EUREF Activities at the CODE EUREF Combination Center

D. INEICHEN [*], T. SPRINGER [†]

Introduction

CODE, the Center for Orbit Determination in Europe, is involved in processing data of the EUREF permanent GPS network in the following ways: On the one hand CODE is one out of 12 EUREF LACs (Local Analysis Centers) which are delivering subnetwork solutions of the EUREF permanent GPS network on a weekly basis. On the other hand CODE acts as EUREF Combination Center and is therefore responsible for combining the delivered solutions of the individual LACs into one official weekly EUREF solution. In addition, EUREF contributes to the realizations of the ITRF (International Terrestrial Frame): multi-year solutions based on all available weekly solutions were submitted to the IERS (International Earth Rotation Service) for the realization of ITRF 96 and ITRF 97. The activities of CODE in connection with it's role as EUREF's combination center is subject of this paper.

Weekly EUREF Solution

Starting from the beginning of 1996, the weekly subnetwork solutions of the EUREF LACs, given in the Solution-INdependent EXchange format (SINEX, see Kouba et al., 1996), are combined into the official weekly EUREF solution. In the combination procedure the SINEX files of the subnetwork solutions are transferred into Bernese format (Rothacher et al., 1996), the primarily applied constraints are removed, and the covariance matrices are rescaled. After stacking the normal equation matrices new constraints are applied to tie the solution to the Terrestrial Reference Frame, at present ITRF 97.

Two different solutions are generated each week:

- A free network solution: well suited to detect problems within the combined solution and to check the consistency of the subnetwork solutions.
- A solution tightly constrained to the Terrestrial Reference Frame: the official weekly EUREF solution.

In addition, the most recent weekly solution is combined with the solutions of the previous six weeks. This comparison gives an insight into the behaviour of the individual sites over a time period of almost two months and provides a measure of the inner consistency of the weekly solutions. The coordinate repeatabilities of this combination are below 2 mm for the north and east component and below 5 mm for the height component.

Since August 1, 1999 (GPS week 1021), the official EUREF combined solution is tied to the ITRF 97 (formerly to ITRF 96). The following sites were selected for the realization of the new reference frame: BOR1, GRAZ, KOSG, MATE, ONSA, POTS, REYK, WTZR, ZWEN, VILL, GRAS NYA1, TRO1, THU1. These stations are tightly constrained (0.1 mm) to their official ITRF 97 coordinates and velocities. More detailed information about the combination scheme may be found in (Bruyninx et al., 1997).

The SINEX files of the weekly EUREF solutions are publicly available at CDDIS (Global IGS Data Center), BKG (EUREF Data Center), and ROB (EUREF Central Bureau).

Multi-Year EUREF Solution

The EUREF permanent GPS network is contributing to the realization of the International Terrestrial Reference Frame (ITRF) with combined solutions of all available weekly EUREF solutions. ITRF is the realization of the ITRS (International Terrestrial Reference System) and consists of a set of sites for which the coordinates (at a certain epoch) and the velocities are given. The EUREF multi-year solutions were submitted to the Central

[*] Daniel Ineichen, Astronomical Institute, University of Berne, Sidlerstrasse 5, CH-3012 Bern, Switzerland e-mail: ineichen@aiub.unibe.ch

[†] Tim Springer, Astronomical Institute, University of Berne, Sidlerstrasse 5, CH-3012 Bern, Switzerland e-mail: springer@aiub.unibe.ch

