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Instituto Geográfico Nacional

Spanish National GPS Reference Stations Network (ERGPS).

R.Quiros, J.A.S. Sobrino, M. Valdés, M.A. Cano, L. Lozano
(rquiros@mfom, jassobrino@mfom, mvaldes@mfom, macano@mfom, llozano@mfom.es)

The Instituto Geográfico Nacional of Spain (IGNE), by its Geodesy Department, is carrying out since 1998 the establishment of a GPS Reference Station Network of Spain (ERGPS) delivered all around Spain which allows millimetric coordinate results, as well as velocity fields in a Global Reference System (ITRFxx), serving as support for another geodetic networks and for technical and scientific works. Most of these stations (10) are been integrated in the EUREF Permanent Station Network. Nowadays, sixteen stations form the national network of the IGNE that provides data to the public user through anonymous ftp.

The main activity during 2002 in this network has been the maintenance of the stations. Due to the continous function, PC's, antennas, receivers and other auxiliary instruments have to be repaired or replaced. At the same time, telephone lines are being replaced for ADSL Internet access. If comunication problems (collapsed lines) can be solved in the data center of IGN-E, data at 5 seconds interval will be served to public users. It is planned to install four more stations, completing the planned whole Spanish GPS Reference Station Network (ERGPS), wich will consist of 20 stations.

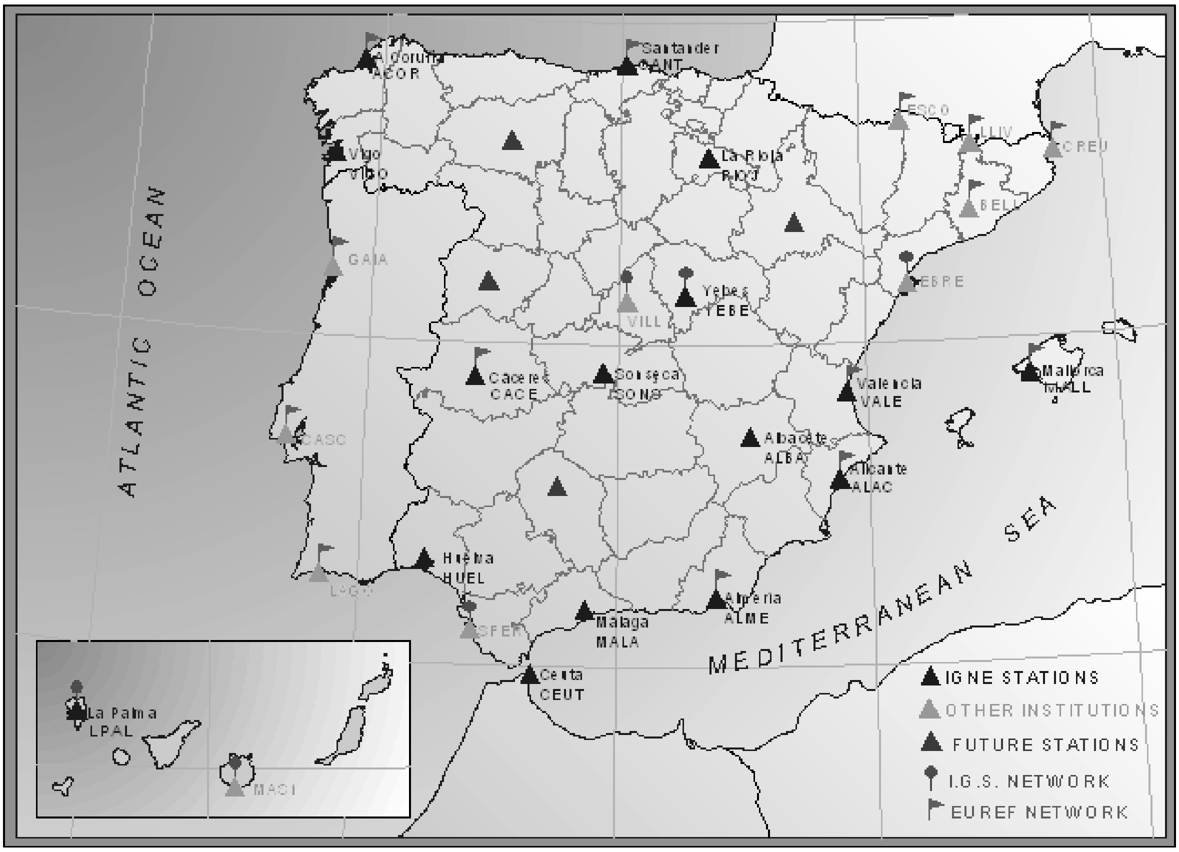

Fig. 1. Current status of the IGN-E network.

