The EUREF Permanent GPS Network : Activities May '96 - May '97 and Future Plans

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Abstract

The organization, the status and the quality of the solutions of the EUREF permanent network have been explained in detail at the EUREF Symposium in Ankara (May 96) [BGA96], [BG96].
This paper aims to give an overview of the activities related to the EUREF permanent network covering the period from May '96 to May '97.
During this last year, the EUREF permanent tracking network has grown with 50% and the number of EUREF data centers and analysis centers has doubled.
In order to optimize the efficiency of the data analysis an EUREF Analysis Workshop was organized in April '97 in Brussels. Special attention went to the tuning of the analysis strategies of the different EUREF analysis centers and to the distribution of the analyzed EUREF subnetworks.
After more than one year of official operation of the EUREF permanent network, most of the "child's diseases" have been cured and with the first submission of the EUREF solution to the IERS the EUREF permanent network is fulfilling without any doubt an important role for the densification of the ETRS89.

Contents

1 Extension of the EUREF Permanent GPS Network

In May '96 the number of tracking stations included in the EUREF network was around 40, presently near 60 stations are part of this network (Figure 1 and Table 1).

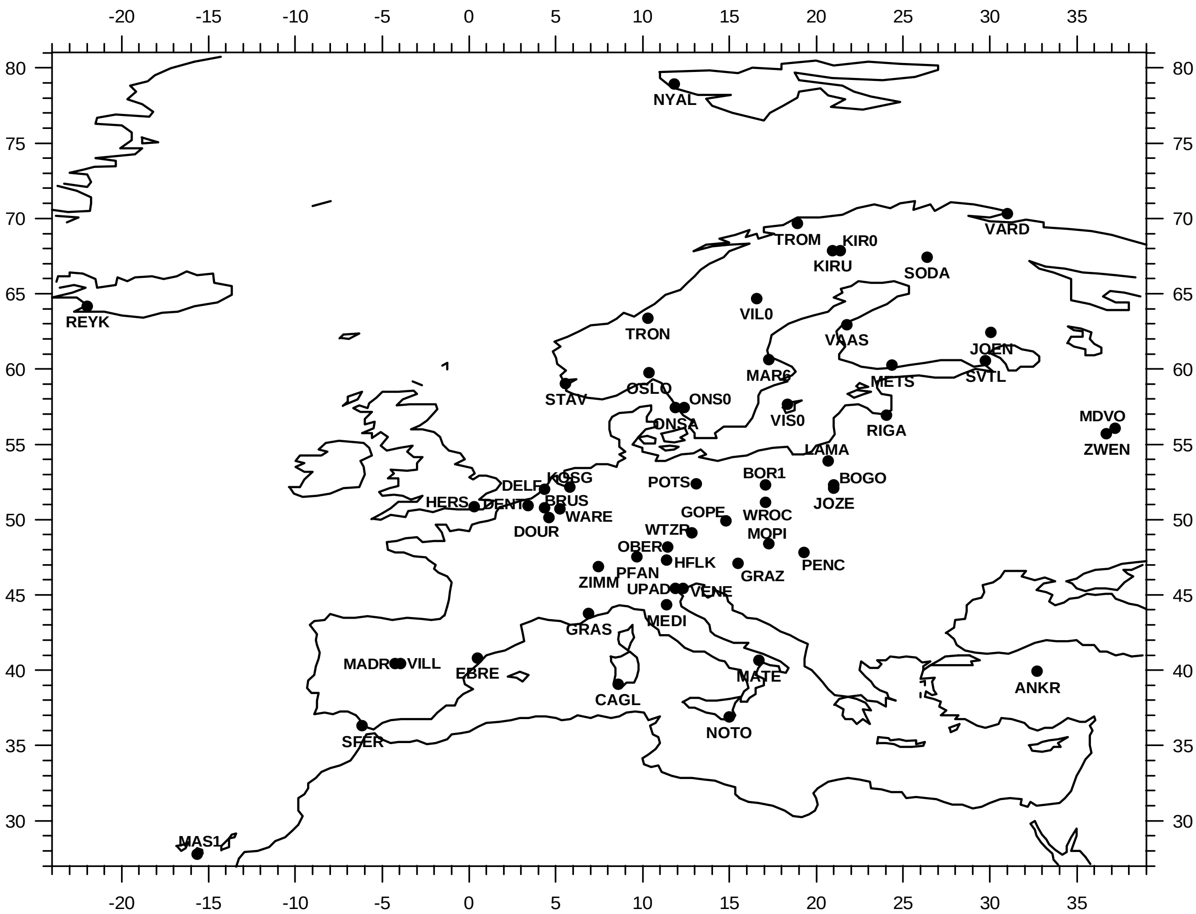

Figure 1: Stations included in the permanent EUREF GPS network (May '97)

Since May '96 twenty GPS permanent stations have been included in the EUREF network ; they are located in Austria (1), Finland (3), Germany (1), Italy (1), Latvia (1), Norway (4), Poland (2), Russia (1), Slovak Republic (1) and Sweden (5).

The Finnish Geodetic Institute is maintaining the Finnish permanent GPS-network, *FinnNet* from which 3 sites were selected to be integrated in the EUREF network.
The Norwegian Mapping Authority (Statens Kartverk) is responsible for the establishment and operation of the permanent GPS network in Norway, *SATREF*. This network consists of 11 stations including the IGS sites Tromsø and Ny-Ålesund. Four other sites have been selected for inclusion in the EUREF network.
A network of 21 permanent GPS reference stations, *SWEPOS*, has been established by the National Land Survey of Sweden and the Onsala Space Observatory. Besides the IGS stations in Kiruna and Onsala, 5 sites from *SWEPOS* were included in the EUREF network.

