

# The EUREF Permanent GPS Network

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## Abstract

This paper details the structure of the permanent EUREF GPS network and the progress which has been made for the implementation of this network.

Based on the paper *"Guidelines for a Permanent EUREF GPS Network"* ([Gur95]) presented at the EUREF Symposium in Helsinki in May 95, the EUREF network has been set up including the following components : permanent GPS stations, Local Data Centers, Local Analysis Centers, one Regional Data Center and one Regional Analysis Center. For each of these components the present situation is outlined.

All the information related to the EUREF permanent network is now accessible in the EUREF Permanent Network Information Center through anonymous ftp and the World Wide Web.

The Pilot Project Phase (April - December 1996) of the International GPS Service for Geodynamics is using the distributed processing approach to consider the EUREF network as the European regional densification of the IGS network.

## 1 Introduction

Resolution No. 3 of the EUREF Symposium in Helsinki, 3-6 May 1995, stated

The IAG Subcommission for the European Reference Frame

endorses the guidelines for a EUREF network of permanent GPS stations presented by the EUREF Technical Working Group

asks the EUREF Technical Working Group to implement and co-ordinate such a permanent network

requests the EUREF members to take the necessary actions to support these activities

proposes to the International GPS Service for Geodynamics (IGS) that the EUREF network be a regional densification for Europe of the global IGS network

The *"Guidelines for a permanent EUREF GPS Network"* ([Gur95]) have been published in the Proceedings of the EUREF Symposium at Helsinki. In these guidelines the following components were distinguished within the permanent network : permanent GPS stations, Operational

Centers, Local Data Centers, a Regional Data Center, Local Analysis Centers, a Regional Analysis Center and a Network Coordinator.

Most of these components existed already, but various activities were not coordinated. Therefore at the EUREF Technical Working Group Meeting in Paris, October 9-10 1995, Carine Bruyninx agreed to fulfill the task of the Network Coordinator responsible for the supervision and coordination of all activities within the EUREF permanent network. The main tasks of the Network Coordinator are explained in [Gur95].

## 2 Permanent GPS Stations

In order to clarify the terminology used for the permanent GPS stations in Europe, 3 types of stations are distinguished :

**IGS stations :** European GPS sites included in the IGS network.

A permanent GPS station is recognized as an IGS station if :

1. IGS standards are followed while installing the station ;
2. the data are made available to the IGS community ;
3. the data are analyzed by at least one IGS Analysis Center or IGS Associate Analysis Center.

**EUREF stations :** GPS sites who are part of the European densification of IGS, but whose data are not necessarily made available through IGS.

A permanent station is recognized as a EUREF station if :

1. IGS standards are followed as much as possible when installing the station ;
2. the data are made available to the EUREF community ;
3. the data are analyzed by at least one EUREF Local Analysis Center or EUREF Regional Analysis Center (see section 4 and section 9.3)

**Local stations :** GPS sites which are mainly used as permanent national reference sites and which are part of a geodetic permanent network.

The stations fulfill (more or less) IGS standards. The data from the local stations are collected by an Operational Center (OC) which sends the data to a Local Data Center. The Local Data Center archives the data and makes them available to the local users (on commercial base or not). Furthermore, it is encouraged to make the data available to EUREF in the frame of specific scientific campaigns. The data from the local stations are regularly analyzed at a Local Analysis Center delivering accurate positions in the national reference frame.

Although the local stations are not directly the concern of the EUREF subcommission, it is important to include these permanent sites in the EUREF database as potential EUREF stations. The agencies operating local stations are encouraged to submit their station information forms to the EUREF Network Coordinator, which will make this information freely available to the EUREF user community. This will discourage the duplication of GPS points. If for a certain GPS project, a particular area is considered, then it will be possible to check the EUREF database to see if there are already any existing or planned points close to this area.

A local network can consist of IGS stations (data available through IGS and processed by an IGS Analysis Center), EUREF stations (data processed by LAC and weekly solutions forwarded to RAC) and local stations (used for local scientific, geodetic, ... applications).

