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Analysis of the ionospheric anomaly at Great Wall Station, Antarctica*

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Abstract In this paper, we use an empirical method to derive the height of maximum electron concentration of the F_2 region and the effective meridional neutral wind at Great Wall Station, Antarctica. The meridional wind is also calculated with the HWM-90 model. Results can be used to explain two anomaly features of ionosphere at Great Wall Station. In summer, peak values of f_0F_2 appear during nighttime. In winter, especially during June and July, f_0F_2 decrease dramatically as compared with summer's one.

Summer anomaly can be explained by combining effects of two causes: thermospheric winds and solar radiation. An important reason for the anomaly is the location of Great Wall Station, which is in both high geographic latitude and middle geomagnetic latitude.

Key Words neutral wind, critical frequency, summer anomaly

1 Introduction

Summer anomaly of the ionosphere at Great Wall Station has been reported (Cao *et al.*, 1992). Thermospheric wind play an important role in determining the anomaly features of f_0F_2 diurnal variation. In this paper, we use an empirical method to derive the effective meridional neutral wind at Great Wall Station. Then predicted values of the meridional wind at Great Wall Station are also calculated using the HWM-90 model. The effects of neutral wind and global circulation on ionospheric anomaly are discussed.

2 Method

The electron concentration in F layer depends upon a number of factors, such as the rate of electron production q, electron loss coefficient β, plasma transport velocity due to neutral wind, electric fields and plasma diffusion. Since Great Wall Station is located in middle geomagnetic latitude, effects of the neutral wind shoud be considered first. Ionospheric plasma can be driven down or up along the magnetic lines depending on the direction of neutral wind. It results in ascent or descent of the height of the maximum electron concentration.

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Ionosonde records give useful informations about the state of the ionosphere. The height of the maximum electron concentration h_mF_2 and the effective meridional neutral wind dV are derived using an empirical model (Miller *et al.*, 1986; Forbes *et al.*, 1988). Hourly values of f_0F_2, $M(3000)$ F_2 and f_0E are used to determine h_mF_2 in this empirical model.

$$h_mF_2=\frac{1490}{M(3000)F_2+\Delta M}-176 \qquad \text{(km)}$$

$$\Delta M=\begin{cases}0.18/(X-1.4) & X>1.7\\ 0 & X\leqslant 1.7\end{cases}$$

where $X=f_0F_2/f_0E$;

$M(3000)F_2$ is factor of Maximum Usable Frequency;

f_0F_2 is critical frequency in the F_2 region;

f_0E is critical frequency in the E region.

An effective meridional neutral wind dV (positive equatorward in m/s) is computed from h_mF_2 using the following formula:

$$dV=(h_mF_2-h_0)/a \qquad \text{(m/s)}$$

where $a=2\{1+0.25\cos[3.14\times(t-14)/12]\}\sin I\cos I$;

t=local time in hours;

I=magnetic dip angle;

h_0 is the reference value of h_mF_2, it is computed using an ionosphere model (Miller *et al.*, 1986).

This derivation neglects the effects of electric field on the F layer. We will compare the results of this derivation with the predictions of the HWM-90 model. Normally, monthly mean values of ionosonde data are used. Hence, monthly mean variation of neutral winds are discussed here. One year's data from Great Wall Station in 1988 are used in this study.

3 Results

The diurnal and seasonal variation of f_0F_2 at Great Wall Station and Horbart in 1988 are shown in Fig. 1. Middle level of solar activity was observed in this yerar. The two stations are located in similar geomagnetic latitudes. Generally mid-latitude-like feature has been observed at Horbart. Summer anomaly has been found at Great Wall Station, where peak values of f_0F_2 appear during nighttime, instead of around noon. This feature can be explained by combining effects of two competing causes: neutral winds and solar effects on ionosphere.

In Fig. 2 the diurnal and seasonal variation of the height of maximum electron concentration h_mF_2 and neutral wind dV at Great Wall Station are presented. The results are computed using the empirical modal described above. Fig. 3 illustrated the predictions

