Mem. Natl Inst. Polar Res., Spec. Issue, **52**, 13–27, 1998

GEOSPACE ENVIRONMENTAL MONITORING AT ZHONGSHAN STATION, ANTARCTICA

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Abstract: Geospace deals with the Earth's middle and upper atmosphere, thermosphere/ionosphere and magnetosphere. This geospace environment is of great scientific and practical interest. Situated in both the cusp region and the ozone controlled area, the Chinese Antarctic Zhongshan Station (69.4°S, 76.4°E) has a unique location for ground-based measurements in monitoring geospace environment. According to the scientific concept of global character of solar-terrestrial system, during past few years at Zhongshan Station has been built a ground-based composite measurement system, with more than 20 different instruments relevant to solar radiation, geomagnetic field, aurora, ionospheric disturbances and middle and low atmospheric phenomena. In the paper the observational strategy, composite instruments, measured data and some preliminary results are described.

1. Introduction

Geospace deals with the Earth's middle and upper atmosphere, thermosphere/ionosphere and magnetosphere. This 'geospace environment' is of great scientific and practical interest, particularly as it is often subject to disturbances. A blast wave from the sun can compress the magnetosphere surrounding the earth and trigger a geomagnetic storm. This often disrupts radio communications and spacecraft systems, and sometimes affect electrical power line systems.

Owing to strong seasonal variation of solar radiation impinging on the earth's surface and the unique magnetic structure over polar region favorable for the direct penetration of solar wind plasma deep into the depth of the atmospheric layers, polar region is one of the key regions for monitoring geospace environment.

The Chinese Zhongshan Station was established in February 1989. It is located in Princess Elizabeth Land Larsemann Hills of East Antarctica, having geographic coordinates of 69°22′24″S and 76°22′40″E. The location of Zhongshan Station is shown in Fig. 1 with respect to the automatic geophysical observations (AGOs) and the HF radar field of view. The annual mean temperature at Zhongshan Station is −9.5°C, with maximum of 9.5°C in summer and minimum of −33.6°C in winter. The midnight sun lasts for 54 days, while the number of days with "Polar night" is 58. The corrected geomagnetic latitude of Zhongshan is about 75° and the equivalent L value is 14. Zhongshan Station is situated under the ionospheric projection of the magnetospheric cusp region at noon, and the polar cap region at midnight, twice passing through the

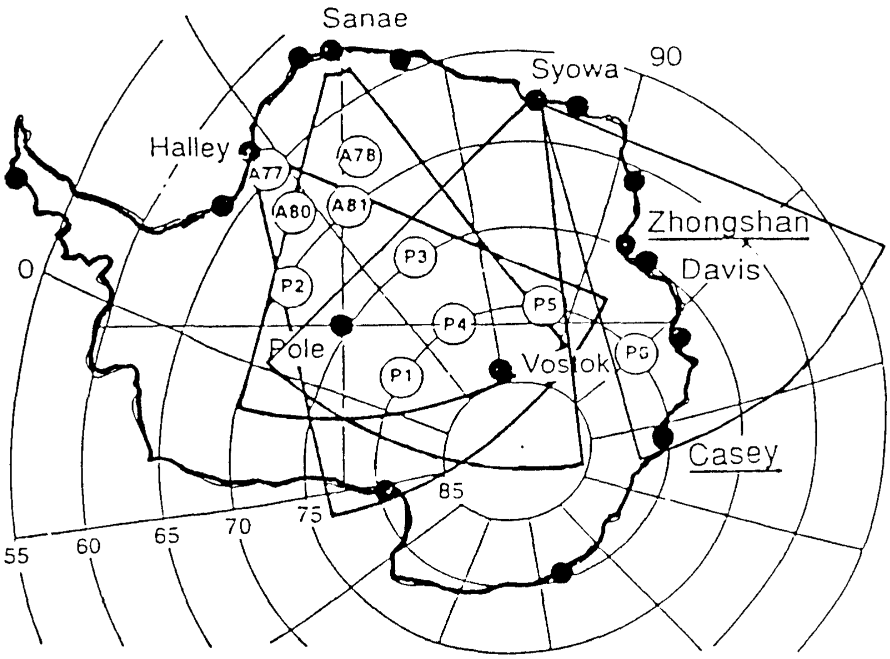

Fig. 1. Location of Zhongshan Station with respect to the AGOs and the HF radar field of view.

auroral oval during a day. Zhongshan Station is also located in the area which was controlled by ozone depletion. The weather is clear in most of the time. It is suitable for both optical and electromagnetic observations. Therefore Zhongshan Station is an ideal ground base for studying important problems related to geospace environment.

Another advantage of Zhongshan Station is that the distance between Zhongshan and the Australian Antarctic station, Davis, is about 100 km. Both Zhongshan and Davis are located under the cusp region, having similar measurement instruments such as magnetometer, scanning photometer, all sky TV camera, riometer, ionosonde and so on. Zhongshan-Davis pair could make a significant contribution to high latitude ionospheric and magnetospheric studies. It is also shown in Fig. 1 that Zhongshan Station has the same L value as South Pole Station with CGMT difference of about 5 hours. The coordinate observations at Zhongshan and South Pole would enlarge the observational time of high latitude phenomena.

In Fig. 2 the Antarctic continent is projected along the Earth's magnetic field lines to the Arctic. It can be seen that the conjugate point of Zhongshan is near Svalbard, a well equipped international ground base for studying solar-terrestrial physics. This figure clearly illustrates the possibilities for carrying out magnetic conjugate observations between Zhongshan and the stations at Svalbard.

During past few years at Zhongshan Station has been built a ground-based composite measurement system, which consists of more than 20 different instruments relevant to solar radiation, geomagnetic field, aurora, ionospheric disturbances and middle and low atmospheric phenomena. In the paper the observational strategy, composite instruments, observations and some preliminary results are described.

