UNITED NATIONS **E/CONF.102/IP.16**

ECONOMIC AND SOCIAL COUNCIL

Nineteenth United Nations Regional Cartographic Conference for Asia and the Pacific
Bangkok, 29 October – 1 November 2012
Item 6(b) of the provisional agenda
Conference papers: Invited papers on achievements and developments in Geographical information management in addressing national, regional and global issues.

Modernization of National Geodetic Datum in China *

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1. Introduction

The datum of surveying and mapping is an important foundation for the national economy, social development, it mainly includes geodetic datum , height datum and gravity datum. The datum of surveying and mapping is the initial data and surface for various measurements and it is also the foundation to determine the geometry, spatial and temporal distribution of geospatial information.

The traditional geodetic datum in China is Beijing geodetic coordinate system 1954, which is a coordinate system using non-geocentric reference ellipsoid, and the reference frame was maintained mainly by the nationwide astro-geodetic network based on astronomical and triangulation measurements through a combined adjustment. The traditional height datum is Yellow Sea height system 1956, which took the mean sea level of several years at Qingdao tide gauge (in Yellow Sea) as a unified datum, it was the first height system for the People's Republic of China and it ended the history of using different height systems. The two systems made important contributions to our economy and social development.

Since China's reform and opening-up, the National Administration of Surveying, Mapping and Geo-information (NASG, which is formerly named State Bureau of Surveying and Mapping, SBSM) has continuously been updating the traditional datum of surveying and mapping. The second datum of surveying and mapping was constructed by establishing Xi'an geodetic coordinate system 1980, the national height datum 1985 and national gravity datum 1985 in 1980's.NASG has strengthened the construction of modern geodetic datum since 1990's by establishment of the national gravity datum 2000 and the national geodetic datum 2000. The regional datum system of surveying and mapping has also developed rapidly.

In order to meet the demand for sustained economic and social development in the

21st century , the modern datum system of surveying and mapping was established to adapt to the high-tech development. They are the renewal and modernization of the national or regional geodetic datum, on the other hand, they continue to update and refine the geodetic reference framework and focus on geodetic mingled with other disciplines and to expand the scope of geodetic services.

2. Traditional geodetic datum in China

NASG completed the measurements of astronomical geodetic network (order I/II) in 1982, which consists of more than 48,000 points. On this basis, the national geodetic coordinate system, named as “Xi'an geodetic coordinate system 1980” was established, which the horizontal accuracy was significantly improved with comparison to the national geodetic coordinate system 1954.

With the development and wide applications of satellite positioning, NASG built high precise national GPS networks of order-A and order-B, with 818 points including 8 continuously operating reference stations (CORS). The network provided a control for three-dimensional geocentric coordinate system for the mainland China, and the accuracy has improved at least two orders of magnitude compared to that of “Xi'an geodetic coordinate system 1980”,that means a new stage occurred in space geodetic network construction in China.

The national GPS geodetic control network 2000 was established in 2003 by NASG cooperating with Military and China Earthquake Administration. The 2518 GPS control points and 28 continuously operating reference stations were combined. On this basis, the combined adjustment between the national GPS geodetic control network 2000 and national astro-geodetic network was also carried out, and the geocentric coordinates of points in the astro-geodetic control networks were derived. The GPS geodetic control network 2000 is used as reference frame of China Geodetic Coordinate System 2000 (CGCS2000).

The current vertical datum of China is national vertical datum 1985 which the origin is located in Dagang tide station, Qingdao. NASG finished an order-I leveling network of 93,000 km including 100 rings in 1984 and an order-II leveling network of 136,000km in 1990. The national vertical datum system 1985 was built based on these leveling networks. Compared to Yellow Sea height datum system 1956, it had some advantages of increased density, improved accuracy and more rational structure. NASG completed re-measurement of the order-I and order-II leveling network from 1991 to 1999, to further improve the accuracy of the national height datum system 1985. The height datum in China is a local system, and there is difference up to meters with international height system. The unification of global height datum will become more and more important with the

development of global economic integration.

Geoid refinement was great improvements in China. The accuracy of geoid has reached decimeter level nationwide, and it is up to cm-level in some provinces. The goal for near future is to improve the national geoid to cm-level.

NASG constructed national gravity fundamental network 1985 in 1985, which included 6 absolute gravity points, 46 relative gravity points and 163 first class gravity points. NASG updated it in 2003 to national gravity fundamental network 2000. The gravity fundamental network 2000 is composed of 21 absolute gravity points,126 relative gravity points and 112 cited points with accuracy of better than $\pm 10 \times 10^{-8} ms^{-2}$.

3. Modernization of National Geodetic Datum in China

The Modernization of national geodetic datum is financed by the government and is planned to update the geodetic datum in China in four years (2012-2016). The tasks of the project are: 1) to establish national GNSS Continuously Operating Reference Station (NGCORS), 2) to establish a national GNSS Geodetic Control Network (NGGCN), 3) to update the National vertical control network, 4) to update the National Gravity fundamental network, and 5) to establish a National Geodetic Data Center (NGDC).

The final aim is to establish a three-dimensional geodetic datum with high precision. The datum will be dynamically maintained, and serve as geometric datum and physical datum, which will enhance the capabilities and services of the surveying and mapping for the economic development and scientific researches.

