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Improvement of Mongolian Height System Using a Satellite Technology

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Abstract

In recent years, development of a proper country-specific height system has become a major challenge for the scholars and specialists working in the field of geodesy. The National Geodetic Services of many countries are trying to establish a new system that can provide the customers and decision-makers with high accuracy basic geodetic data obtained by modern satellite measurements. Although, Mongolia has a long tradition with geodesy and land surveying, the country still lacks a refined height system that can be effectively used for mapping and other purposes. In the present study, we tried to solve the problem related to the Mongolian height system using of a modern satellite technology. The research had some very important results: 1) evaluation of the main height network and height system of Mongolia, 2) development of a new method for calculating the normal height system in Mongolia, and 3) creation of the height unified system by considering surface potential of the global ellipsoidal level as normal.

Keywords

Height System, Astronomy Geodetic Control Network (AGCN), High Accuracy Geodetic Network (HAGN), State Geodetic Network (SGN)

1. Introduction

In Mongolia, there are a very few research studies dealing with a height system and determination of a normal-altitude based on satellite technologies. One of the first studies in this field was conducted by Enkhbayar in 1985. In his research, land movement of Mongolian territory was studied by applying a geodetic method. For the analysis, he used measurement data related to a single polygon of second order leveling network center of the country measured between 1940 and 1945 [1]. In 2002, Altantsetseg evaluated and analyzed the velocity values of horizontal and vertical movements of crustal deformation using regular annual measurements at the Mogod Geodynamic Survey Site in Bulgan Province, Mongolia conducted from 1992 to 1998 [2].

Mongolia has introduced a satellite technology to the practice of geodetic measurements since 1997 [3]. Attempts to determine the normal height using this technology have been made since 2005 [4]. For example, a geoid model has been created by air gravimetric modeling and improvements were made in its accuracy in 2014. Since then, it has been used in map level. However, proper development of this technology was not fully achieved to a firm degree, because of the insufficient systematic development of geodetic network and lack of accurate assessment of accuracy as well as insufficiency of appropriate regional methodologies and techniques.

Generally, the concept of creating a new or refined geodetic supply system that can provide the customers with accurate geodetic data should deal with the establishing a system which could accurately and promptly determine the Earth's surface point location in a given geographical coordinate and general height system, considering the modern-day scientific and economic requirements. This concept should also consider an issue of providing specialists, customers and decision-makers with continuous and reliable real-time data.

In most post-socialist countries, establishment of such a system is mainly related to new organizational and financial requirements, occurred in the processes of geodesy, mapping and cartography due to newly developed market economy. Moreover, it is connected with the changes in geodetic precision and measurement technologies required for development of efficient modern satellite methods. In addition, for proper development of the system, appropriate changes should be made to the traditional requirements and principles for creating a geodetic coordinate system and geodetic control network.

Considering these issues, the modern geodetic supply system should be responsible for the following:

- Fully meet the growing demand for industry and interdisciplinary geodesy products.
- Focus on modern geodesy fundamental research rather than targeting customer's popular demand.
- Create necessary conditions for the efficient use of modern satellite technology.
- Superintend the continuous utilization of the existing and accumulated potentials collected in using traditional geodesy methods.

In geodetic practice, the method of determining a starting point of height from one control point representing the average surface level of the sea has been applied for many years. This has been a challenging issue in a country like Mongolia for creating a height system, because the country is landlocked and situated at the Central Asian highland and borders with Russia in the north and with China in the south. The geography of Mongolia is characterized by great diversity and is divided into such zones as forest taiga, forest steppe, steppe, dry steppe, Rocky Mountains and Gobi [5]. The country is mainly mountainous with an average altitude of 1580 m above sea level. The principal mountains are concentrated in the west, with much of the region having elevations above 2000 m. The highest point is Huiten peak in the Mongolian Altai Mountain Range (4374 m) and the lowest point is Hukh Lake (560 m) in Eastern Mongolia [6].

Within the framework of this research, the rationale for solving the problem associated with the height system has been identified by the use of a modern satellite technology. For this purpose, the GNSS measurements and detailed quantitative spatial model of quasi-geoid were compared with the average value of multi-year observations at the continuously operating origin point. As a result of the study, we solved the problems related to the height network and normal height system of Mongolia.

2. Normal Height and Mongolian Height Control Network

At present, many countries are trying to develop a proper methodology for determination of a normal height and own geoid model. Recently, it has become known that development of a high-precision digital model of quasi-geoid refined by the results of satellite measurements and well-coordinated gravimetric data with geometric leveling data is practically important for determining the normal height with satellite technology. It is also important for replacing the 2nd, 3rd and 4th order of geometric leveling which are commonly used in practice and have low-efficiency-level.

According to the international experiences, the research in this field can be divided into 3 periods.

1) Period 1: From 1995 to 2000. It was a beginning period for the development of a normal height definition satellite technology or the creation of a geoid model (ALAGAC, 1998).

