Status and Prospects of the Permanent EUREF Network

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Abstract

The first official solutions for the EUREF permanent network became available in the beginning of 1996. These solutions were based on individual subnetwork solutions from 4 EUREF Local Analysis Centres. The number of stations in the network at that time was about 30.
Presently close to 90 stations make up the EUREF permanent network with twelve analysis centres delivering weekly solutions. This growth of the network provides an opportunity to take the EUREF network further than its initial purpose, the maintenance of the European Reference Frame. We propose some possible applications and we investigate how the present EUREF network can make a valuable contribution.

1. Introduction

The permanent EUREF network was initially set up for the maintenance and enhancement of the European Terrestrial Reference Frame ETRS89. In the beginning of 1996, about 30 permanent tracking sites and 4 analysis centres formed the basis of this network. Presently close to 90 stations make up the EUREF permanent network with twelve analysis centres delivering weekly solutions.
To guarantee the quality of the EUREF solutions the analysis centres adapted a common analysis strategy and individual subnetworks were redistributed (Bruyninx, 1999). The attention of the station managers was drawn to the fact that antenna changes have to be restricted to the absolute minimum. If changes of the antenna or its direct environment (such as the installation of removal of a dome) are necessary, they have to be reported to the EUREF community.The guidelines describing the responsibilities of the station managers, data centres, analysis centres andthe EUREF Central Bureau have been updated and are available at:
http://www.epncb.oma.be/g_sta_oc.html (Guidelines).

Thanks to these efforts, the quality of the EUREF solutions is presently very satisfactory and the number of problems with tracking sites is reduced to a minimum.

2. Status of the EUREF Permanent Network

Permanent tracking network

Figure 1 shows the stations included in the permanent EUREF network as on August 1, 1999. The number of stations is 89. 56 % of them belong also to the IGS network.

