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China Geodetic Coordinate System 2000*

* **Prepared by Pengfei Cheng, Hanjiang Wen, Yingyan Cheng, Hua Wang, Chinese Academy of Surveying and Mapping**

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CHENG Pengfei，WEN Hanjiang，CHENG Yingyan， WANG Hua

Chinese Academy of Surveying and Mapping, Beijing 100039, China

Abstract

Two national geodetic coordinate systems have been used in China since 1950's, i.e.，the Beijing geodetic coordinate system 1954 and Xi'an geodetic coordinate system 1980. As non-geocentric and local systems, they were established based on national astro-geodetic network. Since 1990, several national GPS networks have been established for different applications in China, such as the GPS networks of order-A and order-B established by the State Bureau of Surveying and Mapping in 1997 were mainly used for the geodetic datum. A combined adjustment was carried out to unify the reference frame and the epoch of the control points of these GPS networks, and the national GPS control network 2000(GPS2000) was established afterwards. In order to establish the connection between CGCS2000 and the old coordinate systems and to get denser control points, so that the geo-information products can be transformed into the new system, the combined adjustment between the astro-geodetic network and GPS2000 network were also completed. China Geodetic Coordinate System 2000(CGCS2000) has been adopted as the new national geodetic reference system since July 2008，which will be used to replace the old systems. CGCS2000 is a geocentric coordinate system associated with an earth ellipsoid defined slightly different from GRS80 (Geodetic Reference System 1980) and WGS84 (World Geodetic system 1984). CGCS2000 is referred to ITRF97 (International Terrestrial Reference Frame 1997) at the epoch of 2000.0, the reference frame of CGCS2000 currently consists of national GPS control network 2000 and the national astro-geodetic network after combined adjustment with the GPS network. In the future, CORS will play an important role in the maintenance of the reference frame of CGCS2000.

1. Introduction

Two geodetic coordinate systems have been used since 1950 in China, i.e. Beijing geodetic coordinate system 1954, Xi'an geodetic coordinate system 1980. The Beijing geodetic coordinate system 1954 was an extension of Pulkovo coordinate system 1942 from the former Soviet Union in China, it was a non-geocentric and local coordinate system, Krassowsky ellipsoid was used as a reference ellipsoid. It was established after the adjustment of the first-order triangulation chains in north-east China. The second-order triangulation networks were adjusted under the control of the first-order chains. The cluster adjustment was completed in later 1960's. The Xi'an geodetic coordinate system 1980 was established in 1982 after the adjustment of first-order and second-order astro-geodetic networks. It was still a non-geocentric local coordinate system and IUGG 1975 ellipsoid parameters were used instead of the old ones. The semi-minor axis was defined parallel to the direction from the center of the earth to the pole JYD1968.0. The reference ellipsoid was oriented to minimize the sum of square of height anomaly of astro-geodetic points, its origin located at Yongle, a small town north to Xi'an, 60km apart. There were about 50,000 first-order and second-order triangulation points with a mean baseline length of 22km. Different kinds of observations were used to establish the network, such as triangulations、electronic distance measuring (EDM) measurements、and astronomical observations. The accuracy of the side is 1/260,000, and that of direction being ±0.9″.

Since 1980's, new satellite geodetic techniques such as GPS have been widely used in China for positioning and other applications, the old coordinate systems cannot meet the necessity of the new techniques. In 2003, the GPS control network 2000(GPS2000) was established after the combination of different GPS networks in China, and afterwards, the combined adjustment between astro-geodetic networks and GPS2000 were carried out. In July 2008, China Geodetic Coordinate System 2000(CGCS2000) was officially adopted as the new national geodetic reference system to replace the old systems.

2. National GPS control network 2000

Since 1990's, three nationwide GPS networks have been established by different agencies. The order-A and Order-B GPS networks were established by the State Bureau of Surveying and Mapping (SBSM), which were mainly used for the geodetic datum in China. The order-I and order-II GPS networks were established by General Staff Bureau of Surveying and Mapping, and the Crustal Movement Observation Network of China (CMONOC) was cosponsored by State Seismological Bureau jointly with General Staff Bureau of Surveying and Mapping, Chinese Academy of Sciences, and State Bureau of Surveying and Mapping, which was mainly used for the scientific research of seismic activities. These networks were established in different times and processed using different reference frames and epochs. In 2003, the combined adjustment of these three GPS networks was finished, the data was reprocessed using ITRF97 and the epoch of 2000.0, resulting the so-called national GPS control network 2000(GPS2000). GPS2000 network consists of more than 2500 stations, the accuracy of coordinates of continuously operating reference stations (CORS) is at the level of millimeter, and the mean accuracy of coordinates is better than ±3cm.

