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 (Zwenigorod, 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.

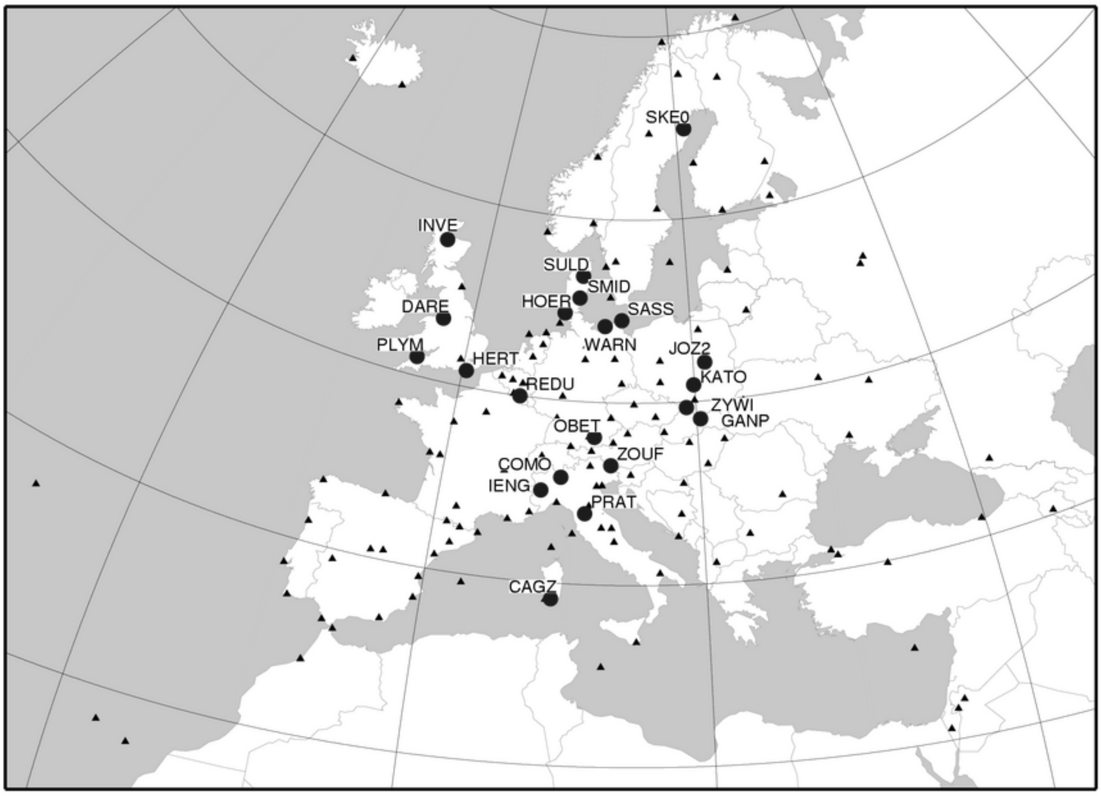

Figure 1 – EUREF permanent tracking network (status June 2004); the circles show the stations added to the network after June 2003.

