The HUNREF2002 Campaign: Re-establishment of the EUREF Network in Hungary

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1.Introduction

In 1991 the EUREF CSH'91 campaign was the 1st eastward extension of the European Reference Frame (EUREF). That time Hungary (together with the former Czecho-slovakia) joined EUREF with the establishment of five points. The realized reference network was further densified in two phases (1991: 21 sites, 1995-7: 1154 points). The created Hungarian GPS Network (OGPSH) was fully relied on the ETRS89 system, represented by the 5 EUREF points.

However the original connection to ETRS89 had several shortcomings. The campaign design (12 hours sessions, 20 degree elevation cutoff, squaring receivers), the orbit quality (that time CIGNET orbits were only available) and the loose and unbalanced connection to the existing EUREF network (only GRAZ and WETT could be used as known and fixed stations) decreased the accuracy of the derived coordinates. As it was proved by later studies the relative (baselines) accuracy was around the specifications, however the reliability of the whole network referencing was questionable.

The first problem indication was provided by the processing of the EUREF BUL'92 campaign, where two of the 5 sites (TARP and CSAN) were included. The results revealed some 5-10 cm discrepancy between the official and campaign-derived coordinates at all components [*Altiner et al, (1994)*]. In order to clarify the situation all five Hungarian points were involved into the EUREF ROM'94 campaign. The data was processed by the BKG and by NOAA. The comparison of the results has shown significant discrepancies. Hence the sources of the contradictions could not be identified the official results are still not published [*Altiner, (2001)*].

Another indication of the coordinate problems were the discrepancies found at the Hungarian-Serbian and Hungarian-Croatian state border measurements, where the different EUREF realizations indicated a bias of some 2-5 cm at the different components.

2. The network design and GPS campaign

Beyond the above described obvious datum problem the re-installation of the national EUREF reference network was also necessitated by the changing geometry and status of the Hungarian EUREF sites. The original 5-site network has been supplemented with two EUVN sites (SATO, NADA) in 1997 and 2 EPN sites (OROS, NYIR) in 2001, 2002 respectively. Taking all the relevant circumstances into account (network hierarchy and geometry, EUREF rules) a new 9-point reference network (see Table 1.) with the following site distribution has been designed:

Station	Site	Status	Approximate coordinates phi	la	ell.ht [m]
PENC	11206M006	EPN	47.7896	19.2815	291.7
SOPR	Sopron	existing EUREF	47.6456	16.6041	320.5
CSAR	Csarnóta	existing EUREF	45.8836	18.2172	314.4
NADA	Nadap	EUVN	47.2557	18.6192	234.6
SATO	Sátoraljaújhely	EUVN	48.3770	21.6323	155.8
OROS	11207M001	EPN	46.5552	20.6713	146.0
NYIR	11208M001	EPN	47.8352	22.1358	203.6
ZALA	Zalaegerszeg	planned perm.	46.8420	16.8418	209.7
TISZ	Tiszagyenda	HGRN[1]	47.3707	20.5369	135.9

Table 1. The proposed Hungarian EUREF stations

As the new EPN stations are situated in the vicinity of existing EUREF sites (TARP, CSAN) those have to be withdrawn from the EUREF catalogue.

