Implementation of the New Korean Geocentric Datum and GPS CORS Management

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Key words: Korean Datum, KTN1910, KGD2002, GPS, CORS Management

SUMMARY

New Korean geocentric geodetic datum - Korean Geodetic Datum 2002(KGD2002), has been adopted since 1st January 2003, replacing the Tokyo datum which has been used in the country since early 20th century. The International Terrestrial Reference Frame 2000 (ITRF2000), which is based on its realization of KGD2002, is applicable with Global Navigation Satellite System(GNSS) technologies. The datum transition will result in the production of a series of Korean maps and marine charts, which will meet international navigation requirements. In this presentation, the brief history of datum in Korea is reviewed, with emphasis on reasons why the government decided to adopt KGD2002. The technical issues regarding realization of KGD2002 are discussed with providing strategies and results of nationwide geodetic network adjustments. Finally, status of GPS CORSs (Continuously Operating Reference Stations) operated in Korea and their management system with services will be outlined.

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1. INTRODUCTION

A datum is defined as any numerical or geometrical quantity or set of quantities which serve as a reference or base for other quantities (DMA, 1983). In geodetic surveying, two types of datums are considered: a horizontal datum which forms the basis for the computation of horizontal control survey that consider the curvature of the earth, and a vertical datum to which elevations are referenced. The horizontal datum is traditionally realized by determining the geodetic position (e.g., latitude and longitude) of an origin point, an azimuth of a line to another geodetic control point, and the geoid separation at the origin point with defining the parameters (e.g., the equatorial radius and the flattening) of the ellipsoid, which should be a best fit to the geoid over a whole country.

A geodetic network extends the datum across a nation for various applications of surveying and mapping. Geodetic surveying techniques, such as triangulation, trilateration, and traverse have traditionally been used to determine the coordinates of the control points within the network. In addition, network adjustment has played an important role in reducing the effect of observational errors in the coordinate estimation to a minimum (Leick, 2004; Rizos, 1996). Considering the abovementioned procedure, it should be noted that a change in the datum parameters affects every point on the geodetic network.

In this paper, the brief history of datum in Korea is reviewed, with emphasis on reason why the government decided to adopt KGD2002. The definition of KGD2002 and technical issues regarding its realization will be discussed. In addition, status of GPS CORSs (Continuously Operating Reference Stations) operated in Korea will be outlined. This is mainly due to the fact that GPS CORSs make a key role in surveying, geodesy and a variety of navigation applications.

2. KOREAN HORIZONTAL DATUM 1910

Geodetic surveying to establish the triangulation network (KTN1910: Korean Triangulation Network) began in Korea in 1910 and was conducted by the Bureau of Land Survey with the cooperation of the Japanese Military Land Survey. The main technique applied for the most of the survey in KTN1910 was the triangulation, so the accuracy was relatively poor. In addition, the adjustment with condition equation was applied to several partitions with non-computer based technique. These low quality observations with rough calculation methods eventually leaded to a large accumulated computational error and disconformity in the network. During this project 34,444 geodetic control points were established along the Korean

Peninsula. Among them, 16,089 were situated in South Korea. Figure 2-1 illustrates the primary network of the KTN1910.

It should be noted that the establishment of the network was accomplished by connecting with the Japanese geodetic network, so the Tokyo datum, so-called Korean Horizontal Datum 1910 has been adopted in Korea. It is well known that the technique used in the Tokyo datum realization was single astronomic point datum orientation, in which the geoid and ellipsoid were assumed to be the same at the origin point, a large systematic error may be introduced in the geodetic network as the survey is expanded. Nevertheless, the Tokyo datum has been used in Korea for a century.

Although there was an attempt in the mid 1980s to establish a Korean datum in the mid of 1980’s by the astronomical geodetic orientation technique which considers the deflection of the vertical at a number of Laplace stations including the datum origin, it could not be connected with the existing geodetic network. This was mainly because the advent of new space geodetic surveying techniques(e.g., GNSS, SLR, VLBI) caused the Korean government to change its plan to establish the global geocentric datum, which is a best fit to the geoid over the entire earth.

