Improvements in the Ellipsoidal Heights of the Argentine Reference Frame

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Abstract. In 1997, the classical argentine geodetic system Campo Inchauspe 69 was replaced by POSGAR 94 (POSiciones Geodésicas ARgentinas), a realization of WGS84 through GPS observations. After the SIRGAS reference frame was available, POSGAR was recomputed following the guidelines given by the SIRGAS working group II. The resulting new frame, termed POSGAR 98, realizes the International Terrestrial Reference System (ITRS). The main scope of this paper is to assess the precision and accuracy of the vertical component for both the 94 and 98 frames. The investigation was carried out using several independent GPS data sets. The results show almost randomly distributed errors of up to 1 m for POSGAR 94. The improvement in the heights is more than ten times when POSGAR 98 coordinates are considered.

Keywords. Reference frame, heights, POSGAR, SIRGAS, ITRS.

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1 Introduction

Between 1993 and 1994, two GPS campaigns were carried out in Argentina by Instituto Geográfico Militar (IGM) in co-operation with the University NAVstar Consortuim (UNAVCO). In total 127 points were occupied, including most of the chain intersections of the Inchauspe 69 reference frame (Rodríguez, 1999) and several tide gauges along the South Atlantic coast. In late 1994, the reference frame was computed at FCAG with funding from a nation-wide program for cadastrial modernization. In early 1995 the new reference frame was available and was officially adopted by IGM in mid 1997 (Brunini, 1999). In the meantime, the results of the SIRGAS project provided access to the highly accurate ITRS in Argentina. In August 1996, SIRGAS Working Group II distributed the intended guidelines for all the South American countries to follow in the computation of their reference frames (SIRGAS WGII, 1997). The adoption of these procedures would ensure the compatibility of the South American reference frames up to the SIRGAS95 reference frame accuracy. In this context, a fruitful collaboration between FCAG and DGFI set the necessary conditions for the complete recomputation of POSGAR. The new frame included all the observations involved in the POSGAR 94 computation plus some more. The new data mainly completed the link between POSGAR and SIRGAS frames and strengthened the network in some regions. The new frame, POSGAR 98, was available in late 1998.

POSGAR 94 and 98 coordinates differ mainly because they refer to different terrestrial reference systems: POSGAR 98 realizes the ITRS, whereas POSGAR 94 realizes WGS84. Some differences, specially in the heights, are due to the different methodology used for the computation of both frames. The GPS observations added in the 1998 computation also contribute to the differences, specially in the north-eastern part of the country.

Comparisons are presented between POSGAR 94 and POSGAR 98 and also with respect to the SIRGAS95 reference frame. These show the differences between both frames as regards precision and accuracy, both in the horizontal and vertical components. In addition, comparisons are shown between both frames and a set of high quality regional networks in order to assess the extent to which the conclusions drawn at only a few SIRGAS stations might be extrapolated to the whole network.

2 POSGAR 94 and POSGAR 98

POSGAR 94 consists of 127 points whereas POSGAR 98 is realized by 136; 111 of these points are common to both frames.

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The main observation campaigns were carried out in summer and autumn 1993 and 1994. Several geodetic double frequency Topcon and Trimble receivers were used. The squaring based techniques used in that time to overcome P-code encryption resulted in poor quality L_2 observable as compared to receivers nowadays available on the market. This resulted in a loss of several baselines plus a large number of discarded observations for the POSGAR 94 computation and a difficult and lengthy pre-processing in the POSGAR 98 case.

POSGAR 94 realizes the WGS84 system (DMA, 1987). This was achieved by constraining the WGS84 coordinates of 20 selected points in the final adjustment of the network. This control set included 19 points in common with the CAP (Central Andes Project) network. They were mainly located in the western part of the country from its northern boundary with Bolivia down to the latitude of –42°. One more control point was located near the DORIS beacon at the Rio Grande Astronomical Station and tied to it by a local survey. The coordinates of the CAP points were provided by Dr. R. Smalley. The DORIS coordinates were provided by the French IGN. All coordinates were transformed into WGS84. No epoch transformation was applied.

The computation of the network was done in two steps: firstly, 660 baselines were computed using Ashtech's GPPS software. The so called ionosphere free floating double difference solution was chosen for all the baselines. Secondly, a least squares adjustment of the whole network by the variation of the coordinates method was performed (Usandivaras and Brunini, 1992). In this adjustment all the baselines were included as weighted but uncorrelated pseudo observations and the WGS84 coordinates of the 20 control points were introduced as direct observations with an a priori error of 3 cm in each component (Usandivaras et al., 1995).