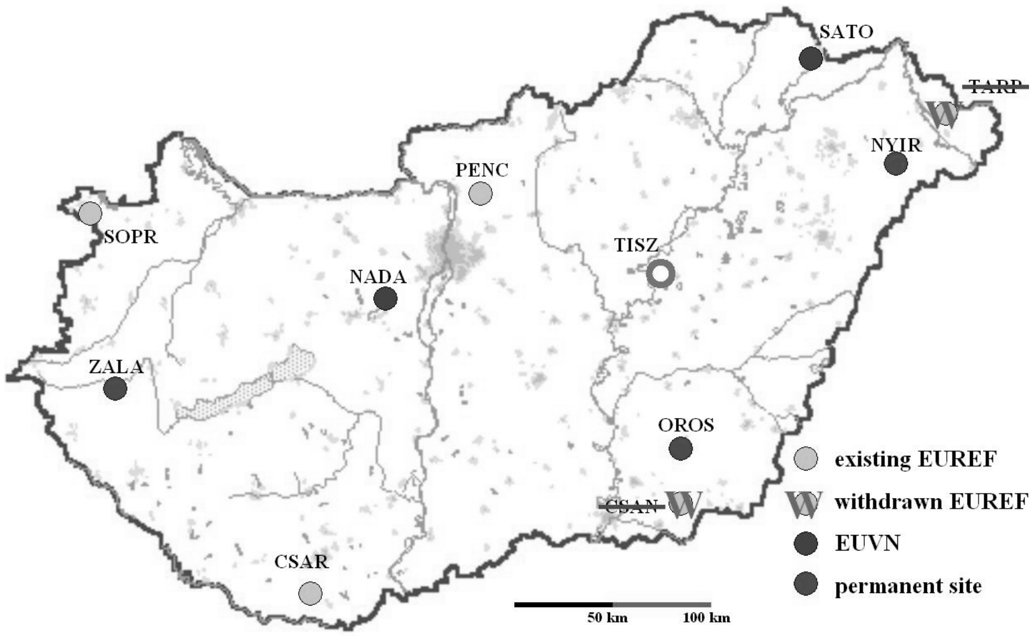

Figure 1. The Hungarian EUREF sub-network design.

[1] Hungarian Geodynamic Reference Network – periodically re-measured

The 5-days GPS campaign has been performed in 24-29 September 2002 noon-to-noon (GPSweek 1185). All sites have been occupied with Trimble 4000SSE receivers and TRM14532 antennae (except SOPR where a TRM22020.00 antenna was installed) using 10 degree elevation cut-off. The measurements were successful, only two days of observation was lost at SATO due to receiver malfunction.

3 Processing

The GPS data has been processed according to the general EUREF standards and specifications:

- IGS orbits and ERPs,
- 10 degree elevation cut-off,
- elevation dependent weighting,
- dry-Niell mapping function
- hourly tropospheric delay estimation

Additional EPN stations (GRAZ, JOZE, OSJE, UZHL, BUCU – see Fig 2.) have been also included into the processed network, where the ITRF2000 epoch 2002.74 coordinates of GRAZ, JOZE and PENC were constrained on the 0.001 m level.
The ITRF coordinates of BUCU could not be constrained as its ITRF velocity was derived from too short observation history and has benn proved to be biased.