	Stations	4 char ID	Country	Lon(E)	Lat(N)	Agency
1	Ankara*	ANKR	Turkey	32.83	39.92	IfAG
2	Borowa Gora	BOGO	Poland	21.02	52.28	ICG
3	Borowiec*	BOR1	Poland	17.07	52.27	ALO
4	Brussels*	BRUS	Belgium	4.36	50.80	ROB
5	Cagliari*	CAGL	Italy	8.58	39.08	ASI
6	Delft	DELF	Netherlands	4.39	51.98	DUT
7	Dentergem	DENT	Belgium	3.40	50.93	ROB
8	Dourbes	DOUR	Belgium	4.59	50.09	ROB
9	Ebre*	EBRE	Spain	0.49	40.82	ICC
10	Pecny*	GOPE	Czech Republic	14.79	49.91	RIG
11	Grasse*	GRAS	France	6.92	43.75	CNES
12	Graz*	GRAZ	Austria	15.49	47.07	ISR
13	Herstmonceux*	HERS	England	0.33	50.87	RGO
14	Innsbruck*	HFLK	Austria	11.39	47.31	ISR
15	Joensuu	JOEN	Finland	30.10	62.39	FGI
16	Jozefoslaw*	JOZE	Poland	21.03	52.08	WUT
17	Kellyville*	KELY	Greenland	-50.94	66.99	NOAA
18	Kiruna	KIR0	Sweden	20.97	67.88	OSO/NLS
19	Kiruna*	KIRU	Sweden	20.97	67.88	ESA/ESOC
20	Kootwijk*	KOSG	Netherlands	5.80	52.17	DUT
21	Lamkowko*	LAMA	Poland	20.67	53.89	OUAT
22	Madrid*	MADR	Spain	-4.25	40.42	NASA/JPL
23	Mårtsbo	MAR6	Sweden	17.26	60.60	OSO/NLS
24	Maspalomas*	MAS1	Spain	-15.63	27.77	ESA/ESOC
25	Matera*	MATE	Italy	16.70	40.63	ASI
26	Mendeleevo*	MDVO	Russia	37.22	56.03	DUT
27	Medicina*	MEDI	Italy	11.38	44.31	ASI
28	Metsähovi*	METS	Finland	24.38	60.22	FGI
29	Modra-Piesok	MOPI	Slovak Republic	17.27	48.37	AGO
30	Noto*	NOTO	Italy	14.99	36.88	ASI
31	Ny-Ålesund*	NYAL	Norway	11.85	78.92	SK
32	Oberpfaffenhofen*	OBER	Germany	11.45	48.14	GFZ
33	Onsala	ONS0	Sweden	11.92	57.38	OSO/NLS
34	Onsala*	ONSA	Sweden	11.92	57.38	OSO/NLS
35	Oslo	OSLO	Norway	10.37	59.75	SK
36	Penc*	PENC	Hungary	19.28	47.78	SGO
37	Pfänder	PFAN	Austria	9.70	47.52	ISR/IfAG
38	Potsdam*	POTS	Germany	13.07	52.38	GFZ
39	Reykjavik*	REYK	Iceland	-21.51	64.09	IfAG
40	Riga	RIGA	Latvia	24.05	56.95	AIUL
41	San Fernando*	SFER	Spain	-6.12	36.28	ROA
42	Sodankylä	SODA	Finland	26.39	67.42	FGI
43	Stavanger	STAV	Norway	5.59	59.02	SK
44	Svetloe	SVTL	Russia	29.78	60.53	IAA
45	Thule*	THU1	Greenland	-68.73	76.56	JPL
46	Tromsø*	TROM	Norway	18.93	69.67	SK
47	Trondheim	TRON	Norway	10.32	63.37	SK
48	Padova*	UPAD	Italy	11.88	45.41	UP
49	Vaasa	VAAS	Finland	21.77	62.96	FGI
50	Vardø	VARD	Norway	31.02	70.34	SK
51	Venezia	VENE	Italy	12.33	45.43	ASI
52	Vilhelmina	VIL0	Sweden	16.56	64.70	OSO/NLS
53	Villafranca*	VILL	Spain	-3.95	40.44	ESA/ESOC
54	Visby	VIS0	Sweden	18.37	57.65	OSO/NLS
55	Waremme	WARE	Belgium	5.25	50.69	ROB
56	Wroclaw	WROC	Poland	17.03	51.06	AUW
57	Wettzell*	WTZR	Germany	12.88	49.14	IfAG
58	Zimmerwald*	ZIMM	Switzerland	7.45	46.87	FOT
59	Zwenigorod*	ZWEN	Russia	36.54	55.46	GFZ

Table 1: Permanently operating stations of the EUREF network. Stations with * are part of the IGS network. Underlined stations are included in the EUREF network since May '96.

AGO	:	Astronomical and Geophysical Observatory, Slovak Republic
AIUL	:	Astronomical Institute, University of Latvia, Latvia
ALO	:	Astronomical Latitude Observatory, Poland
ASI	:	Agenzia Spaziale Italiana, Italy
AUW	:	Agricultural University of Wroclaw, Poland
CNES	:	Centre National d'Etudes Spatiales, France
DUT	:	Delft University of Technology, the Netherlands
ESA	:	European Space Agency, Germany
ESOC	:	European Space Operations Center, Germany
FGI	:	Finnish Geodetic Institute, Finland
FOT	:	Federal Office of Topography, Swizerland
GFZ	:	GeoForschungsZentrum Potsdam, Germany
IAA	:	Institut of Applied Astronomy, Russia
ICC	:	Institut Cartografic de Catalunya, Spain
ICG	:	Institute of Geodesy and Cartography, Poland
IfAG	:	Institute for Applied Geodesy, Germany
ISR	:	Institute for Space Research, Austria
JPL	:	Jet Propulsion Laboratory, USA
NASA	:	National Aeronautics and Space Administration, USA
NLS	:	National Land Survey, Sweden
NOAA	:	National Oceanic and Atmospheric Administration, USA
OUAT	:	Olsztyn University of Agriculture and Technology, Poland
OSO	:	Onsala Space Observatory, Sweden
RGO	:	Royal Greenwich Observatory, England
RIG	:	Research Institute of Geodesy, Czech Republic
ROA	:	Real Instituto y Observatorio de la Armada, Spain
ROB	:	Royal Observatory of Belgium, Belgium
SGO	:	FOMI Satellite Geodetic Observatory, Hungary
SK	:	Statens Kartverk, Norwegian Mapping Authority, Norway
UP	:	University of Padova, Italy
WUT	:	Warsaw University of Technology, Poland