This whole network including data from other stations in Spain is being proccessed with BPE (27 stations), with continous data since 1998. Precision coordinates as well as velocities and time series are being obtained from this whole network including non-EUREF stations.

On the other hand, since the first week of September 2001 (1130 GPS week), the Spanish IGN has started to process an EUREF subnetwork solution, becoming an EUREF Local Analysis Cente (IGE). This subnetwork consists of 23 Iberian stations and the processing is carried out with Bernese Processing Engine, BPE v. 4.2, in a complete automated process. Bernese in IGE has been supported under UNIX platform, but currently LINUX SuSe has been installed and proccessing is being made completely in PC's under LINUX operating system. IGE is currently proccessing a network concerning Spanish and Portuguese stations (plus one French and one Moroccan), but the flexibility of the implementation of BPE under LINUX platform will allow to increase the IGE network through the Mediterranean area, proccessing new stations.

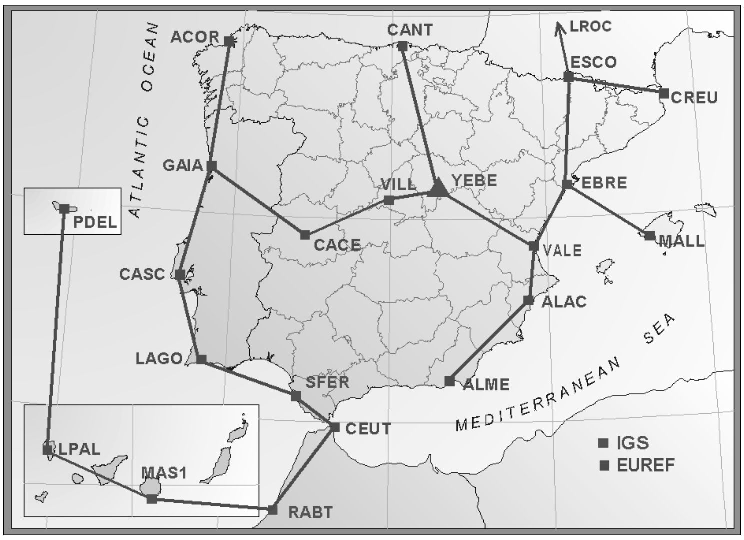

Fig. 2. Proccessing network of IGE.

REDNAP Project

A. Barbadillo, F. de la Cruz, R. Quirós.
(abarbadillo@mfom.es, fcruz@mfom.es, rquiros@mfom.es)

Since 2001 the IGNE is carrying out the REDNAP Project in order to establish a new High Precision Levelling Network in Spain, replacing the former network (forty to seventy years old), which is actually destroyed in a big rate. In 2002, about 2500 bench-marks along 2400 kilometres were monumented in some regions of Spain (Cantabria, Basque Country, Castilla y León, Madrid, Castilla-La Mancha, Aragón and Valencia) bordering the part previously monumented in 2001 in the Northeast of the country. Geometric levelling, gravimetric and GPS campaigns are being carried out in 2003 involving the lines monumented in 2002 . Simultaneously to the gravimetric observation, almost the points are observed by GPS in order to establish an High Precision Geoid. It is assumed that the REDNAP Project will be ended in 2008 for the whole of Spain.