3. Combined adjustment of astro-geodetic control network and GPS2000 network

The national astro-geodetic network was re-processed with the GPS2000 network to densify the reference frame of CGCS2000 and to make connection between CGCS2000 and the old systems, so that the products using the old systems can be transformed into the new system with high accuracy. The coordinates of GPS stations and their variance-covariance information were used to connect the two networks, which occupied the same site as the national astro-geodetic networks. In the combined adjustment, large amount and different sorts data was processed, 2,600 GPS points, 46,000 geodetic baselines, nearly 50,000 geodetic points with 150,000 unknowns. The original measurements from the national astro-geodetic network were used in the adjustment such as astronomical azimuths, directions and EDM distances, zero-order

traverses, etc. After the adjustment, the geocentric coordinates of the astro-geodetic points were provided.

The accuracy of position of 48,583 ground points (except for 336 co-located points) was estimated after the adjustment, the average accuracy of position is ±0.11m. The root mean square(rms) of the position of 30,803 points is smaller than ±0.1m (about 63.4% of total number of points), that of 46,375 points smaller than ±0.3m (about 95.5%), only 658 points with rms of position bigger than ±0.5m (about 1.3%). For the 336 co-located points, the rms of the position of most points is at centimeter level, of which 233 points are within ±0.01m (69.4%), 314 points are within ±0.03m (93.6%), 335 points are within ±0.05m (99.7%), only one point with a rms of ±0.06m. The accuracy of position for GPS points is ±0.01m.

4. Adoption of new geodetic coordinate system in China

The International Terrestrial Reference System (ITRS) is a basis for forming coordinate frames based in the Earth. The general ITRS precepts are the various resolutions of the International Union of Geodesy and Geophysics (IUGG) and the International Astronomical Union (IAU). The international Terrestrial Reference Frame (ITRF) provides the “absolute” long-term datum, namely, the realization of the terrestrial origin, scale, orientation, and their time derivatives.

China geodetic Coordinate System 2000 has been officially adopted as the new national geodetic coordinate system since July 2008 in China, which is closely related to ITRS and will be used to replace the old systems. CGCS2000 is geocentric, the center of mass being defined for the whole Earth including oceans and atmosphere. Its scale is that of the local Earth frame, in the meaning of a relativistic theory of gravitation. Its Z-axis directs from the origin to the reference pole at the epoch of 2000.0, the initial orientation is given by the Bureau International de l’Heure (BIH) orientation of 1984.0, the time evolution in orientation will create no residual global rotation with regards to the crust. Its X-axis directs from the origin to the intersection

between Greenwich meridian and the equator (at the epoch of 2000.0). Its Y-axis completes a right-handed, Earth-Centered Earth-Fixed (ECEF) orthogonal coordinate system.

The geometric center of the CGCS2000 ellipsoid is the same origin, and the rotational axis of this ellipsoid of revolution coincides with Z-axis. The four defining parameters of the ellipsoid are:

Semi-major axis: a=6,378,137.0meters

Flattening : f=1/298.257222101

Earth's gravitational constant: $GM=3.986004418\times10^{14}\,m^3/s^2$

Angular velocity of the Earth: $\omega=7.292115\times10^{-5}rad/s$

CGCS2000 is referred to ITRF97 (International Terrestrial Reference Frame 1997) at the epoch of 1 January 2000(2000.0). The adoption of the new system will allow closer integration with international coordinate frames, global navigation satellite systems, scientific applications and routine spatial data management.

5. Reference frame of CGCS2000

The reference frame of CGCS2000 currently consists of national GPS2000 network and the national astro-geodetic network after combined adjustment with the GPS network. In the future, the reference frame of CGCS2000 will be mainly realized by national continuously operating reference stations (CORS) and high precision geodetic control network.

The national CORS networks will provide Global Navigation Satellite System (GNSS - GPS、GLONASS、Galileo、and Beidou) carrier phase and code range measurements in support of 3-dimensional positioning activities throughout China and its territories. Surveyors, GIS/LIS professionals, scientists, and others can use CORS data to get coordinates with an accuracy of a few centimeters (or even a few millimeters) both

horizontally and vertically. CORS networks have been constructed in many big cities or in some provinces to provide three dimensional geodetic datum in local area. These networks can also be included into the national one according to some criterion.

6. Further works after the adoption of CGCS2000

After the adoption of the CGCS2000, much work need to be done in the near future. The geo-information products in the old coordinate systems will be transformed into the CGCS2000. The products at scales of 1:250,000、1:500,000 and 1:1,000,000 can be used without transformation, because the difference of the coordinates in different systems is within the accuracy of mapping. For the products at scale bigger than 1:100,000, such as 1:50,000, 1:10,000 and so on, transformation is needed. Only the geo-information databases will be transformed, the paper topographic maps at various scales will not be transformed. The 4D databases at scales of 1:50,000 and 1:100,000 will be transformed by the State Bureau of Surveying and Mapping in two or three years. In order to transform the products at scales bigger than 1:10,000, the third-order and forth-order astro-geodetic networks will be re-adjusted by using the original observations controlled by the results of combined adjustment between the GPS2000 network and the national astro-geodetic network.

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