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THE ANALYSIS OF THE STABILITY OF PERMANENT GPS STATION VILNIUS (VLNS)

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Abstract. Lithuania has been participating in the activities of the EUREF permanent network since 1996, when GPS station VILNIUS started regular continuous tracking of GPS satellites. The GPS station was established with a help of the Onsala Space Observatory (Sweden) and was mounted in the territory of Vilnius international airport (Lithuania). Four character identifier VLNS and DOMES number 10801M001 were assigned to VILNIUS GPS station by the International Earth Rotation Service in 1999. VILNIUS station is operated and maintained by the Institute of Geodesy of Vilnius Technical University. The main task of the permanent VLNS GPS station is to take part in EUREF activities and serve as reference to GPS campaigns in Lithuania.

The aim of this paper is to describe the evolution and current status of the technical equipment of VILNIUS station. The paper also presents the analysis of data quality and a few years interval of coordinate determination at VLNS within the EUREF network.

Keywords: permanent GPS station, permanent GPS observations, continuity and integrity of time series of geocentric coordinates.

1. Introduction

GPS station VILNIUS, which is a part of the EUREF permanent network (EPN), is the reference point of ETRS89 (European Terrestrial Reference System of 1989) in Lithuania (Fig. 1) (Investigations… 1999; GPS station… 2002; Investigation… 2004; Development… 2007, 2008; Paršeliunas, Kolosovskis 2005; Parseliunas *et al.* 2008; Paršeliūnas *et al.* 2010a, 2010b; Zakarevičius *et al.* 2008). The main information on the station and GPS data are available on the Internet <http://www.epncb.oma.be> (EUREF… 2011).

Lithuania has been participating in the activities of the EUREF permanent network since 1996, when GPS station VILNIUS started regular continuous observations of GPS satellites. The GPS station was established with a help of the Onsala Space Observatory of Chalmers University (Sweden). The GPS station was mounted in the territory of Vilnius international airport. This station has been operating since the end of 1996, providing daily files of 24 hours continuous measurements (phase and codes on both frequencies) with a sampling rate of 30 seconds.

IERS four character identifier VLNS and DOMES number 1080M001 were assigned to VILNIUS GPS station by the International Earth Rotation Service in 1999. VILNIUS station is operated and maintained by the Institute of Geodesy, Vilnius Gediminas Technical University. The main task of the VLNS permanent GPS station is to take part in EUREF activities and serve as reference to GPS campaigns in Lithuania.

The measurements of GPS station VLNS are used (together with the measurements performed by other stations) (Investigations… 1999; Development… 2007, 2008; Paršeliūnas *et al.* 2010a):

- for determining the coordinates of the VLNS station and their changes in time,
- for studying the movements of Euro-Asian plate and intra-plate movements,
- for defining ETRS (European Terrestrial Reference System) in the Lithuania,
- as reference station data for GPS campaigns both in Lithuania and Europe.

The VLNS station has a category of class A, which means that its positions have 1 cm accuracy during all epochs of the time span of the used observations (Fig. 2).

The process of establishing a permanent GPS Station is very tightly connected with research and educational work of the Department of Geodesy and Cadastre and the Institute of Geodesy of Vilnius Gediminas Technical University (Investigations… 1999; GPS station… 2002; Investigation… 2004; Development… 2007, 2008; Parseliunas, Kolosovskis 2005; Parseliunas *et al.* 2008, Paršeliūnas *et al.* 2010a, 2010b).

http://www.tandfonline.com/loi/tgac20

Fig. 1. A fragment of the EPN network map (EUREF… 2011)

