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# IDENTIFICATION OF THE SPATIAL POSITION OF PERMANENT GPS STATIONS IN THE BALTIC REGION

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**Abstract.** Since the last decade of the 20th century, data on repeated measurements from the Global Positioning System (hereinafter referred to as GPS) have been commonly used globally to investigate the motion of the Earth's crust. With the use of data on repeated measurements in GPS networks (coordinates of GPS network stations, lengths of spans between the GPS stations or other changes of elements), it is possible to detect horizontal motions of the Earth crust that take place in the period between repeated measurements. The most elementary way of detecting the motions of the Earth's crust is a comparison of the coordinates of identical stations of geodetic networks found on geodetic measurements carried out at different moments. The object of this research is the identification of the spatial position of permanent GPS stations, i.e. changes in spatial coordinates within a certain period.

**Keywords:** GPS, EUREF Permanent Network, geocentric coordinate.

## 1. Introduction

The European Reference Frame (EUREF) is a network of permanent reference stations (*EUREF Permanent Network – EPN*) in Europe.

Monitoring and measurement data from permanent GPS stations provide valuable materials not only for improving the geodetic base and accepting new systems of coordinates, establishing and more closely defining the links between various systems of coordinates, and so on, but also for exploring the geodynamic processes that take place in the Earth (Zakarevičius 2003; Zakarevičius *et al.* 2002, 2008, 2010).

The EUREF GPS network consists of about 250 permanent stations (Fig. 1) with precise coordinates in the ETRS 89 system of coordinates. The principal information on stations of the network and data on measurements at those stations are provided on the website of the EPN http://www.epncb.oma.be (EUREF... 2011). On this website, monitoring data (day, hour, or 15 minute) from EPN stations are provided in RINEX format.

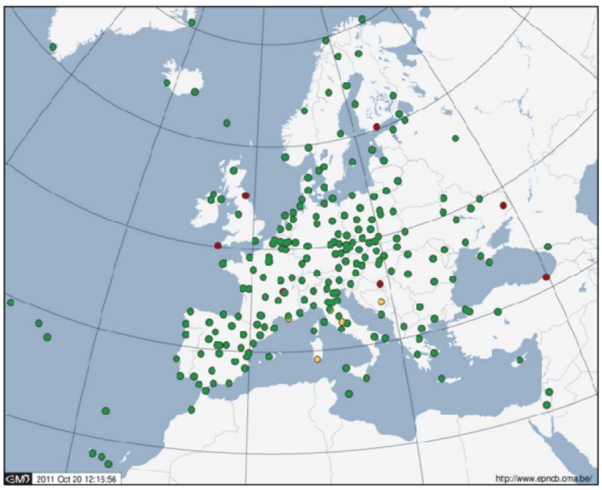


**Fig 1.** EUREF Permanent Network (EUREF... 2011)

The GPS station VLNS (Vilnius) started regular continuous observation of GPS satellites in 1996. This station, which is a part of the EUREF Permanent Network, is the reference point of the European Terrestrial Reference System (ETRS) in Lithuania (Paršeliūnas, Kolosovskis 2005; Paršeliūnas *et al.* 2011). The GPS station VLNS is located on the territory of Vilnius International Airport (Fig. 2).

**Fig. 2.** The GPS station VLNS (Vilnius) (EUREF... 2011)

In the Baltic region, the territory being examined, we chose 1252, 1304, 1357, 1409, 1461, 1513, 1565, 1617 GPS data decisions (from the year 2004 to 2011) of geocentric coordinates (*X, Y, Z*) of the GPS stations *BOR1, HELG, LAMA, MAR6, METS, OSLS, POTS, RIGA, SASS, SULD, VIS0,* and *VLNS* (Fig. 3).

