Geodetic works carried out in the Strait of Gibraltar

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Abstract— **The proximity between Europe and Africa and the fact that the Strait of Gibraltar has historically acted as a link between races, cultures and religions have made absolutely necessary to establish a relationship between the Northern African coast and the Southern European equivalent.**

From the Nineteenth Century the possibility of building a permanent link between both continents through the Strait of Gibraltar has been taken into account.

In order to establish that relationship it is necessary to have coastal zones completely geo-referenced, under the same geodetic system and with a unique projection system.

The paper describes the work carried out in the Strait of Gibraltar for this purpose.

Keywords: Africa, Europe, geodetic link, cartography, Strait of Gibraltar

I. INTRODUCTION

The small separation between Europe and Africa has made since ancient times man has dreamed of establishing there a fixed link between the two continents.

The Strait is primarily a place of passage, and history shows that the events those have occurred in it , have had a very broad impact . The proximity of the coast between Africa and Europe has offered the possibility, throughout history, visual set between the two continents. Now, with the use of GPS , it is not necessary intervisibility between vertices .

Today, the dream of the link, far from being forgotten, is a subject of great interest from Spanish and Moroccan governments . To be more specific, on June 8, 2007, the Minister of Development and his Moroccan counterpart, the European Commission called on political and financial support for the proposed fixed link between Africa and Europe under the Strait of Gibraltar. The project, which has been included in the Infrastructure Plan 2005-2020 of the Ministry of Development, provides for the construction of a rail tunnel double 38.7 27.7 kilometers of which are under the sea.

Between 1982 and 2004 campaigns were conducted geodesic in the Strait of Gibraltar by classical techniques and space, but it was in 1879 when the first campaign was conducted geodesic between neighboring continents.

In 1879, Spanish geodesy and showed a high level, but probably due to the political, economic and social aspects of that period, there was a brake on the development of geodesy and not resume until 1982 when such campaigns .

Thanks to the availability of access to data for all campaigns, appeared the opportunity to analyze different campaigns within the same geographical area with similar objectives and by techniques decline and rise, that is made with classical methods or space.

This article attempts to address the complexity of the link in a unique area, as is the Strait of Gibraltar.

II. 1984 WORKS

The campaigns conducted in 1984 (RGOG 84) and 1989 (RGOG 89) aimed at the establishment of a classic high precision geodetic network (RGOG) [10], which enlazase both coasts of the Strait and that would satisfy the necessary conditions for observation in a first phase by conventional methods (directions, distances and geometric leveling) and spatial methods (GPS) in a second stage .

The first problem to solve was the choice of the most appropriate settlements constitute the network signals, as both topographical and geological features of the area are not favorable for establishing a network optimally configured . It took numerous field surveys and geological studies before making a decision on the location of the vertices and the appropriate number.

The vertices were chosen close to the coasts forcibly and geologically unstable terrain, in order to promote laser distance observation. Intervisibility requirements and limitations given by the laser distanciometry send over another very important factor is the geological stability. Therefore, in this case, could be produced which would affect the local displacements of the area geodynamic study.

Thus, in 1984, the year that takes place long observing campaign RGOG total, shows the difficulty of obtaining a regular geometry, increasing markedly the dimensions of the sides over the sea from the eastern to the western. Furthermore, the presence of prominent impossible Musa Yebel solid optical link between vertices SS7 and VS8 (Figure 1) , so that the latter was resigned to an auxiliary character , while in a second step of applying GPS techniques, would be fully integrated into RGOG .

In 1982 and 1983, were carried out reconnaissance work and construction of the signals and their networks of local control as well as geometric leveling and gravimetric observation of lines needed to provide orthometric height to the vertices.

Also performed referencing the vertices of RGOG north coast First Order Network of Spain , observation VN2 - VN3 triangle - VS8 (Figure 5) and the extent of local control networks of each signal. In one of these vertices VN2 control network established Doppler station [11] with a JMR1 -A receptor and meteorological equipment. Treated observations by the method of Isolated Point (AP) with Precision Ephemeris (PE) provided by the DMA and transferred to VN2 results, it was possible to calculate the coordinates of this season on the Geodetic Reference System 1980 (SGR 80) by applying the transformation formulas SGR NSWC 9Z to 80 , adopting this as the fundamental vertex RGOG .

