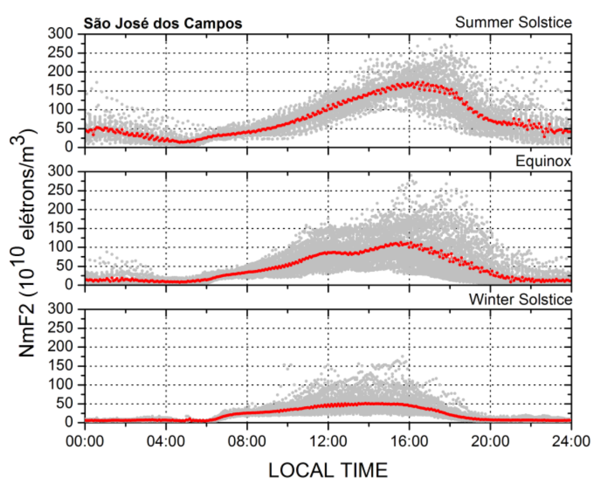

Fig.4 – NmF2 behavior at São José dos Campos during the three seasonal periods

It is observed from these figures that the diurnal variation of N_mF_2 over both stations shows a sharp minimum of about 3-10 electrons/m3 around from 04:00 to 06:00 local time and a broad maximum of N_mF_2 varying in all the three different seasons. As observed for the TEC there is also a significant maintenance of the night-time electron density during summer the solstice and equinox months

During the summer solstice and the equinox, the measured values of N_mF_2 are higher compared to those observed on the winter solstice in both stations. The seasonal differences are related to the elevation of the sun's zenith angle (cos χ) and changes in the neutral atmosphere. This behavior has been seen in TEC measurements.

The day-to-day variability in the day maximum values of N_mF_2 over the low latitude station, of São José dos Campos is significantly high if compared to that observed at the equatorial station of Palmas due São José dos Campos be located under the southern crest of the equatorial ionization anomaly region.

Variation of ionospheric slab thickness

The τ parameter is a first order measure of the shape of the electron density profile of the ionosphere. Study of this parameter at the equatorial and low latitude stations provides information on the vertical ionization distribution in these regions. Besides from the point of view of satellite to ground radio communication, τ is a very useful parameter since it contains all the new information obtainable from TEC measurements, which is not readily available in f_0f_2 (Venkatesh et al., 2011; Titheridge, 1973).

The monthly mean diurnal variation plots of τ over the two different stations Palmas and São José dos Campos for each season are presented in Fig.5 and Fig.6, respectively.

It is observed that in the nighttime the mean value of the τ in both stations during all seasonal periods is twice low if compared to daytime period. After sunrise, τ begins to increase gradually until its maximum value around 13:00 to 15:00 local time due mainly to ultra-violet radiation.

Table 1 gives the mean daytime (08:00 – 16:00 LT) and night-time (20:00 – 04:00) values of ionospheric slab thickness.

From table 1, it is found that the mean daytime values are higher than nighttime for the three seasons in both stations, except during the winter solstice at São José dos Campos. At the equatorial station, the daytime mean value of τ is higher than at São José dos Campos in the summer solstice and equinox months.

It may be readily seen from figure 6 that a strong pos-sunset peak in τ around 19:00 to 20:00 local time at São José dos Campos station during the equinox and mainly during the winter solstice period. In winter solstice, the

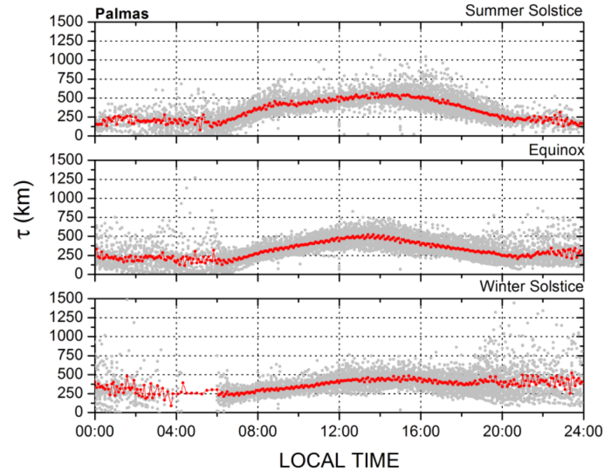

Fig.5 – τ behavior at Palmas during the three seasonal periods

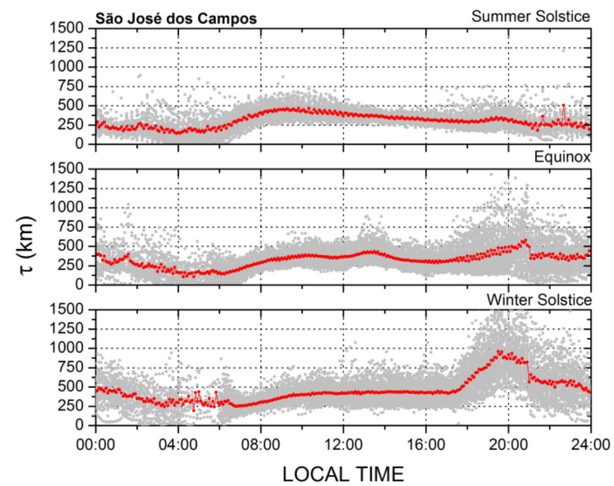

Fig 6 – τ behavior at São José dos Campos during the three seasonal periods

Table 1 – Mean daytime and night-time values of τ

	τ (km)				
Station	Time Sector	Winter Solst.	Equinox	Summer Solst.	Annual
São José dos Campos	Day	408	359	391	386
	Night	548	358	244	383
Palmas	Day	389	422	477	429
	Night	276	246	205	242

slab thickness increases considerably after sunset due to a lowering of the O^+/H^+ transition height (Titheridge,1973). The existence of a pos sunset peak in τ has been reported earlier by Modi and Iyer (1989) and Balan and Baley (1995) due to the secondary fountain effect caused by the post-sunset occurrence of a strong eastward electric field existing over the equatorial latitudes.

Conclusions

The diurnal, seasonal and latitudinal behavior of TEC, N_mF_2 and τ over two different Brazilian stations, Palmas (equatorial station) and São José dos Campos a low-latitude station) during the low solar activity of 2009-2010 has been~~.~~ investigated.

The diurnal variation of TEC shows a sharp daily minimum in the nighttime over both stations during all three different seasons. The day maximum values of TEC are higher during summer solstice months. The day-to-day variability of TEC is higher at São José dos Campos than Palmas due to the influence of the equatorial ionization anomaly. The maximum electron density of the F_2 layer (N_mF_2) at São José dos Campos and Palmas show similar behavior regarding the diurnal, seasonal and latitude variations.

At the low latitude station there is a pronounced post-sunset increase in ionospheric slab thickness around 19:00 local time, except during the summer solstice months. During daytime τ has shown higher values at the equatorial station of Palmas, whereas during nighttime it is observed the opposite.

Acknowledgments

This work was partially supported by Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) under the PROSUP program, and Fundação Vale Paraibana de Ensino (FVE).

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