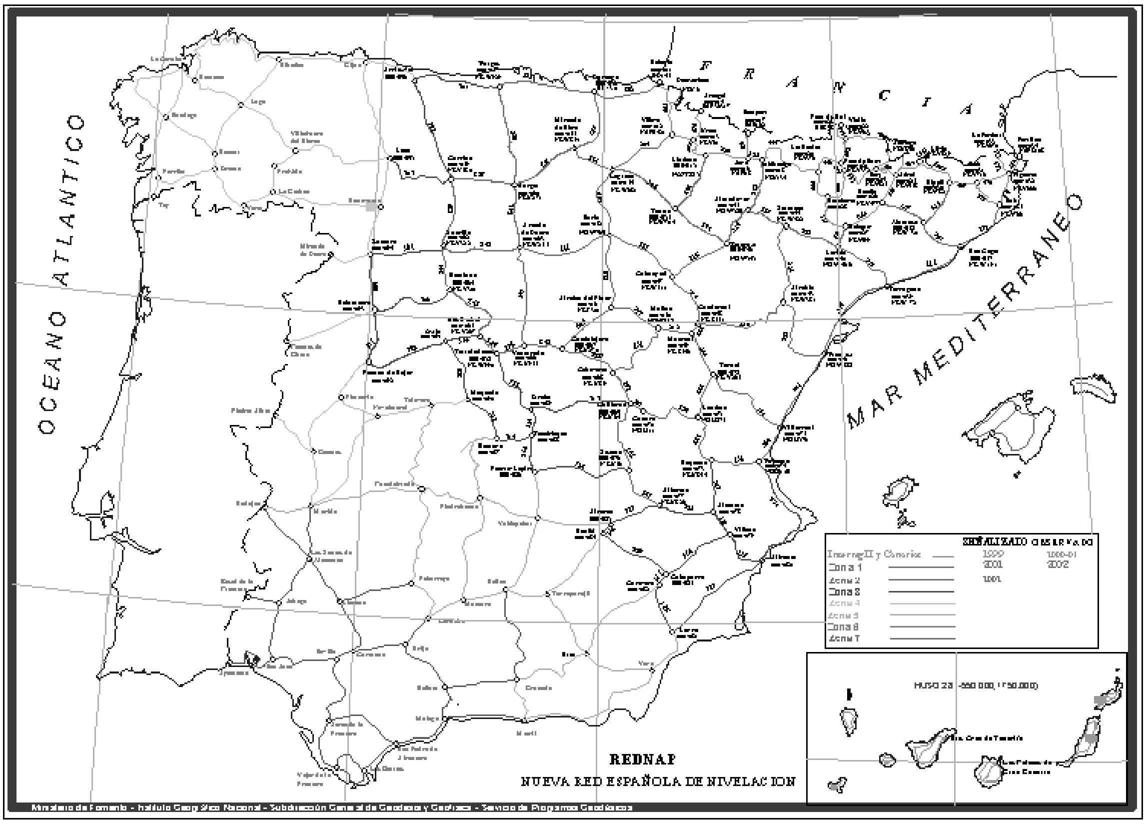

Fig. 3. REDNAP Project: Monumented and planned lines.

