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CONTENTS

Chinese Progress in Geodesy and National Geodetic Datum

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1.1 Progress of CGCS2000 frame

The progresses include the construction of China geodetic coordinate system 2000, Velocity field and plate motion model in mainland China (Wei Ziqing, 2011; Cheng Pengfei, Cheng Yingyan,2011; LV Zhi-ping, 2013), the maintenance of terrestrial reference frame considering non-liner variation(Jiang Weiping, 2010), the initial realization and analysis of the Compass terrestrial reference frame (Wei Na,2013; Zou Rong,2011), and the creation of a new generation of geodetic GGOS products using fusing a variety of geodetic observations and technical methods, etc.

1.1.1 Coordinates and velocity field of CGCS2000

The combined adjustment of more than 1000 stations was carried out in ITRF 2005, achieving the precise coordinates and velocity of CGCS2000 reference frame. In order to accurately obtain coordinates of national CORS stations, global CORS stations in ITRF 2005 are also involved in the adjustment calculation by applying the seven parameter distinguishing method, achieving a total of accurate coordinates of 1079 stations and velocity of 1025stations. The adjustment results of coordinates are as

follows: the precision of N direction is 0.87mm, the precision of E direction is 0.90mm, the precision of U direction is 4.00mm; The adjustment results of velocity fields were as follows: the precision of N direction is 0.12mm/y, the precision of E direction is 0.13mm/y, the precision of U direction is 0.56mm/y.

1.1.2 3-D velocity field model for CGCS2000 Maintenance

3-Dvelocity model of crustal movement in China was established to maintenance theCGCS2000 reference frame. It shows that the error of the horizontal direction movement rate is 0.1~0.25mm/y, the error of the vertical direction movement rate is 0.1~0.25mm/y, which is consistent with the corresponding results from the international institutions. The study indicates that our national terrestrial plates show trend movement toward the east, and western motion vector is significantly greater than the east. The western movement velocity is generally 1-3cm/y, but the east less than 1cm/y. The characteristics of crustal movement weakened from east to west is very obvious, and the results is consistent with the idea from the geologic understanding.

1.1.3 Chinese plate motion model: CPM_CGCS2000

In modeling the national plate motion model, new approach was developed to optimize the reference frame by taking the sudden abnormal deformation into account. A total of 20 sub-plates are identified and the new generation model CPM-CGCS2000 has been established in ITRF2005 by the accurate velocity field based on GPS observations of 10 consecutive years from China’ Crustal movement observation network. The new model precision is better than 1mm/a and this is further verified by transforming the coordinates of 28 CORS stations into CGCS2000. The result shows that there are 2~3cm differences between the

transformed coordinates and the known coordinates of these points in CGCS2000. Moreover, the comparison with the global plate motion models including APkim2005, PB2002, NUVELLA, and the regional model including the national models-Fu Yang and Wei Zi-qing indicate the superior of the new established model.

1.2China’s modern geodetic datum construction

China’s modern surveying and mapping system infrastructure construction (national surveying and mapping project) is by far the largest national geographic space infrastructure projects in China to maintain the national geodetic coordinate frame. This project was started in June 2012. Until June 2014, the national modern geodetic datum has been gradually established. Through the update and perfect infrastructure, the objectives of national modern surveying and mapping system construction include:

(1)Establishing360 national CORS stations built all over country, to realize the backbone of the national coordinate frame;

(2)Establishing 4500 points to the national geodetic network, to achieve relatively evenly covering the entire land area, reasonable density;

(3)Implementing the repetition measurement of the national first-class leveling network, including 775 new basic level points, 7030 ordinary level points, 110 level points on the bedrock and27400 gravity points;

(4)Establishing 50 gravity points co-located with on the national CORS stations;

For providing more accurate datum of the unified national coordinate frame, the national administration of surveying, mapping and geoinformation of China has completed the integrated adjustment using the new geodetic observations during 2014, including the provincial

CORS stations, national CORS stations from the sea area and CORS stations from the crustal movement observation network. The unified national geocentric coordinate datum of high precision has been achieved. The very progress of the coordinate frame will lay a good foundation for the realization and maintenance of the national dynamic geocentric coordinate reference frame.

1.3China's progress in gravity model and geoid refinement

1.3.1 National gravity model

The WHIGG-GEGM01S (GRACE Earth Gravity Model developed by Wuhan Institute of Geodesy and Geophysics) global gravity field model, complete up to degree and order 120, is produced using the GRACE Level-1B data products (Zheng,2012).

Based on the satellite gravity data the global gravity model of 180-order was resolved by the least square method in space domain and by the little arc method (Xu, 2011; You, 2012). Taking the gravity gradient measurement precision effect and terrain effect into account, the satellite gravity data processing method was developed. Besides, Regional gravity field model based on airborne gravity data was established (Jiang, 2013 and 2014). The least square collocation method and the Tikhonov regularization method were both applied in the geodetic data combination for recover the high resolution regional gravity model (Huang MT, 2013; Jiang T, 2014).

