REFERENCE FRAME AND MODEL IMPROVEMENTS IN CEGRN

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ABSTRACT

The CEGRN Consortium decided to reprocess all GPS campaigns according new compiled guidelines. In the contribution these guidelines are introduced. Furthermore it was tested, whether they are also suitable for the first campaigns with their paticularities.

1. INTRODUCTION

The GPS campaigns of Central European GPS Geodynamic Reference Network (CEGRN) provide the basis for investigating tectonic movements in the region of Central Europe. Altogether there are eight campaign solutions from 1994 to 2005 which are all generated by combining the single campaign evaluations of the CEGRN analysis centres. The last (re)processing with unique settings was done in 2002 (Stangl, 2002).

Since then there were some significant changes both in the evaluation software and models and in the reference frames. In this context especially the switch to absolute antenna model and ITRF2005 must be mentioned. Therefore the CEGRN consortium decided to reprocess all campaigns following the new IGS guidelines and procedures.

2. THE CEGRN REPROCESSING GUIDELINES

The most important settings of the CEGRN reprocessing guidelines (see appendix) are:

- **Bernese GPS Software, latest version 5.0 (BSW 5.0)**
- **ITRF2005 coordinates and velocities for the datum sites**
- **no net translation condition in the datum sites**

- **IGS00b orbits and earth orientation parameters (EOP) of Munich/Potsdam – Dresden reprocessing (MDA) (Steigenberger et al., 2006), (IGS, 2007)**
- **absolute antenna calibration values**
- **elevation cut-off 5° and elevation dependent weighting**
- **1 zenith path delay (ZPD) parameter / 1h and 2 gradient parameters / 24h for troposphere modeling at each station**

3. THE ELEVATION PROBLEM

To improve the (decorrelation between ZPD and the) height component it is recommended to choose an elevation cut-off below 10°. In this case it is furthermore recommended to use troposphere gradient parameters. On the other hand the use of low elevation data is essential to estimate reasonable gradients (Dach et al., 2007).

All these recommendations are considered in the CEGRN Reprocessing Guidelines. But there are stations – especially in the early campaigns – with a field elevation cut-off above 10° (Fig. 1). Hence for these stations the estimation of reliable troposphere gradient parameters is not possible. The next and much more important question is, whether the estimated coordinates of these stations are affected thereby?

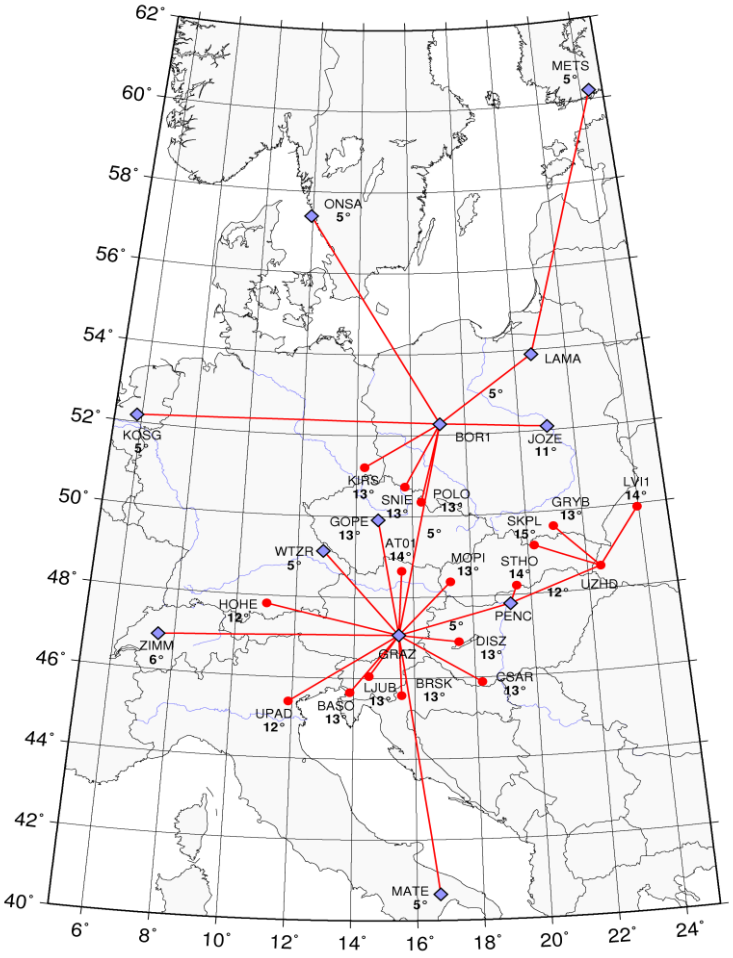

Fig 1. Stations (dot), datum sites (diamond) and formed baselines with elevation of the campaign CEGRN 1994

4. THE EVALUATION VARIANTS

To clarify this question and to investigate the impact of the further developments (orbits and antenna model) several evaluation variants of the first CEGRN campaign in 1994 were done.

