5.1.2. GPS VELOCITY FIELD OF THE BALKAN PENINSULA

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5.1.2.1. Introduction

An important indicator in geodynamical point of view is an eventual station movement of GPS network stations. That concerns the permanent and epoch GPS stations on the territory of the Balkan Peninsula. Determination of the size and direction of the vectors of movement, their analysis and assessment is of significant importance for their further interpretation with a view to present the geodynamical picture of the region.

The main objective here is a study and analysis of the geodynamical behavior of GPS stations of the CEGRN subnetwork covering Balkan Peninsula (BP'CEGRN). For this purpose data from three GPS CEGRN measurement campaigns which include the Balkan Peninsula stations (permanent and epoch) have been involved. GPS data from CEGRN97, CEGRN03 and CEGRN05 campaigns have been used. A subnetwork of 13 stations from CEGRN97 campaign, a subnetwork of 29 stations from CEGRN03 campaign and a subnetwork of 35 stations from CEGRN05 campaign have been processed (Fig. 5.1.2.1.). Seven IGS sites have been used as reference.

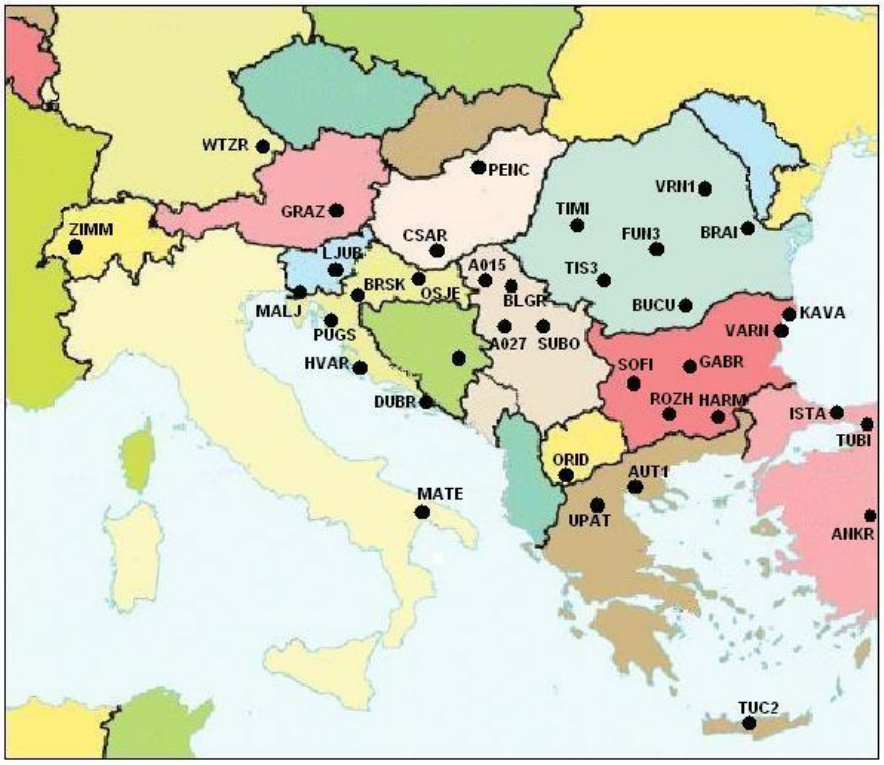

Fig. 5.1.2.1. Balkan Peninsula CEGRN subnetwork stations

The results from data processing of the BP'CEGRN03 campaign (Milev et al., 2004) and BP'CEGRN97 campaign (Milev et al., 2005) are used here. BP'CEGRN05 data have been newly processed for this study (Milev et al., 2006). The ITRF2000 station coordinate and velocity estimations obtained have been compared and analyzed. Station velocity estimations have been compared and analyzed with those ones obtained from NUVEL1A-NNR velocity model and with EPN estimated velocities for the participated EPN stations.

5.1.2.2. Data processing and results

Brief information about processing of GPS data from the participated campaigns is presented in this item.

The standard computation procedure which is applied is the same as it is given in (Milev, Vassileva, Becker, 2006). For obtaining the station velocity estimations the following combined campaign solutions – BP'CEGRN97/BP"CEGRN03, BP'CEGRN97/BP'CEGRN05 and BP'CEGRN03/BP'CEGRN05 have been accomplished.

The main results from processing of the individual campaigns are presented below.

Balkan Peninsula CEGRN97campaign

The number of reference IGS stations for this BP'CEGRN97 campaign was reduced to six as a station BUCU was not in operation at that time. The ITRF2000 coordinates at the epoch of observation 1997.44 for the 13 participated stations have been estimated. For analyzing the accuracy of whole network resulting coordinates from all session solutions have been compared. The values of the standard deviations (in North, East and Up) for each station after comparison of the coordinates are presented in the Fig. 5.1.2.2.

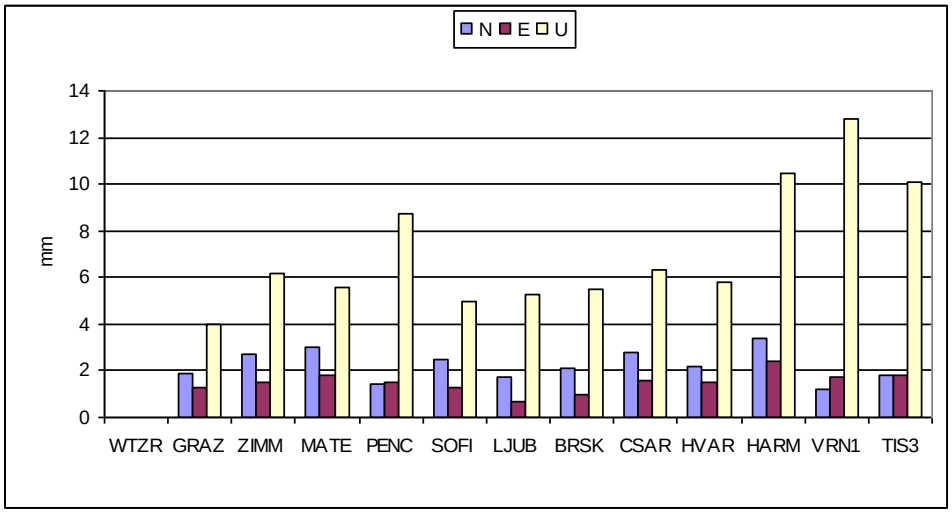

Fig. 5.1.2.2. RMS of comparison of BP'CEGRN97 daily solutions

The results show a good consistence. The maximum deviation of amount 12.8 mm in Up component is for station VRN1.