### 3 EUREF Data Centers

Within the International GPS Service for Geodynamics, the RINEX data from the permanent GPS stations are made available through **IGS Regional and Global Data Centers**. For Europe, the IGS Regional Data Center is located at the Institute for Applied Geodesy (IfAG) in Germany where all RINEX data from the IGS stations, and a part of the EUREF stations are available through anonymous ftp (ftp igs.ifag.de, directory : outdata).

Taking into account the growing number of permanent GPS stations in Europe, it becomes clear that it is not necessary to have the RINEX data from all these stations available at the Regional Data Center.

A set of **EUREF Local Data Centers** (LDC's), such as the Local Data Centers in Graz and Brussels, can give access to the data from a particular European subnetwork. The Local Data Centers will lighten the burden of the Regional Data Center and unnecessary data transmissions through Internet will be avoided. Local Data Centers can filter the data before forwarding them to the Regional Data Center : data collected for local purposes only do not (or should not) appear at the regional level.

The **Regional Data Center** (RDC) continues to make available the data from the regional IGS stations, as well as from the EUREF stations who are not part of a local network and have no Local Data Center. Some Local Data Centers prefer that the data from their local network are also available at the RDC as a back-up system.

The EUREF stations make their data available to EUREF in one of the following ways :

- by sending the data to the Local Data Center which makes the data available from a particular EUREF subnetwork through an anonymous ftp-account or user-login account. The LDC can also send the data from the subnetwork to the Regional Data Center at IfAG.
- by sending the data to the Regional Data Center (IfAG).

In addition to the data files, the SINEX solutions of the EUREF Local Analysis Centers are forwarded to the RDC where they are made available to the Regional Analysis Center and other interested agencies.

### 4 EUREF Analysis Centers

Two types of analysis centers perform the data analysis within the EUREF network :

**the EUREF Local Analysis Centers (LAC) :**

Presently there are 4 LAC's operating (see section 9.3). The Local Analysis Centers process routinely the data from a particular EUREF subnetwork (including IGS and EUREF stations) and perform quality control. This processing can be used for local geophysical or

geodetic applications, such as deformation monitoring, ionospheric analysis, determination of national transformation formulas, . . .

The data analysis is done by following IGS standards as much as possible using the precise IGS (or CODE) orbits and Earth Rotation Parameters. The products delivered by the LAC's are weekly free-network solutions of their local EUREF subnetwork together with some **anchor stations** (= at least 3 geographically well distributed regional or global IGS stations with respect to the area considered).

Taking the time delay of the availability of the precise orbits (products of the IGS Analysis Centers) into account, the products from the Euref Local Analysis Centers should be available within one month. When available, the weekly free-network solutions are forwarded to the EUREF Regional Data Center.

**the EUREF Regional Analysis Center (RAC) :**

The EUREF Regional Analysis Center (RAC) is the Center for Orbit Determination (CODE), located at the University of Bern. CODE is presently including in their routine processing for IGS (as IGS Analysis Center) all the European permanent sites available at IAG.

Independently from the IGS processing, CODE is combining the weekly-free network solutions from the EUREF Local Analysis Centers into one European solution (including the IGS and EUREF stations from the local networks).

The terminology "local" used for the EUREF Local Analysis Centers must be considered in an hierarchical sense and not in a geographical one : EUREF Local Analysis Centers process a subnetwork, which can geographically cover different European countries involved in the EUREF network.

## **5 Relation to IGS**

In January 1996 the International GPS Service for Geodynamics distributed a

“ CALL FOR PARTICIPATION AS IGS REGIONAL NETWORK ASSOCIATE ANALYSIS CENTERS (RNAAC) FOR REGIONAL STATION POSITION ANALYSIS ” (IGS-Mail No 1178).

This "Call for Participation" had as principal goal the implementation of the regional densification of the IGS network.

Until now two types of analysis centers were distinguished within IGS :

**the IGS Analysis Centers (AC)** which produce routinely orbit parameters and Earth Rotation Parameters and annually submit GPS global network solutions to the IERS for subsequent improvements of the ITRF.

**the IGS Global Network Associate Analysis Centers (GNAAC)** which take the free-network solutions from the AC's and produce combined network solutions.