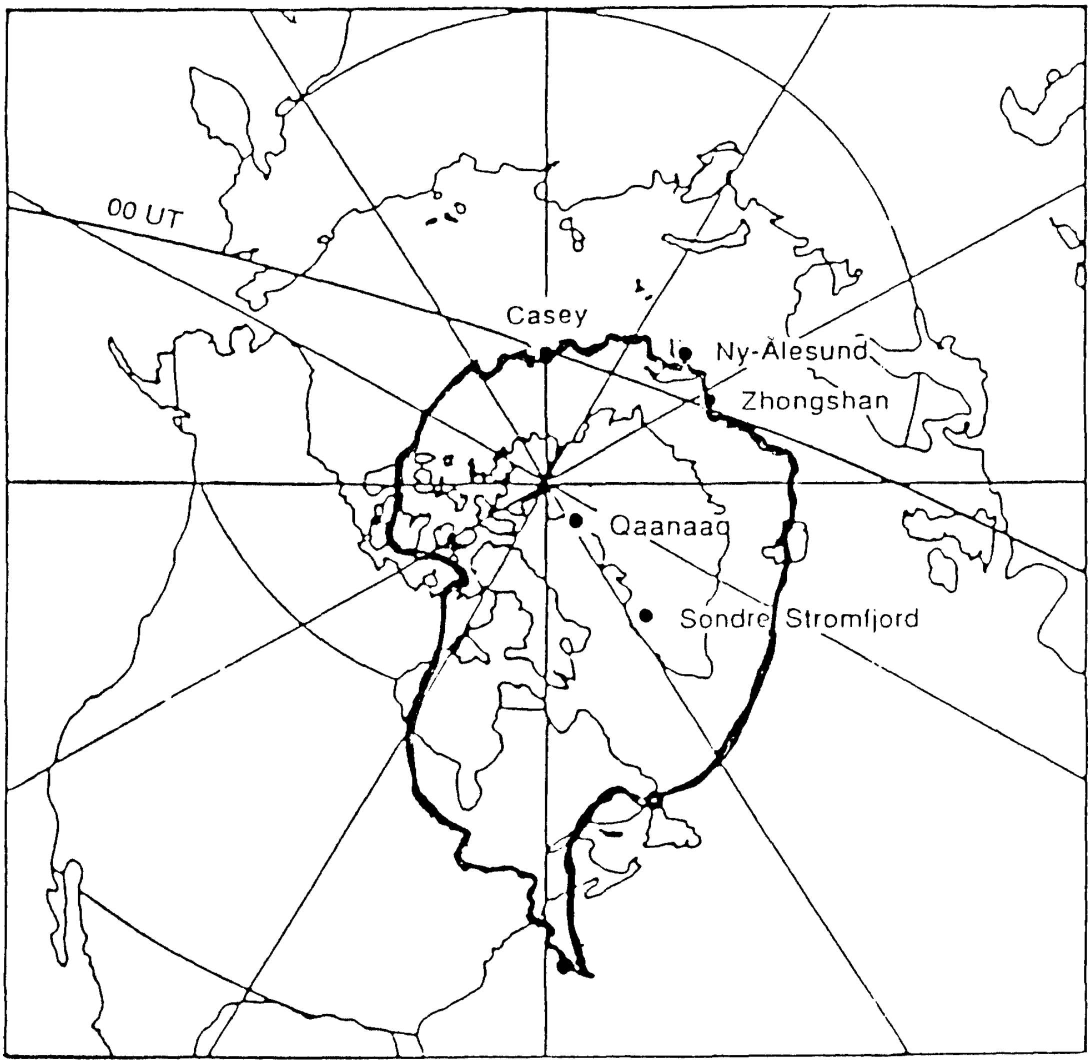

Fig. 2. Projection of Antarctica along the magnetic field lines on to the Northern Hemisphere.

2. Scientific Considerations and Research Contents

Geospace environmental monitoring uses instruments on the ground that routinely record characteristics of the Earth's middle and upper atmosphere, thermosphere/ionosphere, magnetosphere and geomagnetic field. The monitoring data (and the derived indices and models) have many important scientific and practical applications. Data from geospace environmental monitoring will make a significant contribution to the Solar-Terrestrial Energy Programme (STEP) and to the International Geosphere-Biosphere Programme (IGBP).

A program named the global character research of solar-terrestrial system in the Antarctic has been conducted since 1991. The purpose of this program is to study the basic behavior of the coupling and interaction between various regions of solar-terrestrial system, inquire into the response processes and the global effects of the system to the solar electromagnetic and particle radiation, by using both ground based measurements and satellite *in situ* measurements. This program is supported by the National Committee of Science and Technology and the National Committee on Antarctica, and 7 research institutes and universities took part in. The Chinese Zhongshan Station is under cusp region where direct penetration of solar wind is easiest. Observations with composite instruments would be very unique for studying the vertical coupling and interaction. The main research topics include: solar radiation measurement, cusp dynamic observations and modeling, polar ionospheric behaviors and its effects to radio propagation, the mechanisms of Antarctic ozone depletion hole and the effects of solar activities to the middle and low atmosphere, coordinate observations and analysis of solar bursts and responses of various regions of the system.

It should be mentioned that there are two international collaborative studies. One is the cooperative research on upper atmospheric physics between the National Institute of Polar Research, Japan and the Polar Research Institute of China during the period from 1994 to 1999. The scientific objectives are: Auroral particles and auroral emissions in the cusp region, Ionospheric disturbances associated with energetic particle precipitation in the polar cap region, Correlative studies of high latitude ionosphere with HF radar observation from Syowa Station and ground based auroral and ionospheric observations at Zhongshan Station. According to the agreement, 6 measurement instruments include an all-sky TV camera, a scanning photometer, an imaging riometer and so on have been or will be installed at Zhongshan Station. In summer season, 2 Japanese scientists visit Zhongshan Station and install observational systems. In winter time auroral and ionospheric measurement instruments are operated by Chinese scientists.

The other is the space plasma wave studies which is the cooperative research between the University of Newcastle, NSW Australia and the Polar Research Institute of China. The scientific aim of the cooperative project is to study the source and propagation characteristics of ultra-low frequency (ULF) hydromagnetic waves in the 0.001–1 Hz band using identical induction magnetometers located at the Australian Antarctic station, Davis, and the Chinese station, Zhongshan. Under the agreement the University of Newcastle, in cooperation with the Atmospheric and Space Physics Group of the Australian Antarctic Division, installed an induction magnetometer at Zhongshan Station in January 1996, and the Polar Research Institute of China operates and maintains the instrument year round.

3. A Composite Measurement System in Monitoring Geospace Environment at Zhongshan Station

In order to study the global character of solar-terrestrial system, a ground-based composite measurement system has been built at Zhongshan Station during past few years, which contains following observations:

1) Solar radiation
   —10 cm wavelength telescope
   —UV/visible spectroscope
   —solar UV spectroradiometry
2) Magnetic field variations

—standard magnetograms
—magnetic pulsations
—ELF/VLF emissions

3) Auroral data
—all-sky TV camera
—meridian scanning photometers (6300 Å, 5577 Å, 4278 Å)

4) Ionospheric monitoring
—ionogram (analog ionosonde TD-4 in early time and now digisonde DPS-4)
—drift measurement (digisonde DPS-4)
—absorption data (riometers (~ 30 MHz and ~ 50 MHz))

Table 1. Instrumentation on geospace environment monitoring at Zhongshan Station.