Balkan Peninsula CEGRN03 campaign

The ITRF2000 coordinates at the epoch of observation 2003.46 for the participated 29 stations have been estimated and presented in (Milev et al., 2005). The main results from comparison of the six session solutions are presented in the Fig. 5.1.2.3.

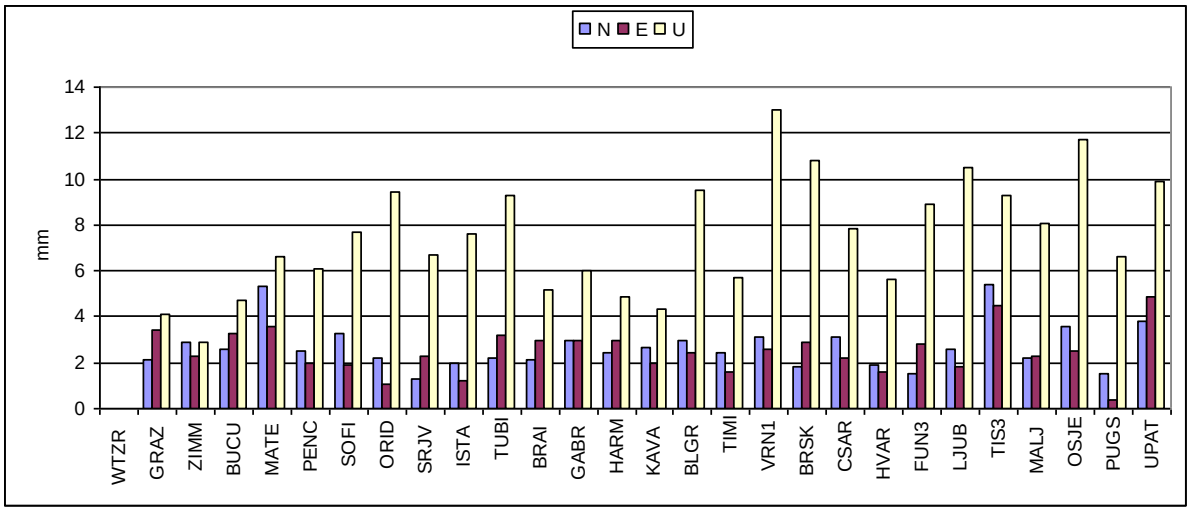

Fig. 5.1.2.3. RMS of comparison of BP'CEGRN03 session solutions

As it is shown the largest deviation of amount 13.0 mm in Up component is again for station VRN1. The rms's in North and East components vary between 1.5 mm and 5.6 mm.

Balkan Peninsula CEGRN05 campaign

The ITRF2000 coordinates at the epoch of observation 2005.47 for the participated 35 stations have been estimated. The results from the comparison of the six session solutions presenting the quality of the network measurements are given in the Fig. 5.1.2.4.

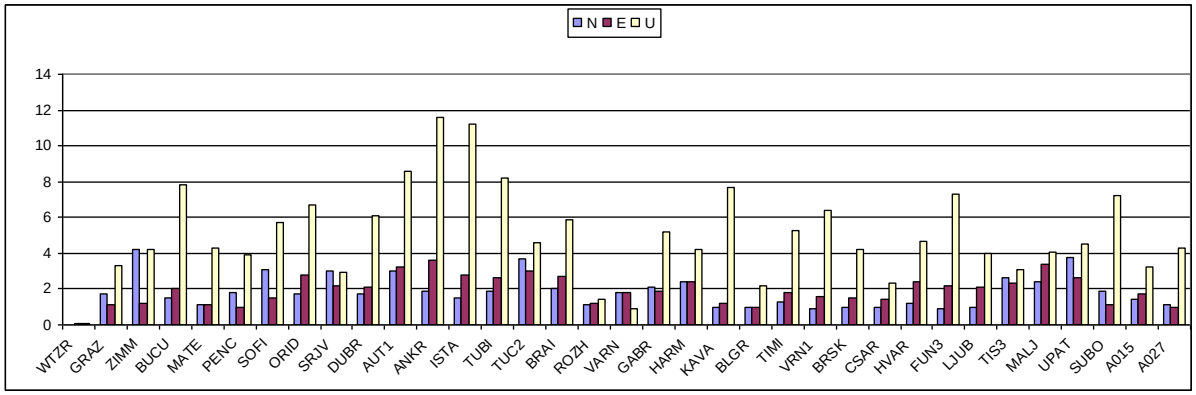

Fig. 5.1.2.4. RMS of comparison of BP'CEGRN05 session solutions

The values of deviations in North and East components vary between 1-4 mm and for Up component between 3-8 mm. Only for stations ANKR and ISTA rms's are about 12 mm. These results show a very good consistence.

5.1.2.3. Comparison and analysis of the results from combined solutions

Before comparing and analyzing the most important from geodynamical point of view results, namely velocity vectors the quality and reliability of station coordinate estimations obtained have been studied and analyzed.

Combined solution of BP'CEGRN97 and BP'CEGRN03 have been already done and published (Milev et al., 2005) and an improved solution is presented here. Combinations of normal equations from BP'CEGRN97 and BP'CEGRN05, and BP'CEGRN03 and BP'CEGRN05 campaign solutions have been processed using Addneq of Bernese Software, Version 4.2.

At first an evaluation of participated stations has been done in two steps:

1) **Evaluation of estimated coordinates only for reference IGS stations and**
2) **Evaluation of all other non-reference station coordinates.**

Then estimated velocities from different combined solutions have been compared and analyzed. Comparison and analysis with NUVEL1A-NNR calculated velocities and EPN estimated velocities has been done as well.

