Monitoring of official national ETRF coordinates on EPN web

Project of the EUREF TWG

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1 Abstract

The EUREF Permanent Network EPN is permanently analyzed by different analysis centers in order to densify the international reference frame ITRF and in order to monitor the European reference frame ETRF. Furthermore, the different European countries adopted realizations of the ETRF in the past years and decades. The described project of the EUREF technical working group (TWG) shows for a sub-set of 14 European countries, how homogeneous the different national reference frames are realized compared to a consistently computed multi-annual solution published by EUREF in Dec., 2008. A collection of all officially used national ETRF coordinates for the EPN stations and its publication on the EPN web pages is a by-product of this project.

2 Introduction

EUREF is responsible for the reference frame realization in Europe. To provide homogeneous coordinates all over Europe is a primary goal of many EUREF activities. Also within the various projects of EuroGeographics and INSPIRE this goal is a key issue because of the rapidly increasing number of GIS data and the necessity of interoperability and data exchange between European countries.

EUREF created already an important basis with the introduction of the European Terrestrial Reference System ETRS89. This was possible with the usage of the GPS technique, which allows coordinate estimation on a global/European scale. ETRS89 was aligned to the international reference system ITRS at epoch 1989.0. Whereas European stations have movements of several centimeters within one year in the ITRS, ETRS89 was fixed to the stable part of Europe (ALTAMIMI, 2008). Most European countries supported this idea and generated in the years since 1989 reference frame realizations (ETRFs) mainly based on GPS campaigns. Many countries defined their new reference frames directly in ETRS89. The calculated national ETRF coordinates, derived from a densification of international permanent IGS stations, were reviewed by the EUREF Technical Working Group (TWG) and were presented in the past at the EUREF symposia. Due to the development in satellite geodesy, national coordinates were generated at different times and different reference frame realizations (ETRFyy). Nevertheless, ETRS89 is a success story and widely acknowledged as the basis for geo-information in the EU.

Since several years the infrastructure for reference frame realizations moved from passive classical markers to active permanent GNSS stations. This is obviously visible in the increased number of permanent stations within the European Permanent Network (EPN) and in the increasing number of national permanent stations. Positioning services are able to provide the national reference frame in real-time.

