CERGOP-2 PROJECT ACTIVITIES OF BULGARIA

G. Milev[1], K. Vassileva[2], M. Becker [3]

[1]Institut of Water Problems, Bulgarian Academy of Sciences
[2]Central Laboratory of Geodesy, Bulgarian Academy of Sciences
[3] Darmstadt University of Technology, Germany

ABSTRACT

This paper summarizes the recent works with respect to the CERGOP-2 project tasks. The main activity was the implementation of the Working Package "Geodynamics of Balkan Peninsula". Major efforts were taken to the maintenance of the operation of two permanent GPS stations in Bulgaria and to arrange for the data transmission to the CERGOP Data Centre in Graz. The CEGRN GPS campaigns of 2003 and 2005 were analyzed together with additional Balkan Peninsula stations. New results on coordinates and velocities for this Balkan Peninsula subnet of CEGRN are computed and will be presented and discussed. The accomplished works on the monograph "Geodynamics of Balkan Peninsula" with the preparation of the manuscripts and the main content of the findings will be outlined.

1. GENERAL

The geodynamical investigations are going to their final and very important stage of the project. Results obtained from the study on the project after the conference in Sarajevo 11-12.11.2005 are shown here. Contributions are related to the project as a whole and mainly to the Working Package 10.7 –"Geodynamics of Balkan Peninsula". Information about the operation of the Bulgarian CERGOP permanent stations is given. Results from data processing of Balkan Peninsula (BP) 'CEGRN05 campaign and from combined data processing of BP'CEGRN03 and BP'CEGRN05 campaigns, their comparison and analysis are presented. The progress of preparation of the monograph – "Geodynamics of Balkan Peninsula" is outlined.

2. CERGOP-2 PERMANENT STATIONS

Permanent stations in Varna and Rozhen are operating in spite of some problems. Station VARN performs regularly. Station ROZH had serious troubles due to strong rains in August and thunder activity last year as it was reported at the previous CERGOP-2 meeting. By that reason it was necessary to change the Topcon receiver with new one. Afterwards it was found that the antenna did not work as well and it was repaired, and

reinstalled on the mast, on the same position. It took relatively long time in spite of the active efforts on Bulgarian part and assistance of the Topcon Company provided the equipment. Data transfer was switched from phone to Internet at both stations.

3. DATA PROCESSING

3.1. GPS data processing of the Balkan Peninsula CEGRN05 subnetwork

Data processing of the Balkan Peninsula CEGRN05 subnetwork (BP'CEGRN05) was accomplished with the Bernese GPS Software, version 4.2.
The number of Balkans stations participating in CEGRN05 GPS campaign amounts to 35 (Fig. 1). Unfortunately some of the stations (UPAT, THES, IGD1) located in the southern Balkans did not participated due to moving of the station to another place or data gaps during the time of the campaign.

Fig. 1. Stations of Balkan Peninsula CEGRN05 subnetwork

The following standard computation procedure was applied:

- **Using precise orbits from IGS final orbit computation in system IGS2000;**
- **Using coordinates for the reference sites Wettzel, Zimmerwald, Graz, Matera, Penc, Bucharest, Sofia referred to the reference epoch of the orbits;**
- **Computation of a set of coordinates at the respective measurement epoch in the ITRF2000 reference frame;**
- **24 hours of 30-second interval data were used for the pre-processing and processing;**
- **A minimum elevation angle of 10 degrees was used as a cut-off angle for the processing;**
- **Application of antenna elevation-dependent phase centre offsets and variations because of different types of antenna are combined (NGS relative values used);**
- **Ambiguities were fixed (QIF ambiguity resolution);**
- **Global ionosphere model was applied;**
- **Estimation of troposphere parameters for the individual stations every 2 hours for each session using the dry Niell mapping function (estimation of full zenith delay),**
- **Processing of double-difference measurements based on the ionosphere-free carrier phase linear combination L3,**
- **One-day free session solutions (daily solutions) were computed with setting a priori coordinate accuracy of ± 0.0001m for the reference site WTZR;**
- **Computation of free campaign solutions covering all 24 hour sessions of the respective campaign with a priori RMS = ± 0.0001m for the reference site;**

Six independent session solutions have been computed with WTZR as reference site and obtained normal equations have been combined for the final solution of the subnetwork. The estimations of station coordinates have been obtained.

