Monitoring crustal deformations in Carpathian fold system

Sofiya Doskich[1], Oksana Moviaka[2], Vladyslav Semenchuk[3]

1, 2. Geodesy and Astronomy Department, Lviv Polytechnic National University, UKRAINE, Lviv, Karpinskyi street 6, E-mail: sofia7730@gmail.com

3. Engineering Geodesy Department, Lviv Polytechnic National University, UKRAINE, Lviv Karpinskyi street 6, E-mail: vsemenchyk@gmail.com

The main territory of Ukraine is located on stable Eastern European platform but some parts are also in the Mediterranean zone: Carpathian fold system and Folded-brylova Building Mountain Crimea. These tectonic structures are characterized by seismicity. Monitoring such seismic active regions is great interest for geodynamic study. Nowadays, monitoring of these regions is more available with development and distribution of GNSS technology. The Department of Geodesy and Astronomy of Lviv Polytechnic National University operate several reference GNSS stations in Carpathian region. These stations are used for engineering purpose but they also have a strong potential for the monitoring of regional and local crustal deformation. This research intends to quantify crustal deformation trend in Carpathian fold system using GNSS technique observations starting from 2013 to 2016. GNSS measurements are processed by Gamit-Globk software. Absolute rates of reference stations have been estimated (22 mm/yr). Horizontal rates show a clear trend – a dextral character. Movement components are in the direction of northern east.

Keywords – GNSS, reference network, crustal deformation, GAMIT-GLOBK software, tectonic structures, Carpathian fold system.

I. Introduction

Nowadays there has been a continued and growing interest using GNSS for monitoring crustal deformation. Many experts around the world [1, 3, 4, 5, 6] are trying to detect the natural disasters event in advance by using GNSS technique. So regional and local networks of GNSS reference stations are elements of a great interest to the study of regional crustal deformations and seismic activity. The Department of Geodesy and Astronomy of Lviv Polytechnic National University operate several (~30) local reference GNSS stations in Southeast part of Ukraine. Until now, these stations have been mostly used for engineering purpose but they also have a strong potential for the monitoring of regional and local crustal deformation. This is important because this part of Ukraine has the seismically active tectonic structure – Carpathian fold system.

II. Carpathian fold system

Carpathian fold system is an arcuate tectonic zone included in the megastructural elevation of the Carpathians on the external periphery of the mountain chain. The Carpathians are divided into three parts: the Western Carpathians and the Southern Carpathians, both of which consist of three bands, and the Eastern Carpathians, which are only 100-120 km in width and consist only of the flysch and volcanic bands. The Eastern Carpathians are known as the Forested or Ukrainian Carpathians. The Ukrainian Carpathians lie on the border of the East European Platform and the Mediterranean Geosynclinal Province. The Carpathian fold system was formed during the Alpine orogeny in the Tertiary period. Carpathian fold system consists of four longitudinal structural zones, which extend from the northwest to the southeast: (1) the outer or overthrust fold zone, 40 km wide, built of Cretaceous and Paleogene flysch; (2) the central synclinal zone, 30–40 km wide; (3) the core of the inner anticlinal zone; (4) a zone of volcanic deposits—trachytes, andesites, rhyolites, and tuffs—separated from the rest of the Carpathians by the Inner Carpathian Valley and the Maramureş Basin, which are covered by horizontal layers from the Miocene period [7].

III. Data and processing

We use data from different GNSS stations of Ukraine. Additionally, we also use data from several stations of the neighbors GNSS networks such as ASG-EUPOS (Poland), ROMPOS (Romania), MOLDPOS (Moldavia), SKPOS (Slovakia) (fig. 1). We considered data available between 2013 and 2016 years.

Fig. 1. Reference GNSS stations

Observation data files are downloaded automatically on a daily basis via ftp-server in Department of Geodesy and Astronomy of Lviv Polytechnic National University. Then GNSS data were processed using the Gamit-Globk software [2] developed by MIT. Using Gamit-Globk the input files were imported the main analysis by software package – Gamit. This program inverted the (constrained) correlation or covariance matrix to the unconstrained normal equation. Reference frame were realized by the EPN/IGS stations from Poland (BYDG, JOZ2, LAMA, USDL), Austria (GRAZ), Moldova (IGEO), Italy (MATE), Russian (MDVJ, ZECK), Germany (POTS, WTZR), Latvia (RIGA), Bulgaria (SOFI), Lithuania (VLNS) and Ukraine(CNIV, GLSV, MIKL, POLV, SULP, UZHL). Seven components of Helmert translation

related to ITRF08 were estimated by minimum constraint method. Following such a strategy allowed to eliminate the errors in network's geometry trigged by some errors in stations.