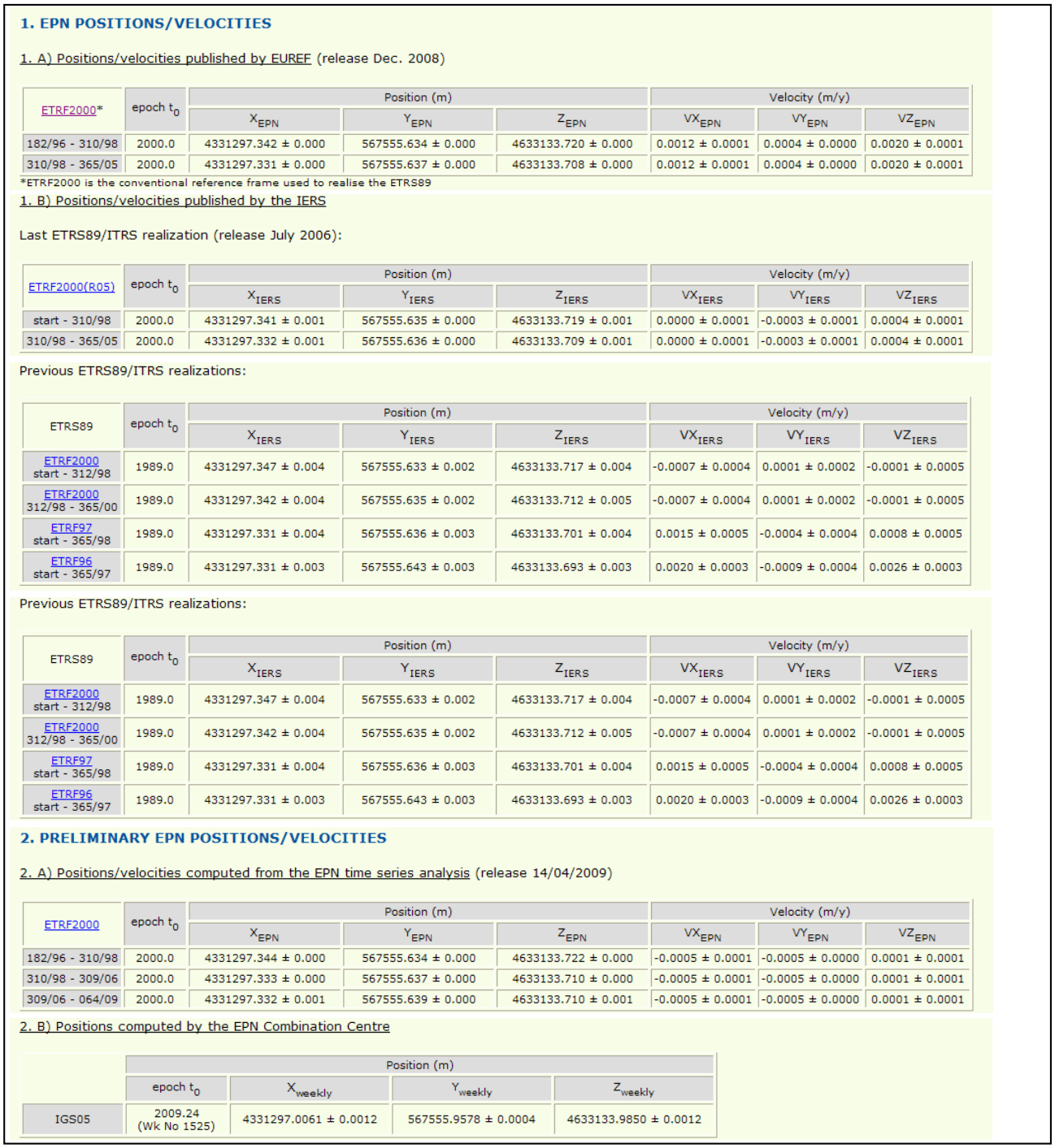
Within EPN all available RINEX data are analyzed by several Local Analysis Centers (LACs) on a weekly basis. Weekly results of individual LACs are combined to weekly EPN solutions (HABRICH, 2008). A milestone was reached in December 2008 with the publication of an EPN densification solution of ITRF2005 (KENYERES AND BRUYNINX, 2008) derived from a cumulative solution on the basis of the weekly EPN combined solutions. These coordinates can be considered as a homogeneous realization of the European reference frame. They might also be called "scientific", contrary to "official national" ETRF coordinates, which are adopted in the different countries.

The idea to compare national ETRF coordinates with scientific ETRF coordinates was born at the EPN LAC workshop in Frankfurt (Oct. 2008) and slightly later at the TWG meeting in Munich (Nov. 2008). As a pilot project 15 countries, represented either by a LAC or a member within the EUREF TWG, were asked to provide their national official ETRF coordinates of their EPN stations in order to allow a comparison. The result of this comparison should prove the homogeneity of the different ETRF realizations. Furthermore, the TWG asked the countries to specify in the national reports of the EUREF meeting in Florence how the official national ETRF coordinates of the permanent stations are maintained. Many detailed information, especially of the countries not listed here, may be found in the corresponding national reports.

In future it is planned to publish, if the countries agree, the national ETRF coordinates also on the EPN web page – eventually also on the CRS-EU web page. Furthermore, it might be possible to setup a service which releases warnings in case that the used national ETRF coordinates exceed a certain level compared to an EPN densification solution. Such a close collaboration within EUREF / EPN strengths the status of the EPN network and proves the homogeneity of the different reference frames in Europe.

3 Coordinates on the EPN web

A very nice overview about the different published ITRF and ETRF coordinates can be found on the EPN web pages (see Fig. 1). Beside the weekly combined solutions and a recently developed cumulative solution (updates every 5 weeks), also the last ITRF and ETRF coordinate publications and the most recent EUREF



1. EPN POSITIONS/VELOCITIES

1. A) Positions/velocities published by EUREF (release Dec. 2008)

ETRF2000*	epoch t_0	Position (m)			Velocity (m/y)		
		X_{EPN}	Y_{EPN}	Z_{EPN}	VX_{EPN}	VY_{EPN}	VZ_{EPN}
182/96 - 310/98	2000.0	4331297.342 ± 0.000	567555.634 ± 0.000	4633133.720 ± 0.000	0.0012 ± 0.0001	0.0004 ± 0.0000	0.0020 ± 0.0001
310/98 - 365/05	2000.0	4331297.331 ± 0.000	567555.637 ± 0.000	4633133.708 ± 0.000	0.0012 ± 0.0001	0.0004 ± 0.0000	0.0020 ± 0.0001

