PRELIMINARY CENTRAL EUROPEAN INTRAPLATE VELOCITIES FROM CEGRN CAMPAIGNS 1994 TO 2005

Ralf Drescher, Matthias Becker, Erik Schoenemann

Institute of Physical Geodesy, Darmstadt University of Technology
64287 Darmstadt, Germany

ABSTRACT

Within the Central Europe Regional Geodynamics Project (CERGOP) for the establishment of a high precision reference frame CEGRN (Central European GPS Geodynamic Reference Network) eight GPS campaign solutions since 1994 are available for velocity estimation. They were used to compute preliminary station velocities in the ITRF2000. This paper reports not only on the results and some comparisons with former solutions published by the CERGOP group but also on the improved options available for velocity estimation with version 5.0 of Bernese GPS Software.

1. INTRODUCTION

As part of CERGOP the GPS campaigns of CEGRN provide the basis for investigating tectonic movements in the region of Central Europe. Observations started in 1994, were repeated yearly up to 1997 and afterwards every two years. The current last campaign was observed in summer 2005. Among other analysis centers the Institute of Physical Geodesy, Darmstadt University of Technology, computed a campaign solution according to the CEGRN rules.

This campaign solution was combined with the previous CEGRN solutions of 1994 to 2003 in order to estimate station velocities. The velocity estimation was computed aligned to given ITRF2000 velocities and coordinates at selected datum sites. The number of stations rose with every campaign. Therefore the combination includes some stations with short time occupation history for the sake of completeness. It is intended as an intermediate solution for quality assessment and strategy development on the way to an official CEGRN velocity combination solution which will be based on the new ITRF2005 and be published later in 2006.

Former results on the velocity and strain field in Central Europe were published e.g. in (Becker et al., 2002, Grenerczy et al., 2005), including observations till 2003 at most.

In addition some new options of the latest version 5.0 of Bernese GPS Software (BSW 5.0), which are valuable for velocity estimation, are introduced.

2. EVALUATION OF CEGRN CAMPAIGN 2005

The CEGRN campaign 2005 was observed from June 20 to 25. It contains 72 official and 20 non-official stations. The outside situated IGS sites Kootwijk, Metsaehoevi, Onsala and Zimmerwald are also included.

The campaign evaluation of Institute of Physical Geodesy (IPG) contains all official stations, the four outside IGS sites and some of the non-official stations. It was computed with new version 5.0 of BSW according to the CEGRN rules (Hefty et al., 2005). The campaign results in form of the SINEX file are the IPG contribution to the common respectively official combination solution for the CEGRN campaign 2005. The latter will be computed by Jan Hefty, chairman of CERGOP work package 5, by a combination of six individual solutions from the CERGOP analysis centers. The IPG evaluation based on BSW 5.0 was found to be in accordance with the other solutions, still based on Bernese 4.2. For the time being it is therefore reasonable to use the IPG evaluation for a preliminary velocity estimation.

3. GENERAL FEATURES OF VELOCITY ESTIMATION WITH BSW5.0

The BSW program for evaluations at normal equation level is now ADDNEQ2. It was already in experimental stage in the previous BSW version 4.2. In ADDNEQ2 the geodetic datum for coordinates and velocities is defined separately by four options. It is possible to compute a completely free solution or to use network constraints. Alternatively single stations can be constrained or fixed. Furthermore the station information file enables the constraining of adjacent stations relatively to each other as well as the renaming or exclusion of stations. Finally – and this is new and especially in our case a beneficial improvement – three dimensional station eccentricities can be defined in the station information file.

4. PRELIMINARY CEGRN VELOCITY ESTIMATION 1994 TO 2005

4.1 SOFTWARE

The velocities were estimated with BSW 5.0 respectively ADDNEQ2. Since the computation was done for the first time with the new software it was for the first time possible to use three dimensional eccentricities. For this purpose it is necessary to rename the eccenter station to center station name in the station information file. Afterwards the numerical values of the eccentricity are introduced under the name of the center station.

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Station information file for CEGRN velocity estimation          11-NOV-05 13:46
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TYPE 001: RENAMING OF STATIONS
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STATION NAME          FLG          FROM                      TO          OLD STATION NAME      REMARK
****************      ***  YYYY MM DD HH MM SS  YYYY MM DD HH MM SS  ********************  *****************
MACI                  001  1999 05 01 00 00 00  1999 07 01 00 00 00  MAC5                  to introduce ecc.
MACI                  001  2005 05 01 00 00 00  2005 07 01 00 00 00  MAC3                  to introduce ecc.
....

