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APPLICATION OF SHORT-TIME GNSS SOLUTIONS TO GEODYNAMICAL STUDIES

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ABSTRACT

The paper presents the results of research related to the application of GNSS solutions in short observational periods in geodynamical investigations. Authors used the 3-hour solution appointed from hour-long interval of about 30 chosen stations on mountainous terrains from over 100 which were worked out. The main aim was to check the correctness of such solutions by the comparison with the daily ones. Some outliers in East component could testify, that tropospheric or ionospheric models used in the data adjustment are not sufficient for so short-time solutions. The second principal problem, which was considered in the present work is the ability to detect diurnal and sub-diurnal oscillations in changes of permanent stations' coordinates. Results show unambiguously, that such oscillations appear in all analysed stations. In the paper there are examples of stations with dominant oscillations in different frequencies. The clear homogeneous in the frequencies was not found among any group of stations. It is therefore difficult to affirm, if their origin comes purely from the geodynamical phenomena.

KEYWORDS: ASG-EUPOS, short-time solutions, frequency analysis, periodic signals

INTRODUCTION

Nowadays geodetic space techniques have reached a level of precision that make them an important tool for Earth system sciences. Important added-value and new areas of application will result from a combination of the fundamental three types of geodetic parameters: surface geometry, Earth rotation and gravity. This is what GGOS (Global Geodetic Observing System) intends to provide. Examples of this modern development are detection and monitoring of tectonic, ice and ocean motion, the determination of mass anomalies and implicitly density anomalies, observation and quantification of mass transport processes in the hydrosphere and in the oceans, estimation of global and regional mass changes in the Earth components, separation of the thermal and mass components of sea level change, ionospheric and tropospheric sounding (Plag and Pearlman, 2009).

The quantities to be delivered from the combination of the three fundamental pillars geometry, gravity/geoid, Earth rotation are small and therefore difficult to determine. In order to be useful for global change studies they have to be derived free of bias and consistently in space and time. In general they are derived from the combination of complementary sensor and observation systems. For example, dynamic ocean topography is to be derived from the accurate measurement of the ocean surface by radar altimetry in combination with a geoid surface provided by gravity satellite missions. It shows that a variety of sensor systems, mission characteristics, and tracking systems have to be combined with utmost precision (Plag and Pearlman, 2009). The interconnections between mass transport processes, and the relations between observable parameters of gravity and geometry and the different processes are sketched in Figure 2.

MOTIVATION

Most of the phenomena pointed out in Figure 2 could be detected through the satellite observations (navigational, altimetric and gravimetric as well). But in the time resolution diurnal, sub-diurnal and instantaneous effects are very difficult to be monitored from space. In case of GNSS observations the problem lies in the time Windows which is used for precise ambiguity determination. Usually it is 24 hours which yields daily solutions. In order to evaluate shorter time resolution and research the short-time phenomena the length of the window has to be reduced as much as possible. Additionally the overlapping has to be applied even though it could implement many correlations into the results.

DATA ADJUSTMENT

In order to determine the stations' positions the data from ASG-EUPOS (Polish Active Geodetic Network) was used. ASG-EUPOS multifunctional precise satellite positioning system established by the

