

Propagation characteristics of the Pc3 frequency range pulsations in the cusp latitudes

Liu Yonghua (刘勇华)¹, Liu Ruiyuan (刘瑞源)¹, Yang Shaofeng (杨少峰)², He Longsong (贺龙松)¹ and B. J. Fraser³

1 *Polar Research Institute of China, Shanghai 200129, China*

2 *Institute of Geology and Geophysics, Chinese Academy of Sciences, Beijing 100101, China*

3 *University of Newcastle, Newcastle 2308, Australia*

Received September 6, 1999

Abstract Two induction magnetometers have been installed at Zhongshan Station and Davis Station, Antarctica respectively. We adopt with cross-spectral analysis technique to analyze the data of the two induction magnetometers, in June, September, December 1996 and March 1997, to investigate the Pc3 frequency range pulsation occurrence and propagation characteristics in the cusp latitudes. The results are summarized as following: At Zhongshan-Davis Stations, the Pc3 frequency range pulsations occur mainly around the local noon/ local magnetic noon and local magnetic midnight respectively. In daytime, the pulsations have a seasonal variation in amplitude, occurrence and temporal range, all of them are smallest in winter. But in nighttime, the pulsations have no such a variation. The pulsation amplitude in nighttime is much larger than the one in daytime all over the year. The pulsation propagating direction is mainly western in daytime and irregularly in nighttime. It can be thought that the different sources of the pulsation and the ionospheric electric conductivity are mainly responsible for these characteristics.

Key words Pc3 frequency range pulsation, cusp latitude, propagation.

1 Introduction

The cusp region is a key area in coupling between the Earth's magnetosphere and ionosphere. ULF plasma waves play an important role during these coupling processes. To study and detect their sources and propagation characteristics would be helpful for understanding the coupling processes.

The Pc3 pulsation is found frequently in the cusp region around local noon and in nighttime respectively. Investigating the meridional distribution of Pc3 amplitude in the high-latitude region, it is found that the maximum of the Pc3 amplitude coincides with the position of the daytime cusp (Bolshakova and Troitskaia 1984). Single site measurements or case studies on Pc3 in the cusp region are also reported (Morris and Cole 1987).

Both Chinese Zhongshan Station (G. Lat. 69. 37°S, G. Long. 76. 38°E; M. Lat. 77. 2°S; INT. Lat. 74. 5°S; L=13. 9) and Australia Davis Station (G. Lat. 68. 58°S,

G. Long. 77. 97°E; M. Lat. 76. 8°S; INT. Lat. 74. 5°S; L=13. 8) are located at the cusp latitude that is favorable to observe solar-terrestrial phenomena in high latitude. An induction magnetometer has been installed successfully in January 1996 at Zhongshan Station, Antarctica under the collaboration between Polar Research Institute of China, University of Newcastle and Australia Antarctic Division. An identical induction magnetometer had been installed at Davis Station earlier. The two induction magnetometers constitute a short-baseline to investigate ULF plasma waves in the ionosphere/ magnetosphere.

The magnetometer is controlled by personal computer and the data are recorded automatically. The time accuracy between the two magnetometers can reach 1 ms through the advance embedding time board and the GPS receiving system (Fraser *et al.* 1991). During southern hemisphere winter of 1992, Australian deployed a temporary array of induction magnetometers at Law Base and a Plateau site respectively for two weeks, which constituted a equal-side triangle with the induction magnetometer at Davis Station. Law Base is very close to Zhongshan Station with a distance of 4 km. Based on the collected data, the Pc1-2 pulsations at southern cusp/cleft latitude were studied (Neudegg *et al.* 1995).

In this paper we study the propagation characteristics of the Pc3 frequency range pulsation in the cusp latitude by using the coordinated data from Zhongshan Station and Davis Station.

2 The method for data analysis

We use two methods to process the data and find that the results are consistent fundamentally. One is using Digital Fourier Transform method to calculate spectral and then select pulsation events in Pc3 band with power peak 6 times more than background level (Nose *et al.* 1998). The other is using filter technique to select pulsation events (Yang* 2000). Hanning window is adopted here. The window width is chosen as twenty minutes, covering 600 digital points for 0.5 Hz sampling frequency. Four months' data were selected. They are March 1997 and June, September and December 1996, representing austral autumn, winter, spring and summer, respectively.