- ## Comparison and analysis of the results for participated IGS permanent stations used as reference

BP'CEGRN97 - BP'CEGRN03

7-parameters Helmert transformations have been applied for the coordinates of the IGS reference stations obtained from combined BP'CEGRN97 - BP'CEGRN03 solution and ITRF2000 official published coordinates at the epochs 1997.44 and 2003.46 respectively.

High values in North component for stations MATE and SOFI occurred in both cases. It is not quite clear if the problem with this station happened in 1997 or in 2003. After marking station MATE the residuals become smaller (Table 5.1.2.1.).

Table 5.1.2.1. Residuals from Helmert transformations between sets of estimated BP'CEGRN97 – BP'CEGRN03 and official ITRF2000 published coordinates of IGS stations for the respective observation epochs with station MATE marked

No	Site Name	Residuals in mm							
		BP'CEGRN97-BP'CEGRN03/ ITRF2000, epoch 1997.44				BP'CEGRN97-BP'CEGRN03/ ITRF2000, epoch 2003.46			
		N	E	U		N	E	U	
1	GRAZ 11001M002	1.9	0.5	-1.6		-3.0	-1.0	3.8	
2	MATE 12734M008	12.9	4.4	0.0	M	18.0	-4.1	-0.8	M
3	PENC 11206M006	1.9	-0.4	6.1		-0.2	0.8	-2.1	
4	SOFI 11100M002	-2.0	-0.1	-1.8		2.0	-0.2	-0.3	
5	WTZR 14201M010	-1.4	-1.5	-5.5		0.3	2.1	-0.2	
6	ZIMM 14001M004	-0.3	1.5	2.7		0.9	-1.8	-1.2	
	RMS/Component	1.8	1.1	4.5		1.9	1.5	2.3	
	RMS of transformation	3.5				2.3			

BP'CEGRN97 - BP'CEGRN05

The residuals from 7-parameters Helmert transformations between sets of coordinates from combined BP'CEGRN97 - BP'CEGRN05 solution and ITRF2000 official published coordinates at the observation epochs 1997.44 and 2005.47 respectively have been obtained. As above the problem in both campaigns is again with station MATE (Table 5.1.2.2.).

Table 5.1.2.2. Residuals from Helmert transformations between sets of estimated BP'CEGRN97 – BP'CEGRN05 and official ITRF2000 published coordinates of IGS stations for the respective observation epochs with station MATE marked

No	Site Name	Residuals in mm							
		BP'CEGRN97-BP'CEGRN05 / ITRF2000, epoch 1997.44				BP'CEGRN97-BP'CEGRN05 / ITRF2000, epoch 2005.47			
		N	E	U		N	E	U	
1	GRAZ 11001M002	3.1	0.7	-2.8		-1.8	-0.7	3.5	
2	MATE 12734M008	19.7	5.8	0.3	M	-22.1	-1.8	1.7	M
3	PENC 11206M006	2.2	-1.1	6.8		-3.4	3.0	1.0	
4	SOFI 11100M002	-3.1	0.2	-1.7		4.0	-1.1	-1.2	
5	WTZR 14201M010	-1.5	-2.3	-5.4		1.1	2.3	-3.5	
6	ZIMM 14001M004	-0.7	2.5	3.1		0.2	-3.5	0.1	
	RMS/Component	2.6	1.8	4.9		2.8	2.7	2.6	
	RMS of transformation	4.1				3.3			

BP'CEGRN03 - BP'CEGRN05

The residuals from 7-parameters Helmert transformations between the sets of coordinates from combined BP'CEGRN03 - BP'CEGRN05 solution and ITRF2000 official published coordinates at the observation epochs 2003.46 and 2005.47 respectively are presented in Table 5.1.2.3.

Table 5.1.2.3. Residuals from Helmert transformations between sets of estimated BP'CEGRN03 – BP'CEGRN05 and official ITRF2000 published coordinates of IGS stations for the respective observation epochs with station BUCU marked

No	Site Name	Residuals in mm							
		BP'CEGRN03- BP'CEGRN05/ ITRF2000, epoch 2003.46				BP'CEGRN03- BP'CEGRN05/ ITRF2000, epoch 2005.47			
		N	E	U		N	E	U	
1	BUCU 11401M001	-14.9	29.6	23.8	M	5.9	-18.8	-33.2	M
2	GRAZ 11001M002	-0.1	-0.1	1.3		-1.3	-0.2	0.5	
3	MATE 12734M008	-3.5	-0.8	0.0		3.4	-1.4	-0.6	
4	PENC 11206M006	0.6	-0.3	-0.7		3.3	-2.1	-3.5	
5	SOFI 11100M002	2.5	-0.7	-0.1		-3.8	3.0	1.6	
6	WTZR 14201M010	0.1	1.1	-0.1		-1.1	-0.5	2.8	
7	ZIMM 14001M004	0.4	0.9	-0.4		-0.4	1.2	-0.8	

	RMS/Component	**1.9**	**0.8**	**0.7**		**2.8**	**1.8**	**2.2**
	RMS of transformation	**1.5**				**2.7**		

The values in North and Up components for station BUCU deviate considerably for both campaigns. The same problem was found in a previous study concerning BULREF'03 campaign (Vassileva, 2004)]. Comparison of estimated coordinates with coordinates from the EPN weekly solution for station BUCU has been done and consistence becomes very good.

Analyzing all above presented results it can be concluded that there was a problem with station MATE occurred most probably in 1997. Station BUCU is problematic in 2003 and in 2005 as well. To study this problem further a new comparison has been done. Using the EPN estimated velocities for BUCU instead the ITRF2000 official published velocities new reference coordinates have been calculated for epochs 2003.46 and 2005.47. The same comparisons have been accomplished but using the new calculated reference coordinates of BUCU. The residuals of this station have been considerably improved (Table 5.1.2.4.).