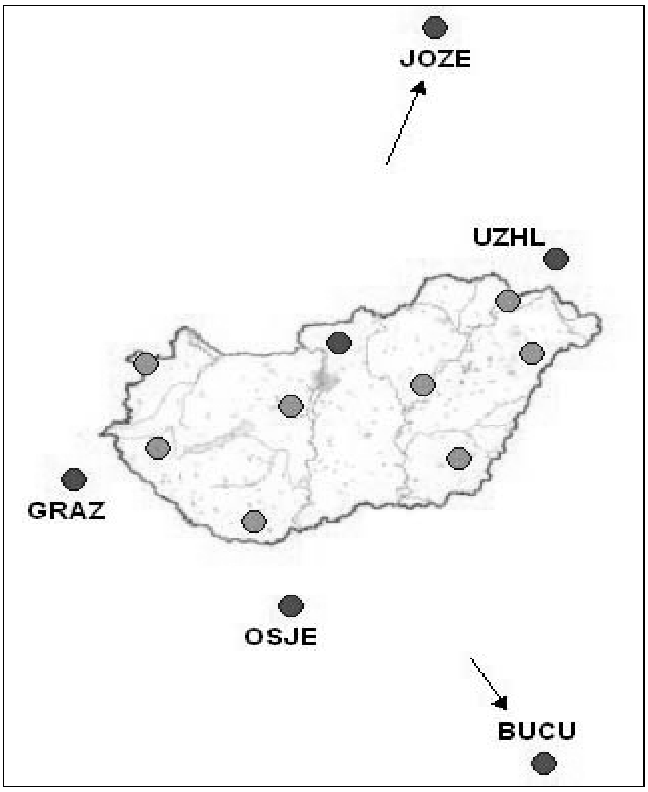

Figure 2. The processed network including EPN sites

Station	X [m]	Y [m]	Z [m]
	vel_X [cm/y]	vel_Y [cm/y]	vel_Z [cm/y]
GRAZ	4194423.858	1162702.653	4647245.375
	-1.76	1.81	0.82
JOZE	3664940.201	1409153.834	5009571.366
	-1.81	1.62	0.74
PENC	4052449.531	1417681.090	4701407.085
	-1.66	1.81	0.82
BUCU	**4093760.919**	**2007793.791**	**4445129.942**
	-1.08	**2.72**	**1.13**

Table 2. ITRF2000 epoch 2002.74 coordinates and velocities of the constrained sites.

Daily solutions have been computed and then combined to a campaign solution. The daily repeatabilities are shown in Figure 3. The repeatability values are excellent, they are in general below 2 mm, only the height component of TISZ has significantly higher value.

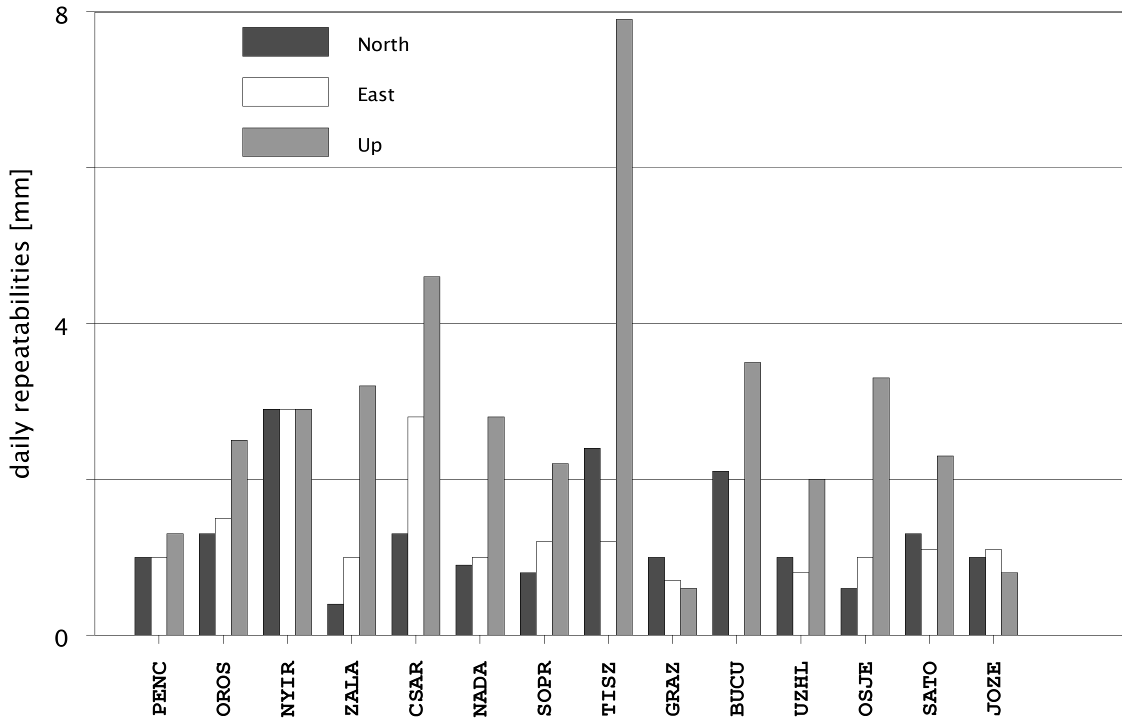

Figure 3. Daily repeatabilities of the HUNREF2002 campaign.