2) Period 2: From 2000-2005. It was a mid-range period for the development of a normal height definition satellite technology or the accuracy improvement of a geoid model.

3) Period 3: From 2005 to the present. Some country-specific technological methodologies have been developed at research level, nonetheless, they still need to be tested in practice. Some countries are improving the accuracy of their geoid models. However, there are countries standing at the stage of creating their geoid models.

Unlike many other countries, Mongolia has a long tradition in geodesy and mapping [7]. The country created 1:100,000 scale topographic maps covering its entire territory between 1940 and 1949. For the mapping, the definition of elevation had been established by the 2nd order of leveling, and based on this, the network of the 3rd and 4th order levels of leveling was created [8].

In order to determine which height system could define the network points height, a calculation was carried out in several lines using orthometric height correction definition formula. The result conformed the correction given in the height measured in "Height catalogue of 2nd, 3rd and 4th order leveling networks points", thus proving that this network is defined in the orthometric height system [9].

The State Administration of Geodesy and Cartography carried out re-measurement at 2nd order leveling network from 1974 to 1990 in the territory of Mongolia, in order to study the earth's crust and soil vertical movement and to upgrade the elevation grid of the country [10]. The conducted re-measurement calculation of the leveling network was performed twice. The first calculation was conducted in 2000 with accuracy of 3 polygons of 3rd order in the mountainous western part. However, it could not meet the accuracy of class 3 polygons of 2nd order and the other polygons were equated to 2nd order leveling precision (**Figure 1**).

The mean square errors of this calculation per 1 km were +6 mm for the 2nd order and +10.1 mm for the 3rd order, accordingly. The next calculation was conducted in 2004. The differences between the two calculations were between 0 and 0.7 mm in central and southern parts of the territory. However, there were differences in the right-sided nodes 2.6 - 3.7 cm and in the left-sided nodes 0.2 - 4.3 cm, respectively [11].

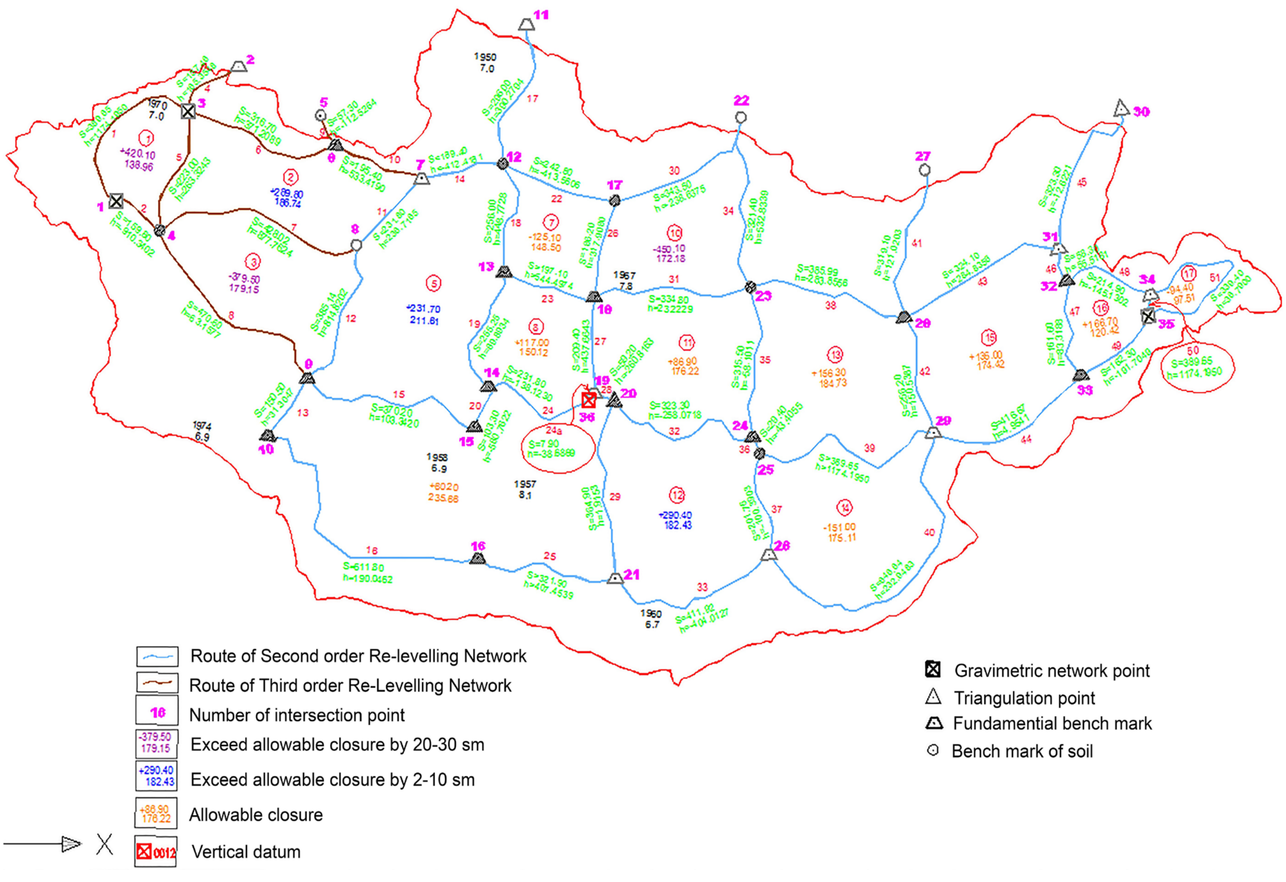


Figure 1. Schematic diagram of the 2nd order leveling network in Mongolia.