As an example, Fig. 1 shows the original data and the filtered pulsations in Pc3 frequency range on geomagnetic D component during 0920 - 0940 UT on 30 August 1996 at Zhongshan Station and Davis Station.

Then, the cross spectra can be obtained by operating Cross Fourier Transform (CFT) technique to the pair of pulsation data for the two stations. After CFT, the frequency having a maximum amplitude among the spectra can be regarded as the most correlated frequency, and the corresponding cross phase can be regarded as the phase difference of the frequency propagating between the two stations. The wave numbers is defined as the phase difference divided by the geographic longitude difference between the two stations. The signs of the wave number mark the propagating direction of the pulsation. In our analysis, the positive value indicates the pulsation propagating from

* Yang SF (2000): Digital filter technique and application on magnetic pulsation, Antarctica. Chinese Journal of Polar Science, 11(1).

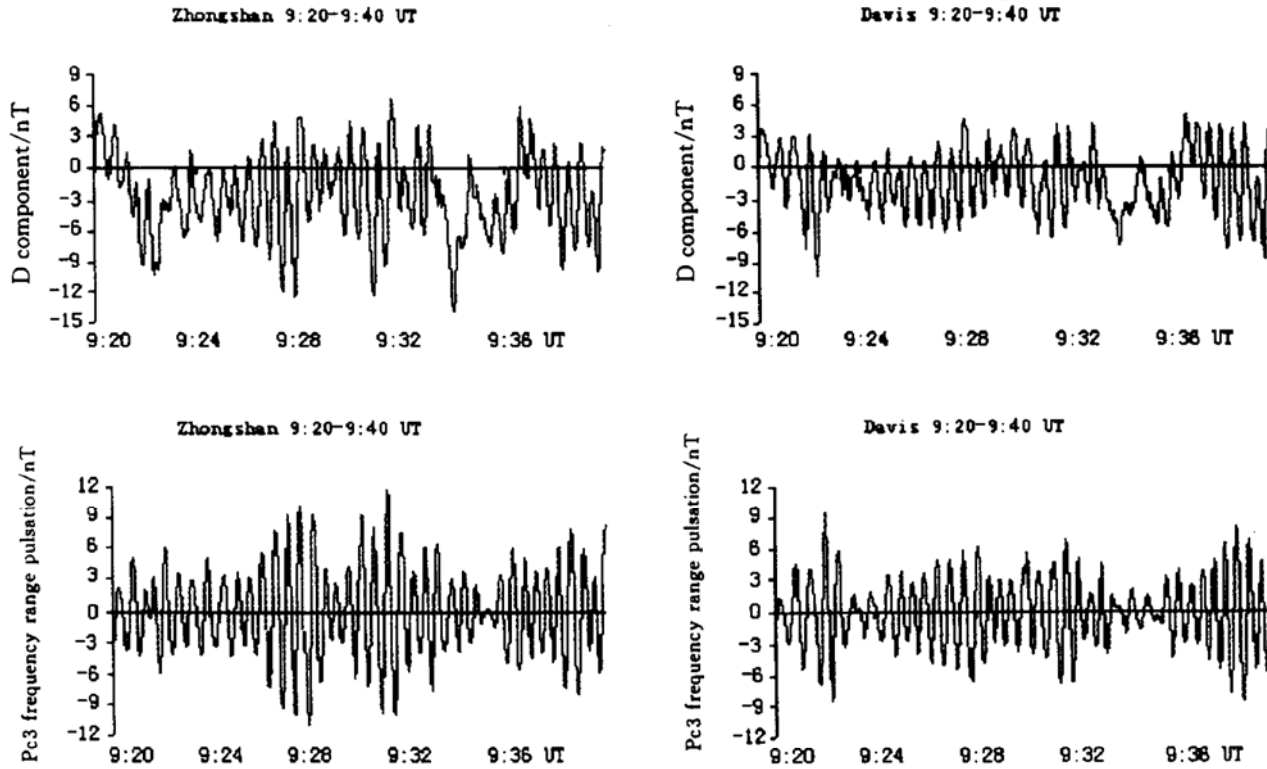


Fig. 1. The original data (upper panels) and the filtered pulsations in the Pc3 frequency range (lower panels) on D component from the induction magnetometers during 0920 – 0940 UT, 30 August, 1996 at Zhongshan Station (left panels) and Davis Station (right panels).