Table 5.1.2.4. Residuals from Helmert transformations between sets of estimated BP'CEGRN03 – BP'CEGRN05 and official ITRF2000 published coordinates of IGS stations for the respective observation epochs using EPN estimated velocity for BUCU

No	**Site Name**	**Residuals in mm**						
		BP'CEGRN03-BP'CEGRN05/ ITRF2000, epoch 2003.46				**BP'CEGRN03-BP'CEGRN05/ ITRF2000, epoch 2005.47**		
		N	**E**	**U**		**N**	**E**	**U**
1	**BUCU 11401M001**	**-6.7**	**9.5**	**15.1**		**-3.6**	**10.5**	**11.2**
2	**GRAZ 11001M002**	**0.5**	**-1.3**	**-4.2**		**1.2**	**-1.3**	**-2.7**
3	**MATE 12734M008**	**7.6**	**0.6**	**0.3**		**0.4**	**-0.2**	**0.9**
4	**PENC 11206M006**	**0.1**	**-2.9**	**-7.4**		**3.6**	**1.4**	**5.6**
5	**SOFI 11100M002**	**2.0**	**-3.2**	**-10.1**		**7.0**	**-7.6**	**-9.2**
6	**WTZR 14201M010**	**-1.5**	**-2.6**	**-1.2**		**-0.7**	**-0.3**	**-3.8**
7	**ZIMM 14001M004**	**-2.0**	**-0.1**	**7.5**		**-0.7**	**0.1**	**6.1**
	RMS/Component	**4.4**	**4.4**	**8.7**		**3.6**	**5.4**	**6.8**
	RMS of transformation	**7.0**				**6.1**		

A reason for this inconsistence is the difference between ITRF2000 and EPN velocity estimations, especially for the V_X and V_Y components [www.epncb.oma.be/_dataproducts/timeseries/series_sp.html] and not in the station itself.

- ## Comparison and analysis of the results for non-reference stations

In the second step an evaluation of non-reference stations have been done. For this purpose comparison between sets of estimated coordinates from combined and individual final campaign solutions have been accomplished applying 7-parameters Helmert transformation.

BP'CEGRN97 - BP'CEGRN03

The results from 7-parameters Helmert transformations between set of coordinates from the combined BP'CEGRN97 - BP'CEGRN03 solution and respective final campaign solutions (BP'CEGRN97, BP'CEGRN03) are shown in Table 5.1.2.6. Problematic stations have been marked.

As it was found in the data processing of 2003 campaign (Milev et al., 2005) very large values of residuals especially in Up component are obtained again for station Brusnik (BRSK) in both transformations. Stations HVAR and TIS3 for 1997 have got high residuals and for 2003 almost all stations show high residuals. After removing of these stations (BRSK, HVAR, TIS3, MATE) from the process of transformation the results have been improved for 1997 (Table 5.1.2.5). For 2003 except stations HVAR and TIS3 also suspected bad station LJUB have been marked (Table 5.1.2.5.).

Table 5.1.2.5. Residuals from Helmert transformations between sets of estimated coordinates from combined BP'CEGRN97 - BP'CEGRN03 solution and individual campaign solutions

No	Site Name	Residuals in mm							
		BP'CEGRN97-BP'CEGRN03/BP'CEGRN97				BP'CEGRN97-BP'CEGRN03/BP'CEGRN03			
		N	E	U		N	E	U	
1	GRAZ 11001M002	2.3	1.9	-4.4		-2.1	2.8	-7.6	
2	MATE 12734M008	12.9	6.9	-6.1	M	-13.8	-4.5	-11.9	M
3	PENC 11206M006	-2.0	0.4	2.0		-2.4	1.3	12.3	
4	SOFI 11100M002	-0.7	2.0	-1.8		1.1	-1.7	-0.7	
5	WTZR 14201M010	-1.0	-1.1	-4.2		0.7	2.6	-4.3	
6	ZIMM 14001M004	-4.3	0.8	-1.6		2.5	-3.6	0.6	
7	BRSK	11.0	29.4	-579.9	M	-8.4	-21.8	327.4	M
8	CSAR	4.0	2.7	-2.7		-5.3	-2.1	4.7	
9	HVAR	13.9	12.8	-39.9	M	-12.5	-10.5	2.6	M
10	LJUB	5.4	-4.7	12.4		-7.0	6.3	-17.7	M
11	TIS3	5.3	-4.8	48.2	M	-5.6	4.7	-52.4	M
12	HARM	-1.0	0.5	-3.2		2.3	-0.5	1.2	
13	VRN1	-2.8	-2.5	3.6		3.1	1.3	-6.1	
	RMS/Component	3.2	2.4	5.4		3.0	2.3	6.4	
	RMS of transformation	4.2				4.8			

Obviously there is an outlier in the height of BRSK but from the transformations is difficult to say in which year. The problem of the other stations is probably in the height, as well.

The above presented results show that there was an error most likely in the height of station HVAR in 1997. For stations BRSK and TIS3 it is not clear if the error (suspected wrong heights) occurred in 1997 or in 2003 because it has appeared in transformation results for both years. The residuals of TIS3 in Up component are in the same order in 1997 and in 2003 and it can be interpreted as an error in the height or as movement.

BP'CEGRN97 - BP'CEGRN05

The results obtained from 7-parameters Helmert transformations between set of coordinates from the combined BP'CEGRN97 - BP'CEGRN05 solution and respective final campaign solutions are shown in Table 5.1.2.6.

Stations BRSK, HVAR, LJUB, TIS3 and VRN1 obtain high values for the residuals from the transformation between combined solution and 1997 solution. Stations BRSK, HVAR, LJUB, TIS3 and HARM show high values for the residuals from the other transformation.

