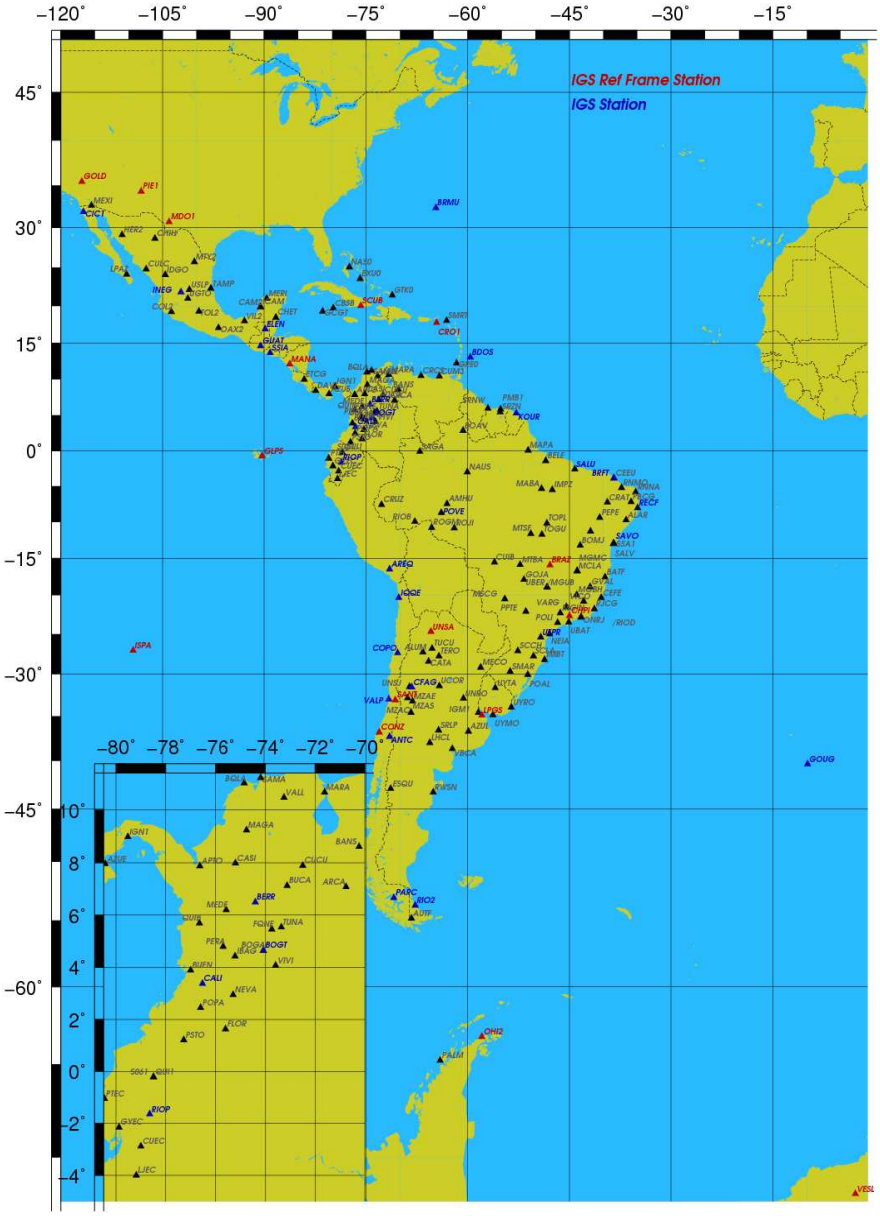
Report of IBGE Combination Centre
Period of SIRGAS-CON solutions: from week 1495 to 1531



Instituto Brasileiro de Geografia e Estatística – IBGE

Coordenação de Geodésia – CGED

August 2009

Abstract.

Since the SIRGAS2008 meeting, the Instituto Brasileiro de Geografia e Estatística – IBGE supported the SIRGAS reference frame as an Official Combination Centre of the SIRGAS-CON network. The official solutions started on week 1495 (August 31, 2008). Since then 3 Local Processing Centres, CIMA, IBGE, and IGAC are responsible to provide weekly solutions that must be available 3 weeks after the date of observation. At the same time, IBGE started the task to combine the weekly solutions from Local Processing Centres and DGFI. The combined solutions must be delivered 4 weeks after the date of observation.

The IBGE Combination Centre, delivers two types of solutions via the IBGE FTP server: free solutions and constrained solutions The procedures adopted for the combination and statistical analysis of results are presented in this report. During this period three other American centres became Experimental Processing Centres and their solutions are combined together with the Local Processing Centres solutions in order to evaluate the consistency and reliability of the SIRGAS official solutions, which will be presented in this report. This report has been written with the contribution of Alberto Luiz da Silva, Jhonnes Vaz and Sonia Costa.

Introduction

The SIRGAS Continuously Observing Network (SIRGAS-CON) contributes with weekly solutions of most Continuously Operating Reference Stations (CORS) in South and Central America, the Caribbean, as well as a few North American stations. One of the objectives of SIRGAS Working Group I is to produce coordinate solutions in IGS SINEX format. Specifically, weekly combinations of submitted sub-network solutions.

This report analyses weekly solutions provided by 3 SIRGAS Local Processing Centres identified in this documentation as:

CIM: Instituto de Geodesia y Geodinámica de la Universidade Nacional de Cuyo IGG-CIMA, Argentina. This centre is in charge of processing SIRGAS-CON stations from the southern SIRGAS-CON sub-network.

