On computation of a homogeneous coordinate time series for the EPN network

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Abstract. Analysis of the official EPN (European reference GPS network) weekly solution series reveals some jumps and systematic seasonal errors caused by fiducial processing strategy and periodical changes in the reference coordinate system, which make it impossible to use official EPN solution for geodynamical investigations. In the present investigation an attempt to compute a homogeneous EPN coordinate time series for all participated stations for period of observations beginning from GPS week 834 is made. Comparison of this series with other EPN solutions is performed including comparison with our previous two-year solution for selected EPN stations obtained from re-processing of the original observations. Results of comparison show that solution based on non-fiducial strategy is most likely free of seasonal errors. It is planned to compute a new EPN combined solution starting with individual solutions submitted by the EPN Analysis Centers.

Keywords. GPS, EPN, European geodynamics, crustal deformations

1 Introduction

GPS observations collected from the European permanent GPS network (EPN) provide unique opportunity for investigation of crustal deformations in Europe. However, analysis of the official EPN weekly solution series reveals some jumps and systematic seasonal errors, especially in the height component. We suspect that the standard fiducial processing strategy used in EPN processing causes these errors due to distortion of coordinate system caused by errors in modeling of movement of fiducial stations if more than one fiducial station is used with tight constraint. Errors in coordinates of fiducial stations, peculiar station motion, local displacements, equipment change, etc. may result in errors distributed over the whole processed network. This distortion will increase towards the edges of the network, especially if fiducial stations are concentrated near the center of the network. Besides periodical changes in the set of fiducial stations make it impossible to use the official EPN solution for investigation of station movement for the whole period of observations, see e.g. Lanotte et al. (1999).

The EPN CB computes another solution that provides a much more stable coordinate time series suitable for geodynamical researches. Unfortunately, it is not distributed in SINEX files, but only in graphical form at the EPN CB web site. This makes it impossible to use this solution in scientific investigations.

In the present investigation, an attempt to compute a homogeneous EPN coordinate time series for all participated stations for whole period of observations beginning from GPS week 834 (epoch 1996.0) using non-fiducial strategy is made.

Obtained coordinate time series was compared with other EPN solutions including comparison with our previous two-year solution for selected EPN stations obtained from re-processing of the original observations. Results of comparison show that solution based on non-fiducial strategy is most likely free of seasonal errors.

2 Project overview

A special project of re-processing the EPN observations with goal to compute an independent coordinate time series for all participating stations for the whole period of observations has been running at the Institute of Applied Astronomy during last two years.

The basis of this project is using non-fiducial (free network) strategy for computation of station coordinates. This strategy has some evident advantages:

1. Such a solution does not cause a distortion of the network.
2. More stations can be used for orientation of a network which makes final orientation of the solution more reliable and dependant to a lesser degree on unmodelled errors in coordinates of fiducial stations.
3. Such a solution can be easily transformed to any reference system and re-transformed to another one using a much simpler procedure than that needed for removing constraints.

Basic theoretical background of using non-fiducial approach to processing GPS networks can be found in Blewitt et al. (1992), Heflin et al. (1992), Zumberge et al. (1997), Dong et al. (1998), Malkin and Voinov (2001). This strategy was successfully tested during processing of the Baltic Sea Level 1993 and 1997 GPS campaigns (Springer and Malkin (1995), Voinov and Malkin, (1999)).

At the first stage of the project we re-processed original GPS observations for selected EPN subnetwork. That processing was made in three steps:

1. Computation of a daily free network solution based on the IGS final orbits and EOP.

2. Computation of a weekly free network solution by averaging of the daily solutions after Helmert transformation to one of the combined days.

3. Transformation of weekly free network solution to ITRF97. (Two modes were explored here: using nine fiducial stations, or using all stations present in the weekly solution. A preliminary conclusion is that the latter strategy provides more stable result.)

The results presented in Voinov and Malkin (1999) showed that non-fiducial strategy provides more stable results in sense of random and systematic errors. Hereafter this series is referred to as "I1".

