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Seasonal characteristics of F region in lower solar activity period at Zhongshan Station, Antarctica

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Abstract Based on data of Digisonde Portable Sounder-4(DPS-4) in 1995 - 1997, we have analyzed the seasonal variations of F region at Zhongshan Station (69. 4°S, 76. 4°E). During the summer of Zhongshan Station, F region ionization is mainly controlled by the solar ultraviolet radiation. Similar to the phenomena in mid-latitude area, the value f_oF_2 is changed with local time. During equinox seasons, soft electron precipitation from the cusp/cleft region seems significant, f_oF_2 is changed with magnetic local time, and shows the magnetic noon phenomenon. In winter, the effect of the solar radiation on the F region is less than that of summer. Instead, F region is affected by particle precipitation from cusp/cleft region as well as polar plasma convection, therefore, the diurnal variation of f_oF_2 is more complex and shows two peaks. F region occurs all day in summer, and seldom appears at midnight in equinox. In winter, F region shows two minimums, one is at midnight and the other is at afternoon cusp. Further analysis of the F region spread indicates that in winter the aurora oval passes over the Zhongshan Station is at 1100 UT - 1500 UT.

Key words F region, magnetic noon phenomenon, F region irregularity zone, Zhongshan Station.

1 Introduction

Digisonde Portable Sounder-4(DPS-4) (Bible and Reinisch 1978; Reinisch 1986), a fully programmable radar, is a useful ground-based instrument for studying structures and dynamic processes of the ionosphere and magnetosphere. In high latitudes, the vertical sounding data can be used to monitor the feature and position of magnetospheric boundaries mapped down into the ionosphere, the associated particle precipitation zones, the electric current system, and the phenomena associated with the auroral oval.

In high latitudes, the ionograms can show some particular ionospheric structures, e.g. F region magnetic noon phenomena (Titheridge 1976), F region irregularity zone (Pike 1971; Piggott and Rawer 1972), lacuna (Olesen 1975) etc.. In this paper, we use three years (1995 - 1997) data to analyze the mean properties of F region in lower solar activity period at Zhongshan Station.

2 Mean properties of F region at Zhongshan Station

DPS-4 was installed at Zhongshan Station in 1995(Liu et al. 1997a). Its sounding frequency is from 1 MHz to 10 MHz, and observational frequency is 4 or 8 times per hour. The drift measurement is immediately after scanning observations. Magnetic Local Time (MLT) of Zhongshan Station is 2 h earlier than Universal Time (UT), and its Local Time (LT) is 5 h earlier, i. e MLT = UT + 2h, and LT = UT + 5h. From the monthly median values at each hour for 1995 - 1997, we have summarized the mean properties of F region at Zhongshan Station. In this paper, we take December, March and June as summer, equinox and winter month of Zhongshan Station, respectively.

2.1 Seasonal properties of F region

Fig. 1. shows the diurnal variation of f_oF_2 in summer of Zhongshan Station. It is shown that f_oF_2 is mainly affected by solar ultra-violate radiation. In Zhongshan's local noon, i. e. 0700UT, the value of f_oF_2 reaches its maximum. Its day-night difference is about 1 MHz. The F region critical frequencies in 1997 are 1 MHz higher than those in 1995 and 1996. This phenomenon is mainly caused by solar activities. In summer of 1997, the mean sunspot numbers are 41.5. It is only 10.8 and 12.7 in 1995 and 1996 respectively.

In equinoxes, the magnetic noon phenomenon is clearly shown in Fig. 2. f_oF_2 reaches its maximum near magnetic noon, i. e. 1000 UT. This high-latitude magnetic noon phenomenon was first noticed by Oguti and Marubashi (1966). Usually the F region critical frequency increases sharply in several megahertz and may remain 1 - 5 h. The phenomena occur within ± 2 h around local invariant magnetic noon. It is observed most frequently between 74° and 78° invariant magnetic latitude and more pronounced