According to the repeated measurement calculations of the 2nd order leveling networks conducted in 1970-1990, permitted measurement error on the lines and landfill should be no more than $\pm 5\sqrt{L}$ km. In this case, 62.5% of the 17 polygons had a maximum allowable value. Meanwhile, 18.7% exceeded permissible levels by 2 - 10 cm and 20 - 30 cm, accordingly. It should be noted that a vertical movement map of the earth crust (height 25 cm) was created using differences of the 1974-1990 and 1940-1949 measurements (Figure 2). In Figure 2, the red color shows the raising earth's crust, while the deep blue represents the getting down earth's crust [12].

In order to improve the accuracy of Mongolian Height Control Network mainly in the agricultural and heavily populated areas, the 1st order height network's 1st line in Ulaanbaatar-Ugiinuur, 2nd line in Ugiinuur-Tsagaanbulan, 3rd line in Tsagaanbulan-Altanbulag, 4th line in Altanbulag-Ulaanbaatar, and 5th line in Ulaanbaatar-Bilgehuul with 1 polygon and 5 lines (Figure 3) were created in 2014-2018 [13]. The network had 5 junction benchmarks, 49 ground control points, 48 following benchmarks, 60 check points, 194 benchmarks of soil, 49 benchmarks of stone and of building's wall. Total length of the network was 1161.72 km and its number of sections was 270, and maximum distance between neighboring benchmarks was 8.02 km. In the meantime, the average distance was 4.30 km, a loop error was 25.7 mm (the permissible disclosure is 102.3 mm) and the mean square error was 0.3 mm on the 1 km leveling line [14].

Gravity measurements were performed at all height points. In addition, 24 hours and 12 hours of GNSS observations were conducted on the ground control points and benchmarks of soil of 1st order height network. Pre-adjustment data screening and least squares net adjustment of data for 1st order height network

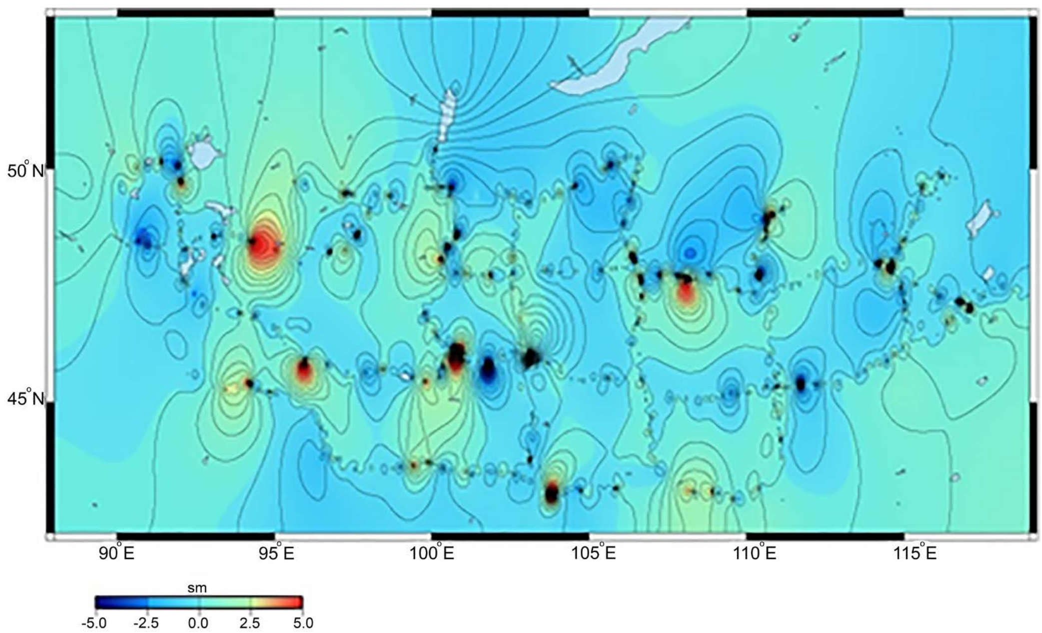


Figure 2. Vertical crustal movement map of Mongolian territory. (Map was prepared using data of 2nd order leveling network).

were carried out using *Credo* software program in accordance with the norms and rules of Mongolia. The quality indicators of the 1st order height network are shown in **Table 1** [14].

