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ANALYSIS OF THE EUREF STATIONS STABILITY ON THE TERRITORY OF BULGARIA

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1. General

◆ European Reference Frame - EUREF was introduced in Bulgaria in 1996 with a resolution of the EUREF symposium in Ankara. 7 stations were officially approved as EUREF stations.

◆ Nevertheless, all 15 stations defined the Bulgarian system BULREF and they were used later as basis for further realisation of EUREF in the country.

◆ Later on four of the EUREF stations were included in the CEGRN GPS measurement campaign of the Central European Geodynamics Project – CERGOP.

♦ All 15 BULREF stations were re-occupied during the consecutive GPS campaign of the second phase of the project – CERGOP-2 in 2003.

♦ Comparison of the results and assessment of the BULREF stations stability have been accomplished on the base of a new processing of both the BULREF'93 data and the CEGRN'03/BULREF'03 data.



2. GPS BULREF campaigns in 1993 and 2003 and data processing

2.1. GPS campaigns

♦ The EUREF GPS campaign for Bulgaria in 1993 was carried out from 12.10.1993 to 16.10.1993. All 15 BULREF stations (fig. 1) were equipped with Trimble 4000SSE receivers and antennas 4000ST L1/L2 GEOD were used in the campaign.

◆ The GPS measurements were carried out in five 24-hours sessions with sampling rate of 15 sec and elevation mask 15°.



Fig. 1. BULREF stations and IGS stations involved in BULREF'93 and BULREF'03 campaigns



♦ The BULREF'03 GPS campaign was carried out within the framework of the CEGRN'03 GPS campaign of the EC Project CERGOP-2 and it is the second campaign for the BULREF network.

♦ The measurements started on 16.06.2003 at 12:00 (UT) and closed on 21.06.2003 at 12:00 (UT). The four Bulgarian CEGRN/BULREF stations -SOFI, GABR, KAVA and HARM were measured in five 24-hours sessions. The other stations (KERM, MAMA, BURG, BERK, GULI, SHUM, VIDI, PANA, SATO, SAPA, PETR, fig. 1) were measured in two 24-hours sessions because of insufficient number of receivers.

♦ A data sampling rate of 30 sec and an elevation mask of 10° was used. Different types of receivers/antenna pairs were used - Trimble 4000 SSI with compact L1/L2 GP antenna, Trimble 5700 with Zephyr / Zephyr Geodetic antenna, AOA SNR-8000 ACT/AOAD/M_T, Trimble 4000 SSE/4000 SST/E L1/L2 GEOD antenna, Leica SR530/AT502 antenna and Sokkia Radian/SK 502 antenna.



2.2. Data processing 2.2.1. BULREF'93 data processing

♦ The original BULREF'93 GPS data were processed with the Bernese GPS software, version 3.5. Four IGS stations - WETT, MATE, GRAZ, ZIMM were involved. Precise CODE ephemerides in system ITRF91 were used.

◆ In 2004 the BULREF'93 GPS data were re-processed in the system ITRF2000, epoch 1993.8. The precise ephemerides were transformed into ITRF2000.

• Final station coordinates in ITRF2000, 1993.8 were obtained.

♦ A 7-parameters Helmert transformation was accomplished for the analysis of the results.

♦ The results from the transformation between the final campaign solution BULREF'93 and official published ITRF2000 coordinates for the observation epoch 1993.8 of the IGS permanent stations show a very good consistence. Transformations between station coordinates of final campaign solution and session solutions also show good consistence except 287-session solution for station WETT.



2.2.2. BULREF'03 data processing

♦ The computations of the BULREF network were performed with the Bernese GPS Software, version 4.2. Precise ephemerides from IGS final orbit computation in system IGS2000 were used. Seven IGS sites – WTZR, ZIMM, GRAZ, MATE, SOFI, PENC, BUCU were involved. A set of final coordinates was compared to the official coordinates of the reference IGS sites

♦ The results of the comparison show a good agreement of coordinates except the residuals in North and East component for site BUCU and in North component for site MATE. After marking site BUCU in the transformation process the obtained results have been improved (table 4).