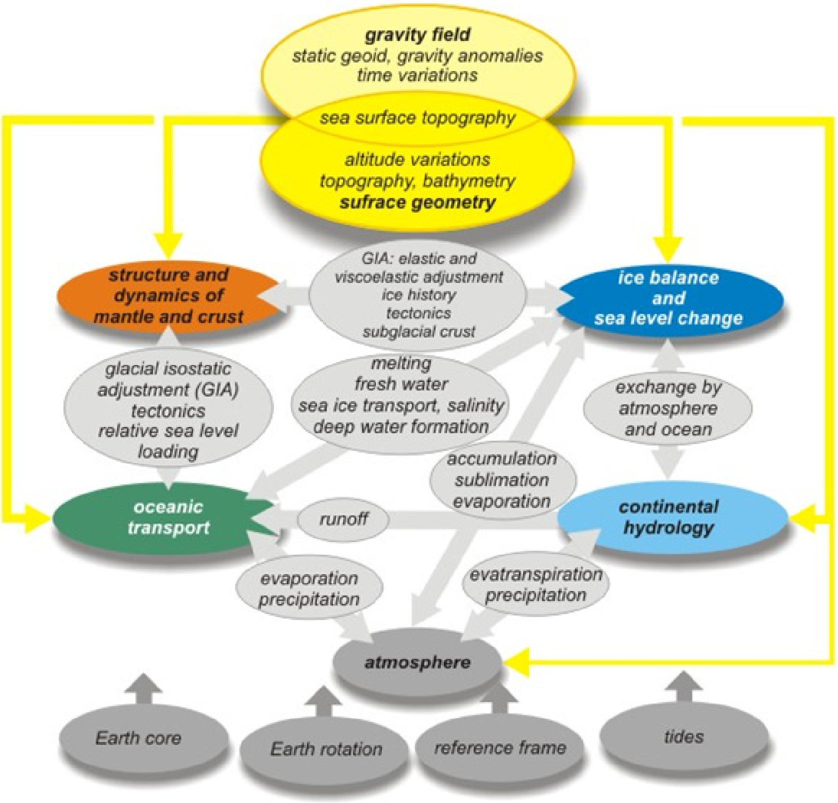


Fig. 1 Interconnections between processes and research themes related to mass transport and mass distribution (Plag and Pearlman, 2009).

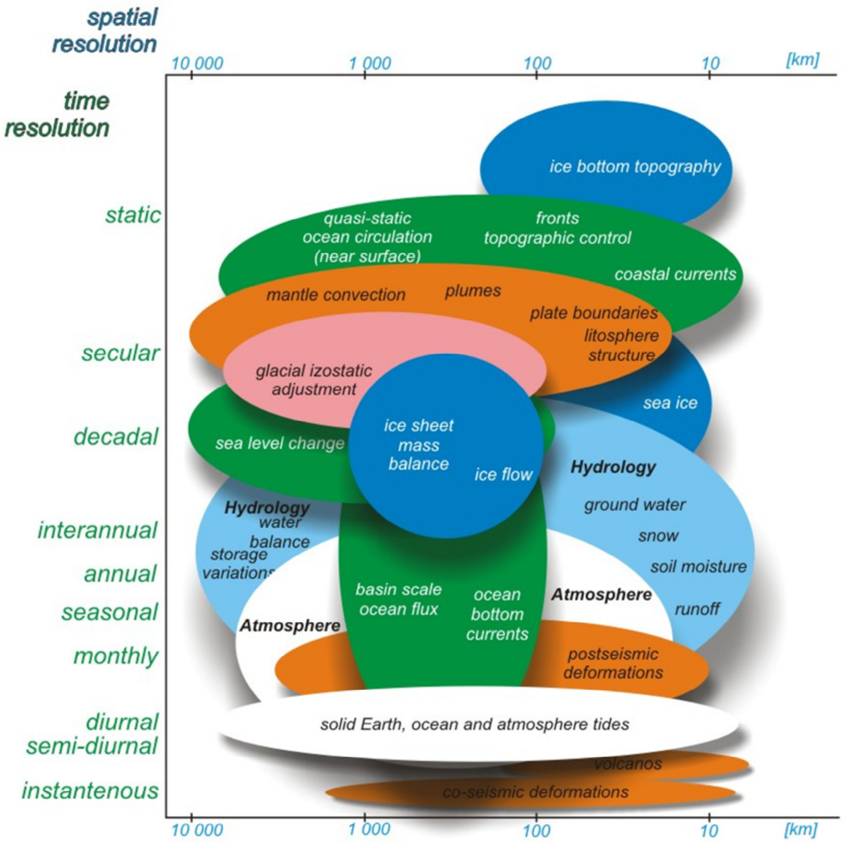


Fig. 2 Mass transport phenomena and mass distribution characteristics.