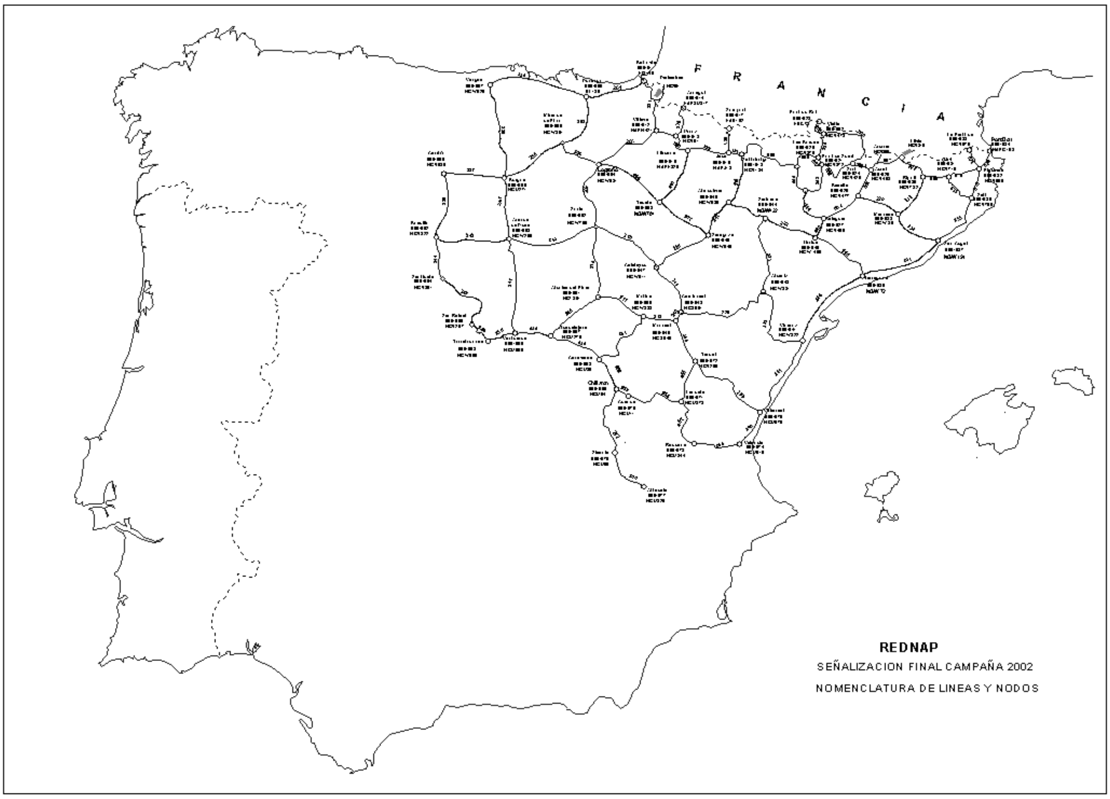

Fig. 4. REDNAP Project: Observed lines.

Zero Order Absolute Gravity Network of Spain

A. Dalda, E. Rodríguez, E. Núñez, M. Fernández
adalda@mfom.es, erpujol@mfom.es, enmaderal@mfom.es, mcfvillata@mfom.es)

Summary

Since the first absolute measurements of gravity in Spain (J. Barraquer 1877 and 1882) no measurements have been performed till 1989. The IGN of Spain has purchased recently the FG5 # 211 absolute gravimeter and a new most precise network called IAGNP (REGA in Spain) will be deployed in the next few years in order to better the actual accuracies.

The very first network

The very first scientific task in Spain from the gravimetric point of view, reported to the IAG Commission, was Barraquer´s work. Now it´s 120 years since his measurements in the National Astronomic Observatory of Madrid.

Eight years later Antonio los Arcos and Príamo Cebrián also measured absolute values of gravity following Barraquer´s method. They choose *Pamplona* (October 1892), *La Coruña (August and September 1893)* and *Barcelona* (November and December 1893); only by Antonio los Arcos are observations in *Observatorio Astronómico de San Fernando* (October and December 1894), and finally Rafael Aparici and Arturo Mifsut in *Valencia* (Otoño de 1895), Eduardo Escribano en *Granada* (1897) and Príamo Cebrián and Felipe de la Rica in *Valladolid* (1901). A total of eight stations including Madrid. We also celebrate 101 years since the first relative measurements with Von Sterneck Pendulums made by Dr. Oscar Hecker in his travel through the Atlantic Ocean (Potsdam, Rio de Janeiro, Lisbon, Madrid) in 1901.

The new network

The National Geographic Institute of Spain (IGNE) has purchase a new free fall absolute gravity device by Micro-G Solutions named FG5#211 in order to observe a new absolute gravity network (IAGN) in the Iberian Peninsula (red triangle stations shown in figure 1) and at least one point in every island (Balearic Islands and Canary Islands). This network will serve for geodetic (supporting the new High Precision Levelling Network) and geodynamic purposes, amomg others. The breakout point for this enterprise was the ICAG2001 (International Comparison of Absolute Gravimeters) which took place in Sévres (Paris) July 2001, where the FG5#211 worked with the expected 1 microgal precision.

It would be desirable that these and more proposed stations fulfil the international standards of the International Absolute Gravity Base-Station Network (IAGBN) and all our efforts will be driven to that purpose so that this work could be widely accepted and useful for the scientific community.

The firsts stations already observed are Madrid IGNE, Madrid CEM, Madrid Astronomical Observatory, Valencia, Sonseca, San Pablo de los Montes and the next projected stations are shown in figure 1. To those, some stations observed by other european and spanish institutions should be added: Valle de los Caídos (FGI and IAG); Tarifa, Ceuta, Alicante, San Fernando, Granada (BKG); Barcelona, and Las Mesas Observatory (Canary Islands).
During 2002 absolute stations in Geophysical Observatory of Santiago de Compostela, Geophysical Observatory of Logroño, Geophysical Observatory of Málaga, Geophysical Observatory of San Pablo de los Montes (Toledo), El Miracle (Lleida), Astronomical Observatory of Fabra (Barcelona), Ebro Observatory (Tarragona), El Puig Monastery (Valencia), and Valle de los Caídos (Madrid, IAGBN station) have been observed by FG5#211 of IGNE.

