SIRGAS Analysis Centre at DGFI
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1. Introduction

The present realisation of SIRGAS is a network of more than 230 continuously operating stations covering Latin America and The Caribbean. This so-called SIRGAS-CON network is weekly processed to generate

a) loosely constrained solutions of station positions for further combinations of the network (i.e. for the computation of multi-year solutions), and
b) weekly station positions aligned to the ITRF.

Due to the large number of stations, the analysis strategy of SIRGAS-CON is based on the combination of individual solutions including different clusters of stations (Brunini et al. 2010). For this purpose, the SIRGAS-CON network is divided in (Figure 1):

a) One core network (SIRGAS-CON-C) with about 110 stations distributed over the whole continent, and
b) different densification sub-networks (SIRGAS-CON-D) distributed regionally on the northern, middle, and southern part of the continent.

These sub-networks (i.e. clusters) are individually processed by the SIRGAS Processing Centres: the core network is computed by DGFI, the other sub-networks by the SIRGAS Local Processing Centres: CIMA (Argentina), IBGE (Brazil), IGAC (Colombia), IGM-Ecuador, LGFS-LUZ (Venezuela), and SGM-Uruguay. The weekly combination of the individual solutions is carried out by the SIRGAS Combination Centres: DGFI and IBGE. The distribution of the SIRGAS-CON stations within the individual clusters guarantees that each station is included in three solutions.

This operational infrastructure is possible thanks to the active participation of many Latin American and Caribbean institutions, who not only make available the measurements of their stations, but also are hosting SIRGAS Analysis Centres in charge of processing the observational data on a routine basis.

As responsible for the IGS Regional Network Associate Analysis Centre for SIRGAS (IGS RNAAC SIR, Seemüller and Drewes 2008), DGFI has to deliver loosely constrained weekly solutions for the SIRGAS-CON network to the IGS (International GNSS Service). These solutions are combined together with those generated by the other IGS Global and Regional Analysis Centres to form the IGS polyhedron. The processing of the SIRGAS-CON network in the frame of the IGS RNAAC SIR also includes the computation of weekly coordinate solutions aligned to the ITRF and cumulative (multi-year) position and velocity solutions for estimating the kinematics of the network. Until 31 August 2008 (GPS week 1495), DGFI processed the entire SIRGAS-CON network in one block. Afterwards, with the introduction of the core network and the densification sub-networks within SIRGAS-CON, as well as the installation of SIRGAS Processing Centres under the responsibility of Latin American institutions, DGFI is now responsible for

a) Processing the SIRGAS-CON-C core network,
b) combining this core network with the densification sub-networks (SIRGAS-CON-D), and
c) making available the official SIRGAS products, i.e.:
   - loosely constrained weekly solutions for further combinations of the network (e.g. integration into the IGS polyhedron, computation of cumulative solutions, etc.)
   - weekly solutions aligned to the ITRF for users in Latin America, and
   - multi-year solutions (positions + velocities) for applications requiring coordinate time-dependence.

According to this, the present report summarizes the activities carried out by DGFI as SIRGAS Processing und Combination Centre between June 28, 2009 (GPS week 1538) and September 25, 2010 (GPS week 1602). The determination of the latest multi-year solution (SIR10P01) for the SIRGAS-CON network is described in Seemüller et al. (2010).

