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The establishment of GPS network in Grove Mountains, East Antarctica

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Abstract The Grove Mountains are located in Princess Elizabeth Land, East Antarctica, extending from 72° to 73°S latitude and 73° to 76°E longitude, covering approximately 8000 km^2 areas. During the 2002/2003 austral summer season, the 19th CHINARE (Chinese National Antarctic Research Expedition) carried out the third expedition in Grove Mountains, East Antarctica. The Geodetic network was established, which can provide ground control for the satellite image map for the multi-discipline expedition in the Grove Mountains where seven permanent GPS benchmarks were set up supported by the helicopter and snow vehicles. All GPS sites besides Z001 were observed at least for one hour using the dual frequencies Trimble 4000ssi GPS receivers. The data were processed by the comprehensive GPS analysis package—GAMIT/GLOBK and the precision is good enough to satisfy with the acquirement of satellite mapping in this area.

Key words Geodetic network, GPS, Grove Mountains, Antarctica

1 Introduction

The Grove Mountains is located at Princess Elizabeth land in East Antarctica, about 400 km from Zhongshan station and 160 km east of the Mawson Escarpment, consists of a scattered group of mountains and nunataks. The range extends 73°-76°E, 72°-73°S, an area of 8000 km^2. The Grove Mountains has great topographical undulation and is densely covered by ice crevasse, the weather there is atrocious (Sun *et al*. 2001). The average temperature in the Grove Mountains in January is -18.5℃ which is 18℃ lower than Zhongshan Station, and the average wind velocity in the Grove Mountains is more than 10 m/s. The daily range of temperature and strong wind frequency in the Grove Mountains are much larger than that of Zhongshan Station (Cheng *et al*. 1999). The Grove Mountains has been one of the Chinese ideal midway stations on the traverse route from Zhongshan station to Dome A.

During the 1998/99 austral summer season, the 15th Chinese National Antarctic Research Expedition (CHINARE) visited the Grove Mountains for the first time for geodetic

and geological research work (Ju and Liu 2000; Chen *et al* 2001). In the following season, the 16th CHINARE carried out the second expedition in the Grove Mountains, the surveyors mapped the core area which covers 110 km^2 at the scale of 1:25000 utilizing the Differential GPS technique (Peng *et al* 2001; Ding and Peng 2001). During the austral summer season, the 19th CHINARE visited the Grove Mountains for the third time, 7 permanent geodetic sites were set up in this area, all of which besides Z001 were observed at least for one hour using the dual frequencies GPS receiver, and prepared for the satellite image mapping.

In recent years, the Grove Mountains is also an area of interest of both Australia and Russian. The Australian National Research Expedition (ANARE) undertook geodetic survey work in the Grove Mountains in the summer 2000/01. A Russian expedition undertook an airborne geophysical survey to the north of the Grove Mountains during the 1999/2000 season (Gary *et al* 2001).

2 Field work

During the 2002/2003 summer season, the 19th CHINARE carried out the third expedition in the Grove Mountains, the main tasks include: geodetic survey, meteorite collection, ice dynamics and geology research etc.

In order to provide the ground control for the satellite image mapping, the surveyors established 7 permanent geodetic benchmarks in Cooke PK, the north part of the Gale Escarpment, Mount Harding, Melvold NTKS, Black NTKS, the south part of the Gale Escarpment and the middle part of the Gale Escarpment, and the GPS control network is shown in Figure 1.

In January 19, 2003, the Z-9 helicopter flew from Zhongshan Station to the camp No. 5 at the foot of the Mount Harding, then to the Cooke PK for GPS measurement and snow sampling etc. This is the first time Chinese helicopter flew to the Grove Mountains under the furious weather conditions without foreign aids.

Shortly after the arrival at camp No. 5, the helicopter carried the surveyors to Cooke PK. Because the wind near the foot of the Cooke PK is strong, the helicopter had to land on ice surface far away. The geodetic benchmark which carved Z001 was set up on a nunatak to the south of Cooke PK, the mark is illustrated in Figure 2. Only 20 minutes data were collected on this point because the helicopter had to fly back in an hour.