Daily repeatability shows a very good consistence. RMS's of individual coordinate residuals from comparison of session solutions are presented in table 1.

Table 1. RMS of station coordinates from comparison of session solutions

No	Station name	RMS (mm)			No	Station name	RMS (mm)		
		N	E	U			N	E	U
1	WTZR 14201M010	0.0	0.1	0.1	18	VARN	1.8	1.8	0.9
2	GRAZ 11001M002	1.7	1.1	3.3	19	GABR	2.1	1.9	5.2
3	ZIMM 14001M004	4.2	1.2	4.2	20	HARM	2.4	2.4	4.2
4	BUCU 11401M001	1.5	2.0	7.8	21	KAVA	1.0	1.2	7.7
5	MATE 12734M008	1.1	1.1	4.3	22	BLGR	1.0	1.0	2.2
6	PENC 11206M006	1.8	1.0	3.9	23	TIMI	1.3	1.8	5.3
7	SOFI 11101M002	3.1	1.5	5.7	24	VRN1	0.9	1.6	6.4
8	ORID 15601M001	1.7	2.8	6.7	25	BRSK	1.0	1.5	4.2
9	SRJV 11801S001	3.0	2.2	2.9	26	CSAR	1.0	1.4	2.3
10	DUBR 11901M001	1.7	2.1	6.1	27	HVAR	1.2	2.4	4.7
11	AUT1 12619M002	3.0	3.2	8.6	28	FUN3	0.9	2.2	7.3
12	ANKR 20805M002	1.9	3.6	11.6	29	LJUB	1.0	2.1	4.0
13	ISTA 20807M001	1.4	2.8	11.2	30	TIS3	2.6	2.3	3.1
14	TUBI 20806M001	1.8	2.6	8.2	31	MALJ	2.4	3.4	4.1
15	TUC2 12617M003	3.7	3.0	4.6	32	UPAT	3.8	2.6	4.5
16	BRAI	2.0	2.7	5.9	33	SUBO	1.9	1.1	7.2
17	ROZH	1.1	1.2	1.4	34	A015	1.4	1.7	3.2
					35	A027	1.1	1.0	4.3

3.2. Combined processing of CEGRN03 and CEGRN05 Balkan Peninsula subnetworks

Normal equations from processing of BP'CEGRN03 [Milev et al., 2004] and BP'CEGRN05 campaigns have been combined (BP'CEGRN03 - BP'CEGRN05) using Addneq program of the Bernese software, version 4.2. The ITRF2000 station coordinate and station velocity estimations for the mean epoch have been obtained. They are referred to the ITRF2000 coordinates and velocities of six IGS permanent stations - WTZR, ZIMM, GRAZ, MATE, SOFI and PENC. Similar comparison is accomplished for BP'CEGRN97, BP'CEGRN03 and BP'CEGRN05 and the results are presented in other contribution.

For analysis of the results seven parameter Helmert transformations have been done. Residuals for station Brusnik show very high values especially in Up component. This station shows the same behaviour as it was presented in [Milev et al., 2005a]. Except this station, which have been marked stations PENC, FUN3, LJUB and TIS3 still remain with high values in Up component for 2003. Residuals from comparison with coordinates in 2005 show high values in Up component for stations GRAZ, FUN3 and TIS3. The results from respective comparisons after marking of the bad stations have been improved (table 2).

