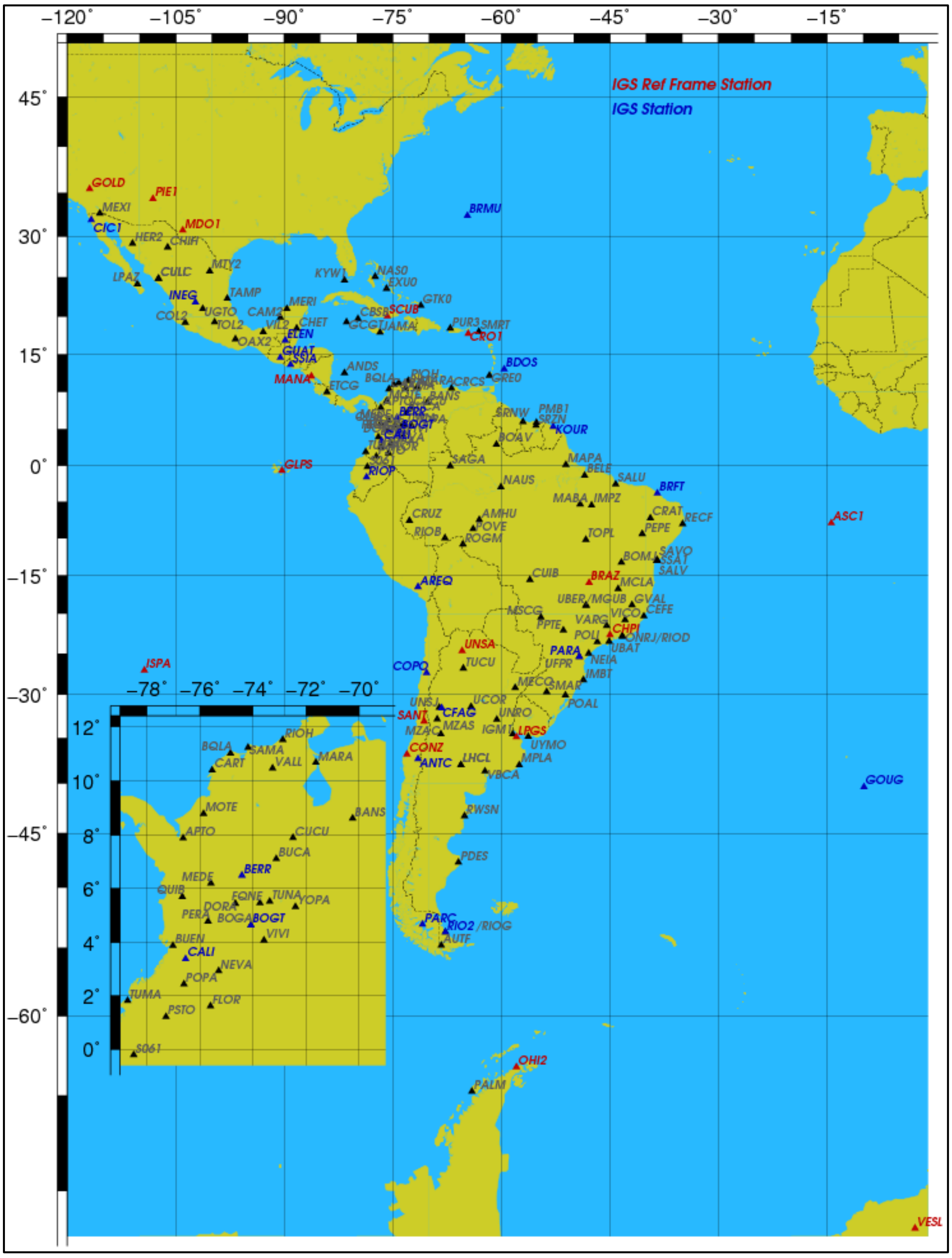
Report on the SIRGAS-CON combined solution

Period: from week 1395 to 1465



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Abstract.

Since the first Workshop of Working Group I, in August 2006, the Instituto Brasileiro de Geografia e Estatística – IBGE has supported the SIRGAS reference frame as an Experimental Combination Centre of SIRGAS-CON network. The SIRGAS-CON densification network has evolved from a hundred continuously operating GPS reference stations and this number is increasing day by day. The goal is to combine the weekly solutions computed by each Experimental Processing Center and generate a cumulative solution that is aligned to the ITRF reference frame. The procedures adopted for the combination, statistical analysis of results, and coordinate time-series are presented. Several factors that affect the quality of solutions, like equipment changes, which can cause a discontinuity on the coordinate time series, are discussed.

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.

The objectives of SIRGAS Working Group I are to:

• Densify the ITRF reference frame in South, Central America and the Caribbean Region, in both a temporal as well as spatial sense in order to provide a kinematic description of the Earth's shape as it changes.

• Produce coordinate solutions in IGS SINEX format. Specifically, weekly combinations of submitted sub-networks solutions, as well as, cumulative solutions.

• Study the effects of crustal motion, including tectonic deformations along, e.g., the west coast of South America and in the Caribbean region.

This report analyses weekly solutions provided by 4 SIRGAS Experimental Processing Centers identified in this documentation as:

CPL : Universidad Nacional de La Plata (UNLP), La Plata, Argentina.
SIR: Deutsches Geodätisches Forschungsinstitut-DGFI.
IBG: Instituto Brasileiro de Geografia e Estatística(IBGE), Rio de Janeiro , Brasil.
IGA: Instituto Geográfico Agustín Codazzi (IGAC), Bogotá, Colombia.
INE: Instituto Nacional de Estadística, Geografía y Información (INEGI), Aguas Calientes, México.