The global mean sea surface model WHU2009 was established by the data fusion of Geosat/GM, Geosat/ERM, ERS-1/168, ERS-2, Envisat-1, T/P and Jason-1 data. The test results show that the mean sea surface (MSS) variations are 2.5 mm/a, 3.2 mm/a, 3.6 mm/a and 6.2 mm/a respectively in four different sea regions from the north to the south of

China Sea (Jin TY, 2011; Sun W, 2013). The global potential W0, vertical deflection, gravity anomaly, tide information, thickness variation of the ice, mass variation of the ocean were also obtained by processing the altimetry data (Chu YH, 2012; 2014; Yang YD, 2011; Guo JY, 2013).

The absolute gravimetry and super-conducting gravimetry independently developed in China have been successfully applied in monitoring the earthquake and in detecting the height variation (Xiao F, 2012; Zhang HW, 2013; Zhao DJ, 2015).

1.3.2 National geoid refinement

The new 2'×2' quadsi-geoid model of China has been established by the Stokes-Helmert condensation method (Li JC, 2012). Many achievements have been made in this field, including the improvement and modification of the classical Molodensky theory (Zhang CY, 2012; Shen WB, 2012), proposing new calculation methods,comparing the different calculation methods for the Stoke's kernel functions(Chu YH, 2012, Zhai ZH, 2012).

By combining the satellite altimetry and satellite gravity as well as the airborne gravity, ship gravity over the sea area of China, the gravity anomaly model and quadsi-geoid model of 2.5'×2.5' resolution have been established in 2014, realized the height datum unification between land and sea area of China. The results show that the geoid model precision is better than 5cm.

1.4 Adjustment and geodetic parameter estimation

1.4.1 Error theory and adjustment

The uncertainty is distinguished from the uncertainty measure and new conceptions on the error theory are developed to meet the new

development in the uncertainty theory (YangYuanxi, 2012). The new definition of general reliability of measurement is proposed by extending the error theory and analyzing the systematic effect of stochastic error and the randomization of systematic error (Zhang Zhenglu, 2012). Besides, the conception of the spatial analysis has been introduced (Shi Wenzhong, 2012). Combining prior information with observing information, Bayesian methods for blunder detection are imposed (GuiQingming, 2010).

Many achievements have been made in the field of the total least squares. A robust method of weighted total least squares with reweighting iteration is proposed, which is based on IGG weight function (Gong Xunqiang, Li Zhilin, 2014). An iterative algorithm to solve the TLS problem by using the principle of indirect adjustment is derived (Lu Tieding, Zhou Shijian, 2010). The total least squares problem for quadratic form estimation has been deeply discussed (Fang Xing, Wang Jin Jin, Li Bofeng, ZengWenxian, Yao Yibin, 2015). The weighted total least-squares problem with constraints: a universal formula for geodetic symmetrical transformations has been discussed and some closed-form formulas have been developed (Fang, 2013; Fang, 2015; Li et al., 2012).

Maximum likelihood estimation in mixed integer linear model with P2 norm distribution has been proposed (Li Bofeng, ShenYunzhong, 2010). The Bias-corrected regularized solution to inverse ill-posed models has been developed (Shen et al., 2012). Theory and methods of inequality constrained least squares has been developed (Zhu Jianjun, Xie Jian, CHEN Yubo, 2011).

1.4.2 Dynamic parameter estimation

The Kalman filtering has been successfully applied in various fields such as GNSS, INS, InSAR. The new study shows the existing adaptive parameter estimators are related to the inner precision, external accuracy and semi external accuracy. The corresponding adaptive estimators are divided into inner precision-based, external accuracy-based and semi external accuracy-based adaptive estimators respectively (Yang Yuanxi, Jing Yifan, Zeng Anmin, 2014). Besides, the influence of the prior covariance errors to the standard dynamic Kalman filtering is obtained (He Zhengbin, Wu Fumei, Nie Jianliang, 2011).

Many theoretical results have been obtained in the dynamic system research field. The discussion on Kalman filter for linear system with colored measurement noise has been obtained (Chang, 2014). The M-estimator-based robust Kalman filter for systems with process modeling errors and rank deficient measurement models, and the robust Kalman filtering based on Mahalanobis distance as outlier judging criterion have been developed (Chang Guobin, Liuming 2015; Chang Guobin, 2014).

1.4.3 Nonlinear least squares

The perturbation analysis of nonlinear ill-conditioned solution is given (Li Fei, 2011), and the closed-form of the Newton method is proposed for solving the distance equations; (Dang and Xue, 2014; Xue et al., 2014). The modification of the Gauss-Jacobi combinatorial adjustment is given (Xue and Yang, 2014). An iterative algorithm for nonlinear total least squares adjustment has been proposed (Hu Chuan, Chen Yi, 2014). The research on the ill-posed nonlinear problem has been obtained (Tang Limin, 2014).

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