The Redefinition of the Geodetic Reference System of Uruguay into SIRGAS frame

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Abstract

In 1908, a systematic geodetic surveys started with cadastral and mapping objetives. Classical operations were carried out along main paralel and meridian chains till 1960's when the Fundamental Geodetic Network was finished.

A common adjustment using the variation coordinates method was performed in 1963, by the US Army Map Service. The whole 1st . Order data available was evaluated giving a mean direction error of 0″.71 and 0″.89 misclosure triangle. The data included 15 bases, 12 astronomical stations and 248 geodetic stations. Hayford Ellipsoid was used and the Yacare Datum was established.

After that, normal geodetic densification of the 1st. Order was performed. The introduction of the EDM in the 1960's, allowed for electronic polygons, getting field operations faster than classical method.

During 1992 the GPS stroke on in our country and quickly remained as the principal tool to get positioning. The 1/50.000 scale cartography was rapidly finished with a couple of submeter receivers.

Two years later, the SGM bought three Ashtech Z-XII receivers, and the Facultad de Ingeniería (Universidad de la República) got Wild-Leica ones. Later on others institutions went into GPS world. The fact allowed Uruguay to participate in SIRGAS Project, and densify the network.

With all this information, a new redefinition of the National Geodetic Reference System was felt needed, in order to adopt a worldwide geodetic and cartography system. GHOST (Geodetic adjustment using Helmert Blocking of Space and Terrestrial data) software

from Geomatics of Canada was used to carry the task out in the frame given by SIRGAS Project. Major steps taken and some results are presented here.

Historical development of the Uruguayan Geodetic Network

The geodesy as a cartographic and positioning tool was born in *1908* with the first systematic surveys in the center of the country. Bamberg and Huetz theodolites and directions methods were used.

In 1914 a triangulation network plan was designed, including four meridian chains and five paralel ones. Clarke ellipsoid was adopted as reference surface.

The Laguna Merim International Chain with Brasil was measured in 1912-1918. In 1917-1919 a survey of the capital of the country was made.The International Río Uruguay Chain with Argentina was observed between 1918 and 1937. In 1946 the first triangulation adjustment was calculated, using Least Squares Method. The complete boundary chain with Brasil first, and the argentinian counterpart later were calculated using 1930 International Ellipsoid as surface reference. In the 1940's a complete Río Negro Valley survey, in the middle of the country, was carried out, with approximately 400 km long. Densification of the geodetic net continues, using better equipments for directions and distances (Wild T4 and T3 theodolites, invar bases and electronics distance meters), until *1961 when the fundamental network planned in 1914 was finished.*

First major adjustment was performed in USA in 1965, using coordinates variation method, involving 248 geodetic station and using the 1930 International Reference Ellipsoid. In 1969 the main geodetic network was included in the South American Datum 69, adding at this time 4 new astronomics stations and 7 geodetic bases in order to improve the net. In 1990 approximately 420 stations have been survey and calculated for the first order. The satellite technology for positioning began in 1993, and Sirgas Project put the net at regional and global level.

SIRGAS Project

Three main geodetic stations (LaPlace stations) were measured with Ashtech ZXII, during a ten days-long campaign in 1995 processing (95/147, 148 and 149 Jdays). At the same time five more stations were observed during three days long with Wild-Leica receivers.

In 1997 a two days campaign was performed (97/116 and 117 Jdays), adding three more stations. Montevideo and Bella Vista stations were used as a link with Sirgas campaign. (Figure 1)

Satellite data processing

Software used for processing GPS data was Bernese version 4.0, developed by Berna University.

GPS data to process comprised two campaigns, observed with both double frecuency/code, Ashtech Z-XII and Leica receivers. 1995 GPS campaign was simultaneous with Sirgas one, using same observation parameters and having eigth stations (three Sirgas), it was processed with 15 º elevation and 30 seconds recording time. 1997 campaign, included five stations measured in two days long, processed at 15 º elevation and 60 seconds recording time.

As baselines distances were ranging from 100-250 km, the pre-processing and processing was developed on modeled observable L3 (ionosphere free linear combination), the files that contain local ionosphere parameters was not necessary be generated. As a manual suggestion was used Saastamoinen troposfere model without meteorological values observed. The receiver phase center correction was applied according file IGS_PHAS.01 .

