Determination of the ETRS89 coordinates of the Active Geodesic Network of Principado de Asturias (Spain)

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The Center of Environmental and Territorial Cartography of the Principality of Asturias (CCATPA) has recently set up the RGAPA project. RGAPA (Red Geodésica Activa del Principado de Asturias) is a RTK/VRS network of the Principality of Asturias (northern Spain). Precise ETRS89 coordinates are obtained using Bernese V4.2 GPS Software and specifications for reference frame fixing in a EUREF GPS campaign. In order to get consistency with ETRS89 coordinates of the ERGPS reference frame solution some studies has been carried out. Processing tasks, results and analysis are discussed.

1. Introduction

ERGPS setting up by the Spanish 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 has been established by regional administrations. RGAPA project is the active network of the Principality of Asturias Community organized an managed at present by CCATPA, which provides real time positioning by means of Virtual Reference Stations (VRS). RGAPA network consist of 8 stations (3 backup stations more in the future) and will be used in the next future in 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 RGAPA network, some GPS campaigns and GPS permanent stations data were processed by the CCATPA using the Trimble Total Control software. Since the main objective in that solution was to get a continuous and homogeneous precise positioning along the whole area and boundaries, ETRS89 coordinates provided by IGNE of closer ERGPS stations (CANT, ACOR, RIOJ and VIGO) were held fixed. This solution can be found at http://www.cartografia.princast.es/cartositpa/.

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

Some studies has been worked out in order to get consistency with ETRS89 coordinates of the ERGPS reference frame solution, and the present official solution is checked.

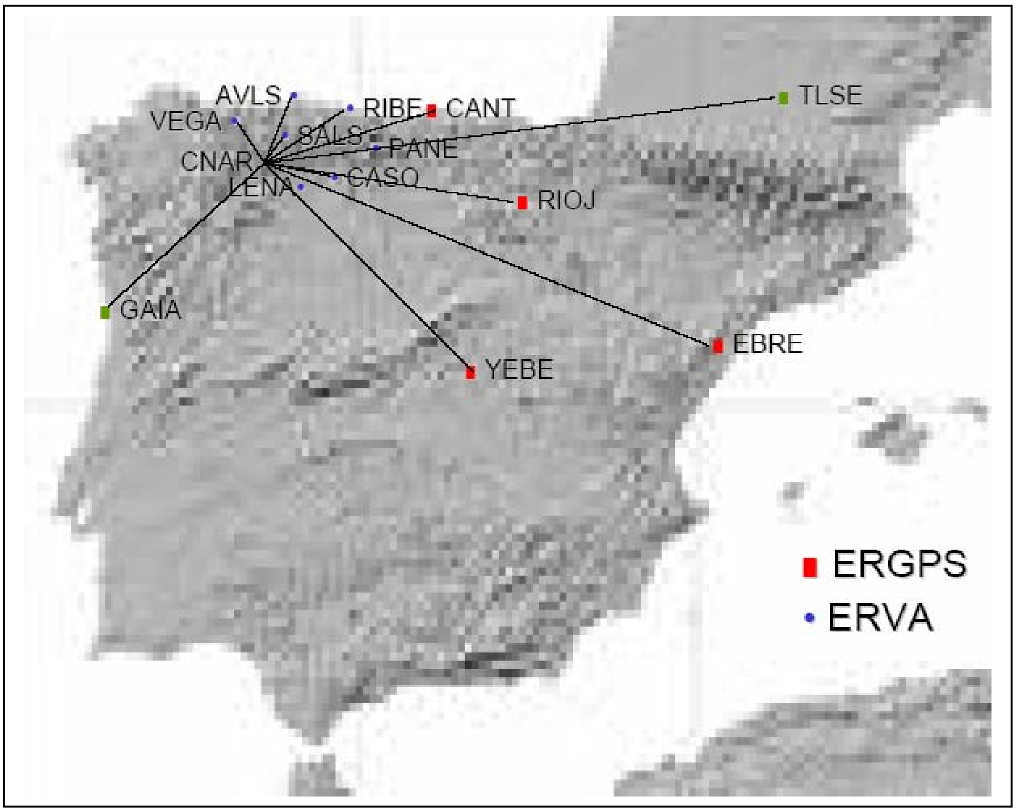

Figure 1.- Single differences schedule used for processing.

2. Processing strategy

The processing and analysis of the data were performed by the Cartographic Engineering, Geodesy and Photogrammetry Department (DICGF) of the Technical University of Valencia (UPV) in cooperation with CCATPA using Bernese GPS software version 4.2 on Windows 98SE PC platform and regarding the procedures specified by EUREF TWG (Boucher, C., Altamimi, Z. , 2007).

