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The absolute gravity measurement by FG5 gravimeter at Great Wall Station, Antarctica

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Abstract Gravity measurement is of great importance to the height datum in Antarctica. The absolute gravity measurement was carried out at Great Wall Station, Antarctica, using FG5 absolute gravity instrument. The gravity data was processed with corrections of earth tide, ocean tide, polar motion and the atmospher, and the RMS is within $\pm 3 \times 10^{-8}$ ms^{-2}. The vertical and horizontal gravity gradients were measured using 2 LaCoaste& Romberg (LCR) gravimeters. The absolute gravity measurement provides the fundamental data for the validation and calibration of the satellite gravity projects such as CHAMP, GRACE and GOCE, and for the high accuracy geoid model.

Key words absolute gravimetry, gravity gradients, Antarctica

1 Introduction

Gravity measurement is of importance to detection of vertical crustal motion, determination of the geoid, studies on postglacial rebound and global sea level due to global warming in the Antarctic. Gravity measurements in the polar region are coordinated by the Scientific Committee on Antarctic Research (SCAR) and the International Association of Geodesy (IAG). The Geoscience Standing Scientific Group (GSSG) of SCAR made the GIANT (Geodetic Infrastructure for Antarctica) program, and the physical geodesy project is one of the programs of GIANT, which main objective is compile and analysis the gravity data to develop a new high resolution geoid for the Antarctic[1]. The main scientific goals of the IAG commission project 2.4 "Antarctic Geoid Project (AntGP)" are to compile gravity data of the entire Antarctic and improve the terrestrial gravity data coverage[2].

Gravity surveys in the Antarctic started in the 1950s. Because of the extreme environment and location, the airborne gravimetry has been the important way in the Antarctic. During 1994/1995 and 1996/1997, the airborne gravity surveys was carried out in the Antarctic Peninsula by British Antarctic Survey (BAS) using LaCoaste& Romberg(LCR) gravimeter[3,4].

Absolute gravity measurements in the Antarctic began in 1990 when transportable instruments had become available. More than 20 absolute gravity measurements have been performed in the Antarctic up to 2006. In 1991, the first absolute gravity site was established in Terra Nova Bay by Italy[5]. During December 12, 2000 to January 25, 2001 and December 31, 2003 to February 9, 2004, the absolute gravity surveys were performed in Syowa Station by Japan using FG5 gravimeters, meanwhile, the relative gravity surveys were performed using TT70 superconducting gravimeters and CT superconducting gravimeters[6-9]. In 1994 and 2001, the absolute gravity surveys were performed in Aboa Station by Finland using JILAg-5 gravimeter[10]. In 1987 and 1991, the relative gravity measurements were carried out in Punta and King George Islands by Uruguay[11]. In 1990 s, German Antarctic Scientific Expedition carried out gravity measurements several times in Queen Maud Land, Antarctica[12]. The gravimetry measurements in the Antarctic are showed in Figure 1.

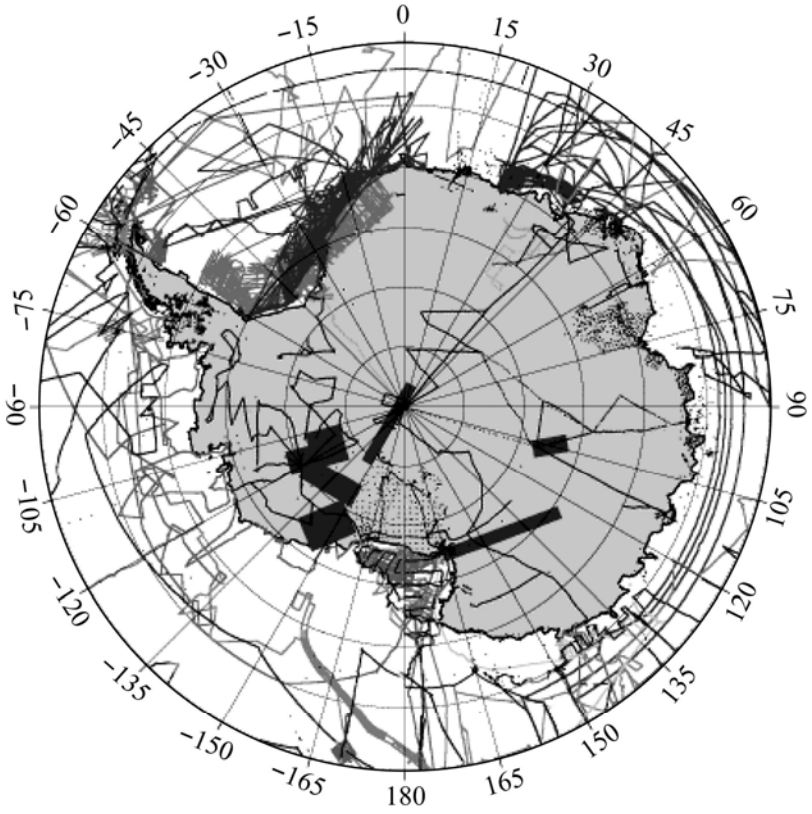

Fig 1 The gravimetry measurement carried out in Antarctica(ADGRAV, 2002)[13].

