The EUREF Permanent Network: Recent Achievements

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Abstract
This document introduces the EUREF Permanent Network (EPN) and describes its present status by concentrating on the major changes to the EPN since the EUREF Symposium of June 2005 held in Vienna. In addition, plans for the future are discussed.

1. INTRODUCTION

EUREF, the IAG (International Association of Geodesy) Reference Frame Sub-commission for Europe, deals with the definition, realization and maintenance of the European Reference Frame, focusing on both the geo-spatial and the vertical components. As such, EUREF has been developing activities related to the establishment and maintenance of the ETRS89 (European Terrestrial Reference System) and EVRS (European Vertical Reference System).
ETRS89 provides geocentric, three-dimensional positions with centimeter accuracy, in a unique homogeneous reference system for the whole Europe, while EVRS does the same for the height. These systems are the basis for geo-referencing in Europe both on a national as on an international level and they have been recommended for adoption by the European Union, EuroControl and EuroGeographics, the consortium of the European National Mapping and Cadastre Agencies.

The ETRS89 is maintained by the EUREF Permanent Network (EPN), a network of continuously operating GPS reference stations maintained in close cooperation with the IGS (International GNSS Service). The primary purpose of the EPN is to maintain and provide access to the European Terrestrial Reference System (ETRS89) and EUREF does this by making available the tracking data of the EPN stations and by generating weekly coordinate estimates for all of them.

While all contributions to the EPN are voluntary, the reliability of the network is based on the principle of redundancy together with extensive guidelines guaranteeing the consistency of the raw GPS data to the resulting station coordinates. Next to its key role in the maintenance of the ETRS89, the EPN supports a wide range of scientific applications such as geodynamics, sea level monitoring and weather prediction.

The EPN Central Bureau (CB), headed by the network coordinator, is responsible for the day-to-day management of the EPN and acts as liaison between station operators and analysis centres, providing the necessary station configuration metadata and ensuring the datasets meet the requirements of the analysis. The EPN CB maintains and verifies the correctness of the station metadata information, monitors the quality of the daily GPS data from all the stations, the hourly data flow and the station coordinates and sends notification emails to station operators when abnormal conditions occur. It makes all this information available through its website http://epncb.oma.be/ and maintains the EUREF and EUREF LAC mailing lists.

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2. Status of the EUREF Permanent Network

Today, the EPN network consists of 190 continuously operating GPS reference stations (Figure 1). Five EPN stations are presently inactive: CAME (Camerino, Italy), DUBR (Dubrovnik, Croatia), NSSP (Yerevan, Armenia), OSJE (Osijek, Crotia) and ZECK (Zelenchukskaya ,Russia). Five stations have been withdrawn from the EPN since June 2005:

- HOER (Hoernum, Germany) withdrawn in June 2005 and replaced by HOER; the platform of the HOE2 antenna had to be moved due to a change of the construction on the roof where the HOER antenna was located.
- MDVO (Mendeleevo, Russia) withdrawn in June 2005 because of a lack of data and perspectives for the future
- IAVH (Rabat, Morocco) withdrawn in August 2005 because of a lack of data and perspectives for the future
- OBET (Oberpfaffenhofen, Germany) withdrawn in September 2005 because it did not fulfil the new EPN/IGS guidelines (too large horizontal eccentricities)
- IGD1 (Athens, Greece) withdrawn in December 2005 because of changes in the company operating the equipment

The 24 new EPN stations that joined the EUREF network since June 2005 are given in Table 1. None of these new stations belongs to the IGS network. All of them submit hourly data, five participate to the EUREF-IP project, two are included in the European Combined Geodetic Network (ECGN) and two are equipped with GPS/GLONASS receivers.