In order to realize the regional densification of IGS, the introduction of a new type of analysis center was necessary : the **Regional Network Associate Analysis Center (RNAAC)**.

These Regional Network Associate Analysis Centers will analyze specific regional cluster(s) of stations following IGS standards and guidelines. They provide free network solutions to the

IGS Global Network Associate Analysis Centers which will be incorporated in a global network solution. RNAAC's are of course free to impose any constraint they wish for their own internal purposes.

With this setup IGS Global Network Associate Analysis Centers will take the weekly free-network solutions from all AC's and the future RNAAC's, and produce combined "dense" network solutions.

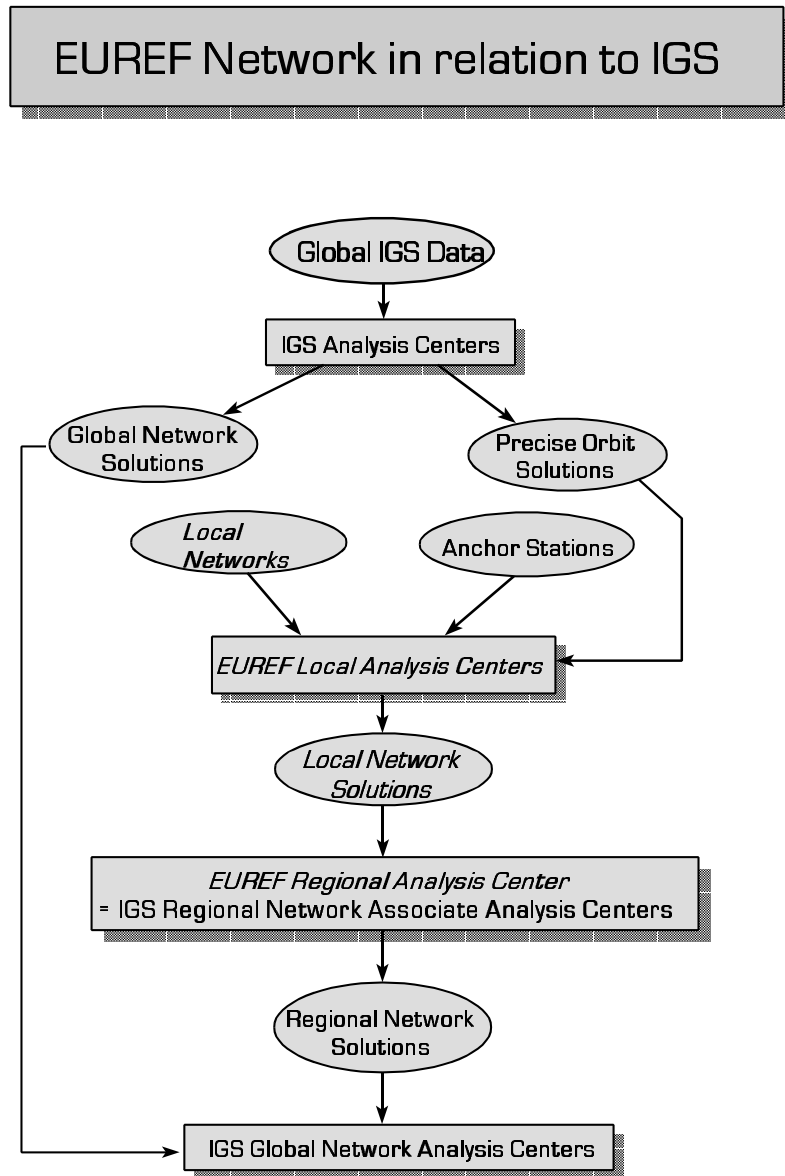


Figure 1: Flow chart describing the set up of the EUREF network in relation to IGS. The rectangles denote analysis; rounded boxes denote data. Italic text shows the components specific for EUREF.

In Europe, there are 2 IGS Analysis Centers : GFZ and CODE and one Global Network Associate Analysis Center located at the University of Newcastle.