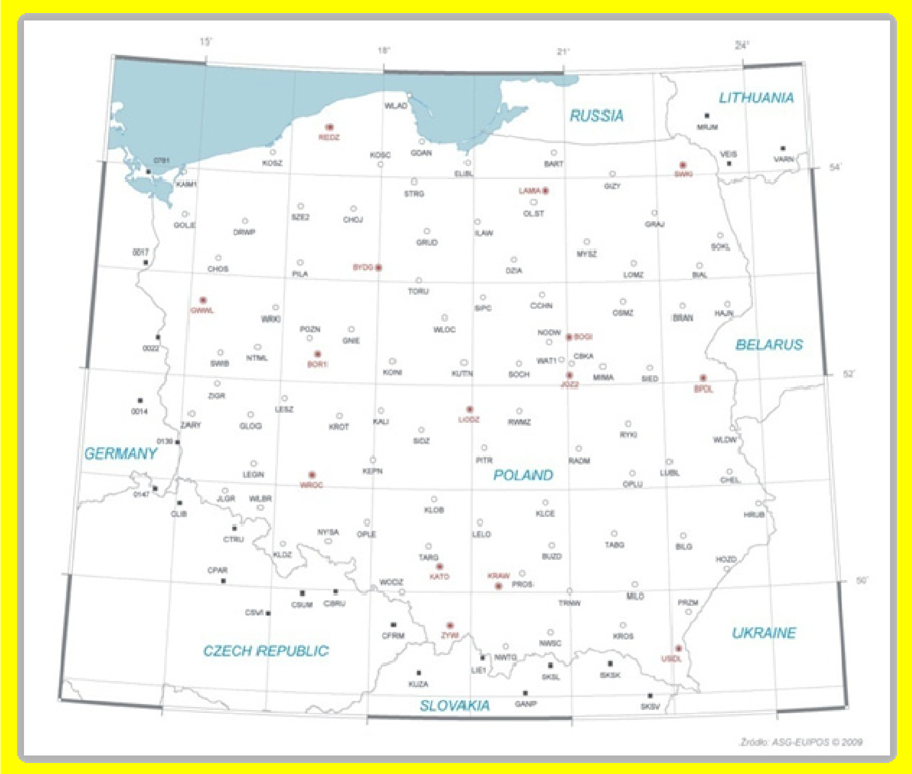


Fig. 3 Adjusted GPS network (www.asgeupos.pl).

Table 1 Data processing strategy and applied models.

Orbit:	IGS precise final orbit
Troposhere:	Saastamoinen – based dry component Wet-Niell mapping function
Ionoshere:	CODE global iono models ionoshere-free linear combination
Ambiguity:	QIF strategy L3/L5 – for baselines shorter than 100km L1/L2 – for baselines shorter than 20km
Planetary ephemeris:	DE40
Solid Earth tides:	IERS2003
Ocean tides:	OT_CSRC
Earth geopotential model:	JGM3
Nutation model:	IERS2000
Ocean loading model:	FES2004

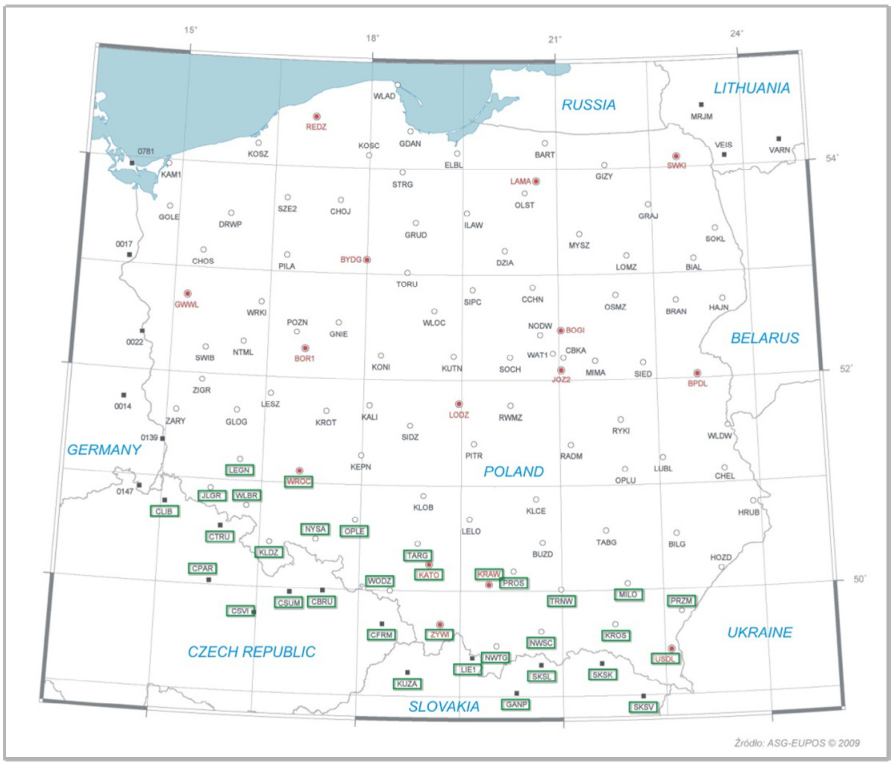
Head Office of Geodesy and Cartography in 2008. It consists of:

- 84 Polish sites with GPS module;
- 14 Polish sites with GPS/GLONASS module;
- 20 foreign sites.

The adjusted network consisted of over 100 stations (Fig. 3), the period covered observations collected from 10.01.2009 to 25.03.2009.

The Bernese software v. 5.0 was used (Dach et. al., 2007) with elevation angle cutoff - 3 degrees and elevation dependent weighting using cos(z). The same strategy as in EPN (EUREF Permanent GNSS Network) processing was applied (www.epncb.oma.be). The particular models are presented in Table 1.