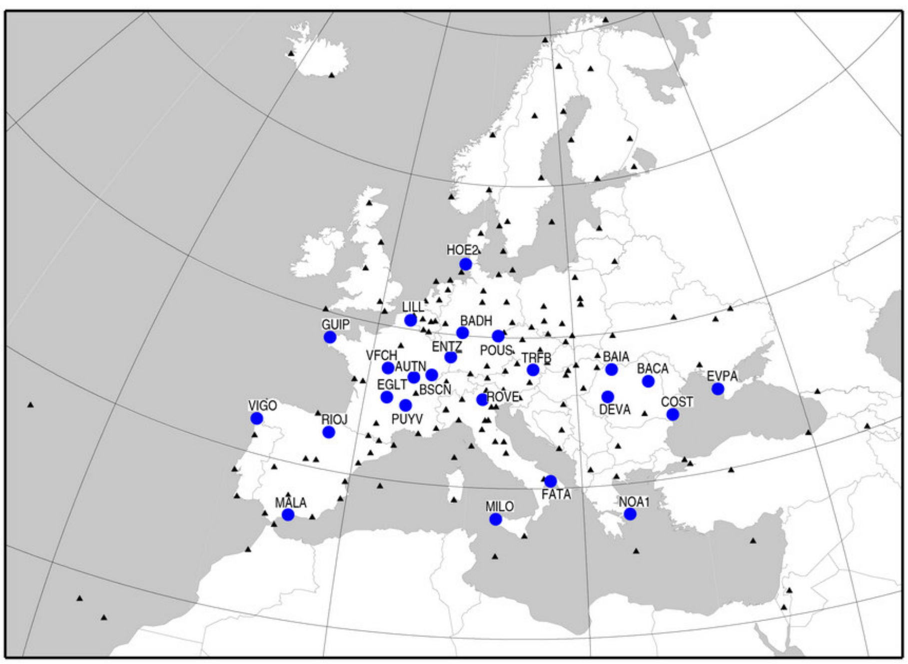

Figure 1 – EUREF permanent tracking network (status June 2006); the circles show the stations added to the network after June 2005.

Station	4char-ID	Country	Date inc.				
Autun	AUTN	France	03-07-2005	H			
Egletons	EGLT	France	03-07-2005	H			
Entzheim	ENTZ	France	03-07-2005	H			
Guipavas	GUIP	France	03-07-2005	H			
Le Puy en Velay	PUYV	France	03-07-2005	H			
Villefranche-sur-Cher	VFCH	France	03-07-2005	H			
Hoernum	HOE2	Germany	07-08-2005	H		IP	GLO
Poustka	POUS	Czech Rep.	16-10-2005	H			GLO
Malaga	MALA	Spain	13-11-2005	H		IP	
Logrono	RIOJ	Spain	13-11-2005	H		IP	
Vigo	VIGO	Spain	13-11-2005	H		IP	
Evpatoria	EVPA	Ukraine	13-11-2005	H			
Taranto	FATA	Italy	13-11-2005	H			
Trapani – Milo	MILO	Italy	13-11-2005	H			
Pernitz	TRFB	Austria	13-11-2005	H	ECGN		
Villeneuve d'Ascq	LILL	France	18-12-2005	H			
Besançon	BSCN	France	18-12-2005	H			
Bacau	BACA	Romania	12-02-2006	H			
Baia Mare	BAIA	Romania	12-02-2006	H			
Constanta	COST	Romania	12-02-2006	H			
Deva	DEVA	Romania	12-02-2006	H			
Rovereto	ROVE	Italy	09-04-2006	H		IP	
Bad Homburg	BADH	Germany	07-05-2006	H	ECGN		
Athens	NOA1	Greece	07-05-2006	H			

Table 1- Tracking stations added to the EPN since June 2005, IP: stations participating to EUREF-IP, ECGN: stations belonging to ECGN network, GLO: stations equipped with GPS+GLONASS receivers.

All EPN stations are minimally processed by 3 EPN Local Analysis Centres (LAC) and up to now the growth of the network has not prevented us from applying this important rule. As a consequence, the size of the subnetworks processed by the LAC has grown over the years, as can be seen in Figure 2.

