Determination of ETRS89 coordinates for the GNSS Reference Station Network of Valencian Community (Spain)

L. García-Asenjo[1], R. Capilla[2], S. Baselga[1], P. Garrigues[1]

[1]Department of Cartographic Engineering, Geodesy and Photogrammetry.
Technical University of Valencia
Camino de Vera s/n 46022 Valencia (Spain)

[2]Valencian Cartographic Institute
Camino de Vera s/n 46022 Valencia (Spain)

The Cartographic Institute of Valencia (ICV) has recently set up the ERVA project. ERVA (Estaciones de Referencia de VAlencia) is a RTK/VRS network that covers the Valencian Community (estern Spain). In this work precise ETRS89 coordinates are obtained using Bernese V4.2 GPS Software and standard specifications for reference frame fixing in a EUREF GPS campaign. In order to get maximum consistency with ETRS89 coordinates of the ERGPS reference frame solution some alternatives have been studied. Processing tasks, results and analysis are discussed.

1. Introduction

ERGPS, which is managed by the Spanish National Geographic Institute (IGNE), is the main project on continuously operating GNSS reference stations in Spain. However, during the last years an increasingly number of GNSS reference stations have been developed by regional administrations. ERVA project is the active network of the Valencian Community, organized and managed at present by the Valencian Cartographic Institute (ICV), which provides real time positioning by means of Network RTK solutions (VRS). ERVA network consists of 7 stations[1] and is expected to be used in the next future for a large spectrum of applications such as surveying works, GIS, engineering projects, etc.

In order to get a first set of ETRS89 coordinates for the ERVA network, some GPS campaigns and GPS permanent stations data were processed by the ICV using the Trimble Total Control software. Since the main objective in that solution was to obtain a continuous and homogeneous precise positioning along the whole area and boundaries, ETRS89 coordinates provided by IGNE for near ERGPS stations (YEBE, ALBA, ALAC) and some Catalonian CATNET stations (EBRE,REUS,AVEL) were held fixed. This solution can be found at http://www.icv.gva.es.

A new solution, using Bernese V4.2 GPS Software and standard specifications for reference frame fixing in a EUREF GPS campaign, has been done in co-operation with the Department of Cartographic Engineering, Geodesy and Photogrammetry (DICGF) of the Technical University of Valencia (UPV).

[1] At this time a new station, AYOR, is being set up by the ICV.

In order to get maximum consistency with official ETRS89 coordinates of the ERGPS reference frame solution, some studies have been worked out and the present ERVA solution has been checked.

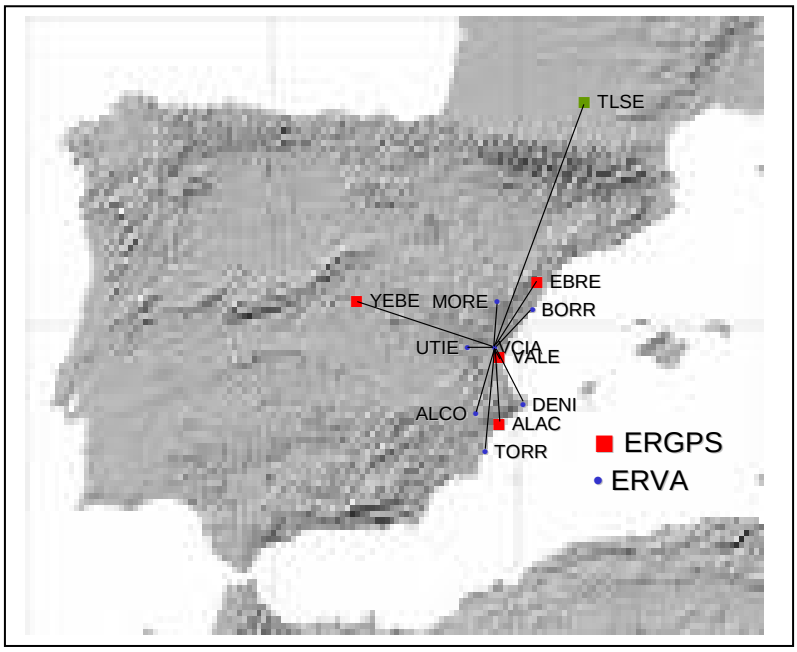

Figure 1.- Single differences schedule used for processing

2. Processing strategy

The data processing and subsequent analysis was performed by the Department of Cartographic Engineering, Geodesy and Photogrammetry (DICGF) of the Technical University of Valencia (UPV) in co-operation with Valencian Cartographic Institute (ICV) using Bernese GPS software version 4.2 on Windows 98SE PC platform and considering procedures specified by the EUREF TWG (Boucher, C., Altamimi, Z. , 2007).