Only GPS observations (RINEX format) were used with carrier phase as a basic observable (double-differences, ionosphere-free linear combination) with reference (datum) to several EPN stations (BOR1, WTZR, METS, POTS, ONSA).



Źródło: ASG-EUPOS © 2009

Fig. 4 Stations considered in this elaboration.

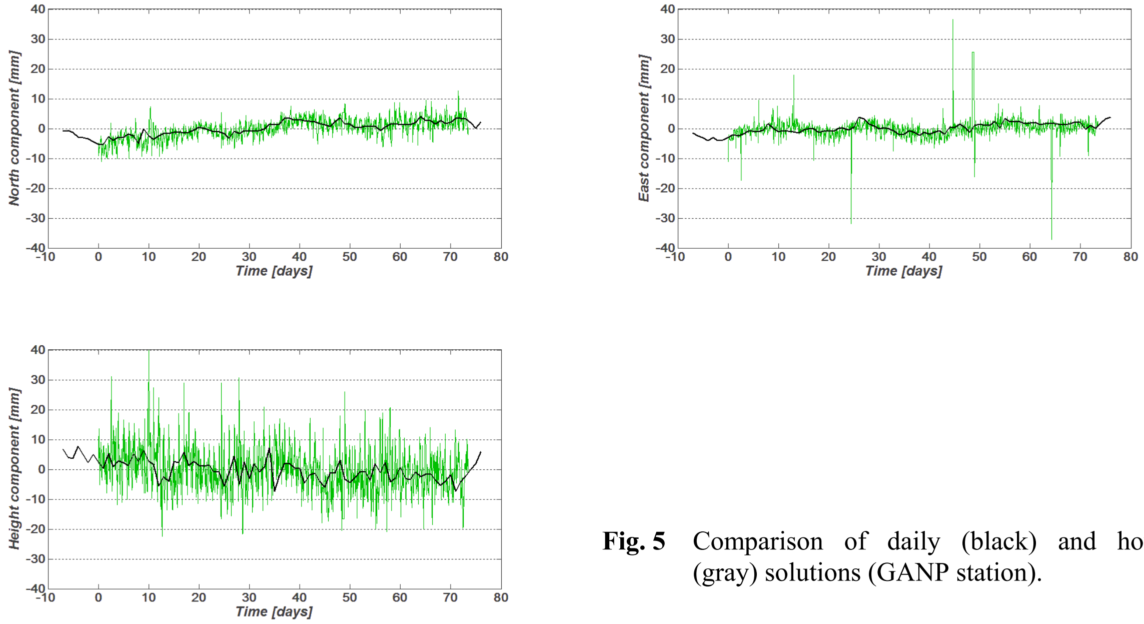


Fig. 5 Comparison of daily (black) and hourly (gray) solutions (GANP station).

In order to obtain short-time solutions the 3-hour window with 1-hour shift was applied. From over 100 stations for further analyses the mountainous sites were chose, because there the biggest geodynamical effects were expected. They were (Fig. 4):

- 7 Czech;
- 6 Slovak;
- 20 Polish.

VALIDATION OF THE RESULTS

Short-term solutions are less reliable than diurnal ones because of the problems with ambiguity determination. The examination of the correctness depended on comparison between diurnal and hourly solutions for the same period. Figure 5 presents such a comparison for all three components for GANP (Poprad Ganovce, Slovakia) station.

Table 2 Standard deviations of the chosen stations' coordinates from 3-hour solution.

Site	σ_B [mm]	σ_L [mm]	σ_H [mm]
CBRU	2.4	4.5	5.6
CLIB	4.5	6.9	9.1
CSUM	2.4	3.5	7.3
WLBR	3.9	5.1	8.4
SKSK	5.1	7.2	12.8
SKSL	4.7	4.5	10.2
JLGR	2.8	3.3	6.9

The same construction of the network as well as input parameters were used in both solutions. Only in several sites the significant discrepancies were discovered, but mostly due to the short time of observations. For most of the stations correlations on the level of 90 % were obtained. Several outliers in East component were noticed, probably because of the short time of particular solutions (3 hours). We suppose that better ionospheric (scintillations, fluctuations of TEC, moving ionosphere perturbations TID) and tropospheric (4D model of water vapour distribution) models should be implemented.

Relatively high consistency of the analysed time series was obtained (Table 2).

DIURNAL AND SUB-DIURNAL OSCILLATIONS

In order to obtain oscillations in the coordinates' time-series FFT procedure and Matlab® software were used. Because of the obtained results the adjusted stations were divided into several groups:

- sites with almost no oscillations,
- sites with strong long-period changes,
- sites with no dominant oscillation,
- sites with dominant diurnal oscillation,
- sites with dominant sub-diurnal oscillations,
- 12-hours,
- 8-hours,
- 6-hours,
- noisy sites,
- sites with strange frequency behaviour.