*ETRF2000 is the conventional reference frame used to realise the ETRS89

1. B) Positions/velocities published by the IERS

Last ETRS89/ITRS realization (release July 2006):

ETRF2000(R05)	epoch t_0	Position (m)			Velocity (m/y)		
		X_{IERS}	Y_{IERS}	Z_{IERS}	VX_{IERS}	VY_{IERS}	VZ_{IERS}
start - 310/98	2000.0	4331297.341 ± 0.001	567555.635 ± 0.000	4633133.719 ± 0.001	0.0000 ± 0.0001	-0.0003 ± 0.0001	0.0004 ± 0.0001
310/98 - 365/05	2000.0	4331297.332 ± 0.001	567555.636 ± 0.000	4633133.709 ± 0.001	0.0000 ± 0.0001	-0.0003 ± 0.0001	0.0004 ± 0.0001

Previous ETRS89/ITRS realizations:

ETRS89	epoch t_0	Position (m)			Velocity (m/y)		
		X_{IERS}	Y_{IERS}	Z_{IERS}	VX_{IERS}	VY_{IERS}	VZ_{IERS}
ETRF2000 start - 312/98	1989.0	4331297.347 ± 0.004	567555.633 ± 0.002	4633133.717 ± 0.004	-0.0007 ± 0.0004	0.0001 ± 0.0002	-0.0001 ± 0.0005
ETRF2000 312/98 - 365/00	1989.0	4331297.342 ± 0.004	567555.635 ± 0.002	4633133.712 ± 0.005	-0.0007 ± 0.0004	0.0001 ± 0.0002	-0.0001 ± 0.0005
ETRF97 start - 365/98	1989.0	4331297.331 ± 0.004	567555.636 ± 0.003	4633133.701 ± 0.004	0.0015 ± 0.0005	-0.0004 ± 0.0004	0.0008 ± 0.0005
ETRF96 start - 365/97	1989.0	4331297.331 ± 0.003	567555.643 ± 0.003	4633133.693 ± 0.003	0.0020 ± 0.0003	-0.0009 ± 0.0004	0.0026 ± 0.0003

Previous ETRS89/ITRS realizations:

ETRS89	epoch t_0	Position (m)			Velocity (m/y)		
		X_{IERS}	Y_{IERS}	Z_{IERS}	VX_{IERS}	VY_{IERS}	VZ_{IERS}
ETRF2000 start - 312/98	1989.0	4331297.347 ± 0.004	567555.633 ± 0.002	4633133.717 ± 0.004	-0.0007 ± 0.0004	0.0001 ± 0.0002	-0.0001 ± 0.0005
ETRF2000 312/98 - 365/00	1989.0	4331297.342 ± 0.004	567555.635 ± 0.002	4633133.712 ± 0.005	-0.0007 ± 0.0004	0.0001 ± 0.0002	-0.0001 ± 0.0005
ETRF97 start - 365/98	1989.0	4331297.331 ± 0.004	567555.636 ± 0.003	4633133.701 ± 0.004	0.0015 ± 0.0005	-0.0004 ± 0.0004	0.0008 ± 0.0005
ETRF96 start - 365/97	1989.0	4331297.331 ± 0.003	567555.643 ± 0.003	4633133.693 ± 0.003	0.0020 ± 0.0003	-0.0009 ± 0.0004	0.0026 ± 0.0003

2. PRELIMINARY EPN POSITIONS/VELOCITIES

2. A) Positions/velocities computed from the EPN time series analysis (release 14/04/2009)

ETRF2000	epoch t_0	Position (m)			Velocity (m/y)		
		X_{EPN}	Y_{EPN}	Z_{EPN}	VX_{EPN}	VY_{EPN}	VZ_{EPN}
182/96 - 310/98	2000.0	4331297.344 ± 0.000	567555.634 ± 0.000	4633133.722 ± 0.000	-0.0005 ± 0.0001	-0.0005 ± 0.0000	0.0001 ± 0.0001
310/98 - 309/06	2000.0	4331297.333 ± 0.000	567555.637 ± 0.000	4633133.710 ± 0.000	-0.0005 ± 0.0001	-0.0005 ± 0.0000	0.0001 ± 0.0001
309/06 - 064/09	2000.0	4331297.332 ± 0.001	567555.639 ± 0.000	4633133.710 ± 0.001	-0.0005 ± 0.0001	-0.0005 ± 0.0000	0.0001 ± 0.0001