Following Bernese 4.2 documentation (Hugentobler, U., Shaer, S.; Fridez, P., 2001) the principles of the processing can be summarized in:

- Use of CODE precise orbits with corresponding Earth rotation parameters and JPL Planetary Ephemeris DE200.
- Use of CODE troposphere files.
- No ION files have been used.
- Use of FES2004 ocean loading displacement model data computed by Onsala Space Observatory(http://www.oso.chalmers.se/~loading/
- Observations from three consecutive days (14^{th},15^{th} and 16^{th} of February 2007) with an interval of 30 seconds.
- The strategy used when forming single difference observations was to form a first baseline from YEBE to VCIA and subsequently from VCIA to the rest of stations. Therefore, all double difference equations contain VCIA station data.
- An elevation mask of 10 degrees was used.

- Application of the NOAA antenna phase centre correction data.
- QIF ambiguity resolution strategy with a 90% of success.
- Free session solutions for every day computed and saved.
- The normal equations from each processing session were combined using ADDNEQ2 program to compute campaign final solution in ITRF05, epoch 2007.123 (15th of February 2007-12:00)

IERS ITRF05 coordinates of IGS points YEBE and TLSE were used as fixed points for the final ERVA07-ITRF05 solution computation. As the official IERS ITRF05 coordinates are referred to epoch t_0 = 2000.0, they were transformed to ITRF05 t_c = 2007.123 by using official IERS ITRF05 velocities.
Final ITRF05 (2007.123) coordinates for the ERVA07 solution are shown in Table 1.

Table 2.- ITRF05 Epoch 2007.1213 coordinates and processing RMS

	Coordinates			RMS values		
Site	**X(m)**	**Y(m)**	**Z(m)**	**X(mm)**	**Y(mm)**	**Z(mm)**
YEBE	4848724.6937	-261632.1693	4123094.1834	0.0	0.0	0.0
TLSE	4627851.8100	119640.0570	4372993.5753	0.0	0.0	0.0
EBRE	4833520.1367	41537.1449	4147461.5721	0.6	0.1	0.5
VALE	4929533.8116	-29050.3654	4033710.1867	0.6	0.1	0.5
ALAC	5009051.1696	-42072.1595	3935057.7683	0.6	0.1	0.5
ALCO	4984687.2024	-41198.8439	3966606.2173	0.7	0.1	0.5
MORE	4849098.5406	-8595.1036	4130986.0894	0.6	0.1	0.5
DENI	4974895.6664	9001.0776	3978089.9651	0.6	0.1	0.5
BORR	4899519.0661	-7115.5070	4069961.6780	0.6	0.1	0.5
VCIA	4932702.7146	-29607.4727	4029833.3051	0.6	0.1	0.5
UTIE	4922873.0057	-103857.4182	4041693.9838	0.6	0.1	0.5
TORR	5033805.1463	-59822.7695	3903319.7840	0.7	0.1	0.6

3. Comparison with EPN Project coordinates

As coordinates and velocities computed by the “EPN Project for time series monitoring” can be considered as the EUREF realization of the ITRS, a first comparison between ERVA07 and EPNs ITRF05 coordinates can be made:

Table 3.- ERVA07 ITRF05 (2007.123)coordinates minus EUREF EPNs

Site	North (m)	East (m)	Up (m)
YEBE	-0.003	0.004	0.005
TLSE	-0.004	0.002	0.011
EBRE	-0.007	0.002	0.007
VALE	-0.004	0.003	0.008
ALAC	-0.006	0.005	0.010
Mean value	-0.005 ± 0.001	0.003 ± 0.001	0.008 ± 0.002

Considering that double difference equations for estimating coordinates have been formed to include VCIA station data and official IERS coordinates were held fixed, we can conclude that ERVA07 ITRF05 solution is consistent with

EPNs ITRF05 coordinates at the sub-centimetre level with a systematic millimetric shift.

4. Transformation into ETRS89

The transformation from ITRF05 (2007.123) coordinates into ETRS89 reference system was done following version 6 of Specifications for reference frame fixing in the analysis of a EUREF GPS Campaign.