Links between absolute stations and many other densification ones for the REDNAP project have been made.

IGNE contributed to the *European Unified Gravity Network (UEGN2002)* sending data from all absolute values known in Spain, as well as relative raw observations.

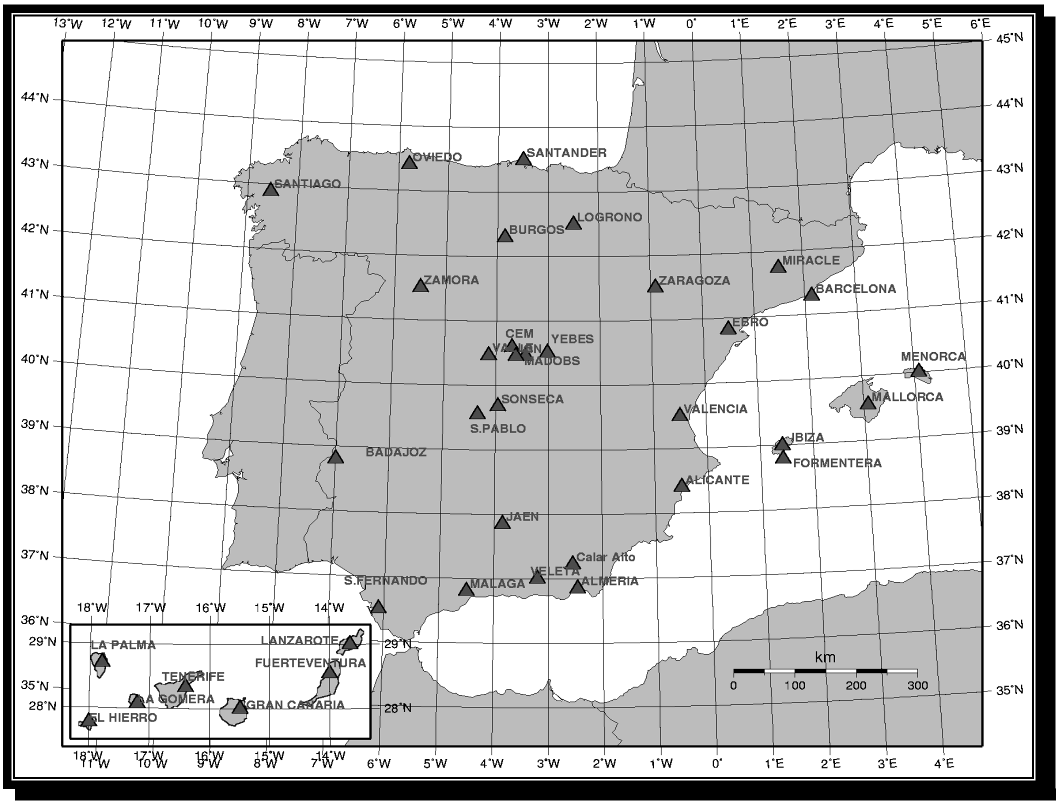

Fig. 5: IAGNP (Iberian Absolute Gravity Network Project).

RECORD (Radio Broadcasting of GPS Differential Corrections)

A. Dalda, F.J.G. Matesanz, J. Celada
(adalda@mfom.es, fjgmatesanz@mfom.es, jcelada@mfom.es)

The RECORD project intends to broadcast GPS differential corrections through RDS non-audible sub-carrier (Radio Data System, Sistema de Datos en Radio) of Radio Nacional de España (RNE) broadcasting stations.

The code differential GPS correction, obtained from pseudodistance observable smoothed with phase, is available in RTCM SC104 format. Further on, it is analyzed and compressed in RASANT 2.6 format (Radio Aided Satellite Navigation Technique). It is in this format in which it is sent to RNE, who send it incorporated to the FM signal broadcasted. A FM/RDS/RASANT receiver decompresses and provides the original RTCM SC04 corrections, which are integrable in most GPS receivers.

Since middle of 1997, the IGNE in cooperation with "Radio Nacional de España (RNE)" has made several tests to broadcast differential GPS corrections, as requested by quite a lot of users, to manage fleets, to control special public services (burning forests, ambulances, public transport, traffic, and so on.). To do that, the IGNE uses software licenced by LVA of NordRhein-Westfallen, under agreement of exclusive use by IGNE and RNE as free official public service.
The main objective of setting up DGPS/RASANT system (named RECORD) is establishing and implementing a public service to terrestrial positioning available to spanish community of GPS users with usual criteria of precision, integrity and availability in this kind of systems.