2. B) Positions computed by the EPN Combination Centre

	Position (m)			
	epoch t_0	X_{weekly}	Y_{weekly}	Z_{weekly}
IGS05	2009.24 (Wk No 1525)	4331297.0061 ± 0.0012	567555.9578 ± 0.0004	4633133.9850 ± 0.0012

Fig 1: Coordinates displayed at the EPN web page (status June 2009). The example shows information for site ZIMM. Corresponding ITRF coordinates are not displayed here. The link for an EPN station XXXX is: (http://www.epncb.oma.be/_trackingnetwork/coordinates/stationcoordinates4onestation.php?station=XXXX).

```
Station DOMES         X             Y             Z        Frame        Epoch       valid from  to
----*----------**-------------**-------------**-------------**-------------**yyyy*mm*dd**yyyy*mm*dd**yyyy*mm*dd
ZIM2 14001M008    4331300.1443    567537.0824   4633133.4977  ETRF93         1993 01 01  2007 11 09
ZIMM 14001M004    4331297.3388    567555.6380   4633133.7174  ETRF93         1993 01 01  1988 01 01
```

Fig 2: Example file `CHE_20081021.ETRF` contains official national ETRF coordinates of Swiss permanent EPN stations. File name is composed of the country name (3-character ISO 3166 code) and the date of the last update.

publication of the ITRF2005 densification solution of the EPN, released in December 2008, can be found. In future, also national official ETRF coordinates can be displayed, if the countries have no objections.

4 EPN densification solution of ITRF2005

For the comparisons shown here we chose the "scientific" coordinates from the EPN densification solution of the ITRF2005, released in Dec. 2008 (BRUYNINX AND KENYERES, 2008). The solution is based on a combination of weekly combined EPN SINEX files (0860 – 1355) and is tied to ITRF2005 using minimal constraints on a selected set of stations of the highest quality (with respect to spatial distribution, observation length, and coordinate repeatability). Important is the fact, that the solution is compliant with relative antenna phase center variation (PCV) models, which is also the case for many national reference frames. The solution has also the advantage, that this publication has a character of a "static/fixed/defined" coordinate set, which is also true for the national reference coordinates, which are kept fix usually for many years.

We used the original SINEX File `EPN_ITRF_C1355.SNX` in the reference frame ITRF2005 (Epoch 2000.0) and converted it to the reference frame ETRF2000 using the transformation formulas ETRF2000(R05) according to (BOUCHER AND ALTAMIMI, 2008). Reference epoch for the comparisons is 2000.0. An alternative method is to use directly the ETRF coordinates published on the EPN web page (identical to the file `EPN_ETRF_C1355.SSC`). To calculate the difference of the national ETRF coordinates with the published scientific densification solution of EUREF using this alternative method was recommended in the questionnaire of the TWG for the national reports. Differences of both methods are on the sub-millimeter level due to the rounding to 1 mm in the SSC file.

5 National ETRF coordinates of EPN stations

15 countries, represented either by a LAC or a member within the EUREF TWG, were asked to provide national official ETRF coordinates for their EPN stations in a specific file format (see Fig. 2). Partly, the files of the countries contain coordinates of additional local national sites not being part of the EPN or sites located in neighbouring countries. This information was not used. Tab.1 and Tab. 2 shows the contribution of the countries. In Czech Republic none of the EPN stations has associated national official ETRF coordinates. The information concerning the used reference frame shown in Tab. 1 is provided by the countries and partly does not follow the recommended naming conventions. This might also reflect that reference frame issues are complex.