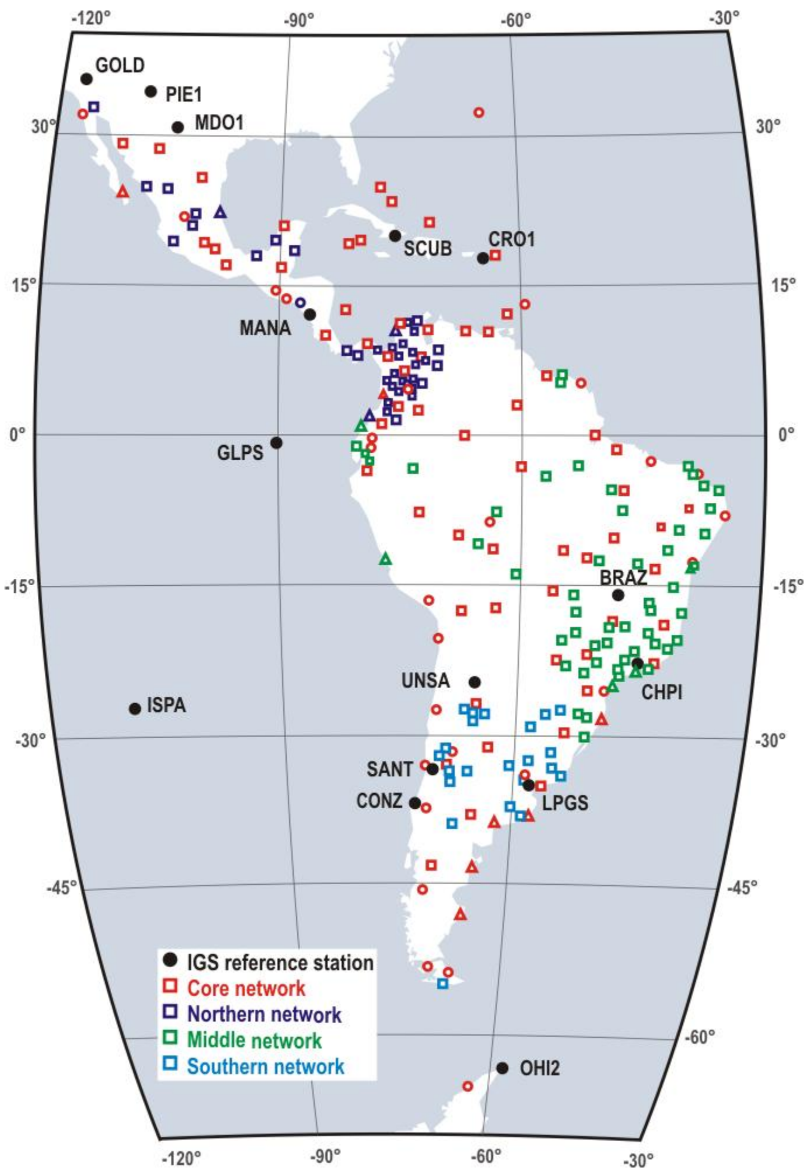


Figure 1. *SIRGAS-CON-C core and SIRGAS-CON-D densification sub-networks (status October 2010).*

2. Routine analysis of the SIRGAS-CON-C core network

The SIRGAS-CON-C core network (Figure 1) is composed by 111 stations homogeneously distributed over Latin America and the Caribbean. The processing strategy is based on the double difference approach using the Bernese Software V. 5.0 (Dach et al. 2007) and follows the IGS and SIRGAS guidelines. The main characteristics are:

a) Elevation mask and data sampling rate are set to 3° and 30 s, respectively.

b) Absolute calibration values for the antenna phase centre corrections published by the IGS are applied (http://igscb.jpl.nasa.gov/igscb/station/general/pcv_archive/).

c) Satellite orbits, satellite clock offsets, and Earth orientation parameters are fixed to the combined IGS weekly solutions (Dow et al. 2009, http://igscb.jpl.nasa.gov/igscb/product/).

d) Phase ambiguities for L1 and L2 are solved by applying the quasi ionosphere free (QIF) strategy of the Bernese software (Dach et al. 2007).

e) Periodic site movements due to ocean tide loading are modelled according to the FES2004 ocean tide model (Letellier 2004). The corresponding values are provided by M.S. Bos and H.-G. Scherneck at http://129.16.208.24/loading/.

f) The Niell (1996) dry mapping function is applied to map the a priori zenith delay (~ dry part), which is modelled using the Saastamoinen model (1973). The wet part of the zenith delay is estimated at a 2 hours interval within the network adjustment and it is mapped using the Niell wet mapping function.

g) Daily free normal equations are computed by applying the double differences strategy (Bernese Software 5.0, Dach et al. 2007). The baselines are created taking into account the maximum number of common observations for the associated stations.

h) Daily free normal equations are combined for computing a loosely constrained weekly solution for station positions (all station coordinates are loosely constrained to ±1 m).

i) Stations with large residuals in the weekly combination (more than 20 mm in the N-E component, and more than 30 mm in the height component) are reduced from the normal equations. Steps (h) and (i) are iterative. Figure 2 shows RMS values for the daily coordinate repeatability in the weekly solutions.

j) The DGFI loosely constrained solutions are made available to be combined with the corresponding solutions delivered by the other SIRGAS Processing Centres. They are given in SINEX format and are identified with the name DGF*wwww*7.SNX: DGF stands for DGFI, *wwww* for the GPS week, and 7 for including the seven days of the week. They are available at ftp://ftp.sirgas.org/pub/gps/SIRGAS/.

The 111 core stations are not always included in all weeks because some of them are at present inactive or the corresponding RINEX are not opportunely available (between the two following weeks after observation). Figure 3 shows the number of stations processed in the weekly solutions between June 28, 2009 (GPS week 1538) and September 25, 2010 (GPS week 1602).

To evaluate the quality of the DGFI weekly solutions for the SIRGAS-CON-C core network, the following steps are carried out:

a) Each loosely constrained weekly solution is aligned to the IGS reference frame (at present the IGS05, once IGS had introduced the new ITRF2008 as reference frame, we will also use it). In this case, the geodetic datum is defined by constraining the IGS reference stations (Figure 1) to their positions computed within the IGS weekly combinations (igs*yy*P*wwww*.snx). To minimize network distortions, the reference coordinates are introduced with a weight inversely proportional to ±1E-04 m. The obtained standard deviation is understood as the formal error of the station positions within the weekly solutions.

b) Residual time series of station positions are computed. For this purpose, the loosely constrained weekly solutions are aligned to the latest SIRGAS multi-year solution (SIR10P01, Seemüller et al. 2010) using a 7-parameter similarity transformation. Then, coordinate time series are generated for each station and mean RMS values are derived from the weekly residuals. This procedure is helpful to identify outliers or jumps of the stations that may cause network deformations within the weekly solutions. Changes caused by the earthquakes of Chile (on 2010-02-27) and Mexico (2010-04-04) (Sánchez et al. 2010b) are excluded of this analysis.