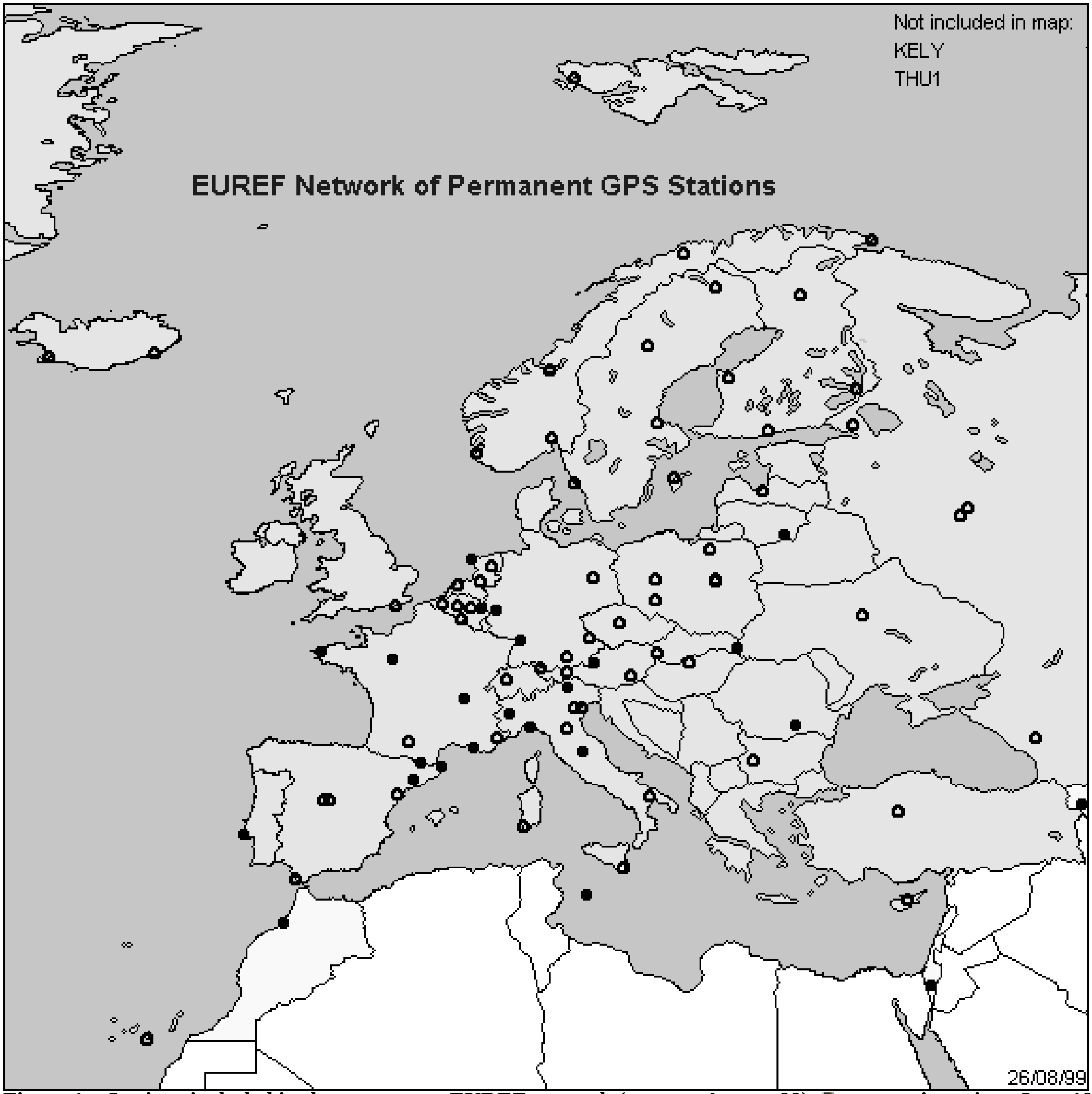

Figure 1 – Stations included in the permanent EUREF network (status – August 99), ● new stations since June 1998

As can be seen from Figure 2, the EUREF network has been steadily growing with about 13 stations each year, since its start in the beginning of 1996.

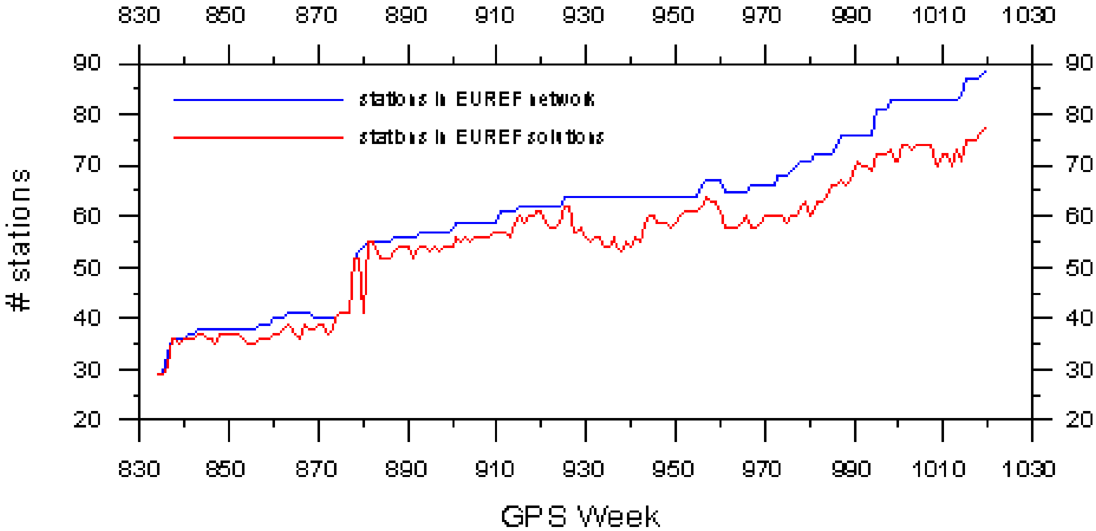

Figure 2 – Growth of the EUREF tracking network

Table 1 summarises the new permanent tracking sites included in the EUREF network since June 1998. As mentioned in (Bruyninx, 1999) there was a general interest at the EUREF symposium in June 1998 to include stations from outside Europe (North Africa, Middle-East) into the routine EUREF processing. Presently the EUREF Analysis Centres are processing a few of these "*Associated EUREF stations*":Rabat (Morocco), Yerevan (Armenia) and Mitzpe Ramon (Israel).