POSGAR 98 realizes the ITRS system. The final solution was constrained by the coordinates of 11 SIRGAS control points. Ten sites were located in Argentina, the one remaining being the Santiago IGS station in Chile. The application of the SIRGAS95 control coordinates required several frame and epoch transformations. The velocities used for the epoch reference changes were taken from the NNR NUVEL 1A model for all SIRGAS95 sites except Santiago, were ITRF94 velocities were judged to be more realistic. The weights applied to constrain the control coordinates in the final adjustment were proportional to their errors as published in the SIRGAS95 final solution (SIRGAS Project commitee, 1997). The final results were referred to SIRGAS95-ITRF94 (Boucher et al., 1996), epoch 1995.4.

POSGAR 98 consists of a complete recomputation of all the observations included in the original input. In addition, six more data sets were included: Four baseline sets completed the link to the SIRGAS frame for points which were not part of the original POSGAR network. A fifth campaign, made by IGM in the north-eastern part of the country to strengthen the reference frame was added. Finally, a number of baselines longer than 500 km, from the 1993 campaign, were included in order to strengthen the western part of the network. As a result, POSGAR 98 was established by 136 points from which 111 are common with POSGAR 94. The computation of the reference frame was made by means of the Bernese GPS Sofware V4.0 (Rothacher et al., 1996). The modelled observable was again the ionosphere corrected phase double difference. The best available final GPS ephemerides were used. Tropospheric delay was modelled a priori with the Saastamoinen, (1973) model plus the mapping function by Niell (1996). Besides, zenith delay correction parameters were estimated for each station every two hours. The antenna phase centre variations were modelled using the IGS.01 model (Rothacher and Mader, 1996). More detailed explanations on the establishment of POSGAR 98 can be found in (Moirano et al., 1998).

3 Differences Between Both Frames

Basically, the three characteristics described in the last section, fiducial information, processing algorithms and input data, cause, in decreasing order of importance, the quality difference between both POSGAR reference frames. Consequently, there are significant differences between POSGAR 94 and POSGAR 98 as regards absolute and relative coordinates. A straightforward method to analyze them is by the estimation of a three-parameter similarity transformation between both sets of coordinates. The resulting translations, shown in table 1, amount to less than 40 centimeters and show the systematic differences between both frames. The residuals of the transformation, described in table 2, can mainly be attributed to the errors in the 1994 realization. This is confirmed further ahead in this work comparing both POSGAR frames with other precise networks.

Table 1. Similarity transformations parameters

	3 parameters	7 parameters
DX (m)	0.283	4.739
DY (m)	-0.147	2.905
DZ (m)	0.395	-0.596
k (mm/km)		0.025
Rx (")		0.082
Ry (")		-0.073
Rz (")		0.143

Table 2. Similarity transformation residuals

	3 parameters	7 parameters
σ(N) (m)	±0.075	±0.063
σ(E) (m)	±0.092	±0.102
σ(V) (m)	±0.392	±0.277
Max(N) (m)	0.212 / -0.149	0.204 / -0.136
Max(E) (m)	0.210 / -0.374	0.199 / -0.365
Max(V) (m)	0.870 / -0.800	0.833 / -0.776

The average of these residuals is below 10 centimeter for the horizontal components, but reaches about 40 centimeters for the height. The largest residuals are about 40 centimeters in the horizontal and around 90 centimeters for the height component. Tables 1 and 2 also show that the estimation of a 7 parameter similarity transformation does not improve the agreement of both frames significantly.

The differences in the relative coordinates between points common to both frames were evaluated by computing and comparing only the shortest possible baseline from each point in the network. The average of these differences was below 10 centimeter for the horizontal component increasing to about 35 centimeters for the ellipsoidal height. The largest residuals were below 30 centimeters for horizontal but for the vertical component some differences were in the order of 1 meter. Figure 1 shows these differences. The baselines considered were sorted according to their length.

To assess the quality of both frames, four independent GPS networks covering different regions of the country were used. The computation procedures were in all four cases analogous to those applied for the POSGAR 98 frame. The measurements were made with similar receivers to those used in the SIRGAS95 campaign. The first network used was the SIRGAS frame. The number of sites was 11, including six POSGAR-SIRGAS points, the remaining five being the result of precise local POSGAR-SIRGAS linking GPS surveys. This test network spans the whole country. The second network, named here CAP, included ten points distributed mainly in the north-western and north-central part of the country. The third network, termed PASMA comprises nineteen sites located in the north-west. Finally, the fourth network has five points distributed in the Neuquen province. Similarity transformations between every network and both POSGAR frames were estimated. The computed transformation parameters were assumed to remove the systematic biases between the compared networks. Thus, the residuals show the relative inconsistencies between the networks. Figure 2 shows the RMS of the residuals for the different networks considered. Vertically striped bars are used for POSGAR 94 and dotted bars indicate comparisons with POSGAR 98. The numbers above the pairs of RMS values indicate the POSGAR 94 to POSGAR 98 residual RMS ratio for a given test network. The left hand side of figure 2 describes the residuals for the horizontal components whereas the right hand side summarises the residuals for the height. The network are sorted on the horizontal axis in order of