The data provided by CPL, DGF, IBG and IGA spans the period of week 1395 to 1465 (71 weeks, from October 2006 to February 2008). The coordinates of 155 stations were estimated using the IGS05 Reference Frame (epoch 1430). The time span provided by INE is 34 weeks, from week 1395 to 1428. The solution of INE processing center was analyzed separately from the others because of the different time span.

The combination of each processing center, as well as, the final solution was achieved using the minimum constraints approach, preserving the original characteristics of the weekly solutions and providing the alignment to IGS05 reference frame. To generate the final solution eleven IGS05 stations in the ITRF2005 were used do define the reference frame. The criteria for station selection were the same as used by ITRF. The following stations were selected for the realization of the reference frame: BRAZ, CHPI, CONZ, CRO1, LPGS, MANA, MDO1, OHI2, SANT, SCUB and UNSA.

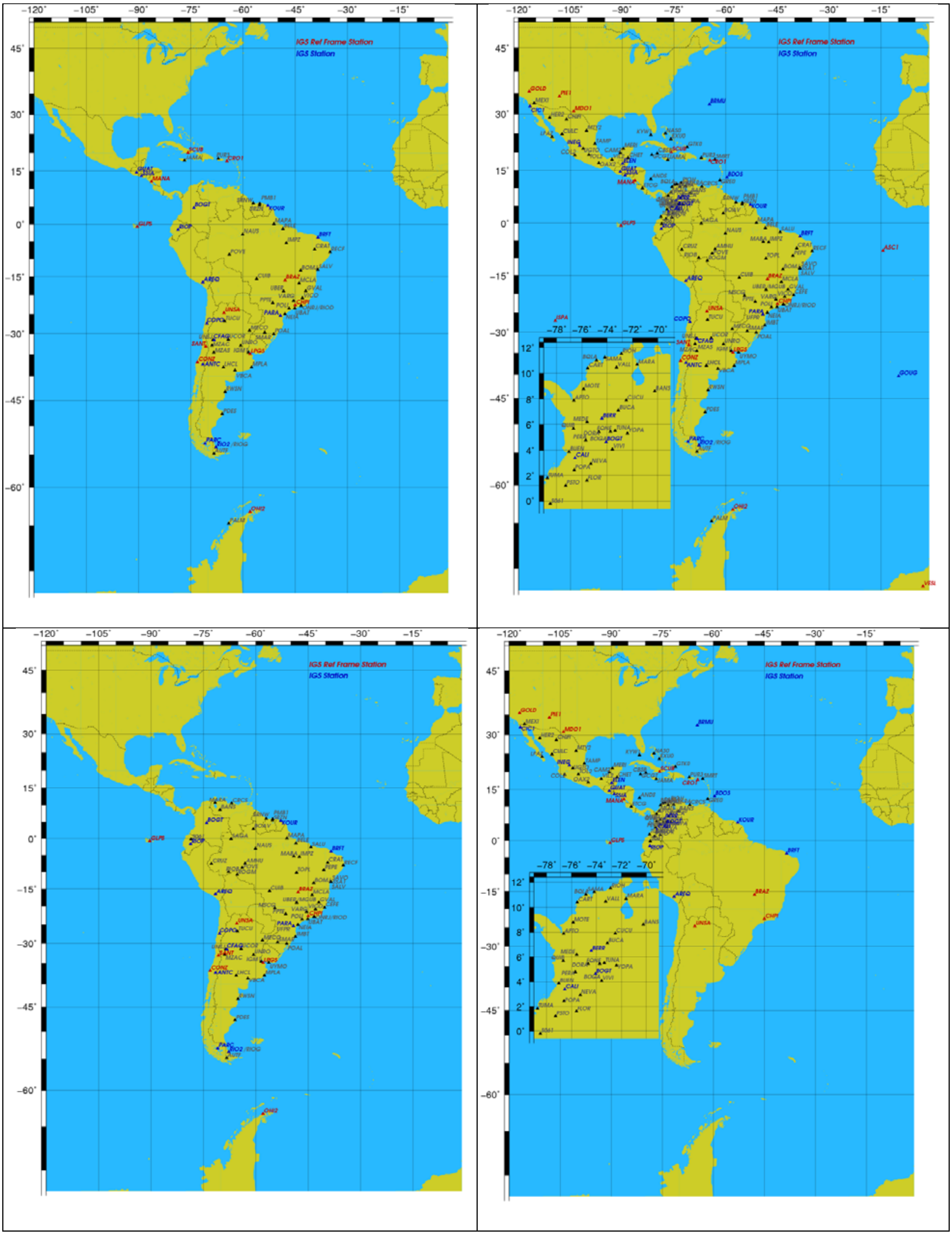
The software used to perform this task is Bernese 5.0. Besides coordinates, and their standard deviations, results of a 7-parameter transformation are presented and analyzed. The information provided by each center were the free weekly solutions in SINEX format.

SIRGAS sub-networks

As mentioned before, at present solutions from 5 sub-networks contribute to the SIRGAS-CON network, but only DGF processes all stations. The SIRGAS-CON network, comprises South, Central, part of North America, and the Caribbean Region. A total of 158 stations from a variety of national networks, including IGS stations in operation during this time span, were processed. Table 1 provides the countries of national/regional densifications and IGS stations included in each solution. The stations included in each sub-network are shown in Figure 1. Annex A provides the number of solutions of each station processed by each center, as well as station information (receiver/antenna combination and antenna height. All centers used Bernese software to generate weekly solutions, with exception of INE that used GIPSY/Oasis.

