Day-to-day Monitoring of the EPN
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1. Introduction

This document describes the present status of the EUREF Permanent Network (EPN), concentrating on the major changes since the EUREF Symposium of June 4-6, 2003 in Toledo, Spain (Bruyninx et al, in press), such as the enlargement of the tracking network, the monitoring tools at the EPN Central Bureau (CB), new EPN guidelines and others.

2. Status of the EUREF Permanent Network

Figure 1 shows the status of the EUREF Permanent tracking Network as in June 2004. The number of EPN stations is 153 from which 7 stations are presently inactive: AMMN (Amman, Jordan), HFLK (Hafelekar, Austria), IAVH (Rabat, Morocco), LINZ (Linz, Austria), MDVO (Mendeleevo, Russia), SBGZ (Salzburg, Austria) and ZWEN (Zvenigorod, Russia). 48 % of the EPN stations belong also to the IGS network. The 21 new EPN stations that joined the EUREF network since June 2003 are given in Table 1.

Figure 1 – EUREF permanent tracking network (status June 2004); the circles show the stations added to the network after June 2003.

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<thead>
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With:
- **BKG**: Bundesamt für Kartographie und Geodäsie, Germany
- **CAO**: Astronomical Observatory of Cagliari, Italy
- **CLRC**: Central Laboratory of the Research Councils, England
- **CRS**: Centro Ricerche Sismologiche, Italy
- **DLR-KN-NL**: German Aerospace Center Institute of Communications and Navigation, Germany
- **ESA/ESOC**: European Space Agency
- **GUGiK**: Head Office of Geodesy and Cartography, Poland
- **INAF**: Astronomical Observatory of Cagliari, Italy
- **INAF**: Istituto Elettrotecnico Nazionale "Galileo Ferraris", Italy
- **KMS**: National Survey and Cadastre, Denmark
- **LMV**: Lantmaeteriet (National Land Survey of Sweden), Sweden
- **MOSP**: Marshall Office of the Silesian Province, Poland
- **NSGF**: NERC Space Geodesy Facility, England
- **OS**: Ordnance Survey, Great Britain
- **POLIMI**: Politecnico di Milano, Italy
- **SHMU**: Slovak Hydrometeorological Institute, Slovakia
- **TOPOGR.DIC**: Dipartimento di Ingegneria Civile Laboratorio di Topografia e Fotogrammetria, Italy
- **WUT**: Warsaw University of Technology, Poland

H: station submitting hourly data
TG: TIGA station
ECGN: ECGN station
IP: EUREF-IP station
TL: Time laboratory
GLO: GPS/GLONASS station
IGS: IGS station

**Table 1** - Tracking stations added to the EPN since June 2003

In the past year, several EPN stations have made a considerable effort to deliver hourly tracking data, bringing the total number of stations to 93, which is 61 % of the EPN stations.
The list of proposed EPN stations is given in Table 2.
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with

UNAVCO : University NAVSTAR Consortium, USA
UGG : University College of Gjøvik, Norway
JAXA : Japan Aerospace Exploration Agency, Japan
MAO : Main Astronomical Observatory, Ukraine
RDAAC-JPL-IRIS : RDAAC-JPL-IRIS, Russia
INOBS : Istituto Nazionale di Oceanografia e Geofisica Sperimentale, Italy
IESSG : IESSG, United Kingdom
BNM-SYRTE : BNM-SYRTE, France
ASI : Agenzia Spaziale Italiana, Italy

Table 2 - Candidate EPN stations

Recently, two stations have been withdrawn from the EPN: PLYM (Plymouth, UK, withdrawn Nov. 2003) and PULA (Pula, Croatia, withdrawn May 2003).

In March 2003, the first call for participation to the ECGN (European Combined Geodetic Network) was released. The ECGN aims at connecting permanent and long-term space geodetic height measurements with repeated gravity measurements and permanent tide gauge measurements in the European coastal regions. Its long-term goal is to get a better height system, which e.g. is essential for understanding and measuring sea-level change. The ECGN is closely linked to the EPN, since the permanent space geodetic height measurements contributing to the ECGN come from a selected set of EPN stations, as can be seen from Figure 2.