IBG: Instituto Brasileiro de Geografia e Estatística(IBGE), Rio de Janeiro , Brasil. This centre is in charge of processing SIRGAS-CON stations from the central SIRGAS-CON sub-network.

IGA: Instituto Geográfico Agustín Codazzi (IGAC), Bogotá, Colombia. This centre is in charge of processing SIRGAS-CON stations from the northern SIRGAS-CON sub-network.

Deutsches Geodätisches Forschungsinstitut-DGFI, identified in this report as **SIR,** processes SIRGAS-CON data from a core sub-network which has stations in stable locations to ensure long-term stability of the reference frame.

The solutions provided by CIM, SIR, IBG and IGA span the period of week 1495 to 1531 (37 weeks, from October 2008 to May 2009), and are available as loosely constrained weekly solution (ccc*wwww*7.SNX) in SINEX format.

During this period three new Experimental Processing Centres became candidates to be Local Processing Centre, they are:

ECU: Instituto Geográfico Militar de Ecuador, IGM-Ec. This centre is responsible for the processing of Equatorian stations and some IGS stations. Their activities started in week 1513 (January 2009).

LUZ: Laboratorio de Geodesia Física y Satelital, Universidad del Zulia, LGFS-LUZ (Venezuela). This centre is responsible for the processing of northern SIRGAS-CON-D stations. Their activities started in week 1525 (April 2009).

URY: Servicio Geográfico Militar del Uruguay, SGM-Uy. This centre is responsible for the processing of southern SIRGAS-CON-D stations. Their activities started on week 1526 (April 2008).

The weekly solutions provided by ECU, LUZ and URY were combined together with the weekly solutions provided by Local Processing Centres and the results were evaluated together. All Centres used the Bernese software to generate weekly solutions.

This report presents an evaluation of results provided by Local Processing Centres and Experimental ones, for the period between august 2008 to may

2009 (GPS week 1495 to 1531), as well as, explore different combination strategies. The combined solution contains 182 stations, which coordinates were estimated using the IGS05 Reference Frame at epoch 2000,09 (GPS week 1513). Four combination strategies were evaluated using the minimum constraints and constrained approach, preserving the original characteristics of the weekly solutions and providing the alignment with the IGS05 reference frame. To generate the final weekly solutions, fourteen IGS05 stations in the ITRF2005 were used for datum definition: BRAZ, CHPI, CONZ, CRO1, GOLD, ISPA, LPGS, MANA, MDO1, OHI2, PIE1, SANT, SCUB, UNSA, and VESL. The software used to combine SIRGAS-CON solutions is Bernese GPS Software v.5.0.

Some facts are important to be mentioned in this report. One is that the IBGE weekly combined solutions were resubmitted for weeks 1517 to 1528. This problem was because the final constrained solution was not defined using the 14 IGS stations mentioned before in this report. The SIRGASMAIL number 152 reports this problem and informs that new solutions were available at the IBGE server.
Another important fact is that the DGFI weekly constrained solutions were resubmitted for weeks 1495 to 1526. The new combined solutions became available at DGFI server in the beginning of May, 2009 (7/5/2009).

SIRGAS Processing Centres

As mentioned before, the present solutions from 3 sub-networks (north, south and middle) contribute to the SIRGAS-CON network, but only DGF processes the core stations that belong to the 3 sub-networks. The SIRGAS-CON network, comprises South, Central, part of North America, and the Caribbean Region. A total of 182 stations from a variety of national networks, including IGS stations in operation during this time span were processed. Table 1 informs the new stations (national/regional densifications and IGS) that were included in the processing of each centre. The stations included in the weekly solutions of each Processing Centre are shown in Figure 1.

Table 1: Information of new stations processed by Local and Experimental Processing centres

centre	Country	New regional stations	New IGS stations
CIM	Brazil, Uruguay, Argentina, Chile	SRLP, UYTA, ALUM, CATA, ESQU, TERO	
DGF		IGN1, LJEC, ESQU, QUI1	
IBG	Brazil, Uruguay, Argentina, Chile, Ecuador, Venezuela and Guianas	CEEU, SCCH, ALAR, GOJA, MGMC, MTBA, GYEC, SRLP, UYTA, PTEC, CUEC, LJEC, BAIR, BATF, MGBH, RNMO, RNNA, QUI1	POVE, SALU, RECF, SAVO, UFPR
IGA	Colombia, Mexico, Central America and Caribbean region	USLP, AZUE, DAVI, IGN1, MAGA, CASI, ICAM, IDGO, QUI1	
ECU	Brazil, Argentina, Chile, Ecuador, Venezuela and Guianas	GYEC, PTEC, CUEC, LJEC, QUI1	
LUZ	Colombia, Mexico, Central	USLP, AZUE, DAVI,	

	America and Caribbean region	IGN1, MAGA, CASI, ICAM, IDGO, QUI1	
URY	Brazil, Uruguay, Argentina, Chile	SCCH, MTBA, SRLP, UYTA, BATF, MGBH, ALUM, CATA, ESQU, TERO	

Tables 2 and 3 give the number of common stations between all sub-networks from SIRGAS-CON combination. Table 4 and 5 summarize the number of stations with redundant solutions. As can be seen on Table 5 the number of stations in more than one solution increased since last year. This redundancy is an important consideration in the combination for detection of outliers and to ensure reliable alignments and covariance matrix scaling.