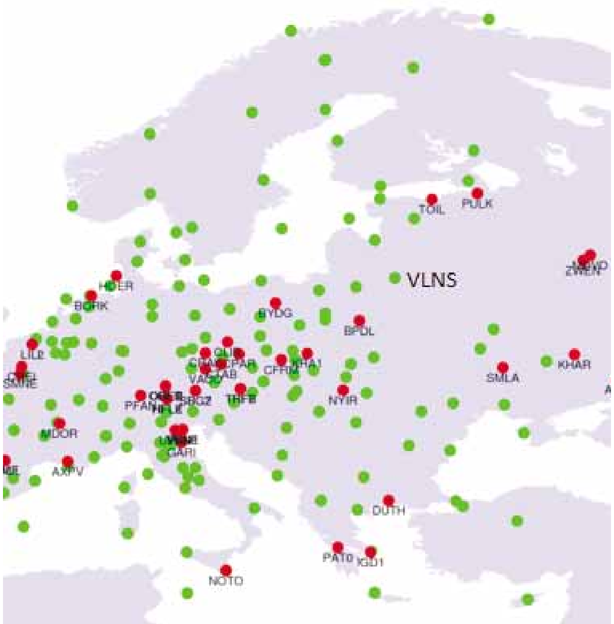

Fig. 2. A fragment of the map presenting station categories (green dots – class A, red dots – class B stations) (EUREF… 2011)

2. Updated technical equipment

Following the standards of International GPS Service (IGS) aiming at precise geodynamical applications, at present, permanent GPS station VILNIUS is equipped with Ashtech GPS receiver Z-12 continuously tracking all visible GPS satellites making measurements using C/A-code, P-code and the carrier phase on both frequencies L1 and L2 and with Ashtech chock ring GPS antenna having Dorne Margolin element (Fig. 3).

Fig. 3. VLNS pier and GPS antenna

It should be stressed that the GPS antenna with no touching has never been removed from the monument. In the only case, snow protecting radom was removed in 2002 as recommended by EPN CB. Such an issue gives good preconditions for the stability and reliability of researching the station position using records over a long time.

The standard operation of the Ashtech Z-12 GPS receiver is 30 s data sampling. The cut-off angle of the elevation mask was set to 5°, which makes almost a clear view of the sky in all directions down to this cut-off angle (Fig. 4).

It should be mentioned that in the summer of 2010, the receiver gave the failure of the memory card that was replaced by a memory card of the same type of a receiver loaned by BKG. Certainly, it was impossible to avoid a long data gap caused by replacing the memory card (Fig. 6).

The GPS reference mark consists of a steel plate with a forced centring hole embedded on the top of a 3.0 m high concrete pier, 30 cm in diameter. The pier is anchored to the ground by a concrete block of 1.5 m in size to a depth of 2.5 m.

The building of the GPS station close to the pier was removed in 2008. Instead, a special metal box was dedicated to put all necessary station equipment (Fig. 5).

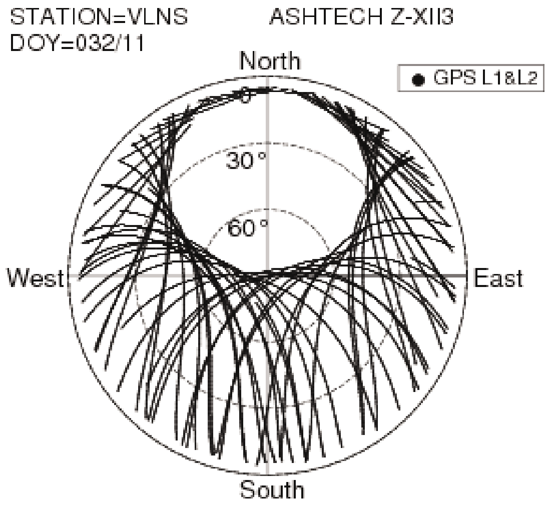

Fig. 4. Sky plot at VLNS station

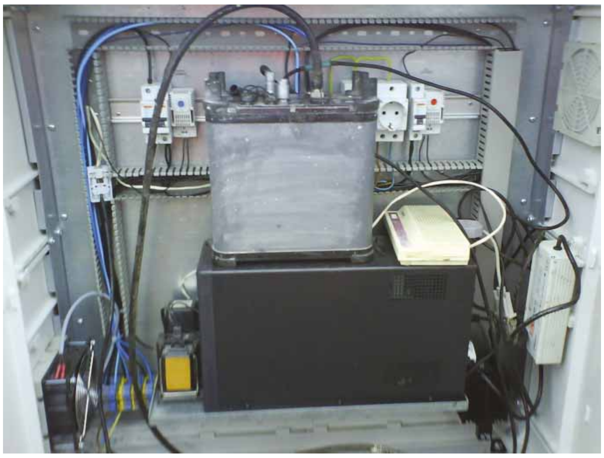

Fig. 5. VLNS GPS receiver box

A special box has been already provided with standard electrical power (220 Volts AC). New power points were installed to supply the GPS receiver and modem. The receiver and modem have a backup with a 12V battery and smart UPS to overcome possible 220 V power source failures. The whole system is capable of working up to 12 h during power breaks without the interruption of any satellite observations. In case of longer power failure, the receiver itself stores the observed data into the receiver memory. In this case, an operation up to 5 days is possible. However, downloading manual data is then necessary.