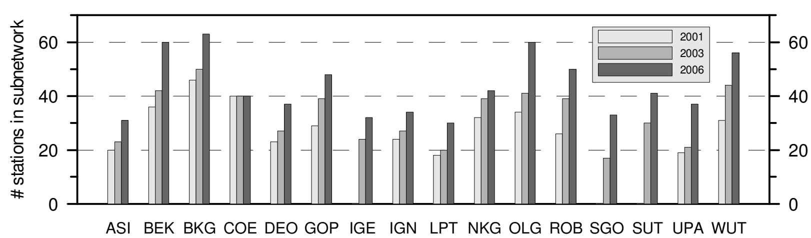

Figure 2 – Size of the EPN LAC subnetworks

3. INTRODUCTION OF ABSOLUTE ANTENNA PHASE CENTRE VARIATION MODELS

In the upcoming months the EPN and IGS will switch to the use of absolute antenna phase centre variations (APCV) for the modelling of the phase centre of the antenna of their permanent stations. In these new models, the effect of the radome on the APCV is taken into account. Presently two types of APCV are available: a first set is based on robot calibrations and a second set is obtained from a conversion of the old relative models. The converted models are less precise than the robot models because they are only valid for elevations above 10° and they do not have azimuthally dependencies like the robot values. It is therefore recommended that proposed EPN stations are only accepted within the EPN when their antenna/radome has absolute robot PCV available. The same principle is valid for existing EPN stations that are planning to change their antenna. Table 2 gives an overview of the present situation in the EPN. Antenna/radome combinations without absolute PCV will be modelled by using the APCV of the antenna only, neglecting the radome, which is a situation far from ideal. Within time, it is expected that this type of equipment will disappear from the EPN.

Antennae/Radomes with absolute calibrations from robot		
AOAD/M_B	NONE	METS
AOAD/M_T	NONE	ANKR BOR1 MAS1 MORP NICO NPLD OBE2 ORID POTS REYK SOFI TRO1 VILL WTZR ZECK
ASH700936A_M	NONE	AJAC SJDV VLNS
ASH700936C_M	SNOW	BOGO
ASH700936D_M	NONE	RIGA
ASH700936D_M	SNOW	ACOR BUCU DRAG DUBR HELG ISTA NEWL TRAB
ASH700936E	NONE	HERS
ASH700936E	SNOW	INVE OSJE PTBB
ASH701073.3	NONE	MLVL
ASH701945B_M	NONE	BRUS CHIZ COST LROC
ASH701945C_M	NONE	DENT DOUR IENG KELY REDU
ASH701945C_M	SNOW	BOGI KATO KIRU KRAW ZYWI
ASH701945E_M	NONE	GRAS WARE
ASH701946.2	NONE	HERT
ASH701946.3	SNOW	GOPE
JPSREGANT_DD_E	NONE	CAGZ UNPG
LEIAT504	LEIS	AUT1 BACA BAIA BSCN BZRG COBA DARE DEVA EGLT GSR1 GUIP NOA1 PLYM ROVE SVTL TUBO VFCH
LEIAT504	NONE	CASC FATA GAIA LAGO LILL PDEL TARS TUC2
TRM14532.00	NONE	JOZE
TRM22020.00+GP	NONE	SRJV
TRM29659.00	NONE	ALAC AQUI BELL BRST CAGL CAME DRES EBRE ELBA EUSK EVPA GANP GENO GLSV GRAZ HOFN KARL KHAR KLOP LAMP LLIV MATE MEDI MILO NOT1 NOTO OSLO OSLS PADO POLV PRAT PULA SFER TLSE TORI UPAD UZHL YEBE ZIMM
TRM29659.00	TCWD	ALME CACE CANT CEUT LPAL MALA MALL RIOJ VALE VIGO
TRM41249.00	NONE	BADH CREU MIKL NYIR PENC SULP
TRM29659.00	SNOW	BORK HOBU
Antennae/Radomes with absolute calibrations converted from relative models		
ASH700936A_M	SNOW	JOEN VAAS
ASH701941.B	NONE	VENE
ASH701945B_M	SNOW	RAMO
ASH701945C_M	SCIT	ZOUF
ASH701945E_M	SCIS	AUTN ENTZ MARS PUYV QAQ1
LEIAT302+GP	NONE	BOLG
LEIAT303	NONE	MANS
LEISR399_INT	NONE	MSEL
TPSCR3_GGD	CONE	COMO HOE2 POUS SASS SNEC WARN
TRM14532.10	NONE	OROS
TRM29659.00	SCIS	RABT STAS TRDS VARS
TRM29659.00	UNAV	DELF EIJS LINZ TERS TUBI
TRM33429.20+GP	TCWD	BUTE
Antennae/Radomes without absolute calibrations		
AOAD/M_B	DOME	NYAL
AOAD/M_B	DUTD	KOSG
AOAD/M_B	OSOD	ONSA
AOAD/M_T	DOME	IAVH
AOAD/M_T	DUTD	SODA WSRT
AOAD/M_T	OSOD	KIR0 MAR6 SKE0 SPT0 VIL0 VIS0
ASH700936F_C	SNOW	LAMA
ASH701073.1	SCIS	THU3
ASH701073.1	SNOW	NYA1
ASH701941.1	SNOW	WROC
ASH701941.B	SNOW	JOZ2
ASH701941.B	UNAV	BUDP SMID
ASH701945C_M	GRAZ	PFAN SBGZ
ASH701945C_M	UNAV	NSSP
ASH701945E_M	UNAV	SULD
ASH701946.2	SNOW	BISK MARJ VACO
LEIAT504	GRAZ	TRFB
TRM14532.00	DOME	MOPI
TRM29659.00	DOME	ESCO
TRM29659.00	GRAZ	HFLK