Unfortunately, this way of computation of coordinate time series requires too much resources and it is very difficult to re-process all EPN observations in such a way. Besides, we faced a problem of obtaining original observations. For these reasons we are trying another way to compute coordinate time series based on reprocessing of existing EPN individual and combined solutions.

So, the second stage of our work is re-processing of available combined EPN solutions. Results of this computation are presented below.

The third stage of the project is planned for the nearest months. We plan to compute a new independent EPN combined solution based on three step approach:

1. Removing the Analysis Center specific constraints when necessary.

2. Computation of a weekly free network solution by averaging of the transformed individual solutions after a 7-parameter Helmert transformation to ITRF2000.

3. Final orientation of the weekly solution w.r.t. ITRF2000.

3 Processing strategy

In the present investigation we used weekly EPN solutions computed at the Bundesamt für Kartographie und Geodäsie, Germany (early at the Center for Orbit Determination in Europe, Astronomical Institute of the University of Bern, Switzerland) and distributed as SINEX files. Hereafter this solution is referred to as "E".

Our processing was made in two steps. At the first one EUR solutions given in SINEX format were deconstrained using algorithms described in Brockmann (1996). Interesting investigation of accuracy of this procedure was made in Mareyen and Becker (2000). After this step we obtained coordinate time series of weekly non-fiducial solutions nearly free of distortion caused by tight constraints.

Next step was to transform free network solutions to ITRF2000. Two solutions were computed: with 6 and 7-parameter Helmert transformation. Time series of transformation parameters are shown in Figures 1 and 2. Solution obtained with 6-parameter transformation is hereafter referred to as "I2", solution obtained with 7-parameter transformation is referred to as "I3".

4 Comparison and conclusions

Comparison of three IAA coordinate time series is shown in Figures 3-6 and Table 1. One can see that all series provide determination of main details in behavior of station position. They are similar to EPN CB solution computed for geodynamical investigations.

Table 1 contains results of determination of week-to-week repeatability (Allan variance) interpreted as random error and amplitude of seasonal term in variation of station coordinates in local ENU system. Comparison shows that I3 solution obtained using 7-parameter Helmert transformation from free weekly solutions to ITRF2000 provides minimum random error and seasonal variations. Of course, the latter may mean merely loss of geophysical signal, but comparison with EPN CB series (available at the EPN Web site) and global solutions shows that that most likely seasonal terms observed in the EPN solution is caused by systematic errors induced by errors in modeling of position of fiducial stations.

Evidently, more thorough consideration should be made to make a choice between using 6 or 7-parameter Helmert transformation of free network solution to ITRF. The first impression is that it is more reasonable to apply 6-parameter transformation to a global network, whereas 7-parameter transformation is more adequate to regional data. This problem will be investigated in more detail after computation of the solution based on new combination of individual solutions provided by the EPN analysis centers.

EPN coordinate time series described in this work is used in comparison of variations of baselengths obtained with GPS and VLBI (Malkin et al. (2001)), which showed a good agreement between two techniques.