Table 2: Number of stations processed by Local Processing centres

Processing Centre	CIMA	DGFI	IBGE	IGAC
CIMA	52	35	44	15
DGFI		110	61	66
IBGE			115	22
IGAC				85

Table 3: Number of stations processed by Local and Experimental Processing centres

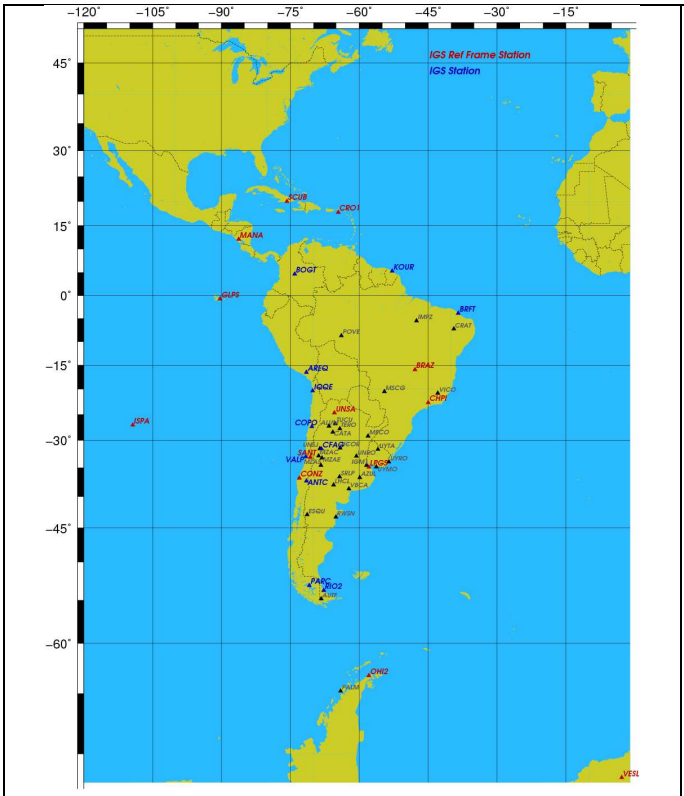
Processing Centre	CIMA	DGFI	IBGE	IGAC	ECU	LUZ	URY
CIMA	52	35	44	15	9	15	30
DGFI		110	61	66	23	60	21
IBGE			115	22	20	20	37
IGAC				85	20	77	5
ECU					28	19	3
LUZ						77	0
URY							42

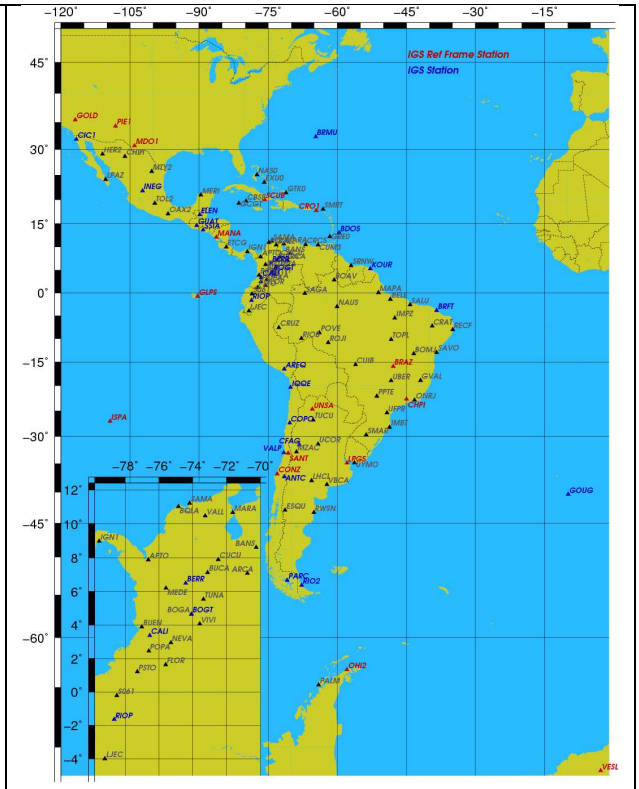
Table 4: Redundancy of solutions, from official processing centres (n°= number of centres processing a given station)

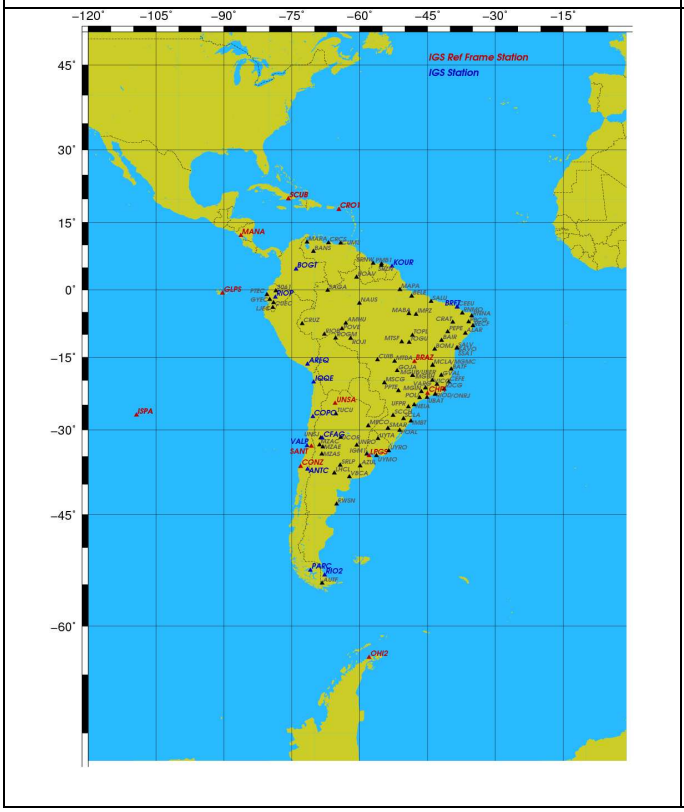
n°of solutions	n°of stations
1	62
2	82
3	24
4	15
Total	182