According to this, the mean formal error of the weekly solutions is estimated in ±1,6 mm. The weekly repeatability (mean RMS values from residual time series) for the entire period (65 weeks) is N = 1,5 mm, E = 2,2 mm, and h = 4,4 mm.

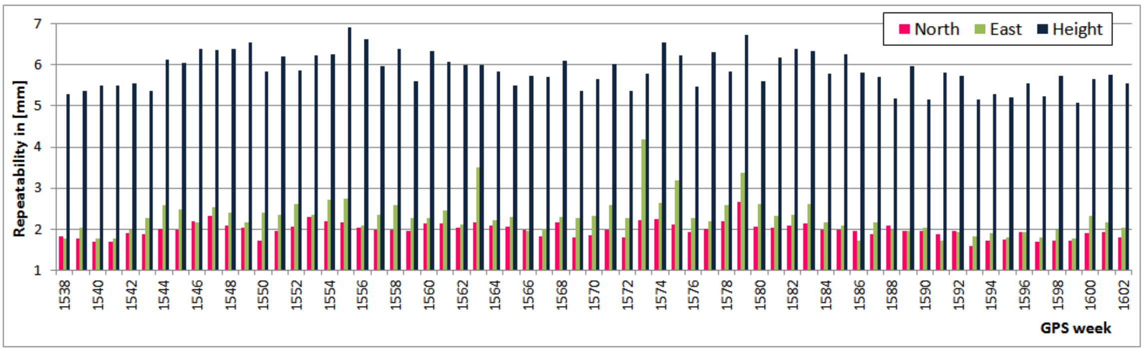


Figure 2. *Daily coordinate repeatability in the DGFI loosely constrained weekly solutions for the SIRGAS-CON-C core network. Mean RMS values are: North: 2,0 mm, East: 2,3 mm, height: 5,9 mm.*

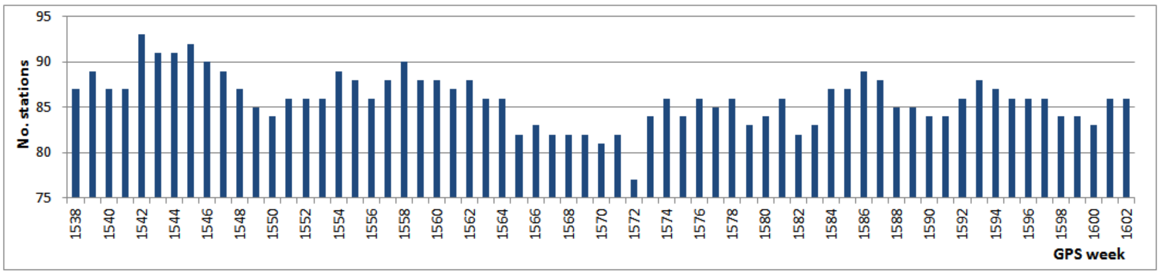
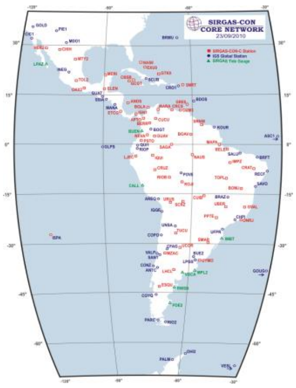
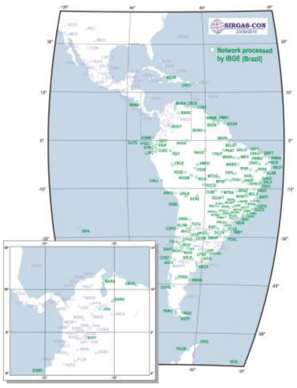


Figure 3. *Number of stations included in the weekly solutions processed by DGFI for the SIRGAS-CON-C core network.*

3. Combination of the individual solutions for the SIRGAS-CON network

The SIRGAS Processing Centres deliver loosely constrained weekly solutions for different clusters of SIRGAS-CON stations (Table 1). In these solutions, satellite orbits, satellite clock offsets, and Earth orientation parameters are fixed to the final weekly IGS values (Dow et al. 2009) and coordinates for all sites are loosely constrained to ±1 m. These individual contributions are integrated in a unified solution by the SIRGAS Combination Centres: DGFI and IBGE. The DGFI combination strategy corresponds to (Sánchez et al. 2010a):

Table 1. *SIRGAS processing centres and distribution of the SIRGAS-CON stations in different clusters.*

Official Processing Centre: **CIMA (CIM)**	Official Processing Centre: **DGFI (DGF)**	Official Processing Centre: **IBGE (IBE)**
		
Centro de Procesamiento Ingeniería-Mendoza-Argentina, Universidad Nacional de Cuyo, Argentina.	Deutsches Geodätisches Forschungsintitut, Germany.	Instituto Brasileiro de Geografia e Estatistica, Brazil.
Southern network and selected sites of the middle network, 110 stations, of them 99 active. GPS weeks: 1538-1602.	Core network, 111 stations, of them 88 active. GPS weeks: 1538-1602.	Middle network and selected sites of the southern network, 141 stations, of them 130 active. GPS weeks: 1538-1602.
Official Processing Centre: **IGAC (IGA)**	Official Processing Centre: **IGM-Ec (ECU)**	Official Processing Centre: **LUZ (LUZ)**
		