Table 2 – List of presently used EPN antennae/radomes with information on availability of absolute antenna phase centre variation models.

4. NEW@EPN CB

4.1 EPN Site Coordinates

The EPN station data together with the site coordinates provide the customers access to the ETRS89 and ITRS. Since February 2006, the EPN CB website provides on-line access to the coordinates of all the EPN stations. Three types of coordinates are made available from
http://epncb.oma.be/_trackingnetwork/coordinates/stationcoordinates.php:

1. *(X_{weekly}, Y_{weekly}, Z_{weekly}), the weekly coordinates computed by the EPN Combination Centre*
   These coordinates are extracted from the most recent weekly combined EPN solution.

2. *(X_{EPN}, Y_{EPN}, Z_{EPN}) and (VX_{EPN}, VY_{EPN}, VZ_{EPN}), the coordinates/velocities computed by the "EPN Project for time series monitoring"*
   These monthly-updated coordinates/velocities are the result of a multi-year adjustment of all the weekly combined EUREF solutions in which outliers have been eliminated and new station positions are estimated after a position discontinuity. It can be considered as the EPNs own realization of the ITRS. They are available through the web page of the EPN Project for "Time series monitoring" (http://epncb.oma.be/_organsiation/projects/series_sp/)

3. *(X_{IERS}, Y_{IERS}, Z_{IERS}) and (VX_{IERS}, VY_{IERS}, VZ_{IERS}), the official coordinates/velocities issued the International Earth Rotation and Reference Systems Service (IERS)*
   These coordinates/velocities are computed by the IERS as a result of a combination of the multi-year coordinate and velocity solutions obtained by several space geodetic techniques (GPS, VLBI, SLR, ...). These official IERS positions are available through the IERS website (http://www.iers.org).

Since the reliability of the EPN site coordinates depends on the length of the observation period and the co-location with other space geodetic techniques, users looking for the coordinates and velocities of one of the EPN stations are recommended to use the coordinates/velocities (X_{IERS}, Y_{IERS}, Z_{IERS}) and (VX_{IERS}, VY_{IERS}, VZ_{IERS}), issued by the IERS. However, the last realization of the ITRS, ITRF2000, does not include stations installed within the EPN after 2000, which is more than half of the EPN stations. For these stations, the user is redirected to the coordinates (X_{EPN}, Y_{EPN}, Z_{EPN}) and velocities (VX_{EPN}, VY_{EPN}, VZ_{EPN}) from the EPN Time Series Special Project. These estimations are typically available when a station has been included in the EPN for a period of at least six months. Last, if none of the other coordinate and velocity sets are available (typically for recent stations), the user can take the (X_{weekly}, Y_{weekly}, Z_{weekly}) coordinates extracted from the most recent weekly EPN solution. These coordinates are given at the mid-epoch of the week and do not have an associated velocity field. Both (X_{IERS}, Y_{IERS}, Z_{IERS}) and (X_{EPN}, Y_{EPN}, Z_{EPN}) are presently given at epoch 1997,0 but can be extrapolated to any chosen epoch using the available velocity vectors.
All coordinates are given in two reference systems: the ITRS and the ETRS89.