The requirements for a station to be officially recognized as a EUREF station are :

- station installed following IGS standards
- the station log file is available at the EUREF permanent network central bureau
- the data from the station are available to the EUREF community
- the data from the station are routinely analyzed by one of the EUREF analysis centers.

Presently, not all the EUREF stations make their available data to the EUREF community. This exception to the requirements will not be allowed anymore in the future. If the data from a candidate EUREF station are not available to the EUREF community, then this station can not be considered as being part of the EUREF network.

2 The EUREF Data Centers

In addition to the Global IGS Data Center at IGN France and the Regional IGS Data Center at IfAG Germany (making available the data of 4/5 of the EUREF network), six EUREF local data centers (listed in Table 2) give access to the data from a particular EUREF subnetwork.
Three of these data centers (ASI, FGI and NLS) became part of EUREF since May '96.

The data from most of the EUREF stations are made available through anonymous ftp.
Exceptions are the stations made available at the data center in Onsala : Riga, Svetloe, Vaasa, Sodankyla, Joensuu, Onsala (ONS0), Kiruna (KIR0), Mårtsbo, Vilhelmina and Visby. These Finnish and Swedish data are made available for EUREF permanent network analysis only and can not be transfered to a third party nor be used in any other activity outside the EUREF permanent network analysis. The

Onsala archive has a login and password only available to those organizations.
The data from the Russian station in Svetloe and the station Riga in Latvia are also made available at Onsala. The data from the Norwegian stations (Oslo, Stavanger, Trondheim and Vardø) are presently not made available. The data center of the Italian Space Agency includes the data from Cagliari, Matera, Medicina, Noto, Padova and Venice.

FUNCTION	ABBR.	OPERATED BY	LOCATION
IGS GDC	IGN	Institut Geographic National	Paris, France
IGS RDC	IFAG	Institute for Applied Geodesy	Frankfurt, Germany
EUREF LDC	ASI	Italian Space Agency	Matera, Italy
EUREF LDC	DUT	Delft University of Technology	Delft, The Netherlands
EUREF LDC	FGI	Finnish Geodetic Institute	Helsinki, Finland
EUREF LDC	GRAZ	Institute of Space Research	Graz, Austria
EUREF LDC	NLS	National Land Survey of Sweden	Gavle, Sweden
EUREF LDC	ROB	Royal Observatory of Belgium	Brussels, Belgium
EUREF CB	ROB	Royal Observatory of Belgium	Brussels, Belgium

GDC : Global Data Center
RDC : Regional Data Center
LDC : Local Data Center
CB : Permanent Network Central Bureau

Table 2: EUREF /IGS data centers in Europe. Underlined data centers are part of EUREF since May '96

3 The EUREF Analysis Centers

EUREF assures that the data from all the stations in its network is processed by at least one analysis center.
Since May '96, five new analysis centers have started routinely processing a EUREF subnetwork (Table 3) : the Nordic Geodetic Commission GPS Data Analysis Center (NKG), the Italian Space Agency (ASI), the Observatory Lustbühel in Graz (OLG), the Geodetic Observatory of Pecny (GOP) and the Federal Office of Topography in Switzerland (LPT).
The NKG is responsible for the processing of the Scandinavian part of the EUREF network. The Italian permanent stations are analyzed by ASI and both the OLG and GOP analysis centers are concentrating on a part of the Central European data.

As a general rule, in order to integrate a local network solution into a regional/global solution, it is necessary that the local network includes at least 3 geographically well distributed anchor stations from the regional/global network in its subnetwork analysis. This means that the EUREF Local Analysis Centers (LAC's) which process routinely the data from a particular EUREF subnetwork need to include at least 3 geographically well distributed EUREF anchor stations included in the combined network obtained from the solutions of the other LAC's in order to enable the merging of the LAC's subnetwork with the remaining part of the EUREF network. It is not necessary that the anchor stations are part of the IGS network.

Permanent GPS tracking stations which are not part of the EUREF network but appear in one of the solutions of the EUREF analysis centers will be eliminated from the solution before creating the EUREF combined solution.
The CODE Analysis Center is responsible for combining all partial solutions into the official weekly EUREF solutions.

AGENCY	LOCATION	SOFTWARE
Italian Space Agency (ASI)	Matera, Italy	Microcosm
Institute for Applied Geodesy (IfAG)	Frankfurt, Germany	Bernese 4.0
Bayerische Akademie der Wissenschaften (BEK)	München, Germany	Bernese 4.0
Observatory Lustbühel Graz (OLG)	Graz, Austria	Bernese 4.0
Federal Office of Topography (LPT)	Wabern, Switzerland	Bernese 4.0
Geodetic Observatory Pecny (GOP)	Pecny, Czech Republic	Bernese 4.0
Royal Observatory of Belgium (ROB)	Brussels, Belgium	Bernese 4.0
Warsaw University of Technology (WUT)	Warsaw, Poland	Bernese 4.0
Center for Orbit Determination in Europe (CODE)	Berne, Switzerland	Bernese 4.1
Nordic Geodetic Commission (NKG)	Onsala, Sweden	Bernese 4.0

Table 3: EUREF local network analysis centers. Underlined analysis centers started EUREF processing after May '96