In addition to the geological characteristics of the land, for the election of the settlements was necessary to keep two conditions imposed by the limitations of measuring instruments:

- separations between adjacent vertices measurable dimensions not exceeding by geodimeters laser.
- similar altitudes for all vertices , avoiding visual very low over the sea and eliminating those settlements that despite their situation very dominant, heavily discrepasen average altitude or whose geometric leveling becomes impossible.

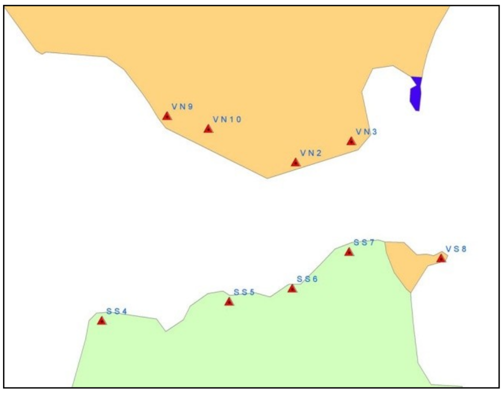

Figure 1. 1984 work configuration

Both reasons besides preclude the optical link between the vertices SS7 and dispense VS8 vertex advised massif Jebel Musa, of impossible access to precise leveling and at an altitude of 840 m, so was resigned to a character assistant.

In conclusion, the 1984 campaign is a Red Classic High Precision formed by four plus four Moroccan Spanish vertices in need of intervisibility and near-shore forcing the difficulty of regular geometry, settlements located in stable but with a network of local control.

Thus, in 1984, the year that takes place long observing campaign RGOG total, shows the difficulty of obtaining a regular geometry, increasing markedly the dimensions of the sides over the sea from the eastern to the western . Given the appalling weather conditions in the area are reduced by 20% for the observation time , where strong winds blow constantly from east to west at high speeds .

It was a small local network around each corner to check that there was no relative displacements between vertices.

The campaign lasted for three months and the means employed to measure directions was Theodolites Wild T-3 and distances, laser Range Master III geodimeters. In International Conference 1987 Vancouver Geodesy was recognized worldwide that the longer distances geodimeter measures were made in the 1984 campaign. The observation method employed was Schreiber [12].

The signage was very refined geodesic structure. Covers were placed on the vertices to minimize the effects of weather and vandalism. The point was clearly marked on the vertical pillar so that it could recover in the event of damage or loss.

Distances are measured at multiple reflection prisms, placed in protective shops .

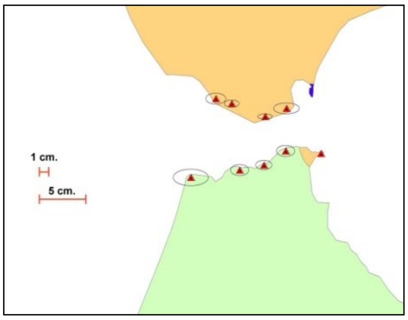

Figure 2 Error ellipses. 1984 works

RGOG84 observation resulted in geodetic coordinates on the ellipsoid SGR80 associated with error ellipses major axis in the range 3 to 95 cm probability (Figure 2).

III. 1989 WORKS. GEODETIC CAMPAIGN FOR THE CONSTRUCTION OF PHYSICAL MAP OF THE STRAIT OF GIBRALTAR 1:100,000

A few years later, when the IGN already had the first GPS equipment arrived in Spain, it was decided to make another campaign using new space techniques.

The First International Seminar on Applied Geodesy the Strait of Gibraltar (Madrid , 8-10 April 1989) , organized by SECEG , recommended in the concluding session RGOG expanding , north and south, the total observation , if possible within the same year 1989 , and the periodic repetition of the same for the control of possible tectonic movements .

The campaign of 1989, to be done with the first GPS equipment arrived in Spain, introduced the innovation to increase the number of vertices of the previous year other than those at locations forced by the needs of intervisibility. The need for proximity of the vertices of the coast RGOG (only way to get laser geodimeters measurable sides) disappeared and there was RGOG extension to the North and the South in search of more stable geologically settlements, thus constituting RGOGA.

Figure 3 1989 works configuration

For reasons of timing, the DCM [13] failed to carry out the construction of their new signals, so that GPS Campaign RGOGA 89 was reduced to four and eleven Spanish Moroccan vertices (Figure 3).

The Navstar constellation was incomplete, testing period and, therefore, had to be found observation windows with four or more satellites above the horizon. Sessions were scheduled 4 hours, over 10 days with 15 second interval of times. The window appeared more favorable night (reducing the possible effects of the ionosphere on a single frequency observations) . The calculation programs available broadcast ephemeris processed. Despite this demonstrated the advantages of this new technology compared to high precision laser measures.