File name	Country	Reference frame
AUT_20090211.ETRF	Austria	ETRF00
BEL_20090127.ETRF	Belgium	ETRF2000
CHE_20081021.ETRF	Switzerland	ETRF93
DEU_20081104.ETRF	Germany	ETRS89
ESP_20090201.ETRF	Spain	ETRF05
FIN_20090119.ETRF	Finland	ETRF96
FRA_20090428.ETRF	France	ETRF93
HUN_20090120.ETRF	Hungary	ETRF00
ITA_20090101.ETRF	Italy	ETRF2000
NLD_20090325.ETRF	Netherlands	ETRF2000(R05)
POL_20090129.ETRF	Poland	ETRF05(R05)
PRT_20090402.ETRF	Portugal	ETRF89
SVK_20090421.ETRF	Slovakia	ETRF2000
SWE_20081024.ETRF	Sweden	ETRF97
Czech Republic	no EPN station with official national ETRF coordinates	

Tab 1: File contribution of the 15 countries of the pilot project containing national ETRF coordinates for EPN stations.

Country	# nat. sites	# EPN sites	EPN sites with collocation to national reference sites
AUT	10	10	GRAZ HFL2 HFLK LINZ PFA2 PFAN SBG2 SBGZ TRF2 TRFB
BEL	4	5	BRUS DENT DOUR WARE
CHE	2	2	ZIM2 ZIMM
DEU	9	20	BORJ BORK HELG HOBU HOE2 HOER KARL KLOP WTZR
ESP	20	35	ACOR ALAC ALBA ALME CACE CANT CEU1 COBA HUEL LEON MALA MALL RIOJ SALA SONS TERU VALE VIGO YEBE ZARA
FIN	4	4	JOEN METS SODA VAAS
FRA	16	19	AJAC AUTN BRST BSCN CHIZ EGLT ENTZ GRAS GUIP LROC MARS MLVL PUYV SJDV TLSE VFCH
HUN	4	5	BUTE OROS PENC SPRN
ITA	20	31	AQUI BZRG CAGL CAME COMO ELBA GENO IENG IGMI LAMP M0SE MATE MEDI MILO NOT1 PADO PRAT ROVE TORI ZOUF
NDL	5	5	DELF EIJS KOSG TERS WSRT
POL	1	17	BOR1
PRT	3	6	CASC GAIA LAGO
SVK	2	4	BBYS GANP
SWE	7	8	KIR0 MAR6 ONSA SKE0 SPT0 VIL0 VIS0

Tab 2: Contribution of national ETRF coordinates for EPN stations.

6 Collocation of EPN stations with national reference stations

At present, May 2009, roughly 220 stations located in 39 countries contribute to the EPN network. Details of the number of EPN sites and the number of sites having official ETRF coordinates are given in Tab.2. The same information is presented graphically in Fig.3.

7 Comparison with EUREF densification of ITRF2005

Analysing the differences between official national ETRF coordinates and the EPN densification solution gives very promising results (see Fig. 4 and 5). In average over all stations we have a bias of only -4 mm, 6 mm, -1 mm (East, North, Up) and a corresponding standard deviation of 10 mm, 9 mm, 13 mm.