Examples of the oscillations mentioned above are presented in Figures 6-12.

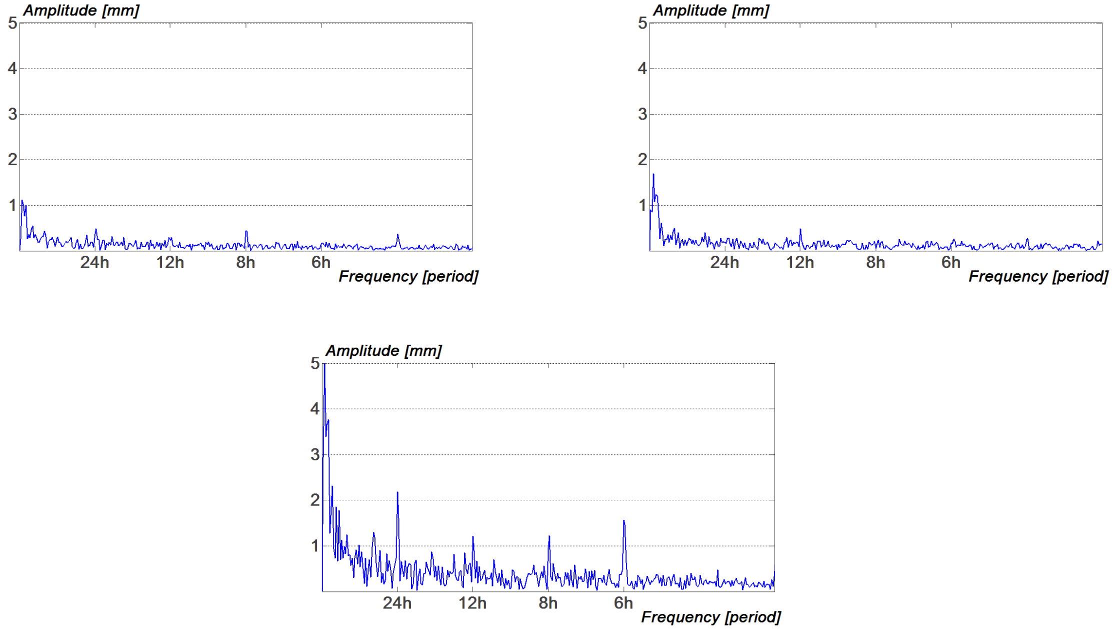


Fig. 6 Spectra of the coordinates of LIE1 (Liesek, Slovakia) station (North, East and Up [mm] from upper left) with dominant long-period oscillations.

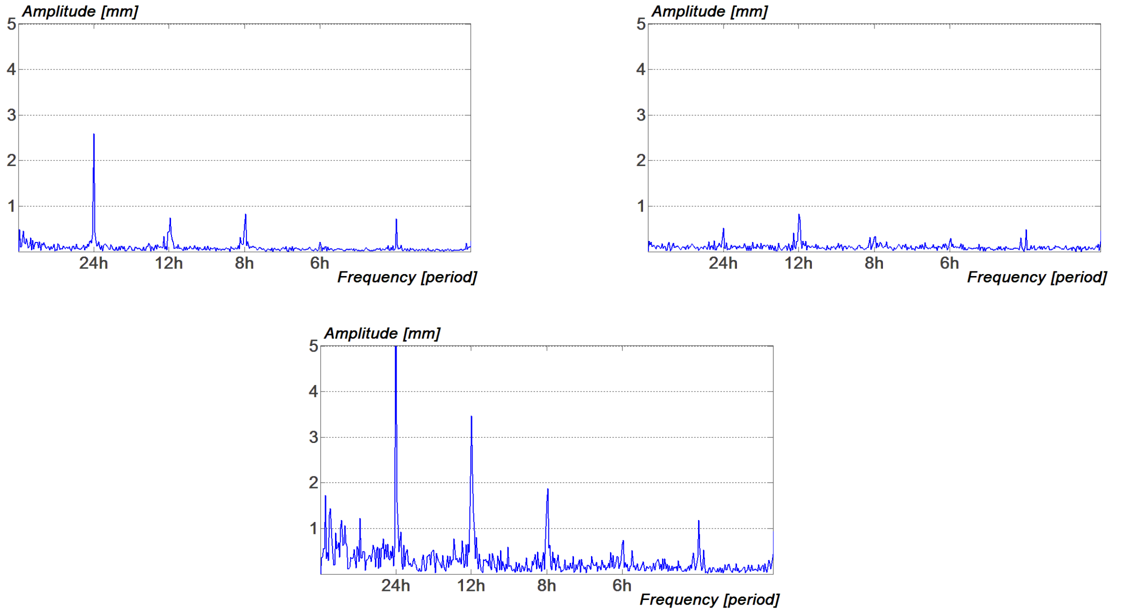


Fig. 7 Spectra of the coordinates of LEGN (Legnica, Poland) station (North, East and Up [mm] from upper left) with dominant diurnal oscillations.