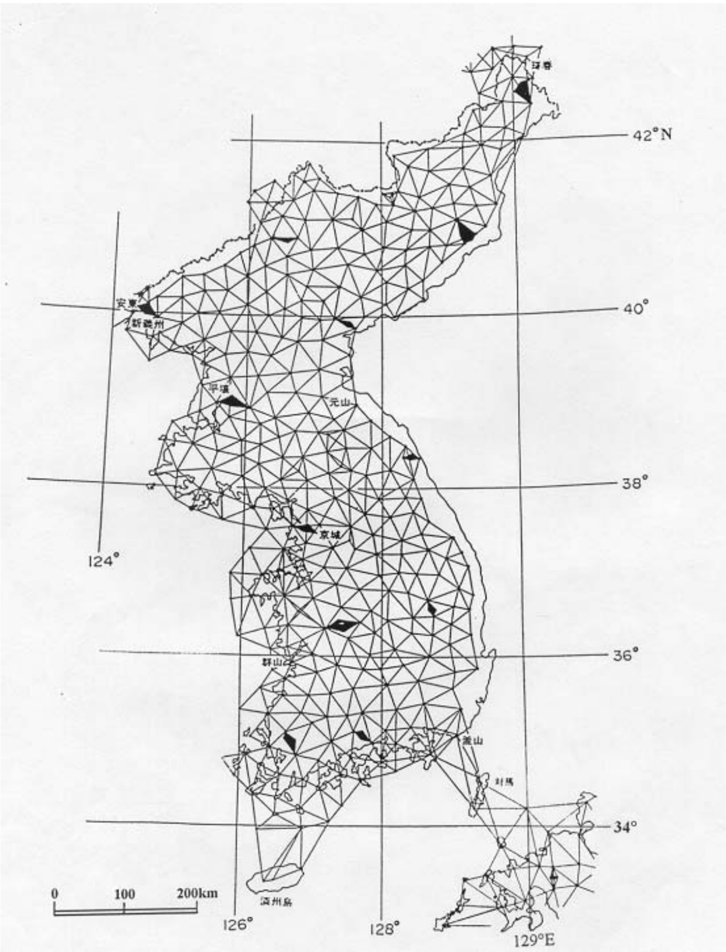

Figure 2-1. Korean Triangulation Network 1910 (Primary Network)

Due to Korean War broke out in 1950 more than 65% of the triangulation points together with the raw data in KTN1910 was destroyed. To reconstruct the country, the government initiated the emergency recovery project for the triangulation points and produced KTN1957. The main purpose of the project was to provide the control points for the national reconstruction, so the rapidness rather than the accuracy and evenness of the network was emphasized. Obviously, this rapid construction of the network aggravated the degradation of the accuracy and the unevenness of the network.

The advanced technology in EDM and high performance computer made the accurate large scale network adjustment possible. In 1975, the National Geographic Information Institute of Korea (NGII) of Korea initiated the first Precision Geodetic Network Campaign (PGNC). Mainly the 1st and 2nd order triangulation points are recovered with the data on approximately 1,200 points obtained for ten years (e.g., 1975-1994). The trilateration technique was used in the 1st and 2nd precision survey, and the network adjustment with those data was performed to publish KTN1987. It is important to note that the measured distances are projected onto the geoid using orthometric height in KTN1987 because there was no geoid model available at that time.

For 3rd and 4th order control points, the 2nd PGNC was initiated in 1987. Total 4,972 points are observed with EDM from 1987 to 1998 and 737 points are observed with GPS from 1997-1998. The instruments used in this campaign other than GPS were Range Master (1976~1978), Range Master (1979~1989), and G-6000 (1990~1994).

3. KOREAN GEODETIC DATUM 2002

The primary requirement for the design of a new geodetic datum was that it should be compatible with international standards and systems, notably with international positioning systems such as Global Navigation Satellite System (GNSS). The new datum is based on the International Terrestrial Reference System (ITRS) and uses the Geodetic Reference System 1980 (GRS80) ellipsoid. The KGD2002 uses International Terrestrial Reference Frame 2000 (ITRF2000) at epoch 1st January 2002, which has a geocetric origin. Hence, the realization was achieved by determining the coordinate sets of the datum origin and the 1st order geodetic control points.

The coordinate of the datum origin was determined from the baseline estimation from the VLBI observation point conducted through Joint Geodetic Project of Korea and Japan in 1995. After completing the VLBI observations, those measurement was sent to NASA to connect the IVS network on November 14, 2000. The adjusted coordinates from this work is based on ITRF 2000 with reference epoch of 1997.0. From January 17 to 26 in 2002, GPS baseline survey (3 sessions; each observation period is 7 hours) and five geodimeter observations were carried out from the VLBI stations to the datum origin marker. Through these observations, the coordinates of origin of KGD 2002 is determined with the reference epoch of 2002.0. That is, the origin coordinates are updated by including the vector of the crustal motion from 1997.0 to 2002.0 (see, Table 3-1).