Table 1: Information of each sub-network processed by 5 Experimental Processing Centers

Center	**Country**	**IGS Reference stations**	**IGS stations**
CPL	**Brasil, Uruguay, Argentina, Chile Guianas**	**GLPS, BRAZ, UNSA, SANT, CONZ, LPGS, CHPI, OHI2, MANA, SCUB, CRO1**	**GUAT, SSIA, JAMA, BOGT, RIOP, AREQ, COPO, CFAG, ANTC, PARC, RIO2, KOUR, BRFT**
SIR	**Argentina, Brasil, Uruguay, Chile, Equador, Colombia, Venezuela, Guianas, Mexico, Central America and Caribbean region**	**GLPS, BRAZ, UNSA, SANT, CONZ, LPGS, CHPI, OHI2, GOLD, PIE1, MDO1, MANA, SCU1, CRO1, ASC1,VESL**	**ELEN, GUAT, SSIA, INEG, CIC1, BRMU, BDOS, RIOP, KOUR, BRFT, AREQ, GOUG**
IBG	**Brazil, Uruguay, Argentina, Chile, Equador, Venezuela and Guianas**	**GLPS, BRAZ, UNSA, SANT, CONZ, LPGS, CHPI, OHI2**	**AREQ, RIOP, KOUR, BRFT, BOGT, COPO, CFAG, ANTC, RIO2, PARC**
IGA	**Colombia, Mexico, Central America and Caribbean region**	**GLPS, BRAZ, UNSA, CHPI, CRO1, SCUB, MANA, MDO1, PIE1, GOLD**	**ELEN, GUAT, SSIA, INEG, CIC1, BRMU, BDOS, RIOP, KOUR, BRFT, AREQ**
INE	**Mexico, U.S. and Caribbean region**	**MANA, SCUB, PIE1, MDO1**	**GUAT, INEG, PUR3, BRMU, CIC1**


-120° -105° -90° -75° -60° -45° -30° -15°
45° 30° 15° 0° -15° -30° -45° -60°
IGS Ref Frame Station
IGS Station
-78° -76° -74° -72° -70°
12° 10° 8° 6° 4° 2° 0°

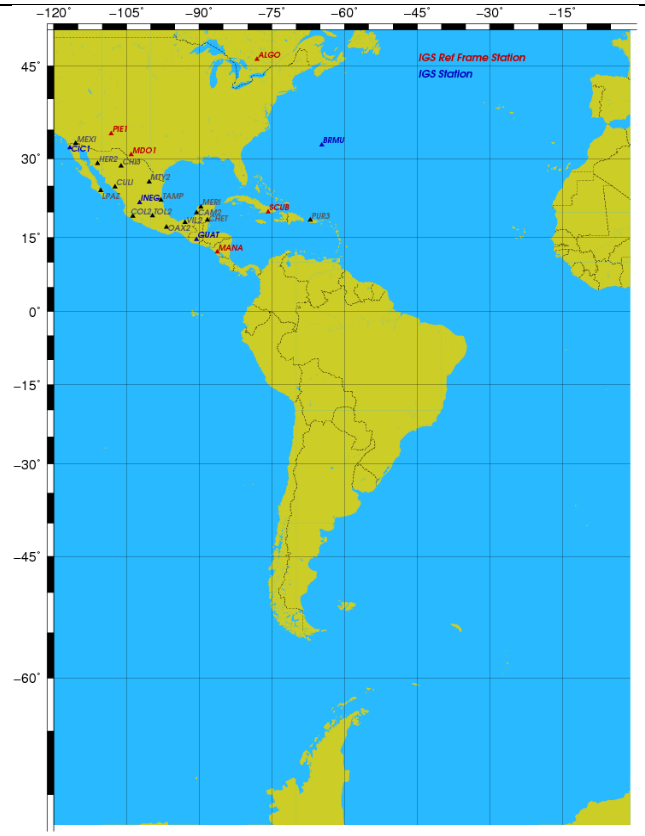


Figure 1: Contributions to the SIRGAS-CON densification network for GPS week 1465: CPL) Universidad Nacional de La Plata-UNLP with a subset of 68 stations; SIR) Deutsches Geodätisches Forschungsinstitut-DGFI with a subset of 155 stations; IBG) Instituto Brasileiro de Geografia e Estatística-IBGE with a of subset of 83 stations; IGA) Instituto Geográfico Agustín Codazzi-IGAC with a subset of 82 stations; INE) : Instituto Nacional de Estadística, Geografía e Información - INEGI with a subset of 24 stations.

IGS05/ITRF2005 Station Selection

The best datum definition for the SIRGAS-CON frame is achieved by the selection of IGS05/ITRF2005 sites with good quality. This selection followed the criteria: ITRF stations of high quality, good distribution over regional network, long observation history, located on rigid parts of tectonic plates, more than one solution and technique for estimation.

Eleven stations (BRAZ, CHPI, CONZ, CRO1, LPGS, MANA, MDO1, OHI2, SANT, SCUB and UNSA.) in IGS05/ITRF2005 were chosen. Unfortunately, some ITRF2005 reference stations are present in the ITRF2005 solution but not in the IGS05 solution, for example: KOUR, BOGT and AREQ. Other ITRF stations went out of operation during this period, like JAMA and RIOG; others like VESL and ASC1 show up only in the solution of one processing center. Station GLPS was not selected because it is located in a region of high tectonic activity. For these twelve stations, coordinates from IGS05 solution were propagated to epoch 2007.4, using the relation $X_{2007.4} = X_{2000.0} + \dot{X}_{2000.0}(2007.4 - 2000.0)$ and IGS05 velocities. Figure 2 shows the distribution of IGS05 Reference stations.