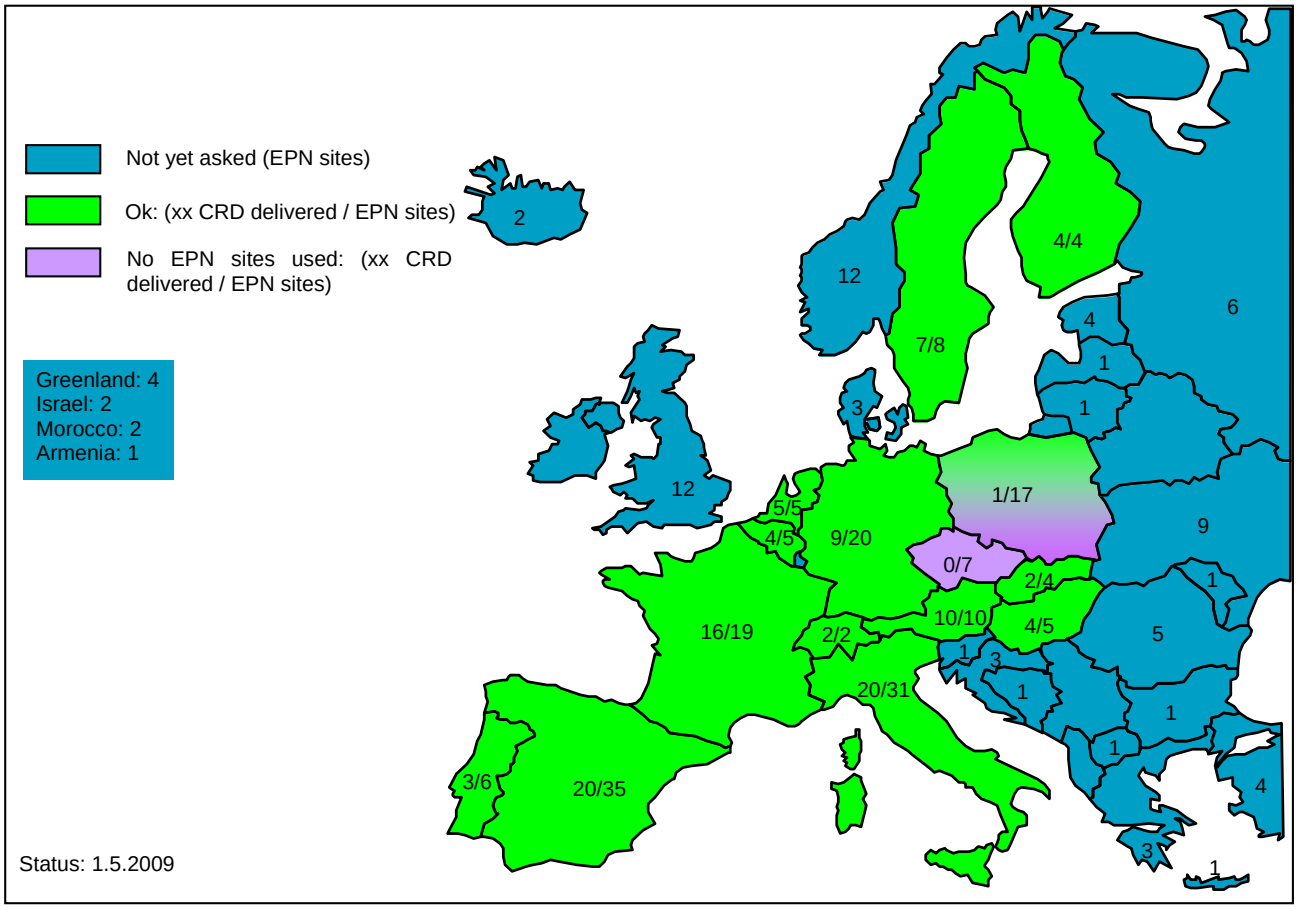


Fig 3: Distribution of the EPN stations with national official ETRF coordinates.

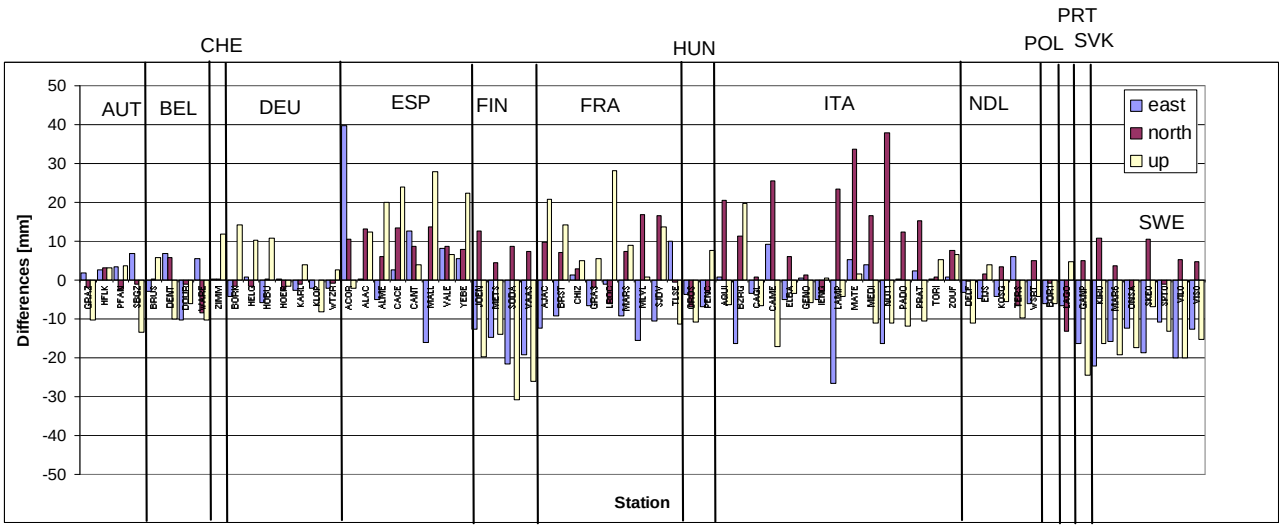


Fig 4: Differences in East, North and Up for 70 EPN stations between official national ETRF coordinates and the EPN densification solution.

