DISPLACEMENTS AT THE GNSS STATIONS

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ABSTRACT

The daily movements of EUPOS®-Riga and LatPos permanent GNSS network stations have been studied. Time series of GNSS station results of both the EUPOS®-Riga and LatPos networks have been developed at the Institute of Geodesy and Geoinformation of the University of Latvia (LU GGI). Reference stations from EUREF Permanent Network (EPN) have been used and Bernese GPS Software, Version 5.0, in both kinematic and static modes was applied. The standard data sets were taken from IGS database. The impact of solid Earth tides on the site coordinate changes has been studied. The Moon and the Sun tide effect is a significant factor causing the GNSS station displacements together with the Earth crust local part. Earth tidal displacements have been obtained by modifying the routine of Bernese GPS Software computing tidal station displacements in accordance with the latest IERS Conventions.

Key words: GNSS, permanent networks, displacements, solid Earth tides

INTRODUCTION

In the framework of EUPOS® regional development project, there have been two GNSS station networks developed in Latvia – LatPos and EUPOS®-Riga, which have been operating since 2006.

The EUPOS® initiative is an international expert group of public organisations coming from the field of geodesy, geodetic survey and cadastre. Partners from 19 Central and East European countries work on the provision of compatible spatial reference infrastructures by using the Global Navigation Satellite Systems (GNSS) GPS, GLONASS and as soon as available - GALILEO by operating Differential GNSS EUPOS® reference station services. The EUPOS® services allow a high accuracy and reliability for positioning and navigation and provide a wide range of geoinformation applications on this basis (EUPOS, 2013).

Time series of GNSS station results of both the EUPOS®-Riga and LatPos networks have been developed at the Institute of Geodesy and Geoinformation of the University of Latvia (LU GGI). The impact of solid Earth tides on these results has been studied.

Earth tide is a phenomenon which has been recognized for more than a thousand years, and its careful analysis started in the 19th century and flourished afterwards. However, the high precision calculations on Earth tides became available just after a reliable model of the Earth’s physical properties and digital computers had been acquired (Sung-Ho Na et al., 2010).

Earth tides and tide deformations are the Earth’s crust vertical movements with a maximum amplitude of up to 30 cm and theoretically precisely determined oscillations. The Earth’s periodic oscillations occur, mainly, as a result of gravitational forces between the Earth, the Moon and the Sun and centrifugal forces of the rotation system (Мельхиор, 1968).

Figure 1. EUPOS® reference station subnetwork in the Baltic countries including LatPos and EUPOS®-Riga

The Moon and the Sun tide effect is a significant factor causing the GNSS station displacements together with the Earth crust local part (Poutanen et al., 1996).

DATA PROCESSING

Static processing

The daily solutions yielding the time series of site X, Y and Z geocentric coordinate variations for EUPOS®-Riga and LatPos permanent GNSS network stations were obtained applying Bernese GPS Software, Version 5.0.
The reference stations were selected among the EUREF Permanent Network (EPN) stations in the surroundings of Latvia. Most frequently 5–8 reference stations were selected from a set of stations: BOR1, JOEN, JOZE, MDVJ, METS, POLV, PULK, RIGA, TORA, VAAS, VISO, VLNS.
The standard data sets were taken from the IGS database – ionosphere and troposphere parameters, satellite orbits, satellite clock corrections, as well as the Earth rotation parameters.
The results of GNSS data processing are station coordinates in the IGS05 coordinate system of the daily solution. These coordinates first were transformed to the European reference frame ETRS89, and then to the Latvian Geodetic Coordinate System LKS-92 with the view of obtaining station horizontal and vertical displacements.

Kinematic processing

The Bernese GPS Software allows the estimation of kinematic, i.e., epoch-wise receiver coordinates (Beutler et al., 2007). This feature has been applied for computing solid Earth tides caused by horizontal and vertical displacements at one of the EUPOS®-Riga network stations – LUNI.
Such displacements can be obtained by modifying the Bernese GPS Software routine TIDE2000.f computing tidal station displacements in accordance with the latest IERS Conventions. Modification is necessary to define that the tidal impact corrections will not be introduced for kinematic stations during data processing.
Processing of mixed, kinematic and static stations has been performed in the same solution allowing to process data from several stations in the baseline mode, one of them kinematic – LUNI, the others static. Eight EPN stations: JOZE, MDVJ, METS, PULK, RIGA, TORA, VIS0, VLNS, were fixed, i.e., static for datum definition in each kinematic double-difference network solution.
The result file of GNSS data kinematic processing includes a priori station coordinates in the IGS05 coordinate system and estimated displacements and RMS in North, East and Up components of rover station in meters with 5-minute sampling interval.