![Figure 2 - EPN stations participating to the ECGN network](image_url)
3. New@epncb

3.1 Additional rapid RINEX observation data quality checks

We have recently added to the EPN CB web site some new web pages showing the results of the monitoring of the long-term quality of the GPS observations. These pages have proven to be a valuable tool for indicating tracking changes. We strongly encourage station managers to regularly check the plots of their stations in order to detect and resolve the possible problems which can occur. The data quality plot pages can be accessed from http://www.epncb.oma.be/ trackingnetwork/qualityplots/XXXX.html with XXXX= the station 4-char abbreviation. The web pages contain:

- a yearly plot displaying the long-term tracking performance based on the daily percentage of GPS observations (refreshed daily);
- yearly and 45-day average plots displaying the number of observations and cycle slips, and the RMS due to the multipath on the observed L1 and L2 (refreshed daily);
- monthly snapshots of the satellite tracking (one plot each month).

3.2 Additional monitoring of the availability of the hourly RINEX data

As a complement to the “Station latency reports” distributed monthly through EUREF mail, we have added some graphics to the EPN CB web site showing the delay of each hourly data file. An example of such graphs is given in Figure 3.

![Figure 3 - Latency of the hourly RINEX data files. Latencies below 10 minutes (horizontal line) indicate that the data are directly useable for near real-time applications.](image)

For more details on the recent implemented quality checks at the EPN CB, we refer to the paper “Quality and latency of the data within the EUREF Permanent Network”, by Carpentier et al (in this volume).

3.3 Coordinate time series

The EPN CB makes available standard coordinate times series for the sake of monitoring the station coordinates. Since May 2004, these coordinate time series are computed using the CATREF software (instead of the Bernese software). CATREF has been developed by Z. Altamimi from IGN France and has been used in the past to compute the ITRF2000 realisation. The main advantage of CATREF is that it allows using the minimal constraint approach (Altamimi, 2002 and 2003). In order to emphasize the change of computation method for the standard time series, we have renamed these time series as “raw time series”. Taking their relation to the “Improved time series”, we are convinced that this new name reflects in a better way for what these time series stand: raw, uncorrected time series.

The computation of the raw time series consists of the following steps

1. extract a reference network from the ITRF2000 solution taking the sites BOR1, BRUS, GRAS, GRAZ, HOFN, JOZE, KELY, KOSG, LAMA, METS, NICO, ONSA, POTS, SFER, TRO1, VILL, WSR, WZTR and ZIMM;
2. replace the constraints on each weekly solution with minimal inner constraints;
(3) combine the weekly solutions from (2) by estimating positions and velocities at the central epoch and weekly transformation parameters between each solution and the reference solution from (1).

(4) after the combination, we compute for each station and each week the residuals between the estimated coordinates (using the estimated velocities) and the coordinates from (2). Outliers are not removed.

The main difference between the new ‘raw time series’ and the old ‘standard time series’ (computed with Bernese) is that within the raw time series the coordinate time series have zero trend, under the condition that over its observation period, the coordinates of the station do not have large discontinuities. However, if a station that had a major discontinuity (due to e.g. an antenna change), then its residuals will show an unrealistic trend, caused by the error in the estimated velocity. An example is given in Figure 4. Ideally, the station should have a zero trend in its residuals and low noise.

**Figure 4** - Raw coordinate time series, computed with CATREF. Left: for a station with a height jump due to an antenna replacement, Right: for a station without large discontinuities.

### 4. Some examples

#### 4.1 REYK

As explained in Section 3, we create graphs that give a yearly overview of the TEQC output quantities. An example of some of these plots is given in Figure 5. It shows the station REYK.