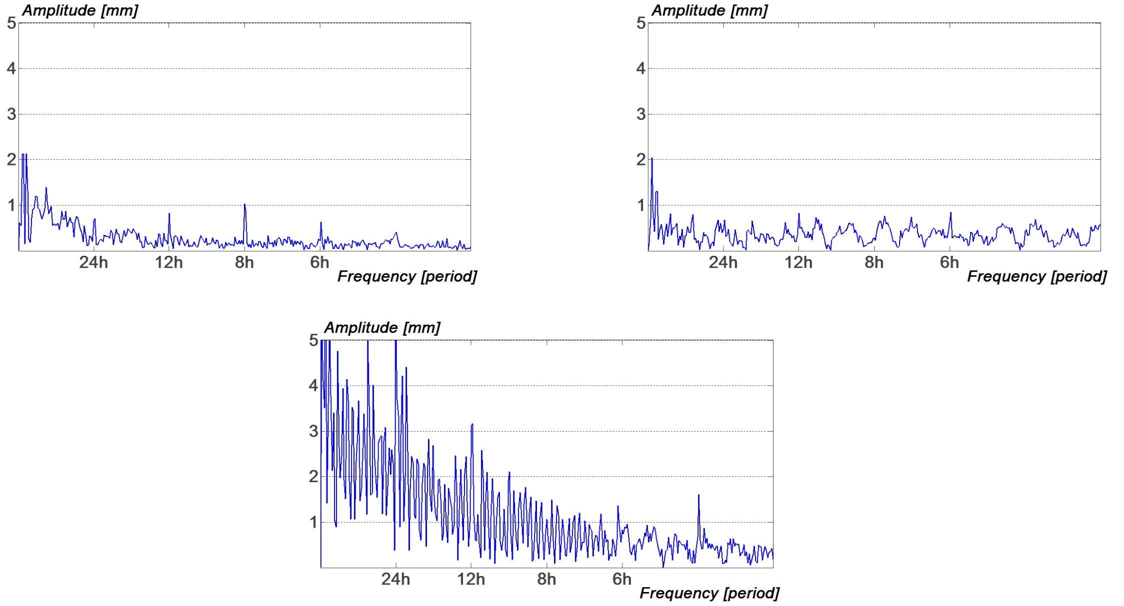


Fig. 8 Spectra of the coordinates of KUZA (Zilina, Slovakia) station (North, East and Up [mm] from upper left) – noisy station.

SUMMARY

1. This research confirmed that using this method of GNSS data processing we are able to obtain reliable information for many further short-time analyses. It was proved by the consistency with daily solutions, but also relatively high consistency of analysed time series was also obtained. The variety of received results excludes systematic errors, which could be introduced by the applied method.
2. Even 4-hour oscillations are clearly seen, so the 3-hour window used in the processing seems to be correct. But the interpretation should be made very carefully because of the 6-hour Nyquist frequency clearly seen in our spectra.
3. Many outliers in East component were obtained. Better ionospheric (scintillations, fluctuations of TEC, moving ionosphere perturbations TID) and tropospheric (4D model of water vapour distribution) models should be implemented.