Started the campaign schedule, its development was hampered almost from the beginning by the powerful storm that broke out in the area, to the point that in the month of November was declared "red alert" for the services Civil Protection . As such unfavorable weather undoubtedly affected the observations, since some of the stations were almost inaccessible to heavy rains destroying access roads to them, so some sessions had to be suppressed and other cut in duration.

The calculation of GPS observations was rather more complicated than usual because of the simultaneous use of equipment and two-frequency, forcing to make separate determinations of baselines with L1 frequency and ionosphere - free.

Bearing in mind that no used ephemeris accuracy and meteorological difficulties encountered, the quality of the results obtained from the different compensations made on baselines calculated by applying the program GeoLab can say that GPS is an ideal tool for this type of observations with a quality / cost ratio much higher than on conventional observations.

At the time of the measurements with GPS techniques, they were in startup phase, allowing fully investigate the possibilities, advantages and disadvantages of these new techniques compared to conventional GPS, giving the opportunity to the National Geographic Institute and Spain to be one of the leading countries in the world in the use of GPS techniques in various fields and applications in civil engineering in particular.

RGOG89 observation resulted in geodetic coordinates on the ellipsoid SGR80 associated with error ellipses major axis of the order of 2 cm at 95% probability, in the case of calculating each vertex and 1 cm to 95 % probability (Figure 4), for calculating vertex 1984 campaign components.

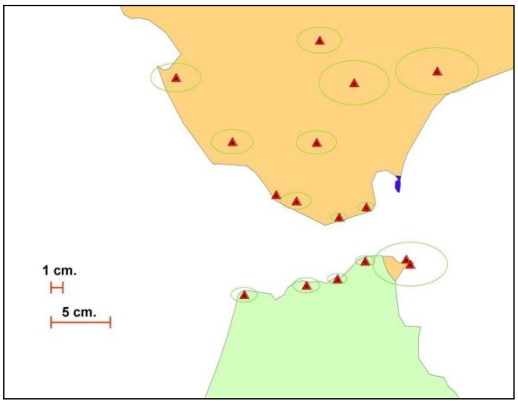

Figure 4 Error ellipses. 1989 works

From the analysis of the ellipses of the campaign, we have seen that the observation was of very good quality. The configuration of the baselines is correct as it provides full coverage of the area. Ellipses increasing in size at those corners farther from the coast, that is, when they are longer baselines. It seems logical due to the limitation and development of the GPS system in 1989, as the observation window in the Strait was small and there were few satellites. Nevertheless substantial improvement is seen in the observation that there GPS 1989 versus 1984 classic watching.

The conclusions are that the campaign was highlighted the superior performance of the use of GPS technology versus conventional observations, especially in an area such adverse climatic characteristics and the accuracy achieved , it can be argued that it is superior to obtained by conventional methods . On the other hand , the time spent ranged from 3 months of the 1984-20 campaign days in 1989 , having also the fact that the vertices Spanish widened five of RGOG (1984) to six further north . Other important advantages are the possibility of bad weather observation and observation without intervisibility.

The quality of the 1989 observation the real possibilities envisioned for accuracy of GPS observations, which were corroborated in the 2004 campaign, when the satellite constellation was complete and GPS receivers were of much better quality .

IV. 2004 WORKS GEODETIC CAMPAIGN FOR CONSTRUCTION PHYSICAL MAP OF THE STRAIT OF GIBRALTAR SCALE 1:25000

After another agreement between the aforementioned Spanish and Moroccan organizations, it was decided the formation of 1:25000 scale map, committing each institution on the completion of its territory.

The features that should meet the said Map were:

- Area to be mapped: the one between the parallels 35 º 42 ' N and 36 º 12' N and meridians 5 º 15 ' W and 6 º 00 ' W.
- Division sheets: the area is divided into 16 sheets (8 North corresponding to South IGN and 8 corresponding to the DC) , whose edges include an arc meridian 7'30 " and parallel arc 11 ' 15".
- Geodetic Reference System : SGR80 .
- Frame of reference: RGEG
- Cartographic representation system : Projection Lambert Conformal Conic Pseudosecante (with the aim of minimizing the linear deformation), with origin at point 35 ° 57'00 " N and 5 ° 37'30 " W of Greenwich. The reduction factor has the value 0.999995266. , Resulting in the standard parallels 55 ° 46'23 "00 and 36 ° 07'36 " north latitude 54.