The strategy to create single diferences files was shortest in both cases.(Figure 2) It means that only number of stations - 1 independent single differences were formed, choosing the shortest paths. The cycle slips automatic detection and correction was made in triple diference, The ambiguities resolution was developed in double diference, solving for 90% of ambiguities in a linear combination L5 (wide-lane). The solved ambiguities were introduced as known values in the final solution.

The final combination of 95 and 97 results were made using coordinates and variance-covariance matrix of coordinates from session/day processings, showing *4 mm maximun difference on the baselines and sigmas less than 3 mm on final cartesian coordinates* Montevideo was used as fixed station. These informations were converted in Ghost input format to integrate in the same adjustment extraterrestrial and terrestrial data. A seven parameters Helmert transformation between Bernese and Ghost GPS software results was made. *Residual less than 3 mm and a RMS of 3 mm was obtained, showing a good agreement between campaigns/software.* An scaled adjustment of both 95 & 97 campaigns in Ghost result on a 1.017 variance factor.

Geodetic Network Adjustment. Results and comments

The final adjustment was made scaling GPS campaign according the preprocessing variance factor obtained (100.7 for 1995 and 108.8 for 1997), resulting on a 1.655 variance factor. *Sirgas stations were included as weighted observed positions* with Sirgas's sigmas.

From this first approximation, a computer program was adapted in order to get geoidal altitudes for each station and improve the Z component. Regional geoidal model developed for Uruguay in 1993, with a thousand of gravimetric stations and GEMT2 model as reference , was used.

Geoidal altitudes were added on the adjustment file later.

Adjustment data is at follows:

* 417 geodetic stations with geoidal altitudes (including 11 GPS stations)
* 2337 horizontal directions
* 66 distances
* 11 astronomic azimuths
* 4 parameters to determine (3 electronic distances and 1 azimuth)
* 1341 normal equations generated.
* 1162 system degrees of freedom
* 0 fixed station
* 3 SIRGAS weighted position equations
* 65 position difference equations

After adjustment a 1.65 variance factor was reached and the maximum horizontal residual was ± 4".

A total of 181 (43.4 %) geodetic stations were classified as First Order, 232 (55.6 %) as Second, 4 as Third and Four Order (1 %).

The weighted contributions of different kind of observations were: directions 92.31 %, distances 3.12 %, azimuths 1.07 %, position difference equations 3.49 %, weighted positions 0.01 %.

Raw azimuths without any reductions, had a maximum residual of ± 1”., mostly of them below of their apriori sigmas.

Distances were classified in 5 groups according the ppm showed (30 up to 3 ppm, 21 3-10 ppm and 15 more than 10-35 ppm). The old invar bases were in first group, meanwhile some electronic ones had to be eliminated due to high residuals, maybe by lack of correct equipment calibration.

Horizontal distortions vectors of the network (Figure 3) due to change of reference system, shown a general direction of 260º and a mean scalar value of 2 m in latitude and -37 m in longitude, with *a maximum of –48 m* in the last one. It is clear the readjustment in longitud caused by GPS observations.

Latitude-longitude standard deviation have values from 0.07-0.44 m, and confidence elipse errors shown a value ranging from 0.2 to 1.2 m for classical observations and some tens of mm for GPS stations (Figure 4).

Conclusions

A major readjustment of the geodetic net was succesfully performed in the Sirgas Frame last July/97. Combination of tridimensional and clasical geodetic observations were possible through the Ghost software use.

A new set of coordinates in ITRF/WGS84, is available to local or international institutions/researches, and mainly for positioning or cartographic use. Clasical stations showed *confidence errors between 0.2-1.2 m and GPS ones, some cm.*

Local cartographic system of reference will change to standard UTM 21 & 22 zones, with WGS84 ellipsoid and coordinates

Further steps will be the development of a more accurate geoidal model introducing some one thousand gravimetric stations and GPS data observed over the levelling net.

Acknowdlegments

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References

Geodetic Survey Data Dictionary. 1987, Ghost documentation. Geomatics of Canada.
Bernese Manual Reference 4.0. 1997 Berna University, Switzerland.