Table 2. Residuals from Helmert transformations between sets of estimated coordinates from combined BP'CEGRN03 - BP'CEGRN05 solution and individual campaign solutions with suspected bad stations marked

No	Station Name	Residuals (mm)							
		BP'CEGRN03-BP'CEGRN05 / BP'CEGRN03				BP'CEGRN03-BP'CEGRN05 / BP'CEGRN05			
		N	E	U		N	E	U	
1	BUCU 11401M001	0.8	-1.9	0.3		-0.4	1.3	-4.6	
2	GRAZ 11001M002	-0.2	3.6	-10.1		6.1	0.7	-16.8	M
3	MATE 12734M008	5.2	2.5	-5.2		-1.6	-1.2	-2.7	
4	PENC 11206M006	-2.1	-0.3	17.5	M	-3.9	3.6	1.8	
5	SOFI 11100M002	-3.5	0.3	5.2		-3.1	0.8	2.9	
6	WTZR 14201M010	-0.2	-2.4	-2.9		1.7	2.5	-4.8	
7	ZIMM 14001M004	-0.8	-5.2	3.9		2.7	-0.7	1.7	
8	ISTA 20807M001	1.8	0.6	-0.1		-0.7	-1.2	5.6	
9	TUBI 20806M001	3.3	-2.3	2.3		-2.4	2.1	7.2	
10	SRJV 11801S001	1.1	0.6	2.1		-0.9	0.3	2.9	
11	ORID 15601M001	-1.2	2.4	0.8		2.1	-1.2	-4.9	
12	BRAI	-3.7	-1.4	4.7		3.9	0.3	-8.2	
13	KAVA	-1.4	-2.8	-6.3		2.3	1.7	4.5	
14	BLGR	-0.3	-2.3	-2.8		-0.5	2.8	1.5	
15	TIMI	-4.6	-0.7	-0.2		4.0	1.0	-4.4	
16	VRN1	2.6	-2.8	-22.8	M	-3.0	1.3	7.7	M
17	BRSK	15.0	-40.5	461.5	M	-14.2	35.2	-435.5	M
18	CSAR	-0.8	-0.8	4.8		1.0	1.4	-0.8	
19	HVAR	5.9	0.9	-6.1		-5.7	1.2	-11.9	
20	FUN3	5.8	-5.9	-42.0	M	-6.2	4.7	21.2	M
21	GABR	-1.6	4.2	-0.9		2.1	-4.5	-0.5	
22	HARM	-2.9	5.7	3.2		3.9	-6.2	-3.7	
23	LJUB	0.6	5.5	-18.3	M	-1.4	-3.9	8.6	
24	TIS3	-2.6	-0.4	-48.9	M	2.3	0.2	22.7	M
25	MALJ	2.8	-1.1	11.8		-3.0	0.0	9.7	
	RMS/Component	2.9	2.7	5.4		2.8	2.5	5.7	
	RMS of transformation	4.0				4.1			

The results from the comparison confirm the above speculation that the outlier for station BRSK occurred in 2003 [Milev et al., 2005a]. The problem with GRAZ station occurred most probably in 2005.

NNR-NUVEL1A station velocities have been also calculated and compared with the estimated GPS velocities and estimated EPN velocities (table 3).

Table 3. Estimated ITRF2000 station velocities from different combined solutions, calculated NNR-NUVEL1A velocities and EPN velocities

