CROREF-05 GPS campaign - preliminary results

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The CROREF-05 GPS campaign was carried out in September 2005, in order to re-observe EUREF GPS points measured within the framework of SLOCRO-94 EUREF GPS campaign eleven years ago. After the initial idea, the project expanded later by including geodynamics and other national reference GPS points, also observed in several previous campaigns. The project was organized and realised in co-operation of State Geodetic Administration of the Republic of Croatia, Mapping Authority of the Republic of Slovenia and Federal Geodetic Administration of Bosnia and Herzegovina. The field work was performed from September 21st to September 23rd, 2005, consisted of two 24 hour sessions. The GPS network contains 28 points in Croatia, 7 points in Slovenia and 5 points in Bosnia and Herzegovina. Despite CROREF-05 project (Croatian Reference GPS campaign 2005) contains the points in Croatia, in the data analysis and processing the whole set of data was included. The preliminary results for all points including obtained error estimates are presented.

1. Introduction

The EUREF activities in the Republic of Croatia started with the first EUREF-1994 Croatia and Slovenia GPS campaign carried out in order to connect Croatian and Slovenian networks to the EUREF-89 reference network. Fifteen new points were included in this campaign (10 in Croatia and 8 in Slovenia). The observations were performed from May 30 to June 3, 1994. In order to establish reference GPS network in Slovenia, the SLOVENIA-1995 GPS campaign was carried out together with CROREF-1995 GPS campaign in Croatia. The GPS network consists of 47 stations in Slovenia and 14 stations in Croatia. The observations were performed from September 25 to October 2, 1995 in two phases with 3 day observation each. The CROREF-1996 GPS campaign was the second EUREF campaign in Croatia and also GPS campaign to determine the first and second order Croatian reference network. The GPS campaign was observed from August 29 to September 12, 1996. After the re-computation of individual GPS campaigns in three epochs (1994.4, 1995.7 and 1996.7) and analysis of computed results, the combined solution CRO-94/95/96 was computed at the middle epoch 1995.55 (Marjanović and Bačić, 2001). Altogether 105 GPS points were included in the combined solution: 11 IGS points, 1 point in Austria, 5 points in Bosnia and Herzegovina, 78 points in Croatia and 10 points in Slovenia.

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2. GPS observations

The GPS observations within CROREF-05 campagin were performed from September 21 to September 23, 2005 consisted of from two 24 hour sessions. The GPS network contains 28 points in Croatia, 7 points in Slovenia and 5 points in Bosnia and Herzegovina (Table 1, Figure 1). The data were recorded with an elevation cut-off angle of 10 degrees and a sampling rate of 15 seconds.

Table 1: GPS points included in CROREF-05 GPS campaign

IGS reference point	4
IGS control point	5
Bosnia and Herzegovina	5
Croatia	28
Slovenia	7
Σ	49

Figure 1: CROREF-05 GPS campaign

3. Processing strategy

The processing and analysis of the data were performed by the State Geodetic Administration in co-operation with Croatian Geodetic Institute using the Bernese GPS software version 5.0 on Linux PC with respect to the procedures specified by EUREF Technical working group (C.Boucher, Z. Altamimi, 2001) and Bernese GPS software documentation (Rothacher and Mervart, 1996; Hugentobler et al, 2005).

The following principles were applied in the data processing:

- use of final IGS precise orbits with corresponding earth rotation parameters,
- use of JPL Planetary Ephemeris DE200,
- use of ocean loading displacement model,
- for the pre-processing and processing 24 hours of 15-second-interval data were used,
- minimum elevation angle of 10 degrees was used,
- application of antenna elevation-dependent phase center corrections, because different types of antennas were combined,
- QIF ambiguity resolution strategy, approximately 90% of ambiguities were solved,
- correlations modelled correctly,
- free session solutions – computed and saved,
- the normal equations from each processing session were combined using ADDNEQ2 program to compute campaign final solution in ITRF-2000, epoch 2005.72.