Instituto Geográfico Agustín Codazzi, Colombia.	Instituto Geográfico Militar, Ecuador.	Laboratorio de Geodesia Física y Satelital, Universidad del Zulia, Venezuela.
Northern network, 111 stations, of them 82 active. GPS weeks: 1538-1602.	Selected sites of the northern and middle networks, 74 stations of them 63 active. GPS weeks: 1538-1602.	Northern network, 111 stations of them 82 active. GPS weeks: 1538-1602.
Official Processing Centre: **SGM-Uy (URY)**	Experimental Processing Centre: **INEGI (INE)**	Experimental Processing Centre: **IGN-Ar (GNA)**
		
Servicio Geográfico Militar, Uruguay.	Instituto Nacional de Estadística y Geografía, México.	Instituto Geográfico Nacional, Argentina.
Southern network and selected sited of the middle network, 74 stations, of them 68 active. GPS weeks: 1538-1602.	Selected sites of the northern network, 26 stations, of them 25 active. GPS weeks: 1563-1602.	Southern network, 60 stations, of them 54 active. GPS weeks: 1550-1602.

a) Individual solutions are reviewed/corrected for possible format problems, station inconsistencies, utilization of erroneous equipment, etc.

b) Constraints included in the delivered normal equations are removed. In this way, unconstrained (condition free, non-deformed) normal equations with correct station information are available for combination.

c) Individual normal equations are separately solved with respect to the same IGS stations used for the GPS orbit computation (the so-called IGS reference frame). In this case, the IGS reference station positions (Figure 1) are constrained to the IGS weekly coordinates (igs*yy*P*wwww*.snx). For the analysed period (GPS weeks 1538 – 1602), the IGS05 reference frame is applied. Once the IGS had included the new ITRF2008 as reference frame, we will use it, too.

d) Station positions obtained in (c) for each cluster are compared with the IGS weekly values and with each other to identify possible outliers.

e) Stations with large residuals (more than 10 mm in the north or east components, and more than 20 mm in the height component) are reduced from the normal equations. Steps (c), (d), and (e) are iterative.

f) Variances obtained in the final computation of step (c) are analysed to estimate scaling factors for relative weighting of the individual solutions (see below item 5.1.5).

g) Once inconsistencies and outliers are reduced from the individual free normal equations, a combination for a loosely constrained weekly solution for station positions (all station coordinates constrained to ±1 m) is computed. This solution is submitted to IGS for the global polyhedron and stored to be included in the next multi-year solution of the SIRGAS reference frame.

h) Finally, a weekly solution aligned to the ITRF is computed. As in step (c), the geodetic datum is defined by constraining the coordinates of the IGS reference stations (Figure 1) to their positions computed within the IGS weekly combinations (igs*yy*P*wwww*.snx). To minimize network distortions, the reference coordinates are introduced with a weight inversely proportional to ±1E-04 m. This solution provides the final weekly positions for the SIRGAS-CON stations.

i) The accumulation and solution of the normal equations are carried out with the Bernese GPS Software V.5.0 (Dach et al. 2007).

j) Resulting files of these procedure are:

   SIR*wwww*7.SNX: SINEX file of the loosely constrained weekly combination.
   SIR*wwww*7.SUM: Report of weekly combination.
   siryyP*wwww*.snx: SINEX file for the weekly combination aligned to the IGS reference frame.
   siryyP*wwww*.crd: Final SIRGAS-CON station positions for week *wwww*.

   The loosely constrained combinations as well as the weekly SIRGAS-CON coordinates are available at ftp://ftp.sirgas.org/pub/gps/SIRGAS/ or at www.sirgas.org.

Before the weekly combinations computed by DGFI for the SIRGAS-CON network are published or made available for users, a quality control is carried out to guarantee consistency and reliability of the SIRGAS products. This quality control is described in Section 5 of this Report.

4. Evaluation of the SIRGAS Experimental Processing Centres by DGFI

SIRGAS promotes the installation of more Processing Centres hosted by Latin American institutions because

a) the national reference frames include an increasing number of continuously operating GNSS stations and each country shall be able to process the data of its own stations, and

b) the required redundancy in the analysis of the SIRGAS-CON network (each station included in three individual solutions) must be guaranteed.

In this frame, institutions interested to install a SIRGAS Processing Centre shall pass a test period of (at least) one year. In this period, they have to align their processing strategies to the SIRGAS guidelines and satisfy the punctuality on delivering their weekly solutions. DGFI as a SIRGAS Combination Centre is responsible for evaluating the weekly solutions delivered by the SIRGAS Experimental Processing Centres, analysing not only their accuracy and compatibility with the official SIRGAS products, but also reviewing if operational aspects related with the punctuality on making available their SINEX files, the observance of the SIRGAS guidelines, accordance with the log files information, etc. are fulfilled. The evaluation of the solutions produced by the SIRGAS Experimental Processing Centres is carried out following the same procedure applied for the SIRGAS Official Processing Centres. In this opportunity, the Experimental Processing Centres hosted by the Instituto Geográfico Nacional (IGN) of Argentina and the Instituto Nacional de Estadística y Geografía (INEGI) of Mexico are considered. Details of evaluation and results are presented in the following Section.