Table 4. Residuals of Helmert transformation between final IGS site coordinates from BULREF'03 solution and official ITRF2000, 2003.46 coordinates. Site BUCU marked

No	Site Name	Residuals in mm			
		Ν	Ε	U	
1	BUCU 11401M001	14.7	-27.1	-17.2	Μ
2	GRAZ 11001M002	-0.7	-3.8	14.1	
3	SOFI 11100M002	1.2	-0.0	-2.1	
4	MATE 2734M008	-3.4	0.0	2.2	
5	PENC 11206M006	1.5	-0.5	-11.8	
6	WTZR 14201M010	0.3	0.9	7.1	
7	ZIMM 14001M004	1.0	3.3	-9.4	
	RMS/Component	1.8	2.3	9.9	
	RMS of transformation	7.0			

◆ To be find some explanation of such a behavior of BUCU site coordinate differences obtained for this site from different solutions at the observation epoch 2003.46 were formed. Differences obtained were very small, especially between CEGRN'03 and BULREF'03 solutions.



◆ The results from Helmert transformations between final network solution and session solutions show high values of residuals in Up component for station BERK in all sessions (from 22,7 mm up to 40,6 mm) and for station MATE in North component only on 170 DoY. After marking this station the residuals from the Helmert transformation are getting smaller Probably the reason for the bad results of station BERK is the technical problem occurred during the campaign.

Analysis of the results from data processing of BULREF'03 shows that the obtained final coordinates are reliable except those ones for IGS site BUCU and for BULREF station BERK.



3. Comparison and analysis of results from the campaigns BULREF'93 and BULREF'03

♦ A multicampaign solution of BULREF'93 plus BULREF-03 was accomplished by use of the program ADDNEQ of the Bernese software version 4.2.

• Estimations of the ITRF2000 coordinates for the mean epoch and station velocities were computed.

♦ For obtaining the velocities of the BULREF stations the ITRF2000 coordinates and velocities of the IGS permanent stations - WTZR, ZIMM, GRAZ, MATE, SOFI and PENC were kept fixed.

◆ A 7-parameter Helmert transformation was accomplished for the analysis of the results. Residuals from transformation between the multicampaign solution BULREF'93-03 and official published ITRF2000 coordinates for the observation epoch 1993.8 of the IGS permanent stations were obtained with high values, especially in North and in East components. After marking the suspected bad stations – WETT and MATE the results were become very small (table 8).



Table 8. Residuals of Helmert transformation between coordinates of IGS sites from
BULREF'93-03 solution and official ITRF2000, 1993.8 coordinates. Sites WETT
and MATE marked

No	SiteName	Residuals in mm			
		Ν	Ε	U	
1	GRAZ 11001M002	3.8	-1.0	0.5	
2	SOFI 11100M002	-1.8	-0.2	-0.3	
3	MATE 12734M008	25.5	5.2	-7.8 M	
4	WETT 14201M009 A	-70.0	-114.3	14.8 M	
5	ZIMM 14001M004	-2.0	1.2	-0.2	
	RMS/Component	3.3	1.1	0.5	
	RMS of	3.5			
	transformation				

◆ The same transformation was accomplished between the multicampaign solution BULREF'93-03 and official published ITRF2000 coordinates for the observation epoch 2003.46 of the IGS permanent stations. The results obtained are similar as above but for sites BUCU and MATE. After marking the suspected bad sites – BUCU and MATE the results have been significantly improve.



◆ The results obtained from transformations show that there are some problems with IGS sites BUCU, WETT and MATE.

♦ As BULREF station HARM participated in another CEGRN'97 campaign its ITRF velocities were estimated and compared from two multicampaign solutions. The results show very similar values and confirm the velocity estimations obtained.

♦ More reliable velocity estimations of the stations will be obtained after including and analyzing the results from the forthcoming CEGRN'05 campaign to be conducted in June 2005 and which will include BULREF/CEGRN stations once more.



4. Assessment of the BULREF stations stability

♦ The velocity estimations obtained from this study show undisturbed behavior for all BULREF stations for the period of 10 years, period between two campaigns.

♦ The values of station velocities are very similar and differences vary of amount maximum up to 2 mm in north component and in east component – maximum of 2.5 mm.

◆ No unexpected jumps occurred in the behavior of stations during that time.

♦ As only two epochs are involved in this study, no final conclusions on the deformations within Bulgaria can be drawn.

♦ The results for the BULREF/CEGRN station HARM are confirmed by the CEGRN analysis and confirm the velocity estimations obtained in this study.



5. Conclusions and suggestions

◆ The comparison and analysis of the processing of two campaigns – BULREF'93 and BULREF'03 show that the results from both GPS campaigns are reliable.

♦ After the proper consideration of the discrepancies in WETT, BUCU and BERK in the respective campaigns, they can be used as a base for their combination and velocity estimation.

♦ The estimations obtained and the accuracy gives the reason to assume that the coordinates of the BULREF stations in the period from BULREF'93 to CEGRN'03/BULREF'03 can be used for respective transformations and comparisons.