4.2 Data Quality Plots

The EPN CB website makes available for all the EPN stations daily updated plots with the time evolution of the ratio of observed dual frequency observations versus the predicted number. These graphs have been changed recently. To generate the graphs, the TEQC (Unavco) program is run twice on each data set: a first time with a standard cut-off angle of 15° and a second time with a cut off of 0°. *Up to the end of 2005, the second run was done using a computed cut off angle (computed based on the RINEX observation data and corresponding to the elevation below which no data are acquired).*

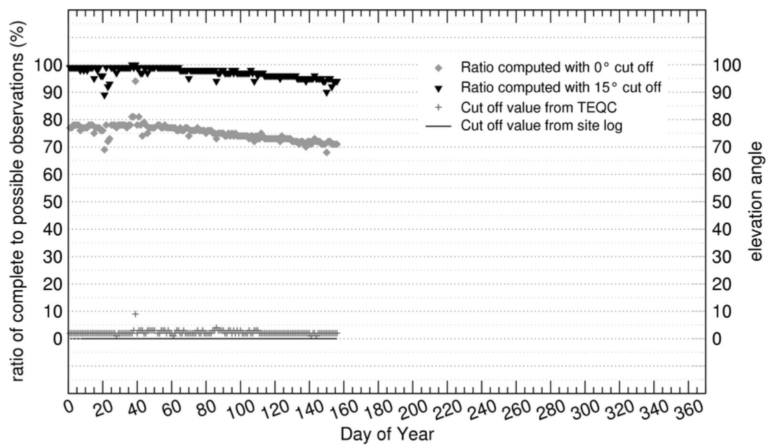

Figure 3 – Ratio of computed to predicted dual frequency observations at VILL (Villafranca, Spain)

In ideal conditions, the percentage, computed for a fixed elevation cut off angle of 15°, should be 100% because following the EPN guidelines the station should have no obstructions above 15°. EPN stations are instructed to track all satellites above 5°, which means that we expect that the computed cut off varies between 0° and 5°. Optimal tracking at low elevations is assured when the values obtained with the 15° and 0° cut off are minimally separated. In addition to the change in the computation of the second TEQC run, now the plots also include information on the cut off given in the site log and a computed cut off defined as the elevation below which no observations are found (see example in Figure 3).

4.3 Divers

In addition, the following sections of the website have been revisited and/or extended within the last year:

- Update "papers section" : http://epncb.oma.be/_newsmails/papers/
- Proposed stations web page revisited to give more details on status of inclusion procedure : http://epncb.oma.be/_trackingnetwork/proposed.php
- Frequently Asked Questions extended : http://epncb.oma.be/_organisation/faq.php
- New calendar page with list of relevant meetings: http://epncb.oma.be/_newsmails/calendar.php
- New interactive EPN map : http://epncb.oma.be/_trackingnetwork/siteinfo.php
- Cleaned time series have been revisited (see paper by A. Kenyeres, in this volume): http://epncb.oma.be/_dataproducts/timeseries/cleanedseries.php

5. FUTURE DIRECTIONS

5.1 Evolving towards a full near real-time network

76% of the EPN stations submit hourly data and these data are used within the frame of several meteorological projects. In addition, there are plans to set up a rapid EPN analysis in order to perform a quick monitoring of the EPN station coordinates. Looking at the spectacular growth of the communication technology it is becoming easier for an EPN to provide hourly data. All new EPN stations already provide hourly data, but some older stations (see Figure 4) do not and they restrain the EPN from becoming completely a near real-time network. Our challenge for the next years will be to make from the EPN a network in which all stations submit hourly data.