Table 5.1.2.6. Residuals from Helmert transformations between sets of estimated coordinates from combined BP'CEGRN97 - BP'CEGRN05 solution and individual campaign solutions

No	Site Name	Residuals in mm							
		BP'CEGRN97-BP'CEGRN05/BP'CEGRN97				BP'CEGRN97-BP'CEGRN05/BP'CEGRN05			
		N	E	U		N	E	U	
1	GRAZ 11001M002	4.3	1.2	-2.2		3.4	-2.6	-9.3	
2	MATE 12734M008	21.8	5.7	-0.1	M	-16.1	-4.5	-4.7	M
3	PENC 11206M006	-1.6	-1.7	5.9		-3.8	1.6	2.9	
4	SOFI 11100M002	-1.3	-1.2	3.3		1.5	-0.4	1.6	
5	WTZR 14201M010	-0.6	-2.0	-1.3		-0.2	3.0	0.2	
6	ZIMM 14001M004	-3.0	2.1	2.4		0.4	-1.2	5.3	
7	BRSK	1.2	1.4	-10.6	M	-10.4	-0.6	-1.0	M
8	CSAR	5.1	0.5	-6.5		-4.0	-1.8	-3.1	
9	HVAR	22.6	10.5	-25.9	M	-19.0	-9.4	10.5	M
10	LJUB	9.7	-0.4	-3.6	M	-9.5	1.5	-4.8	M
11	TIS3	4.8	-9.1	13.3	M	-2.2	4.8	-14.8	
12	HARM	-2.9	1.2	-1.6		9.2	-7.0	-4.3	M
13	VRN1	-0.3	-9.8	-19.1	M	2.7	1.4	2.4	
	RMS/Component	3.3	1.6	4.1		3.0	2.0	4.9	
	RMS of transformation	3.6				4.0			

Analyzing the results from these comparisons it can be concluded that a problem with the height of station VRN1 occurred in 1997. It should be mentioned that residuals of BRSK are not as high as they are in the previous comparison (Table 5.1.2.5) and by this reason it is supposed that an outlier of this station occurred in 2003.

BP'CEGRN03 - BP'CEGRN05

The results from respective comparisons are given in Table 5.1.2.7 as problematic stations are marked. Station Brusnik shows again very high values for the residuals.

Stations PENC, FUN3, LJUB and TIS3 show high values in Up component for the comparison to coordinates in 2003 and stations GRAZ, FUN3 and TIS3 for the comparison to coordinates in 2005.

The results from this comparison confirm the above speculation that an outlier for station BRSK occurred in 2003. The problem with GRAZ station occurred most probably in 2005 and for other stations it is difficult to determine in which year it happened.

Table 5.1.2.7. Residuals from Helmert transformations between sets of estimated coordinates from combined BP'CEGRN03 - BP'CEGRN05 solution and individual campaign solutions

No	Site Name	Residuals in mm							
		BP'CEGRN03-BP'CEGRN05/ BP'CEGRN03				BP'CEGRN03-BP'CEGRN0 / 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			

Table 5.1.2.8. 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)				
		97-03	97-05	03-05	Nuvel	EPN	97-03	97-05	03-05	Nuvel	EPN	97-03	97-05	03-05	Nuvel	EPN
1	BRSK	-16.8	-17.1	-19.2	-14.6		20.8	18.2	9.1	18.0		9.5	11.4	16.2	9.1	
2	CSAR	-17.1	-16.8	-15.7	-15.3		18.5	18.5	18.6	17.8		10.2	9.8	8.7	8.7	
3	HVAR	-18.8	-18.9	-19.2	-14.5		21.1	20.2	17.4	18.3		12.9	13.2	14.3	9.4	
4	PENC 11206M006	-16.6	-16.6	-16.6	-15.7		18.0	18.0	18.1	17.4		8.2	8.3	8.2	8.3	
5	GRAZ 11001M002	-17.5	-17.5	-17.6	-14.8		18.0	18.2	18.2	17.8		8.2	8.1	8.2	8.9	
6	LJUB	-16.2	-16.7	-18.0	-14.4		16.4	17.7	22.0	18.0		11.2	11.3	11.5	9.2	
7	MATE 12734M008	-18.8	-18.7	-18.8	-14.3		19.1	19.1	19.1	18.7		13.1	13.0	13.1	9.7	
8	TIS3	-17.1	-16.9	-16.3	-16.3		14.8	16.5	21.4	17.5		10.0	9.1	6.5	8.2	
9	SOFI 11101M002	-16.5	-16.6	-16.5	-16.2		18.6	18.7	18.7	17.8		7.4	7.4	7.3	8.5	
10	HARM	-16.3	-16.5	-17.0	-16.7		17.5	20.0	26.8	17.6		7.9	6.8	4.1	8.2	
11	VRN1	-16.0	-17.2	-20.5	-17.2		16.5	17.4	19.4	17.0		6.7	7.3	9.4	7.6	
12	WTZR 14201M010	-15.7	-15.7	-15.7	-14.4		17.3	17.2	17.2	17.6		8.7	8.7	8.7	8.8	
13	ZIMM 14001M004	-13.8	-13.8	-13.8	-12.9		18.7	18.5	18.4	18.2		10.0	10.0	10.0	9.8	
14	BLGR			-16.1	-15.7				17.3	17.8				9.1	8.6	
15	TIMI			-14.4	-16.0				20.1	17.6				5.9	8.4	
16	BRAI			-15.8	-17.4				21.2	16.9				4.0	7.4	
17	BUCU 11401M001			-17.7	-17.0	-17.1			19.2	17.3	18.1			7.6	7.8	8.1
18	KAVA			-16.0	-17.4				20.6	17.2				4.6	7.6	
19	FUN3			-21.1	-16.8				15.9	17.2				12.1	7.8	
20	GABR			-17.7	-16.6				25.1	17.6				5.6	8.2	
21	MALJ			-17.5	-14.2				17.6	18.2				12.6	9.4	
22	SRJV 11801S001			-16.8	-15.1	-18.6			19.2	18.1	18.6			10.2	9.0	9.4
23	TUBI 20806M001			-17.9	-17.4	-18.8			19.3	17.3	17.4			7.1	7.7	3.9
24	ISTA 20807M001			-18.3	-17.3	-17.9			22.3	17.4	20.8			5.9	7.8	6.0
25	ORID 15601M001			-15.0	-15.4	-14.8			21.6	18.3	21.0			7.3	9.1	7.9

- **Station velocity estimations and analysis**

The behavior of stations during the period of study is characterized here by the velocity vectors estimated from the combined campaign solutions with Bernese Software, version 4.2. Station velocity estimations have been obtained with respect to the fixed ITRF2000 coordinates and velocities, epoch 1997.0 of reference IGS stations - WTZR, GRAZ, MATE, ZIMM, SOFI and PENC. The ITRF2000 velocity estimations of participated Balkan Peninsula stations from all three combinations and calculated NUVEL1A-NNR station velocities are shown in Table 5.1.2.8. EPN estimated velocities [www.epncb.oma.be/_dataproducts/timeseries/series_sp.html] for EPN stations included in the processing are also presented in this table.