Figure 3: IGS05 Reference stations used to define geodetic datum

SIRGAS-CON Combination Strategy

Basically, two strategies are commonly used by analysis centers to generate combined solutions. One is a constrained solution and the other is an unconstrained, also called "free network", solution. A constrained solution is achieved by tying ITRF stations with heavy weights into the network. This solution is successful if a priori and new coordinates are in a linear domain, otherwise the network will be distorted. The unconstrained solution, implementing a minimum constraints approach, preserves the original characteristics of the network and at the same time provides the alignment to ITRF (7-parameter transformation). Here, we will concentrate on the combination procedure and implementation strategy of SIRGA-CON network using an unconstrained solution.

The four regional solutions described before are combined on a weekly basis into a single SIRGAS-CON combination. Some overlap among these networks provides redundancy for outlier checking and enables the determination of correct relative weighting of the different solutions with respect to each other and to the global IGS weekly solution. The weekly SIRGAS-CON combinations are produced using Bernese software, version 5.0. The sub-network solution provided by INE is analyzed separately from the other centers because of different time span.

The combination strategy is divided into two main parts. The first part produces the unconstrained weekly SIRGAS-CON combination from each sub-network (center) and the second produces the unconstrained final combination from the results of the first part. The following steps describe the combination strategy:

1. Each sub-network solution (solution of each processing center) is aligned to a subset of fiducial stations from the IGS05 solution of epoch 2007.4 by No Net Translation (NNT) conditions. It means that each resulting combined solution is expressed in IGS05 at the central epoch of the sub-network solution.
2. Each sub-network solution's covariance matrix is scaled by the weighted root mean square (WRMS) of the residuals from the transformation in step 1. Typical scale factors are given in Table 2.
3. Residuals are tested for outliers which are removed from each sub-network solution and steps 1-2 are repeated again until all outliers are eliminated from each sub-network solution. This iterative process is to refine the estimation of variance factor. The threshold limits for coordinate repeatability residuals in north, east, and up components are 15 millimeters for east and north components and 30 millimeters for up component.
4. Compare each sub-network combined solutions with IGS05 in order to see network effects through transformation parameters;
5. All sub-network solutions are combined together to give a single combination solution.
6. The combined solution is re-aligned to a subset of fiducial stations from the IGS05 solution of epoch 2007.4 by No Net Translation (NNT) conditions. The covariance matrix of the combined solution is scaled by the WRMS of residuals from the transformation in step 6.
7. Residuals are tested for outliers which are removed from the regional solutions and steps 6-7 are repeated until no outliers remain in the combined solution.

Redundancy is an important consideration in the combination for detection of outliers and to ensure reliable alignments and covariance matrix scaling. In the SIRGAS-CON sub-networks combinations only a small percentage of the stations have redundant solutions, i.e., solutions in more than one regional network. Table 3 gives the number of common stations between all sub-networks from SIRGAS-CON combination. Table 4 summarizes the number of stations with redundant solutions.

Table 2: Covariance matrix scale factors for individual regional solutions.

Sub-network	n° of stations	Scale Factor
CPL	68	4.13
DGF	155	3.10
IBG	83	2.95
IGA	80	2.58
INE	24	0.656

Table 3: Number of stations processed by participating Processing Centers

Center	INE	IBG	IGA	SIR	CPL
INE	24	0	22	22	4
IBG		87	17	86	60
IGA			80	80	16
SIR				155	68
CPL					68

Table 4: Redundancy of solutions (N = number of centers processing a given station)

N	Stations
1	8
2	57
3	80
4	13
Total	158

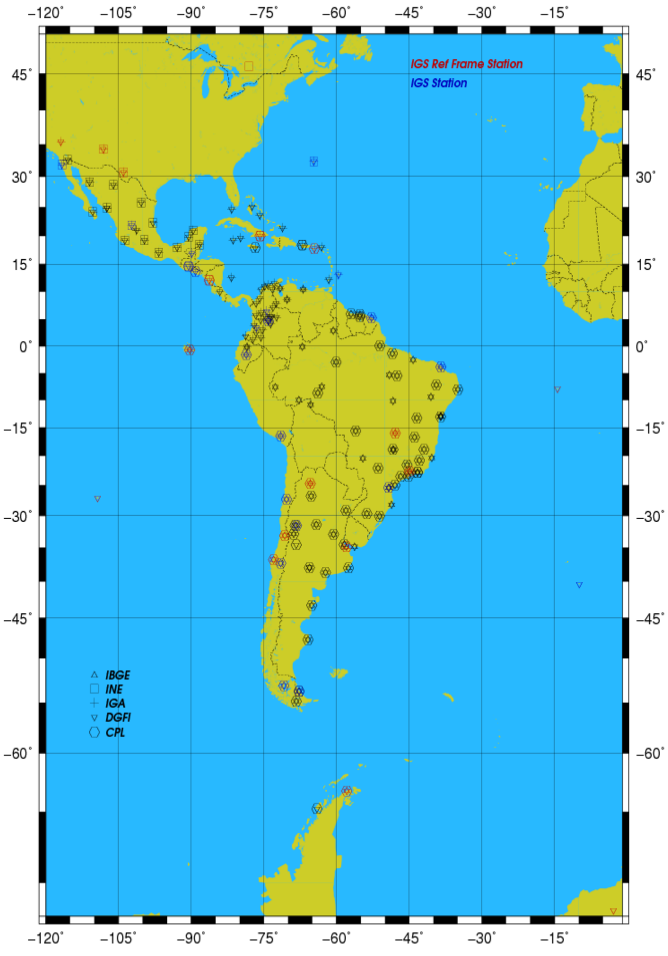


Figure 3: Stations processed by all Processing Centers (CPL, SIR, IBG, IGA, INE) a total of 158.