Davis Station to Zhongshan Station, and negative value indicates the pulsation propagating from Zhongshan Station to Davis Station.

Fig. 2 shows the diurnal variation of amplitude (left) and phase difference (right) of the pulsation on 3 August, 1997 between Zhongshan Station and Davis Station. Here, the frequency having a maximum amplitude is chosen for each block after CFT. In the phase variation, a threshold is set that the corresponding amplitude is greater than 0.3

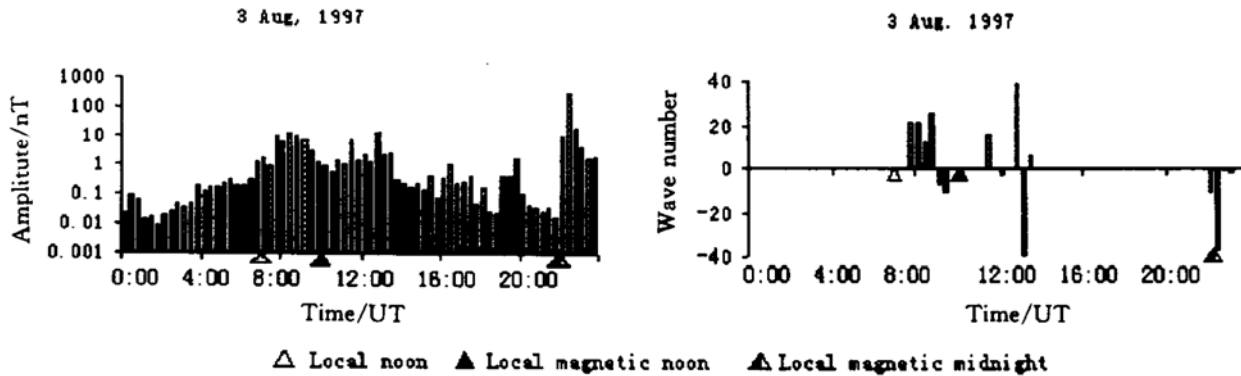


Fig. 2. Diurnal variation of the amplitude (left panel) and phase difference (right panel) of the Pc3 frequency range pulsations on 3 August, 1997 between Zhongshan Station and Davis Station.

nT. From the left panel, it can be seen that the pulsation amplitudes have large values around local magnetic noon and local magnetic midnight respectively. From the right panel, the wave number is mainly positive in daytime which imply that the pulsation propagates from Davis Station to Zhongshan Station around local magnetic noon.

A threshold is set for the maximum amplitude of the pulsation cross spectra in each block data. It is only selected the maximum amplitude that is larger than the threshold (here is 0.3 nT). A small amplitude of cross spectra implies poor correlation of the pulsation between the two stations, which may not come from the same source, so it should be neglected.

The diurnal variation of the amplitude (or phase difference) of the pulsation in Pc3 frequency range in a specific month is obtained by calculating the monthly median values of the amplitude (or phase difference) in that month for each block data. We think that the median value will be more representative than averaged one here. In this calculation, it is demanded that the number of the selected amplitude is greater than 2. Since very small number of the selected amplitude suggests that the wave appears just occasionally and it could be omitted.

The occurrence of the Pc3 frequency range pulsation is expressed by the number of the days having an amplitude larger than the threshold (here is 0.3 nT).

3 Results and discussion

Utilizing the method described above we get the diurnal variations of the amplitude (or phase difference) of the pulsation in Pc3 frequency range for four months. They are March 1997 and June, September and December 1996. The results are shown in Fig. 3 and Fig. 4 respectively. The diurnal variation of the occurrences is shown in Fig. 5.

Both Antarctic Zhongshan Station and Davis Station are year-round investigating stations, and they close to each other with a distance of 113 km. The two stations are located under the ionospheric projection of the magnetospheric cusp in local magnetic noon and located in the polar cap region or the polarward of the aurora oval in the nighttime. Both stations have installed the identical induction magnetometers, which constitute a baseline to investigate the ULF wave propagation.

The right panel of Fig. 2 just displays the diurnal variation of the amplitude of the Pc3 frequency range pulsation for one day. From here we can see that the pulsations mainly concentrate around local noon/local magnetic noon and around local magnetic midnight respectively. In nighttime, the pulsations have very large value sometimes.