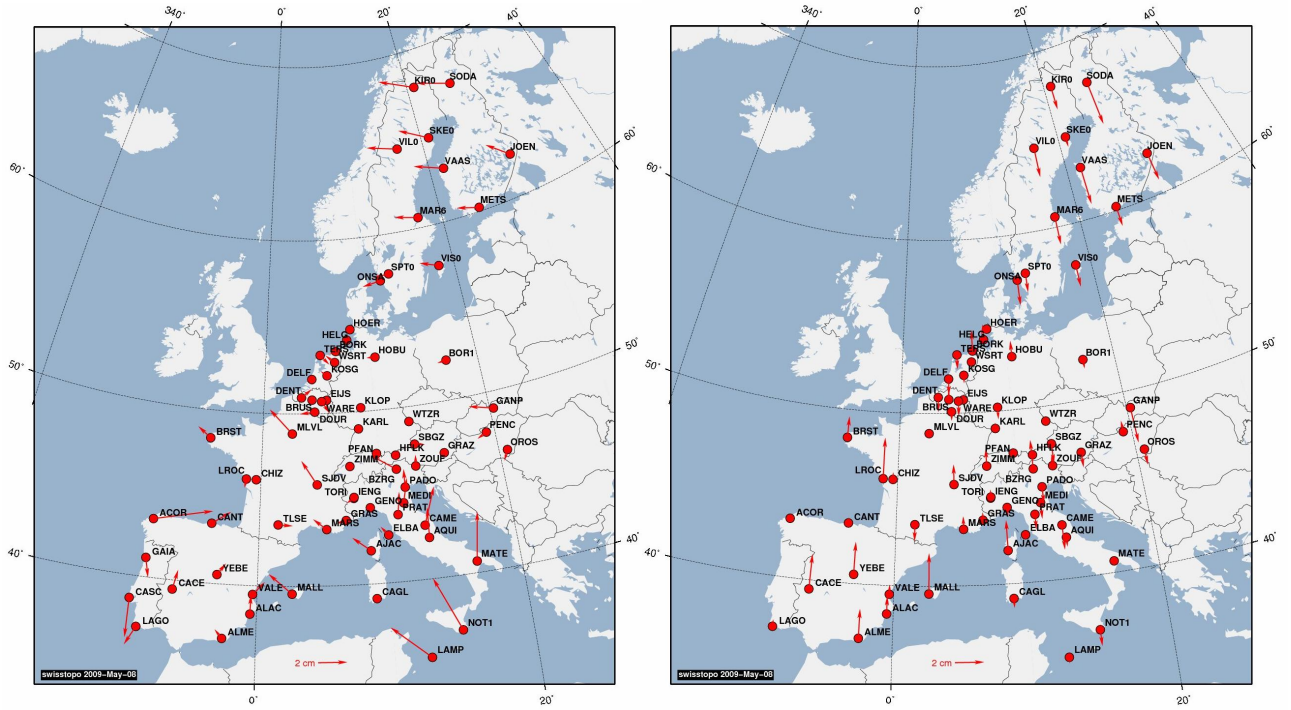


Fig 5: Horizontal differences (left) and vertical differences (right) for 70 stations between official national ETRF coordinates and the EPN densification solution.

This is excellent in view of the different national reference frame realizations due to:

- different reference epochs and ETRFyy reference frame alignment,
- transition from campaigns to permanent networks,
- different analysis models and software used,
- different station setups (antenna changes) – here we compared with the most recent station setup in the EPN densification solution,
- mapping agencies cannot change coordinates frequently,
- stations in regions which are not part of the stable part of Europe (parts in South Italy) or stations which are locally instable.