After the phases of triangulation and restitution made to the IGN and sgraffito commissioned by the company SECEG GEOTEM all work was done based on IHM waiting for the bathymetric survey finalize the Spanish coast .

Today and after more than 30 years , for reasons that are unknown, it has been edited Strait Map scale 1:25000 .

After several years of drought geodesic in the Strait of Gibraltar, in 2004 resumed SECEG collaboration between the Spanish side and the Moroccan SNED. At a meeting of Spanish and Moroccan technicians, we reach the commitment to make the observation for five days in daily sessions of eight hours, and occupying all vertices simultaneously.

This new network configuration includes points not observed in previous campaigns, for what was called RGOG 2004 (Figure 5). Comprising a total of 22 vertices plus four permanent stations, located in San Fernando, Malaga , Ceuta and Rabat. 11 of them in Spain, elected with support from geologists SECEG criteria built for the 1989 and the other 11 in Morocco , built in 2001

The North subnet , ie the vertices Spanish Geodetic Network for Geodynamic Observations (Current RGOG) consists of the five primitive built for the 1984 (VN2 , VN3 , VN9 , VN10 and VS8) , for the five that were added subsequently for the 1989 GPS campaign (Vejer -0039 , Royal -0091 , Carlitos, 5011 , Los Canos -5012 , H -5013 Throat) and as associated with a fiduciary SLR station [16] the vertex San Fernando - 2038. That is, a total of 11 vertices. It also includes three permanent GPS stations on Spanish soil (BAD , SFER , Ceut) . One of them served as a fixed point , Ceut .

As for the points Moroccan soil, they are 11. Also included RABT GPS permanent station (Rabat) , although it is slightly away from the area , is useful because it is a permanent station GPS African plate , where it could also be Ceut station (Ceuta).

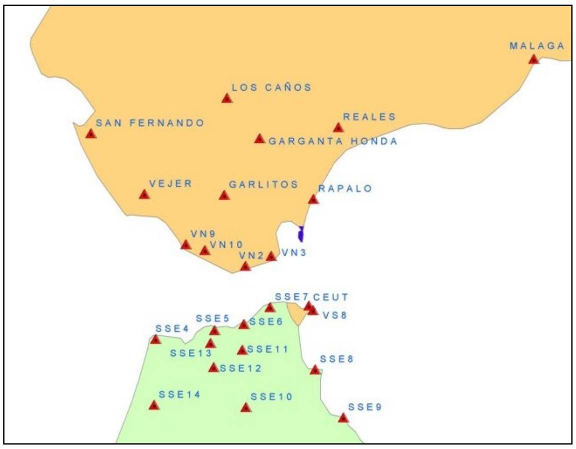

Figure 5 . 2004 works configuration

The observation points non-permanent stations was conducted for five days from September 27, 2004 until October 1, 2004. The observation was simultaneous at all points for eight hours a day . The viewing window changed from day one, whose start was at 11:00 UTC and ended at 19:00 UTC , until the last day with an observation between 7:00 and 15:00 UTC , ahead one hour each day. So he covered the period of 12 hours for all satellites.

The times of observation interval, chosen as optimal and sufficient, was 15 seconds and the elevation mask chosen was 10°. Except the permanent stations and RABT SFER that under its own programming, are 30 seconds and 0°.

Receivers used to simultaneously occupy all vertices were several trademarks, but all capable of observing both code and phase frequencies (L1,L2) and a minimum of 9 channels . Permanent stations used ensure simultaneous reception of up to 12 satellites to have 12 channels. In addition, parking at each station was covered always with the same receiver.

Firstly proceeds to check the quality of the program data tCe using the option of checking the quality of the observations in all observable. This results in the removal of small sections in some of them.

The software used for analysis and final solution has been Bernese version 4.2. with the following strategy: each session was calculated independently and to conclude , in the final process of setting all those sessions have included separate meeting , in turn , the condition of shorter sides .

The resulting calculation gives a set of coordinates for each of the five observation sessions. Comparative study is important , and repeatability between the five different days, which give a good idea of the quality of work .

The observation resulted RGOG 2004 geodetic coordinates with error ellipses major axis of about 4 mm at 95% probability (Figure 6).