Fig. 3 show the diurnal variation of the amplitude of the Pc3 frequency range pulsation in four months. From these results, it can be seen that the pulsations concentrate on two time segments, one is around local noon/local magnetic noon, and the other is around local magnetic midnight. The pulsations appear different characteristics at the two time segments. The amplitude in daytime is much less than that in nighttime. In daytime, the amplitude appears a seasonal fluctuation, having a smaller value in June and a larger value in other seasons. The time coverage in June is narrower than those in other seasons.

These features are due to different sources between daytime and nighttime, and different ionospheric conditions between summer and winter. In local magnetic noon,

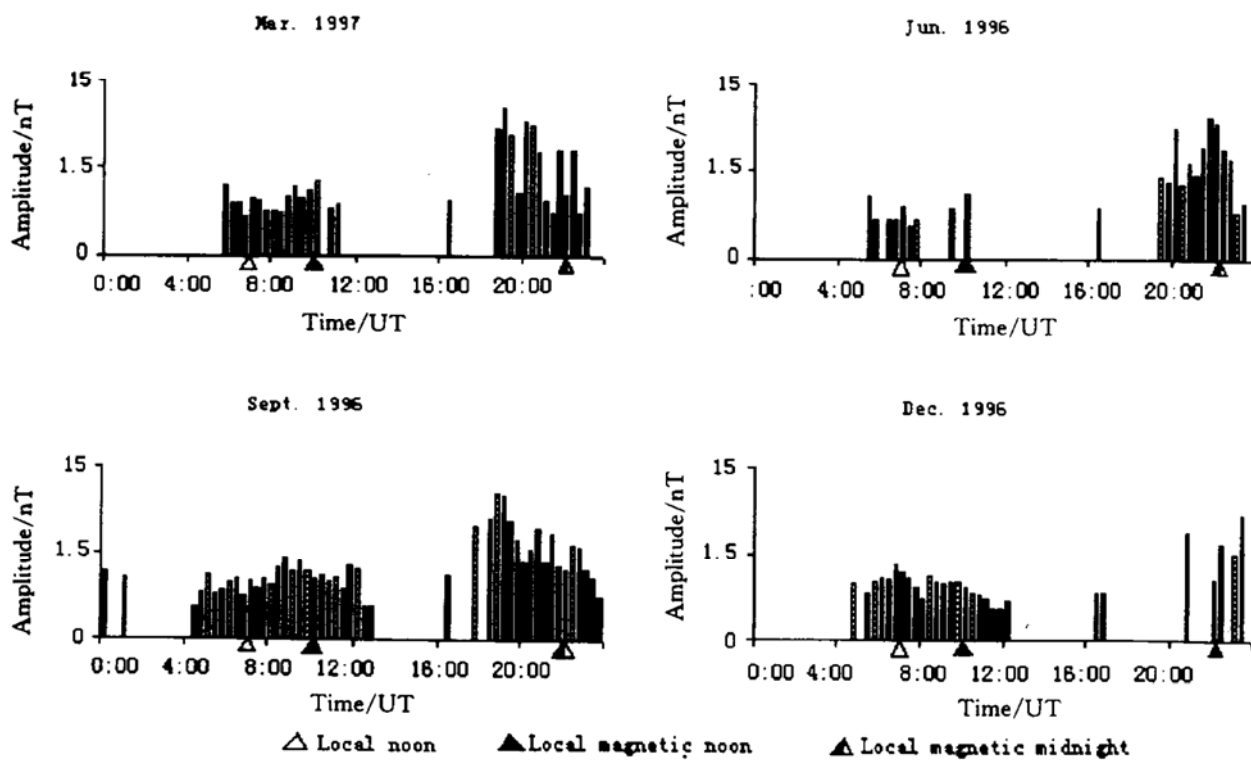


Fig. 3. Diurnal variation of the amplitude of the Pc3 frequency range pulsations in March 1997 and in June, September and December 1996 between Zhongshan Station and Davis Station.