TYPE 002: STATION INFORMATION
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STATION NAME          FLG          FROM                      TO          ...    NORTH      EAST       UP      ...
****************      ***  YYYY MM DD HH MM SS  YYYY MM DD HH MM SS        ***.****  ***.****  ***.****
MACI                  001  1999 05 01 00 00 00  1999 07 01 00 00 00          5.3328   22.5311   -0.7569
MACI                  001  2005 05 01 00 00 00  2005 07 01 00 00 00         -1.9798   -9.3088   -1.2488
....

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Fig. 1. Introducing eccentricities with station information file of BSW 5.0 (excerpt)

4.2 INPUT DATA

The velocity estimation is based on the SINEX files of the official combination solutions for the CEGRN campaigns of 1994, 1995, 1996, 1997, 1999, 2001 and 2003. These files are used together with the above described IPG campaign solution for 2005.

4.3 SETTINGS

The geodetic datum is defined by 17 from 22 involved ITRF2000 sites. For the coordinates a not-net-translation condition was used. The ITRF2000 velocities are strongly constrained by a corresponding small a priori standard deviation. This option is necessary since it is otherwise not feasible to constrain coordinate components of single points (see below). For the remaining five ITRF sites and 56 CEGRN stations velocities were estimated. For doing so the height velocity for stations occupied only two times and some other stations, which are critical in height component, is constrained to zero. An own station information file with all known station identities, station eccentricities and relative constraints for adjacent stations was compiled for the velocity estimation.

4.4 RESULTS

The parameter estimation results in velocities (and coordinates) aligned to ITRF2000. Three dimensional velocities were computed for the five ITRF sites not used for datum and for 35 CEGRN stations. Only horizontal velocities were estimated for 21 other CEGRN stations.

Figure 2 shows the ITRF sites used for datum, the other five ITRF sites, the CEGRN stations and their constrained respectively estimated residual velocities with respect to the Eurasian plate, as described by NUVEL-1A plate tectonic model. In Bulgaria the results of a local densification (campaigns in 1993 and 2003) are also plotted. For some very young stations (e.g. LEND and CLUJ) the residual velocity vectors are rather big and the question arises, how many epochs – counted from 2005 backwards – are needed to obtain reliable velocities.