The coordinates of the reference IGS points Graz, Matera, Zimmerwald and Wettzell-1202 were used for the computation as fixed points. The official set of coordinates in ITRF-2000 reference frame is given for epoch 1997.0. The coordinates were transformed to the observation epoch 2005.72 by using NUVELL1A-NNR velocities as in computation of previous GPS campaigns and combined solution CRO-94/95/96.

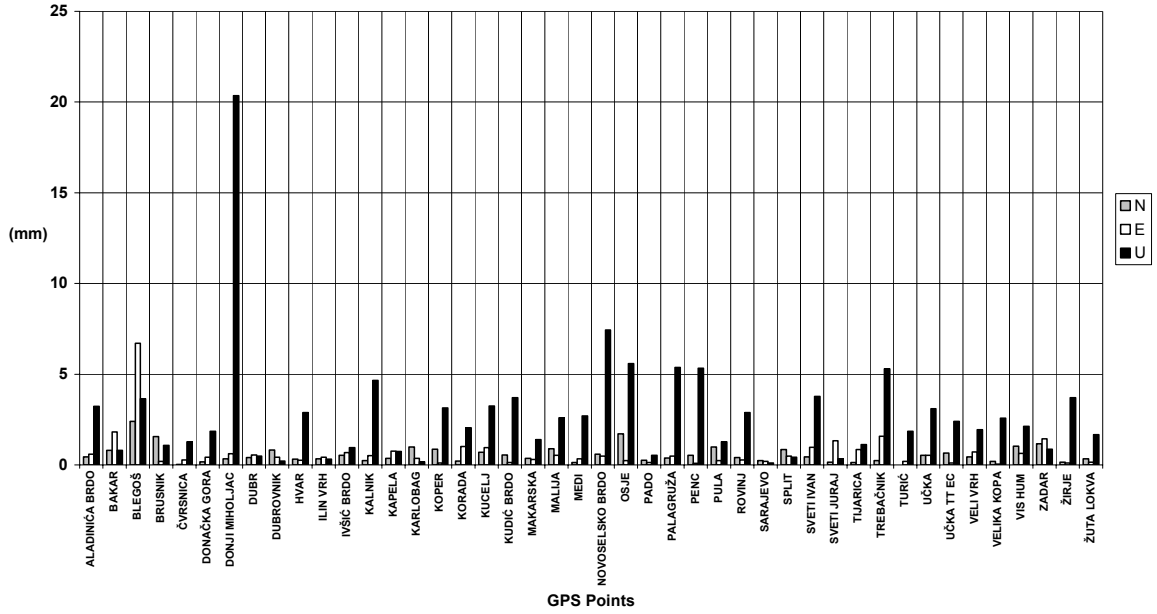
4. Campaign solution

The normal equations from two daily processing solutions computed with GPSEST program were combined using ADDNEQ2 program to get final campaign solution. The results of ADDNEQ2 program printed in output file give also information about the quality and accuracy of campaign solution based on the comparision on individual daily solutions (Figure 2, Table 2). Based on the achieved repeatabilities of daily solutions, the estimated coordinates indicate good quality for all observed points except height component of point DOMI (Donji Miholjac), caused most probably by the vertical movement of GPS antenna mounted on geodetic tripod in soil (heavy rain).

Table 2: Minumum, maximum and mean RMS values (mm)

Values	North	East	Up
Minimum	±0.01	±0.04	±0.10
Maximum	±2.40	±6.69	±20.34
Mean	±0.56	±0.66	±2.75