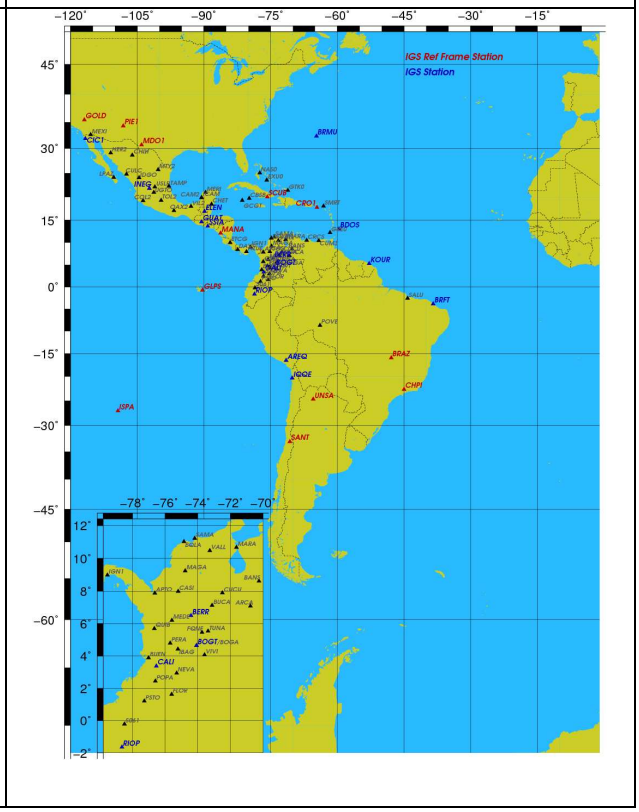
Table 5: Redundancy of solutions, including official and experimental centres (n°= number of centres processing a given station)