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Station	4 char ID	Country	Agency	Date inc.	
Redu	REDU	Belgium	ESA/ESOC	22-06-2003	H
Wessling	OBET	Germany	DLR-KN-NL	29-06-2003	TL IGS
Inverness	INVE	Great Britain	OS	29-06-2003	ECGN
Plymouth	PLYM	England	OS	29-06-2003	
Smidstrup	SMID	Denmark	KMS	29-06-2003	H
Suldrup	SULD	Denmark	KMS	29-06-2003	H
Prato	PRAT	Italy	TOPOGR.DIC	13-07-2003	H
Daresbury	DARE	England	OS	27-07-2003	ECGN
Katowice	KATO	Poland	GUGiK	10-08-2003	H
Zywiec	ZYWI	Poland	GUGiK	10-08-2003	H
Hailsham	HERT	England	NSGF	17-08-2003	H IP GLO IGS
Sassnitz	SASS	Germany	BKG	07-09-2003	H TG ECGN IGS
Jozefoslaw	JOZ2	Poland	WUT	14-09-2003	H IP GLO IGS
Cagliari	CAGZ	Italy	CAO	21-09-2003	H IGS
Skellefteaa	SKE0	Sweden	LMV	05-10-2003	H ECGN GLO
Warnemunde	WARN	Germany	BKG	26-10-2003	H TG IGS
Hoernum	HOER	Germany	BKG	02-11-2003	H GLO
Ganovce	GANP	Slovakia	SHMU	16-11-2003	H
Cercivento	ZOUF	Italy	CRS	11-01-2004	H
Torino	IENG	Italy	IEN	01-02-2004	H TL IGS
Como	COMO	Italy	POLIMI	11-04-2004	H

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
IEN : Istituto Elettrotecnico Nazionale "Galileo Ferraris", Italy
INAF : Astronomical Observatory of Cagliari, 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

and

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.

Station	4 char ID	Country	Agency	Status
Diyarbakir	DYR2	Turkey	UNAVCO	No data
Gjøvik	GJOV	Norway	UCG	Inconsistencies
Maspalomas	GMAS	Spain	JAXA	Hourly data necessary
Kharkiv	KHAR	Ukraine	MAO	Inconsistencies
Obninsk	MOBN	Russian Federation	RDAAC-JPL-IRIS	Hourly data necessary
Forgaria	MPRA	Italy	INOGS	No data
Newlyn	NEWL	England	IESSG	Commitment letter missing
Paris	OPMT	France	BNM-SYRTE	Commitment letter missing
Reggio Calabria	TGRC	Italy	ASI	Inconsistencies

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
INOGS	:	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.

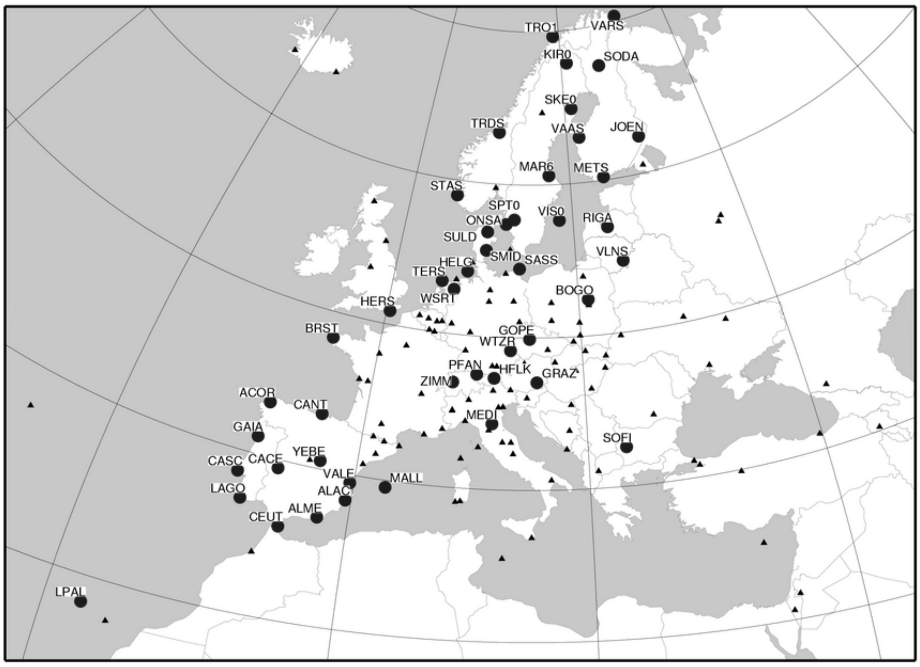

Figure 2 - EPN stations participating to the ECGN network

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.