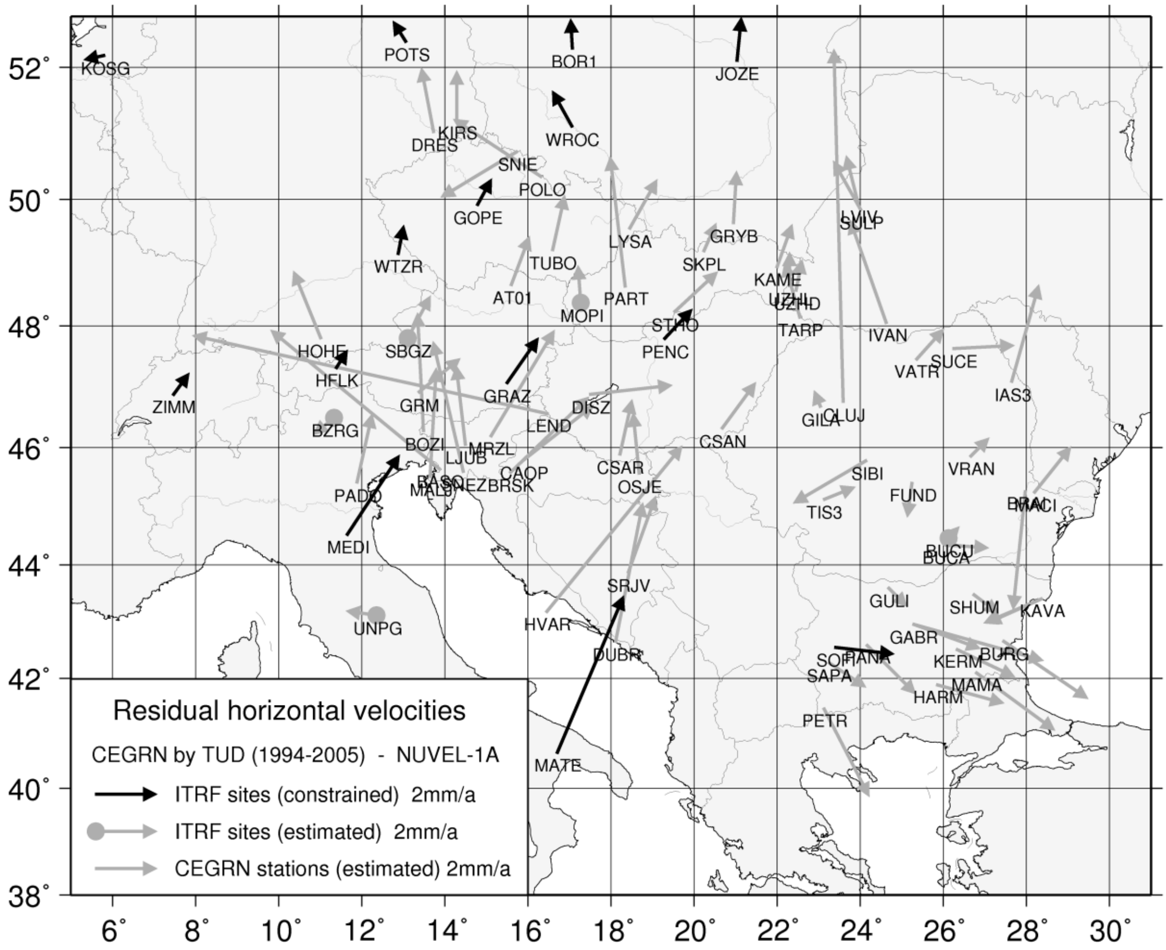

Fig. 2. Estimated horizontal velocities in ITRF2000 minus NUVEL-1A velocities

For this purpose figure 3 presents the estimated velocities in north and east component as function of the number of used epochs for some selected stations, which were observed in all eight campaigns. It becomes clear that it is possible to get correct velocity estimates already from two or three epochs. But in general the usage of at least four epochs (1999 – 2005) is recommendable. A rerun of this empiric analysis with the combination solution for CEGRN campaign 2005 (which is supposed to be better than the single solution of IPG) will perhaps show that three epochs (2001 – 2005) are already sufficient. This relates well to the findings of Lavallee and Blewitt (2002) who determined – although for permanent station time series – the minimum time span of at least 2.5 years for reasonable velocity estimation and a time span of 4.5 years for the reliable averaging out of annual signals. CEGRN campaigns however are not too much affected by annual signals as they are repeated at the same season each time.

Thus the residual horizontal velocities of 42 stations with at least four epochs are plotted in figure 4. They are shown together with properly scaled error ellipses at 2 sigma level. The scaling of the error ellipses from the BSW 5.0 was done by assessment of the formal standard deviation with respect to the standard deviation which is based on the residuals between combination solution and each single campaign. Most of the residual velocities are indicated as significant. However, it should be kept in mind that systematic errors, e.g. caused by centering errors, do not appear (clearly) in estimated standard deviation. Thus the significance should be proved for every single station by screening the above mentioned residuals to detect and eliminate outliers.