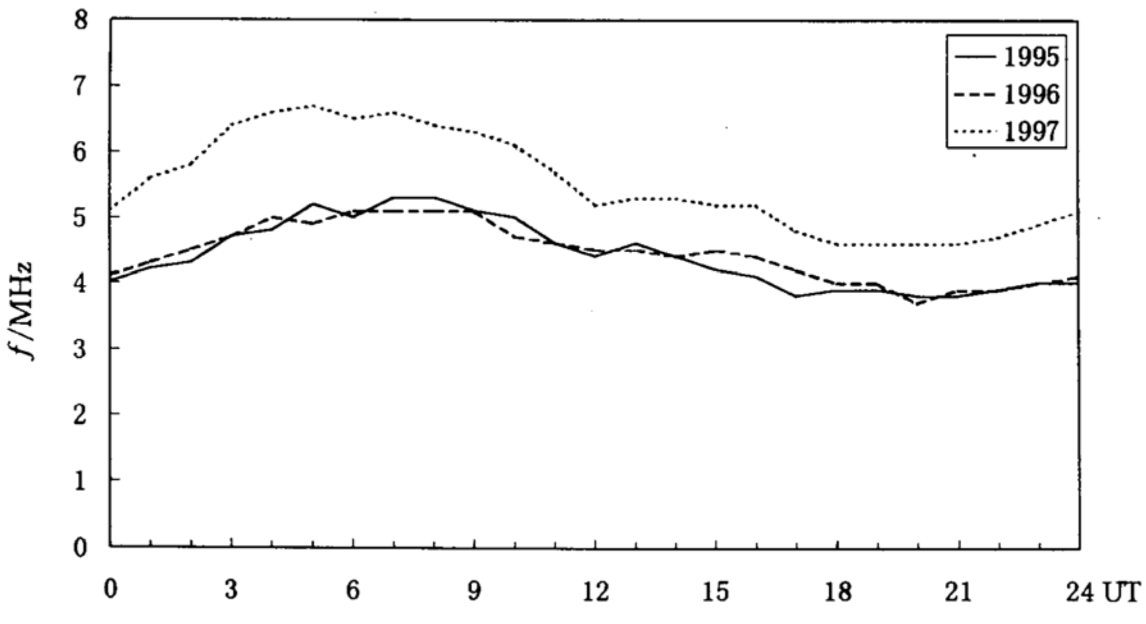

Fig. 1. Diurnal variation of monthly median values of f_oF_2 in summer at Zhongshan Station.

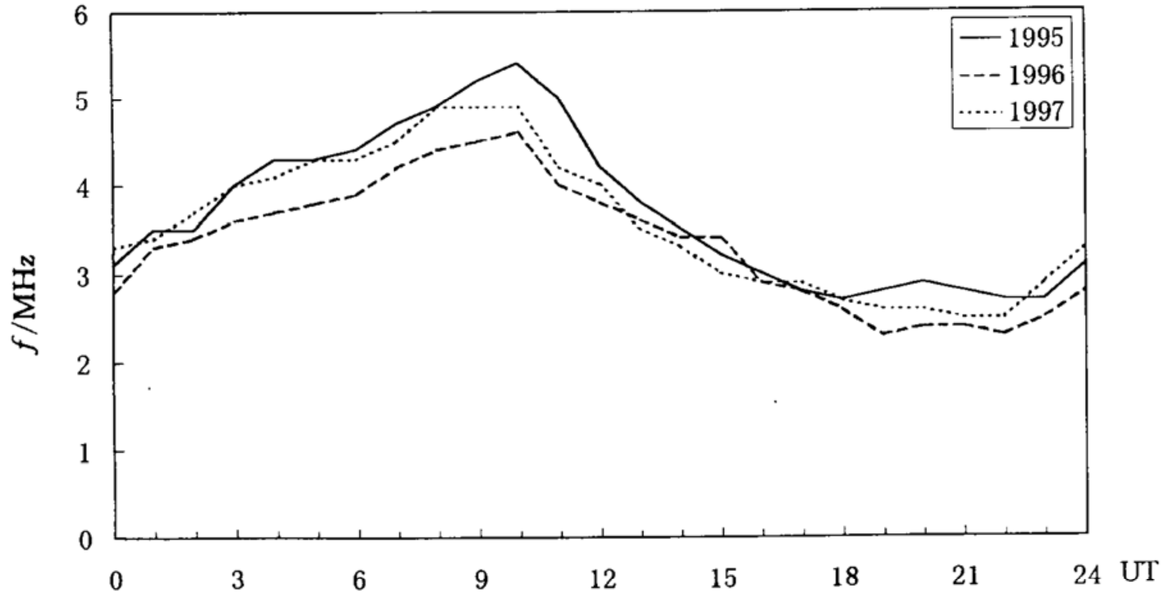

Fig. 2. Diurnal variation of monthly median values of f_oF_2 in equinox at Zhongshan Station.

during the equinoxes. Some evidences show that this increasing of f_oF_2 at magnetic noon is caused by the soft particles with energies less than 1 keV, entering the ionosphere from the magnetospheric cusp/cleft. In equinoxes, the difference of f_oF_2 between day and night is about 3 MHz.