As some data problems were detected ACOR and VIGO stations in Fabruary, both stations were excluded for processing.

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

- Use of CODE precise orbits with corresponding Earth rotation parameters and JPL Planetary Ephemeris DE200.
- Use of CODE troposphere files.
- No ION files has been used.

- Use of FES2004 ocean loading displacement model data computed by Onsala Space Observatory(http://www.oso.chalmers.se/~loading/
- Three consecutive days (14^{th},15^{th} and 16^{th} of February 2007) of 30 seconds interval data.
- The strategy used when forming single difference observations was to form a first baseline from YEBE to CNAR and subsequently from CNAR to other stations. Therefore, all double difference equations contain CNAR station data.
- 10 degrees elevation mask 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 (15^{th}- Feb-2007 12:00)

The IERS ITRF05 coordinates of de IGS points YEBE and TLSE were used as fixed points for final RGAPA07-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. The final ITRF05 (2007.123) coordinates for the RGAPA07 solution are shown in Table 1.

Table 2.- RGAPA07- 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	4833520.1398	41537.1455	4147461.5750	0.8	0.1	0.7
CANT	4625924.4558	-307096.4769	4365771.4190	0.8	0.2	0.7
RIOJ	4708688.3766	-205761.4151	4283609.6152	0.8	0.1	0.7
GAIA	4759095.4514	-718818.5788	4171491.4053	0.8	0.2	0.7
PANE	4632463.7290	-371362.3903	4353899.9133	0.8	0.2	0.8
VEGA	4601467.5128	-568971.7856	4365316.2245	0.8	0.2	0.7
CNAR	4629385.9938	-530836.3657	4341282.9237	0.7	0.2	0.7
SALS	4613647.2872	-505773.2566	4360584.3811	0.8	0.2	0.7
LENA	4636819.6019	-473021.7728	4339900.0553	0.8	0.2	0.7
AVLS	4604379.0136	-476286.9300	4373385.8164	0.8	0.2	0.7
RIBE	4618539.1056	-409516.4904	4365145.6586	0.8	0.2	0.7
CASO	4638385.3984	-433753.9927	4342706.2948	0.9	0.2	0.8

3. Comparison with EPN Project coordinates

As coordinates/velocity 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. Differences are shown in Table 3.

Considering that double difference equations for estimating coordinates has been formed to include CNAR station data and the official IERS coordinates were held fixed, we can conclude that ERVA07-ITRF05 solution is consistent with EPNs ITRF05 coordinates at sub-centimetre level with a systematic millimetric shift.

Table 3.- RGAPA07- ITRF05 (2007.123) coordinates minus EUREF EPNs

Site	North (m)	East (m)	Up (m)
YEBE	-0.003	0.004	0.005
TLSE	-0.003	0.001	0.002
EBRE	-0.006	0.002	0.008
CANT	-0.003	0.001	-0.002
RIOJ	0.004	-0.003	0.001
GAIA	-0.002	0.007	-0.003
Mean value	-0.002 ± 0.003	0.002 ± 0.003	0.002 ± 0.004

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 to use EPNs velocities to estimate velocities into ETRS89 reference system using

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

and consider velocity of CANT as velocity value for all RGAPA stations. RGAPA07- ETRS89 coordinates and velocities obtained are shown in Table 4.

At this point, it is worth to point out the difference between IRTF05 velocity vectors computed by the “EPN Project for time series monitoring” for the stations RIOJ and CANT appear not to be realistic values. If they were true, ETRS89 coordinates of both stations would move between them more than 6 mm/year.

Table 4.- RGAPA07 - 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	4833520.3915	41536.8310	4147461.3223	-0.2	0.6	-0.2
CANT	4625924.7148	-307096.7678	4365771.1627	-1.4	0.0	0.4
RIOJ	4708688.6066	-205761.7114	4283609.2520	0.4	0.0	6.1
GAIA	4759095.6488	-718818.8896	4171491.1363	-0.0	0.7	0.7
PANE	4632463.9880	-371362.6812	4353899.6570	-1.7	0.0	0.4
VEGA	4601467.7718	-568972.0765	4365315.9682	-2.4	0.1	0.4
CNAR	4629386.2528	-530836.6566	4341282.6674	-2.3	0.0	0.3
SALS	4613647.5462	-505773.5475	4360584.1248	-2.2	0.1	0.4
LENA	4636819.8609	-473022.0637	4339899.7990	-2.1	0.0	0.3
AVLS	4604379.2726	-476287.2209	4373385.5601	-2.0	0.1	0.4
RIBE	4618539.3646	-409516.7813	4365145.4023	-1.8	0.1	0.4
CASO	4638385.6574	-433754.2836	4342706.0385	-1.9	0.0	0.3

5. Comparison with other ETRS89 solutions.

RGAPA07-ETRS89 coordinates for EPNs can be compared with EUREF-ETRF05 computed by the “EPN Project for time series monitoring”

Table 5.- RGAPA07- 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	-0.0054	0.0019	0.0087
CANT	-0.0029	0.0018	-0.0017
RIOJ	0.0027	-0.0026	0.0015
GAIA	-0.0019	0.0062	-0.0026
Mean value	-0.003 ± 0.003	0.002 ± 0.003	0.002 ± 0.004

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

Table 6.- RGAPA07- ETRS89 coordinates minus ERGPS IGNE-ETRS89 coordinates.