Item	Start time	Responsible organization	Remark
10 cm solar telescope	1993. 4	BO	
Quartz photoelectric variometer	1992	IG	
Plasma wave measurement	1991	IG	
Induction magnetometer	1996. 1	PRIC	in coop. with UON
VLF receiver	1991. 4	IG	
Ionosonde TD-4	1990. 3	CRIRP	
Digisonde DPS-4	1995. 1	PRIC	
Imaging riometer	1997. 2	PRIC	in coop. with NIPR
Riometer (~30 MHz)	1995	PRIC	
Riometer (~50 MHz)	1990	CSSAR	
VLF navigation signal receiver	1990	CRIRP	
HF field strength meter	1990	CRIRP	
All sky TV camera	1995	PRIC	in coop. with NIPR
Scanning photometer	1995	PRIC	in coop. with NIPR
Surface ozone detector	1995. 1	PRIC	in coop. with NIPR
Ozone-sonde	1993. 3	IAP	
Brewer ozone spectrophotometer	1993	CAMS	
Solar UV spectroradiometry	1990. 2	IAP	
Solar radiometer	1990. 2	IAP	
UV visible spectroscope	1991. 3	CSSAR	
Stratospheric lidar	1993. 3	IAP	
Atmospheric electric field mill	1990. 2	IAP	

Abbreviation of organizations:

BO	Beijing Observatory, Academia Sinica, Beijing 100080.
CAMS	Chinese Academy of Meteorological Sciences, Beijing 100081.
CRIRP	China Research Institute of Radiowave Propagation, Xinxiang 453003.
CSSAR	Center for Space Science and Applied Research, Academia Sinica, Beijing 100080.
IAP	Institute of Atmospheric Physics, Academia Sinica, Beijing 100029.
IG	Institute of Geophysics, Academia Sinica, Beijing 100101.
NIPR	National Institute of Polar Research, Japan.
PRIC	Polar Research Institute of China, Shanghai 200129.
UON	University of Newcastle, Australia.

5) Radio propagation
 —HF field strength and time delay
 —VLF field strength and time delay (navigation receiver)
6) Middle and low atmosphere
 —column amounts of ozone (Brewer ozone spectrophotometer)
 —ozone profile (ozone-sonde)
 —stratospheric lidar
 —atmospheric electric field

The composite system consists of more than 20 different instruments which are listed in Table 1 with start time and responsible organizations in it.

4. Observations and Preliminary Results

Most of the measurement instruments in Table 1 belong to regular observation and long-term monitoring. Some instruments, for example the solar telescope and solar UV spectroradiometry, might be stopped during polar night. Based on the existing measurement data from Zhongshan Station and combined with other data from other places,

Table 2. Specifications of radiotelescope.

Receiving frequencies:	2.84 GHz, 2.74GHz
Frequency width:	10 MHz
Antenna diameter:	2 m
Stability:	1%/hr
Integrating time:	100 ms, 1 ms, 1 s

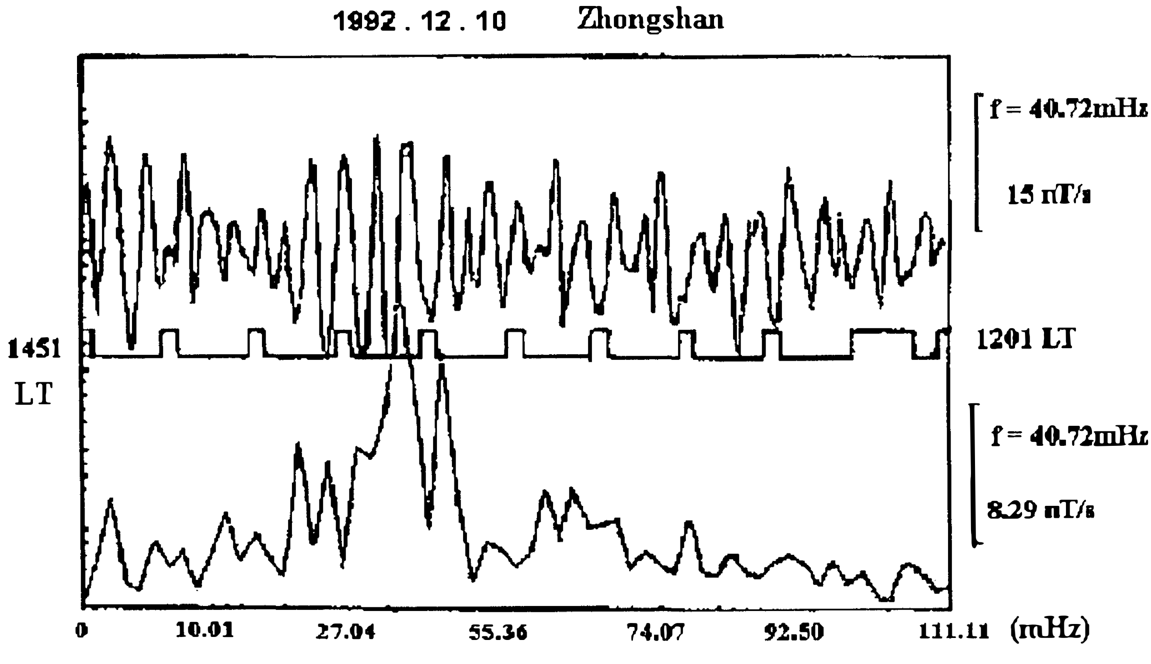

Fig. 3. A sample of Pc3 magnetic pulsations and its Fouier spectrum at Zhongshan Station.