Use of theoretical data

For data control the program ‘solid’ has been applied. It writes solid Earth tide components – North, East, Up, in the local Transverse Mercator system with a central meridian 24°; an Earth-centered GRS80 ellipsoid is applied. The solid Earth tide components are computed for 24 hours at 1 minute intervals in GPS time.
The program implements the conventions described in Section 7.1.2 of the IERS Conventions (2003) (McCarthy et al., 2004). ‘Solid’ does not implement ocean loading, atmospheric loading, or deformation due to polar motion (Milbert, 2012).

RESULTS AND DISCUSSION

Time series analysis

Fig. 2 shows a small part of a 4-year continuous GNSS time series developed at the LU GGI – 18-day vertical displacements at the LatPos and EUPOS®-Riga stations. The figure represents data for 20 LatPos network stations and for 5 EUPOS®-Riga permanent network stations. The dispersion of station vertical displacements is located at a 1,5 cm interval.
An observation time period – from 14th to 32nd day of the year 2010, was selected considering phases of the Moon and other phenomena which increase the impact of tidal forces.
Fig. 3 shows solid Earth tide theoretical vertical displacements at the EUPOS®-Riga station LUNI with coordinates Lat 56.950613022° and Lon 24.116529489° in the GRS80 system for a selected observation time period. The maximum height of the tidal wave was on 28th–29th day of the year 2010 and was equal to 34 cm in the territory of Riga according to the theoretical estimates.
Comparing these charts shown in Fig. 3 and Fig. 4, some coherence can be observed between extreme values of the vertical displacements at the GNSS stations and tidal wave distribution. As well as dissimilar height values at the LODE (orange curve), JEKA (red) and SIGU (violet) stations can be distinguished.