GPS and NUVEL1A-NNR station velocity vectors and their differences are also shown graphically in the Figs. 5.1.2.5., 5.1.2.6. and 5.1.2.7.

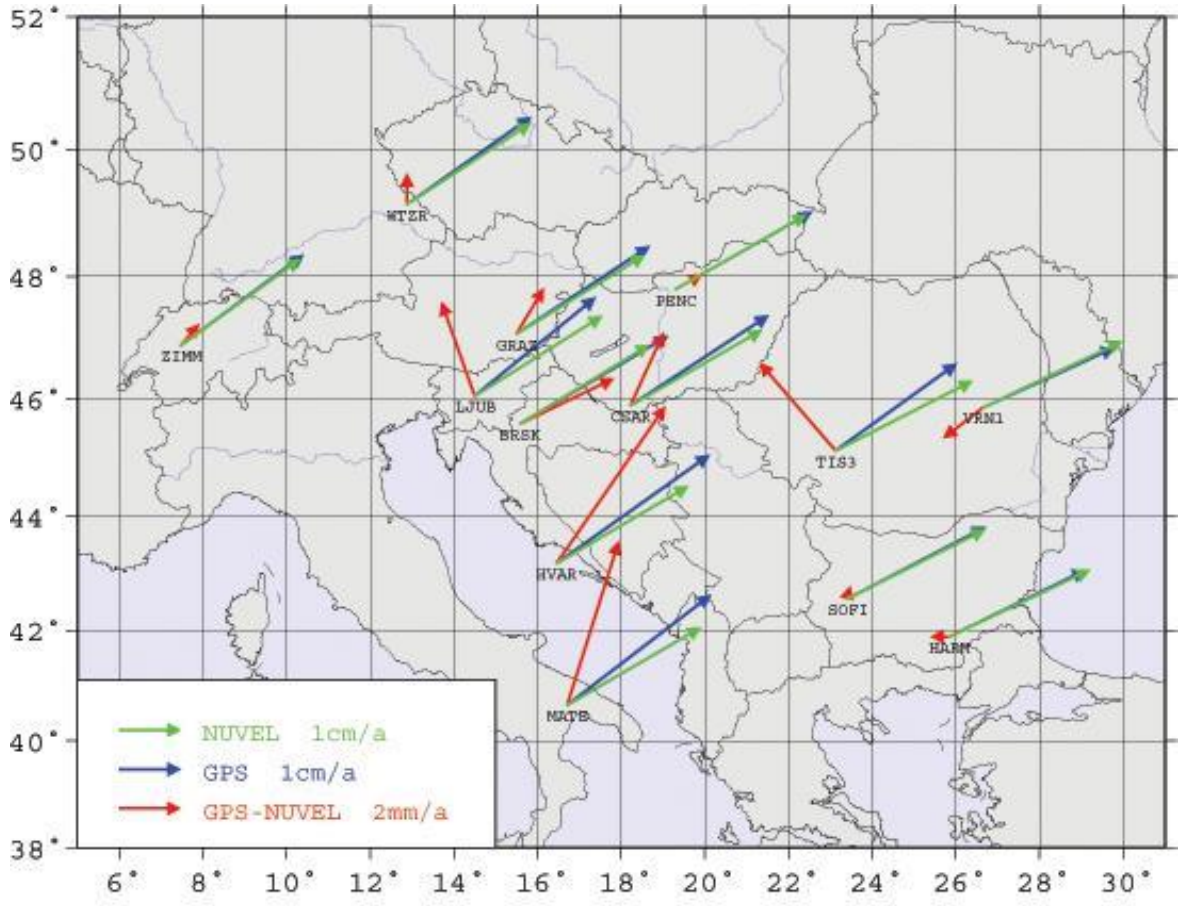

Fig. 5.1.2.5. 97-03'GPS estimated and NUVEL1A-NNR velocity vectors of BP'CEGRN stations and their differences