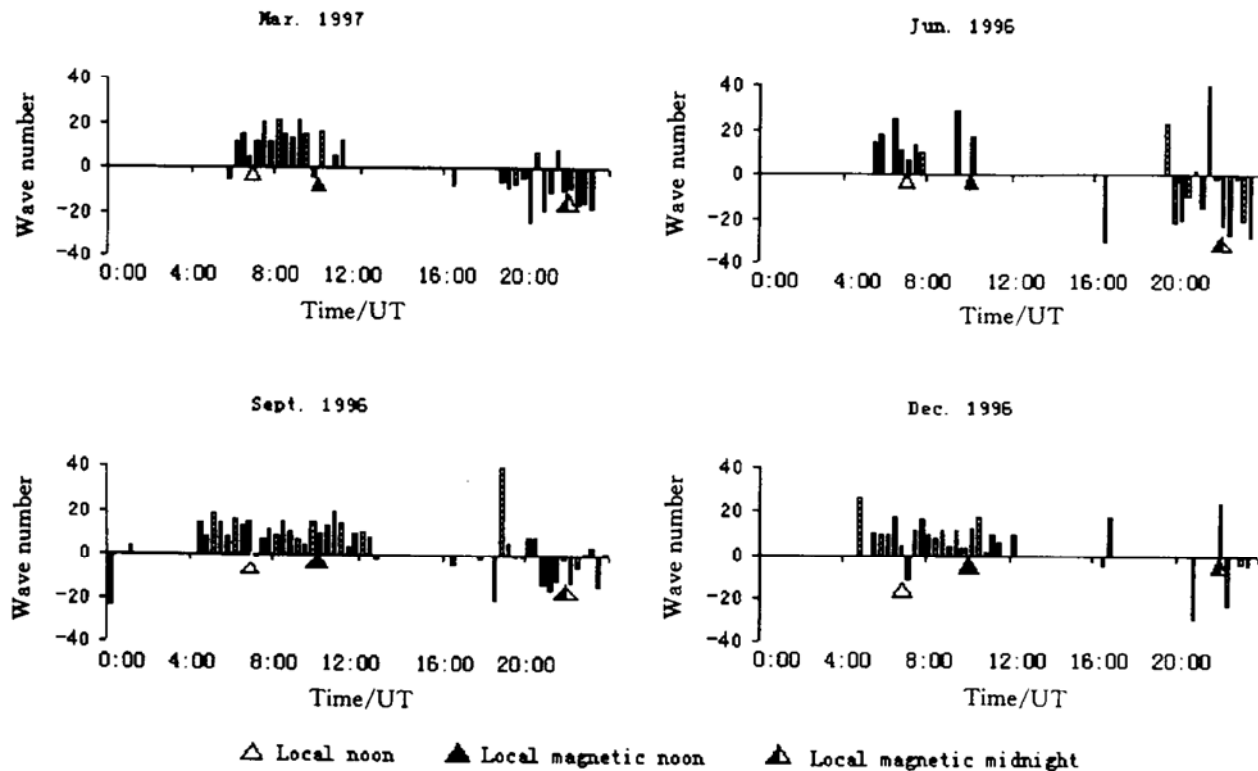


Fig. 4. Diurnal variation of the phase difference of the Pc3 frequency range pulsations in March 1997 and in June, September and December 1996 between Zhongshan Station and Davis Station.

