CONTEMPORARY CRUSTAL MOVEMENTS FROM GPS AND TRIANGULATION DATA

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Abstract. The article discussed a method for joint processing of GPS and classical triangulation measurements to estimate the crustal movements in Central Western Bulgaria region. It was examined the possibility of combining GPS with angular measurements of the first class triangulation network in Bulgaria during the period 1923 - 1930 year. As a result of the processing of GPS and angular measurements are derived horizontal velocities of 15 points. The obtained results indicate the possibility of using the angular measurement of first class triangulation points, together with the GPS, to obtain estimates of the horizontal crustal movements.

Key words: GPS, geodynamics, crustal movements

Introduction

GPS technology is widely used in geosciences. Static GPS measurements are used to determine the crustal movements. Dynamic navigation and GPS definitions are used in geophysics, satellite altimetry, the determination of orbits, physical oceanography, the study of the atmosphere and precise navigation. GPS measurements allow the study of modern tectonics because they provide quantitative assessments of crustal movements in the studied areas. The GPS data provide a good opportunity to study the current geodynamic processes, but the question remains how far back in time can be results interpolated. Combining old triangulation measurements from the twenties of the last century with the GPS measurements made during the last decade can answer this question (Dimitrov, 2011).

In this article a method is discussed for obtaining estimates of the contemporary movement of the crust by processing classical GPS measurements and in the region of central west Bulgaria. This area is of particular interest because of the high population density and high concentration of industrial resources. The results can be used to locate a modern active faults and fault structures.

Processing method

Method of treatment consists in determining the three-dimensional velocity vector at each node of a predefined grid of two-dimensional rectangular region containing measurement data. Having identified the three dimensional velocities of nodes of the grid, the values of the velocity of any point within the region can be adequately approximated by interpolation (Drew and Snay, 1989). Deformations of the corners of the rectangular grid are determined by bilinear function using information from measurements of the geodetic points.

Let P(n,t), L(n,t) and h(n,t) is respectively geodetic latitude, longitude and ellipsoidal height at the moment - t. It is assumed that for a predetermined moment to, there are velocities of the points for which:

$$P(n,t) = P(n,t_0) + u(L(n,t), P(n,t))(t - t_0) \tag{1}$$

$$L(n,t) = L(n,t_0) + v(L(n,t), P(n,t))(t - t_0) \tag{2}$$

$$h(n,t) = h(n,t_0) + w(L(n,t), P(n,t))(t - t_0) \tag{3}$$

Also it is assumed that in a two-dimensional rectangular region it is known three dimensional velocities of the points of vertices of the area, then the velocities at each point in the grid can be calculated by bilinear function.

$$u(L(n,t), P(n,t)) = [u(L_i, P_j)BD + u(L_{i+1}, P_j)AD + u(L_i, P_{j+1})BC +$$

$$+u(L_{i+1}, P_{j+1})AC]/[(A+B)(C+D)] \tag{4}$$

with:

$$A = L(n,t_0) - L_i \qquad B = L_{i+1} - L(n,t_0) \tag{5}$$

$$C = P(n,t_0) - P_j \qquad D = P_{j+1} - P(n,t_0) \tag{6}$$

Similar equations can be written for speeds - v(L,P) and w(L,P).

Data

GPS measurements of eight points in the region of central western Bulgaria conducted by specialists from the Central Laboratory of Geodesy (CLG) in several periods between 1997 and 2006 is used in estimation. Points of the network are stabilized with metal bolts in typical rocks after geological field study Additional GPS measurements were carried out of seven points of the first class Bulgarian triangulation network. Also it is included angular measurements triangulation network conducted during 1926 1930. (Tabl. 1).

Joint processing of GPS and angular measurements from first class Bulgarian triangulation network has been done with the software Dynapg (DYNamic Adjustment Program using a Grid).

GPS ID	epoch 1997	2000	2003	2005	2006
BREZ	X	X			
BUHO	X	X			
LOZE	X	X			
SLIV	X	X			
VERI	X	X			
VLAD	X	X			
PLA1	X	X			
0081			X		
0082			X		
0083			X		
0011			X		
0012			X		
0016			X		
0017			X		
0026			X	X	X