The given service by DGPS/RASANT system will be based upon broadcasting RTCM differential corrections in RASANT format through sub-carrier not audible RDS of RNE broadcasting stations.

The attainment of the objective establishes on a basis of formalization of technical cooperation agreement between IGNE and RNE suscribed to that motive, thus differencial corrections will be broadcasted by FM broadcasting stations of the "Red Técnica de Difusión" of RNE. This corrections will be delivered following international accepted formats (RTCM and UIT´s Recomendation nr. 823), compressed in RASANT format, with free access to all users who have a FM/RDS/RASANT receiver.

Precision given by this system will be better than 5 m 2dRMS (95% of probability). In more restrictive conditions concerning to distance to correction generating point and data availability, the system will reached about 1 m precisions.

The DGPS/RASANT system consists of stations DGPS/RASANT and a Control Centre. The DGPS stations that will work in redundant mode by double reference receiver will have the tasks:

RTCM differential correction generation, evaluation and compression to RASANT format.
Data deliver to RDS net server of RNE through phone line point to point, optical fibre link or equivalent.
Working Integrate Monitoring in each station DGPS by decoding RASANT format to RTCM by a FM/RDS/RASANT receiver.
Observable store setting up a GPS Database.

On its own, the control centre placed in the IGNE facilities in Madrid, will have the following tasks:
To assure intercomunication with DGPS stations.
To monitor and control DGPS parameter, assuring system homogeinity.
To integrate metric precision controls in future peripherical stations.
To download dayly, or by request, of GPS information towards the Spanish National GPS Reference Station Network.

The fact of being in the peninsular periphery inside a radius of 500 km and positions obtained during the period 1997/98 guarantees that the first part of the network set up will be deal with one control centre and two reference stations, one in Madrid (IGNE) and the other in Sta. Cruz de Tenerife (Geophysical Centre of Canary Islands of the IGNE).

Integrity monitoring tests are being made during 1999-2000. For this reason a triple GPS equipment (2RS+IM) has been set up in IGNE facilities, asuring correction´s reliability, continuity and integrity for Canary Islands and Peninsula. A forth GPS equipment in Prado del Rey facility to reinforce the array is also working.

The equipments have been set up in Tenerife similar to that in Madrid station and connected to IGNE Control Center in Madrid through RDSI (TCP/IP).

During 1999 a GPS receiver in broadcasting station of Palma de Mallorca has been installed to get an independent solution for the Balearic Islands region apart from that of the peninsula. This solution is available for RNE2 broadcasting stations (Radio Clásica) of Alfabia and Pollensa.

A remote monitoring service is being installed from Prado del Rey by RNE, in which data and audio broadcasting are verified. IGNE has equiped different regional departments with FM/RDS/RASANT+GPS receivers to get a redundant monitorization.

Digital Audio Broadcasting (DAB) tests have been I carried out for the transmission of real time differential phase corrections with excellent results. As long as the technology will be utilised massively this stage of the project is still not operational (RECORD-2)

Digital radio allows a more effective use of the spectrum holding seven programs in one frequency. The PAD (Programme Associated Data) associates data to each program but is space limited for our purposes. The data channel no associated to audio (NPAD) can hold more bandwidth. In this channel is where the tests have been done.

Such tests were done at RNE headquarters, broadcasting the RTCM phase and code differential corrections, that is type 1, 2, 3, 18 and 19. The data was received at a Grundig Dab200 connected to a laptop computer that output the corrections into a test GPS. Several GPS receivers were test: single frequency, double frequency with and without "on the fly" ambiguity resolution option activated. Both GPS, generator and receptor, used in this test shared the same antenna, and the delay observed was about 2 - 4 seconds.

The last part of the project consists on transmitting RTCM over internet (RECORD-3). The BKG has developed all the software (client and server side) for this purposes. The first GPS station included in EUREF-IP is Madrid. This station is located at IE09 monument (ETRS89 class B network) and consist on tree GPS: Integrity monitor+double reference station. Nowadays Madrid station is broadcasting RTCM messages (1,2,3,16,18 and 19) which allows RTK positioning in all Madrid metropolitan area.