The EUREF Subcommittee has responded to the IGS call for participation and has expressed the willingness of CODE to act as IGS Regional Associate Analysis Center who will deliver weekly free-network solutions for the European region to the IGS Global Network Associate Analysis Centers.

The free-network solutions delivered by CODE to the IGS will be obtained by combining the weekly free-network solutions from the EUREF Local Analysis Centers (see Section 9.3). In this way the EUREF permanent network will fulfill one of its principal goals, which is to be considered as a true densification of the IGS network.

The IGS Pilot Project Phase for the “Densification of the IGS network through Regional GPS Analysis” started on April 1st, 1996 and will run until December 31, 1996.

In May of 1996, the IGS officially accepted the EUREF proposal. A flow chart describing how the EUREF network is implemented in the network of the International GPS Service for Geodynamics is shown in Figure 1 [BBK94].

## 6 Standards for Data Analysis and Solutions Exchange

The EUREF Local Analysis Centers should have :

- an Internet connection in order to be able to get RINEX data files from the Local and Regional Data Center and send the weekly free-network solutions to EUREF Regional Data Center at IfAG.
- the capacity (computer and man-power) to guarantee the routine data analysis of a European subnetwork (more or less 10 stations).
- the GPS processing software used for the EUREF analysis should be able to
  - read RINEX files
  - use precise ephemeris files (CODE or IGS)
  - use elevation dependent phase eccentricity tables, if different antenna types are combined
  - generate free-network solutions in the Software Independent Exchange Format (SINEX, currently version 1.0)

Until now, no strict rules have been put forward for the analysis of the EUREF subnetworks. During the Pilot Project Phase, which is actually going on, the solutions obtained by the different EUREF Local Analysis Centers are compared in order to define the optimal processing strategy [BG96].

The exchange of free-network solutions should be done using the SINEX format. The official version (1.0) of this format is available since April 1996 and its description is available at the EUREF Information Center. Until the time that this format will be implemented by all EUREF Local Analysis Centers, the exchange of solutions between the Local Analysis Centers and Regional Analysis Center will be done according to standards agreed upon by the Network Coordinator, the Local Analysis Center and the Regional Analysis Center.

The weekly free-network solutions are combined by the EUREF Regional Analysis Center in order to obtain for each week one regional European free-network solution, which will be



## 7 EUREF Permanent Network Information Center

Although the IGS has expressed its willingness to act as an *information clearing house* [GN94], it is more efficient to centralize the information concerning the EUREF permanent network in a place located in Europe and dedicated to this purpose only.