**Figure 5** - SUM TEQC output for REYK (Iceland). Left: nr. obs./cycle slip, inverted and multiplied by 1000, right: RMS of L1 multipath. The vertical line indicates the epoch of an antenna change as indicated by the site log.
6

**Figure 6** - Coordinate time series for the station REYK (Iceland). The circle indicates the time period before the antenna change, where the tracking behaviour of the station changed. This tracking change is clearly seen in the Up-component and corresponds with a coordinate jump of about – 5mm.

Following the information in the site log file, REYK changed its antenna at day 164 (red line indicated on the graphs). Strangely, the behaviour of the station tracking already changed before the antenna replacement having a direct influence on the coordinate time series in Figure 6. This example demonstrates the importance of a rigorous monitoring of the GPS observation data.

### 4.2 RAMO

A very peculiar example is RAMO (Mitzpe Ramon, Israel) shown in Figure 7, where following an antenna change on DOY 199, 2000, a quasi-annual term, with decreasing amplitude appeared in the East component of the coordinates. Since it is hard to explain this as a geophysical phenomenon, we have again used the tracking monitoring tools to have a closer look at the behaviour of this station.

**Figure 7** - Coordinate time series of RAMO. After an antenna change in the summer of 2000, a periodic effect appeared in the East-component.

Figure 8 shows the azimuth/elevation angles of the satellites tracked at RAMO for 4 different days, two before the antenna change, and two after the antenna change. From these graphs, we can see that after
the antenna change there is a degradation of the tracking around an azimuth of 180° indicating that the new antenna had a fault. In the mean time, the station operator changed the equipment, but it is too soon to evaluate this change.

Figure 8: Azimuth/elevation angles of observed satellites in the station RAMO. The antenna has a defect and no low elevation satellites are tracked around an azimuth of 180°. Top: before the antenna malfunctioning; bottom: full antenna malfunctioning.

5. **EPN guidelines**

5.1 New ‘Procedure for becoming an EPN station’

Stations that would like to join the EPN should be aware that the "Procedure for becoming an EPN station" has been completely revised. The new procedure is effective since Dec. 2 2003, and can be downloaded via:

http://www.epncb.oma.be/_organisation/guidelines/procedure_becoming_station.html

http://www.epncb.oma.be/_organisation/guidelines/procedure_becoming_station.pdf

The most important change concerns the new requirement to submit a commitment letter guaranteeing that the station will be operated following EPN guidelines for a minimal duration of 5 years.

5.2 Future

The Guidelines for EPN stations urgently need updating. The new version of the EPN guidelines will be based on the new IGS Guidelines. They will be developed in the course of the next year.

6. **Divers**

6.1 EUREF LAC Workshop

On September 17-18, the Fourth EUREF Analysis Workshop was held in Graz, Austria. The minutes of this meeting are available at:

http://www.epncb.oma.be/_newsmails/workshops/EPNLACWS_2003/minutes.html

6.2 News from the IGS
The IGS plans to become more selective when including new stations in its network through the implementation of a new procedure for including new stations in the network. New stations proposed to the IGS will be put in a list of 'Proposed IGS stations'. These stations can only be added to the IGS network if at least one analysis expert (AC, ACC, Working Group, Pilot Project Chair or product coordinator) requests it for the benefit of an IGS product or project. New IGS sites coming out of the ‘Proposed Status’ would be called a ‘Provisional IGS site’ for the first 90 days, after which it would become an ordinary IGS site only if stable operation had been demonstrated.

Besides Proposed and Provisional sites, the IGS also plans to start working with ‘Project sites’ as these sites contributing to an IGS Project. This can be seen currently in the cases of the IGLOS and TIGA stations. Upon termination of the project the Project sites would become Proposed sites.

Another category is ‘Inoperational sites’; sites (excepting the obvious TIGA sites) transmitting no data within 30 days would automatically be placed by the IGS in a list of operational sites.

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Proc. of the EUREF symposium held in Bratislava, Slovakia, June 2-5, 2004