5. Quality control carried out by DGFI in the weekly combinations for the SIRGAS-CON network

The generation of the weekly SIRGAS-CON products (i.e. loosely constrained combinations and station positions aligned to the IGS reference frame) at DGFI includes a quality control at two levels: Firstly, the individual solutions delivered by the SIRGAS Processing Centres (official and experimental) are analysed to establish their quality and consistency. This includes a survey about date of delivering, processed stations, log file observance, etc. Once the individual solutions are reviewed and free of inconsistencies, their combination is carried out by applying the procedure summarized in Section 3. Then, the second quality control concentrates on the results of this combination. Here, the main objective is to ascertain the accuracy and reliability of the weekly solutions for the entire SIRGAS-CON network. It should be mentioned that the DGFI combinations made available for users include the solutions provided by the SIRGAS Official Processing Centres only. Combinations including solutions delivered by the SIRGAS Experimental Processing Centres are for internal control. The procedures, analysis, and conclusions contained in this report are based on the weekly solutions summarized in Table 1.

5.1 Evaluation of individual solutions

5.1.1. Punctuality on delivering weekly solutions

According to the SIRGAS 2008 Resolutions (Brunini, Sánchez 2008), the SIRGAS Processing Centres shall deliver to the IGS RNAAC SIR (i.e DGFI) their weekly solutions in the third week after observation. In the same way, the SIRGAS Combination Centres shall report their results in the fourth week after observation. In general, these punctuality requirements are satisfied. Figure 4 shows the corresponding statistics classified in three main timetables: on time (solutions delivered according to the SIRGAS agreement), delayed (solutions delivered during the following week after deadline), and late (solutions delivered after two o more weeks after deadline).

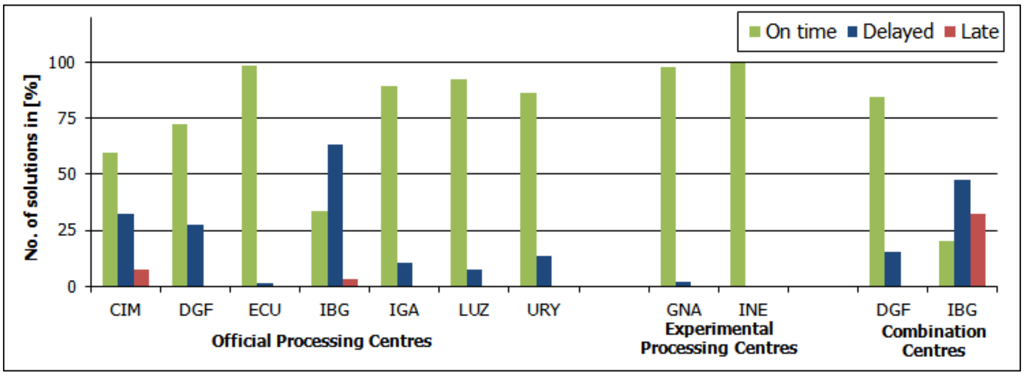


Figure 4. *Percentage of solutions delivered on time, delayed, or late by the SIRGAS Analysis Centres (GPS weeks 1538 to 1602).*

5.1.2 <u>Compatibility with log files</u>

The SIRGAS-CON stations included in the individual solutions shall be identified by the 4-character code together with the IERS domes number and the station information (receiver, antenna, height of the antenna, etc.) shall precisely correspond to the station information contained in the log files. In general, all Processing Centres satisfy these requirements. The few inconsistencies found under this topic were appropriately corrected.

5.1.3 <u>Identification of outliers</u>

To avoid deformations in the combined network, those stations with very large outliers (more than 50 mm in any component) are reduced from the weekly normal equations. The identification of these outliers is carried out by transforming the contributing normal equations to identical a-priori values and generating time series for station coordinates. The loosely constrained weekly solutions delivered by each Processing Centre are aligned to the IGS reference frame by constraining the positions of the IGS05 stations to the values determined within the IGS weekly solutions (Dow et al. 2009). After that, coordinate time series are generated for each station included in the individual solutions. In this way, if one station is processed by three Processing Centres, there will be available three different time series for the same station. By comparing the time series amongst one to another, it is easier to identify outliers and their possible causes: if outliers, jumps, or interruptions are identifiable in the different series, the problems may be individually associated to the station (tracking deficiencies, equipment changes, failure of the data submission, earthquakes, etc.). If outliers, jumps, or interruptions are not present in all time series, the deficiencies may be associated to administrative issues (neglecting of stations, incomplete download of RINEX files, disagreement with the log files, etc.). In this step, a few outliers were identified and the corresponding stations were reduced from the normal equations before combination.

5.1.4 <u>Quality control of the individual solutions</u>

The consistency between the different individual solutions is evaluated by means of (Sánchez et al. 2008):

a) Mean standard deviations of station positions after solving the individual solutions with respect to the IGS reference frame. These values represent the formal errors of the individual solutions.

b) Weekly repeatability of station positions for each Processing Centre to assess the individual precision of the weekly solutions.

c) Comparison with the IGS weekly coordinates for common stations to estimate the reliability of the individual solutions.