In winter(Fig. 3), f_oF_2 attaind the maximum at 0900 UT, which is just between the local noon and magnetic noon. At 1100 UT, f_oF_2 is fallen in 1.5 MHz, and during 1200 UT – 1500 UT, a second peak appears. These properties have been discussed in our former paper (Liu *et al.* 1997b). From the year of 1996, it is found that this

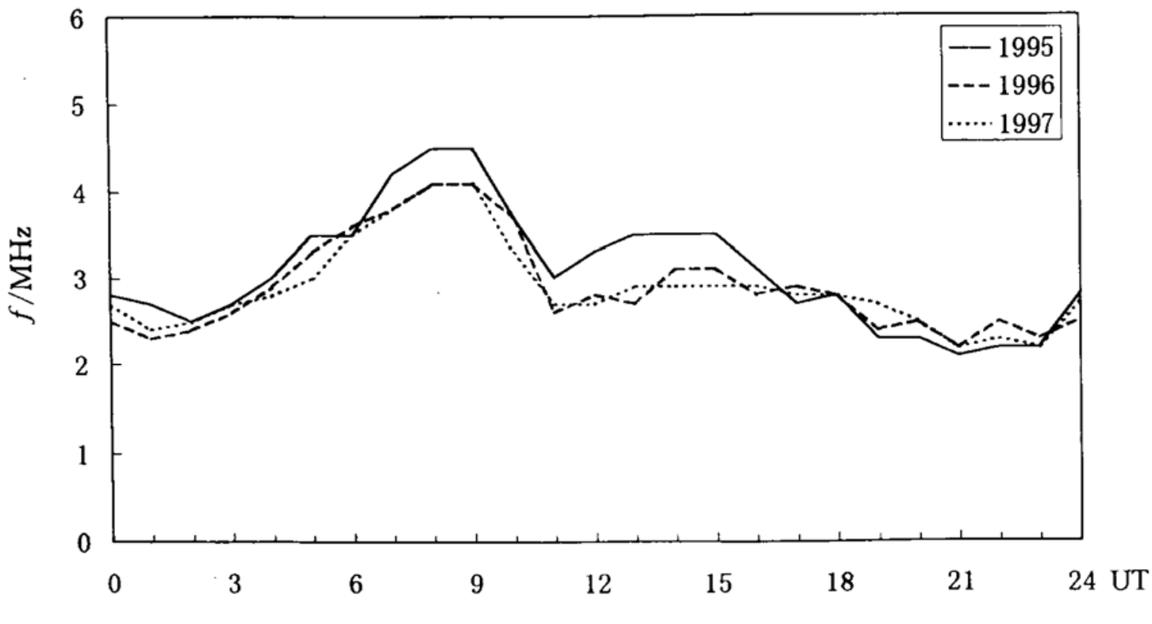

Fig. 3. Diurnal variation of monthly median values of f_oF_2 in winter at Zhongshan Station.

phenomenon occurred from April to August (Fig. 4).

2.2 *The times of F region occurrence*

Fig. 5 shows the statistical results for the f_oF_2 occurrence. In summer, the occurrence of F region is more stable and close to 100%. The probability of F region observation for daytime and nighttime is the same. In equinoxes, only at local midnight the probability is less. In winter, at 1100 UT and 2000 UT, the probability is only 45% and 38%, respectively. We think that the latter time interval is referred to the polar hole (Briton *et al.* 1978), and the former is associated with high latitude trough (Rodger *et al.* 1992).