Table 1. GPS campaign

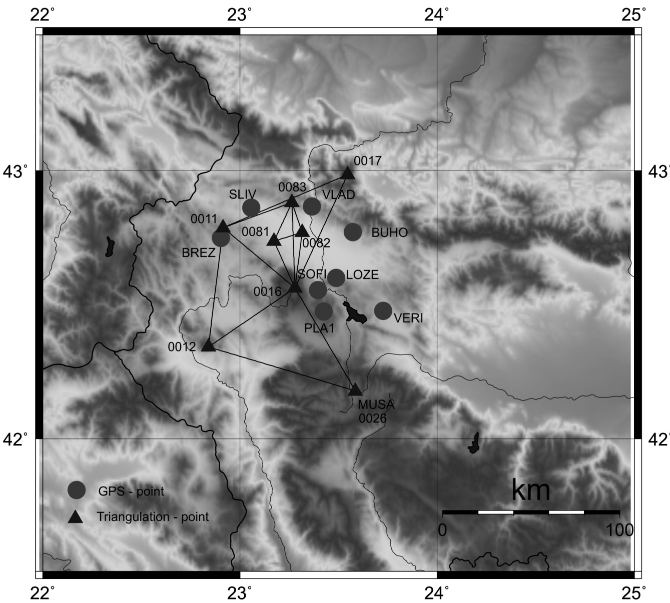

Fig. 1. Network sketch

DYNAPG (Snay, 1996) is a software for estimation of the velocities field of points associated with the movement of the Earth's crust. The program processes the different types of measurements: horizontal directions, distances, azimuths, zenith distance, and vectors derived from measurements with the global positioning system (GPS), and also with very long baseline interferometry (VLBI).

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Dynapg was developed by modifying software Dynap (Drew and Snay, 1989), which in turn is a modification of the software Adjust (Milbert and Kass, 1987). While Ajust assumed that the coordinates of the points remain fixed in time, it Dynapg can calculate both the coordinates of the points, and the parameters characterizing the movements in the earth's crust.

Dynapg uses format NGS – bbook. There are three input files :

Afile – choice of different options and the adjustment data.

Bfile – contains horizontal directions, angles, distances, azimuths and information about the approximate coordinates of the measured points.

Gfile – contains information about the GPS measurements and related information.

Result interpretations

In processing are included measurements of five permanent network stations from IGS with the coordinates and velocities in the coordinate system ITRF2000. As a result were obtained velocities of the points (Tabl. 2). After transformation is obtained velocities of points in a coordinate system ETRF2000 (Tabl. 3).

ST	VN	m	VE	m
	мм/г	мм	мм/г	мм
81	10.4	0.4	24.5	0.4
82	10.2	0.4	24.6	0.4
83	10.0	0.4	25.1	0.4
17	10.5	0.4	24.7	0.4
12	11.5	0.4	23.1	0.4
11	10.5	0.4	24.7	0.4
26	11.3	0.5	22.1	0.5
16	11.5	0.4	23.1	0.4
VERI	10.5	0.4	23.3	0.4
PLA1	10.7	0.4	23.4	0.4
BUHO	9.9	0.5	24.6	0.5
LOZE	10.4	0.4	23.9	0.4
VLAD	9.9	0.5	24.9	0.5
BREZ	10.6	0.4	24.6	0.4
SLIV	10.2	0.5	25.0	0.5

Table 2. Velocities of points from the GPS and triangulation measurements in coord. system ITRF2000

ST	VNE	m	VEE	m
	мм/г	мм	мм/г	мм
81	-2.6	0.4	0.9	0.4
82	-2.7	0.4	1.0	0.4
83	-2.9	0.4	1.4	0.4
17	-3.3	0.4	1.8	0.4
12	-1.6	0.4	-0.7	0.4
11	-2.5	0.4	1.1	0.4
26	-1.6	0.5	-1.8	0.5
16	-2.3	0.4	0.1	0.4
VERI	-2.3	0.4	-0.5	0.4
PLA1	-2.2	0.4	-0.4	0.4
BUHO	-2.9	0.5	0.9	0.5
LOZE	-2.5	0.4	0.2	0.4
VLAD	-2.9	0.5	1.3	0.5
BREZ	-2.4	0.4	1.1	0.4
SLIV	-2.8	0.5	1.5	0.5

Table 3. Velocities of points from the GPS and triangulation measurements in coord. system ETRF2000

Conclusion

It is performed a joint processing of GPS measurements at 15 points in the period 1997-2006 and angular measurements of seven triangulation points in the period 1926 1930. Obtained horizontal velocities of the points in the region agree well with the field of horizontal velocities in Bulgaria and Eastern Mediterranean (Georgiev, 2010). The general movement of the points in the region of Central Western Bulgaria is in the south, which is consistent with extensional movement of southern Bulgaria and northern Greece – South-Balkan extensional area (Burchfiel et al. 2000).

The results of the joint processing of conventional and GPS measurements show the possibility to define crustal movements in areas with relatively weak deformation, also indicate activity in the area and help to clarify the tectonic setting.

