The EUREF Permanent Network Report 2000

Carine Bruyninx, Fabian Roosbeek
Royal Observatory of Belgium, B-1180 Brussels, Belgium
Heinz Habrich, Georg Weber
Federal Agency of Cartography and Geodesy, D-60598 Frankfurt am Main, Germany
Ambrus Kenyeres
FOMI Satellite Geodetic Observatory, H-1373 Budapest, Hungary
Gunter Stangl
Institute of Space Research, A-8042 Graz, Austria

1 Introduction

Within the IAG Commission X, EUREF is the sub-commission, which is responsible for the maintenance of the European Reference System ETRS89. Members of the group are mainly federal survey authorities, universities and research institutes interested in the realization of a unified horizontal and vertical reference frame. Since 1995, the epoch-wise EUREF GPS campaigns were replaced to a great extent by the installation of the EPN, the EUREF Permanent GPS Network (EPN). This was done in close collaboration with the IGS seeking for regional densifications. In 1996 the EPN was accepted as a regional Network Associate Analysis Center (RNAAC) of the IGS for Europe.

2 EPN Management and new Structure

Since its start in 1995, the activities within the EPN are coordinated and guided by the EUREF Technical Working Group (EUREF TWG). A dedicated network coordinator took care of the day-to-day management of the permanent network. With the growth of the network and the tasks involved, EUREF started a re-organization at its 10th yearly Symposium in Tromsø, Norway, June 22nd-24th, 2000. Three units will, from now on, be involved in the management and development the EPN. These are the EPN Coordination Group (CG), the EPN Central Bureau (CB) and the EPN Special Projects (SP).
The EPN CG coordinates all activities related to the EPN. Members are the network coordinator, the data flow coordinator, the analysis coordinator, a representative of the TWG and the special projects liaison persons. The special projects are intended to study newly developing demands and activities based on EPN data and their potential use. Presently two special projects are ongoing, the *"Generation of an EUREF-troposphere product"* and *"Monitoring of the EPN to produce coordinate time series suitable for geokinematics"*. Special projects, if successful, may, turn to EPN products after a 4-year project term.

3 Extensions of the EPN Tracking Network

Figure 1 shows the status of the EUREF permanent tracking network as in June 2001. The number of stations is 118. From these, 47 % of them belong also to the IGS network. To encourage the installation of EPN stations in less dense regions, the EUREF TWG has adopted (November 24, 2000) a new guideline concerning the station location: a minimal distance of 300 km to already existing EPN stations is required, accepting the interest of each nation to have at least one EPN station. Exceptions to this rule are possible for stations submitting **hourly data** or

contributing to EPN Special Projects. Thanks to this new guideline 45% of the EPN stations are now submitting hourly data.