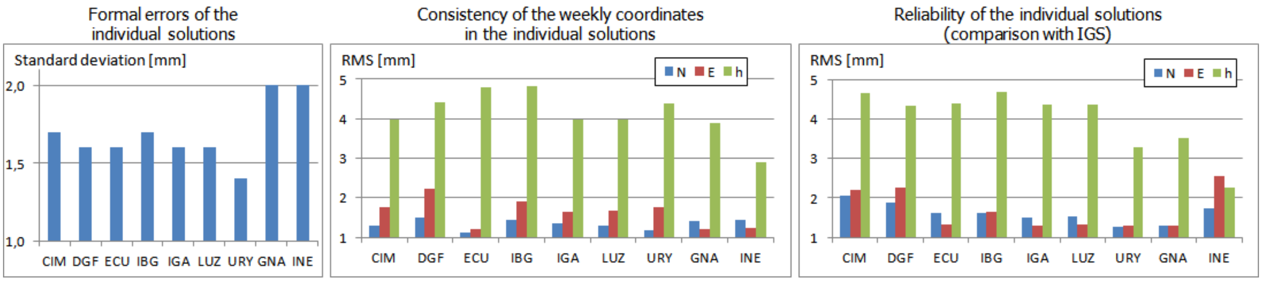


Figure 5. *Comparison of the individual solutions following different evaluation criteria: mean standard deviations (left), weekly repeatability of station positions (center), consistency with the IGS stations (right).*

Results are summarized in Figure 5. In general, the RMS values derived from the station position time series and with respect to the IGS weekly coordinates indicate that the accuracy of the individual solutions is about ±1,5 mm in the North and the East, and ±3,8 mm in the height. The best accuracy estimates in the vertical component correspond to the Processing Centre INE, this can be a consequence of i) stations processed by INE show a very low dependence on seasonal variations, and ii) only 42 INEGI weekly solutions are included in this evaluation (for GNA and the other Processing Centres are considered 55 and 65 weeks, respectively). The reliability of the East component in the INE solutions is a bit poor (2,5 mm) in comparison with the other individual solutions. This may be caused by the location (on the N-W corner of the SIRGAS region) and the elongate geometry of the network processed by this Analysis Centre. To verify this hypothesis, it would be useful that INE includes more SIRGAS-CON stations located in Central America and The Caribbean in its routine computations. Regarding the standard deviations obtained after solving the individual normal equations with respect to IGS05, one can observe that Processing Centres applying the Bernese Software (Table 1) present values about ~±1,6 mm, while Processing Centres using GAMIT/GLOBK (http://www-gpsg.mit.edu/~simon/gtgk/) have values of about 2,0 mm. Changes caused by the earthquakes of Chile (on 2010-02-27) and Mexico (2010-04-04) (Sánchez et al. 2010b) are excluded of this analysis.

5.1.5 Validation of the stochastic models

The relative weighting of individual solutions by means of variance factors is necessary to compensate possible differences in the stochastic models of the Processing Centres. In the SIRGAS-CON weekly combination, these variance factors are calculated from the mean standard deviations obtained after solving the individual normal equations with respect to the IGS reference frame. The variance factors are given with respect to the DGFI standard deviation, since it corresponds to the major SIRGAS-CON-C core network. Table 2 summarizes mean standard deviations and variance factors computed for the weekly combinations covered by the considered period (GPS weeks 1538 - 1602). The obtained values can be classified in two groups according to the software used for processing the GPS measurements. Processing Centres using the Bernese software get a value of about 1,0; Processing Centres using GAMIT/GLOBALK get a value of 0,8.

Table 2. *Variance factors computed for relative weighting of individual solutions in the weekly combination of the SIRGAS-CON clusters. (mean values for the GPS weeks 1538 - 1602).*

Processing Centre	Standard deviation (σ) after solving the individual normal equations wrt IGS05 [mm]			Variance factor ($\sigma_{DGFI}/\sigma_{PC}$)
	Mean	Max	Min	
CIMA	1,71	2,06	1,46	0,9
DGFI	1,58	1,68	1,52	1,0
IBGE	1,70	1,96	1,54	0,9
IGA	1,59	1,68	1,51	1,0
ECU	1,55	1,70	1,39	1,0
LUZ	1,60	1,69	1,47	1,0
URY	1,43	1,63	1,25	1,1
GNA	2,00	2,00	2,00	0,8
INE	2,02	2,31	1,89	0,8

5.2 Evaluation of combined solutions

As already mentioned in Section 3, the weekly combined solutions are aligned to the IGS reference frame by constraining the coordinates of the IGS reference stations (Figure 1) to their positions computed within the IGS weekly combinations (igs*yy*P*wwww*.snx). To minimize network distortions, the reference coordinates are introduced with a weight inversely proportional to ±1E-04 m. This solution provides the final weekly positions for the SIRGAS-CON stations. The quality evaluation of these results is based on the following criteria:

a) Mean standard deviation for station positions after aligning the network to the IGS reference frame indicates the formal error of the final combination;

b) The weekly coordinate repeatability after combining the individual solutions provides information about the internal consistency of the combined network;

c) Time series analysis for station coordinates allows to determine the compatibility of the combined solutions from week to week;

d) Comparison with the IGS weekly coordinates (igs*yy*P*wwww*.snx) indicates the consistency with the IGS global network;

e) Comparison with the IBGE weekly combination (ibg*yy*P*wwww*.snx) fulfils the required redundancy to generate the final SIRGAS products. This comparison is carried out with the final coordinate values (no 7-parameter similarity transformation is applied here).