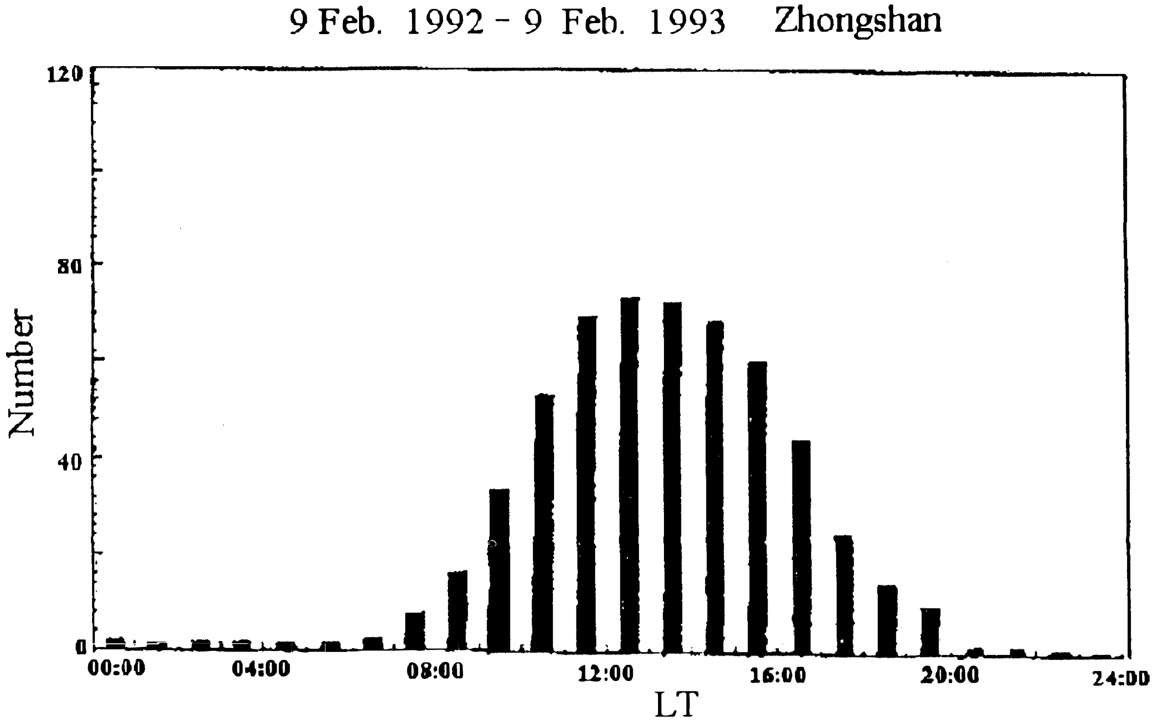

Fig. 4. Occurrence histogram of Pc 3 at Zhongshan Station.

we have done data analysis and theoretical and model studies and get some preliminary results which have shown various distinctive features of the geospace in Antarctica (LIU, 1996).

A solar radiotelescope with high time-resolution for observing solar emissions at 10 cm wavelength has been set up at Zhongshan Station as a timely monitor of energy releases and disturbances from the sun and to give short-term predictions of solar activity and alarm. The specifications of the radiotelescope are listed in Table 2. During 150 days observations in 1993 it recorded 86 solar radio bursts all together which is 3 times more than the bursts recorded at Beijing observatory in the same period, demonstrating that Antarctica is a good place for solar radiation measurements because of less interference and higher sensitivity.

Observations on geomagnetic fields, micropulsations and VLF emissions have been carried out at Zhongshan Station. Three-component data of geomagnetic field are digitized and recorded in a sampling rate of 6 s. It has been shown that there are very often Pc 3 and Pi 2 pulsations recorded at Zhongshan Station (YANG *et al.*, 1997). Figure 3 shows a sample of Pc 3 magnetic pulsations and its Fouier spectrum. Figure 4 shows an occurrence histogram of Pc 3 at Zhongshan Station. According to statistical analysis of Pc 3 pulsations recorded during 9 February 1992–9 February 1993, it can be seen that the characteristics of Pc 3 pulsations are as follows: (1) Pc 3 pulsation events are dayside phenomena which occur mainly from 1100 LT to 1500 LT in summer time. (2) The frequency range of Pc 3 pulsations is concentrated between 22 mHz and 37 mHz. (3) The amplitude of Pc 3 pulsations is large (about 6–7 nT) between 1100 LT and 1500 LT. These features support the hypothesis that the low frequency MHD

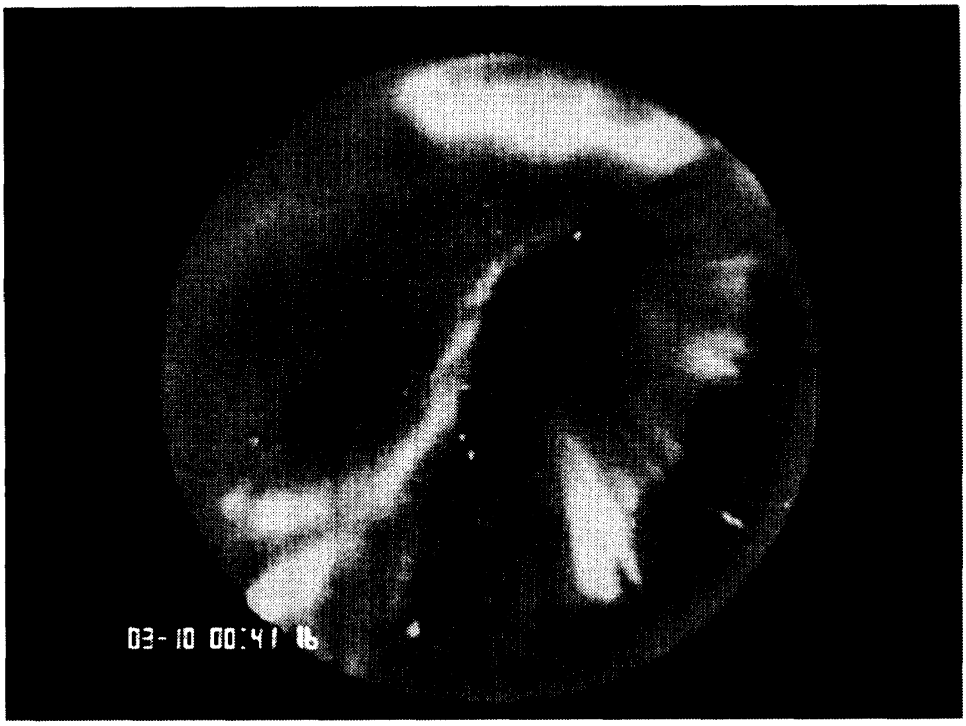

Fig. 5. An all-sky auroral image taken at Zhongshan Station at 0041:16 UT on 10 March 1995. Up directs to the south (poleward), and down to the north (equatorward).

Table 3. Specifications of digisonde DPS-4.