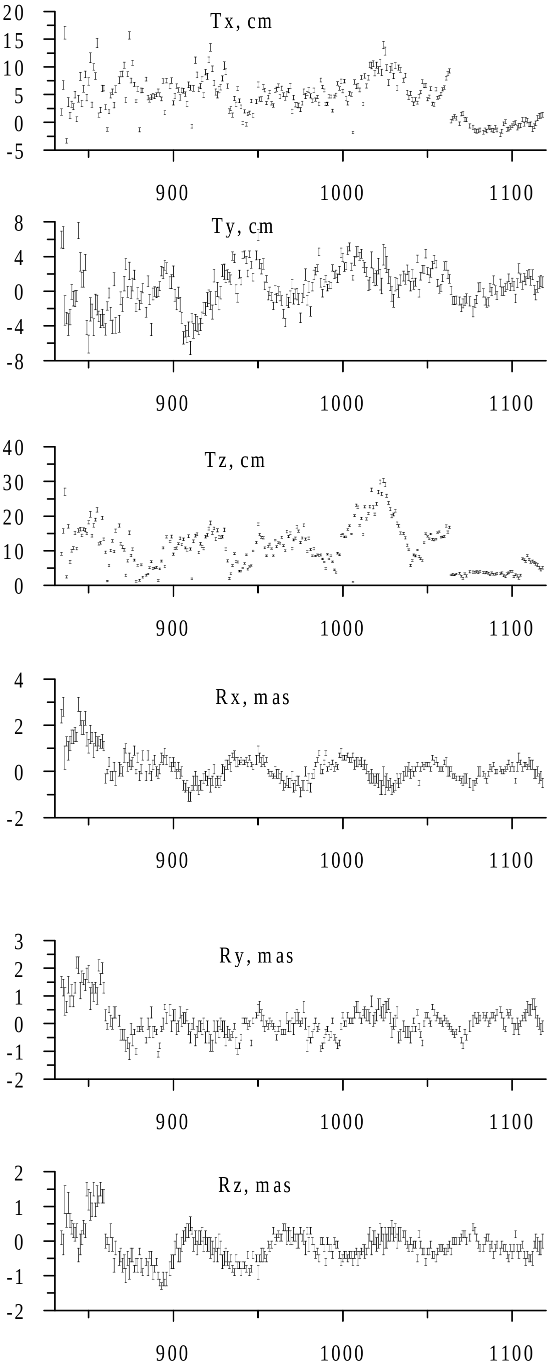

Fig. 1 Time series of transformation parameters between free weekly solutions and ITRF2000 for 6-parameter transformation (R – rotation parameters, T – translation parameters).

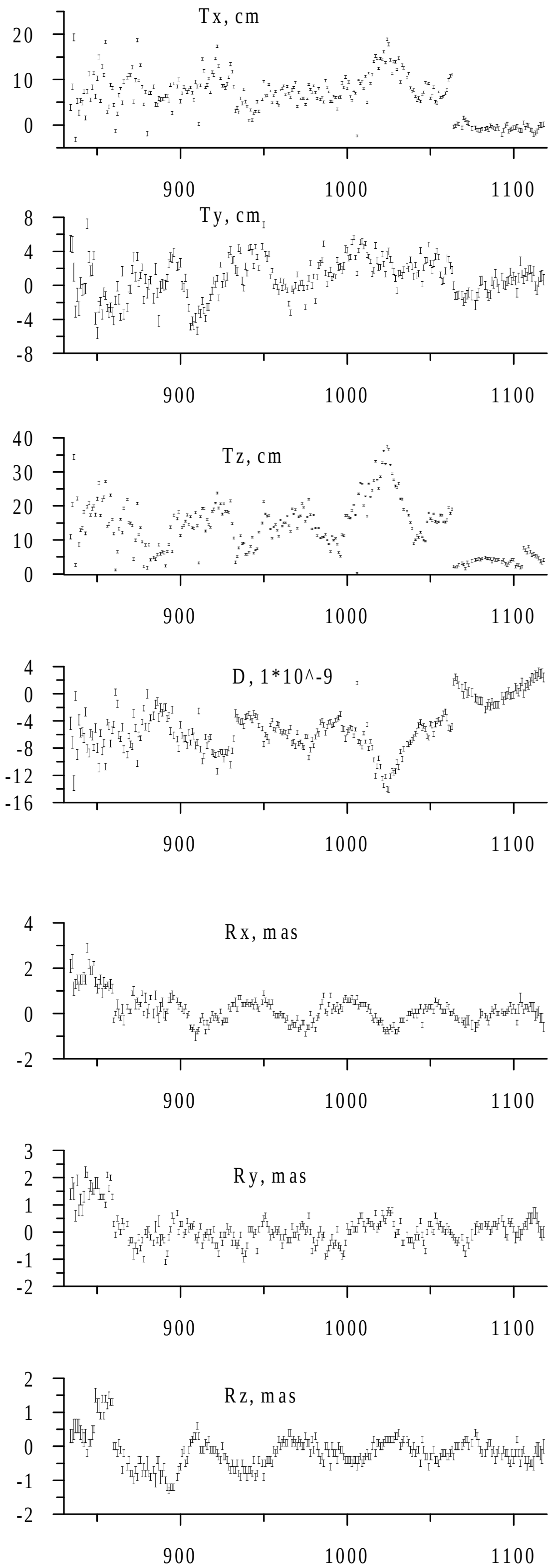

Fig. 2 Time series of parameters for 7-parameter transformation between free weekly solutions and ITRF2000 (R – rotation parameters, T – translation parameters, D–scale parameter).