The 1st order height network's polygon had 10th polygons of 2nd order re-leveling network described above and the lines coincided with lines 26th, 30th, 31st, 34th and 35th of the 2nd order leveling networks. Therefore, the numerical values of the vertical crustal deformation were compared with the measuring difference of heights measured in 2017 and 2018 and also with the measurements of 1940s and 1970s. The rate of the vertical crustal deformation was determined by the following formula:

$$dV = \frac{h_{new} - h_{old}}{dT} \quad (1)$$

where: h_{new}—new measurement or measuring difference of heights measured in 2017 and 2018.

h_{old}—old measurement or measuring difference of heights from 1940's and 1970's.

dT—time between two measurements.

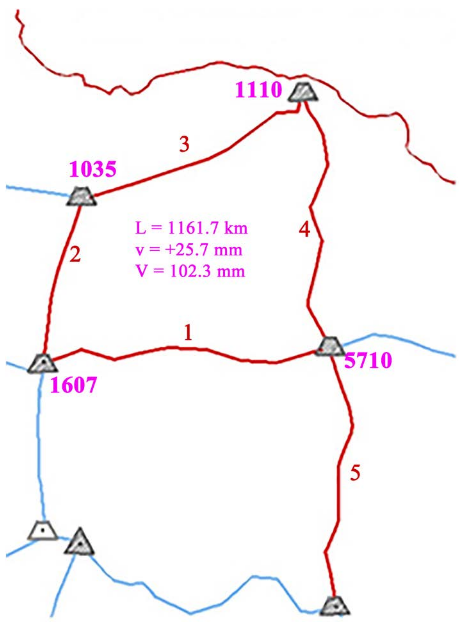


Figure 3. 1st order height network in Mongolia.

Table 1. The quality characteristics of the 1st order height network.

Order	Number of sections / Distance of route, km	Number of sections / Distance of line, km: ≤1 mm $\sqrt{L}$	1.1 mm $\sqrt{L}$ < 2 mm $\sqrt{L}$	2.1 mm $\sqrt{L}$ < 3 mm $\sqrt{L}$	3 mm $\sqrt{L}$ <	The mean square error in 1 km leveling route: Random error, mm	Systematic error, mm
1st	270	167	76	27	-	0.56	0.22
	1161.7	673.1	363.0	135.6	-		

Permissible values of difference of the old and new measurements were $\pm 9\sqrt{L}$ km and the sections exceeded allowable values are given in **Table 2**.

The vertical crustal movement map of 1st order height network's polygon with the difference of 3 measurements mentioned above is drawn by *Surfer* software (**Figure 4**). As can be seen from **Figure 2**, **Figure 4** and **Table 2**, the difference between measurements exceeded the permissible value due to considerable changes in soil cracking, fracturing, ascending and descending for 40 - 70 years. However, it is likely that the measurements of sections greater than the allowable value which are the measurements of 1944, measurement of line-3 in 1977, and measurements of line-4 at 1977 and 2017 (shown in red) for the height I-class network might be suspicious.

3. Satellite Leveling Methodology

In geodesy, classical leveling is considered as the most precise technique for determination of physical heights (orthometric, normal, or normal-orthometric) above the sea level. However, many people assume it as a time consuming and expensive technology [15]. Unlike the traditional approach, concept of satellite leveling is based on a set of activities related to the determination of physical heights based on GNSS-positioning technologies [16]. **Figure 5** shows determination of an orthometric height using satellite measurements.

In the satellite leveling, it is necessary to consider that the sum of the orthometric height and geoid height at a given control point is not equal to the geodetic height determined by the satellite measurements. This is related with the following two factors:

Firstly, the size of the global ellipsoid and counting ellipsoid in a WGS-84 coordinate system are different. Secondly, there are the error's effects of three important parameters as $H_0^\gamma, H_0^G, \zeta_i$ and ζ_0.