Scanning frequency range: 1–40 MHz (frequency in 100 kHz steps)
Frequency band range (6 dB): 20 kHz (minimum pulse width: 66.7 μs)
Receiver sensitivity: −120 dBm
Receive antenna:
Array layout: 4 turnstile loop antennas
Polarization: Right and left circular polarization
Pre-Amp input impedance: 2 kΩ $\pm$20%
Pre-Amp noise: −122 dBm (120 kHz frequency band)
Pre-Amp gain: 10 dB–30 dB
Transmit antenna:
Array layout: Delta antenna
Output impedance: 50 Ω
Output power: 500 W in pulse, 250 W per antenna
Pulse repeat frequency: 50, 100 or 200
Distance precision: 2.5 km, 5 km or 10 km
Amplitude resolution: 3/8 dB
Phase resolution: 1.3°
Maximum doppler range: $\pm$50 Hz
Maximum doppler resolution: 0.012 Hz
Clock standard: GPS signal or rubidium clock

waves in front of Earth's bowshock penetrate into magnetosphere through cusp region and excite Pc 3 pulsations. On the other hand, the characteristics of Pi 2 pulsations are as follows: (1) Pi 2 pulsation events are nightside phenomena which occur mainly from 2100 LT to 0200 LT. (2) The frequency range of Pi 2 pulsations is concentrated between 11 mHz and 15 mHz. (3) The left-handed polarization is dominant and the ellipticities of the left-handed polarization are usually less than 0.4.

An all-sky TV camera and a scanning photometer was installed at Zhongshan Station in 1995 and we obtained 150 auroral video tapes. Figure 5 shows an example of the all-sky auroral images taken at 0041:16 UT on 10 March 1995 at Zhongshan Station (YANG *et al.*, 1997). A personal computer based all sky video image analyzing system has been developed in reference to the ADPRS system (Auroral Data Processing and Retrieving System) at WDC-C2 for aurora, National Institute of Polar Research, Tokyo. A video capture board was adopted for video image A/D converting, the user's interface of this system was constructed by mean of the MS-Windows programming technique and its function is now comparable with ADPRS system. In projection of the all-sky auroral image onto geomagnetic/geographic coordinate, an intensity correction factor concerning the observed zenith angle was introduced for the first time (YANG *et al.*, 1997).

A digisonde portable sounder-4 (DPS-4) was installed at Zhongshan Station by the 11th Chinese National Research Expedition during the austral summer 1994/1995.

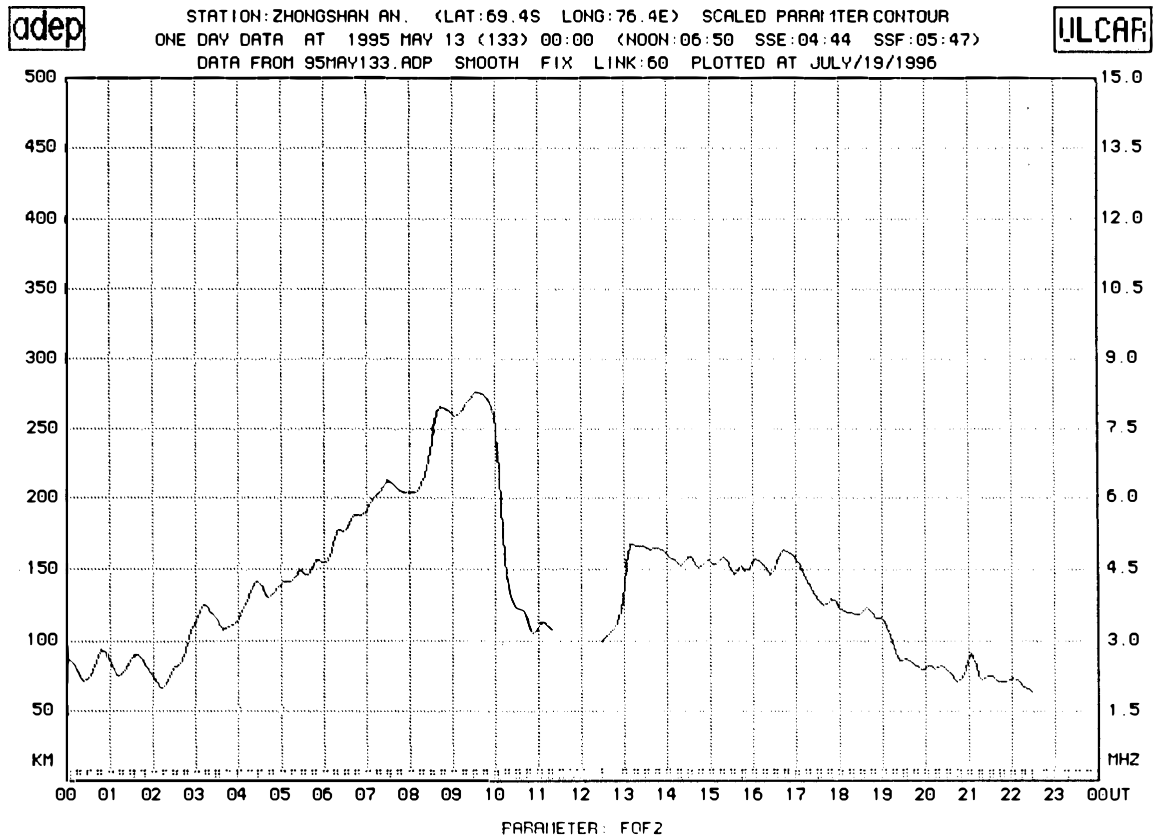

Fig. 6. Diurnal variation of foF2 at Zhongshan Station on 13 May 1995.

The DPS-4, developed by University of Massachusetts at Lowell Center for Atmospheric Research(ULCAR), is a pulse HF Doppler radar controlled by a computer. Specifications of DPS-4 are listed in Table 3. The DPS-4 has been in operation since the 16 th of January 1995, taking both ionograms and drift measurements 8 times per hour. The digital raw data, after processing and analyzing, can be used to study several frontiers, such as ionospheric structures and dynamics, ionospheric irregularities and plasma convections, polar ionosphere-magnetosphere coupling and so on(LIU *et al.*, 1995). From the ionograms can be seen many high latitude ionospheric phenomena, such as severely spread *F*, *F* region magnetic noon phenomena, *F* region depletion in winter night, auroral phenomena, particle precipitation effects in *E* and *D* regions, sporadic *E* and so on (CAO *et al.*, 1995). One important feature in diurnal variation of foF2 (both daily value and monthly medium) in winter is that the maximum value occurs at about 0900 UT that is close to the corrected geomagnetic noon. As an example, Fig. 6 shows the diurnal variation of foF2 on 13 May 1995. Because Zhongshan Station is just under the cusp region at magnetic noon, the peak is most likely due to low-energy electron precipitation into the cusp region, resulted in so called *F* region magnetic noon phenomena. The drift velocities of ionospheric irregularities are derived from the DPS-4 drift measurement. In Fig. 7 the drift velocities are plotted in a CGLT (corrected geomagnetic-local time) coordinate system, showing consistency with an anti-sunward convection pattern in the polar region. These drift data can be