The first step is to transform into ETRS89 at epoch t_c = 2007.123

$$X^{E}(t_c) = X^{I}_{YY}(t_c) + T_{YY} + \begin{pmatrix} 0 & -\dot{R}3_{YY} & \dot{R}2_{YY} \\ \dot{R}3_{YY} & 0 & -\dot{R}1_{YY} \\ -\dot{R}2_{YY} & \dot{R}1_{YY} & 0 \end{pmatrix} \times X^{I}_{YY}(t_c)(t_c - 1989.0)$$

where shifts T_{YY} and rotation rates $\dot{R}1_{YY}, \dot{R}2_{YY}, \dot{R}3_{YY}$ are provided in the Specifications.

The second step is to express coordinates in ETR89 at t = 1989.0 using

$$X^{E}(1989.0) = X^{E}(t_c) + \dot{X}^{E}(1989.0 - t_c)$$

and therefore some estimation of the velocity of each station must be done. Our choice has been using EPNs velocities to estimate velocities into ETRS89 reference system by means of

$$X^{E}_{YY} = \dot{X}^{I}_{YY} + \begin{pmatrix} 0 & -\dot{R}3_{YY} & \dot{R}2_{YY} \\ \dot{R}3_{YY} & 0 & -\dot{R}1_{YY} \\ -\dot{R}2_{YY} & \dot{R}1_{YY} & 0 \end{pmatrix} \times X^{I}_{YY}$$

and considering the velocity of VALE for all ERVA stations. ERVA07- ETRS89 coordinates and velocities obtained are shown in table 3.

Table 4.- ERVA07 - ETRS89 Coordinates and velocities.

	Coordinates			Velocity		
Site	**X(m)**	**Y(m)**	**Z(m)**	**vx(mm/y)**	**vy(mm/y)**	**vz(mm/y)**
YEBE	4848724.9092	-261632.4729	4123093.9090	0.6	-0.0	0.9
TLSE	4627852.0889	119639.7552	4372993.3426	-0.9	0.6	-0.8
EBRE	4833520.3884	41536.8304	4147461.3194	-0.2	0.6	-0.2
VALE	4929534.0633	-29050.6980	4033709.9503	-0.8	1.3	-1.4
ALAC	5009051.4268	-42072.4776	3935057.5066	-1.4	0.2	-0.2
ALCO	4984687.4541	-41199.1765	3966605.9809	-0.1	1.1	-1.5
MORE	4849098.7923	-8595.4362	4130985.8530	-0.5	1.6	-1.2
DENI	4974895.9181	9000.7450	3978089.7287	-0.8	1.1	-1.5
BORR	4899519.3178	-7115.8396	4069961.4416	-0.6	1.4	-1.3
VCIA	4932702.9663	-29607.8053	4029833.0687	-0.8	1.3	-1.4
UTIE	4922873.2574	-103857.7508	4041693.7474	-1.1	1.3	-1.4
TORR	5033805.3980	-59823.1021	3903319.5476	-1.2	0.9	-1.7

5. Comparison with other ETRS89 solutions.

ERVA07-ETRS89 coordinates for EPNs can be compared with EUREF-ETRF05 computed by the “EPN Project for time series monitoring”

Table 5.- ERVA07- ETRS89 coordinates minus EPN EUREF-ETRF05 coordinates.

Site	North (m)	East (m)	Up (m)
YEBE	-0.0038	0.0047	0.0052
TLSE	-0.0042	0.0006	0.0034
EBRE	-0.0060	0.0018	0.0044
VALE	-0.0037	0.0035	0.0036
ALAC	-0.0104	0.0058	0.0077
Mean value	-0.006 ± 0.003	0.003 ± 0.002	0.005 ± 0.002

ERVA07-ETRS89 coordinates can also be compared with ERGPS-ETRS89 coordinates provided by IGNE.

Table 6.- ETRS89-ERVA07 coordinates minus ERGPS IGNE-ETRS89 coordinates.

Site	North (m)	East (m)	Up (m)
YEBE	0.0094	-0.0075	0.0144
EBRE	-0.0068	0.0030	0.0289
VALE	-0.0081	0.0029	0.0490
ALAC	0.0002	-0.0127	0.0481
Mean value	-0.001 ± 0.008	-0.004 ± 0.008	0.035 ± 0.017

A feasible explanation for such differences could be that they were obtained from an ITRF00 solution. As we have no information about the epoch for that solution then no additional analyses can be done.