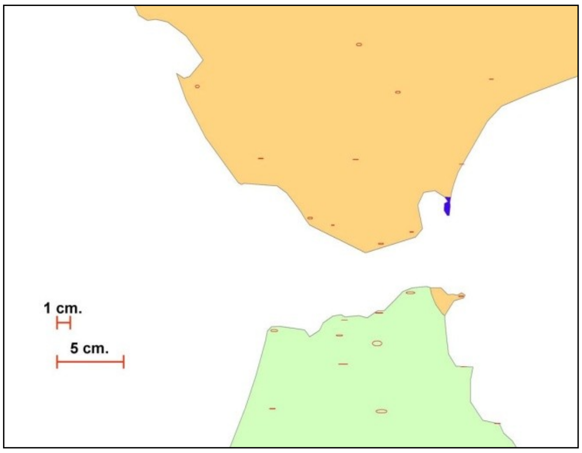

Figure 6 Error ellipses. 2004 works

At the conclusion of the 2004 campaign geodesic can tell from the errors and contrastaciones, that the results are as expected. The observation of eight hours mobile allows clarifications not get much lower than would have been obtained with 24-hour observations. Therefore, the observation method is validated for future campaigns.

As a final result, we show the figures (Figures 7 and 8) showing the vertices of all campaigns and their error ellipses. It can thus make a visual comparison in accuracy is concerned.

Figure 7 Works 84-2004

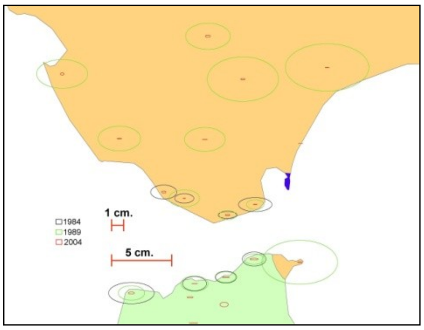

Figure 8 Error ellipses. 1984-2004 works

V. CONCLUSIONS

As conclusions made a comparison chart of all campaigns, which can be perceived clearly and concisely all the features that affected the process of making all campaigns.

TABLE I. WORKS RESUME: 1984, 1989, 2004

CAMPAÑA	1984	1989	2004
Infrastructure access to stations	Good. Built for campaign signs.	Some stations were inaccessible to heavy rains destroying access roads to them.	Easy access to all stations
budget allocation	Good	Part of instruments planned for this season, had to be shipped to Antarctica for use in another project of IGN.	Personal, instruments and means to carry out the campaign.
Staff	Moroccan staff (4 vertices) proved is is not qualified (5 vertices)	The Spanish team extended the previous network of 5-10 vertices. The Moroccan team did not extend its network to 2001.	The network was expanded and consisted of 21 vertices between the two territories. The staff were qualified.
Climatology	Strong wind storms that lengthened the campaign.	Strong winds which considerably affected the observations and infrastructure	No severe wind storms.
Intervisibility between vertices	required	Not required	Not required
signaling	9 vertices constructed in the campaign	All vertices of the campaign (84 and 5).	Spanish territory 11 points + 3 permanent stations. Moroccan territory 11 points in + 1 permanent station.
Signals Maintenance	The team tried to keep following signs for campaigns. The good sign was made by a nail underground. In the absence of (2 of the 4 corners Moroccan) could not be considered durable.	Well maintained for future campaigns.	Well maintained for future campaigns.
instrumental employee	Rangemaster Laser III geodimeters Wild T3 theodolite surveying CERN astrogeodésicos Theodolites DKM 3-A	6 400SLD Trimble (2fr) 2 receivers Trimble ST (1fr). In Spanish Morocco was instrumental as the DCM did not have GPS receivers.	In Spain 11 Trimble 4000SSE Trimble in Morocco in June 4700, 3 and 2 Trimble Leica SR530 400SSI. All frequency doubled.
Instrument status	Good condition	Different types of receptors. Inhomogeneous. Simultaneous use	Good condition

CAMPAÑA	1984	1989	2004
		of equipment and two-frequency.	
Time spent	3 months	20 days	5 days
Observational methods	Classics. Schreiber in all seasons. Doppler observation at a station.	GPS Observation. Due to time some sessions had to be suppressed and other cut. Navstar constellation incomplete. More favorable window at night.	Simultaneous observation at each vertex for 5 days, 8 hours.
Calculation methods	Software using conjugate gradient iterative method.	Post process with precise ephemeris	Post process with precise ephemeris
Calculation ellipsoid	SGR 80	SGR 80	SGR 80

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