Grids & Datums

The People's Republic of China

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The Grids & Datums column has completed an exploration of every country on the Earth. For those who did not get to enjoy this world tour the first time, *PE&RS* is reprinting prior articles from the column. This month's article on The People's Republic of China was originally printed in 2000 but contains updates to their coordinate system since then.

The Chinese civilization spread originally from the Yellow River valley where it probably existed beginning from around 3000 *B.C.* The first valid historical evidence is of the Chou Dynasty (1122-255 *B.C.*). For most of its 3,500 years of history, China led the world in agriculture, crafts, and science. It fell behind in the 19th century when the Industrial Revolution gave the West superiority in military and economic affairs. China is composed of mostly mountains, high plateaus, and deserts in the west; plains, deltas, and hills in the east. The lowest point is Turpan Pendi at 154 m (505 ft); the highest is Mount Everest at 8,848 m (29,029 ft).

China has 23 provinces, 5 autonomous regions, and 4 municipalities for its administrative divisions. Note that China considers Taiwan as its 23rd province, and it has recently acquired two other special administrative regions: the British Colony of Hong Kong (*PE&RS*, January 1998), and the Portuguese Colony of Macau.

The father of scientific cartography was Pei Hsiu (224-271 *A.D.*). In 1707-1717, Emperor K'anghsi commissioned a group of Jesuits to carry out a survey of the Chinese Empire. In 1902, the Manchu government established the Military

Survey Institute and a 1:1,000,000 map series was planned. By 1911, the revolution changed the political horizons, and no noticeable progress was made until 1927 when the first modern series of geodetic surveys were performed by the military until the Sino-Japanese war of 1937-1945. In 1928, the Central Bureau of Land Survey (CBLS) under the Army General Staff was formed. First-Or-der triangulation began in 1929 in Chekiang Province. In 1930, the CBLS organized the first training class in photogrammetry in Nan-king. In 1931, large-scale triangulation projects were also started in Anhwei, Hunan, Hupeh, Kiangsi, and Kiangsu provinces. That same year CBLS started flying aerial photography with one airplane, and by 1935 it was using seven airplanes with cameras using 135 mm and 210 mm focal length lenses.

The Japanese established the Manchurian Principal System (Datum) of 1933 at the origin point, Huan-his-ling (Shinkyo) where: Φ_o = 43° 49′ 36.62″ North, Λ_o = 125° 18′ 15.42″ East of Greenwich, and the defining azimuth to station Ta-hei-shan is α_o = 204° 46′ 54.497″. Of course, accord-ing to Japanese tradition established with the Tokyo Datums of 1892 and 1918, the Bessel ellipsoid of 1841 was referenced where the semi-major axis (a) = 6,377,397.155 meters and the reciprocal of flattening ($^1/_f$) = 299.1528128. (See Grids and Datums on Korea in the November 1999 *PE&RS*.) Back in June of 1980, Frank Kuwamura of the Defense Mapping Agency wrote to me and offered that, "If we denote the Tokyo Datum of 1918 with a "T" subscript, and the Manchurian System of 1933 with a "M" subscript, then $\phi_T = \phi_M + \phi'$ and $\lambda_T = \lambda_M + \lambda'$, where $\phi' = -8.8386'' + 0.00430\,\Delta\phi \cdot 10^{-4} - 0.43463\,\Delta\lambda \cdot 10^{-4} + 0.00001\,\Delta\phi^2 \cdot 10^{-8} + 0.00021\,\Delta\phi\Delta\lambda \cdot 10^{-8} + 0.01041\,\Delta\lambda^2 \cdot 10^{-8} + 0.0017\,\Delta\lambda^3 \cdot 10^{-12}$, and $\lambda' = 17.8824'' + 0.82927\,\Delta\phi$

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$\cdot\ 10^{-4} - 0.40987\ \Delta\lambda \cdot 10^{-4} + 0.03866\ \Delta\phi^2 \cdot 10^{-8} - 0.03971\ \Delta\phi\Delta\lambda \cdot 10^{-8} - 0.01008\ \Delta\lambda^2 \cdot 10^{-8} + 0.002454\ \Delta\phi^3 \cdot 10^{-12} - 0.00186\ \Delta\phi^2\Delta\lambda \cdot 10^{-12} - 0.000978\ \Delta\phi\Delta\lambda^2 \cdot 10^{-12} + 0.0016\ \Delta\lambda^3 \cdot 10^{-12}$. Furthermore, $\Delta\phi = \phi_M - \phi_o$ and $\Delta\lambda = \lambda_M - \lambda_o$ where the units are in arc seconds and ϕ_o and λ_o represent the coordinates of the Manchurian System of 1933 origin point (listed above)."