The reliability of the estimated coordinates was also checked with a comparison to the weekly combined EUREF solution (EUR11857.SNX) at the common points. The Helmert residuals have shown a very good agreement on the few mm-level (see Table 3).

Station	Res_North	Res_East	Res_Up
GRAZ	1.3	**6.1**	-4.8
PENC	0.7	-2.0	3.4
JOZE	-0.9	-0.8	0.7
BUCU	-0.9	2.8	-2.7
UZHL	-1.0	-2.2	0.4
OSJE	0.7	-1.8	3.1
OROS	0.1	-2.1	1.4

Table 3. Residuals [mm] of the 6-parameter Helmert transformation between the free and the EPN weekly combined solutions.

The constrained ITRF2000 solution has been transformed into ETRS89 using the formula of [*Boucher, Altamimi (2001)*]. The corresponding values for the translation parameters T1/T2/T3 are taken from [ibid] Appendix 1, Table 3 (54/51/-48 mm). The rotation values are taken from Appendix 2, Table 4 (0.081/0.490/-0.792 0.001"/year) of the same publication, $\Delta t = 13.74$.

$$\begin{pmatrix} X_E(t) \\ Y_E(t) \\ Z_E(t) \end{pmatrix} = \begin{pmatrix} X(t) \\ Y(t) \\ Z(t) \end{pmatrix} + \begin{pmatrix} T_1 \\ T_2 \\ T_3 \end{pmatrix} + \begin{pmatrix} 0 & -dR_3/dt & dR_2/dt \\ dR_3/dt & 0 & -dR_1/dt \\ -dR_2/dt & dR_1/dt & 0 \end{pmatrix} \bullet \begin{pmatrix} X(t) \\ Y(t) \\ Z(t) \end{pmatrix} \bullet \Delta t$$

$$X_E(89) = X_E(t_c) + X_{VE} \,.\, (1989.00 - t), \; t=2002.74$$

The coordinates in ETRS89 are computed using the values of the constrained network and applying the corresponding transformations. The results are given in Table 4.
The newly derived ETRF2000 epoch 2002.74 coordinates have been compared to the original ETRF89 epoch 1991.84 solution. The differences, presented in Table 5. are showing a good internal consistency, the only exception is SATO EUVN site.

In general we may conclude that the HUNREF2002 campaign provided a reliable solution, with very good internal and external consistency (see Figure 2 with the daily repeatabilities and Table 3 with the comparison of the weekly EPN solution, respectively).

Station	X	Y	Z
PENC	4052449.807	1417680.904	4701406.912
OROS	4110947.198	1551048.432	4608009.827
NYIR	3973293.617	1616277.291	4704746.816
ZALA	4183192.381	1266311.177	4629924.338
SATO	3945622.999	1564760.498	4744941.507
CSAR	4224902.764	1390480.232	4556477.591
NADA	4110020.380	1384712.036	4661276.902
SOPR	4125619.031	1230225.944	4690656.126
TISZ	4052514.509	1518151.776	4669875.495
GRAZ	4194424.125	1162702.456	4647245.198
BUCU	4093761.206	2007793.574	4445129.767
UZHL	3907587.793	1602428.479	4763783.566
OSJE	4237753.556	1432791.462	4531310.057
JOZE	3664940.498	1409153.665	5009571.204

Table 4. The transformed ETRF2000 epoch 2002.74 coordinates

Station	dX [mm]	dY [mm]	dZ [mm]	dN [mm]	dE [mm]	dUp [mm]
PENC	49	-12	19	-19	28	42
CSAR	72	- 4	38	-22	26	74
NADA	54	- 3	30	-17	20	56
SOPR	74	- 6	36	-27	27	73
TISZ	62	- 3	31	-21	25	61
SATO	**39**	**-26**	**19**	**7**	**39**	**32**