From the 2002 evaluation of the 1994 campaign the main settings (Stangl, 2002) and the resulting SINEX file of the combination solution are available. The corresponding coordinates were translated into the datum of the other variants and are called *Solution 0*.

Solution 1 **differs from Solution 0 in the evaluation software (and hence in the internally used models) and in the fact that Solution 0 is a combination of 3 analysis centres (AC).**

Solution 2 **and Solution 1 vary in the used orbits (and EOP).**

Solution 3 **and Solution 2 differ in the antenna model.**

Solution 4 **and Solution 3 vary in the elevation cut-off and in the troposphere modeling. Due to the gradients the main differences are expected in the horizontal component. If they are rather big and elevation dependent the estimated coordinates are probably affected by the elevation problem.**

Solution 4 is representative for the CEGRN reprocessing and the previous solutions can be considered as intermediate steps to it (started from Solution 0 which represents the old processing scheme). The main settings and the precision of all variants are briefly described in table 1.

Table 1. Summary of the settings and results of the evaluation variants

Solution	Software	Orbits and EOP	Datum definition
0	BSW 4.2	ITRF92 (IGS)	originally constraining GRAZ in ITRF97, afterwards translated into the datum definition of the other solutions
1	BSW 5.0	ITRF92 (IGS)	no net translation condition in 12 ITRF2005 datum sites
2	BSW 5.0	IGS00b (MDA)	no net translation condition in 12 ITRF2005 datum sites
3	BSW 5.0	IGS00b (MDA)	no net translation condition in 12 ITRF2005 datum sites
4	BSW 5.0	IGS00b (MDA)	no net translation condition in 12 ITRF2005 datum sites

Solution	Elevation	Troposphere modeling	Antenna calibration	a posteriori RMS of unit weight
0	10°	1 ZPD/h	relative model, radomes not considered	not comparable, because it is a combined solution of 3 AC
1	10°	1 ZPD/h	relative model, radomes considered	1.20 mm
2	10°	1 ZPD/h	relative model, radomes considered	1.11 mm
3	10°	1 ZPD/h	absolute model, radomes considered	1.08 mm
4	5°	1 ZPD/h + Gradients	absolute model, radomes considered	1.07 mm

5. THE RESULTS

The next two figures show the coordinate differences of the evaluation variants in vertical and horizontal component.