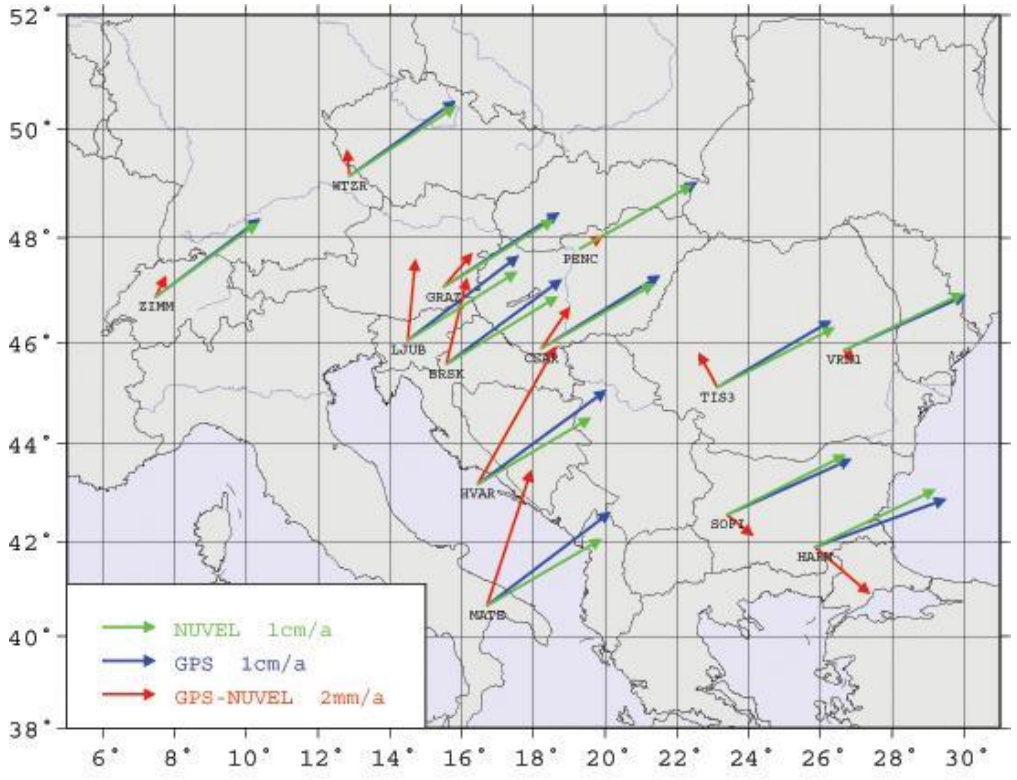

Fig. 5.1.2.6. 97-05'GPS estimated and NUVEL1A-NNR velocity vectors of BP'CEGRN stations and their differences

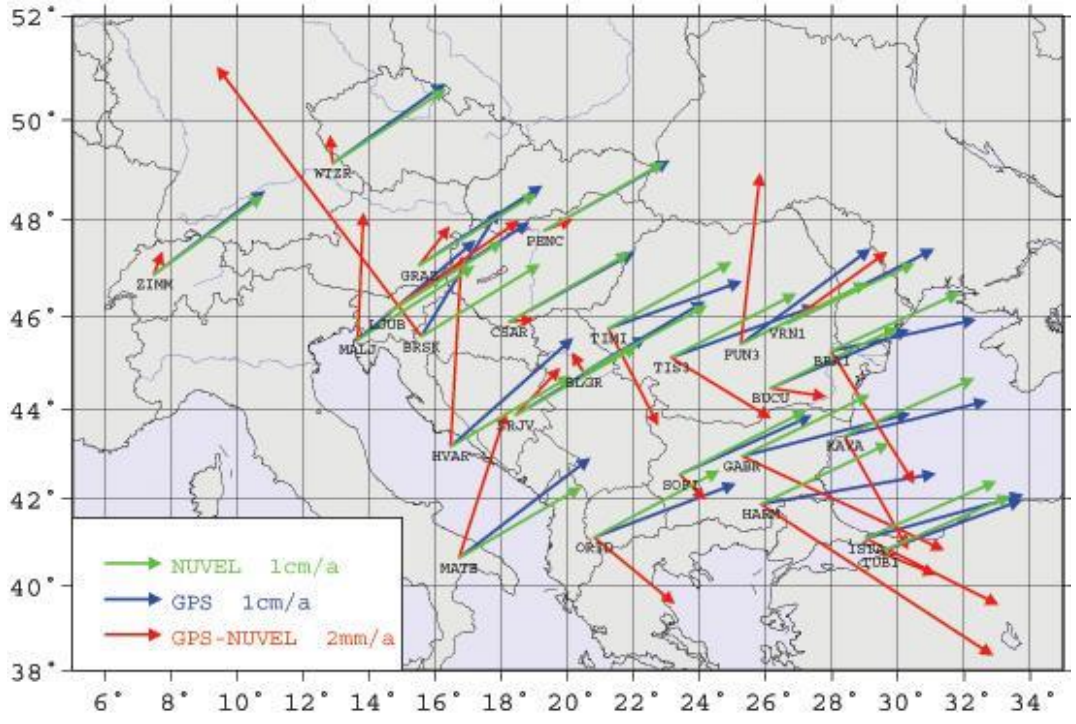

Fig. 5.1.2.7. 03-05'GPS estimated and NUVEL1A-NNR velocity vectors of BP'CEGRN stations and their differences

For most of the stations the estimated velocities from all combined solutions agreed very well. Only estimations in the third combined solution - BP'CEGRN03-BP'CEGRN05 deviate of amount of 1-2.5 mm/y (marked in grey in Table 5.1.2.8). These disagreements mainly concern the above established problematic stations. The agreement with the EPN available estimations (within 0.1-1.9 mm/y) and with the calculated NUVEL–NNR1A velocities are also good with exception for some of the problematic stations. For some of these stations the problem is probably in 2003 as it is supposed in the analysis above but at present for the most stations it can not be localized the campaign where the problem is without additional information.

To compare the above obtained results with the results from data processing of all CEGRN campaigns accomplished by TUD for the area of the Balkan Peninsula [Dresher, -] the velocity estimation from the latter are given in Table 5.1.2.9.

Table 5.1.2.9. Final CERGOP-2 solution for the region of the Balkan Peninsula

STATION	NAME	VX (m/y)	VY (m/y)	VZ (m/y)	VN (m/y)	VE (m/y)	VU (m/y)	Remark
GRAZ	11001M002	-0.0172	0.0182	0.0084	0.0143	0.0221	-0.0018	1
MATE	12734M008	-0.0185	0.0197	0.0134	0.0180	0.0242	-0.0004	1
PENC	11206M006	-0.0175	0.0177	0.0081	0.0133	0.0225	-0.0012	1
SOFI	11101M002	-0.0172	0.0195	0.0076	0.0110	0.0247	-0.0008	1
WTZR	14201M010	-0.0158	0.0174	0.0087	0.0144	0.0205	-0.0010	1
ZIMM	14001M004	-0.0142	0.0185	0.0095	0.0150	0.0202	-0.0010	1
BRAI		-0.0167	0.0176	0.0065	0.0092	0.0234	0.0000	2, 4
FUN3		-0.0156	0.0175	0.0072	0.0098	0.0225	0.0005	2
GABR		-0.0169	0.0222	0.0064	0.0086	0.0273	0.0001	2, 4
KAVA		-0.0153	0.0163	0.0060	0.0083	0.0216	0.0000	2, 4
TIS3		-0.0163	0.0187	0.0089	0.0117	0.0236	0.0009	2
VRAN		-0.0183	0.0171	0.0073	0.0113	0.0235	-0.0008	2
BRSK		-0.0182	0.0196	0.0096	0.0155	0.0238	-0.0017	3
BUCU	11401M001	-0.0178	0.0172	0.0072	0.0110	0.0233	-0.0010	3
CSAR		-0.0173	0.0176	0.0092	0.0143	0.0221	-0.0010	3
HARM		-0.0174	0.0198	0.0073	0.0101	0.0254	-0.0004	3
HVAR		-0.0224	0.0206	0.0103	0.0182	0.0261	-0.0044	3
LJUB		-0.0165	0.0172	0.0106	0.0158	0.0208	-0.0005	3
MALJ		-0.0200	0.0171	0.0085	0.0169	0.0213	-0.0047	3
SRJV	11801S001	-0.0192	0.0178	0.0086	0.0149	0.0230	-0.0031	3