Problems found in each sub-network solution

CPL:

(1) Week solutions 1395 and 1457- a priori constraints matrix block incomplete in SINEX – matrix had to be regularized. NQ0 files from daily solutions were combined to weekly files and included in the combination.
(2) Many problems related with station information file, when using AMSUR.STA_20080417 as reference information.
(3) Station MZAS without domes number. Problem solved in station information file.
(4) Station RIO2 has wrong domes number. Problem solved in station information file.

SIR:

(1) Few problems related with station information file, when using AMSUR.STA_20080417 as reference information.
(2) Station UYMO without domes number in 2 solutions. Problem solved in station information file.
(3) Station UGTO with wrong domes number in 1 solution. Problem solved in station information file.
(4) Station UCOR with wrong domes number in 1 solution. Problem solved in station information file.
(5) Station LHCL with wrong domes number in 1 solution. Problem solved in station information file.
(6) Station MZAE with wrong domes number in all solutions. Problem solved in station information file.
(7) Stations EXU0, GRE0, GTK0, MIA3, NAS0 and SMRT with inadequate domes number. This was kept the way it is.

IBG:

(1) Many problems related with station information file, when using AMSUR.STA_20080417 as reference information.
(2) Station ANTC without domes number in one solution. Problem solved in station information file.
(3) Station MZAS without domes number. Problem solved in station information file.
(4) Station MZAE without domes number. Problem solved in station information file.
(5) Station LHCL without domes number in two solutions. Problem solved in station information file.
(6) Station MECO without domes number in two solutions. Problem solved in station information file.
(7) Station ONRJ without domes number in two solutions. Problem solved in station information file.

(8) Station POLI without domes number in nine solutions. They were excluded from the combination because was used the wrong antenna height.
(9) Station UNSJ without domes number in four solutions. Problem solved in station information file.
(10) Station UYMO without domes number in one solution. Problem solved in station information file.
(11) Stations MEDE, NEVA, POPA and YOPA were excluded from the combination. They are present in 8 weekly solutions.

IGA:

(1) Few problems related with station information file, when using AMSUR.STA_20080417 as reference information.
(2) Stations EXU0, GRE0, GTK0, NAS0 and SMRT with inadequate domes number. This was kept the way it is.
(3) Station UGTO with wrong domes number in 6 solutions. Problem solved in station information file.
(4) Station FQNE with wrong domes number in 1 solution. Problem solved in station information file.

Outlier Rejection in each sub-network (in each processing center solution)

The stations listed in the tables below had their results eliminated from one or more sub-networks solutions due to outlier rejection. Residuals exceeding the threshold of 15 millimeters in East and North component, and 30 millimeters in up component were rejected.

CPL:

Station	Week(s)	Solution(s) / comp. / Residual
BELE	1409 and 1410	15 U 32.01 16 E 35.44
BOGT	1396	2 U 33.91
BOMJ	1439, 1440 and 1460	45 U 53.23 46 U 53.30 66 U 43.81
JAMA	1429	48 N 107.63 48 E -371.06
MANA	1435	41 U -43.97
MZAS	1425	31 U -31.07
NAUS	1429 and 1430	35 U -30.72 36 U -31.86
OHI2	1396	2 U 35.91
POAL	1447	53 U -63.31
PUR3	1419 and 1420	25 U 79.35 26 U 90.09

Important observations: CONZ station has outlier rejection in East component of 11 solutions (1, 2, 3, 4, 64, 66, 67, 68, 69, 70 and 71). These observations were kept in the solution.

GLPS station has outlier rejection in East component of 40 solutions. The residuals variation was from -15.07 until -33.0 millimeters. These observations were kept in the solution.

<u>SIR:</u>

Station	Week(s)	Solution(s) / comp. / Residual
BDOS	1405	11 U -40.49
BELE	1411 and 1414	17 E 30.77 20 U 35.79
BOMJ	1438	44 U 53.16
GOUG	1396 to 1399	1 U -84.22 2 U -137.27 3 U -130.84 4 U -107.32 5 U -120.95
MANA	1397 and 1435	3 U 71.27 41 U -54.99
NAUS	1429 to 1431	35 U -30.15 36 U -34.18 37 U -30.44
OHI2	1395 and 1396	1 U 71.45 2 U 52.05
SAMA	1455	61 U -40.32
SSIA	1426	32 N -47.70 32 E 35.39
CRAT	1428	34 U 37.12

Important observations:

BDOS station has outlier rejection in East component of 9 solutions (1, 2, 3, 4, 5, 6 ,7 ,8 and 16). These observations were kept in the solution.

BOGA station has outlier rejection in Up component of 19 solutions. The residuals variation was from -30.07 until -43.48 millimeters. These observations were kept in the solution.

CIC1 station has outlier rejection in East and North components of 20 solutions. The residuals variation was from -15.00 until -23.9 millimeters. These observations were kept in the solution.

CONZ station has outlier rejection in East component of 26 solutions. The residuals variation was from 15.12 until -25.18 millimeters. These observations were kept in the solution.

GLPS station has outlier rejection in East component of 43 solutions. The residuals variation was from 24.33 until -44.91 millimeters. These observations were kept in the solution.

GOUG station has outlier rejection in East component of 6 solutions. The residuals variation was from -28.32 until -40.52 millimeters. These observations were kept in the solution.

ISPA station has outlier rejection in East component of 13 solutions. The residuals variation was from -31.45 until -48.92 millimeters. These observations were kept in the solution.

LPAZ station has outlier rejection in East component of 32 solutions. The residuals variation was from 41.87 until -20.56 millimeters. These observations were kept in the solution.

