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Mean ionospheric properties in winter at Zhongshan Station, Antarctica*

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Abstract Ionograms taken from a Digisonde Portable Sounder (DPS-4) at Zhongshan Station of Antarctica in 1995 are used to analyse the mean ionospheric properties in winter. The F region is rather unstable in winter and has large diurnal variation. The monthly medium value of f_oF_2 has a main peak around 0900UT when maximum value occurs and a sub-peak between 1300 - 1500UT. It may be affected synthetically by the low energy electron precipitation in cusp region, the high latitude plasma convection and the solar radiation, resulted in so called F region magnetic noon phenomena. Low values of f_oF_2 occur in post-midnight (2000 - 0100UT) when Zhongshan Station crosses the ionospheric polar hole. Sporadic E layer which caused mostly by auroral particle precipitation can be observed almost every day with the highest value of f_oE_s around 1700UT. The diurnal variation of E layer is relatively smooth.

Key words high latitude ionosphere, magnetic noon phenomena, plasma convection, polar hole, Zhongshan Station.

1 Introduction

Ground-based ionospheric observations at high-latitude play a major role in the study of magnetospheric phenomena. Ionograms can be used to study any of the magnetospheric phenomena which affect the ionosphere (Dudeney and Piggott 1978). The collection of typical high-latitude ionograms provides a sound basis for recognizing the characteristic ionogram patterns. Ionograms observed at Zhongshan Station have shown a number of high-latitude phenomena. They are auroral oval phenomena, FLIZ phenomena, slant E_s phenomena and lacuna, F region magnetic noon phenomena, and particle precipitation effects in the E region (Cao *et al*. 1995).

A digisonde Portable Sonder (DPS-4) has been in operation since January 1995 at Zhongshan Station in Antarctica. In this paper ionograms of May, June and July 1995 are used to study the mean ionospheric properties in winter at Zhongshan Station.

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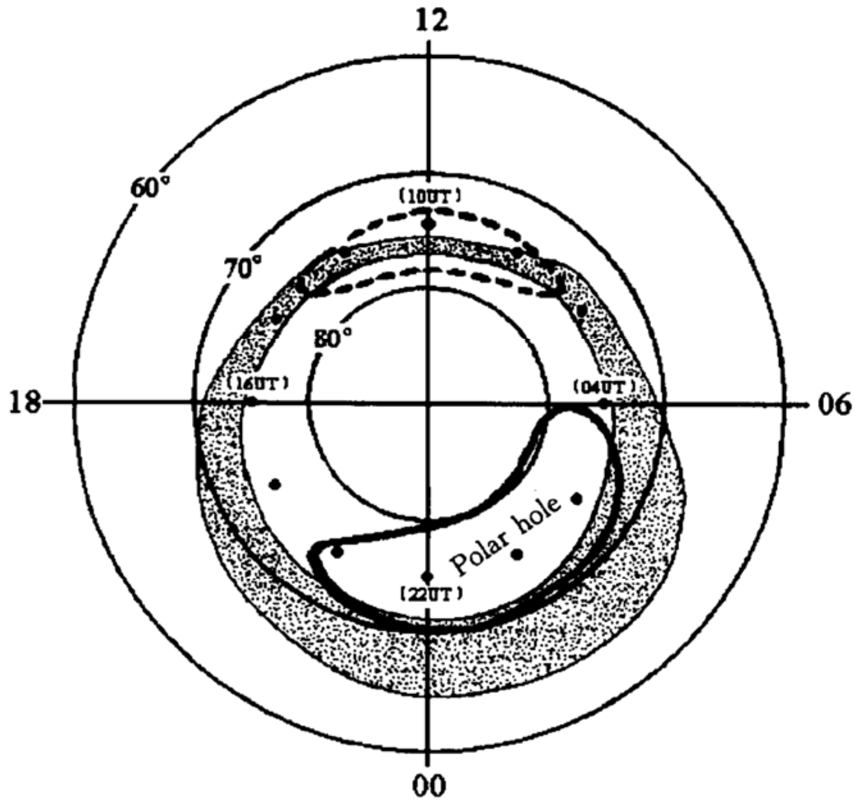

Fig. 1. Approximate locations of Zhongshan Station (black points) relative to the auroral oval (Q=3) and ionospheric polar hole (Crowley *et al.* 1993). The coordinate system is CGLT (Corrected Geomagnetic Latitude and magnetic local Time). A region of intense low-energy electron precipitation centred on magnetic noon is outlined by a dashed line.