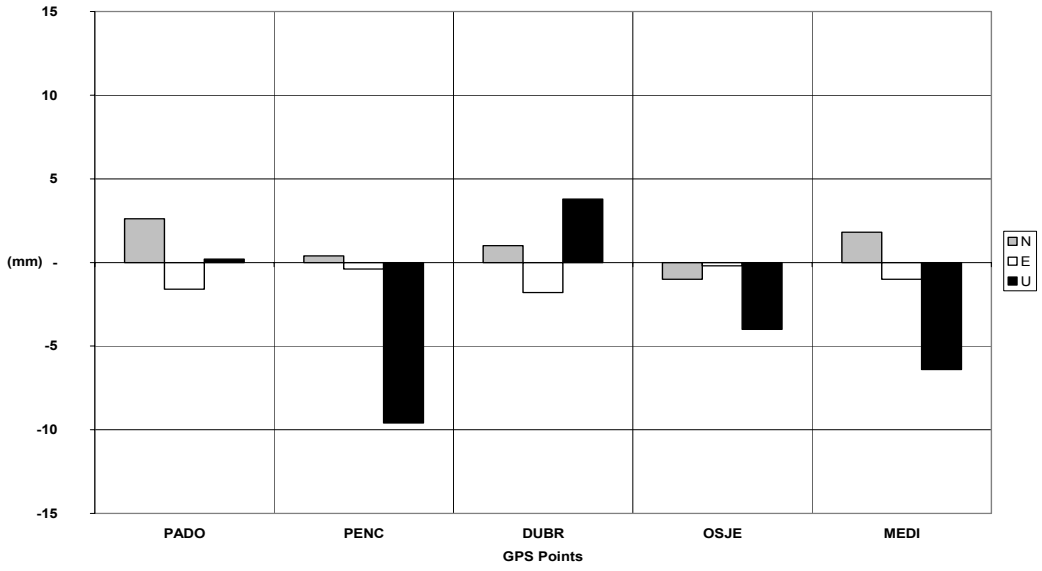
Figure 2: RMS values of comparison of daily solutions for all three components



5. Comparison with EUREF SINEX solution in ITRF system

Just for the comparsion with EUREF SINEX solution for the week 1341 one solution was computed with fixed IGS reference point coordinates transformed into observation epoch by using of ITRF2000 velocites. The results of coordinate comparison of computed IGS control points and EUREF SINEX solution in ITRF-2000, are given in Figure 3.

Figure 3: Differences with EUREF SINEX solution in ITRF system



6. Transformation into ETRF-89

The transformation into the ETRF-89 reference system was done following Specifications for reference frame fixing in the analysis of a EUREF GPS campaign (C.Boucher, Z. Altamimi, 2001):

$$\mathbf{X}\mathrm{e}(\mathrm{t_c}) = \mathbf{X}\mathrm{yy}(\mathrm{t_c}) + \mathbf{T}\mathrm{yy} + \begin{vmatrix} 0 & -R_3\mathrm{yy} & R_2\mathrm{yy} \\ R_3\mathrm{yy} & 0 & -R_1\mathrm{yy} \\ -R_2\mathrm{yy} & R_1\mathrm{yy} & 0 \end{vmatrix} \cdot \mathbf{X}\mathrm{yy}(\mathrm{t_c}) \cdot (\mathrm{t_c} - 1989.0)\,,$$

where

$\mathbf{X}\mathrm{e}(\mathrm{t_c})$	- coordinates in ETRF-89,
$\mathbf{X}\mathrm{yy}(\mathrm{t_c})$	- coordinates in ITRF-2000,
$\mathbf{T}\mathrm{yy}$	- translation parameters (ITRF-2000 to ETRF-89),
$R_i\ \mathrm{yy}$	- rotation parameters (ITRF-2000 to ETRF-89),
$\mathrm{t_c}$	- observation epoch – 2005.72.

7. Comparison with combined solution CRO-94/95/96 in ETRF-89 system

After transformation of the final campaign solution from ITRF-2000, epoch 2005.72 into ETRF-89 system, the coordinates were compared with combined solution CRO-94/95/96 in ETRF-89 system. The results of the coordinate comparison for the observed GPS points are given in Figure 4 and Table 3.