Except for Cooke PK, GPS measurements at the other 6 sites were supported by snow vehicles. On the apparent and flat solid bedrock, the surveyors drilled a hole into the bedrock, then put the screw of the benchmark into the hole and clung it with glue. After the benchmark was stable enough, the GPS antenna was mounted on the benchmark and began the observation. About one hour's data were sampled at each site. The satellite cutoff angle was set to 15 degree and the sample interval was 15 second. Photos were taken from different directions for the benchmark. GPS measurement in the Grove Mountains is shown in Figure 3.

The observation records are shown in table 1.

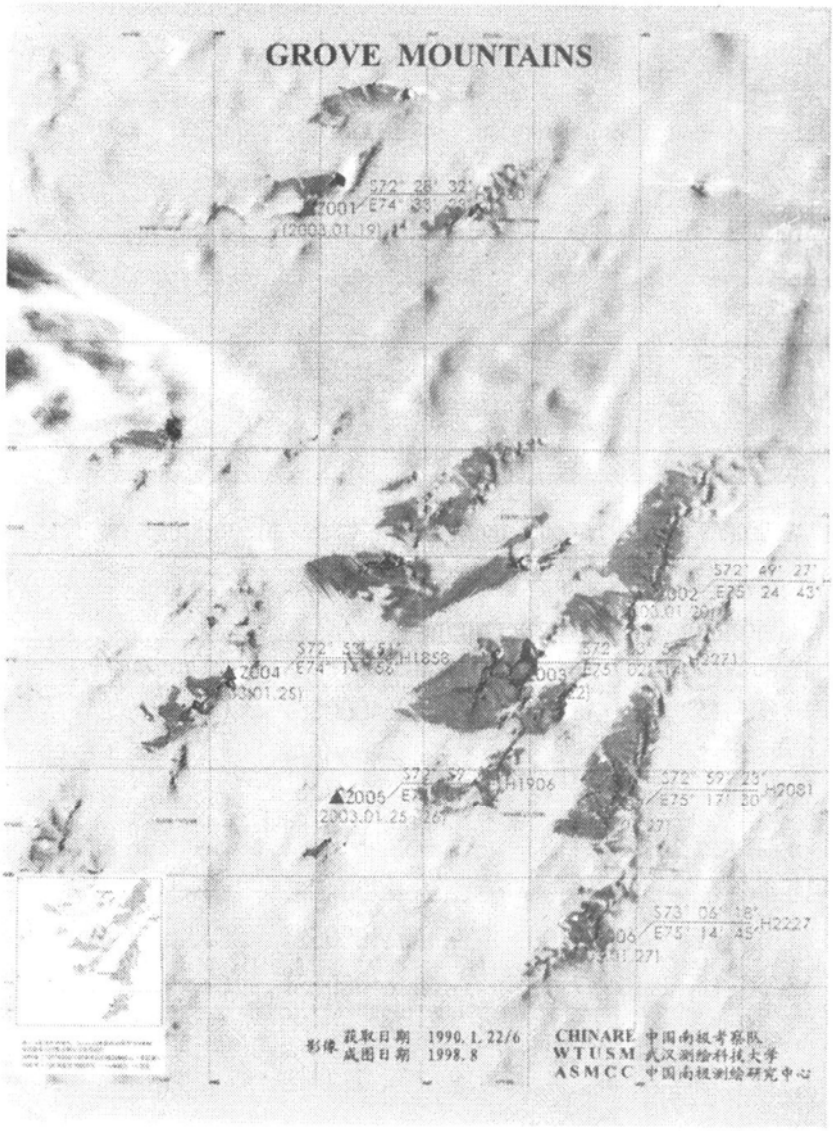

Fig 1 GPS control network in the Grove Mountains, the coordinates of the GPS sites are the approximate coordinates