4 The EUREF Analysis Workshop in Brussels, April '97

In April 1997, a first EUREF Analysis Workshop was organized in Brussels [Bru] with as main goal the discussion of the optimization of the EUREF processing. This workshop was attended by representatives of 8 of the 10 EUREF analysis centers.
Items discussed at the workshop were :

- data analysis recommendations for EUREF analysis centers ;
- a redistribution of the EUREF subnetworks in order to work towards a more smooth number of analysis centers which process a specific EUREF station. EUREF analysis centers have agreed that :
  - when adding stations to their subnetwork, priority will be given to new EUREF stations or existing EUREF stations which are processed by only one LAC
  - when eliminating stations from their subnetwork, priority will be given to those stations who are processed by minimal 4 LAC's
- it was recognized that one of the main problems for the correct interpretation of the coordinate time series are undocumented changes of the antennas or their environment, e.g. snow on the antenna, the use of domes, ...
  A closer contact between the analysis centers and the station managers through the EUREF Central Bureau was therefore strongly encouraged.

5 Evaluation of the Past Year of Activities within the EUREF Permanent Network

5.1 The Products of the EUREF Permanent Network

During the last year the EUREF permanent network has grown impressively and demonstrated to function well. Presently the EUREF permanent network makes available two products :

1. the weekly solutions (in SINEX format) for the EUREF subnetworks computed by the individual EUREF Local Analysis Centers :
   The solutions delivered by the EUREF analysis centers are not necessary free-network solutions. Each analysis center is free to apply constraints on the (ITRF94, epoch of obs.) coordinates on the estimated stations (see Table 4).

CENTER	SITES WITH CONSTRAINTS
ASI	Matera
BEK	none
COE	Kootwijk, Wettzell, Metsähovi
IFG	Kootwijk, Madrid, Wettzell
GOP	none
LPT	Kootwijk, Wettzell, Zimmerwald
NKG	Kootwijk, Metsähovi, Onsala, Wettzell
OLG	Graz
ROB	Brussels
WUT	Kootwijk, Matera, Metsähovi, Onsala, Wettzell

Table 4: Constraints applied by the EUREF analysis centers

2. the weekly EUREF combined solution :
   This solution is a constrained solution. The sites Brussels, Graz, Kootwijk, Matera, Metsähovi, Villafranca, Wettzell and Zimmerwald are constrained to their ITRF94 (epoch of obs.) coordinates.

All these products can be obtained from the Institute of Applied Geodesy (*ftp igs.ifag.de, directory pub/EUREF/CLUSTERS*), the University of Berne (*ftp ubeclu.unibe.ch, cd aiub$ftp, cd euref*) and the EUREF Permanent Network Information System (*ftp ftpserver.oma.be, cd pub/astro/euref/product*).
Table 5 is created daily at the EUREF permanent network information system and monitors the availability of the EUREF products.
The combined EUREF solution is weekly forwarded to the International GPS Service for Geodynamics.

```
****** A B C G I L N O R W
 SNX   S E O O F P K L O U
****** I K E P G T G G B T
****************** Last Update : 27-MAY-97 06:37 (Day 147)
905 -  . . . . . . . . 2 .
904 -  3 2 2 . 2 2 . 3 2 3
903 -  2 2 2 4 2 2 4 4 2 3
902 -  2 3 2 3 3 2 4 3 3 3 +
901 -  3 3 2 4 3 2 4 4 2 3 +
900 -  3 3 2 3 2 2 4 3 2 3 +
899 -  3 2 2 3 2 2 4 3 2 2 +
898 -  2 2 2 4 3 2 4 3 3 3 +
897 -  3 3 2 4 2 3 4 3 2 2 +
```

Table 5: Product availability within EUREF permanent network. Each line gives the delay (expressed in weeks) with respect to the epoch of observation that the SINEX solution from a specific analysis center are available. A "+" at the end of a line means that the combined solution has been computed and is available.

Problems encountered during the past year of EUREF permanent network analysis are :

1. Inconsistencies between the individual subnetwork solutions : for example different antenna heights (WUT and CODE used for MDVO a wrong antenna height of 0.1493 m and GOP used the correct height 0.1456 m).
   This is presently checked at the CODE analysis center responsible for the combination : recently CODE started to distribute weekly "error messages" to the EUREF analysis centers.

2. Inconsistencies between the weekly solutions from one individual analysis center : for example receiver/antenna name or height changes which do not correspond to a real change at the permanent station.

In order to remedy to this problem it was recommended at the EUREF analysis workshop in Brussels that the EUREF analysis centers perform a supplementary quality check of their weekly solution by combining it with previous solutions from their analysis center (for example the previous 5 weekly solutions). Anomalies should show up during this combination and be corrected prior to making the solution available to EUREF .

3. Limited exchange of information between the different EUREF analysis centers.
   One of the goals of the EUREF analysis workshop was to get a closer contact between the responsibles of the different EUREF analysis centers.

4. The distribution of the subnetworks processed by the EUREF analysis centers is not optimal.
   more in Section 5.2

5. In order to optimize the quality of the combined solution, the analysis strategies should be tuned and detailed processing guidelines need to be agreed upon. Furthermore, recommendations for future (and present) analysis centers should be discussed.
   more in Section 5.3

6. Due to the introduction of the new IGS phase eccentricity variation tables around GPS Week 860, a jump in the coordinates of several sites using Trimble 4000ST L1/L2 GEOD antennas was detected (see Figure 2) resulting in unreliable estimates of the site velocities.
   This problem has been corrected by the CODE analysis center on the level of the combined EUREF solution : the EUREF combined solutions from before week 860 were recomputed using the new IGS phase eccentricity tables.