2 Data acquisition

Zhongshan Station has an ideal place for upper atmospheric physics study. It locates in the polar cap region during night, where the energetic particles precipitation causes ionospheric disturbance. Near the geomagnetic local noon, Zhongshan Station locates in the cusp region where the solar wind directly affects on the ionosphere. The approximate locations of Zhongshan Station in relation to the auroral oval (Q=3) and ionospheric polar hole (Crowley *et al.* 1993) are shown in Fig. 1. The key parameters of Zhongshan Station are listed as following. Geographic location: 69.4°S, 76.4°E, LT≈UT+5h; Geomagnetic coordinates: 77.2°S, 120.5°E; Invariant latitude: 74.5°, L=13.9, MLT≈UT+2h.

The DSP-4, developed by the University of Massachusetts Lowell Center for Atmospheric Research (ULCAR), is a pulse HF Doppler radar controlled by a computer. It can measure the amplitude, phase, time delay, frequency, Doppler shifts, angle of arrival and wave polarization from ionospheric echoes. The digital raw data, which are stored in a quarter-inch cartridge, can be used to study several frontiers, such as ionospheric structures and dynamics, ionospheric irregularities and plasma convection, polar ionosphere-magnetosphere coupling. At Zhongshan Station, the DPS-4 runs 8 times per-hour, each time can obtain both scanning ionogram and drift measurement (Liu *et al.* 1995).

3 Mean ionospheric properties

By scaling and processing the ionograms from May 1 to July 31, 1995, the diurnal variations of monthly medium values of f_oF_2, f_oE_s and f_oE in May, June and July 1995 at Zhongshan Station are shown in Fig. 2.

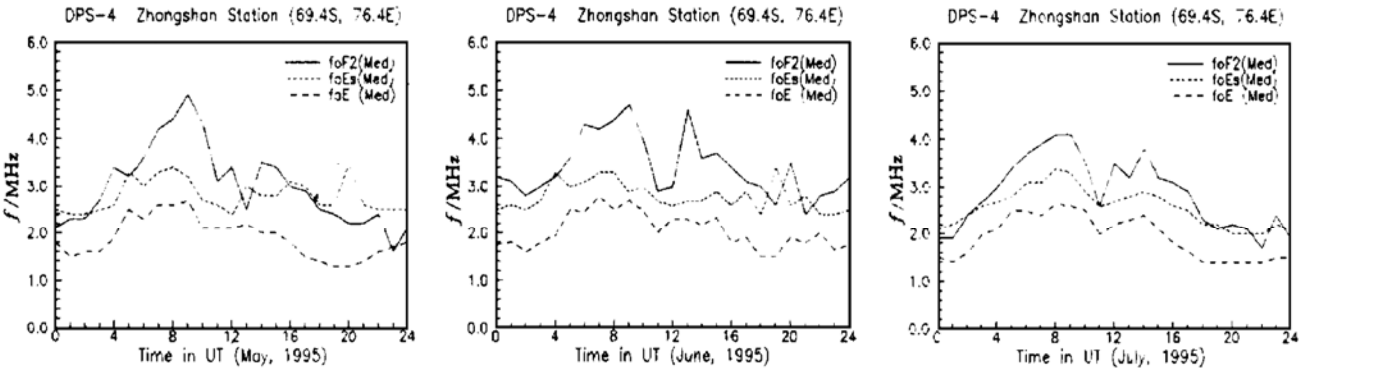

Fig. 2. Diurnal variations of monthly medium values of f_oF_2, f_oE_s and f_oE in winter at Zhongshan Station.

3.1 *Ionospheric F region*

In austral winter, there is large diurnal variation in ionospheric F region which is formed irregularly and unsteadily over Zhongshan Sation. F region can be observed more often in 0300 – 1100UT and 1400 – 1800UT, while it occurs less between 2000UT to 0100UT. Table 1 gives the days when F region was observed on different UT hour in May, June and July, 1995 at Zhongshan Station.