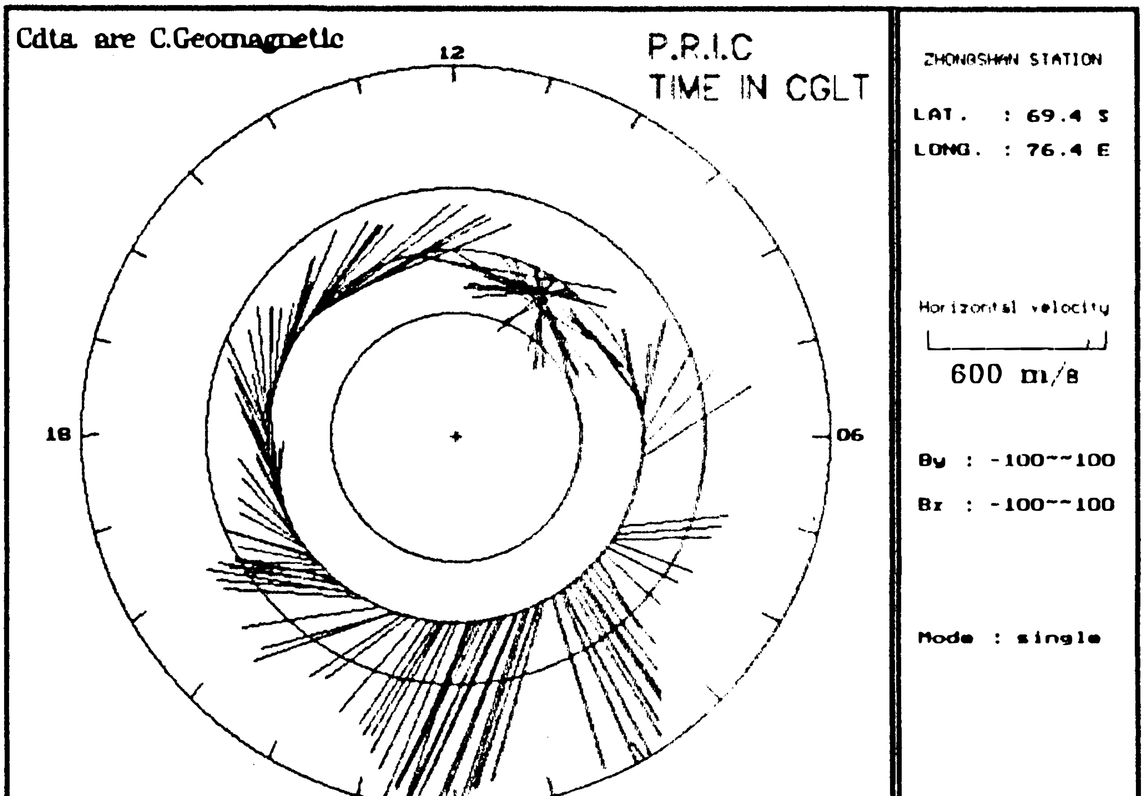

Fig. 7. Drift velocities of ionospheric irregularities with CGLT at Zhongshan Station on 4 December 1995.

used to study the polar plasma convection and its relation to the IMF (interplanetary magnetic field) conditions. The relationship between cosmic ray Forbush decrease and cosmic noise absorption during polar night is analyzed from the data recorded by a riometer at Zhongshan Station (Zong *et al.*, 1993). Using the ionization theory of cosmic ray in the polar ionosphere, the influence of cosmic ray Forbush decrease on the lower ionosphere is well interpreted. By means of VLF propagation effects, the influence of solar flare bursts and particle precipitations on the lower ionosphere has been monitored (Zhao, 1992).

In the middle atmospheric observations we concentrated on the stratospheric properties, the surface UV radiation and atmospheric electric field at Zhongshan Station, which is situated in the ozone depletion controlled area. Figure 8 shows the vertical profiles of ozone (in partial pressure) on 18 April and 10 October in 1993. It can be seen from Fig. 8 that the ozone depletion occurred in Antarctic spring in the altitude range of 13–23 km. The profiles were obtained from ozonesonde observations (Kong *et al.*, 1996). The specifications of ozonesonde are listed in Table 4. Using visible/

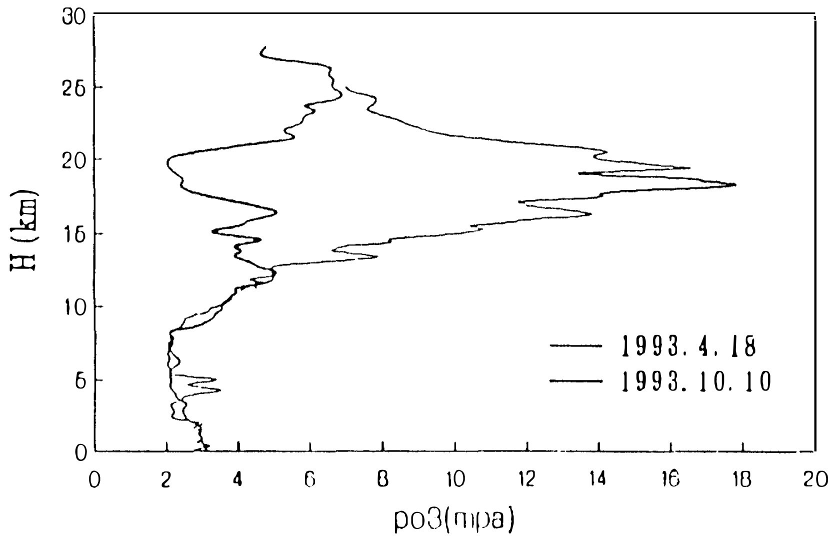

Fig. 8. Vertical profiles of ozone (in partial pressure) at Zhongshan Station on 18 April and 10 October in 1993.

Table 4. Specifications of ozone-sonde.