$$H^G \neq H_0^\gamma + \zeta_0 \tag{2}$$

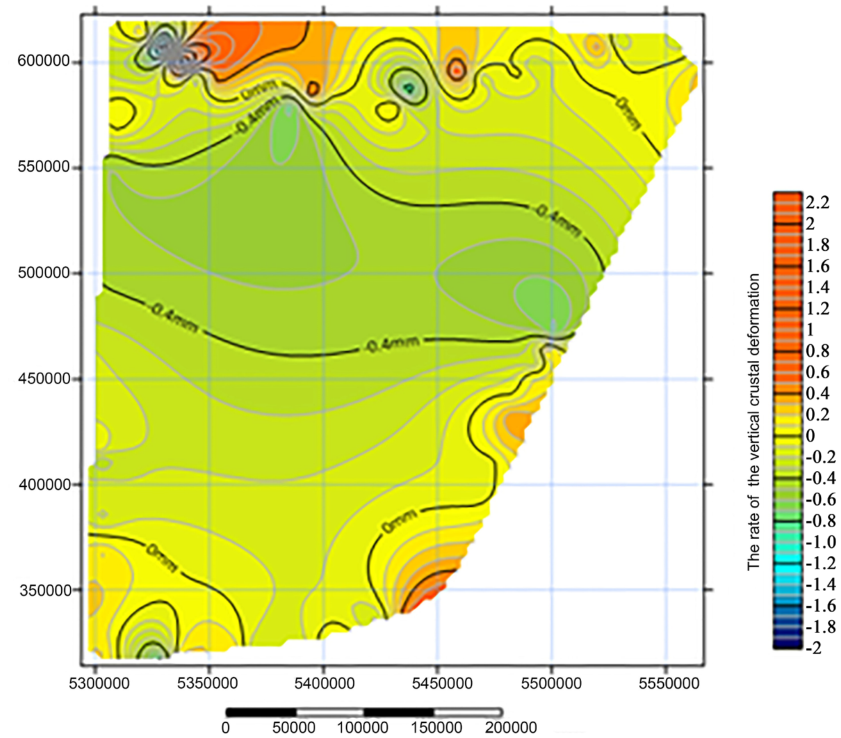
Therefore, in order to determine ζ_i, beside the nature of the change in geoidal height, also the related errors should be taken into account. In a traditional leveling method, it is necessary to fasten the rapport every 5 km, which is the longest leveling route and the distance that can be measured per day. When transmitting the orthometric elevation of the satellite leveling method over long distances, there are special requirements for geoid accuracy, especially when it corresponds to high precision leveling data at 1st and 2nd order leveling network's points.

4. Results and Discussion

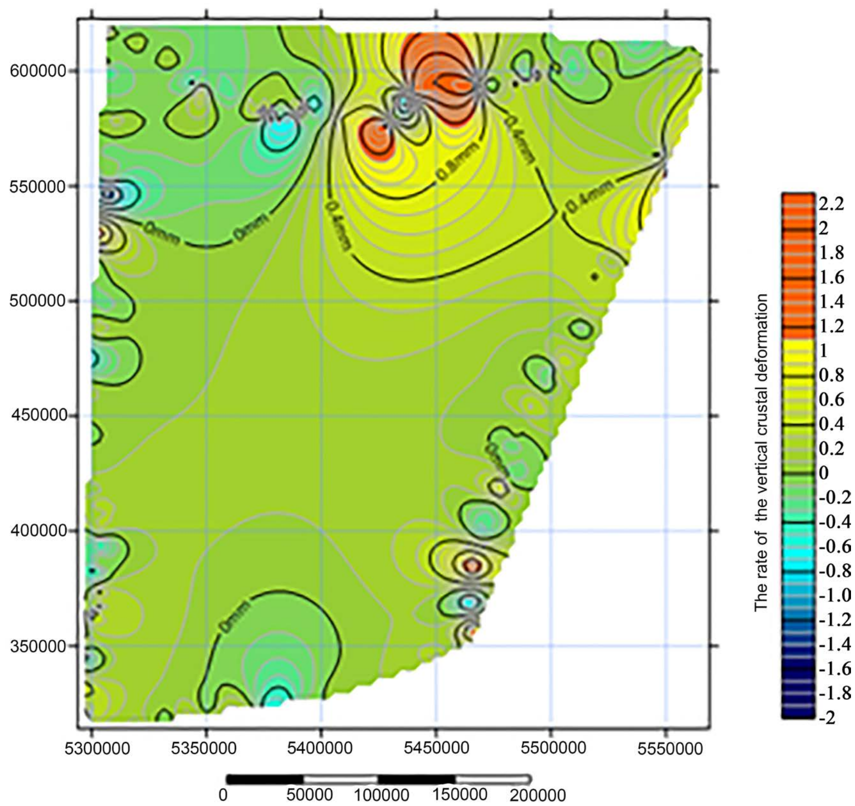
In 2005, the Administration of Land Affairs, Geodesy and Cartography of Mongolia, in collaboration with the National Space Center of Denmark, implemented a project to create a high precision geoid model for the territory of Mongolia, and carry out air gravimetric measurements for determining anomalous gravity in order to improve the World Geopotential Model [4].

Table 2. Sections exceeded allowable values of difference for the 1944, 1978, 2017 measurements.