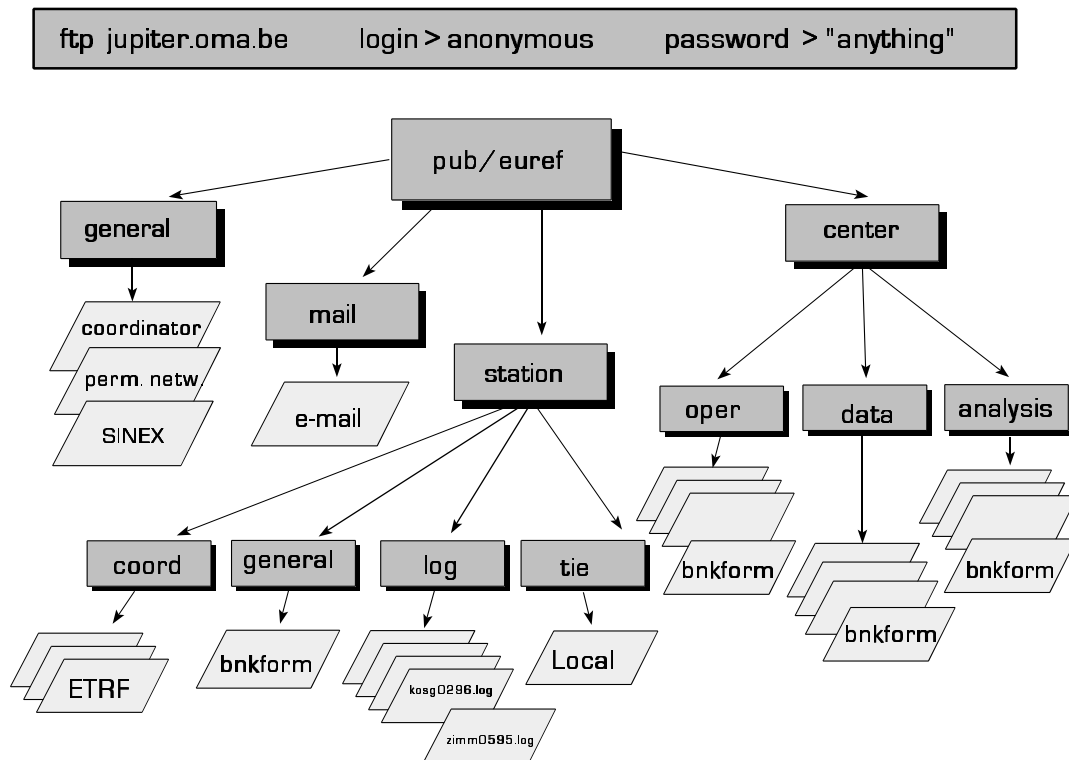


Figure 2: Directory structure of EUREF permanent Network Information Center

An information center regrouping all information relevant to the EUREF permanent GPS network has been created at the Royal Observatory of Belgium (ROB) (see Figure 2). It is accessible through :

### anonymous ftp to jupiter.oma.be :

New stations, Operational Centers, Local Data Centers and Local Analysis Centers who wish to be part of the EUREF network have to contact the EUREF Network Coordinator (e-mail : C.Bruyninx@oma.be) in order to be included in the database. The EUREF Permanent Network Database will not be a completely automated database during the first year : all information (new and updated) will be included in the database after being sent to the Network Coordinator. Once the database is operational, an automated procedure (similar to the one used by IGS) can be constructed for the updating of the information forms.

Agencies responsible for EUREF stations, which are not included in the IGS network should communicate with the Network Coordinator concerning the updating of their Station Information Forms.



IGS stations can continue to communicate with IGS concerning their station, although it is recommended to send a notification by e-mail to the Network Coordinator about important changes concerning the station.

In the EUREF network the emphasis is put on the EUREF Local Data Centers, EUREF Local Analysis Centers and their communication with the Regional Analysis Center. Additionally a “Local Analysis Information Form” has been created and included in the EUREF database.

Blank forms for the EUREF Sites, the Operational Centers, the Local Data Centers and the Local Analysis Centers can be found in the EUREF Information System as shown in Figure 2.

**the World Wide Web : <http://www.oma.be//KSB-ORB/eurefhome.html> :**

This www-site includes a link to the EUREF anonymous ftp account, but gives additionally maps with :

- the operational and future EUREF stations
- the EUREF subnetworks and the EUREF Local Analysis Centers

## 8 Becoming part of the EUREF network

### 8.1 Stations

All European IGS stations are automatically included in the EUREF network.

Permanent stations who wish to become a EUREF station should follow this checklist :

1. Contact the EUREF Network Coordinator (e-mail : C.Bruyninx@oma.be) concerning the intention to install the station, schedule for implementation, and a statement of desire for the station to be included in the European permanent network.
2. If the station is part of a local network, communicate the name of the associated Operation Center and Local Data Center to the Network Coordinator and send a copy of the e-mail to the Local Data Center.  
If the station is not part of a local network, contact the Regional Data Center which will make available the data to get the necessary data transfer information (e-mail : habrich@igs.ifag.de).
3. Follow the IGS standards when installing the station.
4. Download the “EUREF Site Information Form” from the Information Center

```
ftp jupiter.oma.be
login : anonymous
password : ‘anything’
cd pub/euref/station/general
get blnkform.STA
```

and complete it.

5. Once the station is installed and operational, send the EUREF Site Information Form to IGN France (e-mail : altamimi@ign.fr) to have a Domes number and a EUREF number attributed for your station.