Small systematic differences are possible, as for example visible for the Scandinavian stations. The coordinates of the southern stations of Italy show bigger differences in the horizontal components due to tectonic movements which are not taken into account in ETRF (stable part of Europe). The Italian station coordinates are derived at epoch 2008.0 (FAROLFI, 2009 and CAPORALI, 2009) whereas the comparisons were performed 8 years earlier at epoch 2000.0. Most national densifications were realized between the years 1995 and 2000, which therefore gives good results also for regions of the non-stable part of Europe. For the Nordic countries the national coordinates were determined close to epoch 2000.0 (at epoch 1999.5 for Sweden) – comparing the national coordinates with the densification solution at the reference epoch 2009.0 without taking into account the post-glacial rebound results in vertical differences of the order of 9-12 cm.

It should be mentioned, that the EPN densification solution was only used as reference for stations with long enough observation periods. 18 sites were excluded from the comparison, because they were marked as "use with care" in the `EPN_ETRF_C1355.SSC` file due to a short observation span and probably inaccurate velocity estimations. This is also taken to account on the coordinate web page for the EPN sites, where the coordinate values for these sites are displayed in red colour. Also excluded from the comparisons is the Portuguese site GAIA which might have a different physical vertical reference point in the national surveying compared to the EPN analysis.

In case of several stations setups in the EPN densification solution of ITRF2005 due to antenna changes we compared the coordinates of the most recent station setup with the national official ETRF coordinates.

Feedback of these comparisons was provided to all contributing countries. The countries, which did the comparison of the coordinates (e.g. for the national reports) using the information on the EPN-web site, might noticed differences on the sub-millimeter level. This can be contributed to the rounding to 1 mm in the corresponding `SSC` file.

Very positive is also the fact, that there were no objections to publish the nationally used official ETRF coordinates on the EPN web page.

8 Conclusion and Future Plans

The results of this survey of national ETRF coordinates have shown, that the reference system ETRS89 is realized in a very homogeneous way and that the

"scientific coordinates" produced by EUREF, in this study the ITRF densification solution of ITRF2005 published in Dec. 2008, are very well suited as a reference. The proof of „compatibility“ in Europe is essential for many projects within INSPIRE and EuroGeographics. The integration of national ETRF coordinates into the EPN and/or CRS-EU web page is therefore a desirable step forward which demonstrates the collaboration in Europe. From the EUREF point of view, the knowledge of the used national ETRF coordinates is also usefull in relation to discussions and plans of the future development of ETRS89 (LIDBERG ET AL., 2009).

After the initial phase, which will be coordinated by the author of the paper, it is planned, to publish the national ETRF coordinates on the EPN web page and to provide feedback of the comparisons, as shown here in the paper, in a suited graphically and/or numerically way also on the EPN web. Feedback to the countries before publication is guaranteed. In order to have all countries involved in this project we recommend to follow the instructions listed in the yellow coloured box on the next page.

To introduce an update mechanism, as it is already very well established for changes at the station via station log files, is also a requirement for an operational service. Due to the fact, that the official national coordinates are changing less frequent compared to changes at stations, this demand should easily be accomplishable.

A “quick” monitoring service could be an option for the future. With the more frequent updates of EPN accumulative solutions including coordinate and velocity estimation every 5 weeks (KENYERES, 2009) or with the most recent weekly EPN combination (HABRICH, 2008) as reference much faster feedbacks in case of bigger differences to official national coordinates are possible.

Reminder to the national representatives:

- to prepare a list of **official national ETRF coordinates for the EPN permanent stations of the country** using the example file `http://www.swisstopo.admin.ch/swisstopo/geodesy/pnac/divers/etrf_monitor/CCC_YYYYMMDD.ETRF`, if no objections against the publication of national ETRF coordinates on the EPN web page are raised, and
- to **send the file** with the naming convention `CCC_YYYYMMDD.ETRF` (`CCC:` national 3-character ISO 3166 code, `YYYYMMDD:` year, month and day of the information update) **till September 15, 2009** to the author of this paper mailto:elmar.brockmann@swisstopo.ch.

Thanks for your kind cooperation and support!

Fig 6: Procedure for national representatives to provide official national ETRF coordinates for the EPN permanent stations of their country.

In order to transfer the results of this pilot project to an operational product of EUREF, covering all countries, the national representatives, which were not being part of the pilot project, are kindly asked to proceed according to Fig. 6.

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Many thanks in advance to all national representatives sending the official national ETRF coordinates of their EPN stations till September 15, 2009.

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