Table 3-1. The VLBI Results

ITRF 2000 (epoch 1997.0)	Crustal motion (1997.0~2002.0)	ITRF 2000 (epoch 2002.0)	ITRF 2000 (epoch 2002.0), GRS80
X= -3062024.021m	ΔX= -0.145m	X= -3062024.166m	37-16-31.53193
Y= 4055453.834m	ΔY= -0.038m	Y= 4055453.796m	127-03-15.16770
Z= 3841809.998m	ΔZ= -0.051m	Z= 3841809.947m	81.521 m

Table 3-2. The origin of KGD2002

Latitude (deg)	Longitude (deg)	Height (m)
37-16-33.3659	127-03-14.8913	91.253

The datum origin of KGD 2002 is located at NGII and the coordinates are shown in Table 3-2. Subsequently, the 1st order geodetic control stations consisting of 14 GPS CORS stations were readjusted for determining the KGD2002 coordinates. All of the works had been completed by the end of 2002.

4. DENSIFICATION OF KGD2002

The National Geographical Information Institute (NGII) of Korea together with a number of surveying contractors has held GPS observation campaign over the geodetic network since 1996. During these campaigns, about 11,000 points were observed until the end of 2007. The Korean specification for GPS control surveying was applied so that the campaigns could achieve high levels of surveying efficiency and accuracy. Table 4-1 shows a summary of GPS observations obtained by the campaign.

The main differences between the two networks are baseline length and GPS receiver occupation time. As given in the table, while the baseline lengths of the 2nd order network range from 20km to 120km, those of the 3rd order network do not exceed 5km. GPS occupation times were eight hours for the 2nd and four hours for the 3rd order networks, respectively.

Table 4-1. Summary of GPS campaigns held by NGII

Order	Baseline Length	Recoding Time	Number of Stations	Number of Campaigns
2nd Order Net	40~120km	8 hours	200	8
3rd Order Net	2~5km	4 hours	8,744	66

The design of KGD2002 provides for 3 order of geodetic control, such as the 1st, 2nd and 3rd order network. Since the 1st order geodetic network had been adjusted at the stage of the new datum realization, the 2nd and 3rd order network should be re-adjusted to derive their KGD2002 coordinates. This nationwide geodetic network adjustment had been carried from 2005 to 2007.

Figure 4-1 summarizes a network adjustment procedure for the nationwide network adjustment. As shown in the figure, every lower level network was connected to the higher level network by at least three well distributed control points. This ensures that the network being attached can not rotate relative to the higher level network. Hence, the 2nd order nationwide network established by GPS was simultaneously adjusted under the condition that three dimensional coordinates of all the 1st order control points are fixed. On the other hand, the 3rd order geodetic network was installed by both of EDM and GPS technologies. Therefore, the adjustment was separately carried out with respect to different data sets.

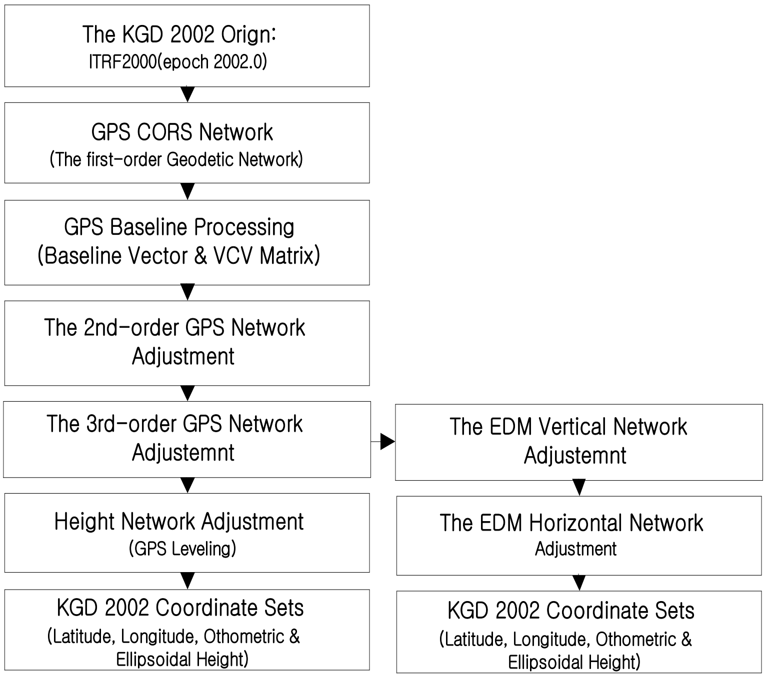

Figure 4-1 Network adjustment procedure for the KGD2002 densification

Figure 4-2. The 3rd order geodetic network (GPS+EDM)