The CBLS established the Nanking Datum of 1935 where: $\Phi_o = 32° 04´ 19.7445˝$ North, $\Lambda_o = 118° 50´ 18.5354˝$ East of Greenwich. A Gauss-Krüger Transverse Mercator Grid is defined at the Datum origin. The scale factor at origin (m_o = 1.0); the False Easting and the False Northing = zero. The ellipsoid of reference is the International (also called the Hayford 1909 and the Madrid 1924) where the semi-major axis (a) = 6,378,388 meters, and $^1/_f = 297$.

In addition to the CBLS surveys and maps, there were myriad local surveying and mapping activities pursued throughout the 20th century in the People's Republic of China. For instance, the Chihli River Com-mission used a Grid for 1:50,000 maps where the Central Meridian is 116° 25´ 24˝ East of Greenwich, the Central Parallel is 37° 20´, the False Easting and False Northing = zero. What projection? Probably a Lambert Conformal Conic because of a paper published by J. T. Fang of the National Geological Survey of China. In 1949, J. T. Fang published a series of papers in *Empire Survey Review* concerning the Lambert Con-formal Projection as applied to China. "It has been decided by the Central Land Survey of China to adopt the Lambert conformal projection as the basis for the co-ordinate system, and, in order to meet the requirements of geodetic work, the whole country is subdivided into eleven zones bounded by parallels including a spacing of 3 ½ degrees in latitude-difference. To each of these zones is applied a Lambert projection, properly chosen so as to fit it best. The two standard parallels of the projection are situated at one-seventh of the latitude-difference of the zone from the top and bottom. Thus, the spacing between the standard parallels is 2 ½ degrees. This gives a maximum value of the scale factor of less than one part in four thousand, thus reducing the distortions of any kind to a reasonable amount." Fang later went on to explicitly list some of the parameters of the "Fifth Zone" where, "The standard parallels of this zone are at latitudes 34° 10´ N and 36° 40´N. Thus, $\phi_o = 35° 25´ 11.84746˝$ as referenced to the International ellipsoid (also called the Hayford 1909 and the Madrid 1924) where a = 6,378,388 meters, $^1/_f = 297$.˝ Example computations are given by Fang for Fourth and Fifth Zone transformations.

In the late 1970s, I had the bright idea of going into business as a consulting cartographer. I moved my family back home to New Orleans and started pursuing the "oil patch" clientele. Lo and behold, I received a telephone call from Houston about the South China Sea. The People's Republic of China tendered bids for the exploration and development of hydrocarbon resources (oil and gas) in the South China Sea, and was looking for companies to perform geophysical exploration of its outer continental shelf. A U.S.-owned company (identity to remain anonymous), "cooked up" a specification for a projection and Grid System for geophysical exploration in the South China Sea. The ellipsoid (and presumably the Datum) was the World Geodetic System of 1972. However, the projection was chosen as the Lambert Conformal Conic with two standard parallels and a latitude of origin equal to the arithmetic mean of the standard parallels. That sort of thing will work on a sphere, but on an ellipsoid (WGS72), it is a mathematical impossibility!

I worked up the two different Grids based on the two exclusive presumptions: hold to the two standard parallels and let the latitude of origin "float," or hold to the latitude of origin and let the two standard parallels "float." I termed those two mathematical possibilities as "PRC South China Sea I" and "PRC South China Sea II." To this day, I get phone calls to the effect, "Hey Cliff, ever hear about PRC South China Sea _XX_?" It never ceases to amaze me that they actually find (and produce) oil out there...

There are some traditional Grid Systems associated with China. "China Belts I and II" are Gauss-Krüger Transverse Mercator Grids referenced to the Clarke 1880 ellipsoid (ersatz WWII systems), where the Central Meridians are at 119° (Belt I) and 113° (Belt II). Scale factor at origin = 0.9994, the False Northing = -2,210,000 meters and the False Easting = 400 Km. These specifications are part of the "British Grids" and, although richly romantic in history, they are lacking in *provenance*.