n°of solutions	n°of stations
1	28
2	55
3	60
4	22
5	6
6	8
7	3
Total	182


IGS Ref Frame Station
IGS Station


IGS Ref Frame Station
IGS Station


IGS Ref Frame Station
IGS Station


IGS Ref Frame Station
IGS Station

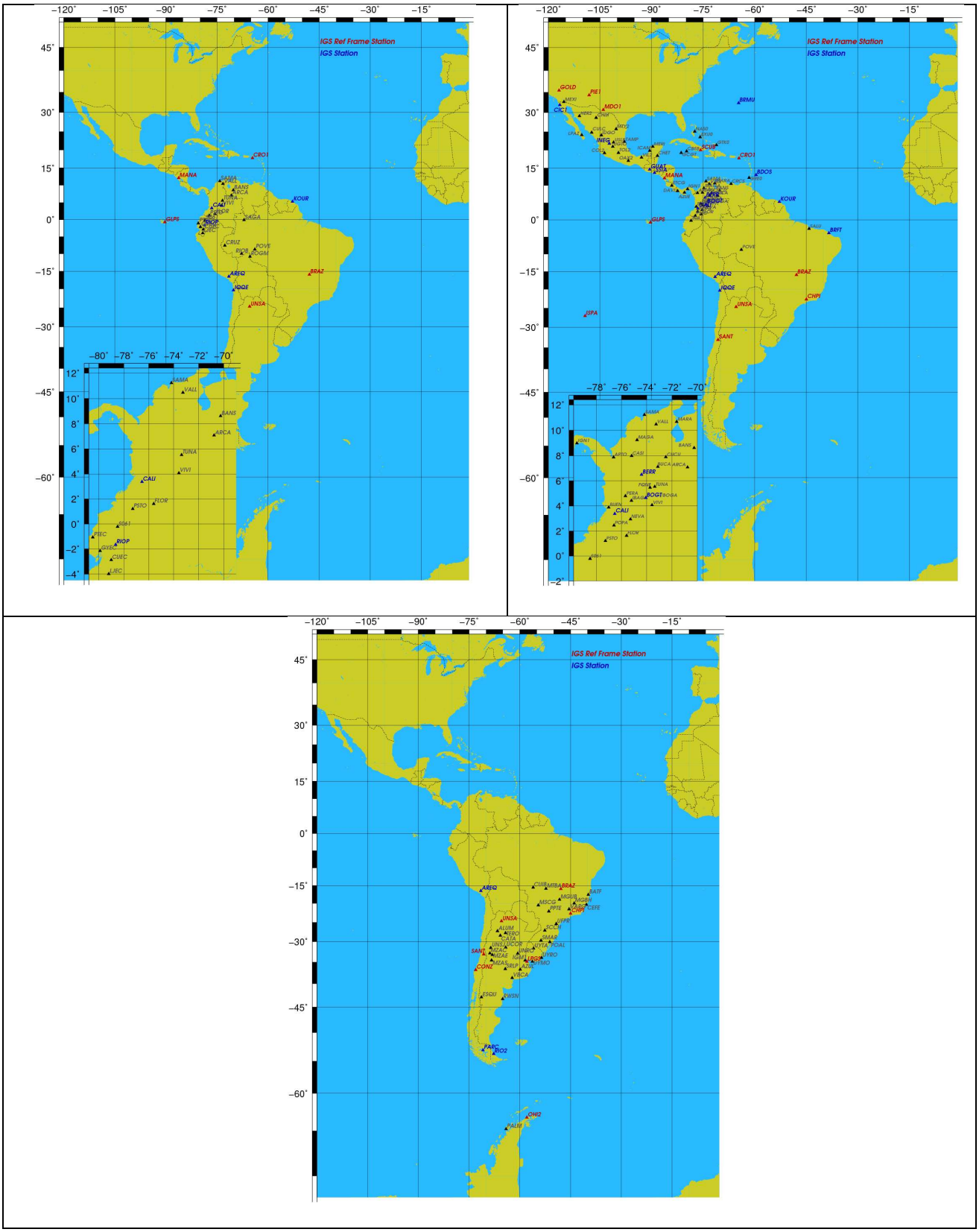


Figure 1: Contributions to the SIRGAS-CON densification network for a period 1495 to 1531: CIM with a subset of 52 stations; DGF with a subset of 110 stations; IBG with a subset of 115 stations; IGA with a subset of 85 stations; ECU with a subset of 28 stations; LUZ with a subset of 77 stations; URY with a subset of 42 stations.

Combination Strategy for Weekly Solutions

For each week the Local Processing Centres and DGFI provide loosely constrained weekly solutions. These four solutions are combined on a weekly basis providing the SIRGAS-CON weekly combination. Two types of solutions are provided by the Combination Centres: the loosely constrained weekly solutions and weekly constrained solutions. The same procedure is done in parallel including the solutions provided by Experimental Processing Centres. The results from Local Processing Centres are available at: ftp://geoftp.ibge.gov.br/SIRGAS/Resultados/Combinacao and from Experimental Processing Centres: ftp://geoftp.ibge.gov.br/SIRGAS/EXPERIMENTAL

Files are identified as:
CCC*WWWW*S.SNX = loosely constrained weekly solution
CCC*YY*P*WWWW*.SNX = constrained weekly solution

Where:
CCC = identifier of processing centre
WWWW = GPS week
YY = year with two digits,. ex: 2009 = 09

The Combination strategy is described in file LEIA_ME.TXT (or READ_ME.TXT) available in the same directory mentioned before. This file is ANNEX A of this report.

Inconsistencies found in each sub-network solution

CIM	Only one solution for stations CRAT, IMPZ, MSCG and VICO Station POVE has RMS of up component higher than 20 mm Wrong antenna height for **OHI2** 66008M005 Up: 0.0375 m -> -0.0080 m Wrong antenna ID for **OHI2** 66008M005 Ant. name: TPSCR.G3 TPSH -> AOAD/M_T DOME Wrong antenna ID for **UYMO** 42301M001 Ant. name: LEIAT504GG LEIS -> LEIAX1202GG NONE
DGF	Only one solution for stations ARCA, BOGA, BUCA, CALI, FLOR, MEDE, POPA, SAMA, TUMA, VALL and VIVI Station NAUS has RMS of up component higher than 20 mm Wrong antenna height for **OHI2** 66008M005 Up: 0.0375 m -> -0.0080 m Wrong antenna ID **GCGT** 80401M001 Ant. name: TRM57971.00 NONE -> TRM41249.00 NONE Wrong antenna ID for **OHI2** 66008M005 Ant. name: TPSCR.G3 TPSH -> AOAD/M_T DOME Wrong antenna ID for **UYMO** 42301M001 Ant. name: LEIAT504GG LEIS -> LEIAX1202GG NONE
IBG	Stations ANTC, NAUS, ISPA have RMS of up component higher than 20 mm Only one solution for station SALV Wrong antenna height for **OHI2** 66008M005 Up: 0.0375 m -> -0.0080 m Wrong antenna ID for **OHI2** 66008M005 Ant. name: TPSCR.G3 TPSH -> AOAD/M_T DOME
IGA	Only one solution for station S061 There is no RMS of residuals above 20 mm. Solutions with good agreement. Wrong antenna ID **GCGT** 80401M001 Ant. name: TRM57971.00 NONE -> TRM41249.00 NONE
ECU	There is no RMS of residuals above 20 mm. Solutions with good agreement.

LUZ	There is no RMS above 20 mm. Solutions with good agreement. Only one solution for station S061 Wrong antenna ID **GCGT** 80401M001 Ant. name: TRM57971.00 NONE -> TRM41249.00 NONE
URY	For a big part of stations the RMS of Up component is above 20 mm Only one solution for station BATF

There were few outliers rejected in each processing centre solution. Results are more consistent than the ones computed last year, this is mainly due to the new procedures established for the AMSUR.STA file.