Table 5. Differences of the 1991 and 2002 realization of the ETR89

4 Implementation of the new solution

Using the newly determined ETRS89 coordinates the EUREF densification network has been re-adjusted and the new text-based and graphical databases have been created. In order to clearly visualise the effect of the coordinate update the new and old values have been compared and a 2D graph of the differences were created (see. Fig.4). On the graph it is clearly seen that the coordinate update corresponds to a rotation, where the rotation axis may lie around WTZR. This could be an indication that an incorrect excentricity value of GRAZ may introduced a bias into the original 1991 solution.

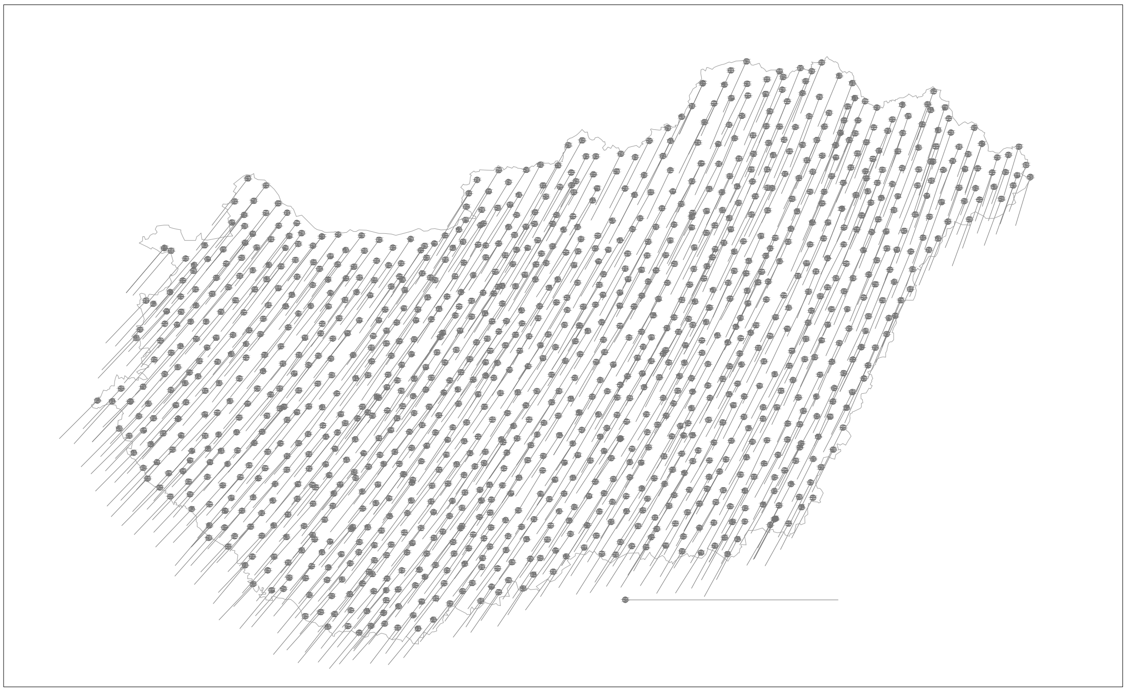

Figure 4. The 2D differences of the original and the new ETRS89 realizations at the OGPSH sites in Hungary.

5 Summary

Due to the changing geometry, role and minor accuracy of the existing Hungarian EUREF subnetwork its unavoidable re-establishment has been performed in 2002. A new, 9-site network has been designed with overlapping of the existing national network and the EPN. A 5-day campaign has been organized in 24-29 September, 2002. The data have been processed according to the EUREF guidelines. Several accuracy and consistency checks have been performed, all tests proved that the new network fits the up-to-date requirements.

The new network is proposed to fully replace the data available at the EUREF database.

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