The quality of the observed data is checked at the Institute of Geodesy following routine procedures and converted to RINEX and Hatanaka compressed formats. Then, the compressed data are sent to the centre of EUREF regional data and is available for regional processing of the EUREF permanent network. Next, GPS measurements are checked and written in the RINEX format (Gurtner, Mader 1990; Estey, Meertens 1999; Hatanaka 1996a, 1996b; Carpentier *et al.* 2004; Takacs, Bruyninx 2002; Kenyeres 2009; Lehmann, Figurski 2000; Kaniuth, Stuber 2005).

VLNS data are processed in four EUREF analysing centres – Nordic Geodetic Commission (NKG) from GPS week 0998, Geodetic Observatory Pecný (GOP) from GPS week 0998, Warsaw University of Technology (WUT) from GPS week 0998 and Military University of Technology (MUT) – from GPS week 1558, leading to a weekly combined solution and time series (Kenyers 2009).

3. Coordinate variations

VLNS data have been processed within the EUREF network since 1999 when VLNS was included in the EUREF permanent network. Regularly updated positions/velocities (see Table 1) are the result of the multi-year adjustment of all weekly combined EPN solutions in which outliers were eliminated and station discontinuities were applied (Kenyers 2009).

Two types of coordinate time series are distinguished:

1. Residual coordinate time series displaying the residuals of Helmert transformation between a cumulative coordinate/velocity solution based on weekly combined EPN solutions and on each of weekly combined EPN solutions:
   – raw time series: coordinate outliers are not eliminated, one coordinate/velocity set for each station (Fig. 6),
   – cleaned time series: coordinate outliers are eliminated, a new coordinate/velocity is estimated if necessary (Fig. 7).
2. Coordinate time series displaying the evolution of the coordinates the time, included in weekly combined EPN solutions:
   – ITRS time series: coordinates of ITRS extracted from a weekly solution as is (Fig. 8),
   – ETRS time series: coordinates of ITRS extracted from a weekly solution and transformed to ETRS89 (Fig. 9).

The three plots of each figure represent North-South (N), East-West (E) and Up (V) components showing the position of the GPS station with time.

Variations in a straight line show the uncertainty (or noise) in the measurement of station position from a single day of GPS data. There are no significant departures from the straight line which indicates the absence of any problem of data processing. Short period movements are mainly caused by earth tides, ocean and atmospheric loading effects, ionospheric and tropospheric refraction.

The gap in data between the spring of 1999 and that of 2002 occurred because of the fault of the GPS receiver and due to the fact that the VLNS station was temporarily excluded from the combined EUREF solution.

From the analysis of the above results, the following conclusion can be drawn: the maximum amplitude of the repeatability value is about 5 mm for the North and East component and 10 mm for the Up component.

The evolution of weekly VLNS coordinates in the ITRF system is shown in Fig. 9.

Table 1. The positions (geocentric coordinates), velocities and accuracy (cumulative solution of GPS weeks 860–160) of the VLNS station

X/Vx, m	Y/Vy, m	Z/Vz, m	σX/σVx, m	σY/σVy, m	σZ/σVz, m
Reference frame ETRF2000 in the epoch of 2005.0					
3343600.971 0.000	1580417.554 0.000	5179337.122 0.000	0.0002 0.0001	−0.0004 0.0000	−0.0001 0.0001
Reference frame ITRF2005 in the epoch of 2005.0					
3343600.621 0.000	1580417.740 0.000	5179337.298 0.000	−0.0182 0.0001	0.0142 0.0000	0.0087 0.0001