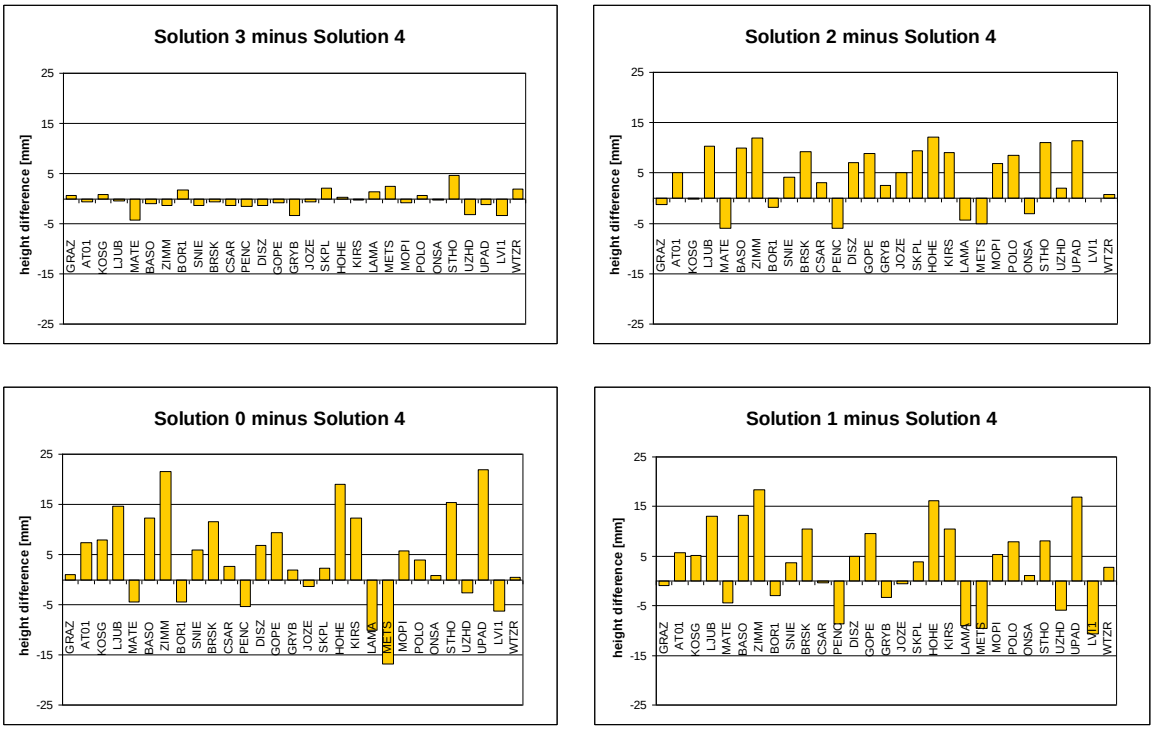

Fig. 2 Vertical coordinate differences: solutions 0 to 3 minus solution 4

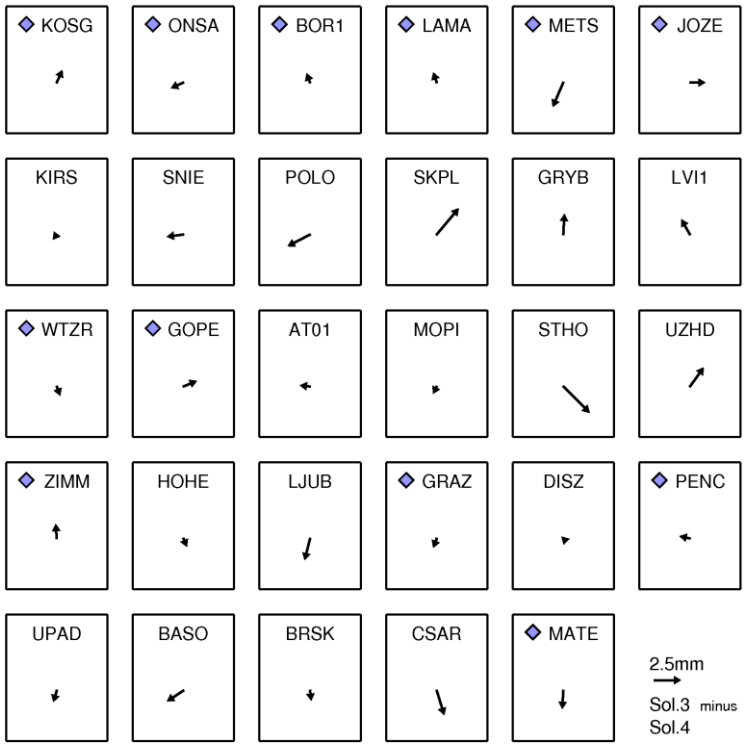

Fig. 3 Horizontal coordinate differences: solution 3 minus solution 4

The results, given in table 1 and the figures 2 and 3, can be described as follows.

The precision, expressed by the a posteriori RMS of unit weight, is considerably raised by the reprocessed MDA orbits (last column in table 1). The switch to absolute antenna model also increases the precision. The changed elevation cut-off and troposphere modeling result in an only small improvement (but in this context it must be considered that only 1/3 of the station really have low elevation data).

The horizontal deviations between Solutions 3 and 4 are shown by the arrows in figure 3. For stations with an elevation of 5° the differences are up to 2.5 mm and 1.2 mm on average. For the other stations with elevations from 11° to 15° they are up to 3.5 mm and 1.6 mm on average. Hence there is an – only small – impact of the elevation problem on the estimated coordinates.

The station heights of the Solutions 0 to 2 are quite similar. There is an obvious disagreement to the Solutions 3 and 4 which have also similar heights (Fig. 2). This behaviour is plausible since antenna model changes influence first and foremost the height component.

6. SUMMARY AND CONCLUSIONS

The most important findings of the analyses are:

- **The elevation problem does not cause coordinate blunders.**
- **The orbits of Munich/Potsdam – Dresden reprocessing result in a clear decrease of the a posteriori RMS of about 10%.**
- **The absolute antenna model leads to a further precision gain and to significant height changes (up to 13 mm).**

REFERENCES

Stangl, G. (2002): Creating a common CEGRN solution – the rules behind. Reports on Geodesy No. 1 (61), 2002, Warsaw, pp. 23-25.

Steigenberger et al. (2006): Reprocessing of a global GPS network, Journal of Geophysical Research, Vol. 111, B05402.

IGSMail Nr. 5558 (2007): http://igscb.jpl.nasa.gov/mail/igsmail/2007/maillist.html

Dach, R., Hugentobler, U., Fridez, P., Meindl, M. (2007): User Manual of the Bernese GPS Software Version 5.0.