Fig 2 GPS benchmark in the Grove Mountains

Fig 3 GPS measurement in the Grove Mountains

Table 1 GPS observation information in Grove Mountains

Site	Date	Start	Finish	Receiver	Antenna Type	Antenna Height
Z001	2003 1 19	10 13 45	10 35 30	Trimble4000SSI	Geodetic L1/L2	0 200 m
Z002	2003 1 20	08 54 15	09 55 45	Trimble4000SSI	Geodetic L1/L2	0 243 m
Z003	2003 1 22	11 20 45	12 38 15	Trimble4000SSI	Geodetic L1/L2	0 200 m
Z004	2003 1 25	16 23 15	17 24 00	Trimble4000SSI	Geodetic L1/L2	0 243 m
Z005	2003 1 25	18 46 15	19 46 30	Trimble4000SSI	Geodetic L1/L2	0 200 m
Z006	2003 1 27	11 35 45	12 38 00	Trimble4000SSI	Geodetic L1/L2	0 200 m
Z007	2003 1 27	15 56 15	16 57 15	Trimble4000SSI	Geodetic L1/L2	0 200 m

3 Data Processing

The GPS data were processed with GAMIT/GLOBK. GAMIT is a comprehensive GPS analysis package developed by MIT and SIO for the estimation of three-dimensional relative positions of ground stations and satellites orbits GAMIT uses both carrier phase and pseudorange observables The most precise information can be obtained by the carrier phase, but with ambiguities on the integer number of wavelengths The software is composed of ARC、Model、SINCLN、DBCLN、CVIEW and SOLVE modules etc (king 2000).

The data were processed using IGS precise ephemeris, several IGS stations around Antarctica such as CAS1, DAV1, MAW1, MCM4, PALM, SYOG and VESL and Zhongshan station were tightly constrained (within 1 cm) at their ITRF2000 values while the sites in the Grove Mounains were loosely constrained (within 100 m). The ephemeris precision is one of the most important factors in GPS data processing and its influence on baseline processing can be given in the formula below:

$$\frac{|\Delta r|}{10|r|} < \frac{|\Delta b|}{|b|} < \frac{|\Delta r|}{4|r|} \qquad (1)$$

Where $|\Delta r|$ is the error of satellite orbit, r is satellite earth center position vector, $|\Delta b|$ is error of the baseline vector, and b is the baseline vector between the two stations

The main limiting factors in GPS baseline processing are listed below:

- The satellite clock offset

- The receiver clock offset
- The influence of ionosphere refraction
- The influence of troposphere refraction
- The phase center correction of the satellite and receiver
- The tidal correction of the station

The quality of the data is also important for the precision and reliability of baseline. The data edit which included fixing the cycle slips and eliminating the remained residuals is the main job in processing data. Based on the data edit, ARC、MODEL and SOLVE can be run sequentially (Jiang *et al*. 2001; Wang *et al*. 2001). The precision of the control points are listed in table 2.

Table 2. The precision of the control points

Site	Location	ΔX(m)	ΔY(m)	ΔZ(m)
Z001	Cooke PK	8.848	10.140	14.173
Z002	the north part of the Gale Escarpment	0.049	0.041	0.034
Z003	Mount Harding	0.409	0.167	0.151
Z004	Melvold NTKS	0.097	0.179	0.124
Z005	Black NTKS	0.277	0.164	0.242
Z006	the south part of the Gale Escarpment	0.070	0.044	0.026
Z007	the middle part of the Gale Escarpment	0.037	0.099	0.088

From table 2, we can see that the precision of Z001 is poor, because of the short time occupation. Besides Z001, the other 6 sites can satisfy with the satellite image mapping at the scale of 1∶50000.

4 Conclusions and suggestions

The precision of the 6 sites in the Grove Mountains except for Z001 are high enough to satisfy with the satellite image mapping at the scale of 1∶50000.

Because of the limitation of the logistic support, short time GPS data were observed at Z001 site. As a result, the precision of Z001 is too low to be used. If it is possible, Z001 should be re-occupied in next expedition and 2–3 more sites should be established in the north part of the Grove Mountains.

The control points in the Grove Mountains can be analyzed together with the points in the Larsemann Hills and Lambert Glacier-Amery Ice Shelf System, this would be of great importance to the research of geodynamics of east Antarctica. In addition, the geodetic network in the Grove Mountains should be combined with the geodetic work undertook by Australian and Russia if possible, which would unify the geodetic reference framework in the Grove Mountains, Larsemann Hills and Lambert Glacier-Amery Ice Shelf System in the east Antarctica.

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