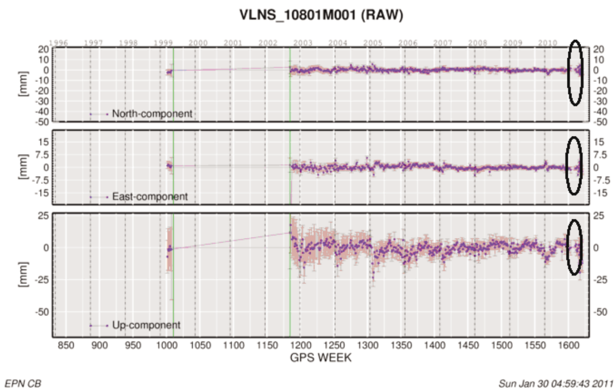

Fig. 6. The evolution of VLNS ETRF geocentric coordinates considering three components: north-south, east-west and up (ellipses show the data gap in 2010) (EUREF… 2011)

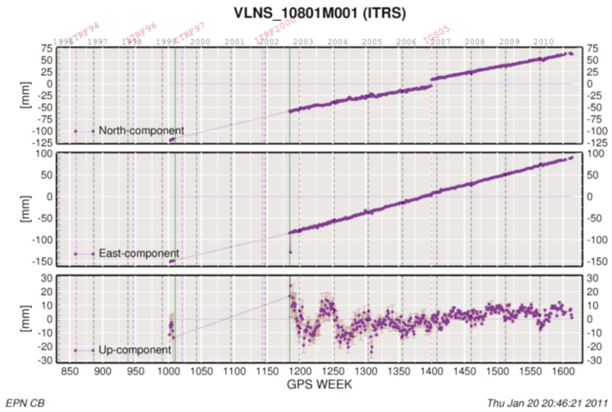

Fig. 8. The evolution of VLNS ITRF geocentric coordinates considering three components: north-south, east-west and up

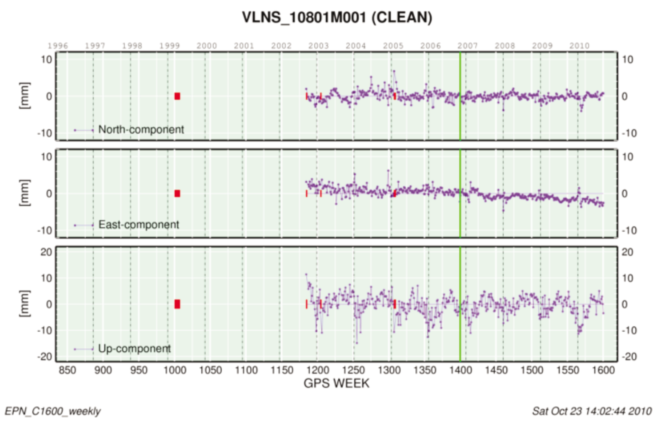

Fig. 7. The evolution of VLNS ITRF geocentric coordinates considering three components: north-south, east-west and up (EUREF… 2011)

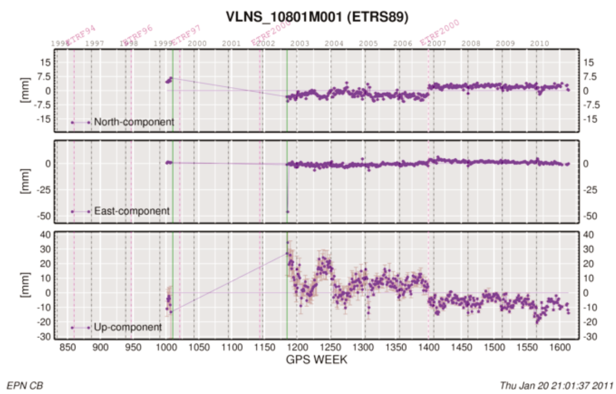

Fig. 9. The evolution of VLNS ETRF geocentric coordinates considering three components: north-south, east-west and up (EUREF… 2011)

The north and east horizontal components exhibit a uniform linear trend reflecting the systematic drift of the movement of the Eurasian tectonic plate towards north-east.

Estimated ETRS89 coordinates (N, E, U) velocities and their uncertainties are calculated as follows (Fig. 10, 11, 12):

$v_N = -0.04 \pm 0.15$ mm/y,

$v_E = -0.48 \pm 0.09$ mm/y,

$v_U = 1.03 \pm 0.48$ mm/y.