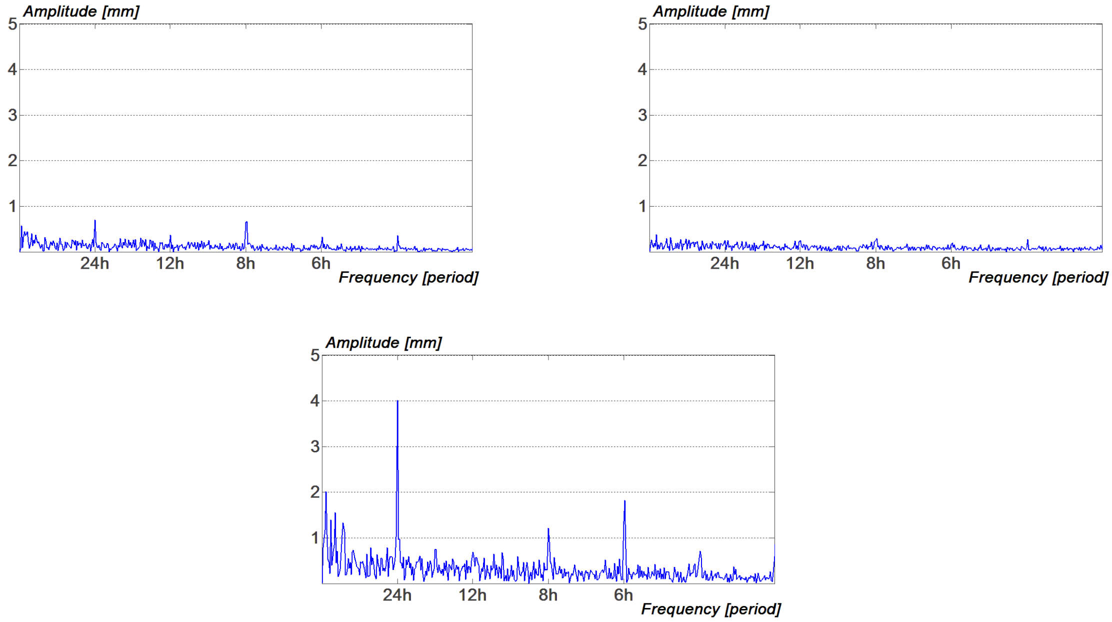


Fig. 9 Spectra of the coordinates of JLGR (Jelenia Góra, Poland) station (North, East and Up [mm] from upper left) with almost no oscillations.

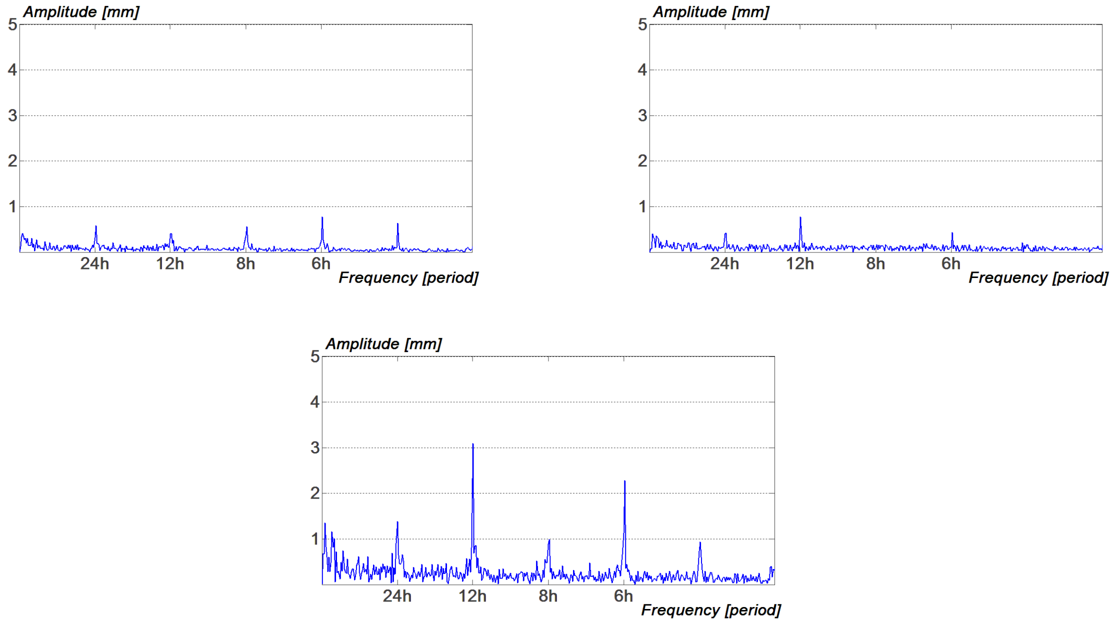


Fig. 10 Spectra of the coordinates of KRAW (Kraków, Poland) station (North, East and Up [mm] from upper left) with dominant 12-hour oscillation.

4. Almost no stations with the same frequency behaviour in all three coordinates were found – lack of visible regularities. It is necessary to distinguish between pure dynamic effects and others (e.g. thermal effects) for proper interpretation.
5. According to these results the verification of the existing models (e.g. IERS tidal model used in the GPS data processing) could be possible.