Final processing of GNSS data from reference stations in the Carpathian fold system gives the station velocities in their north (N), east (E) and altitude (H) components. Annual stations movement velocities are determined from station time series, in units of mm/yr. Final processing of GNSS data from reference stations in the Carpathian fold system gives the station velocities in their north (N), east (E) and altitude (H) components. Annual stations movement velocities are determined from station time series, in units of mm/yr. Statistical analysis which is represented in table 1

TABLE 1

STATISTICAL RESULT OF THE STATIONS VELOCITIES

	Carpathian fold system		
mm/yr	VE	VN	VH
max	23.1	14.6	2.8
mean	22.0	13.8	0.3
St. dev	0.6	0.7	1.7

The analysis of detected movements in the Carpathian region was directed toward an evaluation of movement velocities of structures in the region. The size and direction of the horizontal component of the relative site velocities, determined from measurements on all GNSS stations, are given in Figure 2.

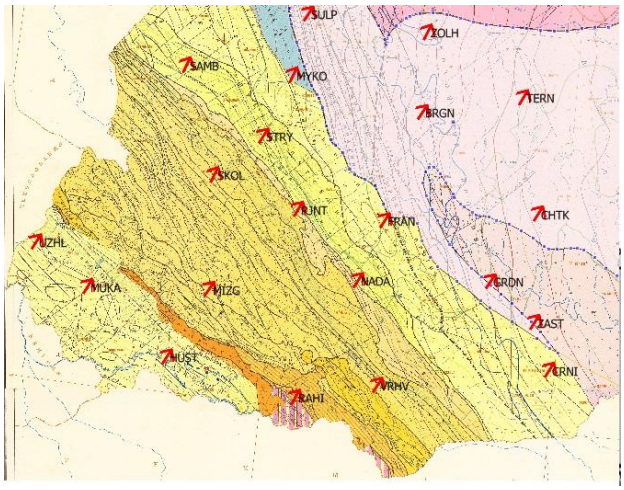

Fig. 2. Geodynamic interpretation of GNSS data of the reference stations located in Carpathian region

The movement components of all stations display a dextral character. Movement components in the direction of northern east. The analysis of the movement trends completed for Carpathian region displayed points toward the importance of geodynamic studies on the local scale. Subsequently, their mutual consecutive linkage will allow the creation of a regional geodynamic model of Carpathian fold system to be compiled.

Conclusion

We draw the following conclusions from our analysis of continuous GNSS data from stations in Carpathian region, spanning between 4 years:

1. Horizontal rates show a clear trend – a dextral character. Movement components are in the direction of northern east. Absolute rates are about 22 mm/yr.
2. According to the results of satellite observations, we can not confidently detect the dependence of the obtained velocities on regional geotectonic.

References

[1] Chen, Y., Ding, X., Huang, D. and Zhu, J.: 2000, A Multi-antenna GPS System for Local Area Deformation Monitoring. Earth Planets Space, 52, 873-876.

[2] Herring, T.A., King, R. W., Floyd, M. A., McClusky, S. C.: 2016, Introduction to GAMIT/GLOBK – Release 10.6. Department of Earth, Atmospheric, and Planetary Science MIT, USA, 44p.

[3] Kaloop, M.R. and Li, H.: 2009, Tower bridge movement analysis with GPS and accelerometer techniques: Case study yonghe tower bridge. Inform. Technol. J., 8: 1213-1220.

[4] Kutoglu, H. S.: 2010. Datum Issue in Deformation Monitoring using GPS. Proceedings of FIG Congress 2010 on Deformation Measurement using GNSS Commission: 5 and 6, Sydney, Australia, April 11-16.

[5] Lim, M. C., Setan, H., Othman, R.: 2010, GPS deformation monitoring and analysis for local cors network: Iskandarnet. Geoinformation Science Journal, Vol. 10, No. 2, pp: 1-14

[6] Rutledge, D., Gnipp, J. and Kramer, J.: 2001. Advances in Real-Time GPS Deformation Monitoring for Landslides, Volcanoes and Structures. Proceedings of 10th International (FIG) Symposium on Deformation Measurements, Orange, CA, 110-121.

[7] http://www.encyclopediaofukraine.com/display.asp?linkpath=pages%5CC%5CA%5CCarpathianMountains.htm