3.1 GNSS CORS network

The establishment of national GNSS CORS network is the most important part of this project. 360 CORS stations will be constructed nationwide, which will be the main reference framework of national geodetic coordinate system including 150 new stations, 150 shared stations and 60 modified stations.

The average distance between these stations is about 200 km to 300 km in western China, and 150 km in north-eastern China and Yunnan, Guizhou, Sichuan provinces, while it is about 70 km to 100 km in Eastern China, Central China and South China, where the economy is highly developed.

The CORS will maintain national three-dimensional geocentric coordinate frame, and support real-time positioning and navigation applications, meanwhile, will provide kinds of server of precise satellite orbit and continuous high precision time-frequency signals etc.

3.2 National GNSS geodetic control network

The national GNSS geodetic control network (NGGCN) and CORS are the framework of the national geodetic coordinate system with uniform distribution, better coverage in mainland China. The network consists of about 4,500 points, including 2500 new station sand 2000 shared stations. NGGCN is designed the average distance of 40 km to 60 km eastern China, and 70 km to 100 km in western China.

3.3 National vertical control network

The national vertical control network consists of 27,400 bench marks with a total leveling route of 122,000 km, which more than 30000 km new route was added based on 90,000 km leveling route in the old order-I leveling network.

The project is designed to install 5 deep rock level stations in the appropriate position in China's northeast, north, central and Xinjiang province, where lacked the rock level point with poor distribution and also add 105 shallow rock points along the first-class level route to control the stability of the network.

3.4 National gravity fundamental network

Absolute gravity benchmarks will be installed on each CORS, and 50 will be selected to National gravity fundamental network 2000, which will improve graph structure and control precision of the national gravity datum system, and improve the form a reasonable distribution and conducive to the long-term preservation absolute gravity infrastructure..

3.5 Data center for geodetic datum

A data center will be established for data management, data processing, data sharing, and other related services. The data center will monitor the operation of the NGCORS, such as data aggregation, data management, system monitoring, and system security. The data center will possess the ability of data management and processing to GCORS, GNSS geodetic control network, vertical control network and gravity fundamental network. The capabilities of daily data managing and data processing from 600 GCORS and the ability to process GNSS geodetic control network are up to 10, 000 points.

4. **Maintenance of CGCS2000**

China Geodetic Coordinate System 2000 (CGCS2000) was adopted as the new geocentric coordinate system of China on July1, 2008. The reference framework of CGCS2000 is composed of two parts, i.e., national CORS network, and national high precision geodetic control network. NASG is in charge of surveying, mapping, and geo-information in China, and promotes the dissemination and applications of CGCS 2000. Most of the geo-information has been converted from the old coordinate systems to the new one with high precision.

GNSS CORS will be the main method to maintain CGCS2000. From first one was built by NASG in Wuhan since 1990's, and then other eight CORS stations were successively built in China up until 1998. 25 CORS stations were constructed by NASG by cooperating with other agencies, these stations play very important role in the maintenance of coordinate framework till 2006. 260 CORS stations have been jointly built by NASG since 2007. The number of national CORS stations is expected to be up to 500 in 2015. There are more than 20 provinces and big cities, where local CORS networks have been established to provide services. Currently, there are about 1200 CORS stations built in these provinces and big cities, and about 500 stations are scheduled. The amount of CORS stations will be up to 2000 in 2015.

China is now developing the Beidou satellite navigation system. The first MEO (Medium Earth Orbit) satellite of Beidou was successfully launched on April 14, 2007, which marked a new stage of Beidou satellite navigation system. Until September 2012, there are already 11 Beidou satellites orbiting the earth. The Beidou signals cover the region from 84°E to 160°E in longitude, and from 55° S to 55°N in latitude. The horizontal accuracy is about 25 m while radial accuracy is 30 m. The velocity accuracy is about 0.4 m/s and timing accuracy is about 50 ns. Beidou system possesses the same capability as other GNSS systems, such as GPS, Galileo. Researches showed that a real-time positioning of several cm can be provided by Beidou, while the accuracy can be improved to cm level after post-processing.

Because the Beidou system is now under construction, the receivers compatible with different GNSS systems will be installed at the national reference stations, so that reference stations using Beidou distribute uniformly in mainland China.

There is also some progress in nationwide or regional geoid determination, a quasi-geoid model CQG2000 with accuracy of decimeter and resolution of 30km was computed in 1990's. The local geoid has been refined in 27 provinces and big cities in the past 10 years.

With the advent of the gravity satellite missions, such as CHAMP, GRACE, and GOCE, the accuracy of earth's gravity field model has greatly improved. For instance, the earth's gravity field model derived from one-month GRACE data is more accurate than that derived from ground observations in the past 30 years. The GOCE will further improve the accuracy of the earth's gravity field. These models will also benefit the regional geoid determination. The new national geoid model with accuracy better than 10 cm can be expected after the project is completed.

5. **Conclusions**

After many years, the geodetic datum in China has been converted from two-dimensional to three-dimensional, from static to dynamic, and from non-geocentric to geocentric coordinate system, the accuracy has also been greatly improved.

The reference frame of CGCS200 will be maintained mainly by NGCORS and NGGCN networks in China, which will also agree well with the international reference frame (ITRF). Beidou navigation and positioning system will play more and more important role in the maintenance of CGCS200 reference frame, especially after its completion in 2020. The new height datum will be maintained by the new leveling networks and geoid. More and more data and technology will be applied in nationwide gravity datum.