1 - datum stations, all 3 components strongly constrained to ITRF2000

2 - height component strongly constrained to 0

3 - all 3 components estimated without constraints

4 - velocity estimation is based on only 2 epochs

The CEGRN velocity vectors of the Balkan Peninsula stations related to Eurasia plate and calculated by the University of Technology Darmstadt are shown in Fig. 5.1.2.8.

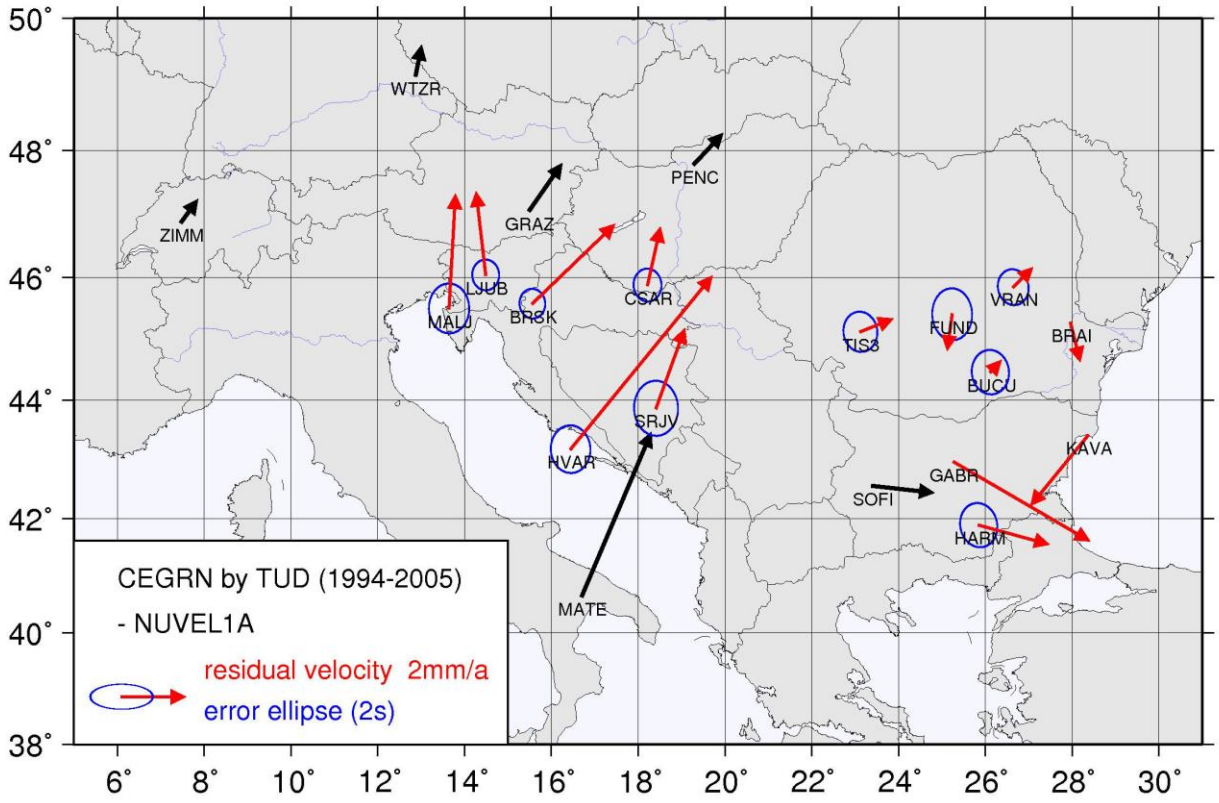

Fig. 5.1.2.8. CEGRN – NUVEL1A velocity vectors of the Balkan Peninsula stations and their error ellipses

The results agree well with the individual solutions computed by the Institute of Water Problems at the Bulgarian Academy of Sciences and listed in Table 5.1.2.8.

5.1.2.4. Conclusion

An attempt to localize the problematic stations and to give some explanation for the problems within the period of three CEGRN campaigns concerning Balkan Peninsula subnetwork is done. On the base of comparisons by Helmert transformation and analysis of the results from combined campaign solutions problematic stations are found. If the problem occurs only in one campaign participated in the comparison then the error in the suspected stations is related to the measurements in this year and it mainly concerns Up component, i.e. height problem. If the problem occurs for the same stations participated in both campaigns then it could be interpreted as an error which is still available in both campaigns or less probably as a movement.

Estimated station velocities from different combined campaign solutions agreed very well for most of the stations and they could be used for further investigations and interpretations. Exception is only for the problematic stations. Their behavior should be analyzed in more detail after having additional information for these stations and also by applying other methods.

The final official CERGOP-2 solution will be published as soon as the new ITRF2005 will be available and as soon as the IGS finally adopts the absolute antenna phase centre corrections. Minor adjustments to the Balkan Peninsula horizontal velocities may be expected due to these processing changes. However, the datum of ITRF2005 is expected to be much more precise and so will be the general velocity field in Central Europe.
The generalized results show that:

- **orientation of the velocity vectors is generally north-east and south-east direction,**
- **horizontal movements are of amount of 2 mm/yr,**
- **results achieved are reliable as they have been obtained by different approaches and by independent researchers,**
- **comparison of the particular solutions within the CERGOP-2 project shows an agreement.**

5.1.2.5. References

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www.epncb.oma.be/_dataproducts/timeseries/series_sp.html.