6. E-mail the Site Information Form including the Domes and EUREF numbers to the Network Coordinator.
7. Once the data are available at a Local or Regional Data Center, the Network Coordinator will contact one of the Local Analysis Centers in order to have the station included in their subnetwork processing
8. If necessary, the Network Coordinator will contact the Local Data Center, Local Analysis Center, Regional Data Center and Regional Analysis Center to get updated information files which will be made available through the EUREF database.

## 8.2 Operational Centers/Local Data Centers/Analysis Centers

Operational Centers responsible for a local network should download the “Operational Center Information Form” from the EUREF Information Center :

```
ftp jupiter.oma.be
login : anonymous
password : ‘‘anything’’
cd pub/euref/center/oper
get blnkform.OC
```

complete it and send it to the Network Coordinator.

For local networks, the agency (=Operational Center) responsible for the network will often act as a Local Data Center. Stations which are not part of a local network are as such not connected to an Operational Center. In this case the organization operating the site will act as Operational Center.

Once the Network Coordinator has been contacted by an Operational Center (OC) concerning the operation of a new GPS station and the availability of its data, he will request from this OC a short description of the Center, giving information on its three main tasks : the GPS station(s), the information file(s) and the kind of operation for the station(s).

Because of the growing importance of the Local Data Centers a “Local Data Center Information Form” has been created, which will be regularly updated by the concerned Agencies. The blank information form can be downloaded from

```
ftp jupiter.oma.be
login : anonymous
password : ‘‘anything’’
cd pub/euref/center/data
get blnkform.LDC
```

In order to have an overview of the subnetworks and the processing strategies all EUREF Local Analysis Centers should get a blank “Local Analysis Center Form” from the EUREF Information Center

```
ftp jupiter.oma.be
login : anonymous
password : ‘‘anything’’
cd pub/euref/center/analysis
get blnkform.LAC
```

complete it and send it to the Network Coordinator.

## 9 Present Status of the EUREF Network

### 9.1 Stations

Figure 3 gives an overview of the stations included in the EUREF network (April 1996).

