The Variation of Ionospheric Slab Thickness at Thailand Equatorial Latitude Station

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Abstract: This paper presents the study and analysis of ionospheric slab thickness (τ) during the solar minimum in year 2006. The ionospheric slab thickness is obtained from the ratio of the total electron content (TEC) to the peak electron density in the F2 region (NmF2). According to the analysis of the total electron content and the peak electron density in the F2 region, the peak electron density in the F2 region by critical frequency (foF2) are determined by ionosonde technique. In addition, the total electron content are determined by the correlation of different time delay of 2 L - band signals from GPS satellites. All three parameters, critical frequency, total electron content, and peak electron density in the F2 region, are analyzed at the Chumphon campus King Mongkut's Institute of Technology Ladkrabang station, located at longitude 99.3 ºE and latitude 10.7 ºN. The analyzed results show that there are irregularities of all parameters during the equinox period and the ionospheric slab thickness at low latitude peaks in the pre-sunrise.

1. Introduction

The ionospheric slab thickness (τ) is a significant parameter since it includes information regarding both the top and bottom sides of ionosphere; further, it indicates the electron density versus height profile. Ionospheric slab thickness may also be regarded as the depth of an imaginary ionosphere that has the same total electron content (TEC) as the actual ionosphere and a uniform electron density is equal to the maximum electron density of the actual ionosphere [1]. The study of ionospheric slab thickness has been carried out by many researchers [2],[3],[4],and [5]. They have found that the slab thickness shows appreciable diurnal, seasonal, and solar activity variations that have considerably dependence on the location of the observation station. This indicates the occurrence of a pre – sunrise peak in the slab thickness for low–latitudes [6],[7] and mid–latitudes [8],[9]. In addition, Chuo [1] presented the variations in slab thickness τ of the ionosphere at low-latitudes ionosphere during 1996-1999, corresponding to half of the 23 rd solar cycle. This study presents the diurnal, seasonal, and solar flux variations in τ for different solar phases. Minakoshi and Nishimuta [5] have studied τ and show that a large peak appears in τ during pre-sunrise at the solar minimum phase and disappear as the sunspot number increase in the mid-latitude; furthermore, this peak begins to reappear at the solar maximum phase, particularly during the winter season. Titheridge [8] presented the pre-sunrise peak in τ due to the downward movement of the ionosphere when the neutral winds that have been maintains the ionosphere decrease or reverse. The early morning peaks in τ may also appear due to the fact that sunrise is earlier at heights above the F2-layer causing some production at the topside, tending to give TEC a lead over NmF2 which is still decaying. Jayachandran et al. [9] presented the ionospheric slab thickness τ during the solar maximum (1981) and minimum (1985) phases of an intense, the 21 st, solar cycle. Hourly values of TEC and NmF2 at Hawaii (low-latitude), Boulder (mid-latitude) and Goosebay (high-latitude) are used in the study. Climatology of the slab thickness is described by the diurnal, seasonal, solar and magnetic activity variations of τ for the different latitude zones. Despite studies of slab thickness in many parts of the world, it has never been carried out in Thailand.

The comparison of TEC, NmF2, and the ionospheric slab thickness parameters is presented in this paper. The data are obtained from Chumphon campus of King Mongkut's Institute of Technology Ladkrabang (KMITL), Thailand, located near the magnetic equator. The measured data cover from January to December 2006; they are analyzed based on the diurnal, monthly, and seasonal variations.

2. Data and Analysis Methodlogy

The variation of ionospheric slab thickness (τ) in 2006, which has low solar activity, can be obtained from the relationship between TEC value and foF2 value. The TEC data are collected from Javad–GPS receiver and foF2 is measured from FM/CW Radar based on the ionosonde technique. Both of the measurement parameters are from Chumphon, KMITL, located at longitude 99.3 ºE and latitude 10.7 ºN, Thailand. The peak electron density in the F2 – region (NmF2) is computed using the equation [1]

$$\mathrm{NmF2} = 1.24\left(\mathrm{foF2}\right)^2 \times 10^{10}\ \mathrm{el/m^3}, \qquad (1)$$

where foF2 is the critical frequency in F2 layer (MHz). The foF2 was obtained from ionograms recorded at interval of 15 minutes at the Chumphon station.

The TEC data were measured from the Javad-GPS receiver (10.7 ºN, 99.3 ºE) of the year 2006. The vertical TEC (TEC_V) is derived from the GPS signals. In the GPS system, every satellite transmits signals using two frequencies (f_1 = 1575.42 MHz and f_2 = 1227.60 MHz). The slant path TEC_{sl} from a satellite to a receiver can be obtained from the difference between the pseudoranges (P_1 and P_2), and the difference between the phases (L_1 and L_2) of the two signals [12]

$$TEC_{sl} = \frac{2\left(f_1 f_2\right)^2}{k\left(f_1^2 - f_2^2\right)}\left(P_2 - P_1\right) \tag{2}$$

$$TEC_{sl} = \frac{2\left(f_1 f_2\right)^2}{k\left(f_1^2 - f_2^2\right)}\left(L_1\lambda_1 - L_2\lambda_2\right) \tag{3}$$

where k, related to the ionosphere refraction, is 80.62 (m^3/s^2). λ_1 and λ_2 are the wavelengths corresponding to f_1 and f_2, respectively.