OAX2 station has outlier rejection in Up component of 9 solutions. The residuals variation was from 33.88 until 37.44 millimeters. These observations were kept in the solution.

IBG:

Station	Week(s)	Solution(s) / comp. / Residual
BELE	1409	15 N 18.54
BOGT	1397, 1400	3 U -30.79 6 U -35.23 11 U -32.81 14 U -31.37
MZAS	1424 and 1427	30 U 45.78 31 U 46.45 32 U 47.25 33 U 42.97
NAUS	1427 and 1428	33 U 49.67 34 U 44.72
UNSA	1458	53 U 32.15

Important observations:
CONZ station has outlier rejection in East component of 15 solutions. The residuals variation was from -17.11 until 17.46 millimeters. These observations were kept in the solution.
GLPS station has outlier rejection in East component of 38 solutions. The residuals variation was from 31.71 until -31.11 millimeters. These observations were kept in the solution.

IGA:

Station	Week(s)	Solution(s) / comp. / Residual
BOGT	1465	71 U -31.50
FLOR	1421	27 E 24.54 27 U 33.49
PUR3	1420	26 U 66.13
SAMA	1455	61 U -42.29
SCUB	1444	50 U -33.50

Important observations:
BDOS station has outlier rejection in East component of 5 solutions. The residuals variation was from -16.97 until 16.27 millimeters. These observations were kept in the solution.
BOGA station has outlier rejection in Up component of 19 solutions. The residuals variation was from -43.72 until 34.09 millimeters. These observations were kept in the solution.
CIC1 station has outlier rejection in East and North components of 20 solutions. The residuals variation was from -15.00 until 31.71 millimeters. These observations were kept in the solution.
GLPS station has outlier rejection in East component of 38 solutions. The residuals variation was from 33.96 until -35.56 millimeters. These observations were kept in the solution.
LPAZ station has outlier rejection in East component of 26 solutions. The residuals variation was from 27.99 until -27.35 millimeters. These observations were kept in the solution.

OAX2 station has outlier rejection in Up component of 9 solutions. The residuals variation was from 32.22 until 36.53 millimeters. These observations were kept in the solution.

INE:

(1) SINEX weekly solutions had to be regularized. This happens when the SINEX does not contain a regular (invertable) constraint matrix, then a warning is issued and the constraint matrix is regularized (by adding an epsilon to the elements). The NEQ obtained is always a free NEQ, i.e. the constraints are removed.
(2) No problems related with station file information;
(3) Few IGS reference stations in this solution.

No outlier rejection was performed in this solution, because of high root mean square repeatability in great part of stations, mainly in East component. This problem might be caused by wrong SINEX manipulations.

SIRGAS-CON Sub-networks Combination Results

A total of 71 weeks (from 1395 (Oct 2006) to 1465 (Feb 2008)) of SIRGAS-CON sub-networks have been combined using the procedure presented before in this report.

The comparison between week time series solutions from a certain sub-network (center) and the combined solution of each sub-network is analyzed by the estimation of seven-parameter Helmert transformation in order to check the fit of each week solution with the combined one. Table 5 summarizes the results of each sub-network showing the mean and standard deviation values of each sub-network solution.

SOL		RMS(m)	TX(m)	TY(m)	TZ(m)	ROT_X(")	ROT_Y(")	ROT_Z(")	SCL(ppm)
CPL	MEAN	0,00458	0,0003	-0,0009	-0,0002	0	0	0	-0,00002
	STDDEV	0,00074	0,0056	0,0047	0,0084	0,0003	0,0003	0,0002	0,00052
SIR	MEAN	0,00525	0,0003	-0,0009	-0,0002	0	0	0	-0,00002
	STDDEV	0,00147	0,0056	0,0047	0,0084	0,0003	0,0003	0,0002	0,00052
IBG	MEAN	0,00425	0,0003	-0,0009	-0,0002	0	0	0	-0,00002
	STDDEV	0,00074	0,0056	0,0047	0,0084	0,0003	0,0003	0,0002	0,00052
IGA	MEAN	0,00471	0,0003	-0,0009	-0,0002	0	0	0	-0,00002
	STDDEV	0,00138	0,0056	0,0047	0,0084	0,0003	0,0003	0,0002	0,00052

Table 5: Mean and Standard deviation of transformation parameters between weekly solutions of each sub-network to combined sub-network solution.

As can be seen, rotation and scale are meaningless in these results. Translations and RMS do not have sensible differences. A high scale value is observed in the first 5 solutions of SIR processing center, as shown in Figure 4. Figure 5 presents the RMS of transformation in each processing center.