No	Station name	V_X (mm/y)			V_Y (mm/y)			V_Z (mm/y)		
		03-05	Nuvel	EPN	03-05	Nuvel	EPN	03-05	Nuvel	EPN
1	BRSK	-19.2	-14.6		9.1	18.0		16.2	9.1	
2	CSAR	-15.7	-15.3		18.6	17.8		8.7	8.7	
3	HVAR	-19.2	-14.5		17.4	18.3		14.3	9.4	
4	PENC	-16.6	-15.7		18.1	17.4		8.2	8.3	
5	11206M006	-17.6	-14.8		18.2	17.8		8.2	8.9	
6	GRAZ	-18.0	-14.4		22.0	18.0		11.5	9.2	
7	11001M002	-18.8	-14.3		19.1	18.7		13.1	9.7	
8	LJUB	-16.3	-16.3		21.4	17.5		6.5	8.2	
9	MATE	-16.5	-16.2		18.7	17.8		7.3	8.5	
10	12734M008	-17.0	-16.7		26.8	17.6		4.1	8.2	
11	TIS3	-20.5	-17.2		19.4	17.0		9.4	7.6	
12	SOFI	-15.7	-14.4		17.2	17.6		8.7	8.8	
13	11101M002	-13.8	-12.9		18.4	18.2		10.0	9.8	
14	HARM	-16.1	-15.7		17.3	17.8		9.1	8.6	
15	VRN1	-14.4	-16.0		20.1	17.6		5.9	8.4	
16	WTZR	-15.8	-17.4		21.2	16.9		4.0	7.4	
17	14201M010	-17.7	-17.0	-17.1	19.2	17.3	18.1	7.6	7.8	8.1
18	ZIMM	-16.0	-17.4		20.6	17.2		4.6	7.6	
19	14001M004	-21.1	-16.8		15.9	17.2		12.1	7.8	
20	BLGR	-17.7	-16.6		25.1	17.6		5.6	8.2	
21	TIMI	-17.5	-14.2		17.6	18.2		12.6	9.4	
22	BRAI	-16.8	-15.1	-18.6	19.2	18.1	18.6	10.2	9.0	9.4
23	BUCU	-17.9	-17.4	-18.8	19.3	17.3	17.4	7.1	7.7	3.9
24	11401M001	-18.3	-17.3	-17.9	22.3	17.4	20.8	5.9	7.8	6.0
25	KAVA	-15.0	-15.4	-14.8	21.6	18.3	21.0	7.3	9.1	7.9
26	FUN3									
27	GABR									
28	MALJ									
29	SRJV11801S001									
30	TUBI20806M001									
31	ISTA20807M001									
32	ORID15601M001									

Large disagreements between NNR-NUVEL1A and GPS velocities are resulting for the problematic station BRSK (in all components) and for stations – HVAR, LJUB, TIS3, HARM, VRN1, BRAI, KAVA, FUN3, GABR, TUBI and ISTA. Disagreements for Bulgarian stations GABR and HARM with respect to the values obtained in a previous study [Milev et al., 2005a] are also evident.

Comparison between GPS velocity estimations from this study and estimated EPN velocities (table 4) shows a very good agreement (within 0,1-0,9 mm/y) except for station TUBI in Up component - 2.4 mm/y. Graphically GPS, NNR-NUVEL1A velocity vectors and their differences are shown in figure 2.