Initial tests employing a 56K modem internet connection over a 50m baseline between two buildings of IGN shown cm accuracy and delays no more than 2-3 seconds. In order to see wireless technology benefits some test points at several distances: 5, 10,15, 20 and 27 Km have been used.

Distance to reference	East difference	North difference	Ellipsoidal height difference	Satellites tracked	Time span	Point
5015	-0.008	0.006	0.028	10	429	BM5
10403	0.003	0.008	0.046	6	105	BM10
10403	0.014	0.023	0.022	8	357	BM10
14649	-0.014	0.055	0.008	5	460	BM15
14649	-0.041	0.034	0.010	9	374	BM15
20493	0.010	-0.008	0.020	7	362	VILLE
20640	0.007	0.021	0.021	9	134	VILLT
27568	No fix					Lomo

Table 1. Fixed solution quality

Acronyms explanation.

BM: Bench mark.
VILLE: Villafranca ESA station Doppler East point
VILLT: Villafranca ESA station roof point
LOMO: Geodetic monument belonging to REGENTE campaign

VILLE and LOMO have precise ETRS89 coordinates while the others one are surveyed from Madrid station.

The average occupation time of each point is 7 minutes, the log file has been splittered into 4 parts: fixed, float, RTCM and autonomous. Most of log file records are fixed solution but “Lomo” monument where fixing ambiguities was not successful.

The results in the tables above are not rigorous, it has only sense to proof what would happen if a user with the same configuration set up a GPS and use the same equipment configuration. The right way of perform such tests is to occupy the points at least for some hours.

The result depends strongly on the satellite configuration: PDOP and number of satellites tracked so the tables can be optimistic or pessimistic but it is a good estimation of what can be expected with this new technology.

From the data provider side the technology solves lots of logistic problems when transmitting with a traditional radio provider (ie. National Radio of Spain and RDS subcarrier), in particular, accessing the broadcasting network and limited bandwidth inconveniences. DAB (Digital Audio Broadcasting) technologies will solve the bandwidth inconvenience but again the network is designed to broadcast an area or a country. This drawback means that the same stream is sent to the whole network. Sending RTCM or RTK for different areas is really difficult.

In the future some stations of ERGPS will be included in the project although it depends on ERGPS manager objectives. Even if it is not possible GPSL1 mapping reference stations (Córdoba, Coruña and Burgos) will be included as soon as possible.

Development of the ED50-ETRS89 datum transition

A. Dalda, F. J. González-Matesanz
(adalda@mfom.es, fjgmatesanz@mfom.es)

Introduction

As results of the recently finished REGENTE (National Geodetic Network using Spatial Techniques) and some recalculation of the third order network (ROI), provided us a double set of ETRS89-ED50 coordinates used to prepare a range of transformation techniques. To absob the heterogeneous behaviour of ED50 3 methods of distorsion modelling were evaluated apart from the classical ones (7/5 parameters, real and complex polynomial).