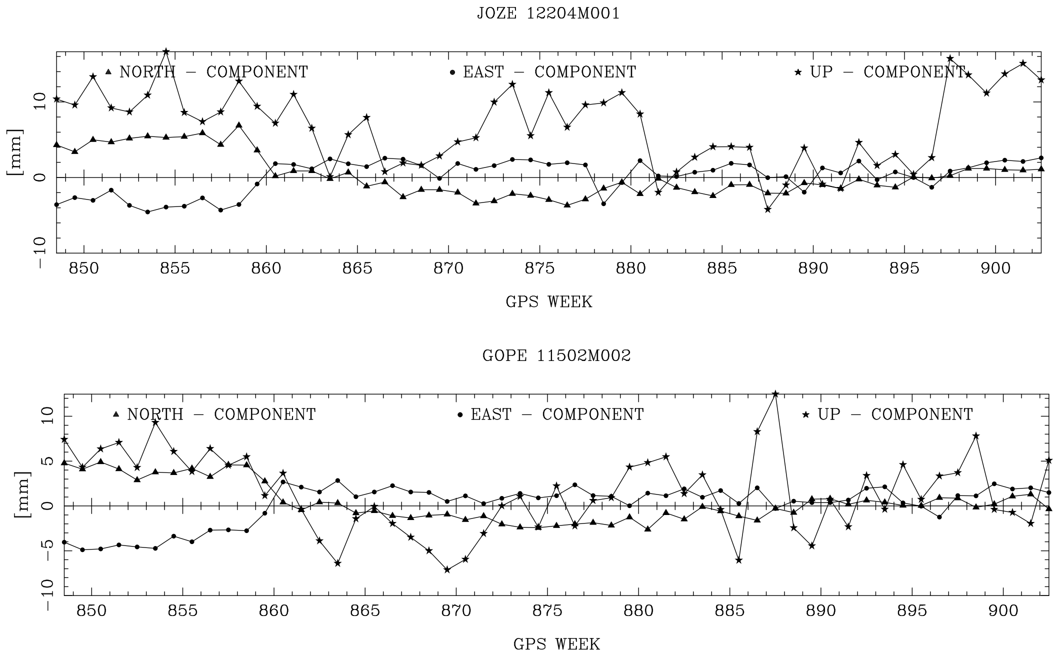

Figure 2: Coordinate time series for Jozefoslaw and Gope (from EUREF combined solution). Both stations use Trimble antennas and due to the use of new phase eccentricity variation tables around GPS Week 860, the east-component of the coordinates shows a jump.

7. The detection, interpretation and eventual correction of jumps in the coordinates of a permanent station (Figures 3, 4 and 5).

The detection should be ameliorated by combining the weekly solution with the solutions from previous weeks and, for the interpretation, a better communication between the analysis centers and the station managers is necessary.

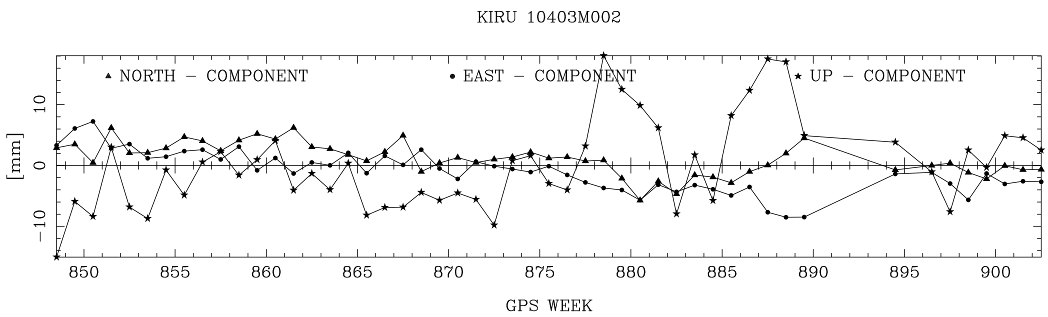

Figure 3: Coordinate time series for Kiruna (from EUREF combined solution). The behaviour of the height component can be explained by the fact that there was snow on the antenna in November '96 (week 878-881) and January '97 (week 886-890)

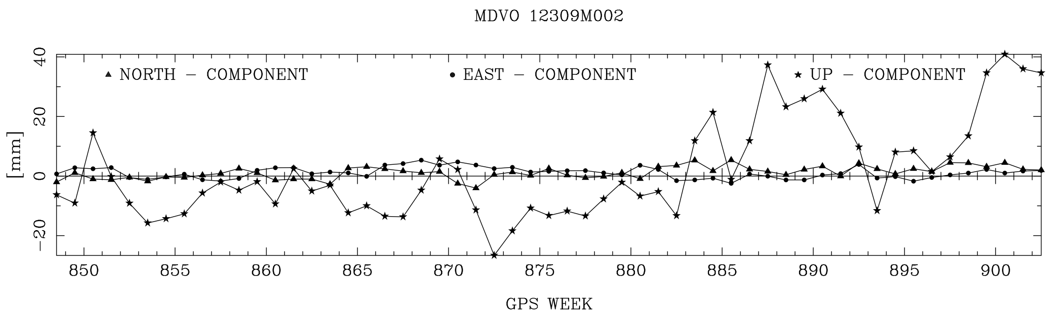

Figure 4: Coordinate time series for Mendeleevo (from EUREF combined solution). The height component shows since GPS week 887 (January '97) a strange behaviour. The source of the problem is not yet found. The receiver operating at Mendeleevo is a Trimble 4000SSE receiver.