Measured height:	≤35 km
Measured range and accuracy	
1) Ozone	$(0\text{–}200)\times10^{-4}$ Pa
2) Pressure	1060–10 hPa, 1–2 hPa
3) Temperature	−80°C–+40°C, ±0.5°C
Carrying frequency	403.5 MHz±5 MHz
Receiving sensitivity	≤−132 dBW
Signal frequency	5800–6800 Hz
Antenna gain	12 dB

UV differential absorption spectroscopy, atmospheric ozone and NO_2 contents during Antarctic ozone depletion were observed (Wang, 1995). Figures 9 and 10 give the variations of atmospheric ozone and NO_2 contents in Antarctic spring, 1991, respectively. The results show that the ozone depletion occurred rapidly during the middle of August and reached a minimum value on 3 October. The variations of atmospheric ozone and NO_2 contents show a good positive correlation and the correlation coefficient reaches 0.69. During the ozone depletion the content of NO_2 is always on low level and

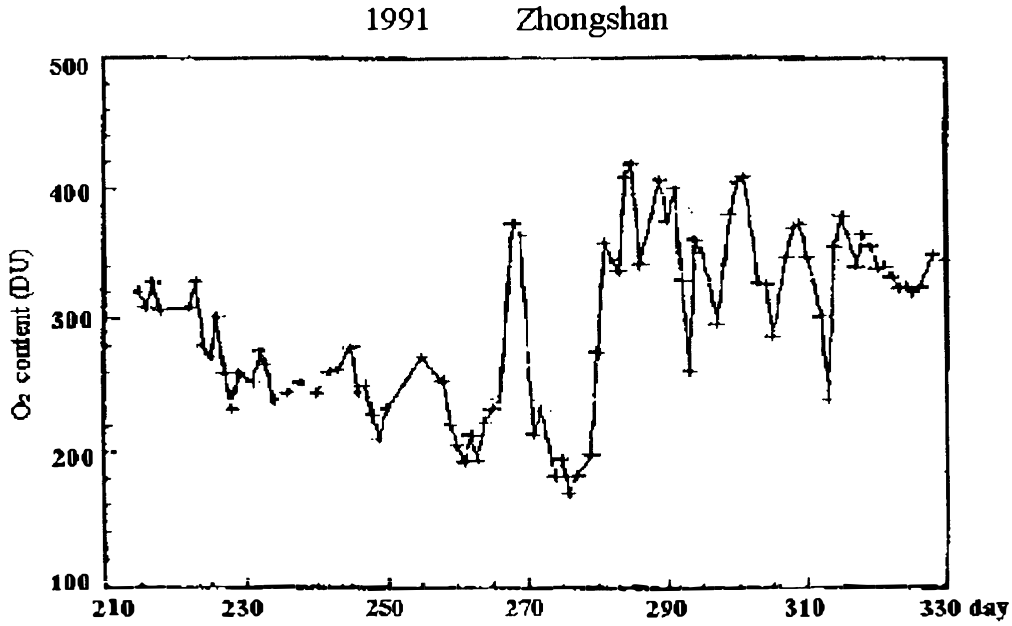

Fig. 9. Variation of atmospheric ozone content in Spring 1991 at Zhongshan Station.

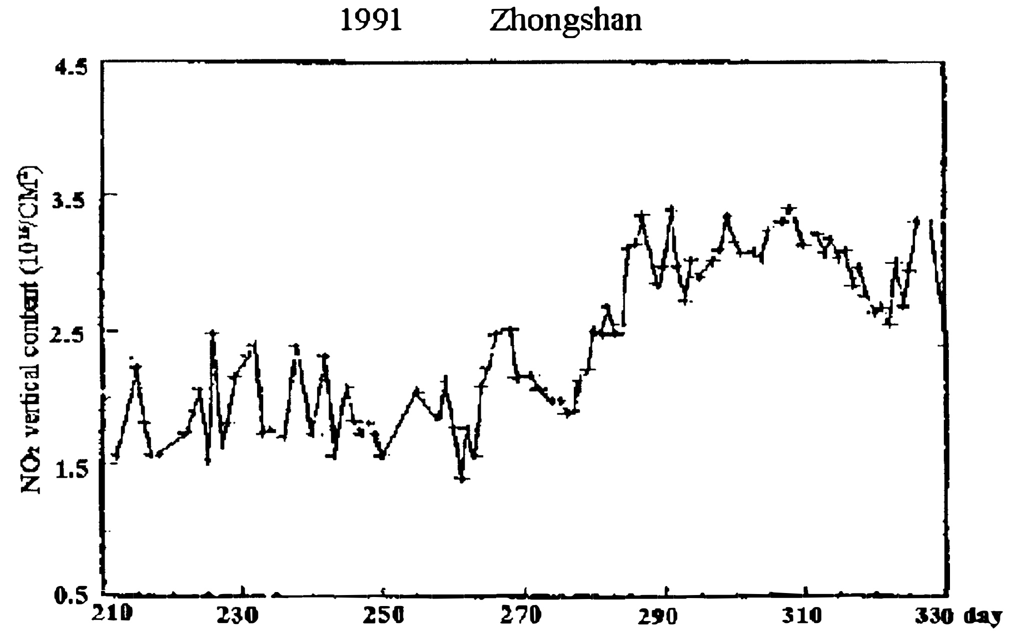

Fig. 10. Variation of NO_2 content in Spring 1991 at Zhongshan Station.

the altitude of the layer is higher. The stratospheric aerosol has been measured by a lidar system (694 nm) since 1993. A total 53 times of lidar observations were made from 27 March to 5 November in 1993 (SUN *et al.*, 1995). The observations show that the stratospheric aerosol particulate matter is noticeably higher in 1993 than in 1990. This is probably due to Mt. Pinatubo eruption in Philippines in June 1991. The vertical profiles of the stratospheric aerosol backscattering ratio are illustrated in Fig. 11, which shows a clear double-layer structure, one layer is at about 12 km altitude, and the other about 25 km. The observations of atmospheric electric field have been conducted at Zhongshan Station since 1990. Figure 12 shows the probability distributions of electric