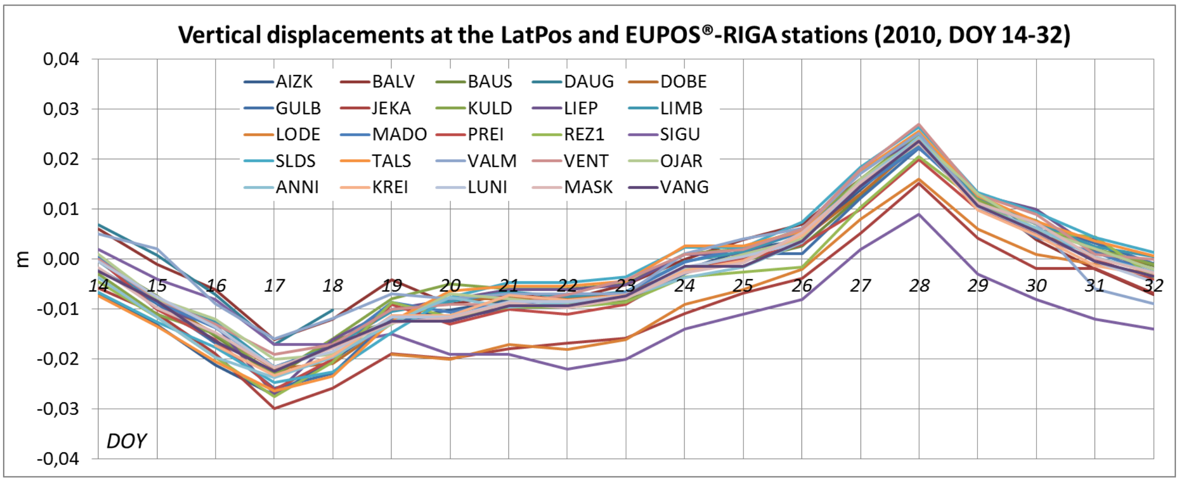

Figure 2. Time series of GNSS station height coordinate,
where DOY – day of year

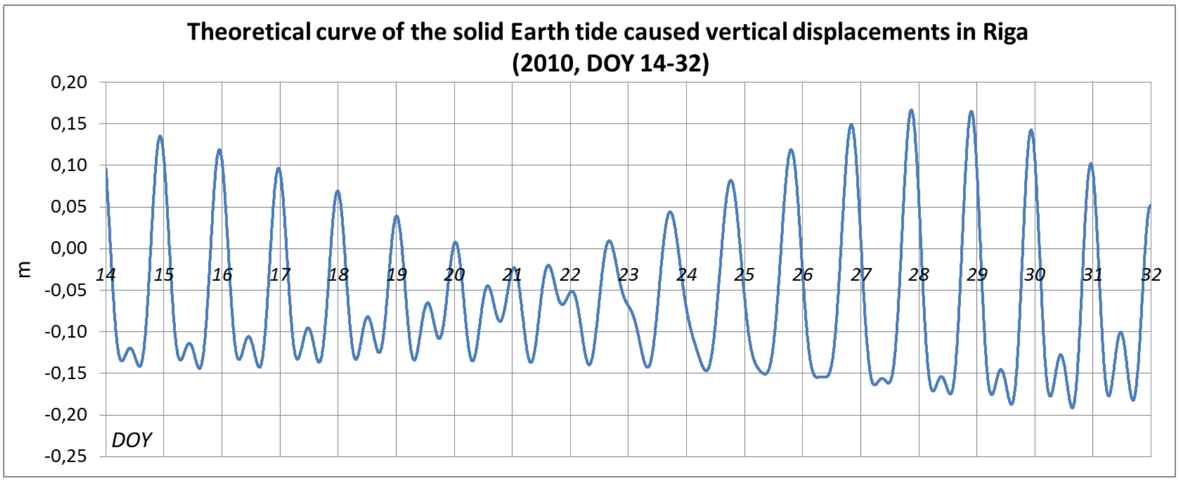

Figure 3. Theoretical vertical displacements due to the solid Earth tide effect obtained by the program 'solid',
where DOY – day of year

Subdaily displacement analysis

The impact of solid Earth tides on the GNSS station coordinate changes during the day has been studied. Earth tidal displacements were obtained by modifying the routine of Bernese GPS Software TIDE2000.f. Consequently, the solid Earth tide corrections of LUNI station displacements were not taken into account in the computing process.

Fig. 4 shows 5-day horizontal and vertical displacements caused by the solid Earth tides at the central station of the EUPOS®-Riga network – LUNI.

Observation time interval – from 27th to 31st day of the year 2010, was also selected considering the strong impact of tidal forces of that time.

For data control, the theoretical curves were obtained by the program 'solid'. LUNI station coordinates Lat 56.950613022° and Lon 24.116529489° were used for this purpose.

Fig. 5 represents comparisons obtained by GNSS data kinematic processing and theoretical results of tidal displacements at the LUNI station in Up (a), North (b) and East (c) components.

The maximum height of the tidal wave in the Up component is about 35 cm. In the case of the North component, this value is about 10 cm.

As can be seen from the Fig. 5, data from the Up and North components correspond to the theoretical curves of tidal waves, but the East component data coincide with the theoretical tidal oscillation curve just partly. Such East component results can be explained by the delayed site reaction to the Earth tidal forces. Of course, human error cannot be ruled out as well.

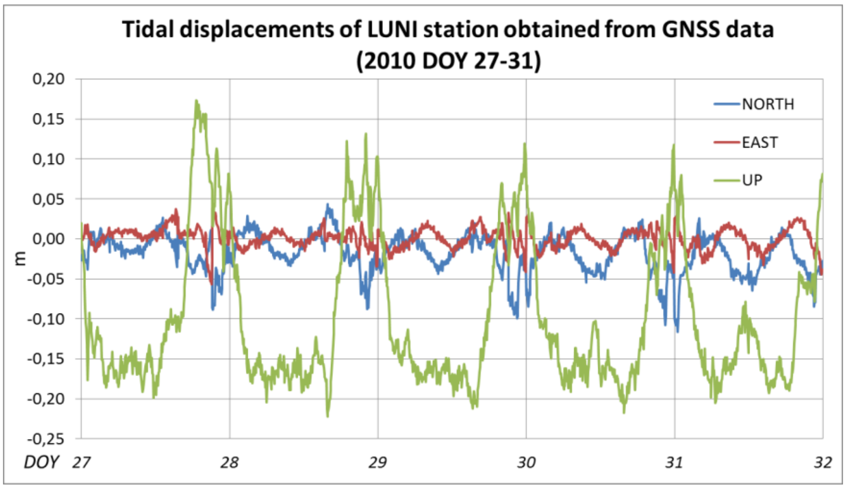

Figure 4. Estimated tidal displacement trajectory in North, East, and Up components for LUNI station