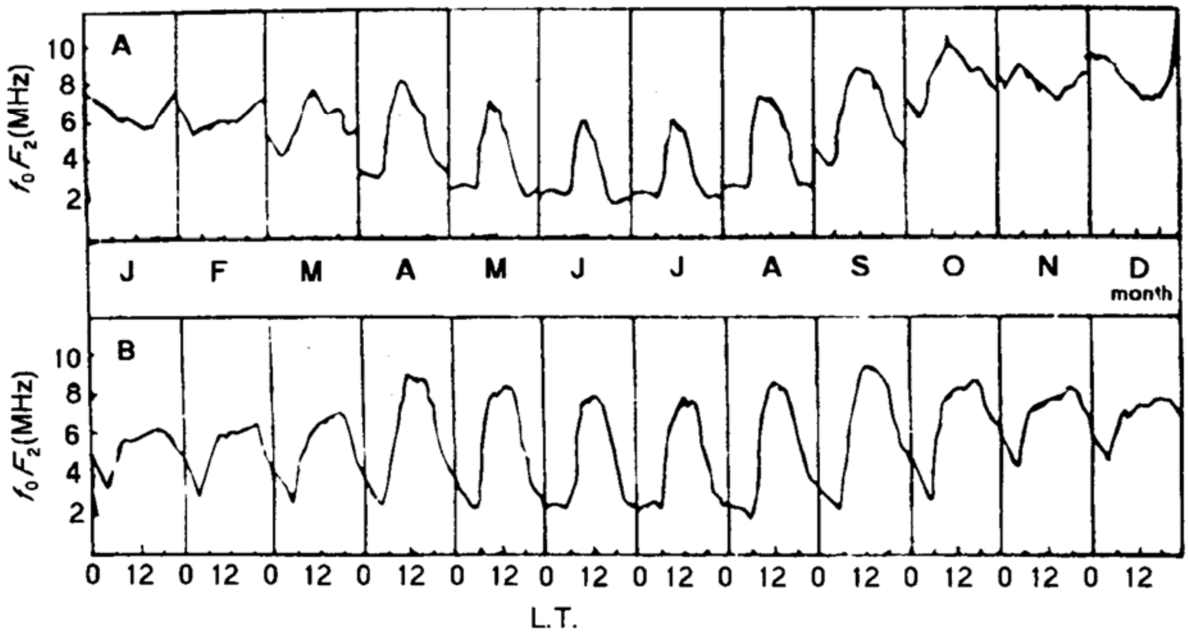

Fig. 1. Diurnal and seasonal variation of f_0F_2 at Great Wall Station (A) and Horbart Station (B) in 1988.

of the meridional wind at Great Wall Station in 1988 using the HWM-90 model. The difference between the predictions and empiricial values of the wind is obvious in summer. From Fig. 2a the variation of h_mF_2 in summer is higher than the variation in winter. This may be related to the influence of the global circulation of the thermospheric wind. It is obvious from Fig. 2 and Fig. 3 that equatorward winds are dominant at night and poleward winds are dominant in the daytime.

We can give a physical interpretation of the summer anomaly. In F_2 layer, electron concentration is determined by the q/β and transport term. In middle geomagnetic latitude region the transport term does not dominate at the F_2 peak. This means that the changes in N_mF_2 are largely determined by local changes in the production and loss terms. The term q/β is a rough estimate of the changes in N_mF_2. The geographic latitude of Great Wall Station is high (62°12′S), and in summer the difference of solar radiation between daytime and nighttime is not large enough. So the difference of factor q between daytime and nighttime is not large enough. Hence the changes of N_mF_2 are affected mainly by the changes of factor β at Great Wall Station. Factor β depends both on the concentration of neutral gases η and on the neutral wind. The values of η during daytime is higher obviously than nighttime . During nighttime β decreases with the decrease of η. At the same time the night's equatorward winds can elevate the the F layer peak to the regions of lower chemical loss. Thus β decreases during nighttime at Great Wall Station. Therefore an enhancement in peak plasma density appears during nighttime in summer. During daytime, increased η and poleward winds result in a reduction in peak plasma densities.

In other seasons, the difference of the solar radiation between daytime and nighttime is large. Consequently, the difference of q between daytime and nighttime is large. Hence, q is a dominant factor resulting in a reduction in peak plasma densities during nighttime, an enhancement in peak plasma densities during daytime.

In winter, generally mid-latitude-like feature has been observed at Hobart. The variation of f_0F_2 in winter is higher than that in summer. The reason is that global circulation transport the gases from summer hemisphere to winter hemisphere. The neutral gases are ionized on the way. Thus, the electron concentration of F layer increase in middle latitude region in winter.