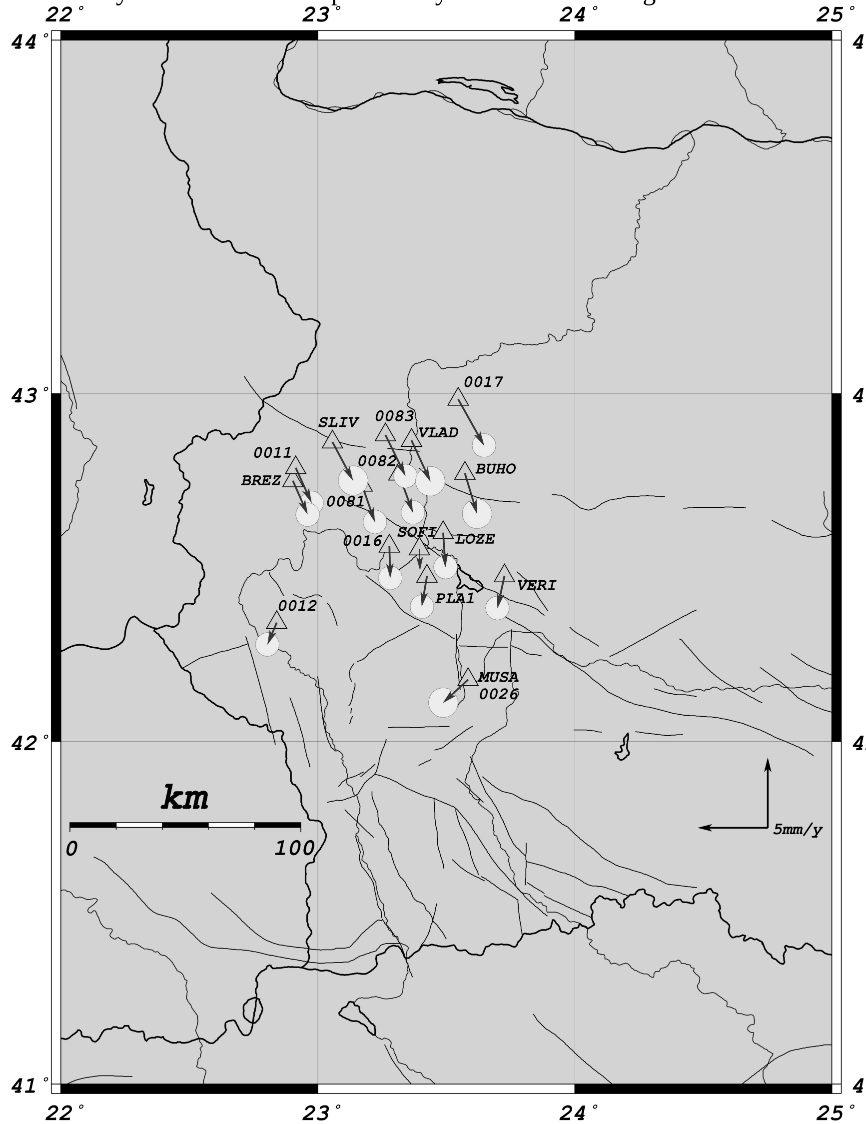

Fig.2. Velocities of points obtained from the analysis of GPS and triangulation measurements to stable Eurasia.

References

Burchfiel, B. C., R. Nakov, T. Tzankov, L. H. Royden, 2000. Cenozoic Extension in Bulgaria and Northern Greece: the northern part of the Aegean Extensional Regime.- In Tectonics and

Magmatism in Turkey and the Surrounding Area (E. Bozkurt, J.A. Winchester and J. D. A Piper, eds.), Geol. Soc., Sp. Publ. 173, 325-352.

Dimitrov, N., 2011. Study of contemporary crustal movements from GPS and classical geodetic measurements in the region of central western Bulgaria. Abstract for acquiring PhD degree, 49str., 14fig.

Drew, A.R. and R.A. Snay, 1989. DYNAP: software for estimating crustal deformation from geodetic data, Tectonophysics, 162, 331-343.

Georgiev, I., 2010. State and permanent GPS networks of Bulgaria - Processing of measurement, analysis and application in geodynamics. Abstract for obtaining the degree "Doctor of Science" 88str., 30 fig.

Milbert, D.G., and Kass, W.G., 1987. ADJUST: The Horizontal Observation Adjustment Program. NOAA Technical Memorandum NOS NGS-47, National Geodetic Information Branch, NOAA, Silver Spring,MD 20910, 53pp.

Snay, R.A., 1996. Documentation for Dynapg Software. NOAA/National Geodetic Survey.

Съвременни движения на земната кора от GPS и триангулачи данни

Н. Димитров

Резюме. В статията е разгледан един начин за съвместна обработка на GPS и класически триангулачни измервания за определяне на съвременните движения на земната кора в района на Централна западна България. Изследвана е възможноста за комбиниране на GPS с ъглови измервания на точки от първокласната триангулачна мрежа на България извършени през перида 1923 – 1930 година. Като резултат от съвместната обработка на GPS и ъгловите измервания са получени хоризонталните скоростите на 15 точки. Получените разултати показват възможността за използване на ъглови измервания на първокласни триангулачни точки, съвместно с GPS, за получаване на оценки на съвременните хоризонтални движения на земната кора.