Table 1. Times of F region being observed in May, June and July, 1995 at Zhongshan station

UT	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
May	4	10	10	19	16	15	23	18	24	27	27	18	9	12	12	17	17	9	10	7	5	2	1	1
June	10	13	15	16	17	14	19	16	19	24	23	12	7	6	9	13	13	13	16	13	5	4	1	8
July	3	3	10	13	13	15	23	20	21	25	23	11	4	5	8	18	16	17	17	11	6	7	1	1

The diurnal variation of f_oF_2 is evident. From Fig. 2 it can be seen that each diurnal variation curve of monthly medium values of f_oF_2 has a main peak around 0900UT and a sub-peak between 1300 – 1500UT. The diurnal maximum value occurs near 0900UT which is close to 1200MLT, the geomagnetic local noon. The decrease of these curves after the maximum value is more rapid than the increase phase. The diurnal minimum value occurs between 2000 – 0100UT.

3.2 *Ionospheric sporadic E layer*

Sporadic E layer can be observed almost everyday in winter at Zhongshan Station. Fig. 3 shows the diurnal variation of monthly medium, upper quartile (UQ) and upper decile (UD) values of f_oE_s in May, June and July 1995. For the upper decile values of f_oE_s, there is a peak between 1500 – 2100UT. For the upper quartile values, the peak occurs around 1800UT, showing the pre-midnight enhancement of f_oE_s.

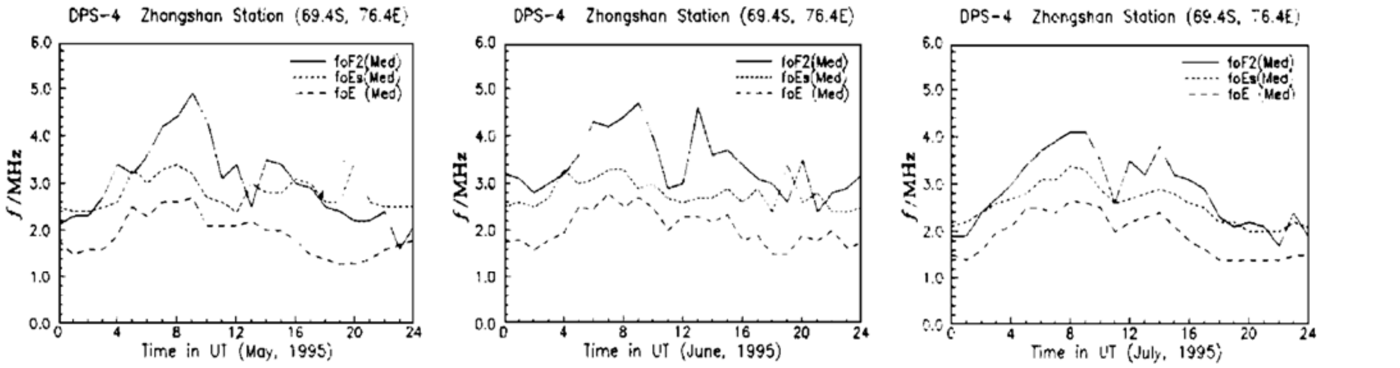

Fig. 3. Diurnal variations of monthly medium, upper quartile and upper decile values of f_oE_s in winter at Zhongshan Station.

3.3 Ionospheric E region

The E region is relative stable and is formed rather regularly in winter. From Fig. 2 it is known that each curve of the monthly medium values of f_oE has a maximum value around 0800UT and a minimum value around 1900UT.

4 Discussion

The production process is primarily photo-ionization of oxygen atoms and nitric oxide molecules by solar ultraviolet radiation and X rays. At high latitude, however, a further important source of ionization is due to the influx of energetic particles (a few electron volts to about 50 keV) from the magnetosphere and magnetosheath, which causes secondary ionization due to collisions with the neutral gas. The height range affected by such particles depends upon their energy. Particles having energies of less than about 1 keV contribute to F region ionization, while those having higher energies affect the lower ionosphere (D and E regions).