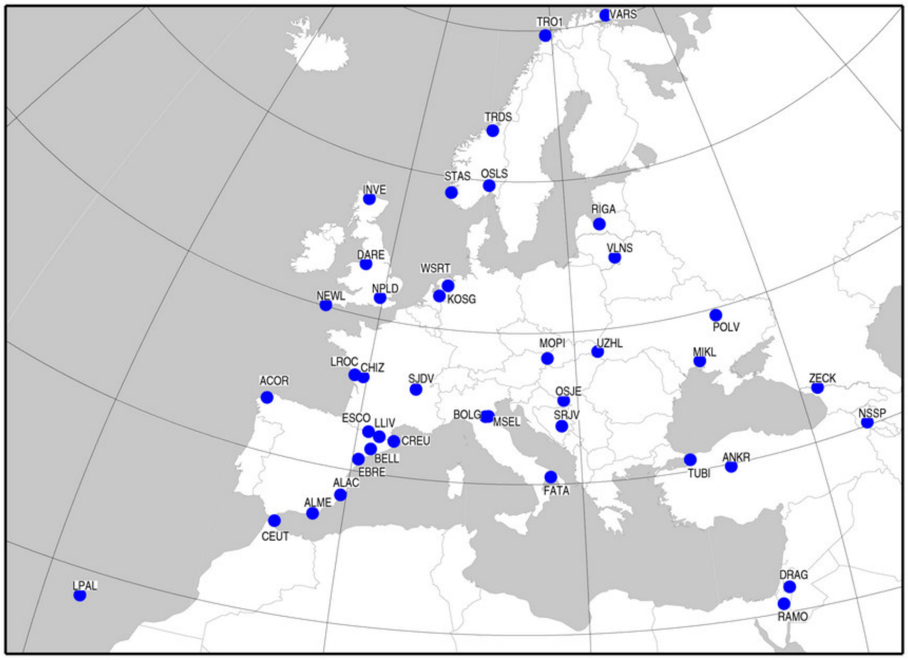

Figure 4 - Map of the EPN stations that do not yet provide hourly data

5.2 Real-time data streams

Presently, 41 stations are distributing real-time data (DGPS, RTK and/or raw data in several formats) within the frame of the EUREF-IP Project (see Figure 5).

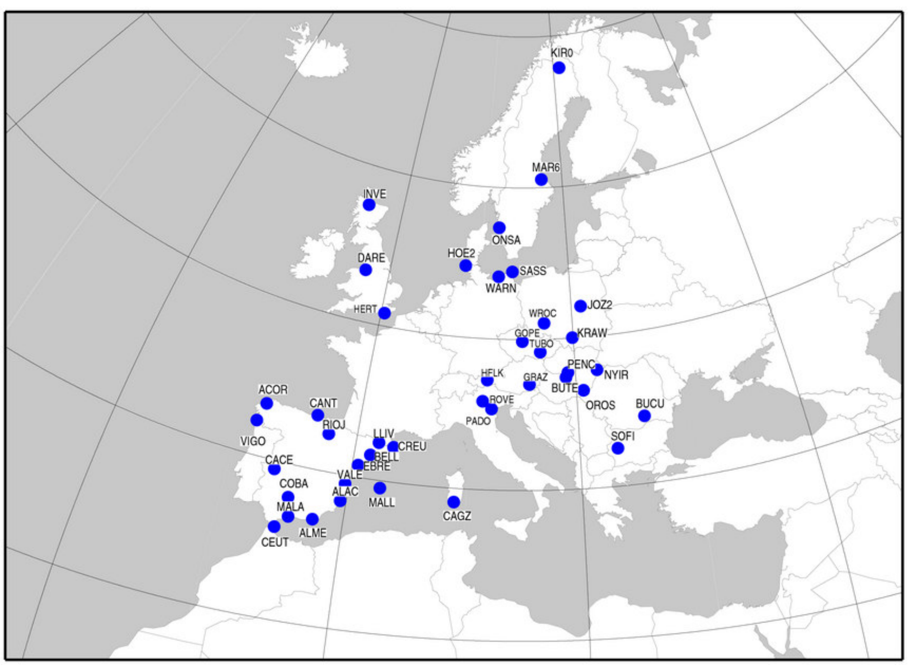

Figure 5 – Map of the EPN stations contributing to EUREF-IP

These real-time data streams are presently not yet part of the routine EPN data stream which contains only the daily and hourly data flow up to now. In order to decide if the real-time data provision will become an integral part of the EPN, several questions have first to be answered:

- What is the minimal requirement for an EPN station to be considered real-time EPN station?
- What is the minimal requirement for an Ntrip broadcaster to be accepted as an EPN broadcaster?
- If we consider DGPS and RTK data streams with the EPN label, is EUREF then responsible for the correctness of the coordinates used to generate the DGPS/RTK data?
- Do we (EUREF) check the quality of the DGPS/RTK or raw data from the real-time EPN stations?

But, the main question is: what is the added-value of the EPN real-time data with respect to already existing networks providing real-time data? These questions are presently discussed amongst the members of the EUREF Technical Working Group.