2.3 *Spread F and location of aurora oval*

It is generally agreeded that the most useful indication of the position of the aurora oval by using ionograms is the presence of relatively low F traces, which can extend to much higher frequencies with strong spread. Zhongshan Station (74.5°Λ) approach from equatorward to the morning sector of aurora oval, and polarward to the afternoon sector. At these periods, ionograms are often expected to show polar spurs and spread F echoes instead of normal ionograms. In our analysis, we use $f_s=(f_xI-f_oF_2)$ as a parameter to investigate the time of aurora oval passing over Zhongshan Station. Fig. 6 shows the diurnal variations of monthly median values of f_s in June for different years. It is shown that F echoes are spread seriously between 1100 UT and 1500 UT in winter. We think the stable spread f_s is caused by auroral oval, and at that time interval Zhongshan Station is beneath auroral oval.

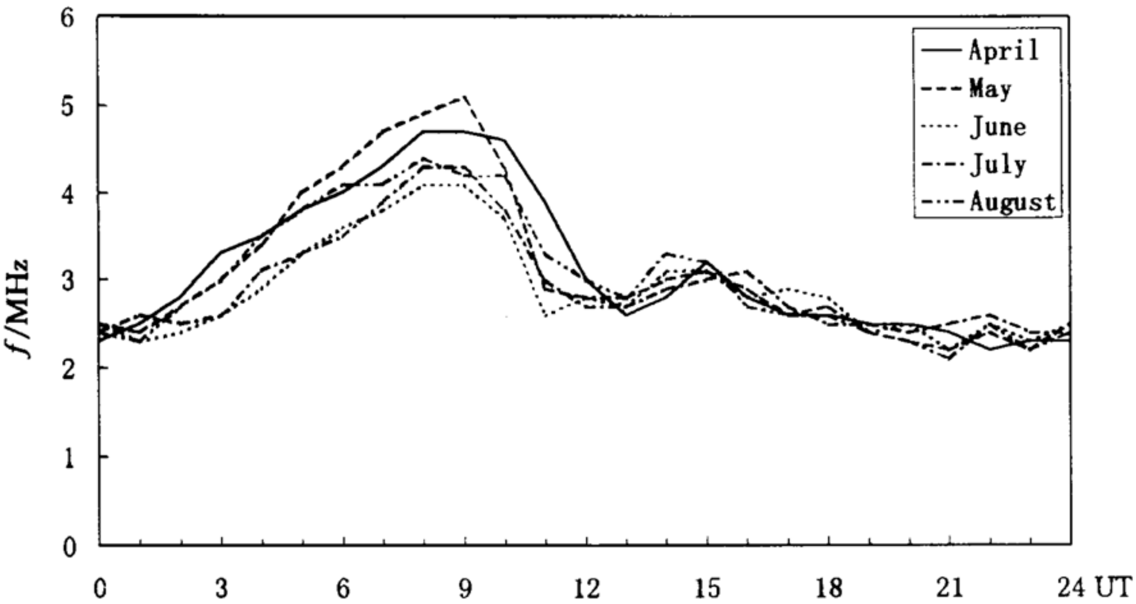

Fig. 4. Diurnal variation of monthly median values of f_oF_2 from April to August in 1996 at Zhongshan Station.

