The Integration of Brazilian Geodetic Network into SIRGAS - Preliminary Results -

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Abstract

Prior to the advent of satellite positioning, geodetic systems were based on a mathematic model of the Earth which best fits over a specific area. The surveys were developed for mapping requirements where precision of a meter was considered satisfactory. With the adaptation of space positioning techniques by the scientific community, the geodetic systems assumed a global character where centimetric precision could be obtained by these systems. As a consequence of the new technologies, the change from local datum to geocentric reference systems is required, in order to make the information compatible on an international level. To this end Brazil has been involved in the definition of the South American Geocentric Reference System (SIRGAS), whose purpose is to establish a geodetic system for the whole of South America. Brazil will complete the next step to accomplish this change.

The integration of Brazilian Geodetic Network to SIRGAS will be carried out through a simultaneous adjustment of the network using the software *Geodetic Adjustment using Helmert Blocking of Space and Terrestrial data* (GHOST). In the adjustment, the GRS80 ellipsoid will be adopted and all Brazilian Network will be constrained by 11 SIRGAS stations within the national area. Terrestrial and spatial data will be combined to generate coordinates for about 5000 stations. Some comparison studies about geoid model quantities to be adopted in the adjustment will be presented as well as some preliminary adjustment results.

1. Introduction

Being responsible for geodesy and mapping in Brazil, the Brazilian Institute of Geography and Statistics (IBGE) started the establishment of the Brazilian geodetic network in the 1940's. Since this time, the survey methods and computations have gone through great transformations resulting in better accuracy.

The first global and simultaneous adjustment of Brazilian net was carried out in 1996. The adjustment results showed some distortions between new realization and the original establishment of the South American Datum 1969 (SAD69) [IBGE, 1996].

Nowadays, the application of spatial positioning techniques requires the choice of a geocentric datum as a reference system. With this in aim, Brazil has been an active participant in the SIRGAS Project, through technical cooperation, as a project data center and by applying the project recommendation about the integration of geodetic network into the SIRGAS reference system [SIRGAS, 1997]. The SIRGAS reference system being the most accurate realization of ITRF in South America.

Brazil is a country of continental proportions and has advantage of an existing classical network, therefore the decision to establish a totally new GPS network could not be supported. The choice was the establishment of an Active Control GPS Network, named Brazilian Network for Continuous Monitoring of GPS – RBMC [FORTES, 1997], with 9 stations (the same as the ones occupied during the SIRGAS Project) together with regional and local GPS networks.

For the integration of the Brazilian network into the SIRGAS System, 11 SIRGAS stations within the country were connected to existing geodetic network stations.

Initially an adjustment of all GPS campaigns up to 1998 was performed, the structure thus formed is known as Brazilian GPS Network. The combination of this network with the classical network in a simultaneous adjustment was possible using Helmert Blocking technique and tridimensional modeling. The classical observations have been previously validated and stored in the last adjustment. There are 56 stations in common between classical and GPS networks.
This paper presents the adjustment data used and the methodology, as well as preliminary results of the integration of the Brazilian geodetic network into SIRGAS system.

2. Terrestrial Data

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All observations for the classical network used in the global adjustment in SAD69 carried out in 1996, were also used in the SIRGAS integration and considering that validation and storage steps had been previously developed, nothing was added for this adjustment.

3. Spatial Data

During the period 1973-1991, IBGE made use of the TRANSIT satellite geodetic positioning system, especially in areas where classical fieldwork was difficult, e.g. Amazon region. For station determination the observational method was point positioning. Program GEODOP V along with precise ephemeris was used in postprocessing in order to get better results from DOPPLER observations. For this adjustment only 179 DOPPLER stations, which are coincident with classical stations, were included.

GPS technology was first used in 1991 and our first experience was the international project GIG91. Nowadays, Brazilian GPS network is composed by all GPS campaigns performed until middle of 1998, which involves 655 stations. The processing of these data was not all the same. Until 1994 a total of 187 GPS stations were processed with TRIMVEC Plus (version D), using broadcast ephemeris, this means the results referred to the original definition of WGS84. Later on data was processed with Bernese version 4.0 [ROTHACHER, 1996] with precise ephemeris, meaning the results referred to IRTFyy. In both cases, the station coordinates and its variance-covariance matrix (VCM) were generated in the final processing stage. The mathematical correlations were handled correctly for the data processed with Bernese software. The data of each individual campaign was transformed to GHOST format and a minimum constraint adjustment was performed. The variance factor obtained from this adjustment was used to scale the VCM. For each campaign this procedure was repeated before it was included in the final adjustment file. For SIRGAS integration we have used a total of 1757 GPS baselines.