6. ETRS89-ERVA07 coordinates expressed in the IGNE-ERGPS frame.

Taking into account the importance of ERVA07- ETRS89 coordinates being consistent with ETRS89-ERGPS coordinates, different transformations were tested and analyzed. Eventually, we found best to transform original ERVA07-ITRF05 (2007.123) into ETRS89-ERGPS by using the following three shifts in order to preserve the relative accuracy of the ERVA07-ITRF05 solution:

Table 6.- Transformation parameters from ERVA07- ITRF05 (2007.123) to ETRS89-ERGPS.

	Geocentric system translations		Local translations in YEBE
Tx	0.215 m. ± 0.005 m.	**Te**	-0.304 m. ± 0.005 m.
Ty	-0.316 m. ± 0.005 m.	**Tn**	-0.360 m. ± 0.005 m.
Tz	-0.276 m. ± 0.005 m.	**Tu**	-0.003 m. ± 0.005 m.

Resulting coordinates for all of the points and residuals for the fixed points are shown in Table 7.

Table 7.-ERVA07-ETRS89 coordinates obtained from ITRF05 (2007.123) using three shifts.

	Coordinates			Residuals		
Site	**X(m)**	**Y(m)**	**Z(m)**	**N (mm)**	**E (mm)**	**U (mm)**
YEBE	4848724.9083	-261632.4848	4123093.9076	-2.6	-8.4	1.3
TLSE	4627852.0246	119639.7415	4372993.2995	-	-	-
EBRE	4833520.3513	41536.8294	4147461.2963	-7.6	9.8	-14.4
VALE	4929534.0262	-29050.6809	4033709.9109	8.8	-3.9	-4.8
ALAC	5009051.3842	-42072.4750	3935057.4925	2.4	2.7	5.9
ALCO	4984687.4541	-41199.1765	3966605.9809	-	-	-
MORE	4849098.7552	-8595.4191	4130985.8136	-	-	-
DENI	4974895.8810	9000.7621	3978089.6893	-	-	-
BORR	4899519.2807	-7115.8225	4069961.4022	-	-	-
VCIA	4932702.9292	-29607.7882	4029833.0293	-	-	-
UTIE	4922873.2203	-103857.7337	4041693.7080	-	-	-
TORR	5033805.3609	-59823.0850	3903319.5082	-	-	-

Differences between this solution and the ERVA solution, which is published at the ICV website, are the following:

Table 8.-ERVA07-ETRS89 coordinates minus ICV-ETRS89 coordinates.

Site	North (m)	East (m)	Up (m)
ALCO	-0.0055	0.0038	-0.0136
MORE	-0.0012	0.0030	-0.0288
DENI	0.0091	0.0122	0.0124
BORR	-0.0056	0.0073	-0.0178
VCIA	-0.0074	0.0167	-0.0183
UTIE	-0.0160	0.0026	-0.0126
TORR	-0.0010	0.0070	0.0092
Mean value	-0.004 ± 0.008	0.008 ± 0.005	-0.010 ± 0.015

7. Conclusions

With the use of IGS products, EPN data and products, and processing with high quality software, like Bernese, it is possible to reach accurate ITRS coordinates in regional areas.

It is difficult to preserve the original high relative ITRS accuracy because of ETRS89 velocities estimation, despite having a well-defined schedule to transform to ETRS89 reference system.

It seems to be mandatory to consider ETRS89 velocities in shouthern Europe. However, in certain cases, official EPNs velocities appear not to be realistic values.

In practice, some transformation are needed in order to adapt new high precision ITRS solutions into older ETRS89 solutions.

Acknowledgements

ERVA Network is integrated with stations VALE, ALAC, belonging to ERGPS, property of the Spanish National Geographic Institute (IGNE), and EBRE station

(CATNET) from the Cartographic Institute of Catalonia. We would like to gratefully acknowledge the co-operation of these institutions, in order to improve the redundancy of ERVA Network in the real time GNSS streams.

References

Boucher, C., Altamimi Z.:Specifications for reference frame fixing in the analysis of a EUREF GPS Campaign. IERS Memo Version 6, Observatoire de Paris.

EUREF Permanent Network
http://www.epncb.oma.be/_organisation/projects/series_sp

Hugentobler, U., Schaer, S.; Fridez, P.: Bernese GPS software Version 4.2. Astronomical Institute. University of Berne. February 2001.

Instituto Cartográfico Valenciano (ICV) http://www.icv.gva.es

Institut Cartogràfic de Catalunya (ICC) http://www.icc.es

Instituto Geográfico Nacional de España (IGNE) http://www.ign.es

On-line Ocean tide loading provider. Onsala Space Observatory http://www.oso.chalmers.se/~loading/