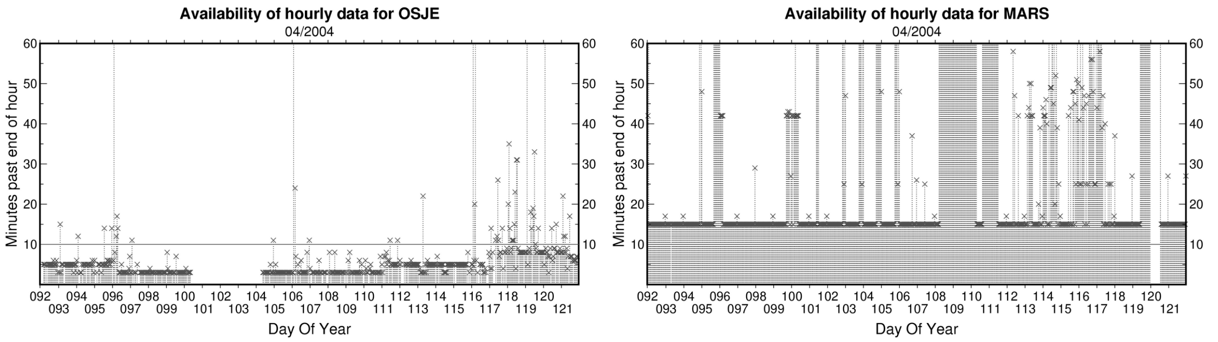

Figure 3 - Latency of the hourly RINEX data files. Latencies below 10 minutes (horizontal line) indicate that the data are directly useable for near real-time applications.

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, WSRT, WTZR 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.

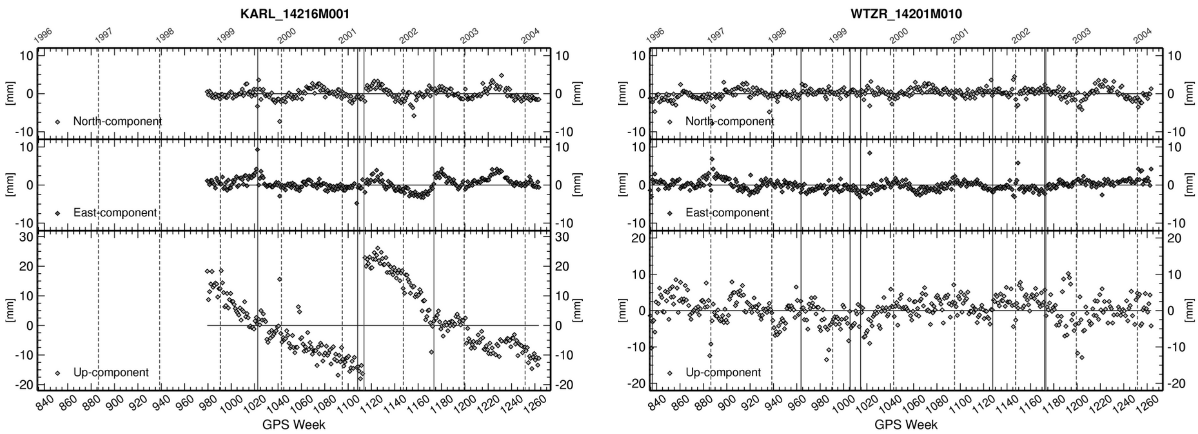

Figure 4 - Raw coordinate time series, computed with CATREF. Left : for a station with a height jump due to an antenna replacement, Right : for a station without large discontinuities.

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.