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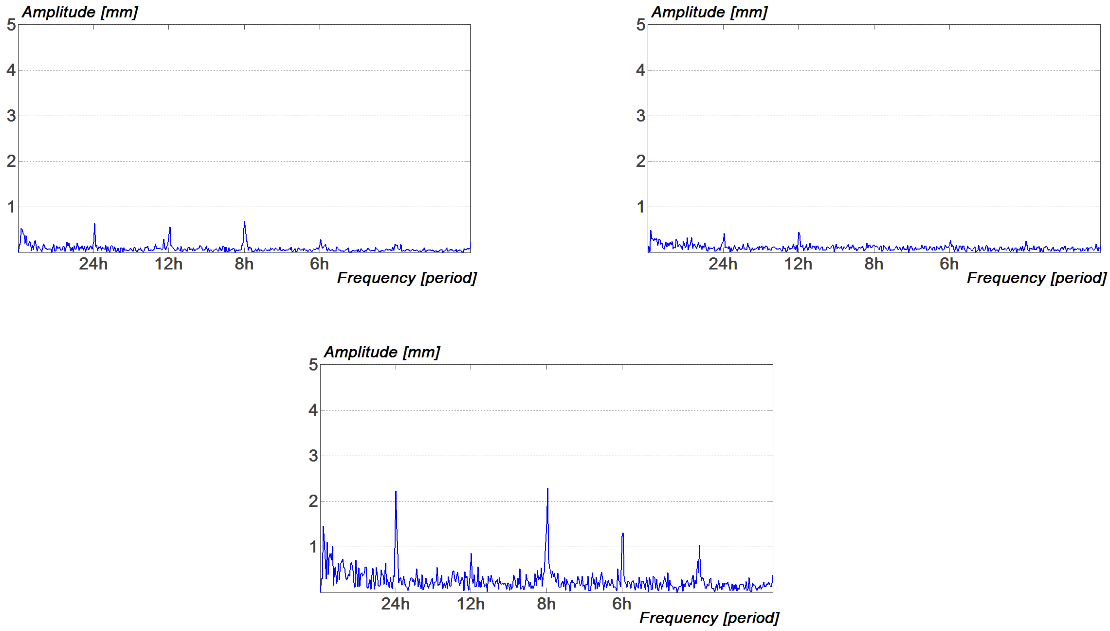

Fig. 11 Spectra of the coordinates of PROS (Proszowice, Poland) station (North, East and Up [mm] from upper left) with dominant 8-hour oscillation.

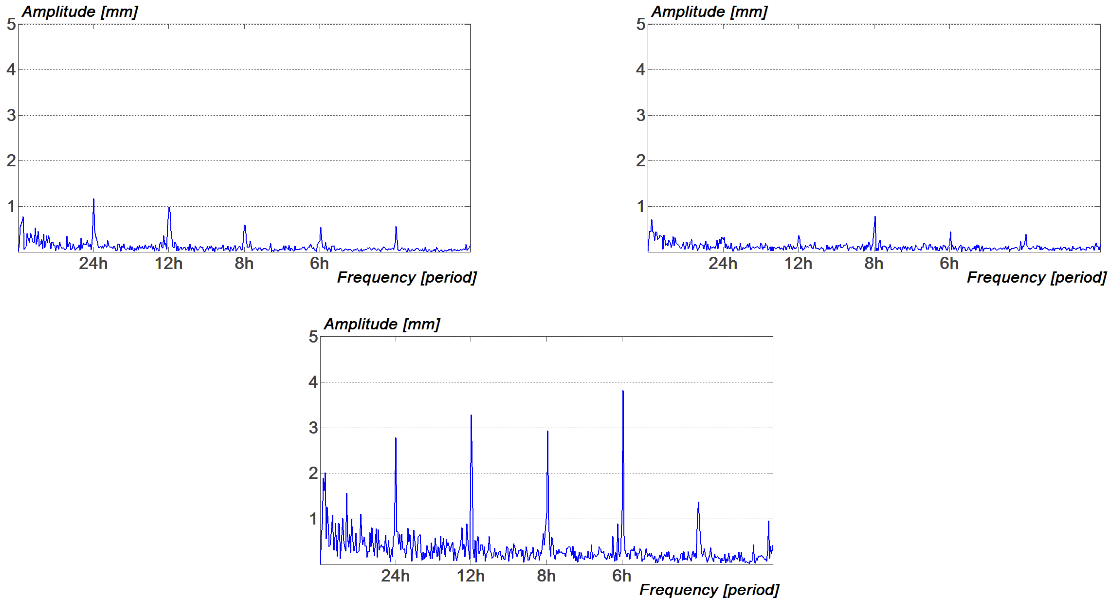

Fig. 12 Spectra of the coordinates of KROS (Krosno, Poland) station (North, East and Up [mm] from upper left) with no dominant oscillation.

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