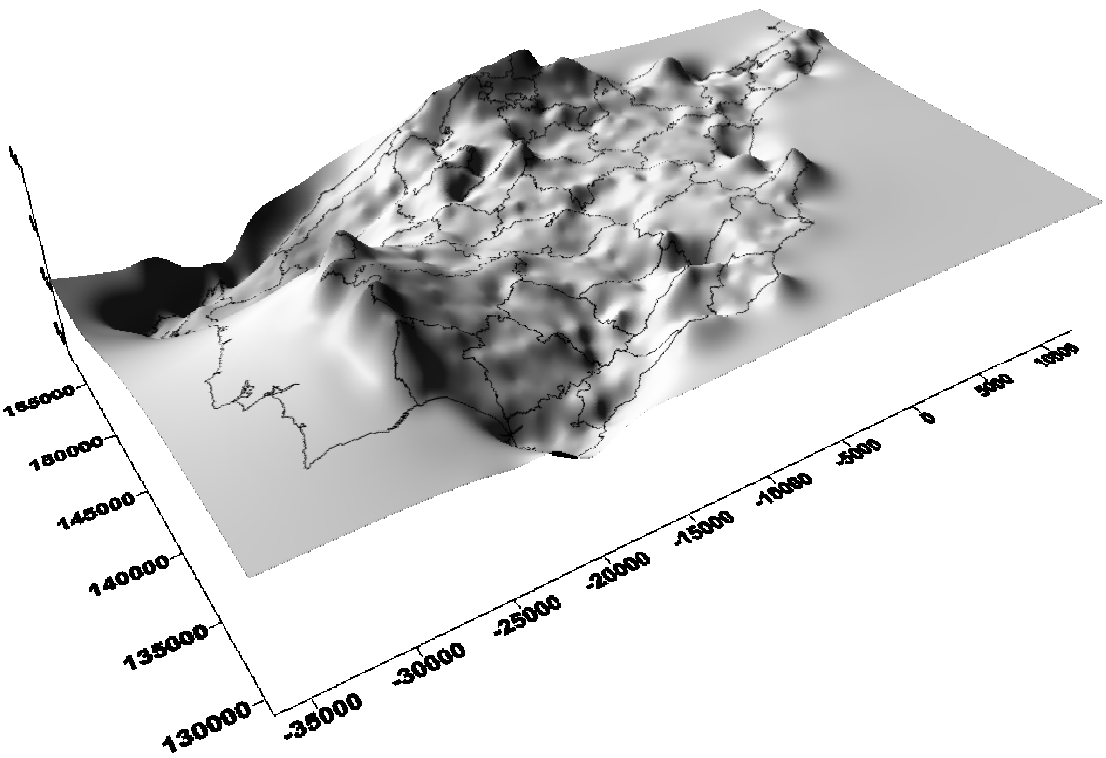

Fig. 6. Longitude distortion

Distortion modelling

In order to test the several methods (Least Squares Collocation, Rubber Sheeting and Minimum Curvature Surfaces) we have created 3 grids, one for each method. The grid was generated using REGENTE monuments (30 Km average distance). For testing the grid a recalculation of the third order network (1400 monuments) was used. The results shows accuracies between 14-18 cm (95%).

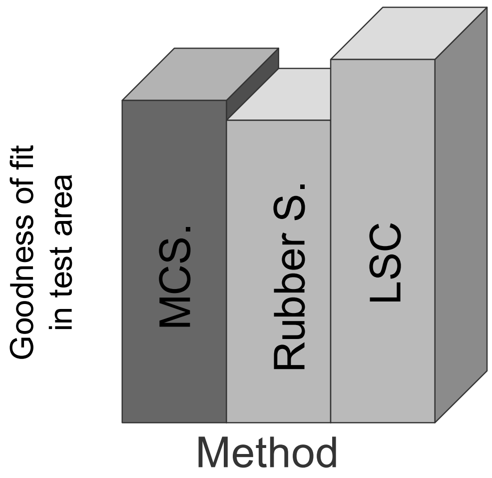

Fig. 7. Overall perfomance of distortion methods

Statistics	E TEST	N TEST
# points	1400	1400
Average	0.00	-0.01
Std Dev	0.07	0.05
Max	0.24	0.19
Min	-0.25	-0.25
Range	0.49	0.43
95%	0.13	0.11
99%	0.16	0.13

Table 2.Points below 25cm. Least Squares Collocation

Estat.	E TEST	N TEST
# points	1395	1395
Average	0.00	-0.00
Std Dev	0.05	0.05
Max	0.23	0.22
Min	-0.24	-0.24
Range	0.48	0.46
95%	0.10	0.09
99%	0.13	0.12

Table 3. points below 25cm. Rubber-Sheeting

Estatistics	E TEST	N TEST
# puntos	1400	1400
Average	0.01	0.02
Std Dev	0.05	0.05
Max	0.24	0.22
Min	-0.24	-0.24
Range	0.48	0.46
95%	0.10	0.10
99%	0.13	0.12

Table 4. points below 25cm. Minimum Curvature Surface

Grid distribution format

The distribution is also an important issue

Conclusions

There is no simple way of making datum transformation using standard conformal procedures since the existence of distortion component is difficult to absorb. Modelling the distortion is the best way to perform the datum change.

However, depending on the specialisation level of the user of this transformation a more specific product need to be prepared. An executable software, web page with Java/Asp components, OCX/DLL tools for developers and grid files in NTV2 format will be built. The NTV2 format was developed by the Geodetic Survey Division, Geomatics Canada and it has been implemented in many software packages. The gridding using minimum curvature technique is easy to achieve and gives us the optimal performance in the transformation. The NTV2 format also provides multiple subgrids of different intervals and let us obtain successive grids as the network is being readjusted in ETRS89.