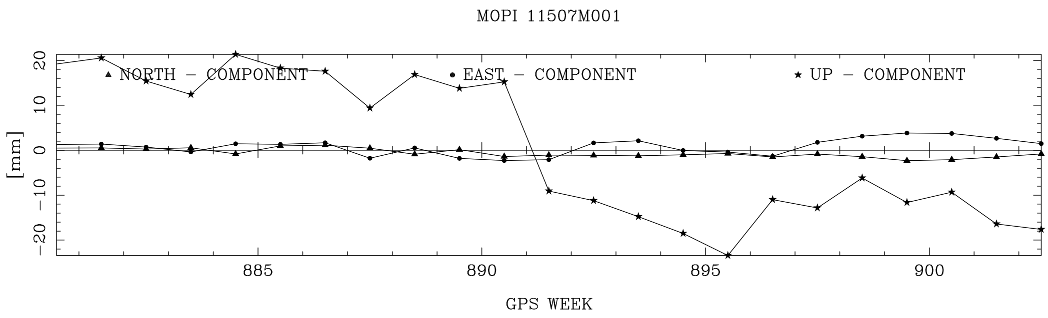

Figure 5: Coordinate time series for Modra Piesok (from EUREF combined solution). A jump of around -2 to -3 cm is detected in the height component at GPS week 891 due to the installation of a dome on the antenne on February 3, 1997. The dome will not be taken of in the future, with one exception: between June 4 - 11, during the next CERGOP campaign.

5.2 The Subnetwork Distribution

The EUREF combined solution is computed by stacking the normal equations (SINEX files) from the EUREF Local Analysis Centers. Stations which are processed by a lot of analysis centers are introduced multiple times into the combined solution and these correlations are not taken into account in the combination procedure. As a result the covariance matrix of the EUREF combined solution will be distorted.
On the other hand, the quality of weekly solution of stations which are processed by only one analysis center is more difficult to assess.
A complete redistribution of the subnetwork processed by each analysis center would be optimal. This rather theoretical proposal is in practice not possible since most of the EUREF LAC's wish to restrict their subnetwork to the geographical area of their interest.

A graph (like Figure 6) with information about the number of LAC's processing the data of each EUREF station is included in the EUREF permanent network information system. All LAC's consult it before changing their subnetwork and try as much as possible to include stations which are only processed by one analysis center and exclude stations which are processed by 5 to 9 analysis centers.

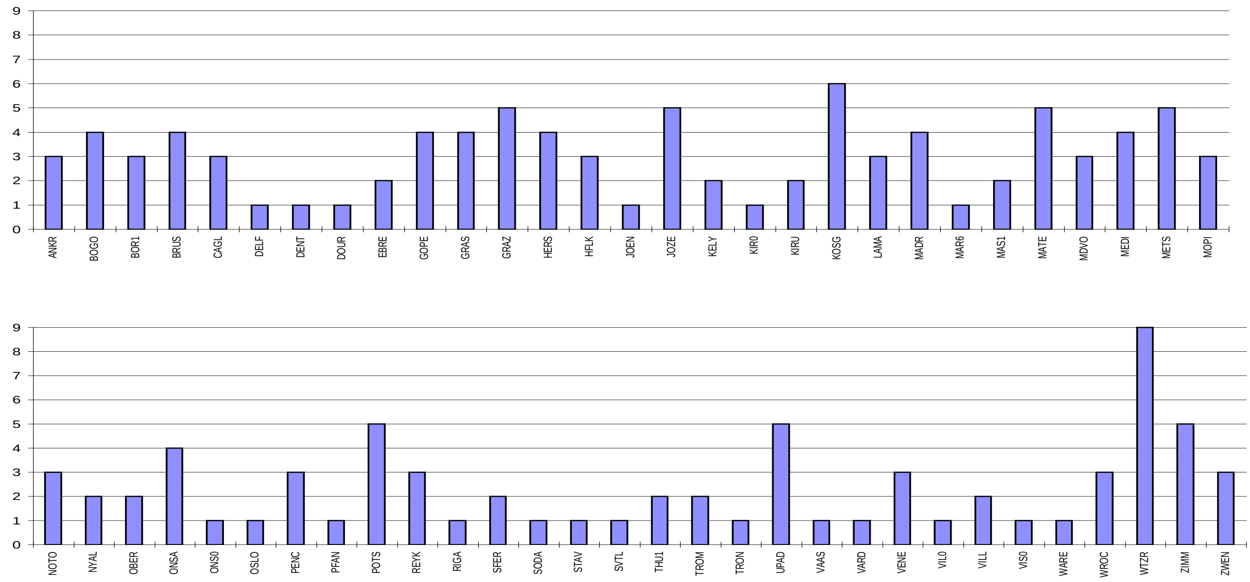

Figure 6: Number of analysis centers (vertical axis) processing the EUREF stations (May 97)

The unhomogeneous subnetwork distribution is also caused by the fact that a lot of LAC's link their subnetwork to the IGS network by including some of the European IGS stations in their subnetwork (this is not necessary as shown in Section 3). The unreliable behavior of some IGS stations in Europe (for example Madrid) coming out of the time series (see Figure 7) should encourage the LAC's to eliminate such a station and introduce instead a neighbouring EUREF station with excellent records in their processing (in the case of Madrid, Villafranca would make a perfect alternative).

Figure 8 shows for each analysis center by how much analysis centers the stations in their subnetwork are processed. For example, for the LPT analysis center all stations of their subnetwork are processed by minimal three analysis centers. The reason for this is that the analysis center of the Federal Office of Topography is presently waiting for the Swiss permanent GPS network to become operational and be included in their subnetwork.