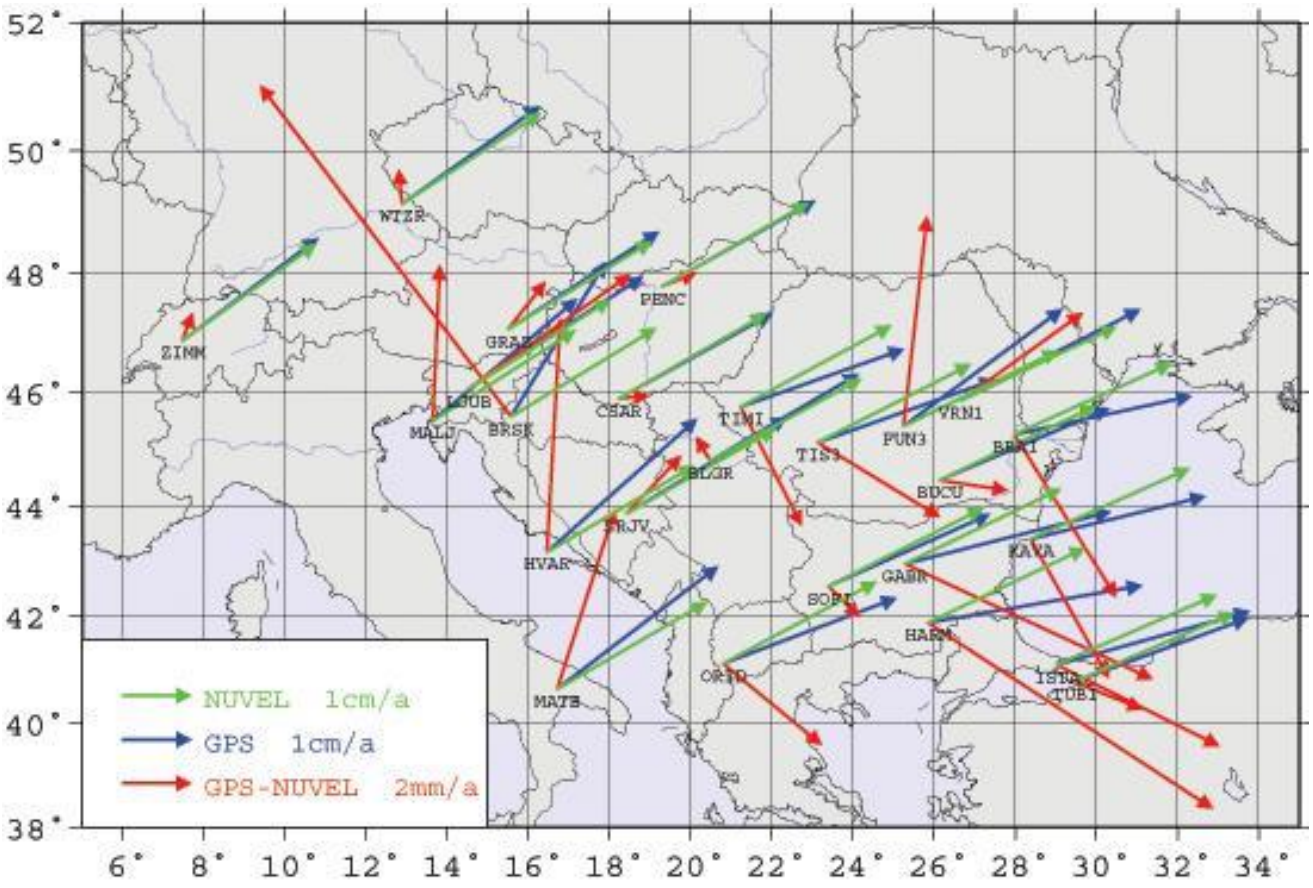

Fig. 2. 03-05'GPS estimated and NNR -NUVEL1A velocity vectors of BP'CEGRN stations

Table 4. Estimated GPS velocities from this study and EPN estimated velocities

STATION VELOCITY ESTIMATIONS						
Station name	**V_X (mm/y)**		**V_Y (mm/y)**		**V_Z (mm/y)**	
	GPS	**EPN**	**GPS**	**EPN**	**GPS**	**EPN**
BUCU 11401M001	-17.7	-17.1	19.2	18.1	7.6	8.1
SRJV 11801S001	-16.8	-18.6	19.2	18.6	10.2	9.4
TUBI 20806M001	-17.9	-18.8	19.3	17.4	7.1	3.9
ISTA 20807M001	-18.3	-17.9	22.3	20.8	5.9	6.0
ORID 15601M001	-15.0	-14.8	21.6	21.0	7.3	7.9

4. PREPARATION OF THE MANUSCRIPTS OF MONOGRAPH "GEODYNAMICS OF BALKAN PENINSULA"

Geodynamics of the Balkan Peninsula is the most active with respect to the other territories, which participate in the project study. It was not considered in previous stages of the project. Organization of the work on the implementation of the activities, investigations and preparation of the individual sections of the monograph is in accordance to the previous presented reports on the project [Milev et al., 2004]. It also concerns the planned monograph contents [Milev et al., 2005b]. Actualization and detail contents are given as attachments here. In fact manuscripts for most of the monograph sections are already received. The rest of them are in process of preparation. It is expected the monograph to be completed in time.

5. CONCLUSION

As a result of the project works accomplished particularly for the territory of the Balkan Peninsula two permanent stations long-term operates. GPS data from CEGRN'97, CEGRN'03 and CEGRN'05 campaigns covered Balkan Peninsula territory have been processed. The analysis, comparison and conclusions confirm the presence of recent crust movements on the territory of the Balkan Peninsula and their character. The results would give additional information for the whole CEGRN network. A following processing and interpretation will outline the geodynamic picture of the Balkan Peninsula. This contribution is a part of the interdisciplinary monograph devoted to the geodynamics of the territory of the Balkans which is in advanced phase of preparation.

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