Table 3 presents mean values of the different applied criteria for the period covering the GPS weeks 1538 - 1602. The mean standard deviation of the combined solutions agrees quite well with those computed for the individual contributions (Table 2), i.e. the quality of the individual solutions is maintained and their combination does not deform or damage the internal accuracy of the entire SIRGAS-CON network. The coordinates repeatability in the weekly combinations provides an estimate of the accuracy (internal consistency) of the weekly combinations of about ±0,9 mm in the horizontal component and about ±2,6 mm in the vertical one. The RMS values derived from the time series for station coordinates and with respect to the IGS weekly coordinates indicate that the reliability of the network (external precision) is about ±1,7 mm in the horizontal position and ±3,7 mm in the height.

The differences respect to the IBGE weekly combinations are within the expected level (less than 1 mm). A description about the IBGE combination strategy (Costa, Silva 2009) is available at ftp://geoftp.ibge.gov.br/SIRGAS.

Table 3. *Evaluation of DGFI weekly combinations (mean values for the GPS weeks 1538 - 1602).*

Criteria	Component	Value in [mm]
Mean standard deviation		1,63
Mean RMS residuals for coordinate repeatability in the weekly combination	N	0,72
	E	1,00
	h	2,58
	Total	2,87
Mean RMS residuals derived from time series	N	1,42
	E	1,33
	h	3,64
	Total	4,13
RMS residuals wrt IGS weekly solutions	N	2,21
	E	1,92
	h	3,84
	Total	4,86
RMS residuals of station coordinate differences between DGFI and IBGE combinations	N	0,36
	E	0,48
	h	0,85
	Total	1,06

6. Impact of seismic events on the SIRGAS reference frame

The western part of the SIRGAS region, i.e. the plate boundary zone between the Pacific, Cocos, and Nazca plates in the west and the North American, Caribbean, and South American plates in the east, is an extremely active seismic area. The frequent occurrence of earthquakes causes episodic station movements (Table 4), which have to be precisely determined and modelled to guarantee (Sánchez et al. 2010b)

a) the reliability of the SIRGAS weekly positions for the week when a seismic event occurs,
b) the appropriate transformation of station positions between the pre-seismic and the post-seismic (deformed) reference frame,
c) the long-term stability of the SIRGAS reference frame.

Table 4. *Seismic events with high impact in the SIRGAS frame since 2000.*

Location	Date	M	Coordinate Change	Affected Stations
Mexicali, Mexico	2010-04-04	7,2	23 cm	MEXI
Chile	2010-02-27	8,8	1 cm - 3 m	See Fig. 6
Costa Rica	2008-01-08	6,1	2 cm	ETCG
Martinique	2007-11-29	7,4	1 cm	BDOS, GTK0
Copiapo, Chile	2006-04-30	5,3	2 cm	COPO
Tarapaca, Chile	2005-06-13	7,9	6 cm	IQQE
Managua, Nicaragua	2004-10-09	6,9	1 cm	MANA
Arequipa, Peru	2001-06-23	7,9	61 cm	AREQ

According to this, always when a strong earthquake shakes the SIRGAS region, DGFI as IGS RNAAC SIR attempts to process as soon as possible the available GNSS measurements to estimate the impact on the reference frame. The usual procedure includes the computation of daily normal equations, which are separately solved with respect to IGS reference stations located outside the SIRGAS region, i.e. in Europe, North America, and Africa (e.g. Figure 6). By comparing daily station positions before and after the earthquake, it is possible to determine displacements of the SIRGAS-CON reference stations associated to the seism. Figures 7 and 8 show the displacements computed by DGFI after the earthquakes in Chile on 2010-02-27 and Baja California, México on 2010-04-04. The first one moved 23 reference stations between 1 cm and 3 m to the west. The second one caused a jump of 24 cm in the south-east direction of the station MEXI.