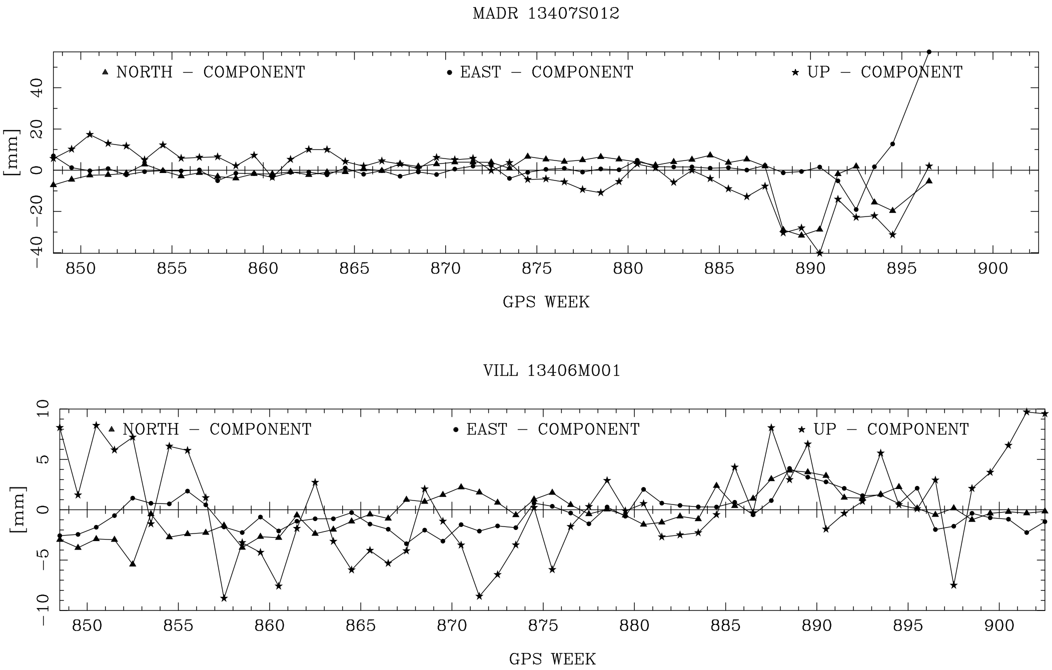

Figure 7: Coordinate time series for Madrid and Villafranca (from EUREF combined solution) : the data from the ROGUE SNR-8 receiver in Madrid shows erronous behaviour since GPS week 889 and has been eliminated from the EUREF combined solution since March '97. The neighbouring EUREF permanent station in Villafranca shows a better behaviour than Madrid.

Four analysis centers (COE, OLG, NKG and ROB) process stations which are not processed by any other analysis center.
Future EUREF LAC's should of course have a significant contribution to the EUREF processing.

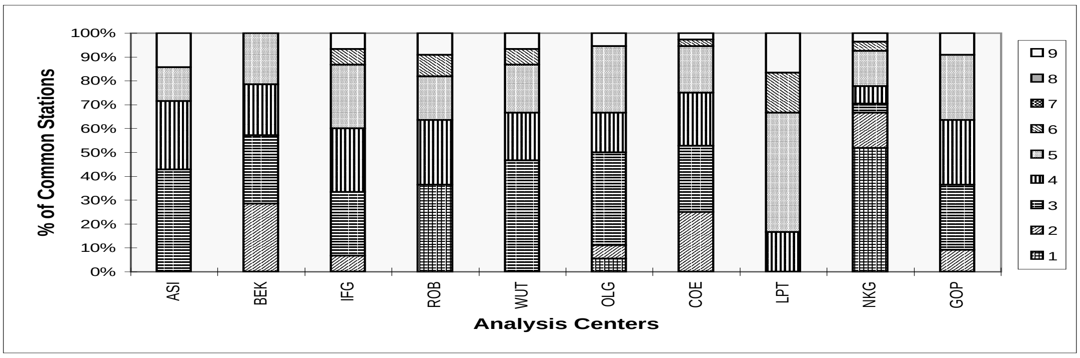

Figure 8: Percentage of stations of a particular EUREF subnetwork which are processed by 1 to 10 analysis centers (May 97)

5.3 Tuning of the Analysis Strategies

Table 6 gives an overview of the analysis strategies used by the 10 EUREF Local Analysis Centers. Although the different strategies seem similar, small differences can be found with respect to troposphere handling, etc...
All analysis centers, with the exception of ASI, use the Bernese Software for their data analysis. The

Italian Space Agency uses the Microcosm Software and has therfore some differences in analysis strategy with respect to the other analysis centers. The Microcosm software includes at present the ocean loading correction, which has a significant effect on some of the stations in the EUREF network (Figure 9).

	ASI	BEK	COE	GOP	IFG
SOFTWARE	Microc.^{o}	Bern4.0	Bern4.1	Bern4.0	Bern4.0
MIN. ELEV.(degr)	15	19	20	19	20
SAMPL. RATE (s)	30	180	180	180	180
TROP. EST.	2h	4h	2h	2h	2h
constr.$^{(1)}$	0.01	0.1,5	5,0.1	0.1,5	5,0.1
input$^{(2)}$	SA	SA	SA	SA	SA
AMBIG. RESOL.	none	QIF	QIF	QIF	QIF
ORBITS/ERP	IGS	IGS	CODE	IGS	IGS
PHASE ECC.	IGS	IGS	IGS	IGS	IGS

	LPT	NKG	OLG	ROB	WUT
SOFTWARE	Bern4.0	Bern4.0	Bern4.0	Bern4.0	Bern4.0
MIN. ELEV.(degr)	20	20	15	10	15
SAMPL. RATE (s)	180	180	180	180	180
TROP. EST.	2h	2h	2h	2h	2h
constr.$^{(1)}$	0.1,5	0.1,5	0.1,0.02	0.1,5	0.1,5
input$^{(2)}$	SA	SA	GRAZ$^{(*)}$	CODE$^{(**)}$	CODE
AMBIG. RESOL.	QIF	QIF	L5/L3	QIF	QIF
ORBITS/ERP	CODE	IGS	CODE	CODE	CODE
PHASE ECC.	IGS	IGS	IGS	IGS	IGS