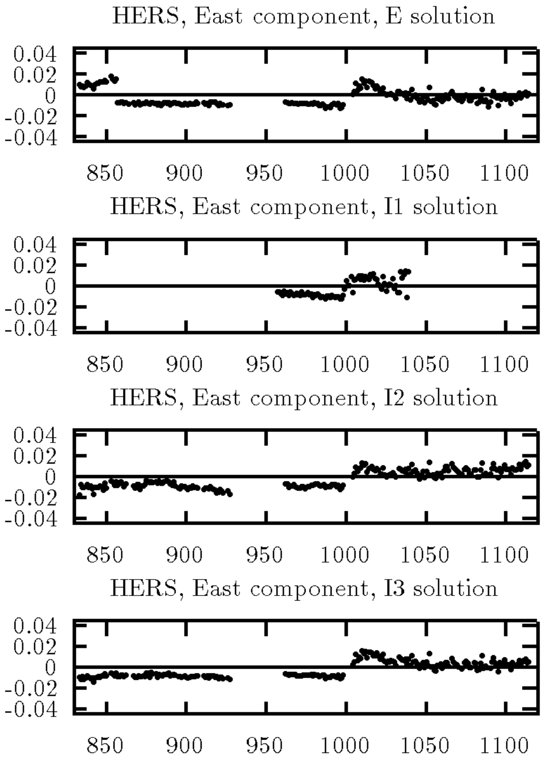

Fig. 3 Comparison of four solutions for HERS.

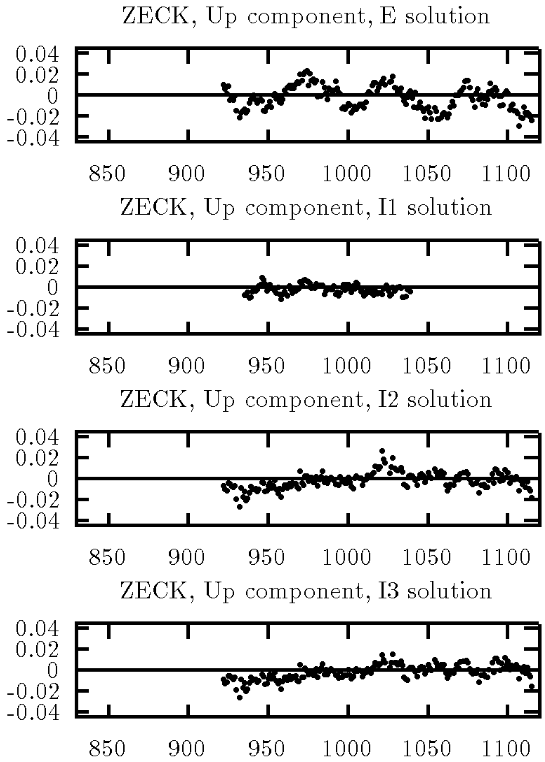

Fig. 5 Comparison of four solutions for ZECK.

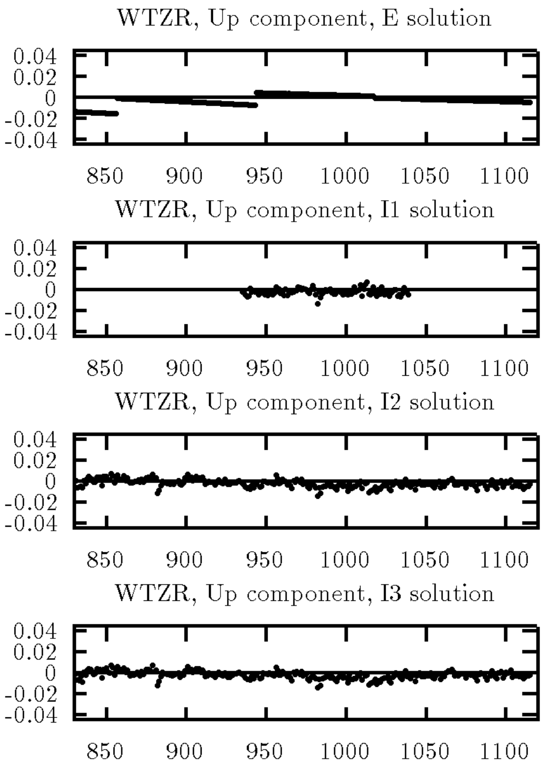

Fig. 4 Comparison of four solutions for WTZR.

