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RESEARCH OF NATIONAL GEODETIC NETWORK USING GNSS METHODS

A. Celms, J. Rusiņš, I. Reķe
Latvia University of Agriculture

Key words: GNSS, elevation, I class leveling

Introduction

In the world as well as in Latvia the Global Navigation Satellite System (GNSS) advantages are in use. With the help of them we are obtaining plane coordinates and heights anywhere on Earth. We perform leveling even few days from one place to another, but with the GNSS measurements in static method collecting data at least 4 hours it is possible to obtain almost similar accuracy of data as leveled. This research was developed to determine how accurate data it is possible to obtain using GNSS measurements.

The study aim is to determine the accuracy of measured points using GNSS static method in 4 hours session. To achieve the goal the following tasks are set: 1) to perform global positioning measurements in the national I class levelling network; 2) to calculate measured points height above sea level; 3) to evaluate the accuracy of executed measurements.

There are 3 measurement sessions performed – 14th December 2012, 22th November 2013 and 27th November 2014 in the whole territory of Latvia at the same time using global positioning in static mode 4 hours long. The global positioning was chosen because of their simplicity – using global positioning and calculating ellipsoidal coordinates it is possible to observe the height difference control in height system datum point and regional main geodetic points. On these points where are not possible to do direct GNSS observations there are still need for precise levelling works.

Another use of GNSS methods is for new point height detection of national height system. For these works there is a need for precise geoid model in whole state territory. In Latvia a target has set to detect heights in whole state territory with a 2 cm accuracy but till 1st December 2014 was used a geoid model with just 8 to 10 cm accuracy [1].

From 1st December 2014 there is a new quasigeoid model LV’14 available developed by Latvia Geospatial Information Agency [2]. The new model has 4 cm accuracy.

There are also produced new more precise satellites with better defence form signal interruption. Since 2013 these satellites run in space.

Increasing the accuracy of GNSS there are also a possibility with global positioning to maintain the earth crust movements and develop earth crust movement models.

Materials and Methods

Before measuring the national geodetic network points we did point inspection. Each point was visited onsite to detect horizon above point and possibility to use GNSS methods for its height determination, the point location conformity to point abris, global positioning real time measurements to detect location of satellites above point. If the point does not meet the requirements we searched for the next point on leveling line till found an appropriate geodetic point for GNSS measurements.

The measurement has taken 4 hours long in the morning about 10 to 14 o’clock in Latvia Positioning System Base Station (LatPOS) network. LatPos is GNSS Continuously Operating network of Latvia. On each point was installed GNSS receiver – Leica, Trimble, Topcon or GeoMax receiver. The measuring was done in the whole territory of Latvia on I class leveling network points – ground marks 1415, 1001, 37, 1155, 1537, 1636, 1727, 8248 and fundamental marks 1484, 0608, 3389 and 1463 (Fig.1).

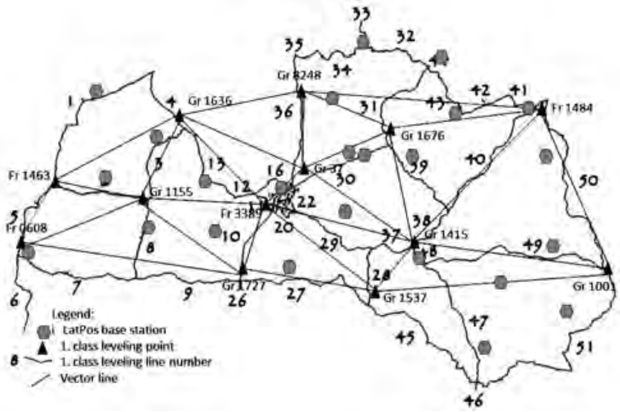

Fig. 1. GNSS vector placement and measured I class levelling points

For precise data processing and adjustment there were collected data from 3 nearest LatPOS base stations from LatPOS home page respectively choosing respective base stations. The data from GNSS receivers and LatPOS stations were used for data adjustment and point height determination. Data adjustment was done in *Trimble Business Centre* adjustment program (Fig. 2).