A total of 603 coordinate parameters (e.g., latitude, longitude, and ellipsoidal height at 201 control points) were estimated from the adjustment by making use of 2,313 observations. Upon examination of the network accuracy of the estimated coordinate resulting from this adjustment, absolute confidence regions with respect to 95% probability were computed for the horizontal and vertical coordinate component. The average size of the ellipsoids and bars is about 2cm and 5cm, respectively (Lee et al., 2006; Lee et al., 2007). However, both of the RMS and maximum values are relatively large. This is mainly caused by control stations situated in the offshore islands about 150km from the seashore.

Figure 4-2 presents the 3rd order geodetic network consisted of GPS and EDM network. In the case of GPS network, adjustments were successively performed with respect to the 16 block networks. In these adjustments, all available 2nd order control points within the block network, and the 3rd order control points, overlapped with adjacent networks whose coordinates had been estimated from a preceding block network adjustment. This approach avoids the repetitious estimation of the overlapped points between two adjacent block networks. The series of over constrained adjustments estimated KGD 2002 coordinate sets of 8,744 controls.
The absolute confidence regions with respect to 95% probability from the final over constrained adjustments indicate that the network accuracy of the estimated coordinates of the 3rd order points averaged better than 1cm and 2cm in the horizontal and vertical components, respectively (ibid). However, it is important to note that this accuracy does not reflect the uncertainty of the 2nd order points fixed in the adjustments.

EDM data set for the seven areas are rebuilt for the adjustment. Since the data is still based on the old datum, the coordinates of the data is transformed by applying the coordinate transformation parameters. For each EDM point, the geoidal height from EGM96 model is applied to obtain the ellipsoidal height based on the GRS80.

The measured distance, projected onto GRS 80, and BL ellipsoidal coordinate network adjustment is performed by fixing 2nd order or 3rd order GPS control points. Results of the adjustments indicated that the overall fitness of adjusted position (MSE of unit weights) better than 1.6 arcsec which corresponds to 1.6 cm approximately. The standard deviations of the adjusted distance measurements are better than 0.1cm in most of the areas (Lee et al., 2006).

5. CONTINUOUSLY OPERATING REFERENCE STATIONS (CORS)

Continuously Operating Reference Stations (CORS) are defined as GPS (GNSS) receivers located permanently at sites having very accurately pre-determined coordinates. A CORS tracks GPS satellites continuously 24 hours a day. A CORS may be an individual receiver or may form part of a group of receivers, which is referred to as a CORS network. Such a network spans areas of several tens of kilometres, or be regional, continental or even global in scale. In this section, current status and future of Korean CORS management will be outlined.

5.1 Current Status

Currently, more than more than 70 GPS CORS are currently being operated in Korea by several government organizations and a research institute for their own applications. Figure 5-1 illustrates map of GPS CORSs with their responsible agencies. The networks established by NGII, Ministry of Government Administration and Home Affairs(MOGAHA) are the ones for surveying & geodetic applications, but Korean Astronomy and Science Institute(KAO) and Korea Institute of Geoscience and Mineral Resources(KIGAM) are the ones for scientific applications.

However, it is important to note that MOGAHA network has been recently integrated with that of NGII, since The Division of Cadastre (DOC) was merged with NGII in early this year 2008. On the other hand, Division of Maritime Affairs (formerly MOMAF, Ministry of Maritime Affairs and Fisheries) has been operating the CORSs to provide the real time DGPS services using maritime radio beacon.