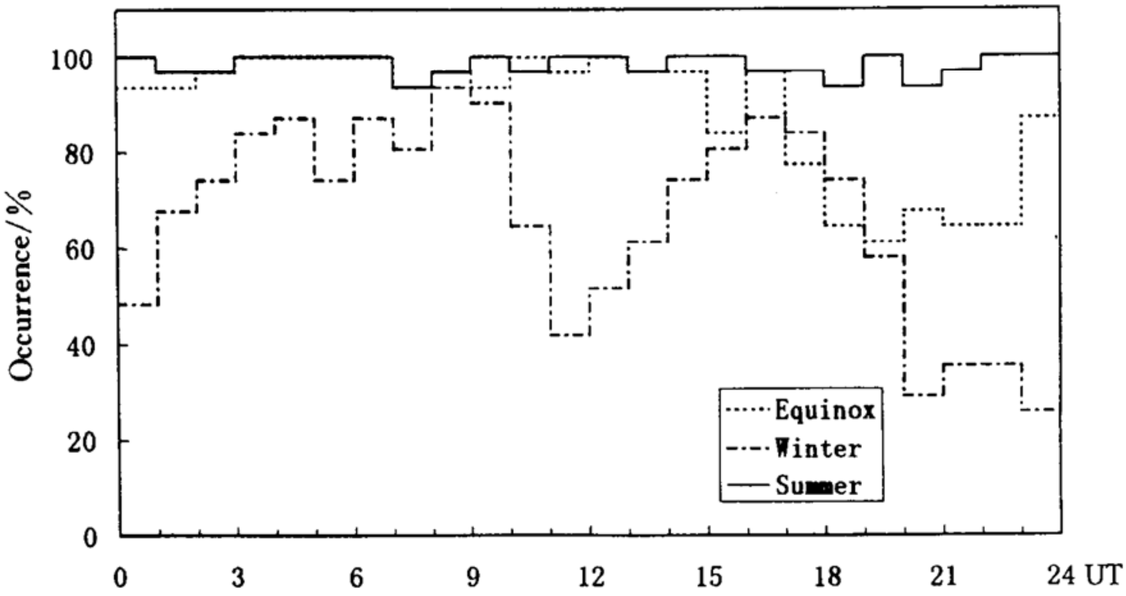

Fig. 5. Occurrences of F region in summer, equinox and winter in 1996.

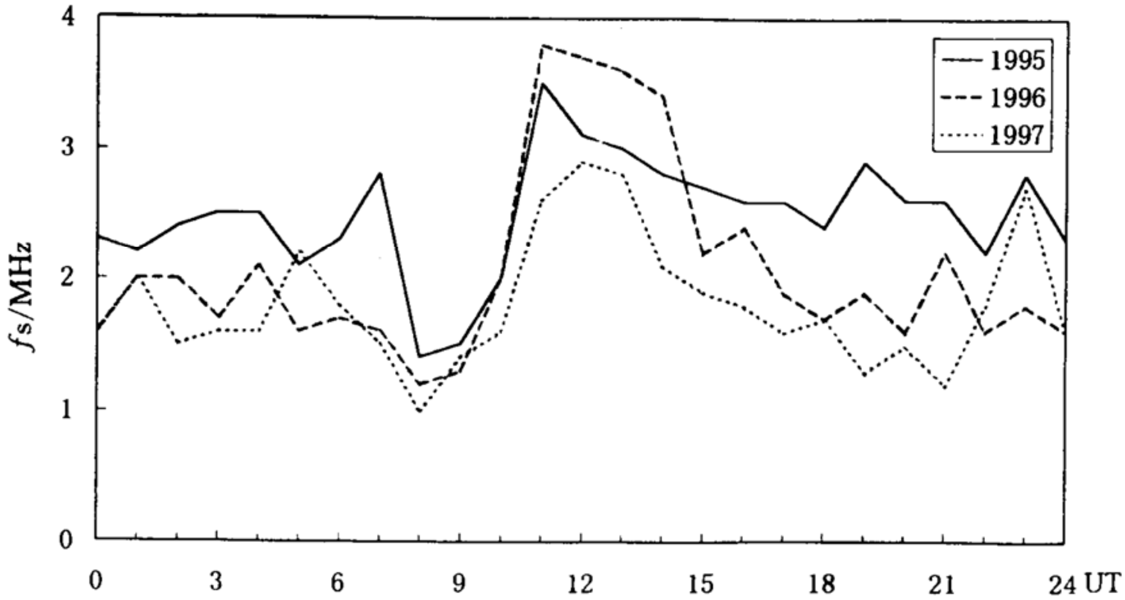

Fig. 6. Diurnal variation of monthly median values of $f_s = f_x I - f_o F_2$ in winter.

3 Discussion and conclusions

The maximum of F region critical frequency appears at local noon in summer. This seems reasonable because that F region ionization is mainly affected by the solar ultraviolet radiation.

The magnetic noon phenomena can be seen clearly in the variation of $f_o F_2$ in equinox seasons. So the soft electron precipitation dominated the F region ionization around the magnetic local noon of Zhongshan Station.

In winter, two peaks appear in the diurnal variation of f_oF_2. One peak locates between the local noon and magnetic local noon, that means the soft particle precipitation still dominates this region. In 1100 UT, F region critical frequency is reduced to 2.5 MHz, and at that time the occurrence of F region also has a minimum. It shows a high-latitude trough exists in this region. The main reason forming trough is caused by the high relative ion-neutral velocity (Lockwood *et al.* 1987). The plasma will be depleted via ion outflows and by increasing the ion-neutral loss reaction rates. The minimum of occurrence of F region appeared at midnight is caused by polar hole of southern polar cap.

From the analysis of spread F region, we found auroral oval is at overhead of Zhongshan Station at 1100 UT - 1500 UT.

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