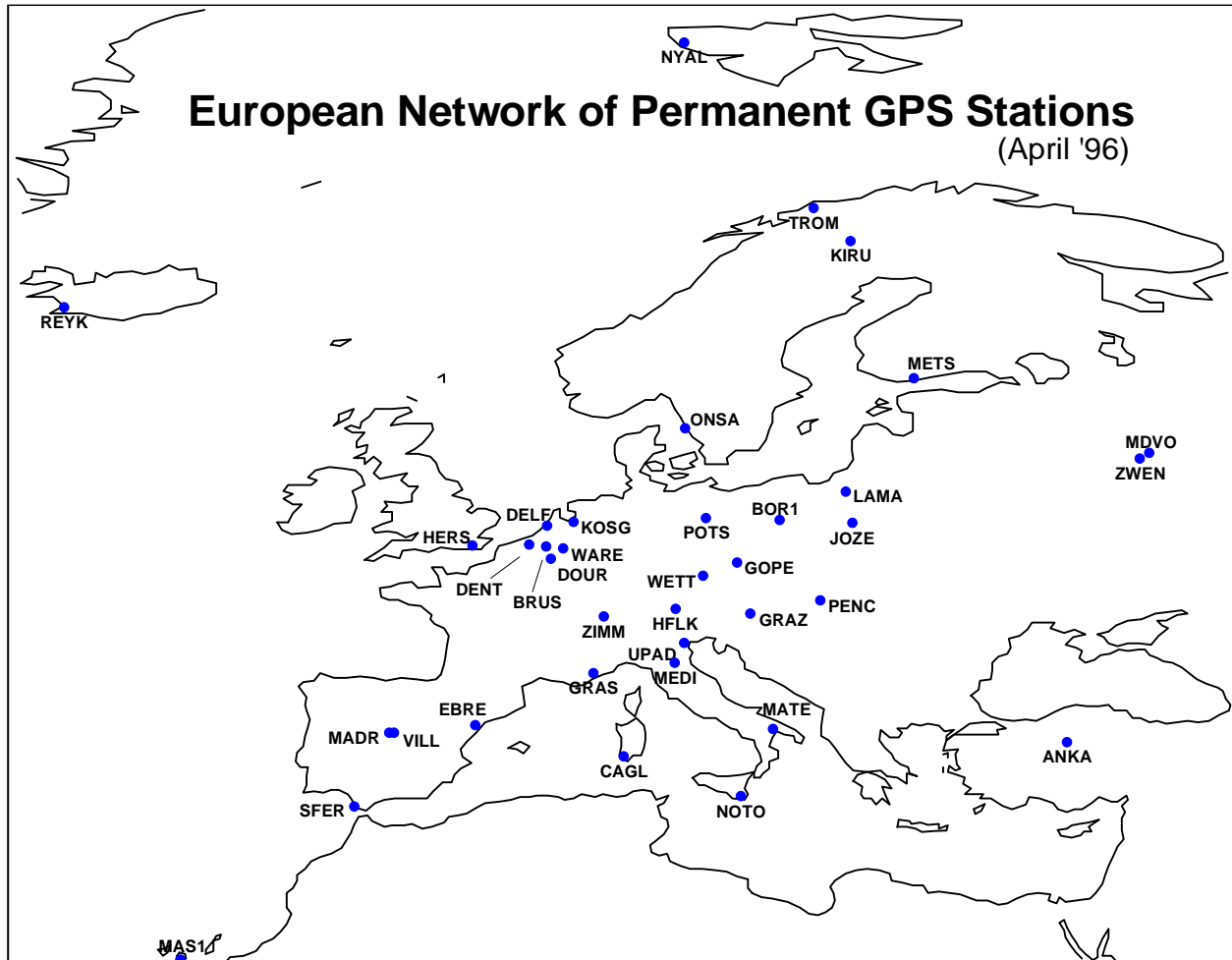


Figure 3: Stations included in the EUREF network

### 9.2 Local Data Centers

Several Local Data Centers are presently making available the RINEX data of local subnetworks within EUREF. Some of the data available at the Local Data Centers are also available at the Regional Data Center at IfAG.

The following Local Data Centers are presently operating :

1. GRAZ : of the Austrian Academy of Sciences Institute of Space Research, Department of Satellite Geodesy, giving access to a part of the Central European permanent stations

2. DUT : of the Delft University of Technology (Mathematical Geodesy), giving access to the Dutch EUREF and IGS stations, and the stations of the Dutch *Active GPS Reference Network (AGRS)*
3. ROB : of the Royal Observatory of Belgium, giving access to the Belgian EUREF stations

In some of the LDC's the data from the local networks are freely available for the EUREF community, but are only available on a commercial base to local users.

### 9.3 EUREF Local/Regional Analysis Centers

At present 4 EUREF Local Analysis Centers are processing a European subnetwork of stations :

1. Institute for Applied Geodesy (IFG): computing a "*regional European subnetwork*" including 13 IGS stations and started in January 1995
2. Bayerische Akademie der Wissenschaften (BEK): computing a "*Mediterranean Subnetwork*" including 13 stations and started in November 1995
3. Royal Observatory of Belgium (ROB): computing a BENELUX subnetwork of 4 EUREF permanent stations and 7 IGS stations, started in January 1996
4. Warsaw University of Technology (WUT): computing a "*Central European Subnetwork*" including 11 stations and started in February 1996

Table 1 gives an overview of the subnetworks processed by the EUREF Local Analysis Centers (Status April 1996).

Two analysis centers have expressed their intention to participate to the EUREF processing as future EUREF Local Analysis Centers :

- Observatory Lustbühel Graz (OLG): computing a "*Central European Subnetwork*" concentrated on Austrian stations, starting in the summer of 1996
- Nordic Geodetic Commission (NKG): computing a "*Nordic Subnetwork*", starting in the summer of 1996.

As mentioned before, the CODE processing center is at present fulfilling the role of the EUREF Regional Data Center which combines weekly the free-network solutions from the EUREF Local Analysis Centers into one European solution delivered to IGS.

## 10 Conclusions

The EUREF network of permanent GPS stations is presently starting to be well organized. With the creation of EUREF Local Data Centers and Local Analysis Centers, the principle of distributed processing has shown to a worthwhile alternative.