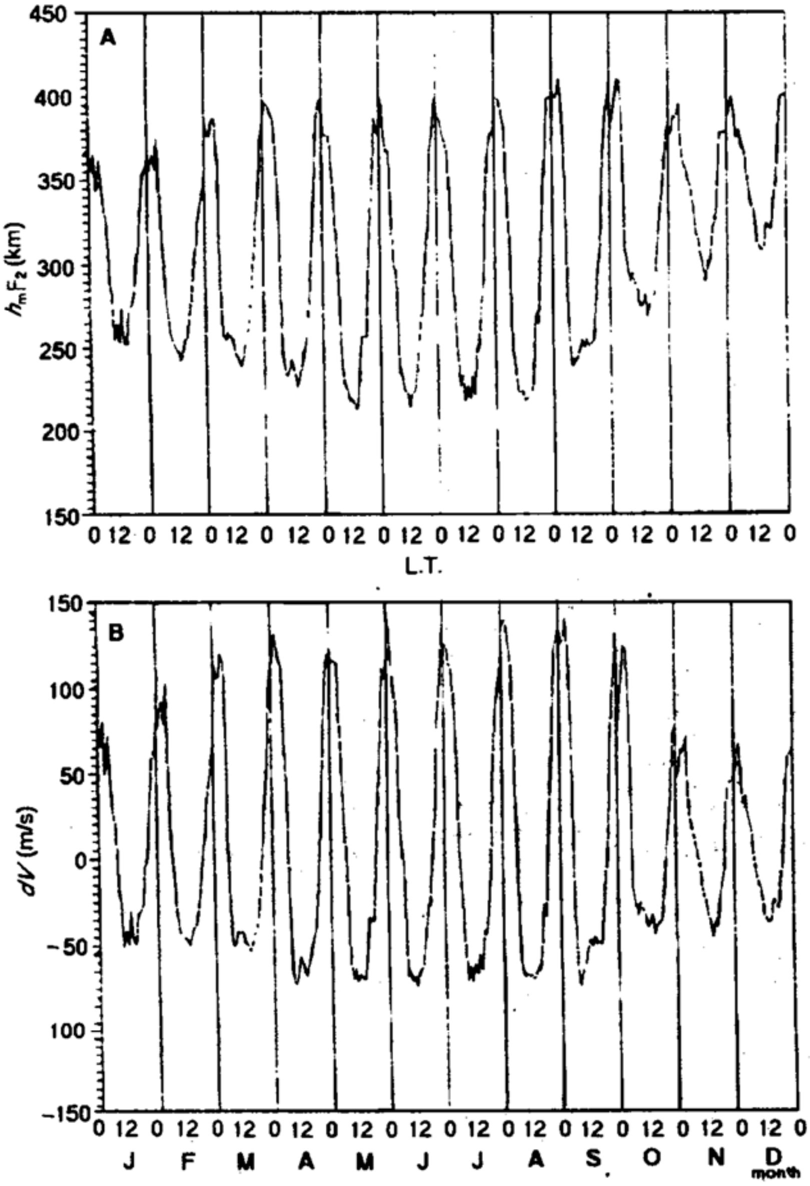

Fig. 2. Diurnal and seasonal variation of the h_mF_2(A) and neutral winds dV (B) at Great Wall Station in 1988.

Another difference of f_0F_2 variation between Great Wall Station and Hobart is shown in Fig. 1. The f_0F_2 values in winter are lower than that in summer at Great Wall Station. One interpretation to this feature can be given. Since Great Wall Station is located in geographical high latitude region, the difference of solar radiation between summer and winter is very large. It cause large difference of electron concentration between summer and winter. The effect of global circulation on electron concentration is not as important as that in geographical mid-latitude region.

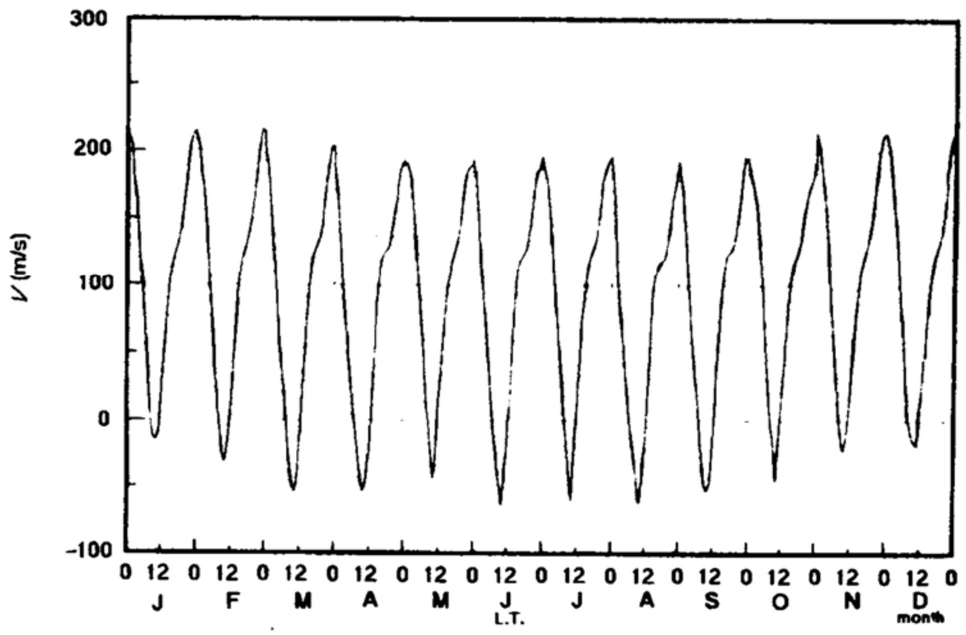

Fig. 3. Variation of the predictions of the HWM-90 model in the meridional wind at Great Wall Station in 1988.

4 Conclusion

We have used an empirical method to obtain height of the maximum electron concentration of F_2 region and the meridional neutral wind at Great Wall Station. The results of meridional neutral wind have been compared with the predictions of the HWM-90 model.

There are two anomalies of f_0F_2 diurnal variation at Great Wall Statioin as compared with mid-laditude-like features. In summer, f_0F_2 peak values appear during nighttime. In winter, f_0F_2 decrease dramatically as compared with summer's one. These anomalies could be explained by combining effects of solar radiation, neutral wind and global circulation. Great Wall Station is in both high geographic latitude and middle geomagnetic latitude. This is an important reason resulting in the aforementioned ionospheric anomalies.

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