In 1985, GreatWall Station was established during the first Chinese National Antarctic Scientific Expedition (CHINARE) in King George Islands, West Antarctica. The relative gravity survey was performed using LCR gravimeter, the g value is 982208.682 ±0.021 mgal[14]. In 2004/05 austral summer season, the first Chinese absolute gravity survey was performed during 21st CHINARE using FG5 gravimeter in GreatWall Station, meanwhile, the relative gravity surveys were also performed using LCR gravimeters. This paper describes the results of the absolute gravity survey, the relative gravity surveys will be reported elsewhere.

2 Field work

In 2004/2005 austral summer season, the absolute gravity survey was performed during 21st CHINARE using FG5 gravimeter in Great Wall Station, West Antarctica. The FG5 operates by using the free-fall method. An object is dropped inside a vacuum chamber. The descent of the freely-falling object is monitored very accurately using a laser interferometer. The free-fall trajectory of the dropped object is referenced to a very stable active-spring system called a superspring. The optical fringes generated in the interferometer provide a very accurate distance measurement system that can be traced to absolute wavelength standards. Absolute standards of length and time provide the means to achieve a calibrated gravity value that does not drift over time. The instrumental accuracy of FG5 is about 2 μGal[15-18].

Two absolute gravity sites were set up in the Great Wall Station area, one is C001, the other is C002. Both sites were located on stable, relatively level ground. The concrete piers were established to provide the smallest micro-seismic signals. The observation room was set up at site C001.

The absolute gravity measurements were carried out at site C001 during February 6-7 and at site C002 during February 8-9, 2005. The drops were repeated every 10 s, the average of 120 drops was a set. Each measurement last no lest than 12 hours. The information of the observations at the two sites are shown in table 1.

Table 1 The gravity measurement field observation at Great Wall Station

Site	Sets	Drops	Ratio
C001	49	5700	96.9%
C002	62	7196	96.7%

3 Data processing

The Micro-g Solutions software (shortly, G) was used to process the absolute gravity data. G allows users to change interactively and select processing parameters and/or sets and drops by standard controls. If necessary, prior to processing a data set the user may select and/or modify the appropriate processing parameters and determine which sets and/or drops would be included in the processing or not. G processes data sequentially, that is, each set is processed in the order it was observed. If a change is made in the processing parameters, it is necessary for all data to be completely reprocessed. The accuracies of measurements at C001 and C002 sites are shown in figure 2.

The final gravity value is obtained after applying correction of earth tides, ocean loading, local atmospheric effect and polar motion effect, the rms ith in $\pm 3 \times 10^{-8}$ ms^{-2}. The results are shown in table 2.

Table 2 The results of the absolute gravity measurement at Great Wall Station

Site	Date	G value at 1.3 m (10^{-5} ms^{-2})	G value at ground (10^{-5} ms^{-2})	Rms (10^{-5} ms^{-2})
C001	2005.2.6-7.	982207.629	982208.089	±0.003
C002	2005.2.8-9.	982206.938	982207.372	±0.003