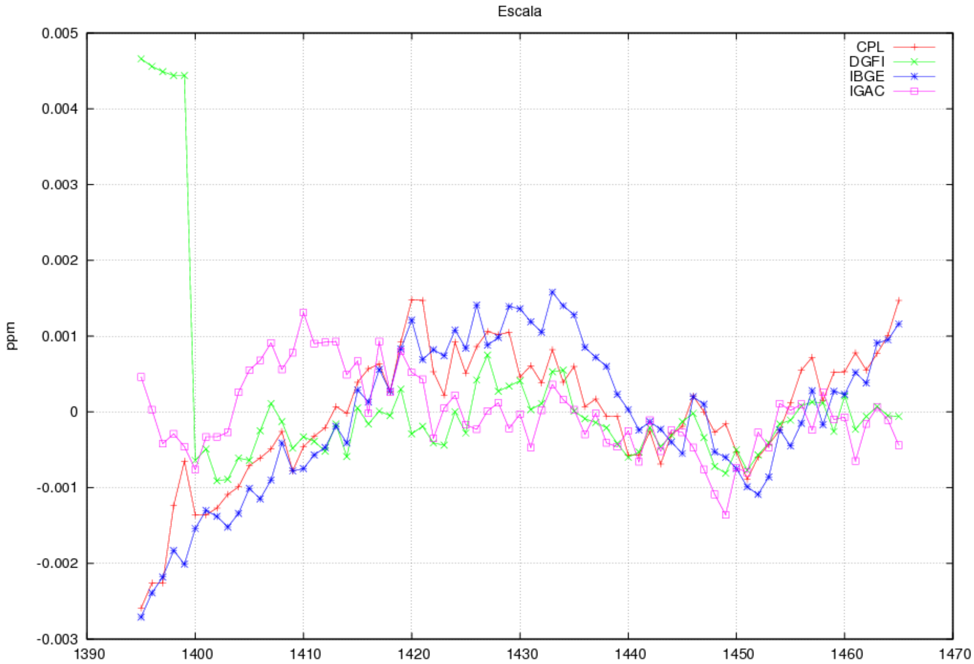


Figure 4: Scale estimated in the weekly solution of each processing center.

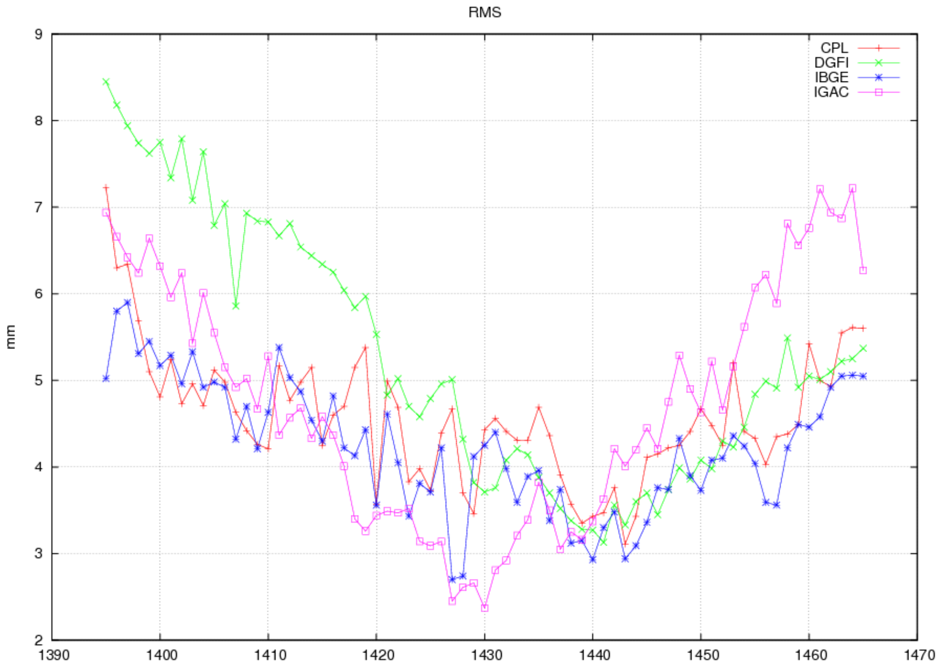
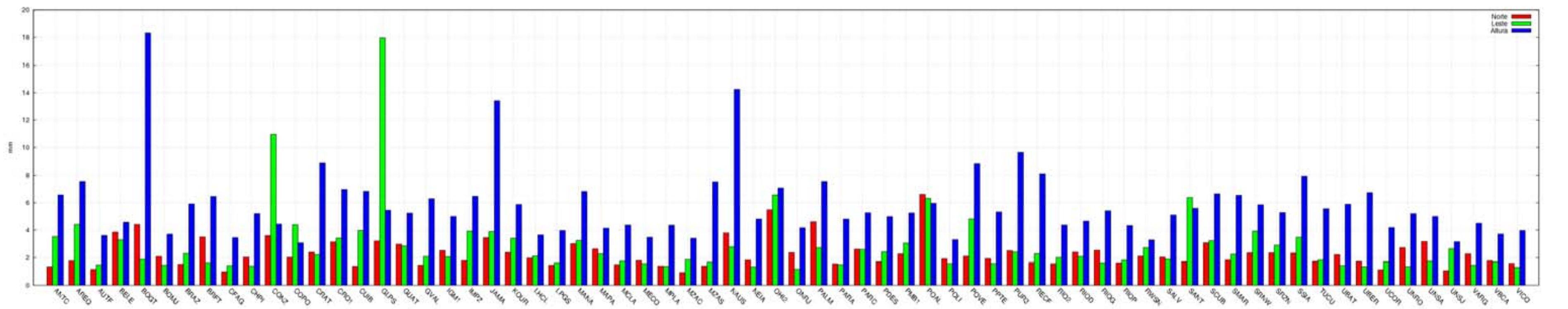
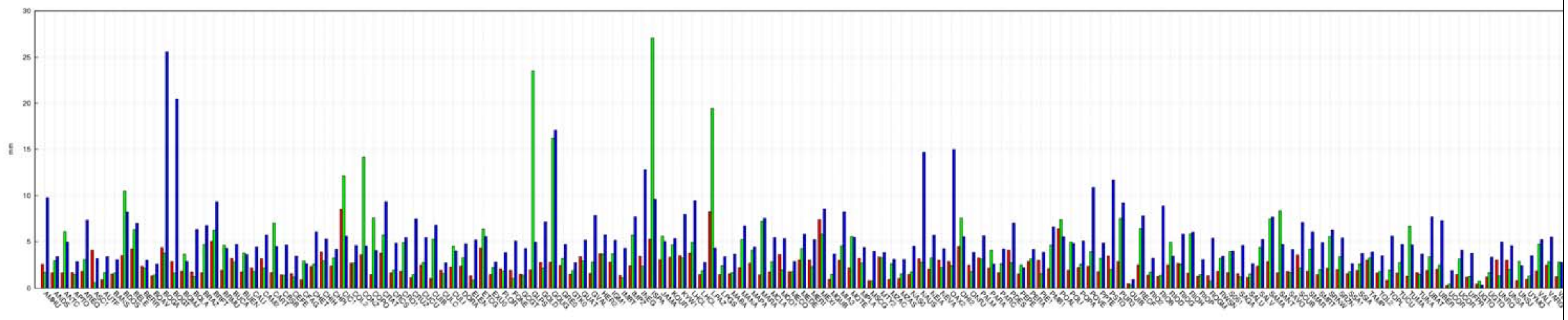