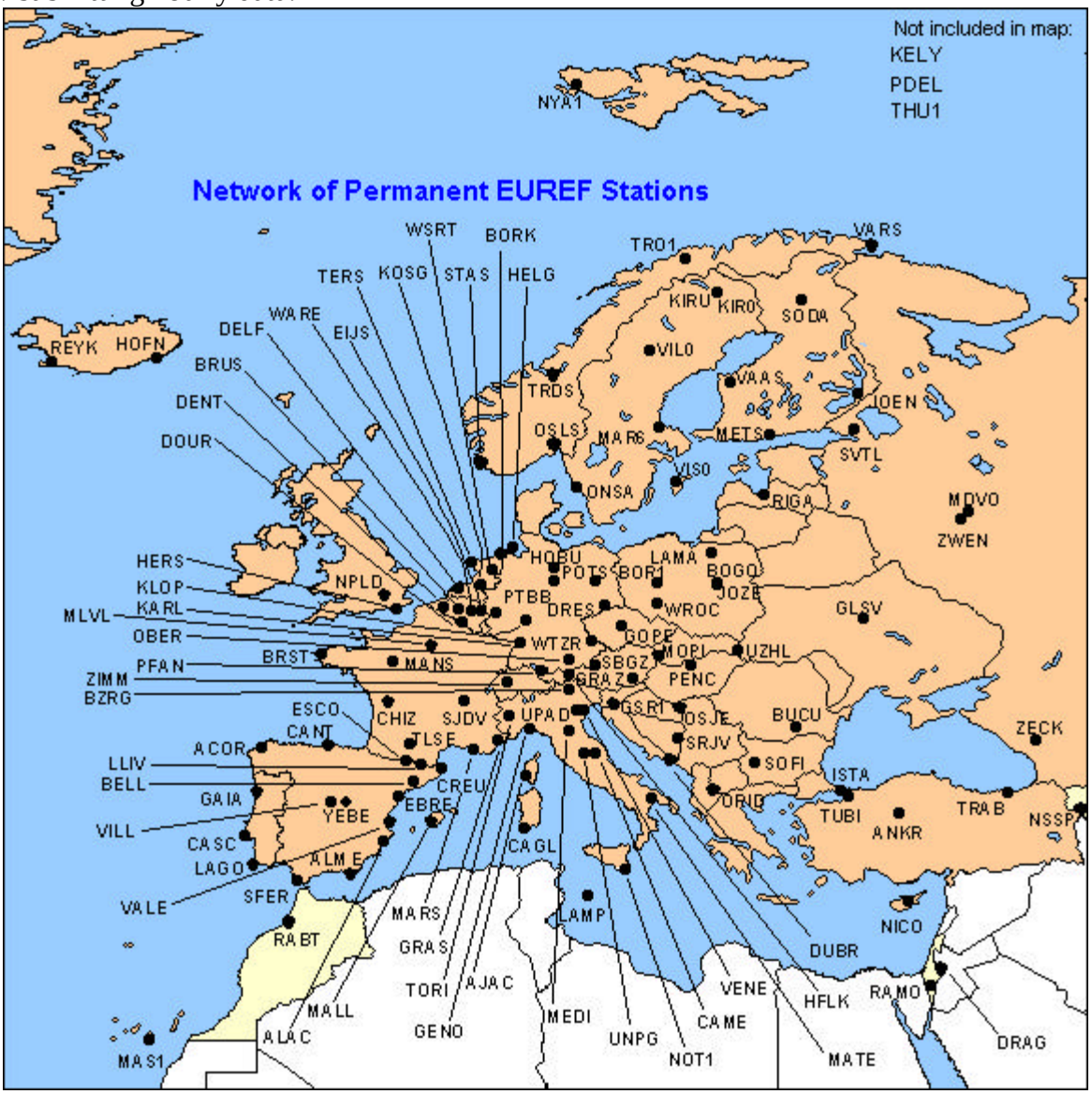

Figure 1 – EPN tracking network, as of June 2001

4 EPN Data Flow

During the year 2000, the data flow within the EPN was considerably increasing since several EPN stations started transmitting hourly data together with daily data. Up to now, the delivery of daily transfers is still advisable for approximately 10% of the stations: they are still not delivering routinely the full 24 files/day.

The quality of the daily data flow has improved: at the EUREF Data Centre (BKG), the proportion of bad files (unreadable or wrong contents) fell from 1% to 0.05%. A part of this improvement was achieved by introduction of checking routines at the EPN Data Centers (DC). Unfortunately the checking procedures are not yet consistent at all DCs. Recommended checks are:

- The unix/Hatanaka compression/decompression test

- Teqc, to get a basic overview of the data quality
- A test for the correspondence between file name and contents (e.g. wrong day).

If an error was found during transfer the file should be rejected.

The Regional Data Centre at BKG is the only EPN data center holding the majority of the EPN data. This single-center-dependency puts the EPN is a vulnerable position. A preparation for a mirror DC is under way. In case of outages users will have the possibility to switch from the Regional DC to the mirror, and this for both data input as data retrieving. This procedure is already working for the Local DCs.

5 Data Analysis

The observations of the EPN are currently analyzed by 13 Local Analysis Centers (LACs): ASI (Nuova Telespazio S.p.A., Space Geodesy Centre, Italy), BEK (International Commission for Global Geodesy of the Bavarian Academy of Sciences, Germany), BKG (Bundesamt für Kartographie und Geodäsie, Germany), COE (European solution created at CODE (Centre for Orbit Determination in Europe), DEO (Delft Institute for Earth-Orientated Space Research, Delft University of Technology, Netherlands), GOP (Geodetic Observatory Pecny, Czech Republic), IGN (Institut Géographique National, France), LPT (Bundesamt für Landestopographie (L+T), Switzerland), NKG (Nordic Geodetic Commission), OLG (Observatory Lustbühel Graz, Austria), ROB (Royal Observatory of Belgium), UPA (Universita di Padova, Italy) and WUT (Warsaw University of Technology, Poland).

The LACs submit weekly solutions of their subnet in the SINEX format (SINEX, 1996) to the EUREF Data Center at BKG .

The EPN Network Coordinator selects the subset of stations of each LAC in order to guarantee that each station is processed by at least 3 LACs. This resulting redundancy is used for quality control and outlier detection ; the individual LAC solutions are successively compared to the combined solution. Stations or even complete LAC solutions which show such a difference to the combined quantity that exceeds a predefined range (5 mm for the position or 10 mm for the height) are excluded in the final combined solution. Graphical visualization tools, e.g., the plot of correlation coefficients of the coordinates, are used for quality control.

Combination Scheme

The ADDNEQ program of the Bernese Software (Beutler et al., 1996) is used to combine the weekly SINEX files. At that time the a priori constraints of the station coordinates are removed. The normal equations are first combined into a free network solution, where 13 stations are selected to define the “minimum constrained conditions” in the ADDNEQ program. This solution is used for outlier detection.

After the exclusion of all outliers the official EUREF solution is generated where the coordinates of 13 stations are fixed to the ITRF-97.