(o) : MicroCosm software Vs. 9608.0, developed by Van Martin System Inc., Rockville, MD, USA (a commercial version of GEODYN - NASA)
(1) : absolute and relative constraints used for tropospheric zenith path delay estimation
(2) : input values for tropospheric model
(*) : atmospheric parameters based on mean weather conditions in Graz
(**) : using CODE's estimation of tropospheric zenith path delays
SA : using standard atmosphere

Table 6: Analysis strategies used by EUREF Local Analysis Centers

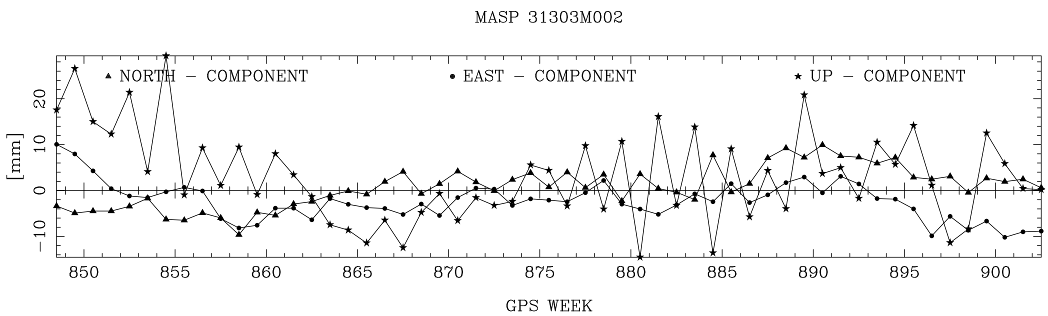

Figure 9: Coordinate time series for Maspalomas (from EUREF combined solution). The weekly solution for the height component shows a period behaviour of more or less 14 days. Taking into account that Maspalomas is located on the island Gran Canaria, the most probable cause is effect of ocean loading, which is not modelled in the Bernese 4.0 Software.

The following recommendations for the analysis of EUREF subnetworks were agreed upon at the EUREF Analysis Workshop in Brussels :

- sampling rate : 180 sec (if possible)
- minimal elevation : 15 degrees (recommended)
  It is agreed upon that a 15 degrees cut off angle improves the repeatability of the height component significantly with respect to a minimal elevation angle of 20 degrees.
  There was some discussion about going to an elevation angle lower than 15 degrees, this should de-correlate the height component, but it is only efficient if elevation dependent weighting of the observations is introduced and if the mapping function of the troposphere is reliable below 15 degrees of elevation. It seems that in the future there could be some changes with this respect in the IGS community, but it is too soon now to give more details.
- tropospheric zenith path delay estimation : each 2 hours, 10 cm a priori absolute weight and 5 m relative (recommended)
- ambiguity fixing (recommended) significantly improves the repeatability of the east component of the station coordinates
- orbits and ERP need to be consistent (IGS or CODE) (required)
- use of IGS phase eccentricity elevation dependent tables (strongly recommended)

All LAC's need to keep the CODE processing center informed about changes in their processing strategy so that the LAC's covariance matrix rescaling can be done accordingly.

6 The EUREF Permanent Network Information System

The EUREF permanent network coordination is performed at the Royal Observatory of Belgium : a fully documented information system (including descriptions of the permanent GPS stations, Local Data Centers, Local Analysis Centers and their subnetworks) is operational and maintained.

In January '96 the anonymous ftp server of the EUREF Permanent Network Central Bureau changed from

jupiter.oma.be
to
ftpserver.oma.be or 193.190.249.203
cd pub/astro/euref

The address of the Web site (http://www.oma.be//KSB-ORB/EUREF/eurefhome.html) did not change.

The EUREF Permanent Network Central Bureau checks weekly the consistency between the headers of the RINEX data files and the station description files in the database and station responsibles are contacted if necessary. The product availability is monitored and reports on the combined EUREF solution are made available as feedback to the contributing analysis centers.

7 What about the Future?

7.1 Extensions of the EUREF Permanent Network

Several European countries are presently in the stage of setting up a national permanent GPS network. Examples are Austria, Switzerland, Germany and Denmark.

New permanent GPS sites are planned in Austria (3-4), Bulgaria (1 in Sofia), Cyprus (1), Denmark (3), England (1 in Morpeth), France (2 in Toulouse and Marseilles), Germany (10-15), Greece (1 in Dionysos), Iceland (1), Italy (1 in Genova), Lithuania (2 in Vilnius and Suurupi), Malta (1), the Netherlands (2 in Westerbork and Terschellingen), Portugal (1 in Cascais), Romania (1), Slovenia (1), Spain (2) and Switzerland (5).

7.2 Yearly Submission of the EUREF Solution to the IERS

In May of 1997, CODE submitted the combined EUREF solution to the IERS. As a result the EUREF permanent stations will be included in the next ITRS realization. As usual C. Boucher and Z. Altamimi will compute the transformation formula's between this ITRS realization and the ETRS.
This submission of the EUREF solution to the IERS will require a rigorous follow up of all receiver/antenna changes in the EUREF sites in order to avoid misinterpretation of the computed station velocities.

Taking into account that the EUREF permanent stations will be included in the ITRF96 list of stations published by the IERS, each of them can be used in the future as anchor stations for the densification of the EUREF Network.

Since EUREF products are available in the *Software Independent Exchange* (SINEX) format, they can be used to link European GPS campaigns of limited duration to the EUREF permanent network. This presumes that the quality and availability of the EUREF products can be guaranteed which is only possible if the contributing analysis centers agree to take part of an official EUREF Service.

References

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[BGA96] C. Bruyninx, W. Gurtner, and Muls A. The EUREF Permanent GPS Network. In *Report on the Symposium of the IAG Subcommission for the European Reference Frame (EUREF) held in Ankara 22-25 May 1996*, volume 57 of *Veröffentlichungen der Bayerischen Kommission für die Internationale Erdmessung*, pages 123–130, 1996.

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