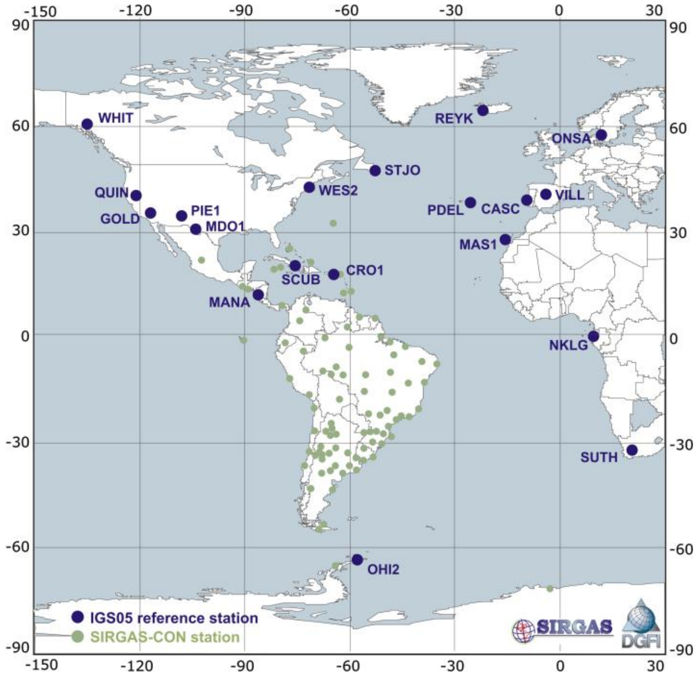


Figure 6. *IGS reference stations applied for the datum realization in the analysis of GNSS data to determine the impact of the earthquake in Chile (on 2010-02-27) on the SIRGAS reference frame.*

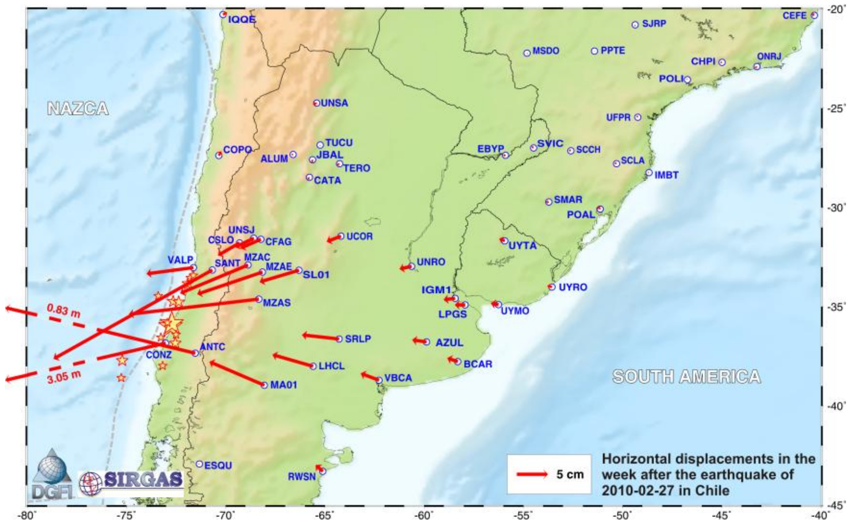


Figure 7. *Horizontal displacements of SIRGAS-CON stations caused by the earthquake in Chile (on 2010-02-27).*

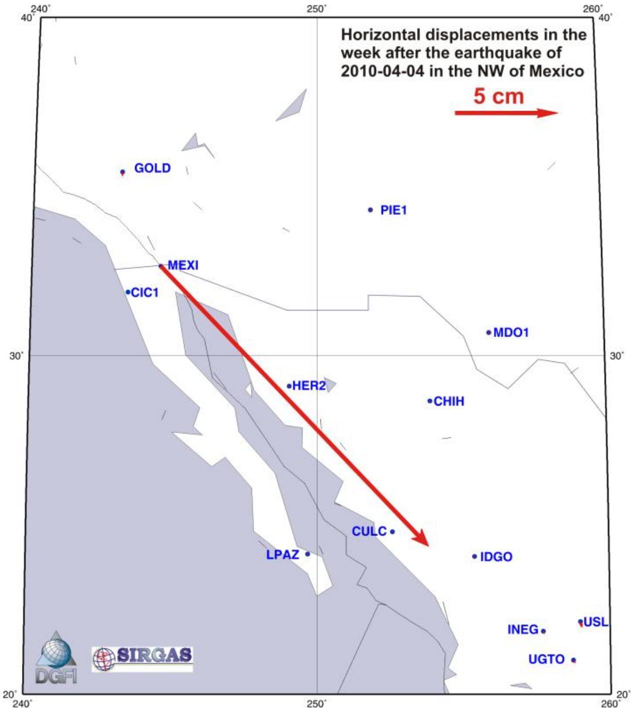


Figure 8. *Horizontal displacement of the SIRGAS-CON station MEXI caused by the earthquake in Baja California, México (on 2010-04-04).*

Conclusions

DGFI as a SIRGAS Combination Centre reviews, evaluates, and combines on a weekly basis the individual solutions delivered by the SIRGAS Analysis Centres: seven Official Processing Centres (CIM, DGF, ECU, IBG, IGA, LUZ, URY) and two Experimental Processing Centres (GNA, INE). The official SIRGAS products (i.e. loosely constrained weekly solutions and weekly solutions aligned to the IGS05) released by DGFI include the individual solutions of the Official Processing Centres only. Analyses including contributions from the Experimental Processing Centres are for internal control. The results for the analysed period (GPS weeks 1538 – 1602) permit to conclude that all Processing Centres (official and experimental) satisfy the administrative and quality processing requirements defined in the SIRGAS guidelines. Their weekly solutions are at the same accuracy level with respect to each other and with respect to final weekly combinations. In general, the accuracy (internal consistency) of results is ~ ±0,9 mm for the horizontal position and ~ ±2,6 mm for the vertical one, while the realisation accuracy with respect to the IGS05 frame (external precision) is about ±1,7 mm for the horizontal components and ±3,7 mm for the vertical one.

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