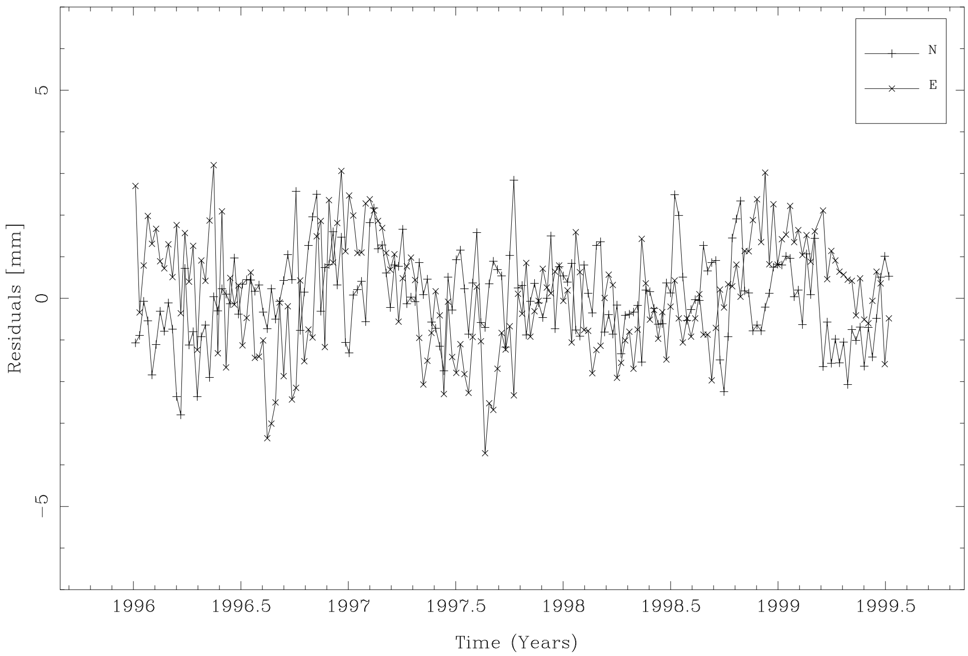

Figure 1: North and East residuals of weekly coordinate estimates with respect to the multi-year solution for site Kootwijk (KOSG), The Netherlands.

Bureau of the IERS which is in charge of realizing and maintaining the ITRS. So far, the EUREF multi-year solutions contributed to the realizations of ITRF 96 and ITRF 97 and are supposed to contribute to future reference frames as well (e.g. ITRF 2000).

The multi-year solution is based on the results of the weekly EUREF combined solution stored in so called normal equation files, where besides the estimated coordinate values the full variance covariance information is saved. These weekly solutions are combined to multi-year solutions making use of the principles of stacking normal equation systems, a very fast and flexible method to generate GPS solutions based on long data spans (Brockmann, 1997).

The IGS precise GPS orbits and the Earth orientation parameters are implicitly held fixed in the combined solution (since they were already introduced for the computation of the weekly solutions). In addition, the velocities of a set of selected sites are constrained to the velocities of the previous ITRF realization. The parameters solved for are the coordinates and velocities of all sites. If the available data span of a site is too short to estimate reasonable velocities (less than six months) the respective velocities are constrained to values stemming from the NUVEL-1A-NNR model.

Having done such a solution, the coordinate time series of all sites are checked for possible jumps. If a jump is detected for a certain station a new set of coordinates has to be set up in order to avoid disturbed velocity estimates. Note that the velocity estimates before and after the jump are constrained to give identical values. There are various reasons for the occurrence of such jumps: replacement of the antenna, mounting of antenna radomes, change of antenna environment, or aging receivers. It can be stated, however, that only few sites showed this kind of problems and that the coordinate time series are normally very smooth. The RMS over all weekly EUREF solutions and all sites is 2 mm for the horizontal component and 6 mm for the vertical component. An example of a station with an excellent performance over a time period of more than 3 years may be found in Figure 1 (site Kootwijk).

Doing the combination of the whole time series one has to pay attention to changes of the used reference frames (orbits, Earth orientation parameters). Table 1 shows the history of the reference frames used to align the