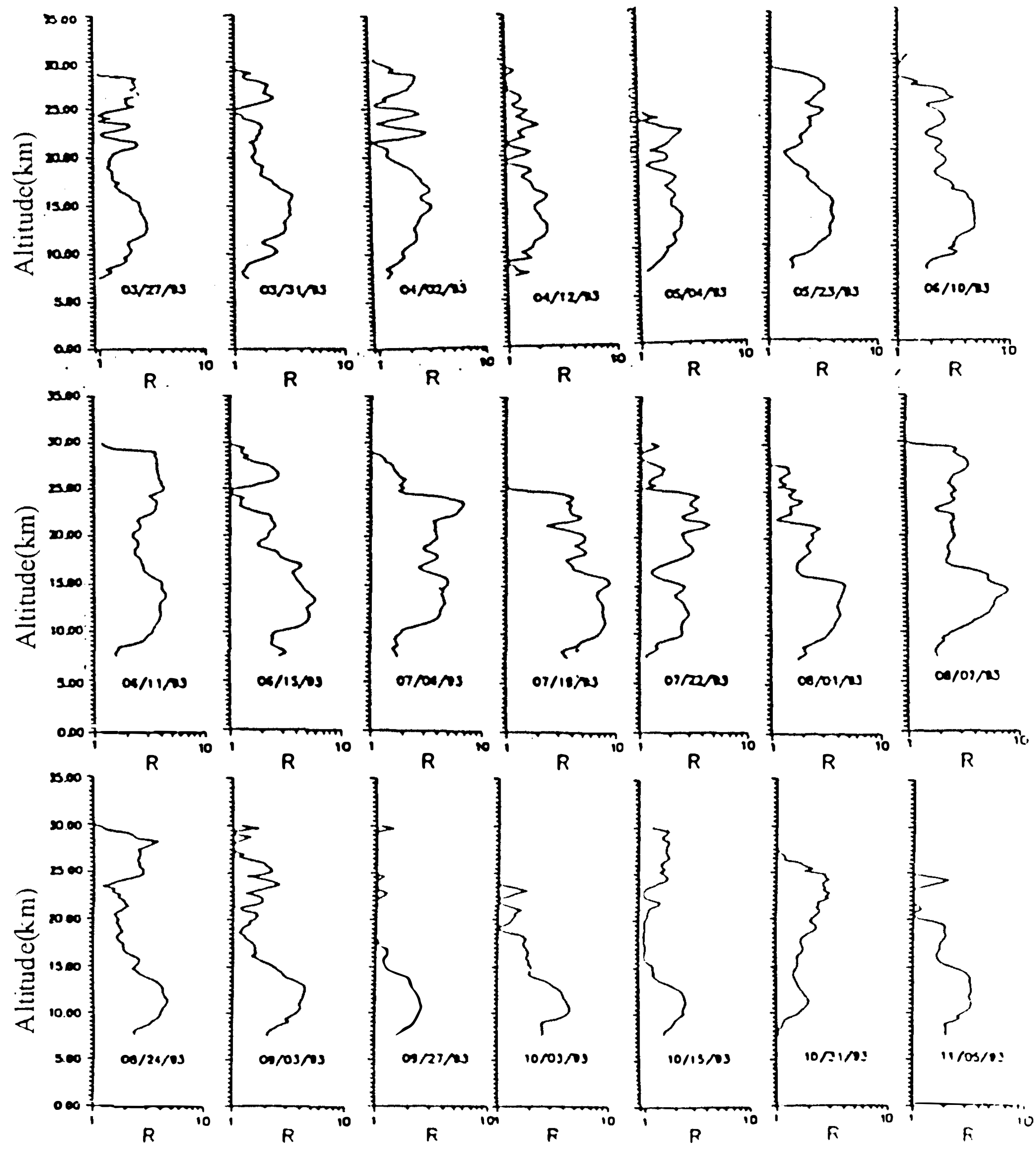

Fig. 11. Profiles of the stratospheric aerosol backscattering ratio R (z) at Zhongshan Station.

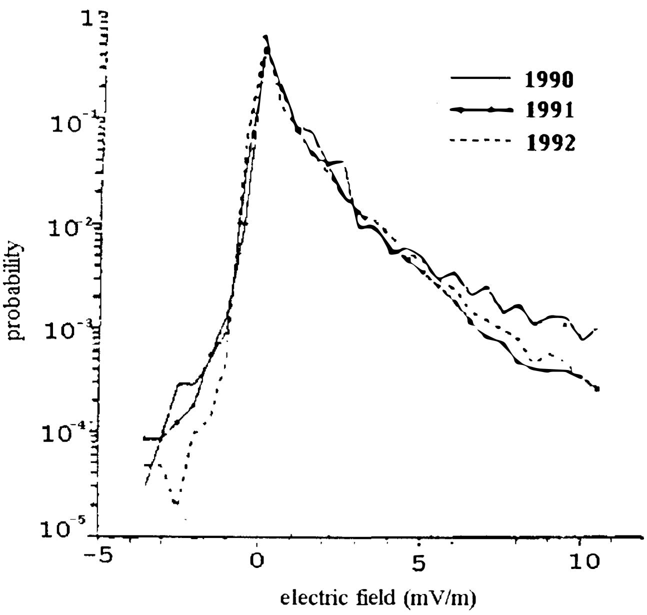

Fig. 12. Probability distributions of electric field strengths at Zhongshan Station for 1990, 1991 and 1992.

field for 1990, 1991 and 1992 (Lü *et al.*, 1995). We have deduced the average characteristics such as spectra in several time scales, seasonal variation, typical features in different weather and so on. These fundamental features can be considered as 'background' and will be applied to the analysis of the controlling factor in formation of this average characteristics of electric field and furthermore to explore the response of atmospheric electric field to all kinds of disturbances.

5. Summery and Future Work

The geospace environment is of great scientific and practical interest. The geospace environment monitoring is an important part of research which closely related to the Global Change. Analysis and interpretation of synoptic measurements are essential to understanding the physical phenomena affecting our environment, developing reliable predictions of their occurrence, and appreciating their consequences for society. The value of long-term monitoring will be manifested in the future.

The Chinese Zhongshan Station has a unique location for ground-based measurements in monitoring geospace environment. In order to study the global character of the solar-terrestrial system, a ground-based composite measurement system has been built at Zhongshan Station during past few years, which consists of more than 20 different measurements relevant to solar radiation, geomagnetic field, aurora, ionospheric disturbances, and middle and low atmospheric phenomena. Preliminary results have shown various distinctive features of the geospace over Antarctica. It is revealed that the cusp/cleft region, since its special configuration, plays an important role in the coupling among the solar wind, magnetosphere, ionosphere and middle atmospheres as well as global behavior of the solar-terrestrial system, and the ground-based observations can supply a diagnosis of these processes.

The composite measurement system will be further developed and improved in future. As one of main stations in the planning 120° E meridional observation chain, Zhongshan Station will be further equipped through constructing an HF coherent scattering radar, upgrading the existing lidar, setting up optical instruments and so on.

The cooperative research on upper atmospheric physics with Japan and the space plasma wave studies with Australia have been implemented very successfully and will be continued. International cooperations are welcome at Zhongshan Station.

Acknowledgments

The authors gratefully thank many of their colleagues for various discussions. This work was supported by the National Natural Science Foundation of China under Grant 49634160 and the Chinese Antarctic Administration.

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(Received January 31, 1997; Revised manuscript accepted September 2, 1997)