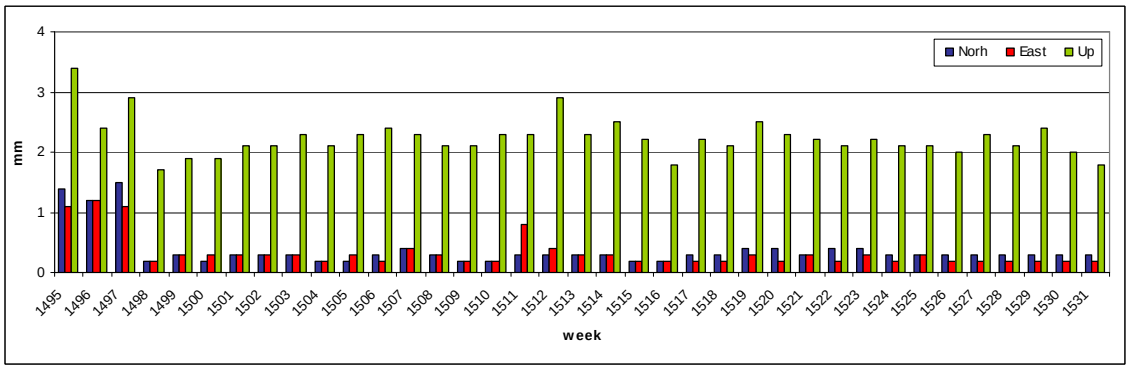


Figure2: RMS of residuals of Helmert transformation between the weekly coordinates of IBGE and DGFI solutions (IBGyyPwwww.crd and SIRyyPwwww.crd).

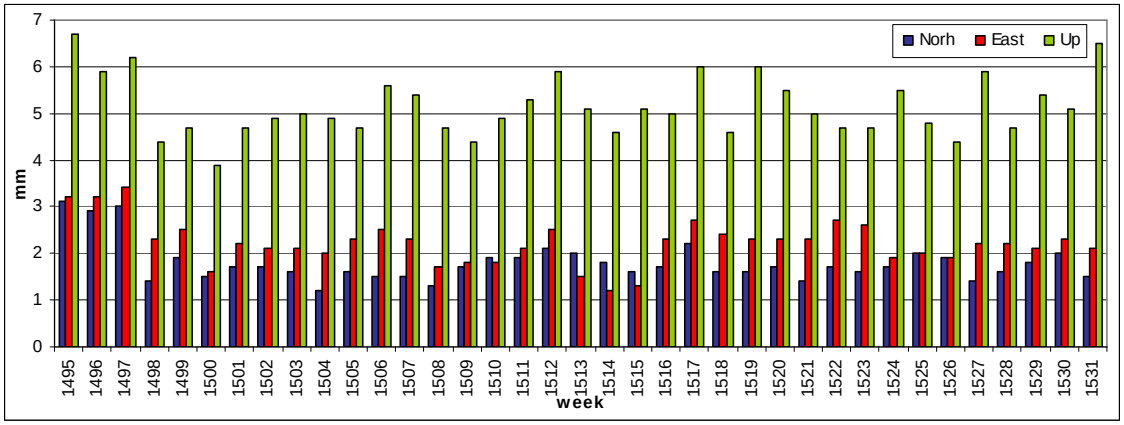


Figure 3: RMS of residuals of Helmert transformation between the weekly coordinates of IBGE and IGS solutions (IBGyyPwwww.crd and IGSyyPwwww.crd).

Comparing constrained weekly coordinates calculated by IBGE Combination Centre with the weekly values of DGFI and IGS for the common stations, it is observed that the residuals of a Helmert transformation between IBGE and DGFI are smaller than the residuals of Helmert transformation between IBGE and IGS (Figures 2 and 3).

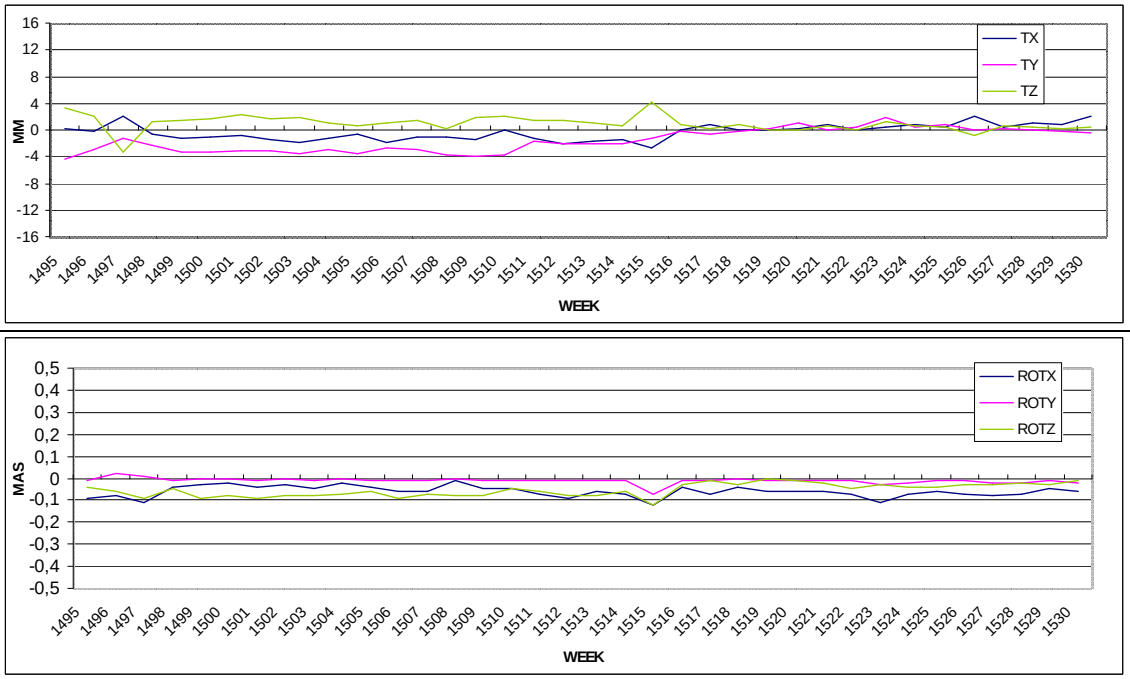


Figure 4: Transformation parameters (translations and rotations) between constrained weekly solutions of IBGE and DGFI.