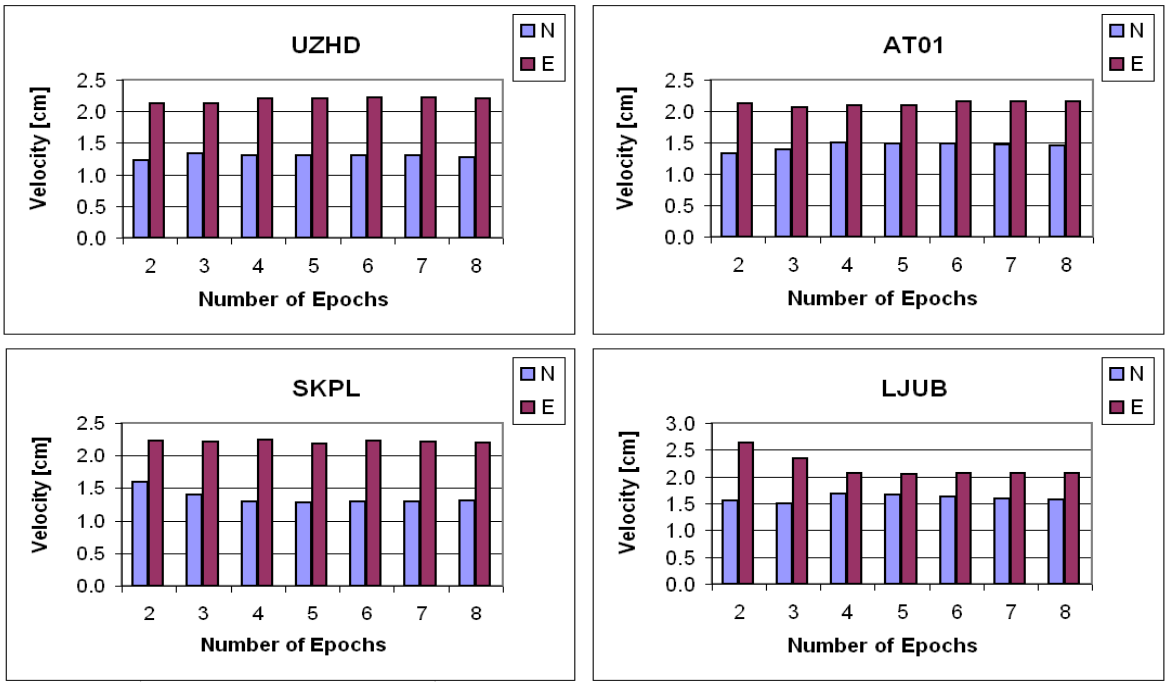

Fig. 3. Estimated velocities as function of used epochs, counted from 2005 backwards