The network of permanent GPS stations (present and future) is almost completely covering Europe, although it would be nice to have some supplementary sites in the South-West and East of Europe.

|      | BEK | IFG | ROB | WUT |
|------|-----|-----|-----|-----|
| ANKR | X   | X   | -   | -   |
| BOR1 | -   | -   | -   | X   |
| BRUS | -   | X   | X   | -   |
| CAGL | X   | -   | -   | -   |
| DELF | -   | -   | X   | -   |
| DENT | -   | -   | X   | -   |
| DOUR | -   | -   | X   | -   |
| EBRE | X   | -   | -   | -   |
| GOPE | -   | -   | -   | X   |
| GRAS | X   | -   | -   | -   |
| GRAZ | -   | X   | -   | -   |
| HERS | -   | X   | -   | -   |
| HFLK | -   | -   | X   | X   |
| IRKT | -   | -   | -   | -   |
| JOZE | -   | -   | X   | X   |
| KIRU | -   | -   | -   | -   |
| KIT3 | -   | -   | -   | -   |
| KOSG | -   | X   | X   | X   |
| LAMA | -   | -   | -   | X   |
| MADR | X   | X   | -   | -   |
| MAS1 | X   | -   | -   | -   |
| MATE | X   | X   | -   | X   |
| MDVO | -   | -   | -   | X   |
| MEDI | X   | -   | -   | -   |
| METS | -   | X   | -   | X   |
| NOTO | X   | -   | -   | -   |
| NYAL | -   | -   | -   | -   |
| ONSA | -   | X   | -   | X   |
| PENC | -   | -   | -   | X   |
| POL2 | -   | -   | -   | -   |
| POTS | -   | X   | X   | -   |
| REYK | -   | X   | -   | -   |
| SFER | X   | -   | -   | -   |
| THU1 | -   | -   | -   | -   |
| TROM | -   | -   | -   | -   |
| UPAD | X   | -   | -   | -   |
| VILL | X   | -   | -   | -   |
| WARE | -   | -   | X   | -   |
| WETT | -   | X   | -   | X   |
| WTZR | -   | -   | X   | -   |
| ZIMM | X   | -   | X   | -   |
| ZWEN | -   | X   | -   | -   |

Table 1: Overview of the different subnetworks in the distributed processing of the EUREF network (“X”= station included in processing, “-”= station not included in processing)

At present there are 4 EUREF Local Analysis Center who are processing routinely the data from the EUREF permanent network, together with the CODE processing center who is processing almost the complete network. As shown in Table 1, there are still some stations which are not processed by a Local Analysis Center.

With the growing number of permanent GPS sites within the EUREF network, there is a need for more Local Data Centers making available the data from EUREF subnetworks.

## References

- [BBK94] G. Blewitt, Y. Bock, and J. Kouba. Constructing the IGS Polyhedron by Distributed Processing. In *Proceedings of IGS Workshop : Densification of the IERS Terrestrial Reference Frame through Regional GPS Networks.*, pages 21–36, Pasadena, California, November 30 - December 2 1994.
- [BG96] E. Brockmann and W. Gurtner. Combination of GPS Solutions for Densification of the European Network: Concepts and Results derived from 5 European Associated Analysis Centers of the IGS. In *Report on the Symposium of the IAG Subcommittee for Europe (EUREF) held in Ankara 22-25 May 1996*, volume (in press) of *Veröffentlichungen der Bayerischen Kommission für die Internationale Erdmessung*, 1996.
- [GN94] W. Gurtner and R.E. Neilan. Network Operations, Standards and Data Flow Issues. In *Proceedings of IGS Workshop : Densification of the IERS Terrestrial Reference Frame through Regional GPS Networks.*, pages 45–57, Pasadena, California, November 30 - December 2 1994.
- [Gur95] W. Gurtner. Guidelines for a Permanent EUREF GPS Network. In *Report on the Symposium of the IAG Subcommittee for the European Reference Frame (EUREF) held in Helsinki 3-6 May 1995*, volume 56 of *Veröffentlichungen der Bayerischen Kommission für die Internationale Erdmessung*, pages 68–72, 1995.