

NATIONAL REPORT ON ABSOLUTE AND SUPERCONDUCTING GRAVIMETRY

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The Earth's gravity field contains abundant information on mass's distribution and movement among the Earth system, which directly reflects the basic properties of the Earth's spheres layers, namely the characteristics of distribution and its variation of density. It is known that the mass density is one of the most fundamental, direct and important quantities to studying varieties of environment changes and geodynamic features. In recent years, on the basis of international cooperation project such as the Global Geodynamic Project (GGP), the gravity cooperation in east Asia between China and Japan and the national key science project named monitoring network on crustal movement in China, the Institute of Geodesy and Geophysics, Chinese Academy of Sciences (IGG, CAS) has carried out a plenty of field and scientific investigations by using advanced FG5 absolute and GWR Superconducting Gravimetric (SG) techniques and achieved much excellent progress, which are summarized as below:

I. ABSOLUTE GRAVITY REFERENCE NETWORK IN CHINA MAINLAND

In the recent years, the establishment of the absolute gravity network and absolute gravity reference have been developed with FG5-112 absolute gravimeter. By the end of the year of 2006, measurements of absolute gravity at about 100 stations in China mainland are completed with the precision of 2~5 μ Gal ($1\mu\text{Gal} = 10^{-8} \text{ms}^{-2}$) in which repeat operations had been carried out at majorities of the stations (Zhang et al, 2005a; Zhang et al, 2005b). The results provided the national gravity fundamental network 2000 with gravity reference with precision of 5 μ Gal (Qiu et al, 2004). As Wang et al (2004) mentioned, the establishment of the national network of the absolute gravity reference supplied important information for the national basic surveying and mapping, earthquake monitoring and studying on regional tectonics and geodynamics.

Combining with the repeat mobile observations of gravity, the image of gravity variation nowadays has been constructed firstly, which contributed to the important reference for middle and long term predictions of earthquakes events (Hsu et al, 2003). The monitoring on crustal movement and geodynamic study corresponding to the regional gravity change was carried out under the cooperation with Kyoto university in Japan. In this cooperation, the stations involved in our country were Wuhan, Shanghai, Kunming, Beijing, Nanning, Urumchi, HongKong, Lhasa, Xi'an, Xining and so on. Sun et al (2006b) investigated the comparison among the FG5 instruments of Kyoto

University, Geographical Survey Institute in Japan and IGG, CAS in China. Wang et al (2004) and Liu et al (2005) carried out the tests on gravity changes at three gorges region before and after the storage of the large amount of water mass, and established a regional absolute gravity network with μGal precision at tide gauge stations in southeast China coastal area, in Dianxi, Yunnan province and in Tibetan plateau in order to develop the research on ground sedimentation, crustal movement and plateau uplift. After several year of hard work, the absolute gravity reference and absolute gravity network had been improved one order of magnitude in precision than the reference network during the period of 8th five-year project. Meanwhile, density of the gravity stations and the coverage rate had been increased significantly, which provided with more accurate parameters of ground based gravity field for the study of the gravity model constructing and the geoid refining.

II. RESEARCH ON GRAVITY VARIATION AND ITS MECHANISM

By analysing the repeat observations of high precision gravity network, the information of variations of absolute gravity field was obtained, which contributed to the earthquake prediction, studies on variation of sea surface and geodynamics with μGal precision. By analysing the results of the repeated absolute gravity measurements during the period from 1998 to 2004, Wang et al (2004) found the decrease trace of gravity field over the area of Tibetan plateau, which showed the uplift of Tibetan plateau with speed of 8.7 mm/yr. They found the decrease of gravity over north China region while increase over the coastal lines regions of the southwest China and southeast China. These phenomena were consistent with the leveling results that the crust over southeast China was descending, which reflected the characteristics of the vertical movements in Chinese continent. Zhu et al (2003) pointed out that the Ms8.1 earthquake in Kunlun mountain area occurred at the high gradient of maximum negative gravity change belt, which corresponded to the high strain area derived from GPS observations. And Wang et al (2004) also found the gravity change due to this earthquake. To study the crustal movement of coastal area in southeast China and variation of sea surface, Liu et al (2005) obtained the characteristics of horizontal displacement of coastal area in China relative to Europe-Asia frame and the characteristics of the vertical displacement relative to ITRF2000 using the gravity station and GPS co-site network constructed at 6 tide gauge stations, which contributed positively to monitoring the large scale crustal movement and tectonic deformation.

III. TIDAL GRAVITY AND LOADING EFFECTS OF ATMOSPHERE AND OCEAN TIDES

By comparing the gravity observation obtained with SG and FG5 gravimeters, the scale of SG gravimeter was accurately determined by Sun et al. Xu et al (2003) and Sun et al (2006a) developed the researches on Earth tides over China mainland, HongKong and Antarctic area. Tian et al (2005) and Ducarme et al (2006) synthetically analyzed the long term global SG observations in the GGP network and accurately determined the tidal parameters including the ones of long period tides. Xu et al (2004) investigated the global distribution characteristics of tidal parameters.