The evolution of ETRS89 geocentric coordinates (*X, Y, Z*) is shown in Fig. 10, 11, 12.

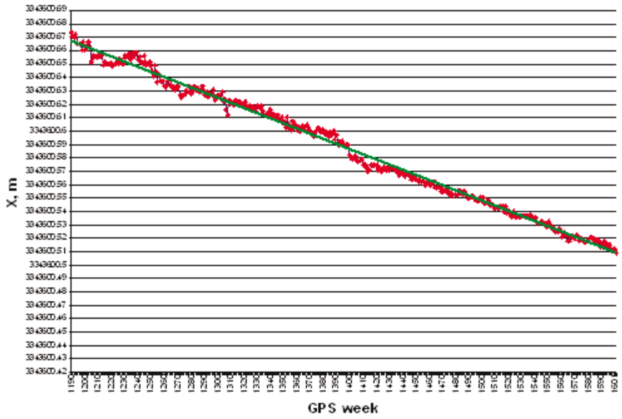

Fig. 10. The evolution of VLNS ETRS89 geocentric coordinates

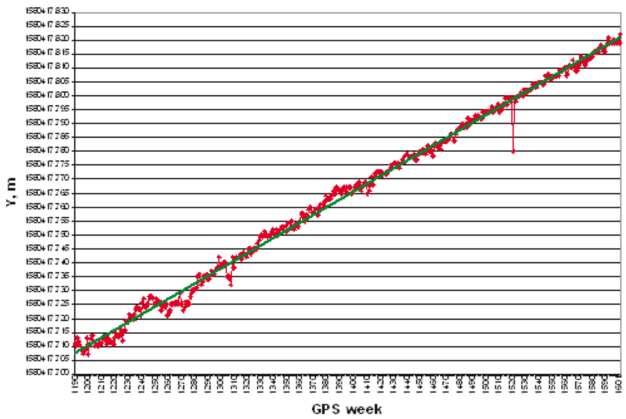

Fig. 11. The evolution of VLNS ETRS89 geocentric coordinates

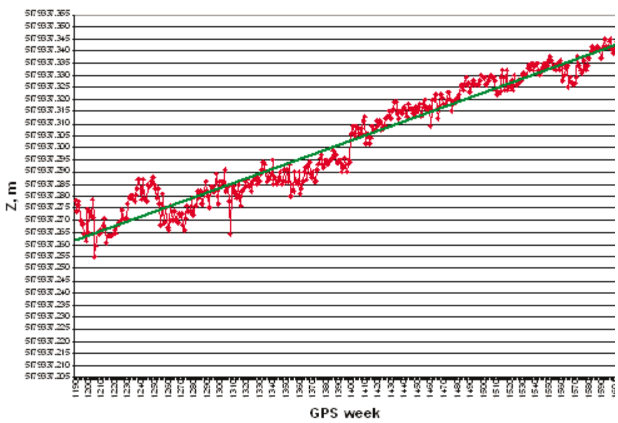

Fig. 12. The evolution of VLNS ETRS89 geocentric coordinates

The velocities of ETRS89 geocentric coordinates (*X*, *Y*, *Z*) are as follows:

$v_X = -20.0$ mm/*y*,

$v_Y = 13.6$ mm/y,

$v_Z = 8.0$ mm/y

4. Conclusions

1. VILNIUS (VLNS) permanent GPS station is reference to GPS activities in Lithuania. The more than ten-year period of observations has proved the good quality and stability of the reference site, GPS antenna and receiver.
2. It should be stressed that the GPS antenna has not been changed during the whole period of observations which gives good premises for the stability and reliability of the station.
3. The estimated ETRS89 coordinates (*N*, *E*, *U*) velocities and their uncertainties are calculated as follows: $v_N = -0.04 \pm 0.15$ mm/y, $v_E = -0.48 \pm 0.09$ mm/y, $v_U = 1.03 \pm 0.48$ mm/y.
4. The range of variability in the jump size is similar to the North and East component (less than 5.0 mm). The range of variability in the jump size is larger for the Up component (up to 10.0 mm) rather than for the North and East ones. The Up component has seasonal changes in the form of a sinusoid.

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