In general, at Zhongshan Station the diurnal peak value of f_oF_2 is affected synthetically by the low energy electron precipitation in cusp region, the solar radiation and the high latitude plasma convection. The sun is below the horizon almost through all the winter at Zhongshan Station, the effect of solar radiation is relative weak. Solar radiation is not the main factor in winter so that a smooth variation of f_oF_2 with solar zenith angle can not be seen distinctly in Fig. 2, and around the solar local noon which is equal to 0700UT, the maximum value does not occur. For the large value of f_oF_2 near the magnetic local noon which is equal to 1000UT, low energy electron precipitation in cusp region is the main factor, resulted in so called F region magnetic noon phenomena. Studies of the fluxes of electrons and protons at energies less than 1 keV provide direct evidence that solar wind plasma enters the earth's atmosphere through the high-latitude cusp in the magnetosphere and reaches the ionosphere at invariant magnetic latitudes between 70° and 80° (Heikkila and Winningham 1971). Zhongshan Station locates in this region. This additional ionization is sufficient to increase the value of f_oF_2.

The occurrence of the sub-peak of f_oF_2 is effected probably by the auroral particle precipitation and eastward zonal electric field. During 1200 – 1500UT, Zhongshan Station locates under the auroral oval where the electron density of E region may enhance by the influence of auroral particle precipitation. This region also exits the eastward electric field so that plasma may be drifted upward. F-region plasma enhancements can be observed.

According to the representative plasma drift configurations (Heppner and Maynard 1987), plasma drifts from the day side of the earth across the polar cap, to the midnight side, then return on either side of the polar cap. Under magnetic quite and solar minimum winter conditions, an F region depletion known as the the ionospheric polar hole develops in the dawn sector in a region where plasma is trapped in the polar cap on a confined trajectory and does not receive either solar illumination or ionizing particle precipitation. In this region the antisunward convection speed was approximately equal and opposite to the corotation speed, and the plasma therefore moved extremely slowly in the solar-inertial reference frame. The deepest depletion occurs in a location where plasma took about 1 day to convect around a trajectory of a few degrees in diameter (Sojka *et al*. 1981). The hole is characterized by depletions in all the measured ion densities and by a minimum in electron temperature. The total ion concentration measured in the polar hole reaches values as low as 2×10^2 cm^{-3} and is extremely variable in time (Brinton *et al*. 1978). Studies by using data from the AE-C satellite (Brinton *et al*. 1978) and the ground-based observatories (Crowley *et al*. 1993) illustrate that ionospheric polar holes tend to develop on the nightside from 2100 – 0600MLT between 70°– 80°Λ during solar minimum winter conditions. Figure 1 shows the approximate locations of Zhongshan Station relative to the polar hole in CGLT coordinates. During 2000 – 0100UT, Zhongshan Station locates in polar hole. Therefore low values of f_oF_2 can be seen during these time as shown in Fig. 2, and fewer times of F region can be observed as shown in Table 1.

At Zhongshan Station, most of the sporadic E is of the auroral type. It occurs when the particle precipitation is varing rapidly in space and time and, as its name implies, is closely associated with the presence of active auroral. The diurnal upper decil value of f_oE_s at Zhongshan Station has a pre-midnight of CMLT enchancement. It may be caused by the secondary ionization of the auroral particles which penetrate into the E region.

5 Summary and conclusions

The mean ionospheric properties in winter at Zhongshan Station are summarized as following:

(1) F region magnetic noon phenomena exists in winter at Zhongshan Station.

The diurnal peak value of f_oF_2 near 0900UT is probably affected synthetically by the low energy electron precipitation in cusp region, the solar radiation and the high latitude plasma convection. Soft energy electron precipitation in cusp region is the main factor.

(2) The occurrence of the sub-peak of f_oF_2 between 1300 – 1500UT is affected probably by the auroral particle precipitation and eastward zonal electric field. Auroral F-region plasma enhancements can be observed.

(3) During 2000 – 0100UT fewer times of F region were observed and low values of f_oF_2 occured which verify the existence of the ionospheric polar hole.

(4) Most of the sporadic E in winter is of the auroral type at Zhongshan Station. It may be caused by the secondary ionization of the auroral particles which penetrate into the E region.

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