Ionospheric slab thickness over Kokubunji during solar maximum

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Abstract Ionospheric slab thickness was determined by using GPS-derived TEC and the ionospheric maximum electron density observed by an ionosonde at a mid-latitude site Kokubunji (139.5E, 35.7N) for the period of 1999-2001. It is found that the slab thickness has spring-autumn symmetry. Its daytime level is higher than nighttime one in summer. Daily variation shows the largest difference of more than 400 km in winter. varied linearly with EUV and F10.7.

Introduction

With the total electron content (TEC) and the peak electron density of the F2 layer NmF2, the slab thickness can be defined by D=TEC/NmF2. It has been an important parameter in that it is linearly correlated with the scale height of the ionosphere, which is related to the electron density profile. It also reflects variation of the neutral temperature. The study of the slab thickness has been made by many researchers [1, and references therein]. The pre-sunrise peak and the post-sunset increase in the slab thickness have been reported in detail.

This paper aims to clarify the characteristics of the slab thickness derived from data obtained with GPS and ionosonde observation at Kokubunji (139.5° E, 35.7° N) during the solar maximum.

Data description

With GPS data from a dense GPS Earth Observation Network (GEONET) of Geographical Survey Institute, Japan [2], 15-min time series of the TEC over Japan is determined with a spatial resolution of 2 degrees in longitude and latitude, respectively [2]. The TEC is from a 2°×2° mesh centered at (139° E, 35° N).

Bottom-side sounding by ionosonde is operated routinely every 15 min at Kokubunji. foF2 is manly scaled from ionograms. The NmF2 is computed with: $NmF2=1.24(foF)^2\times10^{10}$ el/m^3, where foF2 is in MHz. The slab thickness D, in km, is calculated by using the formula: D=TEC/NmF2. The analysis of the slab thickness in this paper is concentrated on three years period from 1999 to 2001, when the solar activity was at its maximum.

The solar radio flux and Mg II core-to-wing ratio (proxy of EUV) were downloaded from National Geophysical Data Center (NGDC) web site. The geomagnetic index Kp was downloaded from OMNIWeb of NASA Goddard Space Flight Center (GSFC).

A general prospect

Figure 1 shows noon values of the ionospheric parameters over Kokubunji for the period of 1999-2001. Shown in the third panel is daily value of the solar indices F10.7 and EUV (Mg II). The last panel gives the geomagnetic index Kp. For the slab thickness, D, the midnight values are also plotted (thin line in the second panel of Fig. 1). The smooth curves overlapped are 81-day running averages of corresponding parameters. The TEC and foF2 display semiannual and annual variations. The TEC and foF2 generally show broad peaks near the spring and autumnal equinoxes, and is at its lowest level in the summer between May and August. While the peak values are approximately symmetric, the TEC peak in 2000 spring is about 20~30 TECU larger than that in autumn. The slab thickness has annual variation. The noon value shows a broad peak, 350~400 km, near summer solstice and the lowest level, 200~250 km, near winter solstice.