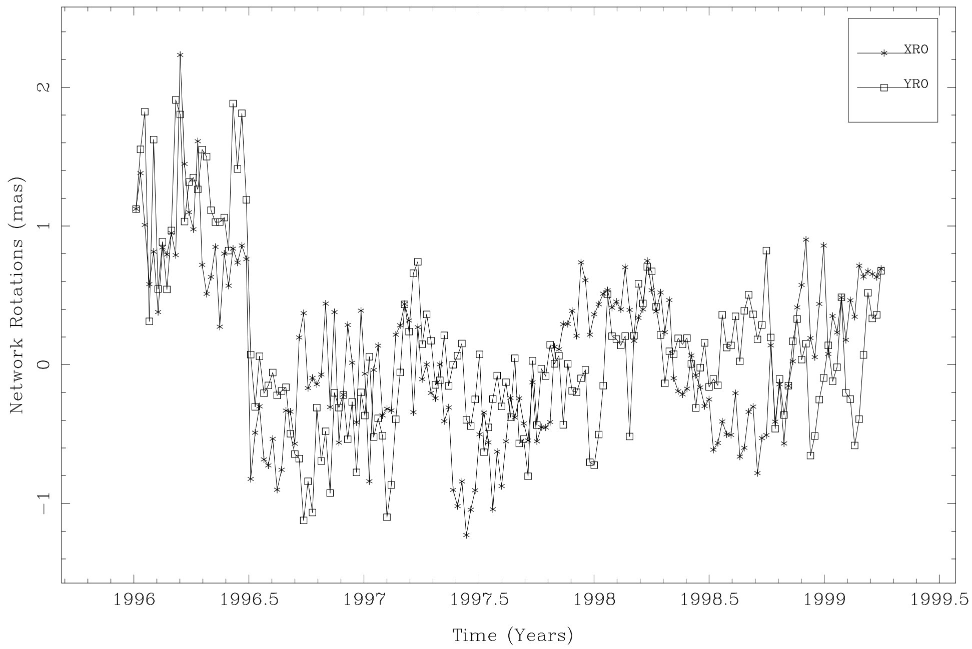

Figure 2: Effect of reference frame changes (IGS orbits) on regional GPS network solutions (X- and Y-rotations).

weekly EUREF solutions to the Terrestrial Reference System (note that there was no ITRF 95 realization).

Especially the transition from ITRF 93 to ITRF 94 has to be handled with care because there are significant rotations between the two reference frames (Springer, 1999). These rotations show up in the respective IGS precise orbits as well. Since the IGS orbits are kept fixed for the EUREF processing the reference frame changes may deteriorate the coordinate and velocity estimates of the multi-year solutions. There are two possibilities to resolve the problem:

- The first possibility is to transform the orbits into the required reference frame prior to doing the data processing. The effects of the reference frame changes on the orbits have been fairly well documented and distributed using the IGS mail service (IGSCB, 1999)
- The second possibility is to transform the results of all weekly solutions (normal equation files) into the same reference frame using known or estimated transformation parameters.

For the EUREF permanent network the latter option was chosen since a reprocessing of the corresponding weekly solutions is not feasible. Therefore – in order to avoid inconsistencies – Helmert parameters were estimated between the EUREF solutions in the ITRF 93 reference frame and the EUREF solutions in the ITRF 94 and ITRF 96 reference frame. For this purpose all weekly solutions were combined without applying any constraints on the site coordinates. The Helmert transformation parameters were estimated for each individual weekly EUREF solution with respect to the combined solution. The time series of the X- and Y-rotation parameters are shown in Figure 2. They correspond quite well with the IGS values determined by means of 13 global IGS sites (-1.3 mas and -0.9 mas for the X- and Y-rotation, see IGSCB, 1999). In contrast to the transition from ITRF 93 to ITRF 94 no significant

Table 1: Reference frames used for the alignment of the EUREF solution to the Terrestrial Reference System.

GPS Week	Date	Reference Frame
834-859	Dec 95 - Jun 96	ITRF 93
860-946	Jun 96 - Mar 98	ITRF 94
947-1020	Mar 98 - Aug 99	ITRF 96
1021	Aug 99	ITRF 97