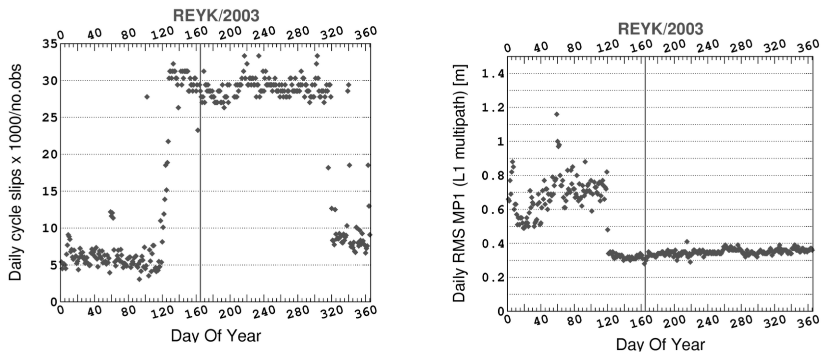

Figure 5 - SUM TEQC output for REYK (Iceland). Left: nr. obs./cycle slip, inverted and multiplied by 1000, right: RMS of L1 multipath. The vertical line indicates the epoch of an antenna change as indicated by the site log.

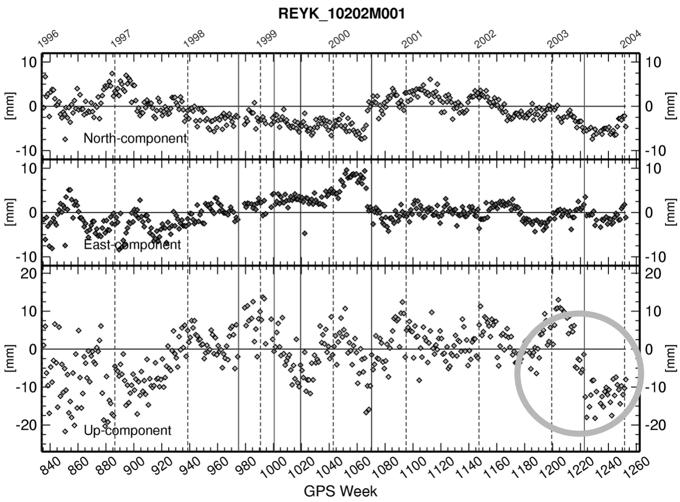

Figure 6 - Coordinate time series for the station REYK (Iceland). The circle indicates the time period before the antenna change, where the tracking behaviour of the station changed. This tracking change is clearly seen in the Up-component and corresponds with a coordinate jump of about – 5mm.

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.

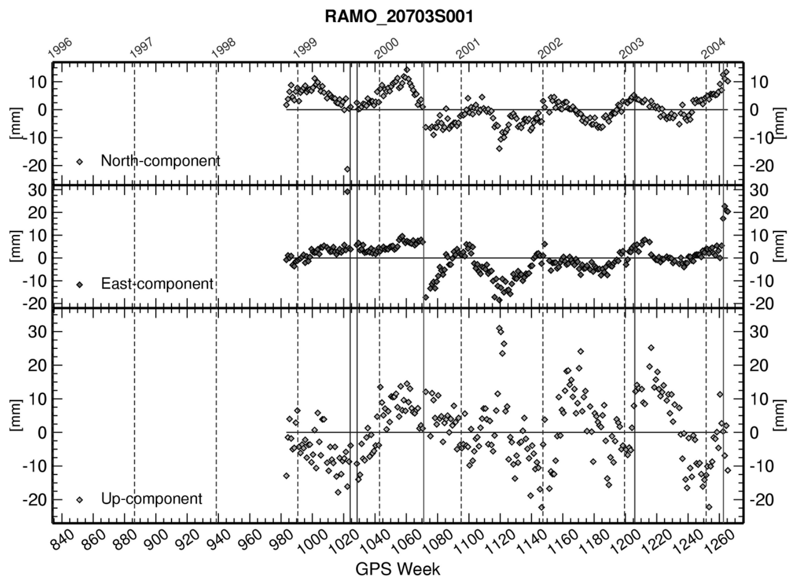

Figure 7 - Coordinate time series of RAMO. After an antenna change in the summer of 2000, a periodic effect appeared in the East-component.