4. Geoid Undulations and Deflections

The mathematical model of the adjustment software requires that every occupied network station in the horizontal database must have an associated geoid undulation and components of the deflection of the vertical. Previously, deflections were available for only 5% of the network and the last geoid model version for South America was based on geopotential model GEMT2. Considering the facts previously reported, it was decided to generate all the geoid information using two geopotential models, OSU91A and EGM96. Program TSCHERN was used for OSU91 and program F477 was used for EGM96, in the both cases geoid entities were based on the set of fully-normalized spherical harmonic coefficients of gravitational potential to degree and order 360. The values of the geoid components estimated by the two programs were compared to geoid undulations computed from GPS and DOPPLER observations on 316 stations in Brazil. The statistical analysis of this comparison is listed on Table 1a. Although, statistics parameters are very similar, EGM96 was chosen because of smaller differences in maximum and minimum values.

	DOP/GPS X OSU91A	DOP/GPS X EGM96
Average	-0.100	0.260
Std. Dev.	2.01	2.02
Minimum	-6.26	-4.97
Maximum	5.24	4.96

Table 1a – Comparison between observed geoidal heights with GPS/DOPPLER and geopotential models OSU91A and EGM96.

5. SIRGAS Integration

The GHOST software was chosen for the adjustment of the Brazilian geodetic network because of these features:

(1) Use of Helmert Blocking method for partitioning large geodetic networks[BEATTIE, 1987];
(2) Tridimensional mathematical model with fixed heights, allowing the combination of classical and GPS networks.
(Note: Canada used the GHOST software in the NAD83 adjustment)
(3) GHOST software was installed at IBGE on the DOS/PC and UNIX/Hp platforms.

The defined strategy for block partitioning is based on the Cholesky algorithm for normal equation reduction and solution. Appropriate selection of a minimum number of junctions stations between blocks, minimizes the computational effort in the adjustment by isolating zero from non zero areas in the matrix.

As can be seen in figure 2.a, the geodetic network was divided into 8 lower level blocks. Pairs of blocks were joined by a junction level in three different levels. Following is summary of the Terrestrial and Spatial observations that were combined:

Nr. of Directions	:	16913
Nr. of Distances	:	1534
Nr. of Azimuths	:	389
Nr. of Positions Equations	:	179
Nr. of Positions Difference Equations	:	1757
Nr. of Partial Reduced Normal Eqs.	:	12

The unknowns of adjustment include the coordinates of 5381 stations as well as the 15 auxiliary parameters

described bellow:
– 1 orientation for azimuths in FCK5;
– 7 scale parameters for distances of classical network;
– 7 transformation parameters between WGS84 and ITRFyy.

Studies are in progress to decide if it is necessary to transform differents ITRFyy' solutions to SIRGAS epoch (1995.4). The 11 SIRGAS station formed the integration by introducing overly constrained VCM along with the SIRGAS coordinates.

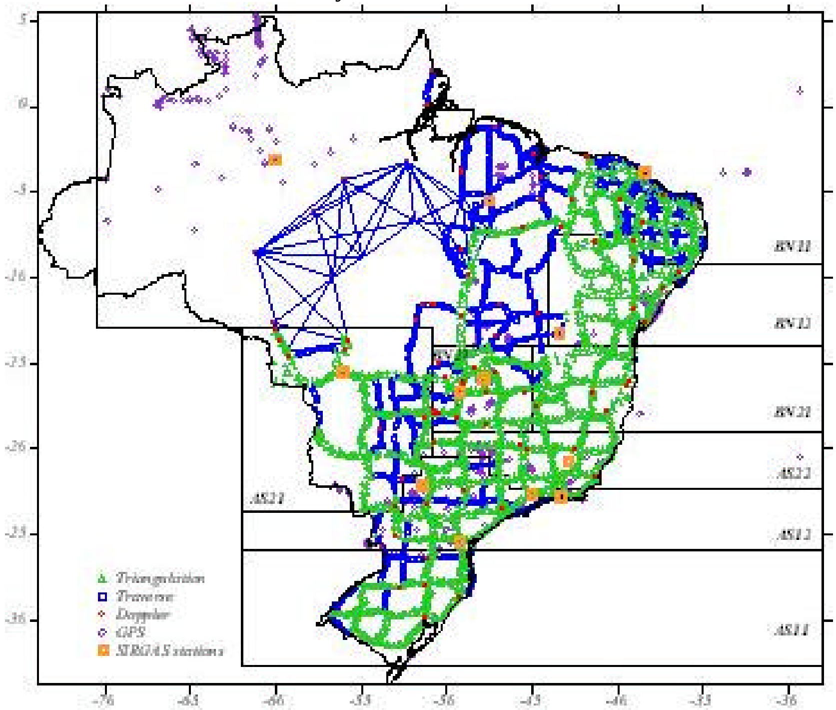
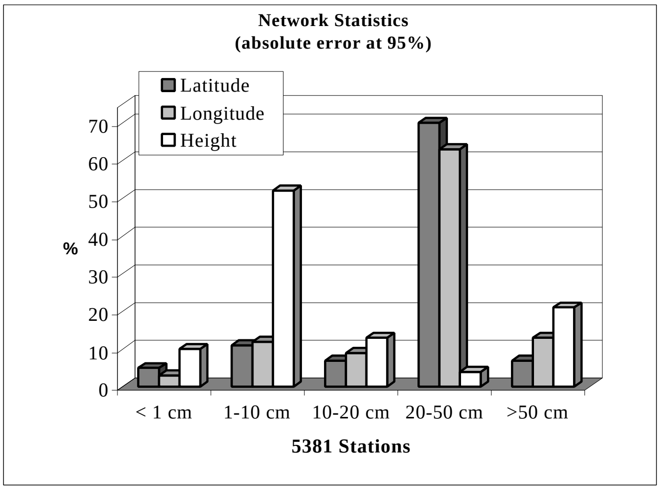
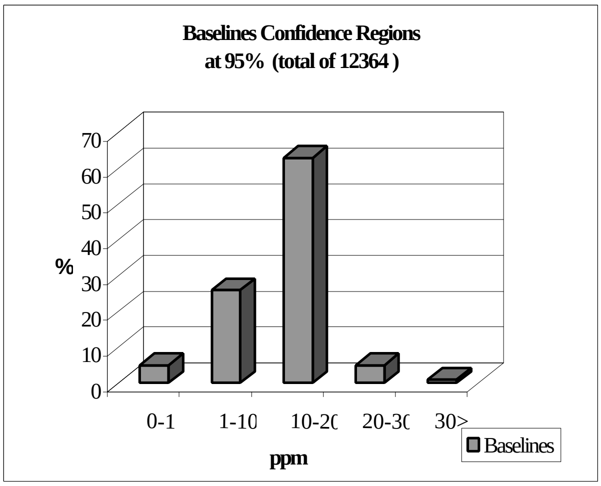