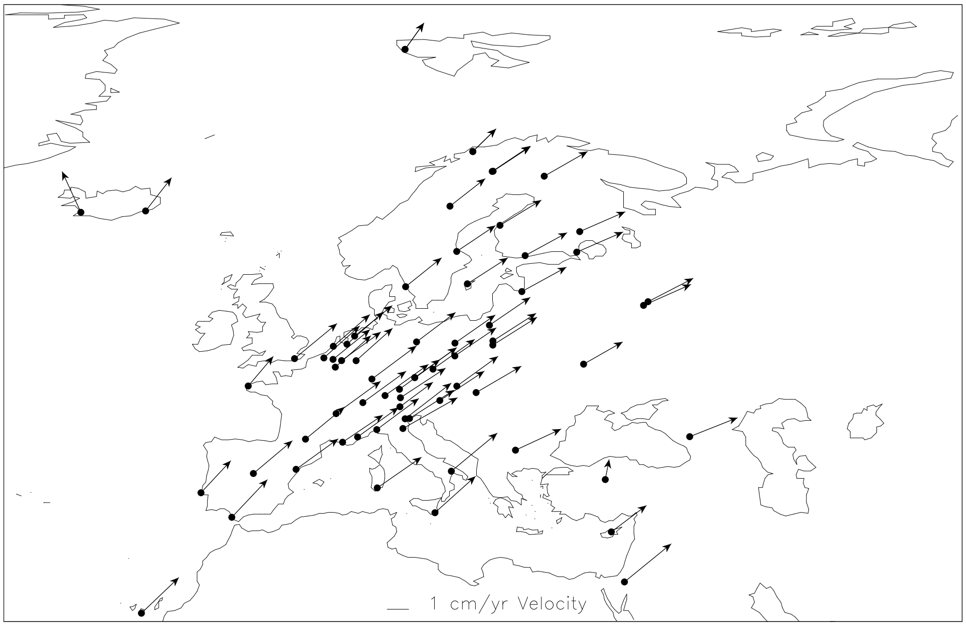

Figure 3: EUREF Velocities based on the weekly EUREF solutions of GPS weeks 834–1007, not shown on map are sites KELY and THU1, Greenland.

changes are noticed for the transition from ITRF 94 to ITRF 96. A map of the estimated velocities, based on the weekly EUREF solutions of GPS weeks 834–1007, may be found in Figure 3.

EUREF's Contribution to ITRF 97

Since August 1, 1999 all IGS and EUREF products are aligned to the ITRF 97. Besides the EUREF solution, 4 VLBI, 5 SLR, 5 GPS, 3 DORIS, and one multi-technique (SLR+DORIS) solution added to the realization of ITRF 97. EUREF contributed with a solution containing coordinate and velocity estimates of 67 stations. The weighted RMS values for position and velocity, derived from the combination of the EUREF solution with the other contributing solutions, are below 2 mm (Boucher, 1999). This proves that the EUREF multi-year solution is a solution of high quality and that the ITRF 97 is significantly influenced by the EUREF contribution.

Outlook

Since July 25, 1999 the task of the EUREF Combination Center was transferred to the BKG (Bundesamt für Kartographie und Geodäsie, Frankfurt, Germany). We wish our colleagues and friends a lot of success and satisfaction with their new function.

References

Bruyninx, C., et al. (1997), The EUREF Associate Analysis Center: 1996 Annual Report, in International GPS Service for Geodynamics, 1996 Annual Report, Jet Propulsion Laboratory, Pasadena, California

Brockmann, E. (1997), Combination of Solutions for Geodetic and Geodynamic Applications of the Global Positioning System (GPS), Astronomical Institute University of Berne, Ph.D. thesis, June 1996

Boucher, C., Z. Altamimi, P. Sillard (1999), The 1997 International Terrestrial Reference Frame (ITRF 97), IERS Technical Note 27, Central Bureau of IERS, Observatoire de Paris, May 1999

IGSCB(1999), IGS mail no. 1391, International GPS Service Central Bureau, Jet Propulsion Laboratory, Pasadena, CA, USA, http://igscb.jpl.nasa.gov/mail/mail.html

Kouba, J., et al. (1996), SINEX–Solution-Independent Exchange Format Version 1.00, Proceedings of the IGS Analysis Center Workshop, Silver Spring, Maryland, USA, IGS Central Bureau, JPL, Pasadena, California, USA, March 19-21,1996

Springer, T. (1999), Modeling and Validating Orbits and Clocks Using the Global Positioning System, Astronomical Institute University of Berne, Ph.D. thesis

Rothacher, M., and L. Mervart (eds.) (1996), Bernese GPS Software Version 4.0, Astronomical Institute, University of Berne, Switzerland, September 1996