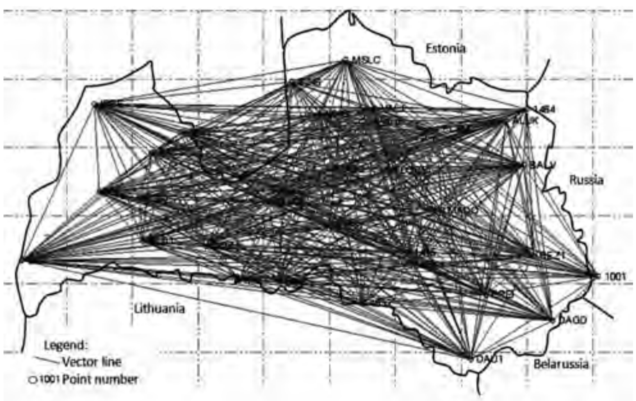

Fig. 2. GNSS vectors to LatPOS and I class leveling network points

The *Trimble Business Centre* program shows the accuracy of this 4 hour long session. For doing data adjustment it is necessary to respect the LatPOS base station validate coordinates to get precise data. From this program were received vector accuracy from LatPOS base station to measured point, measured point coordinates and height. From these data there were calculated the elevations between measured points and these results compared with elevations from Latvia Geospatial Information Agency geometric levelling data.

Results and Discussion

Vector accuracy from *Trimble Business Centre* program adjusted data allows to determine precise point coordinates and height. In Table 1 you can see the vector accuracy from 14th December 2012 session. The vector accuracy determines the height accuracy so allowing to precise determine elevation between measured points.

From the Table 1 we can conclude that the root mean square vector accuracy is 0.015 m but vector accuracy to measured geodetic points is 0.017 m.

Table 2 shows the height difference in three measuring sessions in year 2012, 2013 and 2014.

Table 1

GNSS vector accuracy on 14th December 2012 session

From point	To point	H, Prec, m	V, Prec, m	V^2 (vector)	V^2 (to point)
Madona	Jēkabpils	0,003	0,010	0,000100	–
Madona	1415	0,004	0,013	0,000169	0,000169
Madona	Lielvārde	0,006	0,017	0,000289	–
Jēkabpils	1415	0,004	0,014	0,000196	0,000196
Lielvārde	Jēkabpils	0,005	0,014	0,000196	–
Lielvārde	1415	0,006	0,017	0,000289	0,000289
Rēzekne	Preiļi	0,003	0,011	0,000121	–
Rēzekne	Dagda	0,003	0,011	0,000121	–
Preiļi	Dagda	0,004	0,012	0,000144	–
Preiļi	1001	0,007	0,020	0,000400	0,000400
Dagda	1001	0,004	0,013	0,000169	0,000169
Rēzekne	1001	0,007	0,020	0,000400	0,000400
Palsmane	1484	0,008	0,025	0,000625	0,000625
Palsmane	Balvi	0,006	0,016	0,000256	–
Balvi	1484	0,004	0,016	0,000256	0,000256
Balvi	Alūksne	0,003	0,009	0,000081	–
Palsmane	Alūksne	0,005	0,013	0,000169	–
Alūksne	1484	0,004	0,014	0,000196	0,000196
			SV=sum	0,004177	0,002700
			d=SV/n	0,000232	0,0003
			s=SQRT(d)	0,015233	0,017321

Table 2

Point heights from GNSS measurements using 3 nearest LatPOS base stations

Session year	Point No	Height, m	Calculated height error, m	Point No	Height, m	Calculated height error, m
2012	1001	138,649	0,035	1676	58,536	0,020
2013		138,662	0,016		58,531	0,006
2014		138,677	0,034		58,509	0,028
2012	1155	94,52	0,020	1727	31,884	0,036
2013		82,026	0,017		32,381	0,022
2014		82,016	0,036		32,387	0,031
2012	1415	76,842	0,038	37	7,383	0,042
2013		76,853	0,023		7,357	0,020
2014		76,861	0,034		–	–
2012	1484	156,812	0,040	8248	4,723	0,021
2013		156,739	0,021		4,722	0,008
2014		156,731	0,038		4,694	0,030
2012	1537	80,589	0,050	608	–	–
2013		80,458	0,023		5,727	0,019
2014		80,381	0,034		5,641	0,022
2012	1636	6,857	0,049	3389	–	–
2013		6,852	0,031		12,474	0,016
2014		–	–		12,394	0,029

This table shows point height difference in 3 sessions measuring point with GNSS receiver. The biggest difference in three years period is point 1155 because this point was replaced because road construction works. Height difference can be influenced from geoid model which accuracy is to 10 cm. From Table 2 the calculated height errors are practically equal thereby showing the geoid model influence on point heights.

Table 3 shows the measured point heights with GNSS receivers for the data adjustment using all LatPOS base stations.

Comparing data form Table 2 and Table 3 the calculated height difference using 3 nearest LatPOS base stations and all LatPOS base stations is minimal.As the main accuracy the Table 4 shows the measured point mutual elevations.