Figure 2.a: Brazilian Geodetic Network and Helmert Block Division





Tables 2.b and 2.c: Absolute and Relative errors at a significance level of 95%.

A significance level of 95% was chosen for accuracy analysis of adjustment for both absolute and relative errors. Tables 2.b and 2.c show that results was as expected for a classical network. For GPS network, 80% of the absolute errors are between 1 to 10 cm. Analyzing 1219 baselines, 60% of the relative errors are between 0.1 to 1 PPM.

6. Relation of SAD-69 to SIRGAS

Established at the end of 1960's, the SAD-69 is the official geodetic datum adopted by Brazil. Considering the different satellite positioning techniques used, it becomes necessary to analyze these differences by solving for transformation parameters between various geocentric reference systems, as NWL-10D, NSWC-

9Z2 and WGS-84. As well the agreement between SAD-69 and SIRGAS is required. In 1997 with SIRGAS results a set of transformation parameters between SAD69 and SIRGAS were computed from 4 stations (Curitiba, Cachoeira Paulista, Brasília, Presidente Prudente), being:

– Translation in x : 67.327 ± 0.036 m
– Translation in y : -3.899 ± 0.036 m
– Translation in z : 38.292 ± 0.036 m

A set of 4 transformation parameters (translations and translations/scale) in each Helmert Block was solved for in the adjustment. Table 3.a shows the values obtained for translations and scale parameters as well as the standard deviations computed in the new adjustment.

Block Code	**Nr. of St.**	**DX (m)**	**Std.Dev.**	**DY (m)**	**Std.Dev.**	**DZ (m)**	**Std.Dev.**	**Scale (ppm)**	**Std.Dev.**	**Variance factor**
AS 11	530	-66.031	0.520	2.879	0.669	-39.073	0.460	-0.266	0.151	0.8
AS 12	824	-65.421	0.356	2.004	0.410	-39.457	0.233	-0.326	0.092	1.6
AS 21	596	-65.607	0.368	2.526	0.505	-39.281	0.199	-0.409	0.102	0.9
AS 22	503	-66.356	0.552	2.984	0.550	-38.866	0.292	-0.051	0.130	0.8
BN 11	1267	-65.208	0.209	2.551	0.192	-38.890	0.043	-0.320	0.045	1.0
BN 12	474	-67.759	0.749	4.091	0.626	-38.530	0.186	-0.030	0.155	0.6
BN 21	408	-66.671	0.847	3.230	0.769	-38.756	0.338	-0.277	0.186	0.6
BN 22	592	-65.785	0.747	2.312	0.830	-39.083	0.330	-0.392	0.182	0.9
TOTAL	5194									

Table 3.a: Transformation parameters between SAD69 and SIRGAS for each Helmert Block area.

7. Conclusion

The results of final adjustment system integrated into SIRGAS will be available to the community at the beginning of 1999. Some studies are being made for adoption of SIRGAS system for mapping. The first step is the estimation of an adequate set of transformation parameters in order to reduce the digital map coordinates to the SIRGAS system in a more automatic fashion. The conversion of analogue maps to digital format is a slow process requiring much work, but efforts are underway to finish this process as soon as possible.

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