Stations	4 char ID	Country	Lat (N)	Lon (E)	Agency
Bellmunt de Segarra	BELL	Spain	41.60	001.40	ICC
Brest	BRST	France	48.38	355.50	IGN
Bucarest	BUCU	Romania	44.46	026.12	BKG
Bolzano	BZRG	Italy	46.50	011.34	UGB
Cascais	CASC	Portugal	38.69	350.58	IPCC
Cadaqués	CREU	Spain	42.32	003.32	ICC
Eijsden	EIJS	Netherlands	50.75	005.78	DUT
Euskirchen	EUSK	Germany	50.67	006.76	BKG
Genova	GENO	Italy	44.40	008.92	NTS
Rabat *	IAVH	Morocco	33.98	353.13	JPL
Karlsruhe	KARL	Germany	49.01	008.41	BKG
Lampedusa	LAMP	Italy	35.50	012.61	ASI
Llívia	LLIV	Spain	42.48	001.97	ICC
Le Mans	MANS	France	48.02	000.16	ESGT
Marseille	MARS	France	43.28	005.35	IGN
Yerevan *	NSSP	Armenia	40.23	044.50	JPL
Mitzpe Ramon *	RAMO	Israel	30.60	034.76	SOI
Salzburg	SBGZ	Austria	47.80	013.11	ISR
St. Jean des Vignes	SJDV	France	45.88	004.68	CNRS-GA
West-Terschelling	TERS	Netherlands	53.36	005.22	DEOS
Torino	TORI	Italy	45.06	007.66	PT
Perugia	UNPG	Italy	43.12	012.36	IIA
Uzhgorod	UZHL	Ukraine	48.63	022.30	MAONASU
Vilnius	VLNS	Lithuania	54.65	025.30	VIVGTU

* associated EUREF sites

ASI :	Agenzia Spaziale Italiana, Italy
BKG :	Bundesamt für Kartographie und Geodäsie, Germany
CNRS-GA :	CNRS - Geosciences Azur, France
DEOS :	Delft Institute for Earth-Oriented Space research, Netherlands
DUT :	Delft University of Technology, Netherlands
ESGT :	Ecole Superieure des Geometres et Topographes, France
ICC :	Institut Cartografic de Catalunya, Spain
IGN :	Institut Géographique National, France
IIA :	Ist. di Ingegneria Ambientale, Italy
IPCC :	Instituto Portuguës de Cartografia e Cadastro, Portugal
ISR :	Institute for Space Research, Austria
JPL :	Jet Propulsion Laboratory, U.S.A.
MAONASU:	Main Astronomical Observatory of the National Academy of Sciences of Ukraine, Ukraine
NTS :	Nuova Telespazio S.p.A., Italy
PT :	Politecnico di Torino, Italy
SOI :	Survey of Israel, Israel
UGB :	Ufficio Geodetico di Bolzano, Italy
VIVGTU :	Geodetic Institute of Vilnius Gediminas Technical University, Lithuania

Table 1- New EUREF permanent tracking sites since June 1998

Table 2 gives a list of permanent tracking sites that are expected to become part of the EUREF network in a close future.

Stations	4 char ID	Country	Lat (N)	Lon (E)	Agency
A Coruna	ACOR	Spain	43.36	008.40	IGN
Alicante	ALAC	Spain	38.34	000.48	IGN
Davos		Switzerland	46.83	009.92	FOT
Dubrovnic		Croatia	-	-	CSA
Escòrnacrabes	ESCO	Spain	42.69	000.98	ICC
Istanbul	ISTA	Turkey	-	-	TUI
Jungfraujoch		Switzerland	46.55	007.98	FOT
Locarno		Switzerland	46.17	008.83	FOT
Marne la Vallée		France	48.50	002.35	ENSG
Morpeth		United Kingdom	-	-	UN
Ochrid		Macedonia	-	-	MSA
Tirana		Albania	-	-	-
Trabzon		Turkey	-	-	UT
Ventspils		Latvia	-	-	-

Table 2 - Candidate EUREF permanent tracking sites.