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 to soon now to evaluate this change.

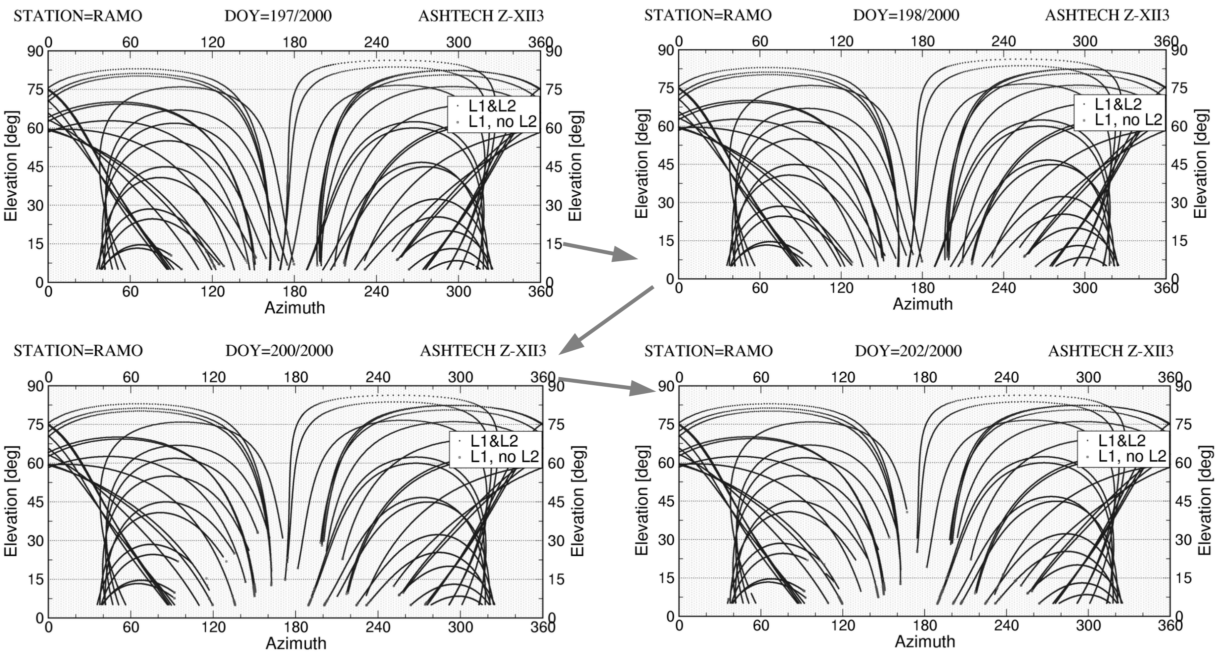

Figure 8: Azimuth/elevation angles of observed satellites in the station RAMO. The antenna has a defect and no low elevation satellites are tracked around an azimuth of 180°. Top: before the antenna malfunctioning; bottom: full antenna malfunctioning.

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 year.

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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References

Altamimi Z. (2002)
How to Express a Regional GPS Solution in the ITRF
Proc. of the IGS workshop 'Towards Real-time', Ottawa, Canada, April 8-11, 2002, pp. 137-138 (on-line at http://igscb.jpl.nasa.gov/overview/ottawa_ws.html)
Altamimi Z. (2003)
Systèmes de Référence Terrestres : Définition et Réalisation
Ecole d'été, Forcalquier, France, August 28, 2003
Estey L.H. and C. Meertens (1999)
TEQC: The multi-purpose toolkit for GPS/GLONASS data
GPS Solutions, 3, No 1, 42-49
Carpentier G, C. Bruyninx and F. Roosbeek (in press)
Quality and latency of the data within the EUREF Permanent Network
Proc. of the EUREF symposium held in Bratislava, Slovakia, June 2-5, 2004