URUGUAYAN GEODETIC NETWORK WITH GEOIDAL MODEL WGS84

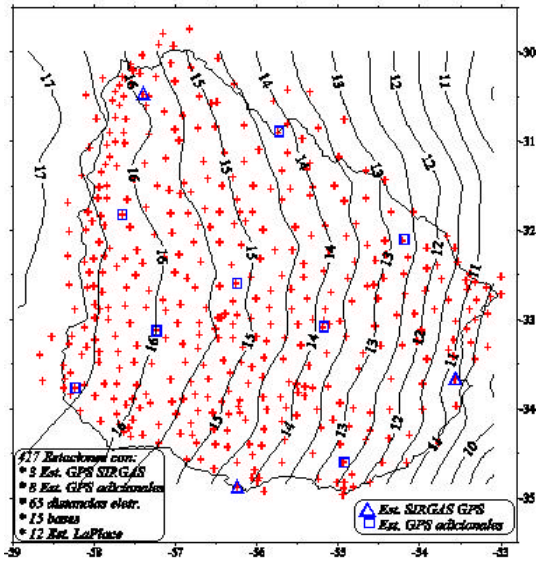

FIGURE 1

GPS LINES MOUNTED FOR PREPROCESSING 95 & 97 Campaigns

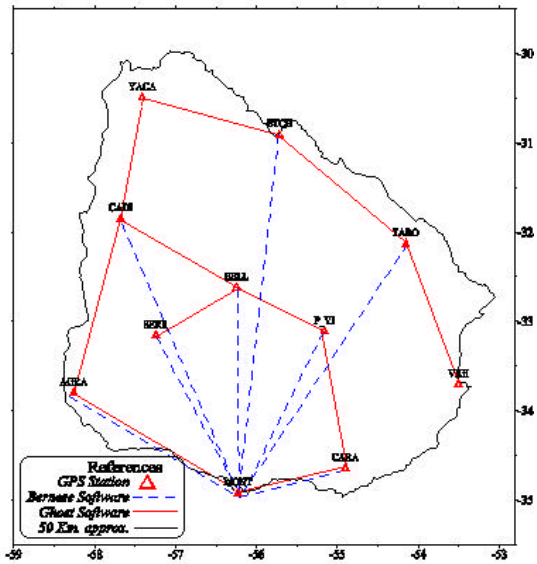

Figure 2

HORIZONTAL VECTORS OF DISTORTIONS YACARE DATUM - GRS 80

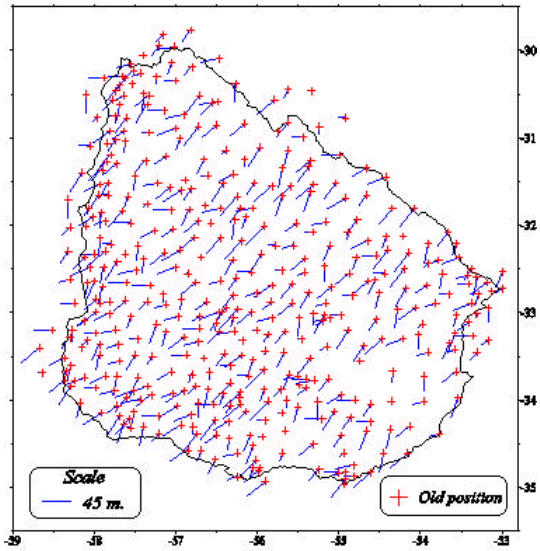

Figure 3

CONFIDENCE ELIPSE ERRORS GPS NETWORK STATIONS

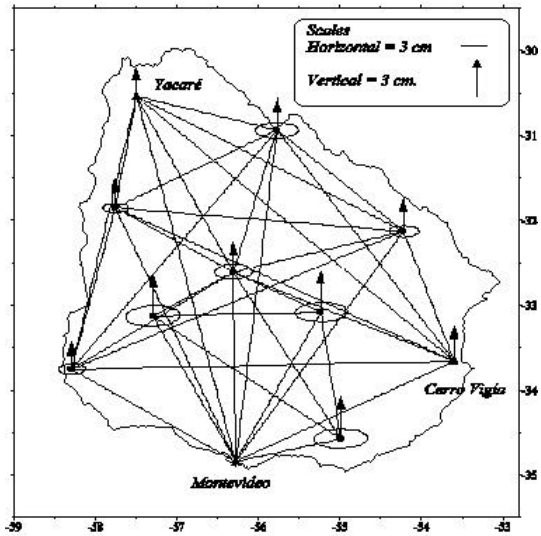

Figure 4