№	Name of sections	Distance between 2 points, km	Difference of height, m			Variance, mm				
			h_{1978}	h_{1944}	h_{2017}	1978-1944	Allowable value	2017-1944	2017-1978	Allowable value
1	2	3	4	5	6	7	8	9	10	11
The 1st order height network's 1st route "Ulaanbaatar-Ugiinuur" (The 2nd order leveling networks 31st route "Ulaanbaatar-Tsatsain undur ovoo")										
1	Bm 57- Bm 252	8.6	55.4368	55.4597	55.4289	−22.9	26.39	−30.8	−7.9	26.39
2	Bm 252 - Bm 443	9.3	63.7862	63.8176	63.8027	−31.4	27.45	−14.9	16.5	27.45
The 1st order height network's 2nd route "Ugiinuur-Tsagaanbulan" (The 2nd order leveling networks 26th route "Tsatsain undur ovoo-Khailantiin khiid")										
1	Cont 1607 - Tr.p Ugii	8.7	−8.6864	−8.7221	−8.7163	35.7	26.55	5.8	−29.9	26.55
4	Bm 96 - Bm 157	9.7	−10.7874	−10.754	−10.7821	−33.4	28.03	−28.1	5.3	28.03
5	Bm 157 - Bm 84	10.2	−19.9521	−19.8914	−19.9555	−60.7	28.74	−64.1	−3.4	28.74
The 1st order height network's 3rd route "Tsagaanbulan-Altanbulag" (The 2nd order leveling networks 30th route "Altanbulag-Khailantiin khiid")										
1	Bm 272 - Bm 268	9.2	−96.0146	−96.0104		−4.2	27.30			
2	Bm 268 - Bm 383	16.8	−130.9640	−130.9612	−205.6368	−2.8	36.89	44.5	102.6	53.32
3	Bm 383 - Bm 115	9.1	21.2392	21.2901		−50.9	27.15			
4	Bm 288 - Bm 72	10.1	105.0959	105.0578	105.0872	38.1	28.60	29.4	−8.7	28.6
5	Bm 248 - Bm 411	9.1	−31.7350	−31.7	−31.7245	−35.0	27.15	−24.5	10.5	27.15
6	Bm 87 - Bm 55	79.8	−69.4278	−69.3565		−71.3	80.40			
7	Bm 55 - Bm 269	10.5	6.4982	6.5075		−9.3	29.16			
8	Bm 269 - Bm 188	9.9	70.1876	70.1552		32.4	28.32			
9	Bm 188 - Bm 503	9.8	−109.0658	−109.0392	−126.4313	−26.6	28.17	−54	132.8	116.1
10	Bm 503 - Bm 46	26.5	−47.9387	−47.8378		−100.9	46.33			
11	Bm 46 - Bm 2152	19.6	−13.4875	−13.5064		18.9	39.84			
12	Bm 2152 - Bm 1752	10.3	36.6699	36.6996		−29.7	28.88			
The 1st order height network's 4th route "Altanbulag-Ulaanbaatar" (The 2nd order leveling networks 34th route "Altanbulag-Ulaanbaatar")										
1	Foll 1643 - Bm 1454	11	15.9596	15.9619	113.0682	−2.3	29.85	438.9	465.1	40.65
2	Bm 1454 - Bm 1482	9.4	96.6435	96.6674		−23.9	27.59			
3	Bm 1314 - Bm 1438	14.8	−112.3962	−112.3541	−112.3597	−42.1	34.62	−5.6	36.5	34.62
4	Bm 1438 - Bm 1535	6.2	134.612	134.598	134.5868	14	22.41	−11.2	−25.2	22.41
5	Cont1473 - Bm 1527	10.2	35.0438	35.1153	35.1045	−71.5	28.74	−10.8	60.7	28.74
6	Bm 1527 - Bm 1455	16.6	85.488	85.5321	−0.6662	−44.1	36.67	49.7	108.6	45.36
7	Bm 1455 - Bm 1478	8.8	−86.2628	−86.248		−14.8	26.70			
8	Bm 1478 - Bm 1474	9.9	−12.727	−12.7283	−12.8013	1.3	28.32	−73.0	−74.3	28.32
9	Bm 1474 - Bm 1458	7.3	12.0365	12.0603		−23.8	24.32			
10	Bm 1458 - Bm 1497	8.4	−62.7269	−62.704	129.6367	−22.9	26.08	10.0	132.6	51.15
11	Bm 1497 - Bm 1759	16.6	180.1945	180.2704		−75.9	36.67			
12	Bm 1729 - Bm 1468	10.2	105.8475	105.8502	105.8897	−2.7	28.74	39.5	42.2	28.74
13	Bm 1468 - Cont 1426	9.2	−40.9883	−40.9909	−55.2734	2.6	27.30	−57.6	−45.4	38.92
14	Cont 1426 - Bm 1030	9.5	−14.2397	−14.2249		−14.8	27.74			
15	Bm 1748 - Bm 1757	10.9	20.0696	20.0531	20.0842	16.5	29.71	31.1	14.6	29.71
16	Bm 1757 - Bm 1412	9.6	245.1086	245.0966	245.068	12	27.89	−28.6	−40.6	27.89
17	Bm 1412 - Bm 1710	9.9	12.8686	12.6948	12.8688	173.8	28.32	174.0	0.2	28.32
18	Bm 1710 - Bm 1670	10.1	−119.444	−119.2779	−119.4467	−166.1	28.60	−168.8	−2.7	28.60



(a)



(b)

Figure 4. Vertical crustal movement map of 1st order height network's polygon (a—using measurement data of 1944 and 2017, b—using measurement data of 1978 and 2017, using data from 1944 and 1978 is shown in Figure 2).