This table shows the elevations from measuring data with GNSS and I class levelling data from Latvia Geospatial Information Agency. Elevations between GNSS measurements are likewise but different from geometric levelling data. The biggest difference between GNSS measurements and geometric levelling data is 35 cm but the smallest difference is 3.5 cm.

Most clearly point elevations shows graphically (Fig. 3). Fig. 3 shows point elevations in all three sessions using 3 nearest LatPOS base stations.

Table 3

Point heights from GNSS measurements using all LatPOS base stations

Session year	Point No	Height, m	Calculated height eror, m	Point No	Height, m	Calculated height eror, m
2012	1001	138,636	0,035	1676	58,55	0,020
2013		138,631	0,016		58,531	0,006
2014		138,686	0,034		58,513	0,028
2012	1155	94,510	0,020	1727	31,893	0,036
2013		82,041	0,017		32,382	0,022
2014		82,013	0,036		32,385	0,031
2012	1415	76,917	0,038	37	7,378	0,042
2013		76,841	0,023		7,362	0,020
2014		76,862	0,034		–	–
2012	1484	156,802	0,040	8248	4,734	0,021
2013		156,734	0,021		4,729	0,008
2014		156,724	0,038		4,701	0,030
2012	1537	80,579	0,050	608	–	–
2013		80,440	0,023		5,759	0,019
2014		80,380	0,034		5,645	0,022
2012	1636	6,863	0,049	3389	–	–
2013		6,893	0,031		12,475	0,016
2014		–	–		12,381	0,029

Table 4

Calculated point elevations between levelling lines

		2012		2013		2014	
Leveling line	Geometric leveling elevation, m	Measured elevation with GNSS using 3 nearest LAtPOS base stations, m	Difference, m	Measured elevation with GNSS using 3 nearest LAtPOS base stations, m	Difference, m	Measured elevation with GNSS using 3 nearest LAtPOS base stations, m	Difference, m
1484–1001	–18,073	–18,163	0,090	–18,077	0,004	–18,054	–0,019
1001–1415	–61,841	–61,807	–0,034	–61,809	–0,032	–61,816	–0,025
1415–1484	79,926	79,970	–0,044	79,886	0,040	79,870	0,056
0608–1636	1,306	–	–	1,125	0,181	–	–
0608–1155	76,366	–	–	–	–	–	–
0608–1727	26,770	–	–	26,654	0,116	26,746	0,024
1636–1155	75,060	–	–	–	–	–	–
1636–3389	5,406	–	–	5,622	–0,216	–	–
1636–37	0,155	0,526	–0,371	0,505	–0,350	–	–
1636–8248	–2,165	–2,134	–0,031	–2,130	–0,035	–	–
1155–3389	–69,304	–	–	–	–	–	–
1155–1727	–49,597	–	–	–	–	–	–
3389–1727	20,073	–	–	19,907	0,166	19,993	0,080
1727–1537	47,856	48,705	–0,849	48,077	–0,221	47,994	–0,138
3389–37	–5,252	–	–	–5,117	–0,135	–	–
3389–1537	67,929	–	–	67,984	–0,055	67,987	–0,058
37–8248	–2,320	–2,660	0,340	–2,635	0,315	–	–
37–1676	51,435	51,153	0,282	51,174	0,261	–	–
37–1415	69,667	69,459	0,208	69,496	0,171	–	–
37–1537	73,175	73,206	–0,031	73,101	0,074	–	–
8248–1484	151,902	152,089	–0,187	152,017	–0,115	152,037	–0,135
8248–1676	53,755	53,813	–0,058	53,809	–0,054	53,815	–0,060
1676–1484	98,147	98,276	–0,129	98,208	–0,061	98,222	–0,075
1676–1415	18,221	18,306	–0,085	18,322	–0,101	18,352	–0,131
1415–1537	3,508	3,747	–0,239	3,605	–0,097	3,520	–0,012
1537–1001	58,371	58,060	0,311	58,204	0,167	58,296	0,075

As seen in Fig. 3 measured elevations in year 2012 session differs from 0.031 to 0.34 m, elevations in year 2013 session differs from 0.004 to 0.315 m and elevations in year 2014 session differs from 0.012 to 0.135 m. Considering that geoid model of Latvia LV'98 has an accuracy till 10 cm it can be concluded that some measured point elevations are smaller than geoid model accuracy.

Fig. 4 shows point elevations in all three sessions for data adjustment using all LatPOS base stations.