5.3 Integration of GLONASS data into the EPN

29 EPN stations are presently operating GPS/GLONASS equipment (see Figure 6), but their GLONASS data are not used for the generation of the weekly EUREF coordinates, mainly because of the lack of combined IGS GLONASS orbits with the same latency as the IGS final GPS orbits. However, recently, the situation has changed: the latency of the IGS GLONASS orbits is now almost similar to the IGS final GPS orbits. In addition:

- the majority of the EPN LAC have the software capable of processing GPS+GLONASS observations
- the number of commercially available GPS+GLONASS receivers is growing
- GLONASS has been revitalized with a constellation of 18 satellites expected in 2007

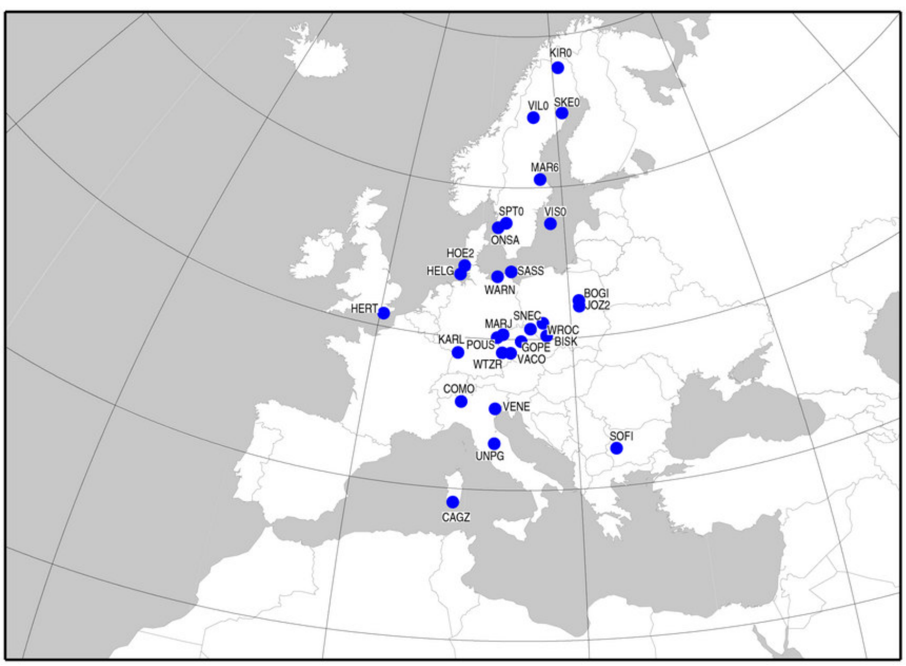

Figure 6 – Map of the EPN stations equipped with GPS/GLONASS receivers (status June 2006)

So, there a many reasons to think about including GLONASS into the routine operation of the EPN. At the data level, mixed GPS and GLONASS data files are already available in the EPN data centers, so no change is necessary here. At the EPN CB, however, all data quality checks are presently only based on GPS. The EPN CB is therefore now preparing to add GLONASS observations to its quality checks. Concerning the analysis, some EPN LAC have expressed at the LAC workshop in Padua in March 2006 their interest to add GLONASS observations to their routine data analysis and it was decided that the LAC wishing to do so could go ahead. The main problem here is that the number of GPS/GLONASS in the individual subnetworks is often small (see Figure 7) and that maybe a redistribution of the subnetworks could be necessary in the future in order to fully exploit the GLONASS data. For more details we refer the interested reader to (Bruyninx, in press).

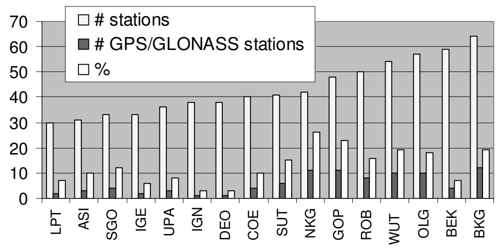

Figure 7 – Distribution of the LAC networks in terms of GPS/GLONASS stations

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References

Bruyninx C. GPS and GLONASS Data Analysis using Station from the EUREF Permanent Network (in this volume)