Data analysis

The data analysis within the EUREF network is based on the distributed processing approach where 12 Local Analysis Centres (AC) process a subnetwork of the EUREF network. Two of these analysis centres started recently to submit solutions to EUREF:

- Institut Géographique National (Marne-la-Vallée, France), submitting solutions since November 1998
- University of Padova (Padova, Italy), submitting solutions since December 1998

The EUREF Web pages show the subnetwork processed by each of the individual analysis centres at: http://www.epncb.oma.be/analcent.html .
The analysis centres are each processing between 11 to 39 stations. 77 % of the EUREF stations are processed by 3 AC's, 6 % by 4 AC's

and 17 % of the stations is only processed by two AC's.
Up to now, the combination of the individual solutions was performed by the CODE analysis Centre. However, from GPS week 1020 (July 25, 1999) on, this responsibility has been taken over by the Bundesamt für Karthographie und Geodäsie in Frankfurt, Germany.

3. Multi-disciplinary Applications

The growth of the EUREF tracking network provides an opportunity to take the network further than its initial purpose, the maintenance of the of the European Reference Frame. This opportunity was formally recognised at the ninth EUREF symposium held from June 2 to June 4 1999, via Resolution 4:

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The IAG Subcommission for Europe (EUREF)

considering that the primary purpose of establishing the Permanent EUREF Network was the maintenance of the
ETRS89,  and

recognising the achievements of the project,

requests the national mapping agencies represented in CERCO to acknowledge that the Permanent EUREF Network is
the best possible realisation of ETRS89 and to support this activity, and

recognising that the data, structure and results of the Permanent Network are valuable for a wide variety of
scientific investigations,

invites agencies and organisations interested in these investigations (such as geodynamics, sea level
monitoring and meteorology) to closely collaborate with EUREF.
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Geodynamics

More than three years of weekly EUREF solutions are now available. Each week when a new EUREF solution becomes available the EUREF CB combines it with the previous sets of weekly solutions. The resulting coordinate time series are made available at the EUREF Web pages. They give for all EUREF stations an indicator about the stability of the stations, but in addition to this they are a valuable information for all these people who are interested in geodynamics in Europe.

Numerical Weather Prediction

In November 1998, EUREF initiated an hourly data upload test phase. About 18 EUREF stations (Figure 3) make their hourly data available at the European Regional Data Centre at BKG. Up to that time, most of the stations made available their data with a delay of 1 to 3 days.

Figure 3 - Map of the EUREF stations submitting hourly tracking data to BKG (O: hourly observation data available, ●: hourly observation and meteorological data available)

The availability of hourly data can be useful for near-real time applications such as atmospheric water vapour determination.
Only a few of the EUREF analysis centres attempt presently to use the tropospheric zenith path delays, which are a by-product of their routine data analysis, for meteorological applications. To achieve highest confidence for these tropospheric zenith path delays, these activities need to be coordinated at the EUREF level. First, all the analysis centres participating in the project should adopt a common format for the exchange of the tropospheric zenith path delays. The format adopted by the International GPS Service for the exchange of tropospheric estimates is well suited for this purpose. Then, a similar procedure to what the IGS is doing should be used to combine the individual estimates into one troposphere solution for the complete EUREF network (Gendt, 1998). The centre responsible for this combination still needs to be identified. Ideal would be that this centre has close links with the meteorological community to guarantee the validation of the EUREF results.