Figure 4: Differences with combined solution CRO-94/95/96 in ETRF89 system

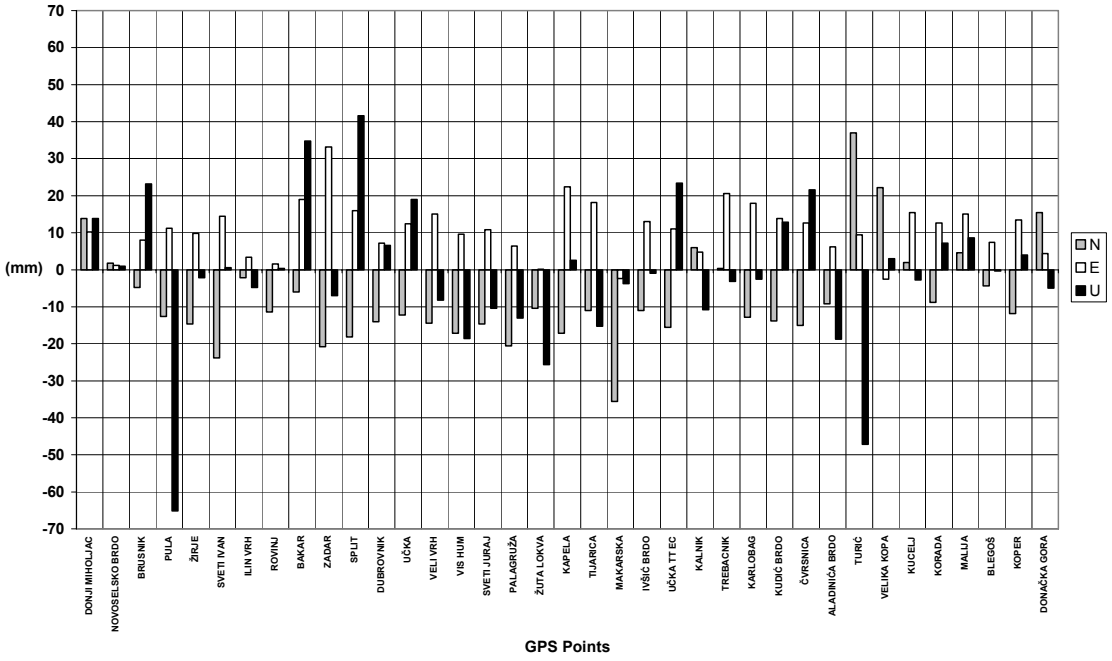


Table 3: Minumum, maximum and mean differences with combined solution CRO-94/95/96 in ETRF-89 (mm)

Values	Difference North	Difference East	Difference Up
Minimum	0.4	0.2	0.4
Maximum	37.0	33.2	65.2
Mean	13.2	11.2	13.2
RMS	±9.3	±8.0	±9.3

Larger differences based on two solutions, CROREF-05 and CRO-94/95/96, could be caused by some movements or by erros due to measurement of antenna height. The reason for such larger differences are not probably geodynamic movements but poor quality of point monumentation. Also, two solutions are based on two different ITRF systems. The CROREF-05 solution is processed and adjusted in ITRF-2000, epoch 2005.72. The computation of CRO-94/95/96 was done in two steps, after the processing of individual GPS campaigns in ITRF-1996 at observation epoch (1994.4, 1995.7 and 1996.7), in order to compute combined solution of all three GPS campaigns at the middle epoch, station velocities were computed on the basis of NUVEL1A-NNR model and used as input values in adjustment process. That means, beside different ITRF system, applied velocity model influenced computed coordinates.

8. Conclusion

The CROREF-05 GPS campaign was carried out to re-observe GPS points in Croatia observed between 1994 and 1998. The expected differences between CROREF-05 solution and combined solution CRO-94/95/96 in ETRF89 system are estimated to be round ±2 cm. After the comparison of coordinates it is obvious that only few points have significant difference greater than expected value. On the basis of the repeatabilities of daily solutions, the estimated coordinates indicate good quality for all observed points except height component of point Donji Miholjac. The possible reason for that could be the vertical movement of GPS antenna mounted on geodetic tripod in soil caused by heavy rain. The accuracy derived from the repeatability of daily solutions amounts to ±0.6 mm in the north component, ±0.7 mm in the east component and ±2.8 mm in the height component.

9. References

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