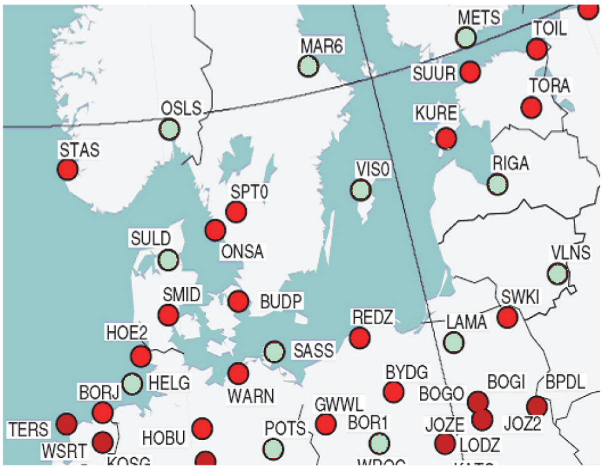


**Fig. 3.** A detail of a map of the *EPN* network (The green points – the stations of the EUREF GPS network used in the research, the red points – the stations of the EUREF GPS network not used in the research) (EUREF... 2011)

## 2. Research methodology and research results

The displacements of the coordinates of the stations of the EUREF GPS networks were calculated according to formulas (1)–(3):

$$\Delta X_i = X_i^{'} - X_i, \quad (1)$$

$$\Delta Y_i = Y_i^{'} - Y_i, \quad (2)$$

$$\Delta Z_i = Z_i^{'} - Z_i, \quad (3)$$

where $X_i$, $Y_i$, $Z_i$ is the geocentric coordinates of the EUREF GPS network stations obtained by first measurements; $X_i^{'}$, $Y_i^{'}$, $Z_i^{'}$ – the geocentric coordinates of the EUREF GPS network stations obtained by second measurements; $i$ = 1, 2, … n.

## 3. Research results

The results of calculating the displacements of the geocentric coordinates of the stations (*X*, *Y*, *Z*) according to the data of measurements for 7 years (2004–2011) are provided in Tables 1–3.

**Table 1.** The displacements of geocentric coordinate *X* of the EUREF GPS network

| The name of the station | ΔX, mm | | | | | | |
|---|---|---|---|---|---|---|---|
| | From the year 2005 to 2004 | From the year 2006 to 2005 | From the year 2007 to 2006 | From the year 2008 to 2007 | From the year 2009 to 2008 | From the year 2010 to 2009 | From the year 2010 to 2011 |
| BOR1 | –18 | –9 | –31 | –16 | –20 | –18 | –14 |
| HELG | –26 | –4 | –25 | –10 | –14 | –14 | –16 |
| LAMA | –19 | --- | --- | –12 | –18 | –18 | –14 |
| MAR6 | –10 | –15 | –29 | –8 | –13 | –19 | –5 |
| METS | –11 | –18 | –33 | –15 | –14 | –21 | –31 |
| OSLS | –17 | –15 | –25 | –7 | –22 | –14 | –9 |
| POTS | –10 | –16 | –22 | –16 | –15 | –27 | –13 |
| RIGA | –15 | –25 | –25 | –18 | –16 | –20 | –23 |
| SASS | –13 | –13 | –20 | –13 | –18 | –19 | –13 |
| SULD | –17 | –10 | –27 | –11 | –13 | –14 | –12 |
| VIS0 | –14 | –16 | –30 | –11 | –16 | –15 | –14 |
| VLNS | –13 | –21 | –28 | –19 | –18 | –24 | –17 |

**Table 2.** The displacements of geocentric coordinate *Y* of the EUREF GPS network

| The name of the station | ΔY, mm | | | | | | |
|---|---|---|---|---|---|---|---|
| | From the year 2005 to 2004 | From the year 2006 to 2005 | From the year 2007 to 2006 | From the year 2008 to 2007 | From the year 2009 to 2008 | From the year 2010 to 2009 | From the year 2010 to 2011 |
| BOR1 | 17 | 17 | 14 | 16 | 12 | 15 | 16 |
| HELG | 14 | 18 | 12 | 16 | 15 | 17 | 15 |
| LAMA | 15 | --- | --- | 15 | 14 | 15 | 16 |
| MAR6 | 17 | 12 | 12 | 14 | 12 | 19 | 16 |
| METS | 16 | 12 | 15 | 15 | 14 | 14 | 1 |
| OSLS | 16 | 14 | 12 | 13 | 9 | 14 | 15 |
| POTS | 17 | 15 | 16 | 15 | 11 | 16 | 17 |
| RIGA | 15 | 18 | 9 | 13 | 13 | 14 | 9 |
| SASS | 17 | 13 | 17 | 15 | 15 | 14 | 16 |
| SULD | 15 | 20 | 10 | 15 | 15 | 18 | 12 |
| VIS0 | 17 | 13 | 14 | 15 | 15 | 14 | 14 |
| VLNS | 13 | 14 | 15 | 14 | 14 | 13 | 12 |