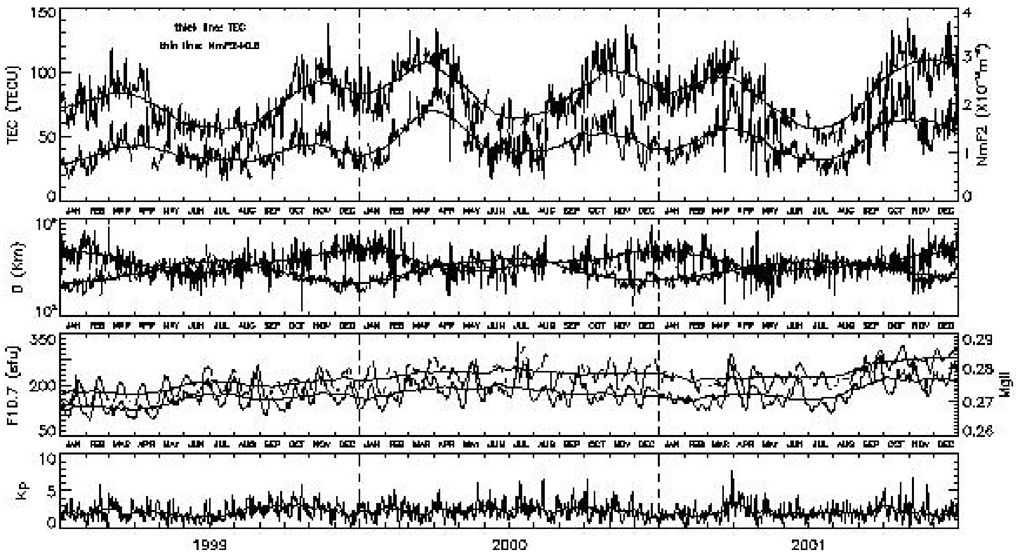

Fig. 1 Ionospheric parameters over Kokubunji. Also shown are the solar and geomagnetic activities for the period of 1999-2001.

The midnignt value is just in the opposite phase. The peak near winter solstice has a level of 500 km, and the valley near summer solstice is about 300 km. The time when the noon value equals to that of midnight was in May and August in 1999, in April and August in 2000, and in April and September in 2001. Dependence of the ionospheric parameters on the solar activity is hardly detailed in Fig. 1. However, the linear correlation between F10.7 and Mg II is clearly collapsed sometimes when F10.7 is larger than 100 sfu. The dependence on the geomagnetic activity can be observed in the severe day-to-day variations.

Seasonal and diurnal variations

To inspect ionospheric seasonal variations during solar maximum in detail, median values of the ionospheric parameters over Kokubunji in March, June, September and December 2000 are shown in Fig. 2. While there is spring-autumn asymmetry in TEC and NmF2, the slab thickness, D, in spring and autumn are consistent with each other. It was about 300 km in midnight. From midnight, the D increases with time to presunrise. The D in equinoxes decreases from sunrise and reaches its minimum at about 7 LT. It then increases gradually until evening. It decreases from evening till the midnight. The higher level of nighttime D means a higher level of the scale height. It confirms contribution of electrons in high altitude. The smallest difference of slab thickness between day and night occurs in summer. And it is only in summer that the daytime level is higher than that in at night. This means a larger scale height which indicates that the the equatorward wind in summer force the plasma upward along the magnetic field lines where the electron loss coefficient is sufficiently small to ensure certain electron density at certain level. In winter, the largest D can be 400 km more than the smallest one. It should point out that different from other seasons the D keeps increase from evening through midnight. The largest D in winter nighttime indicates contribution from the plasmasphere. Titheridge [3] explained that the scale height could be increased by plasma from the magnetosphere or the increase of H ions.

Solar activity dependences

Shown in Fig. 3 are the variations of the ionospheric parameters over Kokubunji with F10.7 for the period of