Current Grid Systems attributed to the People's Republic of China find their roots in the Russian (USSR) origins of assistance. For in-stance, the Russia Belts for China are identical with the UTM specification with the exceptions or variations that the scale factor at origin is unity rather than 0.9996, and the ellipsoid of reference is the Krassovsky 1940 where the semi-major axis (a) = 6,378,245 m, and ($^1/_f$) = 298.3. A variation on this is known as the three-degree Belts, and the location of the Central Meridians are simply a (half) scalar of the six degree belts

UPDATE

"Surveying & mapping datum is a key infrastructure of national economy, social development, state security and information construction, an important foundation for determining natural geographic elements and the geometric configuration and spatial & temporal distribution of earth surface artificial facilities, and the initial numerical data for various surveying tasks and the basis reference for accurate demonstration of the geographic space distribution in the real world by making use of map. China's surveying & mapping datum consists of geodetic datum, vertical datum, sounding datum and gravity datum.

Since its founding in 1949, with a view of meeting the requirements of economic construction, the People's Republic of China has set up China Geodetic Coordinate System (Beijing Coordinate System, CGCS 1954), Huanghai Vertical Datum 1956 and Gravity Fundamental Network 1957, which represent the first-generation datum reference system for surveying and mapping of China.

Since 1980s, China has strengthened upgrading and reconstruction of the first-generation datum reference system for surveying and mapping and gradually built a national horizontal control network consisting of 48,000 points:

namely, China Geodetic Coordinate System 1980 (Xi'an Coordinate System), which has a significantly-improved precision than CGCS 1954; it has completed the National Vertical Datum System 1985 comprised of the Class-A national leveling network with 100 loops and a total distance of 93,000 kilometers and the Class-B national leveling network with a total distance of 136,000 kilometers. Compared with the Huanghai Vertical Datum System 1956, National Vertical Datum System 1985 features higher density, higher precision and more rational structure; moreover, China has completed its National Gravity Fundamental Network 1985, which is comprised of 6 gravimetric datum points, 46 basic gravimetric points and 163 first-class gravimetric points. As the second-generation datum reference system for surveying and mapping of China, Gravity Fundamental Network 1985 features higher density and precision compared with Gravity Fundamental Network 1957.

Since 1990s, China has further accelerated the modernization of the datum reference system for surveying and mapping. In 1997, China completed its high-precision national GPS Network A and Network B, realizing the nationwide coverage with three-dimensional geocentric coordinates, 2 orders of magnitude higher than the national horizontal control network 1980. In 2003, China built the national GPS geodetic control network 2000 that is comprised of 2,500 points. In 2004, China built the national geodetic control network 2000, which consists of approximately 50,000 points and enjoys much higher positioning precision than ever. In 2003, China built the National Fundamental Gravity Network 2000, which is a new-generation national gravity datum comprised of 19 datum points and 119 fundamental points. Compared with National Fundamental Gravity Network 1985, National Fundamental Gravity Network 2000 features higher precision and more rational density and distribution of points. In 2001, China set up its first decimeter-level quasi-geoid model (CQG2000), on which the sea level elevation can be determined rapidly by making use of satellite space positioning technologies and geoid model, thereby providing a supplementary approach to traditional leveling height survey within a certain range of precision.

So far, China has basically set up a relatively complete datum reference system for surveying and mapping, including national GPS geodetic control network 2000 comprised of over 2,500 points and national geodetic control network 2000 comprised of approximately 50,000 points, as well as the national fundamental gravity network comprised of 19 datum points and 119 fundamental points, marking the start of the construction of the modern Chinese datum reference system for surveying and mapping.

Since 2006, China has further accelerated optimization and upgrading of the existing datum reference system for surveying and mapping, focused on replacing the traditional reference ellipsoid-centric and two-dimensional coordinate system with the geocentric and three-dimensional coordinate system, intensified the construction of the reference station for satellite positioning continuous operation and connected it to the international coordinate reference framework and maintained the coordinate framework through the reference station and the satellite geodetic control network; meanwhile, China has attached greater importance to acceleration of the geoid refinement, improvement of the resolution and precision of geoids as well as gradual replacement of traditional national high-level leveling; in addition, China has strived to increase the quantity of ground absolute gravimetric points, focused on speeding up the development of measurement of airborne gravity and satellite gravity and enriching gravimetric data with different scales.