**Table 3.** The displacements of geocentric coordinate *Z* of the EUREF GPS network

| The name of the station | ΔZ, mm | | | | | | |
|---|---|---|---|---|---|---|---|
| | From the year 2005 to 2004 | From the year 2006 to 2005 | From the year 2007 to 2006 | From the year 2008 to 2007 | From the year 2009 to 2008 | From the year 2010 to 2009 | From the year 2010 to 2011 |
| BOR1 | 6 | 15 | 14 | 9 | 6 | 3 | 15 |
| HELG | –8 | 21 | 20 | 15 | 13 | 10 | 10 |
| LAMA | 6 | --- | --- | 20 | 10 | 7 | 7 |
| MAR6 | 19 | 8 | 17 | 17 | 15 | 4 | 37 |
| METS | 13 | 6 | 16 | 12 | 12 | 2 | –7 |
| OSLS | 1 | 9 | 17 | 19 | 2 | 9 | 20 |
| POTS | 13 | 5 | 22 | 7 | 14 | –6 | 14 |
| RIGA | 12 | 1 | 20 | 6 | 11 | 4 | 4 |
| SASS | 11 | 7 | 30 | 11 | 6 | 5 | 11 |
| SULD | 1 | 13 | 16 | 12 | 10 | 5 | 14 |
| VIS0 | 11 | 7 | 14 | 14 | 10 | 11 | 12 |
| VLNS | 12 | –1 | 21 | 5 | 6 | 2 | 9 |

The displacements of geocentric coordinates (*X, Y, Z*) of the EUREF GPS network stations are provided in Figures 4–6.

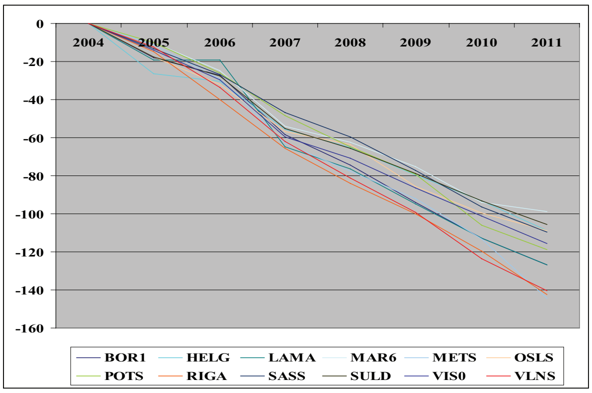


**Fig. 4.** The displacements of coordinate *X* of the stations (mm)

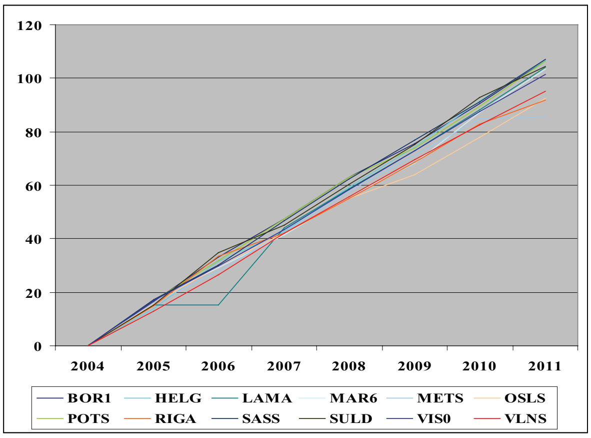


**Fig. 5.** The displacements of coordinate *Y* of the stations (mm)

It may be seen from diagrams (Figs. 4–6) of the displacements of the coordinates of the stations that the difference between the coordinates of the same stations increases annually: the changes in coordinate *X* of the stations are moving in a negative direction, and the coordinates *Y* and *Z* are going in a positive direction.