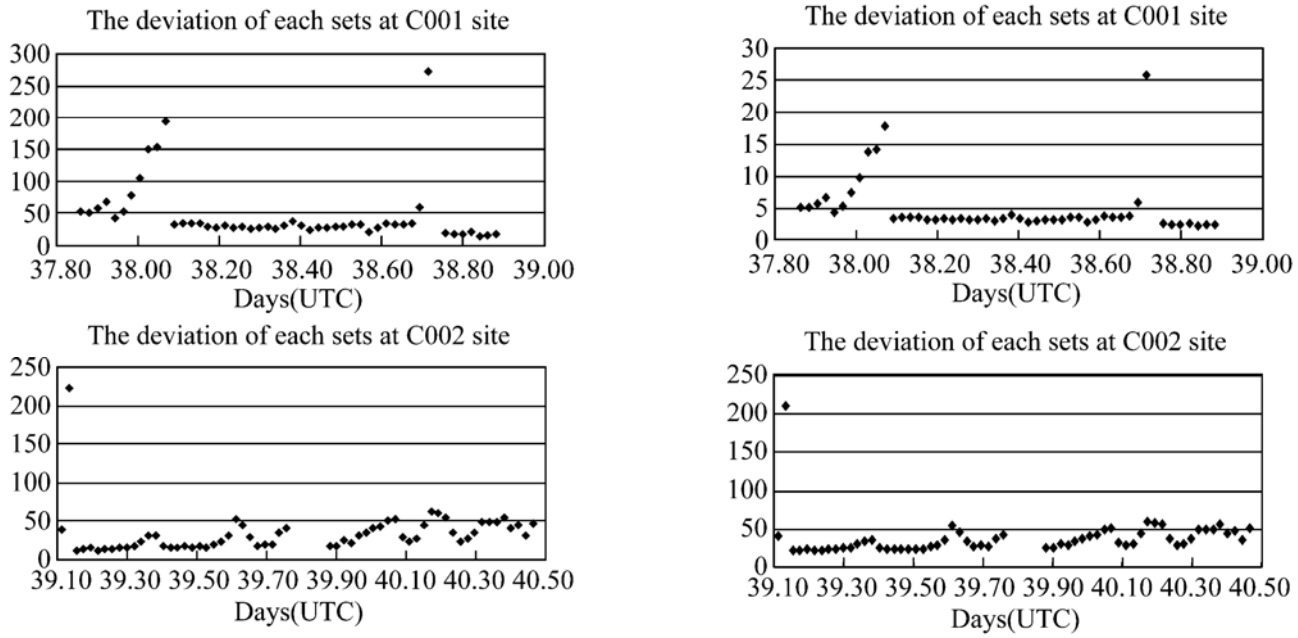

Fig 2 The accuracies of the measurements of each set at C001 and C002 sites

4 Horizontal and vertical gravity gradients

Two LCR-G relative gravimeters were used to perform the horizontal and vertical gravity gradients measurements at C001 and C002. The vertical gradient was determined between the pier and the plane which is 1 m high, the observation order was plane-pier-plane or pier-plane-pier. The observation data was processed with the tidal correction and zero drift correction to make the error within $\pm 3 \times 10^{-8}$ m s^{-2}. The horizontal gradient measurement was performed from the central point, then to corner 1, corner 2, corner 3, corner 4, corner 3, corner 2, corner 1 and central point. The scale factors of the two relative gravimeters were determined between C001 and C002. The results of vertical gravity gradients, horizontal gravity gradients and scale factors are shown in table 3, 4, and 5.

Table 3 The result of vertical gradient measurement

Site	Date	Segment	Segment gap (10^{-5} m s^{-2})	Rms(10^{-8} m s^{-2})	H(m)	Vertical gradient (10^{-5} s^{-2})
C001	2005.2.12	C001-ccz5	-0.4020	±1.553	1.137	-0.3536
C002	2005.2.10	C002-cch5	-0.3687	±1.104	1.104	-0.3340

Table 4 The result of horizontal gradient measurement

Site	Date	Segment	Segment gap (10^{-5} m s^{-2})	Rms(10^{-8} m s^{-2})	Dist (m)	Horizontal gradient (10^{-8} s^{-2})
C001	2005.1.1	C001-ccz1	-0.0318	1.864	0.652	-48.8
		C001-ccz2	-0.0177	1.896	0.633	-28.0
		C001-ccz3	-0.0146	1.542	0.642	-22.7
		C001-ccz4	-0.0169	1.980	0.641	-26.4
C002	2005.1.1	C002-cch1	-0.0152	1.085	0.348	-43.7
		C002-cch2	-0.0055	1.738	0.365	-15.0
		C002-cch3	-0.0090	0.965	0.372	-24.2
		C002-cch4	-0.0069	1.926	0.370	-18.6

Table 5 The scale factor of the relative gravimeter

Instrument	Date	Segment gap (10^{-8} ms^{-2})	Real segment gap (10^{-8} ms^{-2})	Scale factor
LCR-G-800	2005. 2. 14	-716. 5607	-698. 7	1. 025563
LCR-G-796	2005. 2. 14		-698. 2	1. 026297

5 Conclusions and discussions

During 2004/2005 austral summer season, the absolute gravity measurement was carried out at Great Wall Station, Antarctica, using FG5 absolute gravity instrument and the RMS is within $\pm 3 \times 10^{-8}$ ms^{-2}. The vertical and horizontal gravity gradients were measured using 2 LaCoaste& Romberg (LCR) gravimeters. The absolute gravity measurement provides the fundamental data for the validation and calibration of the satellite gravity projects such as CHAMP, GRACE and GOCE, and for the high accuracy geoid model.

During 2008/2009 austral summer season, the absolute gravity measurement will be carried out at Zhongshan Station, East Antarctica, which can set up the gravity datum for the inland ice sheet gravity measurement. The repeated absolute gravity measurements are planed to be carried at both Great Wall Staiton and Zhongshan Station in the next a few years. The absolute gravity, GPS data and tide gauge will be combined together to study the vertical crustal movement, postglacial rebound and sea level change.

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