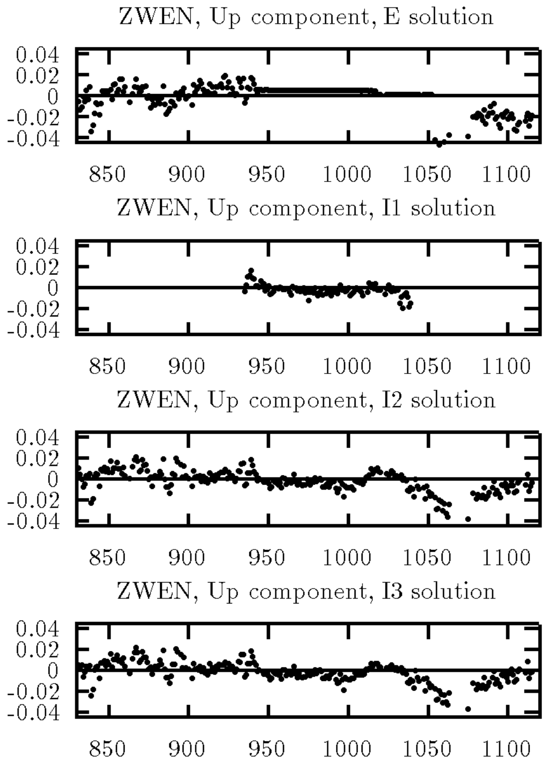

Fig. 6 Comparison of four solutions for ZWEN.

Table 1. Statistics for 10 non-fiducial stations common for all compared solutions.

Station		Allan variance, mm				Annual term, mm			
		E	I1	I2	I3	E	I1	I2	I3
GLSV	dE	1.2	1.2	2.0	1.6	1.0	0.6	5.7	1.2
	dN	1.1	1.1	1.1	1.3	1.7	1.4	1.7	1.3
	dH	3.7	3.0	2.4	2.0	7.0	3.5	3.5	2.7
JOZE	dE	0.9	0.9	1.0	1.8	0.7	0.9	1.5	0.5
	dN	0.8	0.8	0.8	0.8	0.9	0.4	0.3	0.5
	dH	3.1	2.9	2.5	1.9	3.7	1.6	0.9	1.3
LAMA	dE	1.2	1.1	1.1	1.5	0.4	0.4	2.3	0.4
	dN	0.9	0.9	0.9	1.0	0.3	0.7	1.1	0.7
	dH	2.9	3.0	2.0	1.6	5.6	2.8	2.5	1.9
MDVO	dE	1.5	1.4	2.2	2.5	0.3	0.6	5.2	0.2
	dN	1.1	1.3	1.1	2.3	0.5	1.0	0.8	1.0
	dH	5.6	5.1	5.4	4.3	6.6	6.4	1.2	1.3
MEDI	dE	1.8	1.7	2.0	3.2	1.9	1.8	1.6	1.8
	dN	2.4	2.6	2.5	2.0	1.9	2.2	1.4	3.4
	dH	2.7	2.8	2.7	1.8	3.3	1.7	2.0	1.3
METS	dE	1.1	1.3	1.4	1.8	2.2	0.3	2.8	0.5
	dN	1.8	1.9	2.0	1.2	2.6	1.6	2.9	1.1
	dH	4.0	3.5	2.9	2.8	4.9	0.9	3.5	3.0
NOTO	dE	1.2	1.4	1.1	2.1	1.1	0.8	1.4	0.9
	dN	1.3	1.5	2.2	1.0	3.0	0.9	7.5	1.7
	dH	3.0	4.7	2.7	2.0	2.2	4.1	2.3	3.1
SVTL	dE	1.3	1.7	1.8	1.9	1.1	1.1	4.2	0.7
	dN	1.0	1.2	1.3	1.2	1.0	0.6	2.7	0.5
	dH	4.4	3.2	3.4	3.0	6.9	1.9	2.6	1.9
WSRT	dE	0.6	0.9	0.8	1.3	0.4	0.6	0.9	0.1
	dN	0.8	1.1	0.9	0.7	0.3	0.6	0.9	0.6
	dH	2.3	2.7	1.9	1.6	1.0	2.1	2.0	2.3
ZECK	dE	1.4	1.5	2.6	2.1	2.1	0.6	7.8	2.4
	dN	1.4	1.7	2.0	1.7	1.2	1.0	5.0	1.9
	dH	3.8	2.6	3.8	2.8	11.8	0.5	5.3	3.2
Mean	dE	1.3	1.6	1.6	2.0	1.6	1.2	3.3	0.9
	dN	1.2	1.5	1.5	1.2	1.4	1.1	2.4	1.3
	dH	3.5	3.5	3.0	2.9	5.0	2.6	2.6	2.2