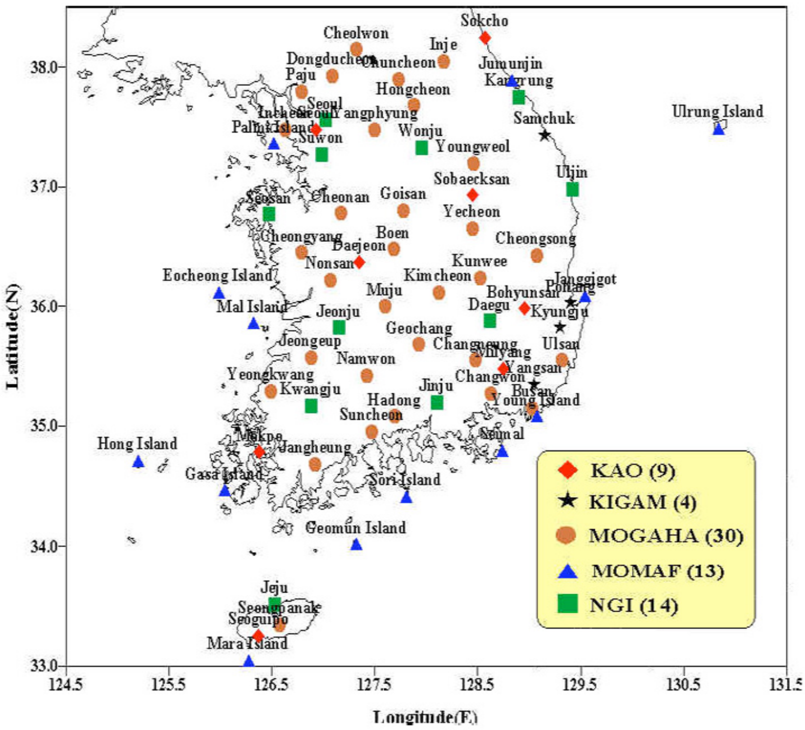

Figure 5-1. Map of GPS CORSs operated in Korea (Park et al., 2002)

NGII CORSs consisting of 14 stations underpins the KGD2002 and mainly supports geodetic control surveys. Their observations are stored in a database server, which makes available to external users, who want to reduce data with their own observations to derive post-processed baseline solutions. Recently, the NGII CORSs were upgrade to provide network-RTK services by broadcasting VRS(Virtual Reference Station) data using Code Division Multiple Access (CDMA) network. The VRS system comprises RTKNet server, GPStream server and CORS. The connection between main servers and CORSs is made by IP/VPN communication network. Rinex formatted VRS is also available to obtain from the service webpage for post-processing application (see, more details in http://vrs.ngii.gov.kr).

Former DOC CORSs were comprised of 30 stations which supported cadastral survey. However, the MOGAHA CORS provides only Rinex formatted raw data for post-processing applications. Although DOC CORS did not service Network-RTK, pilot studies had performed for analysing its feasibility to apply for cadastral surveys.

KAO network has been established for scientific applications (e.g., crustal movement, ionospheric monitoring and so on). Currently, 9 CORSs are being operated, in which inter-spacing ranges from 100 km to 200 km. Like NGII and former DOC network, KAO also provide Rinex formatted raw observations for post-processing applications

5.2 Future

It is expected that CORS will be core geodetic infrastructure in near future, for example maintenance and upgrade of geodetic datum, support real time positioning and so on. Therefore, Ministry of Land, Transport and Maritime Affairs(MLTM) has endeavour to develop a next generation control stations based on CORS technology in order to efficiently maintain an accurate geodetic system which can be compatible with international standard and support a variety of surveying and positioning application raging from decimetre level to few millimetre accuracy.

This can be achieved by integrating existing CORS networks and upgrading their functionalities. As the first phase, two CORS network(e.g., NGII and former MOGAHA) consisting of 44 stations, were integrated in May 2008. The integration includes the published coordinates referring to the same geodetic datum and the network management system, which leads to provide cost effective positioning solutions by minimizing GPS observations period. This CORS network which is a new surveying infrastructure including cadastral reform applications, can be achieved by reducing CORS spacing up to 50 km.

The second phase of the development of MLTM will upgrade the integrated network (consisting total of 61 stations) with another CORS networks(former MOMAF), the network can be support a variety of post-processing or real-time positioning applications including intelligent transportation systems(ITS) services in land or sea.

5. CONCLUDING REMARKS

New Korean geocentric geodetic datum - Korean Geodetic Datum 2002 (KGD2002), has been adopted since 1st January 2003, replacing the Tokyo datum which has been used in the country since early 20th century. The International Terrestrial Reference Frame 2000 (ITRF2000), which is based on its realization of KGD2002, is applicable with Global Navigation Satellite System (GNSS) technologies. The datum transition will result in the production of a series of Korean maps and marine charts, which will meet international navigation requirements. In this paper, the brief history of datum in Korea is reviewed, with emphasis on reasons why the government decided to adopt KGD2002. The definitions of KGD2002 and technical issues regarding its realization have been discussed with providing nationwide geodetic network adjustment. In addition, GPS CORSs (Continuously Operating Reference Stations) and their services have been outlined and future of CORS based control stations is also described.

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