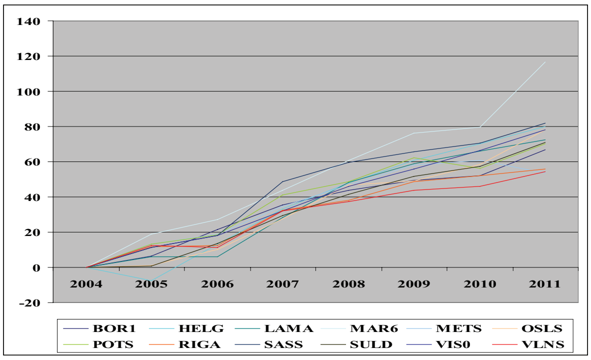


**Fig. 6.** The displacements of coordinate *Z* of the stations (mm)

The displacements of coordinates of the stations in the period between 2004 and 2011 are the following: the coordinates *X* and *Y* – over 100 mm, the coordinate *Z* –70–80 mm on average (Table 4).

**Table 4.** The displacements of the coordinates of the stations between 2004 and 2011 according to measurement data from GPS stations

| The name of the station | Δ*X*, mm | Δ*Y*, mm | Δ*Z*, mm |
|---|---|---|---|
| BOR1 | –127 | 107 | 67 |
| HELG | –109 | 107 | 80 |
| LAMA | –127 | 104 | 72 |
| MAR6 | –99 | 104 | 117 |
| METS | –145 | 85 | 53 |
| OSLS | –109 | 93 | 78 |
| POTS | –119 | 106 | 70 |
| RIGA | –142 | 92 | 56 |
| SASS | –109 | 107 | 82 |
| SULD | –106 | 105 | 71 |
| VIS0 | –116 | 101 | 78 |
| VLNS | –141 | 95 | 54 |

The average annual changes in the geocentric coordinates of the stations are shown in Table 5.

**Table 5.** The average annual changes in the coordinates of the stations between 2004 and 2011

| The name of the station | Δ*X*, mm | Δ*Y*, mm | Δ*Z*, mm |
|---|---|---|---|
| BOR1 | –18 | 15 | 10 |
| HELG | –16 | 15 | 11 |
| LAMA | –18 | 15 | 10 |
| MAR6 | –14 | 15 | 17 |
| METS | –21 | 12 | 8 |
| OSLS | –16 | 13 | 11 |
| POTS | –17 | 15 | 10 |
| RIGA | –20 | 13 | 8 |
| SASS | –16 | 15 | 12 |
| SULD | –15 | 15 | 10 |
| VIS0 | –17 | 14 | 11 |
| VLNS | –20 | 14 | 8 |

The stability of the permanent GPS station Vilnius (VLNS) was studied by E. Paršeliūnas *et al.* The velocities of ETRS89 geocentric coordinates (X, Y, Z) are as follows (Parseliūnas, Kolosovskis 2011):

$$v_X = -20.0 \text{ mm/y},$$
$$v_Y = 13.6 \text{ mm/y},$$
$$v_Z = 8.0 \text{ mm/y}.$$

In the present research it was found that the average annual changes in coordinates of the station VLNS (Vilnius) in the period between 2004 and 2011 was:

$$X_{ave} = -20.0 \text{ mm/y},$$
$$Y_{ave} = 14.0 \text{ mm/y},$$
$$Z_{ave} = 8.0 \text{ mm/y}.$$

It is clear that the present research results correlate with those of other researchers' studies

## 4. Conclusions

1. It was found that the difference in the coordinates of the same stations increases annually: the changes in coordinate X of the stations are increasing in the negative direction, and the coordinates Y and Z are moving in the positive direction.
2. The displacements of the coordinates of the stations in the period between 2004 and 2011 was over 100 mm for coordinates X and Y and about 70–80 mm for coordinate Z.
3. The average annual displacement of geocentric coordinates: coordinate X – about 17–18 mm/year, coordinate Y – 14 mm/year, and coordinate Z – 9–10 mm/year.
4. The displacements of the stations will enable deformations and stresses of the Earth's crust to be assessed.

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