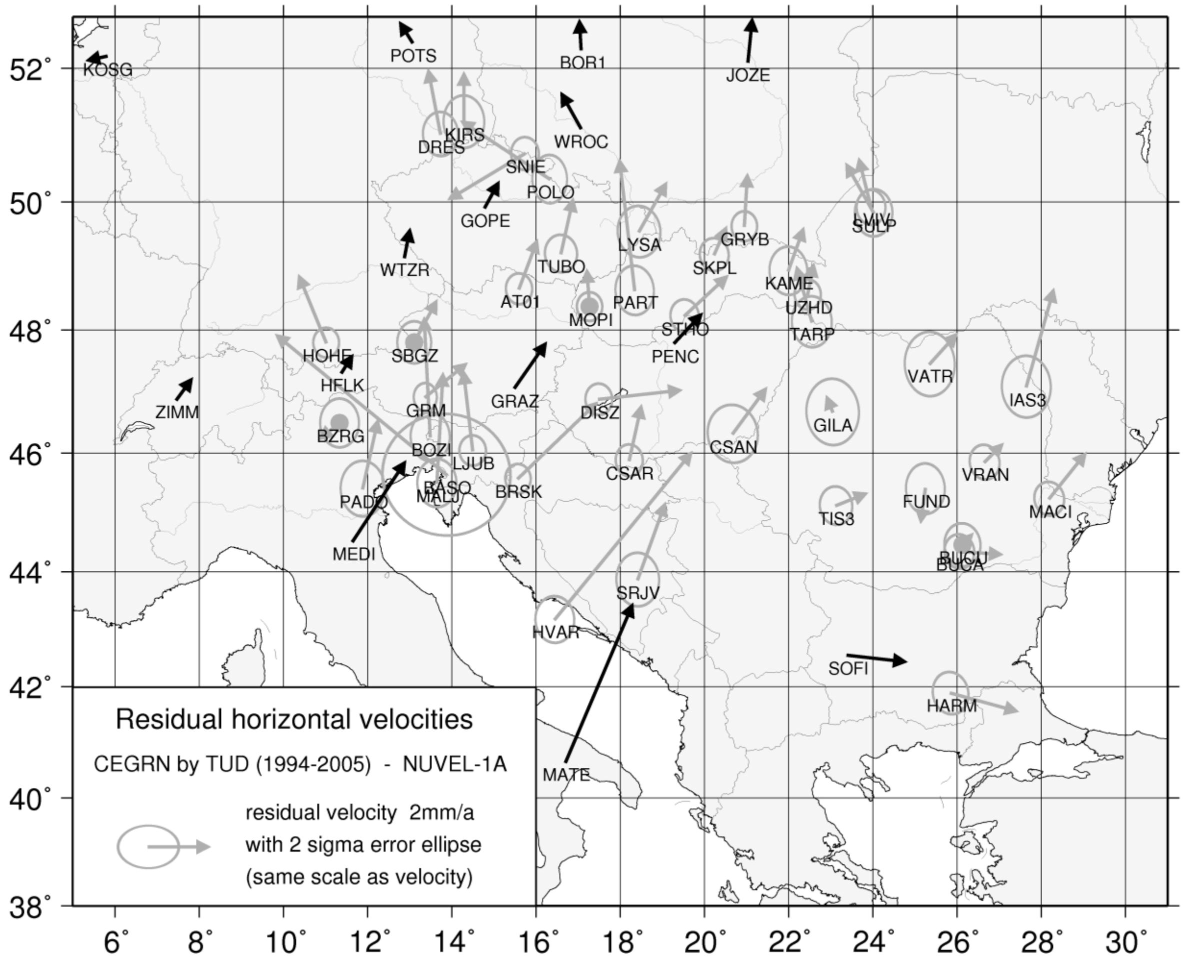

Fig. 4. Estimated horizontal velocities in ITRF2000 minus NUVEL-1A velocities

Table 1 contains the mean values of residual horizontal velocities with respect to NUVEL-1A in north and east component and their standard deviations. These values are consistent with the behavior of the Eurasian ITRF2000 core sites (Altamimi and Boucher, 2001), which can be considered as a general confirmation. It must be emphasized that this general agreement – proven by a mean value – does not eliminate the possibility of intraplate deformations as shown for instance in Grenerczy (2005).

Table 1. Mean values of residual horizontal velocities w.r.t. NUVEL-1A (computed from 42 stations with at least four epochs)

	N [mm]	E [mm]
Mean value of residual velocity	**1.6**	**0.3**
Standard deviation of mean value (1s)	**0.2**	**0.2**

Figure 5 shows the estimated height velocities with 2 sigma error bars, again after appropriate scaling and only for stations with at least four epochs. In general the height changes are not significant. This evaluation is corroborated by the computed mean value and its standard deviation (see table 2).