On the basis of the theory of elastic Earth's response to surface load and standard atmospheric model, combing the variation of the global atmospheric pressure and temperature, Luo et al (2005) studied the time-space and frequency characteristics of atmospheric load effect by numerical method, i.e. convolution of air pressure and atmospheric loading Green's function, which provided an atmospheric load correction model for high precision measurements of ground gravity, tilt, displacement and strain. Hu et al (2006) investigated the frequency dependence of atmospheric gravity signals utilizing long term global SG observations. With the latest global ocean tide models, Zhou et al (2005; 2006) calculated the load correction vectors for all the GGP network stations. Combing the local ocean tide models in China coastal area, this work improved significantly the correction precision of gravity and tilt observations. Sun et al (2005a; 2005b) synthetically investigated the adaptabilities of Earth's tide models and ocean tide models by using the global SG observations.

IV. EARTH'S FREE CORE NUTATION AND EXPERIMENTAL MODEL OF TIDAL GRAVITY

According to the characteristics of nearly diurnal resonance observed from gravity observations and stacking the long term, continuous and high quality gravity observations obtained at 19 GGP stations distributing in different areas globally, the parameters including resonant period, resonant intensity and quality factor of Earth's Free Core Nutation (FCN) were accurately determined after effectively eliminating the effects of atmosphere, ocean and environment around stations. The results were in good agreement with the ones resulted from space geodetic techniques such as Very Long Baseline interferometry (VLBI). Sun et al (2003) and Xu et al (2004a) investigated the difference of the resonant period between determined and theoretical ones. By using gravimetric technique, that the realistic dynamic eccentricity of Earth's liquid core was 5% larger than the one derived under the hypothesis of hydrostatic equilibrium was proved by this study. Sun et al (2004) and Xu et al (2004a) studied the variation characteristics of the tidal gravity parameters and solved the parameters of nearly diurnal resonance of the Earth's tides and the dependent factors of amplitude factors on latitude (O_1 and M_2). The experimental tidal gravity models were constructed with considering of the free oscillation of the Earth's liquid core. Their results showed that the mean differences of the amplitude factors of four main constituents between the experimental Earth tide model and the ones obtained by SG observations were all small than 0.2%, which agreed well with the latest Earth tide model. The mean discrepancy of the amplitude factors was $\pm 0.06\%$ in which the diurnal results were in good agreement with Mathews' theoretical model (2001) and semidiurnal results were in better agreement with Dehant's model (1999). These results provided with accurate correction model for Earth tidal gravity for the ground and space based geodetic techniques.

V. DETECTION OF EARTH'S FREE OSCILLATION AND ITS INVESTIGATION

By synthetically analyzing the observations obtained with global superconducting gravimeters at five stations during Peru Ms7.9 earthquake, all the spherical oscillation modes were accurately

detected by Lei et al (2005). And from analyzing the SG observations at Wuhan station during Sumatra large earthquake, many free modes of Earth's free oscillation including 50 harmonic modes were detected. It was the first time in China that the harmonic spherical modes series had been detected systematically by gravimetric technique, which could be used as new basic observational achievements for the research of the deep interior of the Earth. Additionally, the triplets of some modes were also found, which were very accurate especially for those of ${}_0S_2$ and ${}_0S_3$ modes (Park et al, 2005). By using global SG observations, during the period of the Sumatra large earthquake, Hu et al (2006) found the coupling toroidal modes and lower degree spherical spectral splitting phenomena, it could provide with the new important reference for the study of the Earth's deep interior.

Using the high quality of continuous SG observations at 13 stations globally in the GGP network, the possibility in the detection of long period core modes was investigated by Xu et al (2005), in which four globally spectra peaks with periods of 16.55, 15.79, 11.00 and 10.09 hour were found in the inter-tidal bands. The further analysis showed that these peaks possibly resulted from long period oscillation of the Earth's liquid core. Further more, 8 globally spectra peaks were found in sub-tidal band. Sun et al (2006c) studied the temporal variation features of these signals using wavelet technique. The researches by Sun et al (2004) and Xu et al (2005) showed that the Slichter mode was one of the possible sources of these signals. Of course, to get a definite conclusion, the more knowledge on structure of the deep interior of the Earth and improvement of dynamic research methods to Earth's liquid core are being expected.

VI. RESEARCH ON EFFECT OF POLAR MOTION ON GRAVITY

The effect of polar motion on gravity was investigated by using the global SG observations and Earth's rotation data provided by the IERS. The theoretical calculation showed that energy of product spectra of annual and Chandler wobbles concentrated at the periods of about 436.68 and 377.36 day while the one according to the observation concentrated at the periods of 438.60 and 362.32 day. Consequently, the differences between mentioned periods above are 0.4% and 3.9% respectively for Chandler and annual wobbles (Xu et al, 2004b; Yang et al, 2004). Meanwhile the gravity tidal parameters were obtained as 1.1613 ± 0.0737 and $-1^\circ.30 \pm 1^\circ.33$ respectively for amplitude factor and phase lag, which was very close to the simulation using zonal tide theory by Xu et al (2004a). It was showed that the gravity change caused by polar motion could be effectively detected accurately by superconducting gravimetric technique.

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