The graph shown in **Figure 6**, illustrates the difference between the geoid heights obtained as a result of air gravimetric measurements and geoid height measurements as defined by the EGM96, EGM08 of World Geopotential Model, along the 47˚ parallel of the Mongolian territory [17]. As seen, the geoid height at the HADN points determined by gravimetric data can be accurately converted to a Baltic Height System using the formula (3) at each point for the geodetic heights obtained at satellite measurements.

$$\zeta_i = \zeta_{gr} + \Delta\zeta_e \quad (3)$$

where:

ζ_i—value of the height of the geoid at the points of the AGCN and the HAGN, obtained from the data of the satellite and geometric leveling.

ζ_{gr}—geoid height calculated by the use of gravimetric data.

$\Delta\zeta_e$—correction for gravimetrical geoid.

To make the correction across the territory of Mongolia, GPS measurement results were used at junction points of the 2nd order leveling network from 14 to 15 September 2010. The difference values were calculated by comparing the height of the geodesy at these points determined by the radar gravimetric geoid and the GPS, and the orthometric height determined by the geometric leveling

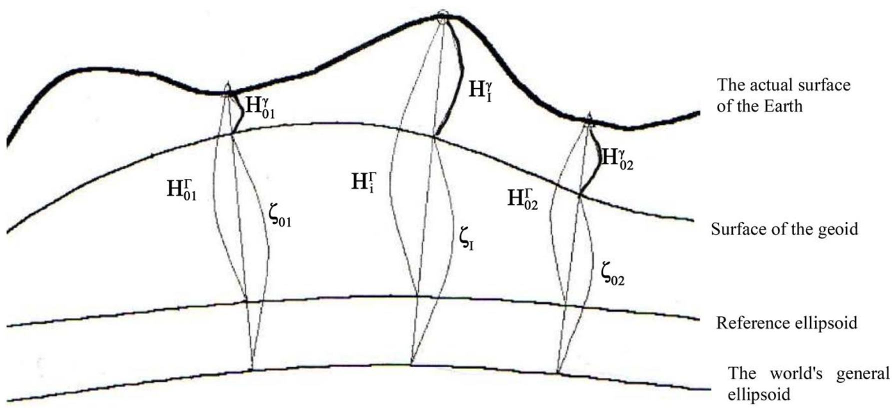


Figure 5. Determination of an orthometric height using satellite measurements.

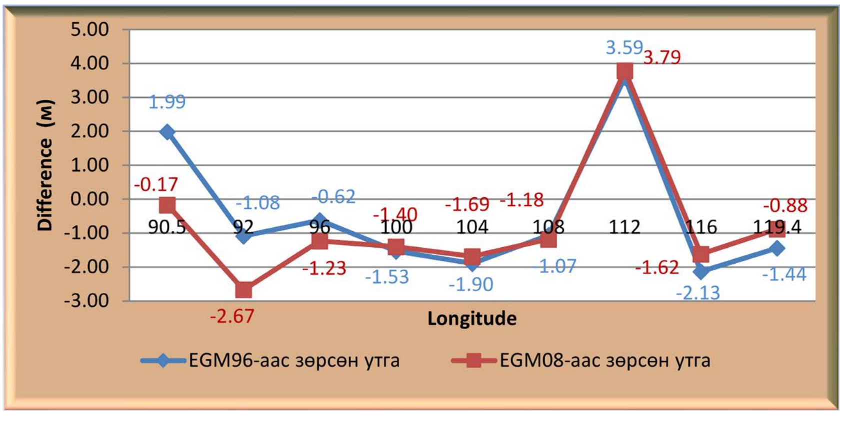


Figure 6. Geoid height difference cutting, calculated by goeid height and radar gravimeter data taken from earth geopotential model of the Mongolian territory (parallel-47˚).

of 1945, and used as height elevator in Mongolia [9].

In the territory of Mongolia, the difference values are from −40 cm to +40 cm in zone 46, from 0 to −100 cm in zone 47, from −20 to +20 cm in zone 48, and from 0 to +70 cm in zone 49. In the 50th zone, it is from −70 to +20 cm. As seen, the height definition accuracy of the geoid is limited within the territory of Mongolia if the radar-gravimetric geoid model is used [9].

In modern satellite method, HAGN should be structured in equal parts with agricultural and industrial areas as well as densely populated sites of cities, towns, and roads. Each section must be performed together on three nodes of the SGN main and subnet [18]. The neighboring sections must have 2 - 4 general points depending on the size of the section. In sparsely populated territories, when constructing vector NGN, the distance between adjacent points can be increased to 50 km.

If SGN is established as open vector migration, transferring coordination and height in sequence can be used in 4 - 5 vectors for chain shape sequent vector. It cannot be used in more cases.

For SGNs with such structures, total length of the connection system must be pre-set for the direct connection points to the three HAGN and AGCN points. Further thickening is performed relative to these connective points and used as the supporting data [19]. Given all this, it is necessary to carefully plan the satellite technology in relation to the high orthometric accuracy requirements.