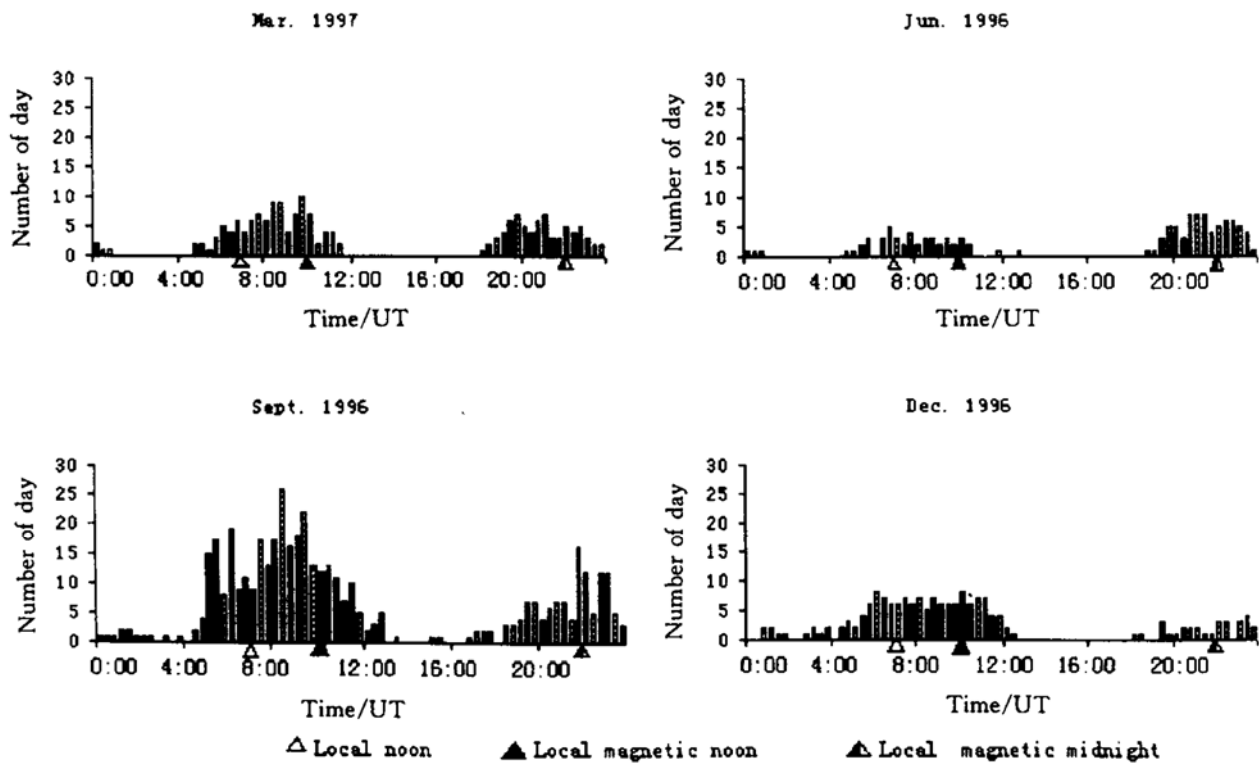


Fig. 5. Diurnal variation of the occurrence of the Pc3 frequency range pulsations in March 1997 and in June, September and December 1996 between Zhongshan Station and Davis Station.

both stations are located under the ionospheric projection of the magnetospheric cusp. The ULF magnetic hydrodynamic waves would be able to propagate to the ionosphere along the field lines in the cusp regions from magnetosheath/magnetopause. They would induce the Pc3 frequency range pulsations at ground when they propagate in the ionosphere over the stations. The ionospheric condition will effect the ULF wave propagating in it, including the pulsation amplitude and occurrence at the ground. June is in middle austral winter. In June, the ionosphere over the stations is lack of solar radiation, therefore there is a low ionization ratio and low electric conductivity. This point is confirmed by the results of the digisonde observation at Zhongshan Station (Liu *et al.* 1997). The ionosphere with low conductivity will be unfavorable for the ULF wave to propagate. Therefore, the Pc3 has relative small amplitude, narrow temporal coverage and small occurrence in the dayside in June.

In the seasons other than austral winter (June), the ionosphere over stations is lit by solar radiation, especially in the local noon/local magnetic noon. During these time, the ionospheric electric conductivity has a large value relatively, which is favorable for the ULF to propagate. Therefore, the pulsation has relative large amplitude, large occurrence at ground and wide temporal coverage.

The above conclusion is consistent with the result that power amplitude of low frequency pulsation shifts towards high value in association with the increased ionospheric conductance during local summer (Ballatore *et al.* 1998).

In nighttime, the Zhongshan Station and Davis station are located at polar cap region or at the polarward of the aurora oval. During the magnetic substorm, which

originates in the magnetospheric tail, a great amount of charged particles are moving towards the Earth and finally precipitating to the ionosphere. During this course, strong fluctuation will be produced in the ionospheric current system. The Pc3 range pulsations could be induced coincidentally at the ground. These processes are accompanied with tense ionospheric ionization. A significant energy will be released into the ionosphere. During these time, the observed Pc3 range pulsations have very large amplitude and have no relationship with season. In nighttime, some of the Pc3 range pulsations are irregular morphologically.

According to the results shown in Fig. 4, the propagating directions of the Pc3 frequency range pulsation are mainly western in daytime, from Davis Station to Zhongshan Station. However, in nighttime, the observed propagating directions are irregularly.