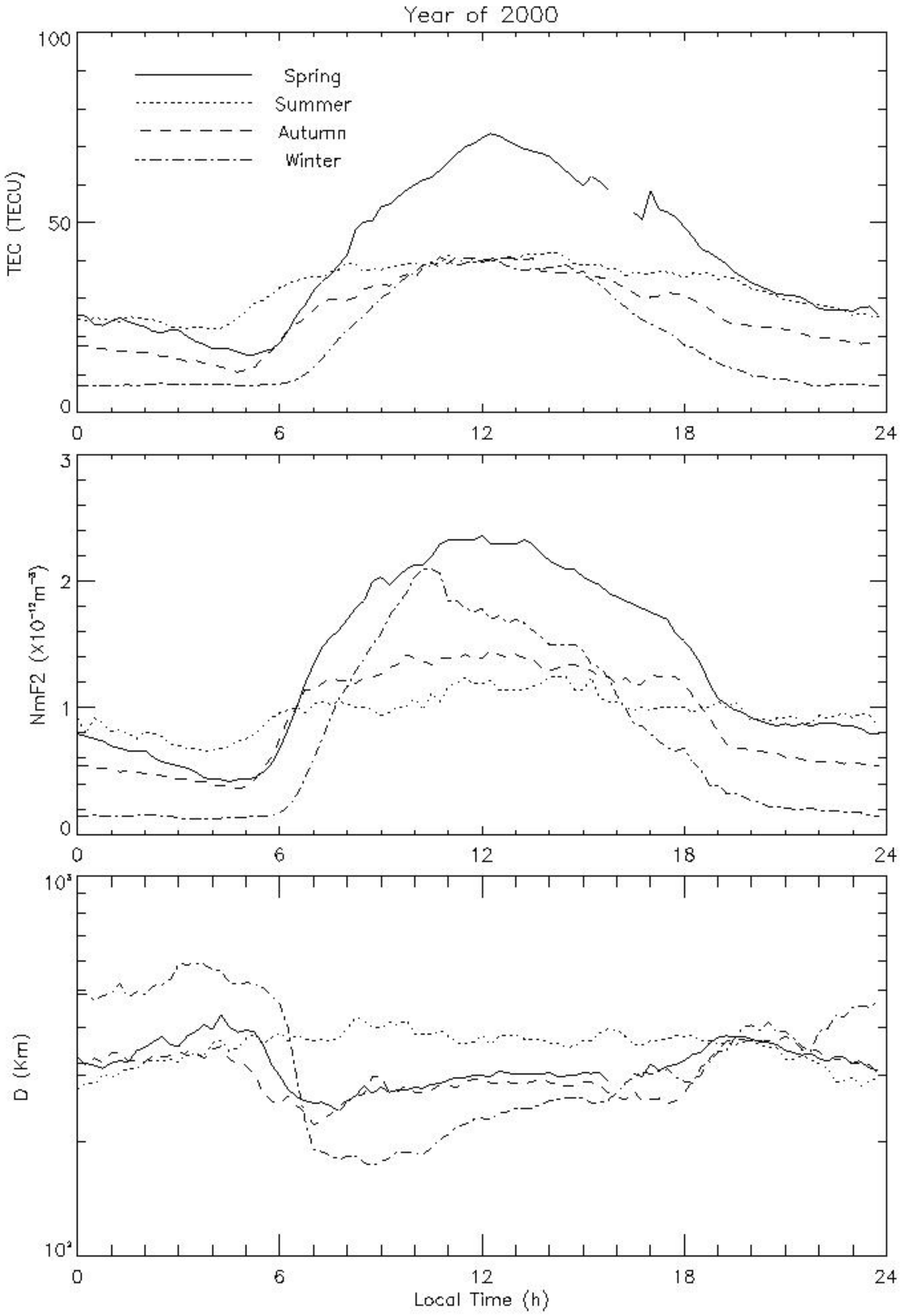

Fig. 2 Ionospheric parameters for the four seasons of 2000.

1999-2001. The slab thickness is linearly correlated with the F10.7. This is especially true in winter. There is also linear correlation between D and MgII, though it is not shown in the paper. NmF2 has a nonlinear correlation with F10.7, but it is linearly correlated with MgII. The TEC is generally correlated with both F10.7 and MgII.

Summary

The slab thickness, D, over Kokubunji was studied for the period of 1999-2001. The main findings can be summarized as: (1) The annual variation of noon D value is in a opposite-phase with the midnight one; (2) D in daytime is larger than that in nighttime in summer; (3) The largest difference of D during winter days can be 400 km; (4) D is linearly correlated with solar activity.