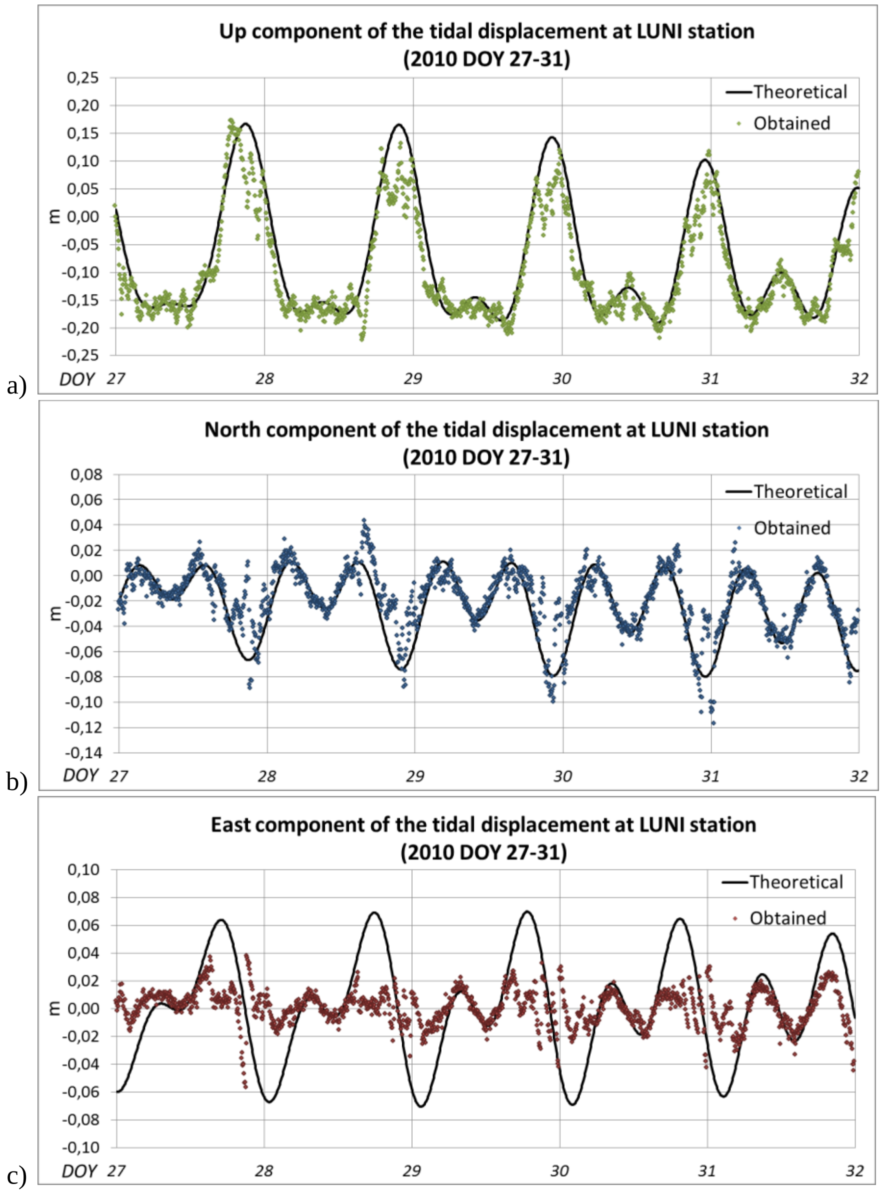

Figure 5. Estimated and theoretical tidal displacement data in Up (a), North (b) and East (c) components for LUNI station

CONCLUSIONS

Some coherence can be observed between extreme values of the vertical displacements at the LatPos and EUPOS®-Riga permanent GNSS network stations and the solid Earth tide caused vertical displacements.

Outlying height values of LODE, JEKA and SIGU stations were identified for a selected period of time. The possible reason could be the seismic activity at some areas of Latvia, or periodic influence of solid Earth tide impact, or GNSS station antenna problems.

An assessment of the influence of the above mentioned factors on the obtained data is in progress and will be prepared, when complete information and all results of the 4-year continuous GNSS time series are summarized.

The effect of solid Earth tides on the GNSS antenna's position may be obtained by applying kinematic processing.

The maximum height of the tidal wave in the Up component at the EUPOS®-Riga station LUNI is about 35 cm, and in the North component this value reaches 10 cm for selected observation time interval. However, the East component estimates of the solid Earth tide caused displacements show delayed reaction to the tidal forces.

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