The vertical TEC, in el/m^2, is computed from [13]

$$\mathrm{TEC_V} = \mathrm{TEC_{sl}} \times \cos\chi , \tag{4}$$

where the zenith angle χ is computed using the equation

$$\chi = \arcsin\left(\frac{R_e \cos\alpha}{R_e + h}\right), \tag{5}$$

where α is the elevation angle of the satellite, R_e is the mean radius of the Earth, and h is the height of the ionospheric layer, which is assumed to be 400 km in this paper.

The total electron content (TEC) and the peak electron density in the F2 region (NmF2) are then used to compute the variation of ionospheric slab thickness (τ), in km, using [1]

$$\tau = \mathrm{TEC/NmF2}, \tag{6}$$

where NmF2 is the peak electron density in the F2 region (electrons/m^3).

The data and analysis method are classified into 3 seasons including equinox (March, April, September, and October), summer (May, June, July, and August), and winter (November, December, January, and February).

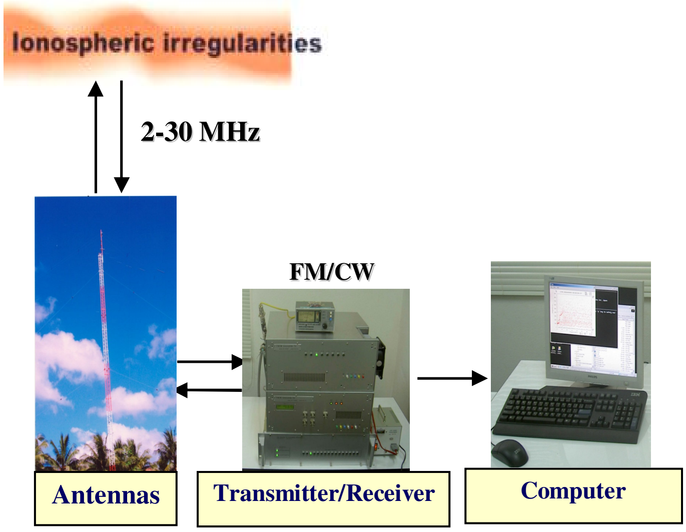

Figure 1. Ionospheric sounding technical equipment

In Fig. 1, the Ionospheric sounding technical equipment is shown. This system consists of FM/CW ionosonde, antenna and a computer. The FM/CW continuously transmits the radio frequency signal in the range of 2-30 MHz reflect ionosphere and receives an echo. For each round, the transmitter starts from 2 MHz and increases the frequency with an increment of 100 KHz per second up to 30 MHz. The data collection of next round starts at every 15 minutes. And computer collections datas then these datas are automatically uploaded to campus of KMITL in Bangkok to be analyzed.

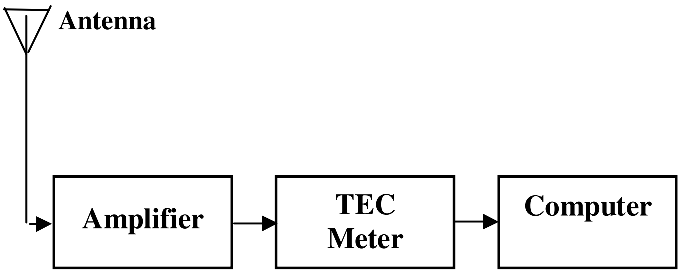

Figure 2. TEC measurement system

In Fig. 2, the block diagram of TEC measurement consists of a microstrip antenna, an amplifier, a TEC Meter JAVAD, and a computer. The microstrip antenna type is right hand circularly polarized and receives two GPS signals with L1 = 1575.42 MHz and L2 = 1227.60 MHz. The amplified signal from amplifier is then sent to the TEC Meter JAVAD which consist the GPS receiver. The GPS receiver in TEC Meter JAVAD works when it continuously receives 4 GPS signals or up to 12 GPS signals that can be received with TEC values.

3. Results and Discussions

We present the results of four parameters: foF2, TEC, NmF2, and τ. The emphasis is on equinox, summer, and winter seasons. The seasonal result for the F2-layer critical frequency (foF2) are shown in Fig. 3. It represents a similar trend in variation of foF2, increasing during sunrise hours (around 06:00 LT), reaching the highest value during post-sunset hours (around 17:00-20.00 LT), and decreasing during nighttime hours, until the lowest level during pre-sunrise hours (around 03:00-06:00 LT). Considering the seasonal result, the foF2 values occur at post-sunset in equinox are higher than those for other seasons. During pre-sunrise hours, the foF2 values are minimum for all seasons. In Fig. 4., the maximum and minimum levels of TEC and NmF2 occur around the same time of day for all three seasons. The highest values of TEC and NmF2 are seen during the equinox. During day time, the ionospheric slab thickness ranges between 500 and 600 km. The ionospheric slab thickness level then increases at noon according to solar flux activity [11]. During nighttime, the slab thickness level that is higher than that during daytime is between 800 and 1200 km. The highest level on ionospheric slab thickness occurs around 05:00 LT. In addition, we observe that the maximum value of τ occurs when the peak electron density in the F2 region is at the lowest level, while the total electron content is relatively flat. The ionospheric slab thickness decreases after 06:00 LT. The lowest level on ionospheric slab thickness occurs in equinox and the highest level on ionospheric slab thickness occurs in summer.