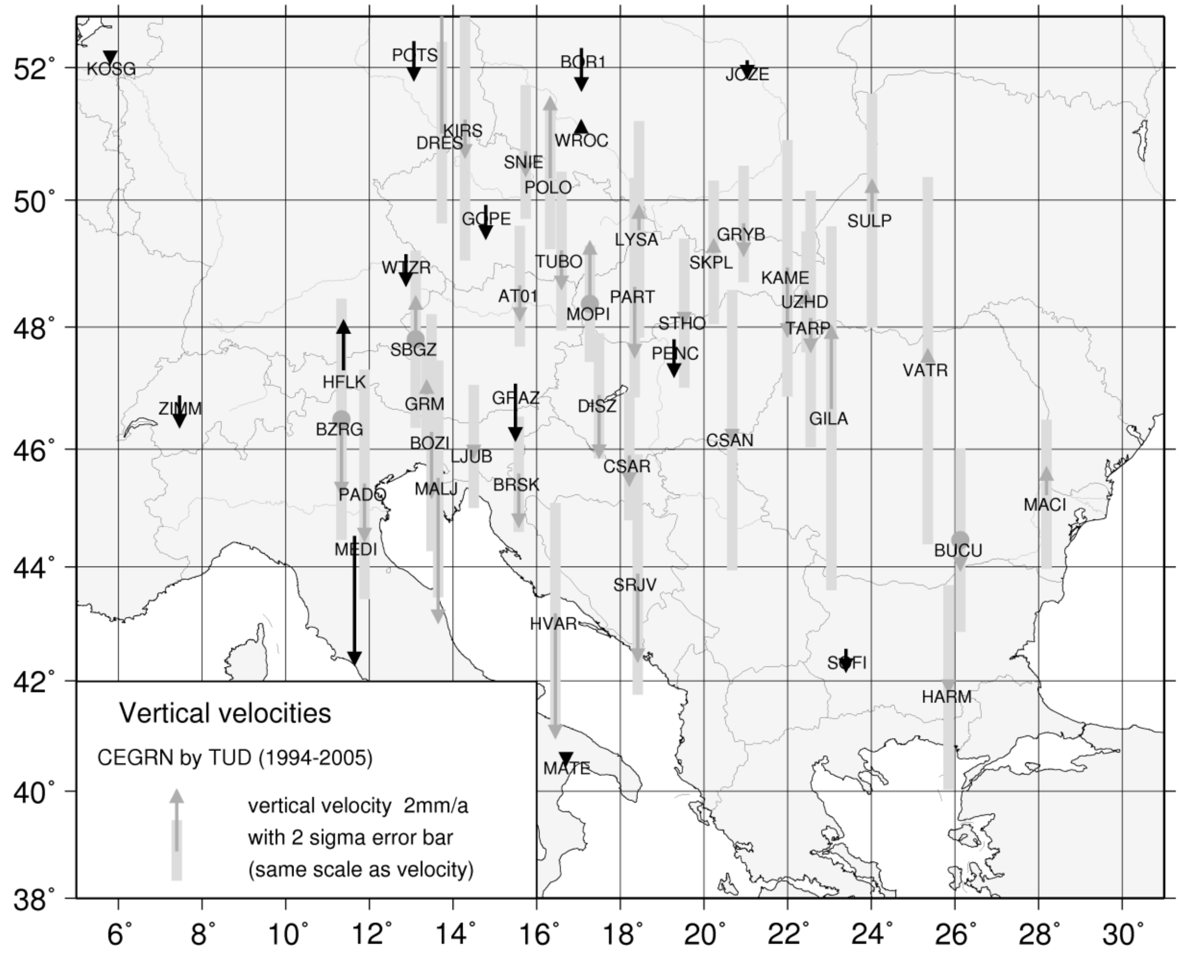

Fig. 5. Estimated vertical velocities in ITRF2000

Table 2. Mean value of estimated vertical velocities (computed from 37 stations with at least four epochs)

	N [mm]
Mean value of vertical velocities	-0.5
Standard deviation of mean value (1s)	0.3

As a further result the velocities for the five ITRF sites, which were not used for defining the geodetic datum, are derived (table 3 and 4).

Table 3. Residual velocities for the five not constrained ITRF sites w.r.t. ITRF2000

Site	N [mm]	E [mm]	U [mm]
BUCU	5	-6	-11
BZRG	-3	-1	-7
MOPI	-1	1	-15
SBGZ	-2	-2	-40
UNPG	-1	-1	-43

Table 4. Residual velocities for the five not constrained ITRF sites w.r.t. NUVEL-1A

Site	N [mm]	E [mm]	U [mm]
BUCU	0	0	-1
BZRG	-1	-1	-3
MOPI	1	0	2
SBGZ	1	1	1
UNPG	0	-1	-1

In contrast to the residual velocities with respect to NUVEL-1A the velocities with respect to ITRF2000 are obviously not realistic. So a problem in the ITRF coordinates, especially in height component, is evident.

Finally the IPG velocity estimation was compared to some other solutions from the CERGOP-partners

- **G. Grenerczy (1991-2004) (Grenerczy et al. 2005)**
- **J. Hefty (CEGRN 1994-2005),**
- **A. Caporali (CEGRN 1994-2003) and to**
- **the last official CEGRN velocity solution 1994-2001 (Becker et al. 2002).**

The first three comparisons indicate in general a very good agreement. The biggest differences arise in Romania. This is reasonable because of the newly applied three dimensional eccentricities there. Due to this reason and the shorter time interval available the consistency compared to the last official CEGRN velocity estimation is worse.

5. CONCLUSION AND OUTLOOK

The CEGRN 2005 GPS campaign was successfully evaluated with Bernese GPS Software version 5.0 and the compatibility to other solutions from BSW 4.2 was shown. A promising preliminary velocity estimation from CEGRN campaigns 1994 to 2005 was done with the new version of Bernese GPS software as well. Additional observations could be used since it was for the first time possible to apply three dimensional eccentricities required at a number of sites due to monument destruction or related station changes. Thus the results for the Romanian stations seem to be improved with respect to previous solutions.

Future work will be a reprocessing with the official combination solution for CEGRN campaign 2005 with respect to the new ITRF2005, which is expected to become available after May 2006. The new velocity estimation will also integrate latest results from the CEGRN permanent GPS stations installed in the last two years and additionally IGS and EPN SINEX files at the respective common epochs.

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