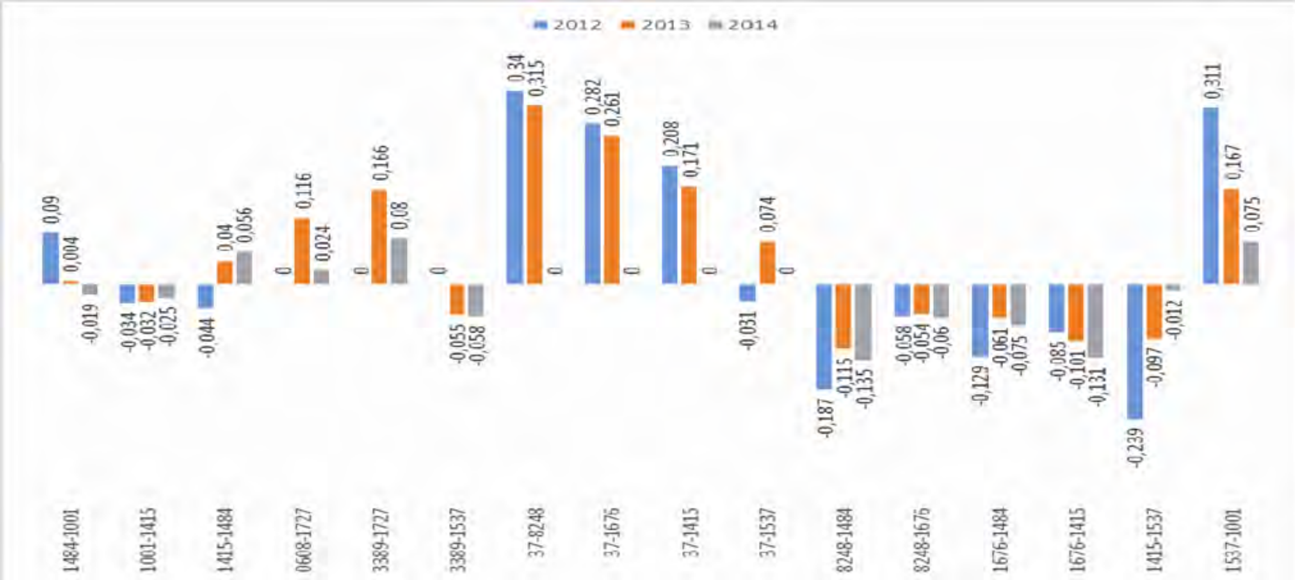

Fig. 3. Elevations between points using 3 nearest LatPOS base stations

Fig. 4. Elevations between points using all LatPOS base stations

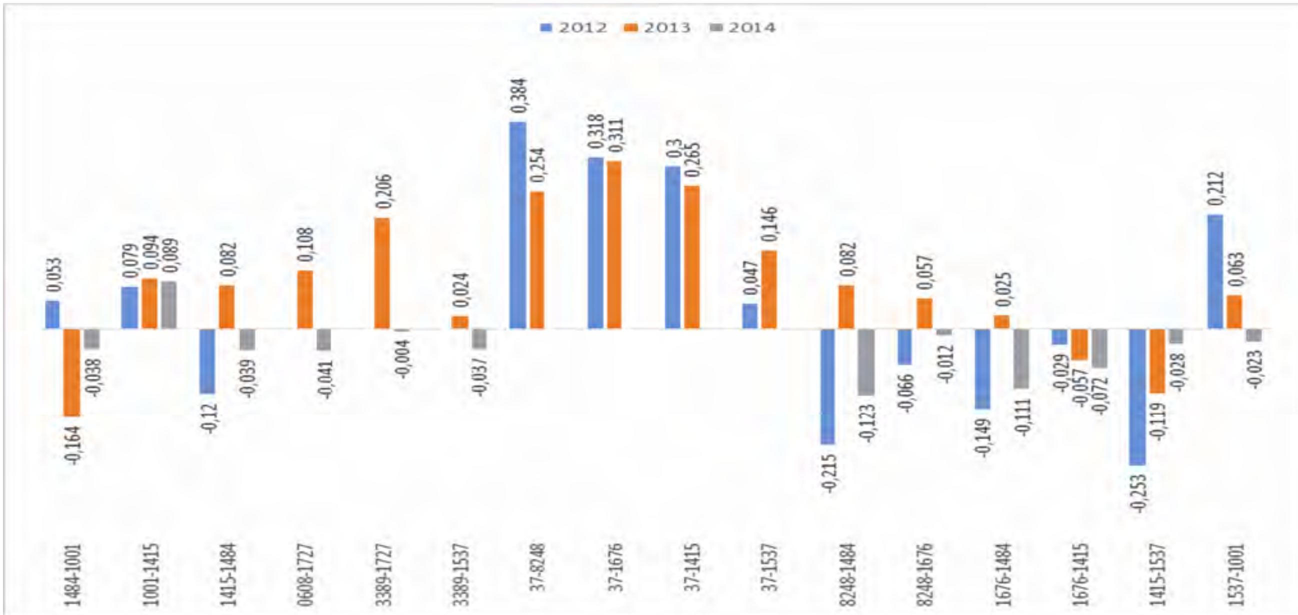

Fig. 5. Elevations between points using all LatPOS base stations

As seen in Fig. 4 measured elevations in year 2012 session differs from 0.026 to 0.324 m, elevations in year 2013 session differs from 0.030 to 0.313 m and elevations in year 2014 session differs from 0.010 to 0.128 m.

Comparing Fig. 3 with Fig. 4 better results can obtain for the data adjustment using all LatPOS base stations.

Since 1st December 2014 in territory of Latvia as a national height system use Latvia Normal height system epoch 2000,5 (LHS-2000,5) which are related to European Vertical Reference System. Next we will view the data about height differences after a new height system – LHS-2000,5 (Table 5).

Table 5

Point heights by GNSS measurements using 3 nearest LatPOS base stations, LHS-2000,5

Point No.	Height, m		
	2012	2013	2014
1001	138,820	138,846	138,848
1155	94,731	82,188	82,169
1415	76,900	76,911	76,918
1484	156,946	156,755	156,883
1537	80,661	80,538	80,454
1636	7,124	7,120	–
1676	58,650	58,633	58,625
1727	32,062	32,500	32,565
37	7,533	7,509	–
8248	4,829	4,935	4,858
608	–	5,838	5,754
3389	–	12,633	12,488

Information from Latvia geospatial Information Agency is that the average height difference between Baltic Normal Height System 1977 and LHS-2000,5 is 15 cm. Comparing adjusted data the difference is 5.8 to 26.8 cm. In Latvia the experts are still discussing about the new height system implementation and its precise working.

Fig. 5 shows the elevation differences in LHS-2000,5.

As seen in Fig. 5 elevations in year 2012 session differs from 0.029 to 0.384 m, elevations in year 2013 session differs from 0.024 to 0.311 m and elevations in year 2014 session differs from 0.012 to 0.123 m.

Conclusions

1. Measuring with GNSS receiver on static mode 4 hour long the average accuracy of vectors till 0.02 m.

2. For taking measurements with GNSS receiver it is necessary to has a open horizon above measured point.