In order to check the coordinate time series, a free network combination of the last seven EUREF combined solutions is routinely computed. This may lead to the exclusion of more stations and may require an additional iteration of all combination steps.

Introduction of a new Local Analysis Center

A new LAC located at the Delft University of Earth-Orientated Space Research, Netherlands (DEO) submitted its first solution on GPS week 1095. It is the first LAC within the EPN using

GIPSY software (Web and Zumberge, 1995). The original solution from DEO could not be combined, as is, with the other 12 contributions, using the ADDNEQ program. However, using a different scheme, the combination could be performed. This different scheme was based on the estimation of a seven-parameter Helmert transformation between the station coordinates of the individual solutions and a "reference solution". In a second step those transformed coordinates were combined. Some investigations explained that the original combination could not be performed because of the very small (0 to 0.1) correlation coefficients between the station coordinates in the DEO SINEX solution. After some small changes in the processing scheme of DEO, significant correlations of 0.5 to 1.0 between the station coordinates showed up in the DEO SINEX files. As a result, since the beginning of GPS week 1100, the ADDNEQ program has successfully been used to add the DEO solution to the EUREF combined solution.

Weighting of Solutions

The various analysis softwares used by the LACs requires a scaling of the co-variances of each solution before the combination, and this in order to remove the software specific differences. For the LACs working with the Bernese Software, the SINEX files include the RMS of unit weight (δ), which is used as the weighting factor : all elements of the covariance matrix are multiplied with the factor $1/\delta^2$ when the SINEX files are converted to normal equations. However, the RMS of unit weight is not available from the GIPSY and Microcosm solutions, which are the two other GPS data analysis packages contributing to the EPN. In addition to the weighting with $1/\delta^2$, an external weight file is introduced to scale each normal equation file in the combination. The factors given in this weight file are currently empirically determined to result in an equal contribution of all LAC solutions to the combined solution. It is clear that the weighting scheme is currently still one of the topics of investigation.

6 Time Series Special Project

The EPN may be considered as a kinematic network, where the stations have an increasing role in geokinematic interpretation as well. The quality of the EPN kinematic products (coordinate time series, velocities) is highly dependent on the station monumentation/data quality and the combination scheme used. In 2000, an EPN SP has been established in order to improve the EPN performance with a careful analysis and overview of each station encompassing the coordinate time series, the stability of the monumentation and the environmental effects. The SP is a joint effort of 6 different groups, where each group is responsible for a specific sub-region of the whole EPN. The groups are also encouraged to involve additional, non-official EPN sites into the analysis in order to derive a more detailed kinematic pattern of Europe.

To help the assessment of station quality and kinematic relevance, the SP contributed significantly to the preparation of the new IGS GNSS log format.

In the 1st work phase, the coordinates jumps and outliers are determined and collected into a uniform station problem file. This work is in progress, a retrospective analysis will be completed by the end of 2001. In the following work phases the spectral properties (periodical effects, noise spectra) of the time series will be analyzed.

Using all collected information an improved multi-year combination solution and time series are computed and also updated regularly. The improved time series including a table with station problems are displayed on the EPN CB Web pages (www.epncb.oma.be/series_sp.html). These pages also summarize all activities related to the SP.

7 Troposphere Special Project

Within the routine analysis of a network of ground-based GPS receivers, tropospheric parameters are part of the estimation. Longer series of the zenith path delays, for example, support climate research. Therefore EUREF decided to create a Special Project “Troposphere Parameter Estimation”.
Similar to combining weekly SINEX files for the derivation of a combined coordinate product, BKG is going to produce a combined troposphere solution with input from the individual troposphere solutions of all ACs, which contribute to the coordinate solution. Their analysis is carried out in post processing mode on the basis of precise orbits. Initially supported by GFZ, the combination will be done following today’s IGS standards (Gendt, 1997): epoch-wise combination of the single solutions as weighted mean with rigorous outlier detection in consecutive steps; biases between the individual solutions have to be taken into account. As a result two weekly files will be produced. (1) A summary file with some statistics about e.g. the frequencies of the analyzed sites and about the accuracies of a single AC solution. This file provides feedback to the contributing ACs. (2) An output file (EURwwwwd.TRO) with the combined troposphere estimates from which the estimates for a single site can easily be extracted. The coordinates, as a necessary part of this file, will be taken from EUREF’s official combined SINEX file.
Beginning with GPS week 1108 the first ACs delivered their daily troposphere solution files to BKG. Thus, the testing of the combination software could be started. A common tropospheric sampling rate of 1 hour is desirable while at the beginning most of the solutions have a two-hour sampling rate.

8 Outlook

The analysis guidelines, adopted in April 1997 by the EUREF AC's to guarantee the homogeneity of the EUREF solution have aged. New analysis guidelines have been developed at the EUREF Analysis Centers Workshop held in Warsaw, Poland in May 2001. The EPN AC’s have agreed to switch to the new analysis guidelines on GPS week 1130 (September 2, 2001). More details about the new guidelines will be available in next year’s annual report.

9 References

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