Site	North (m)	East (m)	Up (m)
YEBE	0.0094	-0.0075	0.0144
EBRE	-0.0063	0.0032	0.0331
CANT	0.0115	-0.0207	0.0294
RIOJ	0.0195	-0.0817	-0.0446
Mean value	0.009 ± 0.011	-0.027 ± 0.038	0.008 ± 0.036

An feasible explanation for such differences could be that they were obtained from a ITRF00 solution. As we have no information about the epoch for that solution no additional analyses can be made.

6. RGAPA07-ETRS89 coordinates expressed in the IGNE-ERGPS frame.

Taking into account the importance of RGAPA07- ETRS89 coordinates being consistent with ETRS89-ERGPS coordinates, different transformations were tested and analyzed. Eventually, we found best to transform original RGAPA07-ITRF05 (2007.123) into ETRS89-ERGPS using the following three translations was the better option to preserve the relative precision of the RGAPA07 solution:

Table 6.-Transformation parameters from RGAPA07-ITRF05 (2007.123) to ETRS89-ERGPS.

	Geocentric system translations		Local translations in YEBE
Tx	0.214 m. ± 0.005 m.	**Te**	-0.297 m. ± 0.005 m.
Ty	-0.309 m. ± 0.005 m.	**Tn**	-0.357 m. ± 0.005 m.
Tz	-0.272 m. ± 0.005 m.	**Tu**	-0.002 m. ± 0.005 m.

Coordinates and residuals for the fixed points are shown in Table 7.

Table 7.- RGAPA07 -ETRS89 coordinates obtained from ITRF05 (2007.123) using three translations.

	Coordinates			Residuals		
Site	**X(m)**	**Y(m)**	**Z(m)**	**N (mm)**	**E (mm)**	**U (mm)**
YEBE	4848724.9081	-261632.4782	4123093.9111	4.1	-5.3	15.2
TLSE	4627852.0244	119639.7482	4372993.3030	-0.3	12.7	-8.0
EBRE	4833520.3542	41536.8367	4147461.3027	-9.4	-2.5	-13.0
CANT	4625924.6702	-307096.7857	4365771.1467	6.4	-4.5	5.7
RIOJ	4708688.5910	-205761.7240	4283609.3429	-	-	-
GAIA	4759095.6658	-718818.8876	4171491.1330	-	-	-
PANE	4632463.9434	-371362.6992	4353899.6410	-	-	-
VEGA	4601467.7272	-568972.0944	4365315.9522	-	-	-
CNAR	4629386.2082	-530836.6745	4341282.6514	-	-	-
SALS	4613647.5016	-505773.5655	4360584.1088	-	-	-
LENA	4636819.8163	-473022.0816	4339899.7830	-	-	-
AVLS	4604379.2280	-476287.2388	4373385.5441	-	-	-
RIBE	4618539.3200	-409516.7992	4365145.3863	-	-	-
CASO	4638385.6128	-433754.3015	4342706.0225	-	-	-

The differences between this solution and the RGAPA solution which is published at the published at the CCATPA website are the following:

Table 8.- RGAPA 07-ETRS89 coordinates minus CCATPA-ETRS89 coordinates.

Site	North (m)	East (m)	Up (m)
CANT	0.0122	-0.0065	-0.0054
RIOJ	0.0057	-0.0077	0.0107
PANE	0.0140	-0.0041	-0.0080
VEGA	0.0199	-0.0004	-0.0152
CNAR	0.0155	-0.0014	-0.0087

SALS	0.0159	-0.0009	-0.0035
LENA	0.0139	-0.0022	-0.0067
AVLS	0.0168	-0.0028	-0.0080
RIBE	0.0149	-0.0041	-0.0088
CASO	0.0133	-0.0039	0.0017
Mean value	0.014 ± 0.004	-0.003 ± 0.002	-0.005 ± 0.007

7. Conlusions

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.

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.

Centro de Cartografía Ambiental y Territorial del Principado de Asturias (CCATPA) http://www.cartografia.princast.es/cartositpa/

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.

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/