On July 1, 2008, the high-precision, geocentric, three-dimensional and dynamic national geodetic coordinate system 2000, which is China's new-generation geodetic coordinate system, was officially put into operation. Now, the state-level fundamental surveying & mapping results have been transferred to the National Geodetic Coordinate System 2000, and the existing fundamental surveying & mapping results have been or have been basically shifted to the Geodetic Coordinate System 2000 in Zhejiang, Gansu, Jiangxi, Fujian, Guangdong, Shandong, Henan, Beijing and Shanghai. The construction of satellite positioning continuous operation reference stations has been unfolded step by step. The satellite navigation positioning continuous operation reference station network with centimeter-level real-time positioning precision has been completed or is being built in 24 provinces (autonomous regions, municipalities), and over 1,200 continuous operation reference stations have been newly built. The work related to quasi-geoid refinement has been carried out in 26 provinces (autonomous regions, municipalities), of which 25 have completed the work and 23 have reached the centimeter-level precision. Based on the quasi-geoid refinement, GPS C network construction and Class-C leveling survey have been carried out in most provinces, municipalities and autonomous regions.

In June, 2012, the project of infrastructure construction of the national modern datum reference system for surveying and mapping (phase I), which is a major special surveying & mapping project of China during the 12th "Five-year Plan" period, was officially kicked off. The project is expected to, in the next 4 years, build 150 reference stations, reform 60 GNSS positioning continuous operation reference stations and make direct use of 150 reference stations, thus forming a national satellite positioning continuous operation datum network consisting of 360 reference stations; build 2,500 satellite geodetic control points, make direct use of 2000 points, thus forming a 4500-point national satellite geodetic control network, which constitutes the new-generation geodetic datum framework together with the national satellite positioning continuous operation datum network; build and rebuild 27,400 height control points, lay 110 leveling bedrock points, deploy the national Class-A leveling network with a length of 122 thousand kilometers and form the national modern vertical datum framework; deploy 50 national gravimetric datum points, improve the national gravity datum infrastructure; build 1 national surveying & mapping datum data center and form the national modern surveying & mapping datum management service system. Through the implementation of infrastructure construction of the national modern datum reference system for surveying and mapping, China plans to complete a high-precision, geocentric, dynamic, practical and uniform national datum reference system for surveying and mapping in 2015.

At the end of 2012, Beidou (COMPASS) navigation satellite system covered the most areas in the Asia-Pacific region and was officially put in commercial operation. And construction and maintenance of the modern datum reference system for surveying and mapping that is based on GNSS (GPS, GLONASS, GALILEO and COMPASS) have started in some areas in China." *(Approved by: National Administration of Surveying, Mapping and Geoinformation of China 28 Lianhuachi West Road, Haidian District, Beijing, 100830, China, 2013-12-20)*

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BOOK**REVIEW**

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ther development of the archive not only of US imagery but worldwide. However, undoubtedly the most significant highlight of this time period was the decision to provide Landsat imagery in the entire archive free of charge to anyone. This development has opened up not only the academic/research components of Landsat imagery but also has provided for countless commercial applications.

Chapter 6, the final chapter, is entitled "Landsat: Dedicated to Continuous Earth Observation" and presents a summary of the overarching themes from the book as well as the lessons that have been learned. This chapter is followed by a short epilogue that contains a little more information about Landsat 8 and some final thoughts. There are then three appendices: the first presenting state of the archive maps for all missions, the second presenting information about concurrent Landsat operations, and the third containing miscellaneous information about many who worked on Landsat including the various Landsat Science Team members through the years. These first two appendices present the USGS archive as of 2008. Fortunately, since that time the USGS has worked hard to almost double the archive by retrieving much of the international imagery that is available. The book concludes with a very extensive bibliography and then an index, both making the information in the book easy to access.

In reading and reviewing this book, I am reminded of all the effort, commitment, and energy that has gone into producing a 45-year continuous archive of amazing imagery of our home planet. It is truly a phenomenal accomplishment. To have all this information, including lots of inside stories that could easily be lost to future generations, all in one place is a great blessing to our remote sensing community and beyond. The Landsat legacy will continue to live on and is more secure than it has ever been. However, this book provides all of us with a great history of where we have been and the struggle to get to where we are today. I guarantee that you will want to read this book to learn about this history and then you will keep it to refer to it often as we continue to grow the Landsat legacy.