A bilateral collaboration with the COST Action 716 entitled "Exploitation of ground-based GPS for Climate and Numerical Weather Prediction (NWP) Applications" would certainly be favourable for all parties. This COST action responds to a need to develop and demonstrate a ground-based GPS data exploitation scheme for NWP and to analyse the data exploitation schemes for climatic applications. COST Action 716 involves also people from the meteorological community and will therefore provide the necessary validation of the zenith path delays estimated within the EUREF network.

Tide Gauge Monitoring

The GPS and sea level communities have been discussing GPS positioning at tide gauges for many years. EUREF also, recognised in 1995 the importance of monitoring tide gauges using permanent GPS stations (Resolution 2 of the EUREF symposium in Helsinki in 1995 (Gubler and Hornik, 1996)).
The purpose is to correct relative sea-level histories for vertical crustal motion. This means that we need to estimate vertical velocity at each site with an accuracy better than 1 to 2 millimetre per year over a 5 year interval (Woodworth, 1997).

Since recently a few EUREF stations are collocated with European tide gauges. For example, the Delft University of Technology has installed a permanent tracking station at the Terschelling tide gauge, which is one of the tide gauges in Europe with the longest history. Also in Marseilles (France), Brest (France), Eijsden (the Netherlands) and Cascais (Portugal) permanent EUREF stations are collocated with tide gauges. It is clear that some of the permanent stations collocated with tide gauges are geodetically too unstable and therefore not well suited for EUREFs primary objective, the reference frame maintenance.
A proper classification of the EUREF stations following their field of applications is therefore one of the points that should be taken under consideration.

Concerning the data analysis, EUREF can, thanks to the distributed data analysis, offer at least two to three analysis centres that will process the data set. This is a positive factor, given the difficulty of eliminating systematic errors in the vertical.

4. Conclusion

Thanks to its steady densification, its faster data availability and the growth of collocations with other instruments, the permanent EUREF network is now open to contribute to a new field of applications, such as meteorology and sea level monitoring.
This new involvement of EUREF implies supplementary investigations and investments in manpower.
If the overlapping data processing, which is the basis for the strength of the EUREF solutions, needs to be guaranteed, then new EUREF stations need to be chosen carefully. Possible criteria are:

- Densification of regions with no (or few) permanent tracking stations
- Collocation with tide gauge instruments
- Collocation with meteorological instruments, iono sondes, water vapour radiometers, etc…

The main problem associated with the multi-disciplinary applications is the fact that each of them has its own criteria for permanent stations. Identifying permanent stations that fulfil several of them is very difficult, sometimes even impossible. For example: the primary objective of the permanent EUREF stations, reference frame maintenance, cannot be guaranteed for all stations collocated with tide gauges. This implies that the EUREF community will have to discuss how to deal with this situation. One possibility is to classify the EUREF stations following their field(s) of application(s). Another possibility is to accept only EUREF stations, which, as a minimum, fulfil the specifications for reference frame maintenance.

5. References

Bruyninx C. (1999)

> *An Evaluation of Last Years Activities within the EUREF Permanent GPS Network*
> Proc. of "Symposium of the IAG Subcommission for Europe held in June 1998 Bad Neuenahr", Ed. E. Gubler, H. Hornik, Bundesamtes für Kartographie und Geodäsie, Frankfurt am main, Germany, EUREF Publication, No. 7/I, pp. 43-46

Gendt G. (1998)

> *Combination Format, SINEX.TRO.0.01*
> ftp.gfz-potsdam.de/pub/igstrop/

Gubler E., H. Hornik (Eds.) (1996)

> *Proc. of "Symposium of the IAG Subcommission for Europe held in May 1995 Helsinki"*, Bayerischen Akademy der Wissenshaften, München, Germany, EUREF Publication No. 4

Woodworth P.L. (1997)

> *Introduction ot the Workshop on Methods for Monitoring Sea Level : GPS and Tide Gauge Benchmark Monitoring, GPS Altimeter Calibration*
> Proc. of "Workshop on Methods for Monitoring Sea Level", Eds. R.E. Neilan, P.A. Van Scoy,
> P.L. Woodworth, JPL, Pasadena, US, pp 3-10