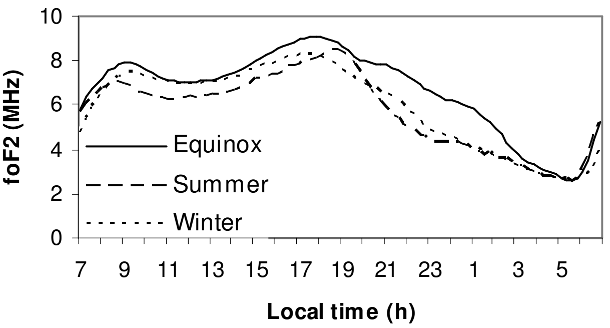

Figure 3. The critical frequency for the three seasons of 2006

Moreover, we analyzed and discussed more details on the ionosperic slab thickness characteristics. In table 1., we give the average ionospheric slab thickness according to seasonal daytime (08.00-16.00 LT) and nighttime (20.00-04.00 LT) for the year 2006. We found that the nighttime value of ionospheric slab thickness in winter, 1164.87 km, is the highest level for all the seasons in year 2006 but the lowest level on ionospheric slab thickness in equinox, 827.19 km. Furthermore, the daytime value of ionospheric slab thickness is at the highest level in summer, 678.66 km, and the lowest level in equinox, 591.97 km.

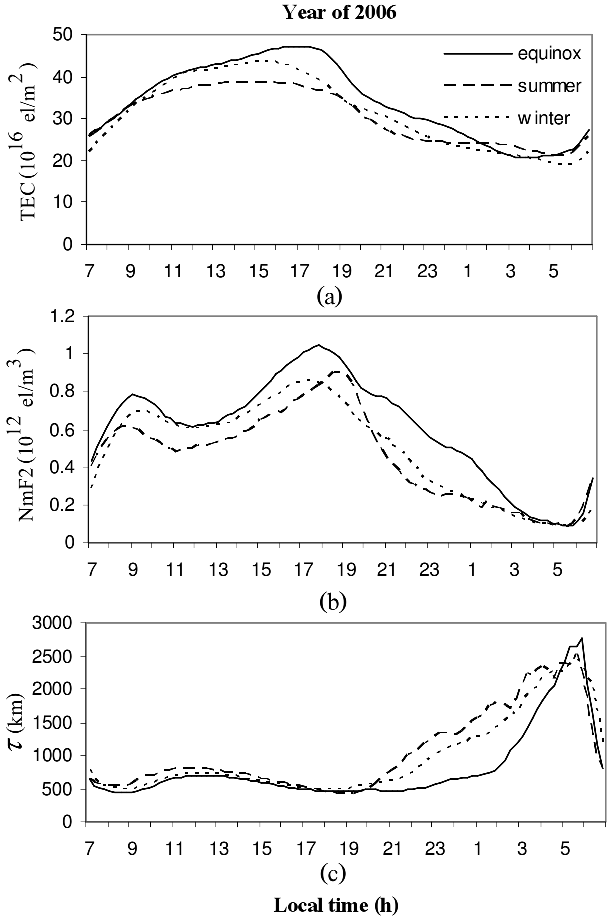

Figure 4. Ionospheric parameters for the three seasons of 2006

(a) Total electron content (TEC)

(b) Peak electron density in the F2 region (NmF2)

(c) Ionospheric slab thickness (τ)

Table 1. The average on ionospheric slab thickness, in km, at daytime (08.00-16.00 LT) and nighttime (20.00-04.00 LT) is for three seasons in year 2006.

	Equinox	Summer	Winter
Day	591.97	678.66	622.75
Night	827.19	1141.99	1164.87

4. Conclusions

This paper presents the comparison of four parameters; foF2 TEC, NmF2, and τ during January-December 2006. The data used in studying and analysis were obtained from Chumphon equatorial latitude station, Thailand. The analyzed data are varied in diurnal, monthly and seasonal variations. The results are obtained for Chumphon from the present study as follow.

1. The minimum values and the maximum values of TEC and NmF2 occur in the same time and the trend of variations is similar to all three seasons.

2. The foF2 and NmF2 occur in the same time and the trend of variations is similar to all three seasons.
3. The τ values are maximum around 05.00 LT which is pre-sunrise.
4. The average of τ values during the daytime is minimum in equinox and the average of τ values during the nighttime is maximum in summer.
5. The τ values depend on three parameters; latitude, season, and sunspot number.

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