APPENDIX

Version 1.3 of Guidelines for CEGRN Reprocessing (state 07.05.2007)

1. General Options

- Recommended software: BSW5.0
- Daily intervals (0-24h)
- Use of IGS00b orbits and corresponding EOP of Munich/Potsdam Dresden Reprocessing[4]
- Outside IGS sites have to be included (ONSA, ZIMM, KOSG, METS, MATE)
- TRP a priori model and mapping function: dry Niell model with dry Niell mapping function
- Estimation of zenith path delay (ZPD), see 2.
- Mapping function for estimation of ZPD: wet Niell
- Elevation dependent weighting
- Fixing of ambiguities
- The choice of baseline geometry and method of ambiguity fixing is in the responsibility of analysis centers
- The a priori site coordinates should be at accuracy of some centimetres (necessary for reliable ZPD estimates).
- Absolute PCO/PCV should be taken from
  a) if available: individual values (from EPN file), otherwise:
  b) if available: type mean values from Geo++ company, otherwise:
  c) igs05_1402.atx
  Darmstadt University of Technology compiled a corresponding ATX resp. BSW5.0 file which is official for the CEGRN reprocessing.
- Elevation ≥ 5° [1]
- Processing of all sites for each campaign (available RINEX files at OLG server), limitation to official CEGRN sites during combination (in case of hardware and/or software capacity problems however, limitation to official CEGRN sites is possible).
- Use of the EPN station information file (*.STA [3]**)** supplemented with CEGRN station information (available at http://cergops2.iwf.oeaw.ac.at/CEGprojresult.html)

2. Options related to processing steps

A processing up to and including ambiguity fixing

B last run GPSEST with fixed ambiguities

C campaign solution with ADDNEQ2

A [2]	- ITRF2005 at mean time of campaign (ITRF2005 CRD and VEL) - official CEGRN PCO/PCV file [3] - orbits and EOP in IGS00b frame [4]
B	- ITRF2005 at mean time of campaign (ITRF2005 CRD and VEL) - official CEGRN PCO/PCV file [3] - orbits and EOP in IGS00b frame [4] - constraining of JOZE (0.1mm in X,Y,Z) - ocean loading corrections, FES2004 [3] - sampling rate of 180 sec - correlations correctly modelled - estimation of hourly zenith delays (a priori sigma 5.0m/5.0m) - estimation of TRP gradients [1] (1pair/24h, Tilting, a priori sigma 5.0m/5.0m)
C	- ITRF2005 at mean time of campaign (ITRF2005 CRD and VEL) - minimum constraint solution (no net translation condition) at selected sites which are part of all campaigns: BOR1 GRAZ JOZE KOSG LAMA METS ONSA PENC ZIMM WTZR MATE GOPE

[1] From theoretical point of view the elevation cut-off 5° in combination with estimation of ZPD gradients is critical for stations with a higher elevation cut-off field setting. According to some corresponding trials made at OLG there is in fact no significant impact on the estimated coordinates.

[2] Nevertheless previous results according guidelines, version 1.0 can be used

[3] Corresponding files are available at the server

[4] The products of Potsdam Dresden Reprocessing (orbits, EOP and SAT_YYYY.CRX) are publicly available. See IGS mail 5558 or EUREF mail 3185 for more information.

3. Inclusion of additional sites

Although their status in CEGRN is not finally clarified, as well the IGS/EPN sites GLSV, ORID, GSR1, BOGO, KRAW, MIKL as CAOP (2001-2005) and PUGS (2003-2005) should be included. The RINEX files of these stations should already be on the OLG server in the campaign directories.

4. Outlier elimination

- If there is one clear outlier (10 mm in North/East, 20 mm in height) in the campaign solution, the station can simply be eliminated for this day.
- If there is a station with obvious problems at several days, a more sophisticated strategy should be chosen. One possibility is a refinement of the formed baselines. A second option is a phase outlier elimination in the pre-processing (save Residuals, RESRMS and SATMARK). As the number of excluded observations depends on the set phase outlier limit, it must be chosen reasonable.

5. Delivery of results

For each campaign daily results and a combination solution are requested.

a) Daily results:

- TRO

b) ADDNEQ2 campaign solution (according 2. C) with TRP gradients, without TRP ZPD (pre-elimination after_stacking or in case of software capacity problems except_for_boundaries):

- STA, ADDNEQ2.OUT
- CRD, COV (w.r.t CRDs)
- SNX, NQ0

The results should be delivered to Günter Stangl, Graz (guenter.stangl@oeaw.ac.at) until October 2007