When elevation networks based on satellite technology are developed, the following measurements can be performed [20]:

1) Choosing the measurement methods (static, kinematic, etc.), adjusting the baseline observation to the required accuracy. The processing uses the ephemeris of GPS.

2) At least two or more elevation points are selected by the metering station and the height of the other points is determined based on the network equation.

3) The height of the geoid at the point/station/is determined by EGM08, and geoid model using air gravimetric data. In addition, orthometric height should be defined.

4) After determining the ellipsoid (geodesy) height and geoid elevation of the base station, transfer them to other nodes in the network.

For the determination of geodetic height differences by the use of satellite technology, the following conditions are generally used:

1) Keep work stations within a radius of 20 km from check points. If radius exceeds 20km, the observation time must be at least 2 hours for the first and second grade points.

2) Keep the height of the tool steady to reduce the error of antenna height measurements.

3) Use a dual frequency receiver.

4) Use the same geodetic antenna.

5) Repeat the measurements at least twice at the position of different satellites in different conditions.

6) Get the minimum height angle at 15˚.

7) Analyze the measurement data using complex ephemeris.

8) Apply " free ionosphere" calculation in the baseline over 10 km.

9) Use the relative height value of the geoid. The relative height of the geoid is determined by the difference of the absolute height of the geoid at both ends of the base straight line.

On the basis of the analysis, it is seen that the geodetic base network of Mongolia based on satellite technology can be divided into such categories as basic, high accuracy, 1st class, local, and urban. It should form a new integrated spatial system that consists of the three existing networks [12] [21] [22] [23].

a) *Geodetic base network*

Height of the network consists of overall 14 points, 3 of which belong to 2nd category and 11 of which relate to 1st category with accuracy of the geometric leveling II distributed throughout Mongolian territory equally, mainly in center of provinces. The average length of the network side is 550 km.

b) *High-accuracy geodetic network*

The network consists of 54 points, of which 12 are in the gravimetric class 1, 36 are in the gravimetric category 2, 1 is in the astronomical and geodetic category 1, and 5 are level II loops. The distance between the points is about 220 km.The relative error of the mutual position of the network nodes should not exceed 1×10^{-7}.

c) 1*st grade network of geodesy*

The average length of the line between the network nodes in this category is 30 - 35 km. If one point covers an area of 1000 sq. km, it should be about 1000 points throughout country. In the less populated areas, it should covered area of 2000 sq.km, and the average network length could be 40 - 50 km. The mean square error of the mutual position of points should not exceed 1.0 - 1.5 cm.

d) *Regional and urban geodetic networks*

In urban and economically developed areas with high population density, geodetic networks should be established more densely than any of the above cases. In such places, average distance between the points of the geodetic network should be 10 - 15 km.

Theoretically, if the distance of base lines between two points is 205 - 300 km, by satellite measurements: the orthometric height accuracies of $\Delta\zeta \le 8\text{cm}$, $\Delta\zeta \le 17\text{cm}$, $\Delta\zeta \le 25\text{cm}$ will be achieved by 2nd order, 3rd order and 4th order leveling. If these conditiona are not fulfilled, then it is necessary to add extra points and check orthometric height value in the catalog. In this way, further identification and evaluation of the traditional geodetic measurement-based height system's rationale, determined during establishment of a new satellite-based geodetic network, would be performed simultaneously.

5. Conclusions

Elaboration of a new system, providing the customers, specialists and decision-makers with accurate basic geodetic data obtained by modern satellite measurements became a major challenge for the National Geodetic Services around the world. Unlike many developed and developing countries, Mongolia had a long tradition in geodesy, cartography and mapping. The country created 1:100,000 scale topographic maps covering its entire territory in 1940s. Different activities were carried out to improve the methodology, traditional approach and applications of geodesy and mapping technology using own personnel and in cooperation with other countries. For example, at the beginning of a new millennium the Administration of Land Affairs, Geodesy and Cartography of Mongolia, in collaboration with the National Space Center of Denmark, implemented a project to develop a high precision geoid model for the territory of Mongolia, and carry out air gravimetric measurements for determining anomalous gravity in order to improve the World Geopotential Model. In this study, we solved the problem related to the Mongolian height system by the use of a modern satellite technology. For the analysis, the GNSS measurements and detailed quantitative spatial model of quasi-geoid were compared with the average value of multi-year observations at the continuously operating origin point. As outcomes of the research, the following key issues could be identified:

1) It is not necessary to take any sea surface level as a starting point by using basic parameters of geodesy for developing a height system. However, the basic parameters must meet the high accuracy requirements.

2) By the use of a modern satellite technology, it is possible to develop the normal height system of Mongolia, considering it as part of the geodetic supply system.

3) For further development of the normal height system of Mongolia, it should be taken such measures as the evaluation of the country's geoid model and its accuracy, and accuracy improvement of the geoid height model, based on a high-grade gravimetric grid. Consequently, for determination of the normal height, satellite measurements could be applied instead of a geometric method.

4) The modern development of the height system might contribute to the regional and global geodynamic studies and further improvement of the global geopotential model.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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