From Figure 4 it can be observed that after week 1517 DGFI and IBGE constrained solutions (IBGyyPwwww.crd and SIRyyPwwww.crd) have a better agreement. The reasons for that should be further analyzed.

Evaluation of new combinations strategies for a period 1495 to 1531

Four combination strategies are proposed for a period of 37 weeks (1495 to 1531 GPS week) of SIRGAS-CON, they are:

Strategy	Description	Reference of Coordinates
(1)	Minimum constraint conditions: the solution is aligned to a set of IGS stations, from IGS05 (IGS05_R.CRD) realization, applying the "no net rotation" and "no net translation" conditions.	IGS05_R.crd coordinates. propagated to week 1513, using IGS05_R.vel
(2)	Minimum constraint condition: the solution is aligned to a set of IGS stations, from IGS05 week (IGSyyPwwww.CRD) realization, applying the "no net rotation" and "no net translation" conditions.	IGS week solution 1513 (IGS09P1513.crd)
(3)	Constrained solution: constrain coordinates of a selected set of IGS05 stations to their a priori coordinates for geodetic datum definition. The strength of the constraints is σ = ±1E-06 m in all components.	IGS05_R.crd coordinates. propagated to week 1513, using IGS05_R.vel

(4)	Constrained solution: constrain coordinates of a selected set of IGS05 stations constrained to their a priori coordinates for geodetic datum definition. The strength of the constraints is σ = ±1E-06 m in all components;	IGS week solution 1513 (IGS09P1513.crd)

A set of selected IGS05 stations, called fiducial stations in all strategies are: BRAZ, CHPI, CONZ, GOLD, ISPA, LPGS, MANA, MDO1, OHI2, PIE1, SANT, SCUB, UNSA e VESL. The reference epoch is (the middle of the time interval):2009-01-07, 00:00:00(2009.02), GPS week 1513. Table 6 presents important information and scale factor of each Processing Centre.

Table 6: Covariance matrix scale factors for individual regional solutions and RMS of repeatability.

Proc. Centres	n°of stations	Number of weeks	Scale Factor
CIM	52	37	2.98
DGF	110	37	2.54
IBG	86	37	3.16
IGA	85	37	2.46
ECU	28	19	2.14
LUZ	77	7	2.47
URY	42	6	1.82

The comparison between weekly time series solutions of each processing centre and the final combined solution, strategy (1), is analyzed by the estimation of seven-parameter Helmert transformation in order to check the fit of each centre solution with the combined one (Table 7).

In the Table 7, which shows transformation parameters between Processing Centre solutions and the combined one applying the strategy (1), that rotations are meaningless in these results, but some translations of 1 and 2 cm can be seen on ECU and URY results. A high scale value is observed in ECU and URY solutions as well.

Table 7: Helmert transformation parameters with respect to combined solution: MIN CONST. SOLUTION + IGS05_R propagated to week 1513, epoch 2009.02 (strategy 1).

	RMS(m)	Tx(m)	Ty(m)	Tz(m)	Rot_X(")	Rot_Y(")	Rot_Z(")	scl(ppm)
CPL	0.00248	0.0014	-0.0024	-0.0040	-0.0001	-0.0001	0.0002	0.00013
DGF	0.00143	0.0020	-0.0004	-0.0013	0.0000	0.0000	0.0000	0.00005
IBG	0.00105	**0.0005**	**-0.0052**	**-0.0088**	0.0001	0.0001	0.0000	**-0.00060**
IGA	0.00099	-0.0003	-0.0001	0.0005	0.0001	0.0000	-0.0001	-0.00005
ECU	0.00221	**0.0204**	**0.0129**	**0.0058**	-0.0001	-0.0001	0.0006	**0.00142**
LUZ	0.00358	0.0055	-0.0015	0.0000	0.0002	-0.0002	0.0000	0.00001
URY	0.00475	**0.0037**	**0.0114**	**-0.0058**	0.0003	-0.0003	0.0004	**0.00095**

Table 8 shows the RMS of repeatability from the four combination strategies confirming the good internal agreement of solutions. Only three stations present high RMS, they are: VARG, OHI2 and CRAT.

Table 8: RMS of repeatability (mm)

Strategy	North (mm)	East (mm)	Up (mm)
(1)	1.78	2.17	4.36
(2)	1.77	2.15	4.33
(3)	1.65	1.82	3.92
(4)	1.63	1.80	3.79

Tables 9 and 10 present the transformation parameters estimated between weekly IGS solution, epoch 2009,02 (GSP week 1513) and each combination strategy, in order to check the external fit of each strategy. As can be seen, rotation and scale are meaningless in these results; translations values are bigger in strategies (1) and (3)

Table 9: Transformation parameters between IGS05 weekly solution (week 1513) and each combination strategy.