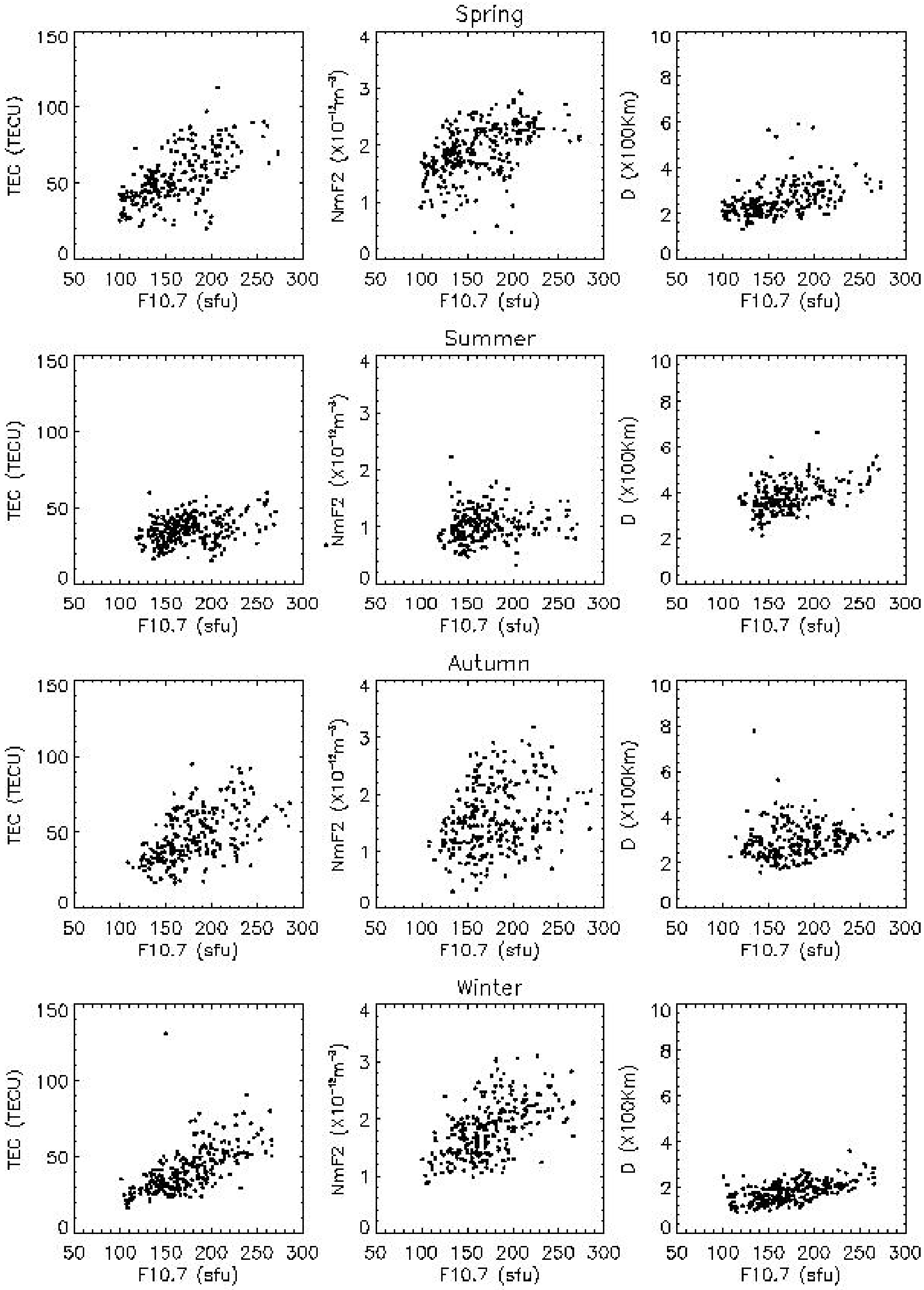

Fig. 3 Ionospheric dependence on solar F10.7.

Reference

[1] B. Jayachandran, T. N. Krishnankutty, and T. L. Gulyaeva, “Climatoligy of ionospheric slab thickness,” *Ann. Geophys.* Vol.22, pp25-33, 2004.

[2] G. Ma and T. Maruyama, “Derivation of TEC and estimation of instrumental biases from GEONET in Japan,” *Ann. Geophys.* Vol. 21, pp2083-2093.