3. For getting equitable results for obtaining point elevations it is important to do the session for all measuring points at the same time. Calculation of elevations form point measuring at different time can be incorrect.

4. In Baltic Normal Height System 1977 the measured elevations in year 2012 session differs from 0.031 to 0.34 m, elevations in year 2013 session differs from 0.004 to 0.315 m and elevations in year 2014 session differs from 0.012 to 0.135 m.

5. In LHS-2000,5 the elevations in year 2012 session differs from 0.029 to 0.384 m, elevations in year 2013 session differs from 0.024 to 0.311 m and elevations in year 2014 session differs from 0.012 to 0.123 m.

6. To compare this kind of data it is necessary to obtain them with in geodesy tested methods and instruments.

7. It is advisable to do such geodetic point measuring session every year and then compare data with other sessions.

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Дослідження національної геодезичної мережі з використанням методів ГНСС

А. Целмс, Я. Русінс, І. Реке

З розширенням технологічних можливостей для геодезичних вимірювань зростає вплив глобальної навігаційної супутникової системи. Використовуючи ГНСС, виконують вимірювання у горизонтальній і вертикальній площинах – координат і висот точок. Метою дослідження є визначення точності виміряних точок з використанням GNSS статичним методом в чотиригодинній сесії.

Исследование национальной геодезической сети с использованием методов GNSS

А. Цэлмс, Я. Русинс, И. Реке

С расширением технологических возможностей для геодезических измерений возрастает влияние глобальной навигационной спутниковой системы. Используя ГНСС, выполняют измерения в горизонтальной и вертикальной плоскостях – координат и высот точек. Целью исследования является определение точности измеренных точек с использованием GNSS статическим методом в четырёхчасовой сессии.

Research of National Geodetic Network Using GNSS Methods

A. Celms, J. Rusiņš, I. Reķe

Increasing the technologic possibilities for the geodetic measurements a greater impact occupies a Global Satellite Navigation System. Using GNSS there are performed measurements both horizontal and vertical plane – coordinates and point heights. The objective of research is to determine the accuracy of measured points using GNSS static method in 4 hours session.