Strategy	Tx(mm)	Ty(mm)	Tz(mm)	Rot_X(")	Rot_Y(")	Rot_Z(")	scl(mm/km)
(1)	**-3.5**	**-4.2**	**7.4**	**-0.00005**	**-0.00005**	**-0.00016**	**0.0002**
(2)	0.8	-1.6	5.4	-0.00003	-0.00005	-0.00013	0.0002
(3)	**-6.1**	**-3.7**	**5.8**	**-0.00021**	**-0.00000**	**-0.00023**	**0.0002**
(4)	-1.0	-1.4	2.9	-0.00009	-0.00002	-0.00005	0.0000

Table 10: Transformation parameters between SIR weekly solution (week 1513) and each combination strategy.

Strategy	Tx(mm)	Ty(mm)	Tz(mm)	Rot_X(")	Rot_Y(")	Rot_Z(")	scl(mm/km)
(1)	**-0.4**	**-3.7**	**5.2**	**0.00000**	**0.00003**	**-0.00007**	**-0.0003**
(2)	3.4	-1.3	3.2	0.00002	0.00004	-0.00005	-0.0003
(3)	**-3.5**	**-2.4**	**3.0**	**- 0.00013**	**0.00006**	**-0.00015**	**-0.0001**
(4)	1.2	-0.7	0.7	-0.00004	0.00006	0.00002	-0.0003

Table 11: RMS of coordinates´ residuals between each combination strategy and week solution (1513) of IGS and SIR

	IGS			SIR		
Strategy	North (mm)	East (mm)	Up (mm)	North (mm)	East (mm)	Up (mm)
(1)	1.4	2.0	3.6	1.4	1.6	4.0
(2)	1.4	2.0	3.6	1.4	1.6	4.0
(3)	**3.1**	**2.2**	**6.2**	**1.9**	**1.6**	**4.6**
(4)	1.1	1.5	3.9	1.5	1.5	3.9

Table 11 shows that the four strategies proposed have a good consistency with IGS and SIR solution, even that bigger RMS were found in strategy (3). The residual of 5 cm is found in OHI2, this was caused because processing centers CIM, DGF and IBG were using wrong antenna height for week 1516.

Conclusions

A total of 182 stations were available for the final solution of seven processing centers (four are official ones). The results were satisfactory even considering the small problems related to antenna/receiver identifications and antenna height.

It is still necessary to add more redundant solutions for as many stations as possible from SIRGAS-CON-D. Many SIRGAS-CON stations are still in only one regional solution and therefore have no independent quality control check.

Solutions between combination centres are consistent even considering different datum definition strategies for their constrained solutions.

It is suggested to change the Experimental Processing Centres with solutions analyzed in this report to official processing centres, considering that they are providing results with good quality.

ANNEX A

==========
Description of the directory´s content:
ftp://geoftp.ibge.gov.br/SIRGAS/Resultados/Combinacao/
==========

The files of this directory are the weekly results, in SINEX (SNX) format, of combined solutions from results provided by four processing centres:

CIMA: Instituto de Geodésia y Geodinámica de la Faculdad de Ingeniería de la Universidad Nacional de Cuyo (Argentina)
DGFI: Deutsches Geodätisches Forschungsinstitut (Alemanha)
IBGE: Instituto Brasileiro de Geografia e Estatística (Brasil)
IGAC: Instituto Geográfico Agustín Codazzi (Colômbia)

Each Processing Centre is responsible for the processing of a group of stations that belong to the SIRGAS-CON network.
More information about SIRGAS-CON network is available at www.sirgas.org.

In this directory two types of solutions can be found: loosely constrained weekly solutions (which can be used for future computations) and constrained weekly solutions (the solutions are highly constrained to a set of IGS05 stations). The following identifications are adopted for SINEX files:

CCCWWWWS.SNX ==> loosely constrained weekly solutions
CCCyyPWWWW.SNX ==> constrained weekly solutions
where:
CCC = identification of the Processing centre
WWWW = GPS week
yy = 2 digit year, e.g.: 2008 = 08

Combination Strategy:
(1) Constraints are removed from the weekly solutions of each Processing centre, using the free network solution strategy;
(2) The free network solution of each processing centre is aligned to a set of stations that belong to IGS05 (2000.0)
Reference network applying “no net rotation” and “no net translation” conditions. The IGS05 stations are: BRAZ, CHPI, CONZ, GOLD, ISPA, LPGS, FLOWS, MDO1, OHI2, PIE1, SANT, SCUB, UNSA and VESL.
(3) The coordinates from step (2) of each processing centre are compared with IGS05 coordinates propagated to week epoch and between themselves to identify possible high residuals. The stations with residuals exceeding 10 mm in horizontal components and 20 mm in the vertical component will be analized and possibly removed from the solution. In the case of station exclusion the steps (1) and (2) will be repeated for the refinement of final solution and consequently the variance factor of the estimate.
(4) The covariance matrix of each solution is scaled by the variance factor or scale factor.
(5) The normal equations of each solution are combined to produce the loosely constrained weekly solution (CCCWWWWS.SNX) applying a weight of 1 meter to all stations.

(6) The normal equations of each solution are combined to produce the constrained solution (CCCyyPWWWW.SNX) applying a weight of 1E-04 meters for IGS05 stations mentioned in step (2).