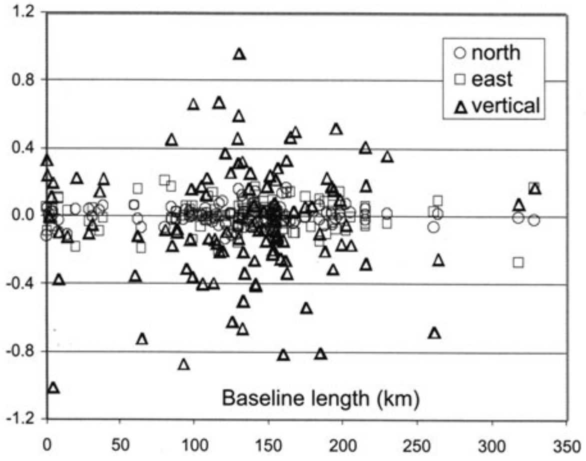

Fig. 1 Differences in meters between the components of the shortest baseline from each point [m]

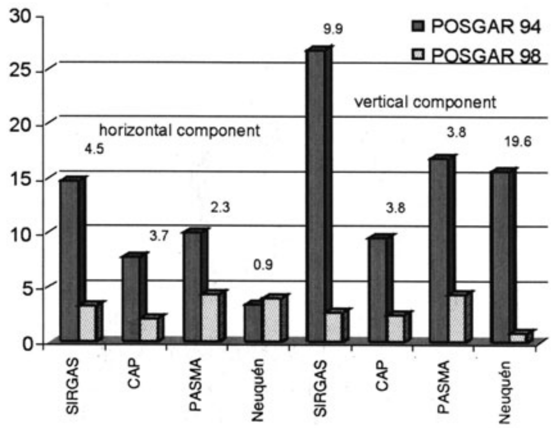

Fig. 2 Agreement of POSGAR 94 and POSGAR 98 with four examples of high quality regional networks [cm]

decreasing size. The agreement between the four networks considered and POSGAR 98 is always below 5 centimeters for both, horizontal and vertical components. When POSGAR 94 is considered the situation gets significantly worse, especially for the heights. The horizontal components are worse by a factor that goes from near 1 to 5 times, increasing with the size of the network. For the heights, the agreement of POSGAR 94 with the test networks is worse by a factor of up to 20 times. This behaviour of the heights does not appear to be related to the size of the network.

4 Accuracy of Heights for POSGAR98

Ellipsoidal heights in POSGAR 98 are highly consistent with the SIRGAS95 and ITRF94 reference frames. This is true for the control points that established the reference frame as shown in figure 2 for the comparison between POSGAR 98 free solution and SIRGAS where an agreement better than 4 cm is seen. Figure 2 however also shows that other points in the network also show the same level of agreement with independently measured and computed networks. In fact, the agreement of POSGAR 98 with all test networks shows a steady level remaining below 4 cm for all cases. This might indicate the accuracy of the ellipsoidal heights for the POSGAR 98 reference frame to be in the order of a few centimeters.

5 Conclusions

The results shown in the preceding section indicate significant improvements on both, accuracy and precision of POSGAR 98 reference frame as compared with POSGAR 94. This is particularly true for the height component, which has been improved by a factor shown to be larger than one order of magnitude. Large and randomly distributed errors in the vertical coordinates of the POSGAR 94 frame were corrected in the new realization. Moreover, POSGAR 98 refers to SIRGAS95-ITRF94 realization of ITRS within a few centimetres. This ensures the compatibility of this new reference frame with all the national geodetic networks in South America established in the framework of the SIRGAS project. These facts should be seriously taken into account at present times when discussions are on course towards the establishment of a new vertical reference system for Argentina, a task which is being done under the management of the SIRGAS project Working Group III.

Finally, it is considered relevant to mention that the development of the experience for the establishment and maintenance of modern high precision geodetic reference frames in the South American countries should be considered as one of the most important outcomes of the SIRGAS project. In the particular case of Argentina this was possible thanks to the assistance of DGFI.

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