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References

Blewitt, G., M. Heflin, W. Bertiger, F. Webb, U Lindqwister, and R. Malla,(1992). Global Coordinates With Centimeter Accuracy In The International Terrestrial Reference Frame Using The Global Positioning System, *Geophys. Res. Lett*., 19, pp. 853-856.

Brockmann, E., Combination of Solutions for Geodetic and Geodynamic Applications of the Global Positioning System (GPS) (1996). Ph.D. Dissertation.

Dong, D., T.A. Herring, R.W. King (1998). Estimating Regional Deformation from a Combination of Space and Terrestrial Geodetic Data. *Journal of Geodesy*, 72, pp. 200-214.

Heflin, M. B., W.I. Bertiger, G. Blewitt, G., Freedman,~A., Hurst, K., S.M. Lichten, U. Lindqwister, Y. Vigue, F. Webb, T. Yunck, and J. Zumberge (1992). Global Geodesy Using GPS Without Fiducial Sites, *Geophys. Res. Lett*., 19, pp. 131--134.

Lanotte R., C. Ferraro, A. Nardi, C. Sciarretta, and F. Vespe. The CGS VLBI EUR98 Geodetic Solution and Comparison with the CGS GPS Results (1999). In: W. Schlueter, H. Hase (eds.) Proc. 13th Working Meeting on European VLBI for Geodesy and Astrometry, Viechtach/Wettzell, Feb 12-13, 1999, pp. 101-107.

Malkin, Z., N. Panafidina, and E. Skurikhina (2001). Comparison of Baselengths of European Stations Derived from VLBI and GPS Observations. *All-Russian Astronomical Conference, St.Petersburg, 6-12 Aug 2001*.

Malkin, Z.M., and A.V. Voinov (2001). Preliminary Results of Processing EPN Network Observations Using a Non-Fiducial Strategy. Phys. Chem. Earth (A), 26, pp. 579-583.

Mareyen, M., and M. Becker (2000). On the removal of a priori restrictions from GPS network solution in a SINEX format. *Algemeine Vermessungs-Nachrichten*, 11-12, pp. 405-411.

Springer, T.A., and Z.M. Malkin, Analysis of the Baltic Sea Level 1993 GPS Campaign (1995). In: J. Kakkuri (ed.), Campaign. *Rep. Finn. Geod. Inst*., 95:2, pp. 87-104.

Voinov, A.V., and Z.M. Malkin, Preliminary Results of the BSL 1993 and 1997 GPS Campaigns (1999). In: M. Poutanen, J. Kakkuri (eds.), Final results of the Baltic Sea Level 1997 GPS Campaign. *Rep. Finn. Geod. Inst*., 99:4, pp. 51--68.

Zumberge, J., M. Heflin, D. Jefferson, M. Watkins,, and F. Webb (1997). Precise Point Positioning for the Efficient and Robust Analysis of GPS Data from Large Networks, *J. Geophys. Res*., 102, pp. 5005—5017.