It is unclear so far actually why the pulsation propagating directions are mainly western in day time at Zhongshan-Davis Stations since in cusp region the magnetospheric dynamics is very complicated. This problem may have some relation to the current systems, the westward electrojet and the magnetosheath particle precipitation in the cusp region. The particle precipitation can modulate the current and the modulation can be transported via the westward electrojet (Posch *et al.* 1999; Roostoker and Lam 1978; Sutcliffe and Rostoker 1979).

In nighttime, the magnetic storm/substorm occurs over a large space area. The charged particles may precipitate to the ionosphere over the stations in west or in east randomly at some length. The ULF or the disturbance spread away from the precipitate place. So the observed Pc3 frequency range pulsation on the ground propagate irregularly.

4 Summary

A baseline has been established by installing two induction magnetometers at Zhongshan Station and Davis Station, Antarctica respectively. We adopt with cross-spectral analysis technique to analyze the two induction magnetometer data for four months: March 1997, June, September and December 1996, to investigate the Pc3 frequency range magnetic pulsation occurrence and propagation characteristics in cusp latitude. The results are summarized as following:

(1) At Zhongshan-Davis Stations, the Pc3 frequency range pulsations occur mainly around the local magnetic noon and local magnetic midnight respectively.

(2) In daytime, the pulsation amplitude is the smallest in winter (June). But in nighttime, the amplitude has no such a variation. The temporal range of the pulsation is narrower in winter than those in other seasons.

(3) The pulsation amplitude is much larger in nighttime than in day-time all over the year.

(4) In daytime, the propagating direction of the pulsation is mainly western. In nighttime, the propagating direction is irregularly.

It can be thought that the different sources of the Pc3 frequency range pulsations and the different ionospheric electric conductivity are responsible for these pulsation characteristics.

It is worth to point out that we just have two stations to observe the pulsations now. So we can only investigate the projection of the pulsation propagation to the baseline between Zhongshan Station and Davis Station, which are along west-east direction. In order to study the pulsation propagation characteristics along north-south direction, we need more observation sites.

Acknowledgements The project is supported by National Natural Science Foundation (No. 49634160) and Youth Oceanographic Foundation of State Oceanic Administration (No. 97602).

References

- Ballatore B, Lanzerotti LJ, MacLennan CG (1998): Multistation measurements of Pc5 geomagnetic power amplitudes at high latitude. *Journal of Geophysical Research*, 103(A12): 29,445 - 465.
- Bolshakova OV, Troitskaia VA (1984): Relationship between the high-latitude maximum of Pc3 intensity and the daytime cusp. *Geomagnetizm i Aeronomiia*, 24:776 - 779.
- Fraser BJ, McNabb PW, Menk FW, Waters CL (1991): A personal computer induction magnetometer system for recording geomagnetic pulsation. *ANARE Research Notes*.
- Liu SL, He LS, Liu RY (1997): Mean ionospheric properties in winter at Zhongshan Station, Antarctica. *Chinese Journal of Polar Science*, 8(2): 133 - 138.
- Morris RJ, Cole KD (1987): Pc3 magnetic pulsations at Davis, Antarctica. *Planetary and Space Science*, 35:1437 - 1439.
- Neudegg DA, Burns GB, Fraser BJ, Menk FW, Morris RJ, Hansen HJ, Underwood MJ (1995): Sources and propagation of ULF wave near the austral polar cusp: Implication for mapping the dynamics of high latitude geospace. *ANARE Antarctic Research Note* 95:152 - 167.
- Nose M, Lyemori, Nakabe S, Nagai T, Matsumoto H, Goka T (1998): ULF pulsations observed by the ETS-VI satellite: Substorm associated azimuthal Pc4 pulsation on the nightside. *Earth Planets Space*, 50:63 - 80.
- Posch JL, Engebretson MJ, Wetherwax AT, Detrick DL, Hughes WJ, MacLennan CG (1999): Characteristics of broadband ULF magnetic pulsations at conjugate cusp latitude stations. *Journal of Geophysical Research*, 104(A1):311 - 331.
- Roostoker G, Lam HL (1978): A generation mechanism for Pc5 micro-pulsations in the morning sector. *Planetary Space Science*, 26:493.
- Sutcliffe PR, Roostoker G (1979): Dependence of Pc5 micropulsation power on conductivity variations in the morning sector. *Planet. Space Sci.*, 27:631.