Figure 5: RMS of transformation between weekly solution of each sub-network to the combined solution of each processing center.

The repeatability RMS values of each station in each sub-network solution is given in Figure 6. The stations with RMS higher than 10 mm in the Up component are: BOGA, BOGT, GOUG, NAUS and OAX2. The stations with RMS higher than 10 mm in the East component are: CONZ, GLPS, ISPA and LPAZ.

CPL	
SIR	

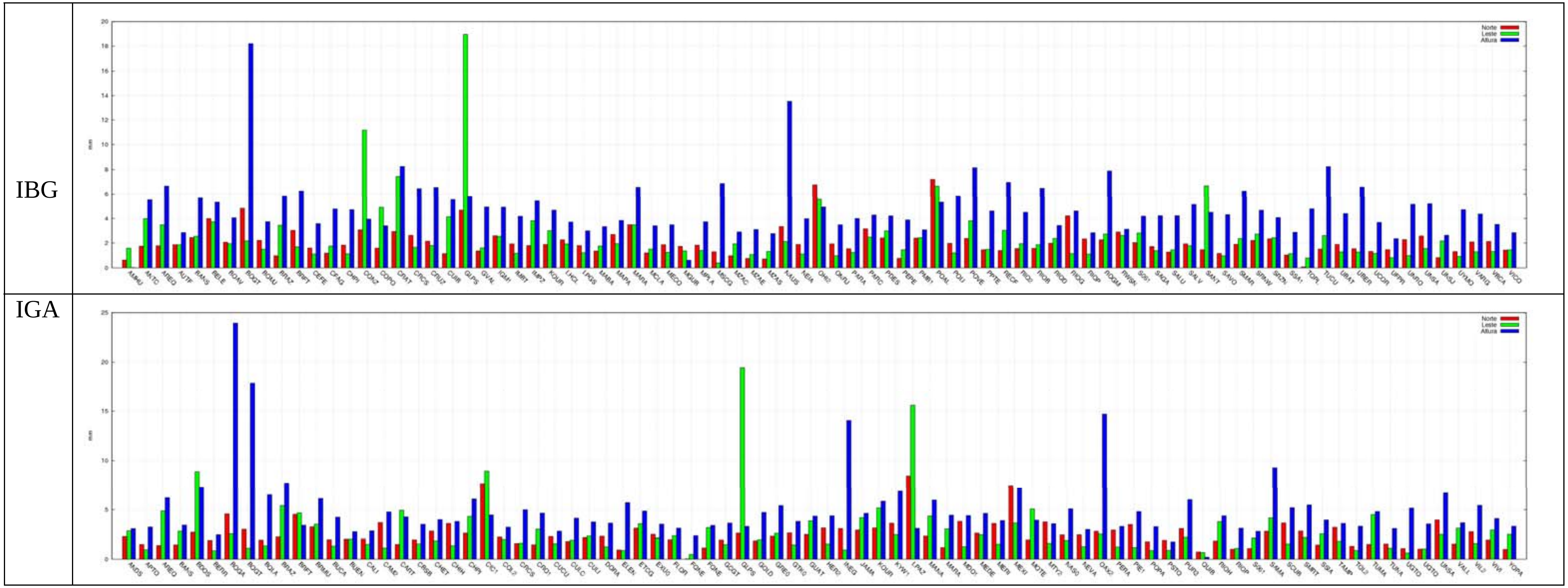


Figure 6: RMS of residual station repeatability in each sub-network solution.

Over all of these weeks the RMS of the residuals for each sub-network solution are about 3 mm for north and east component and 5 mm vertically.

Table 6 : Transformation parameters between IGS05(epoch 2007,4) and each sub-network combination.

SOL.	RMS (mm)	TX (mm) / σ ±	TY (mm) / σ ±	TZ (mm) / σ ±	ROT_X / σ ± (")	ROT_Y / σ ± (")	ROT_Z / σ ± (")	SCL / σ ± (ppm)
CPL	3.4	-5.5 / 4.0	-4.0 / 2.4	3.7 / 2.3	-0.00011 /0.00007	-0.00003/ 0.00008	-0.00024/ 0.00014	0.0005/ 0.0003
SIR	4.7	1.7 / -2.6	2.5 / 1.8	-3.4 / 2.1	0.00012/ 0.00007	0.00003/ 0.00007	0.00008/ 0.00010	0.0005/ 0.0003
IBG	2.3	-9.9 / -3.3	-12.6 / 2.4	15.5 / 2.4	- 0.00054/ 0.00008	0.00005/ 0.00008	- 0.00037/ 0.00010	0.0005/ 0.0003
IGA	4.2	2.4 / 4.8	2.0 / 2.9	0.2 / 4.7	- 0.00000 /0.00017	- 0.00005/ 0.00009	0.00014/ 0.00018	0.0004/ 0.0004

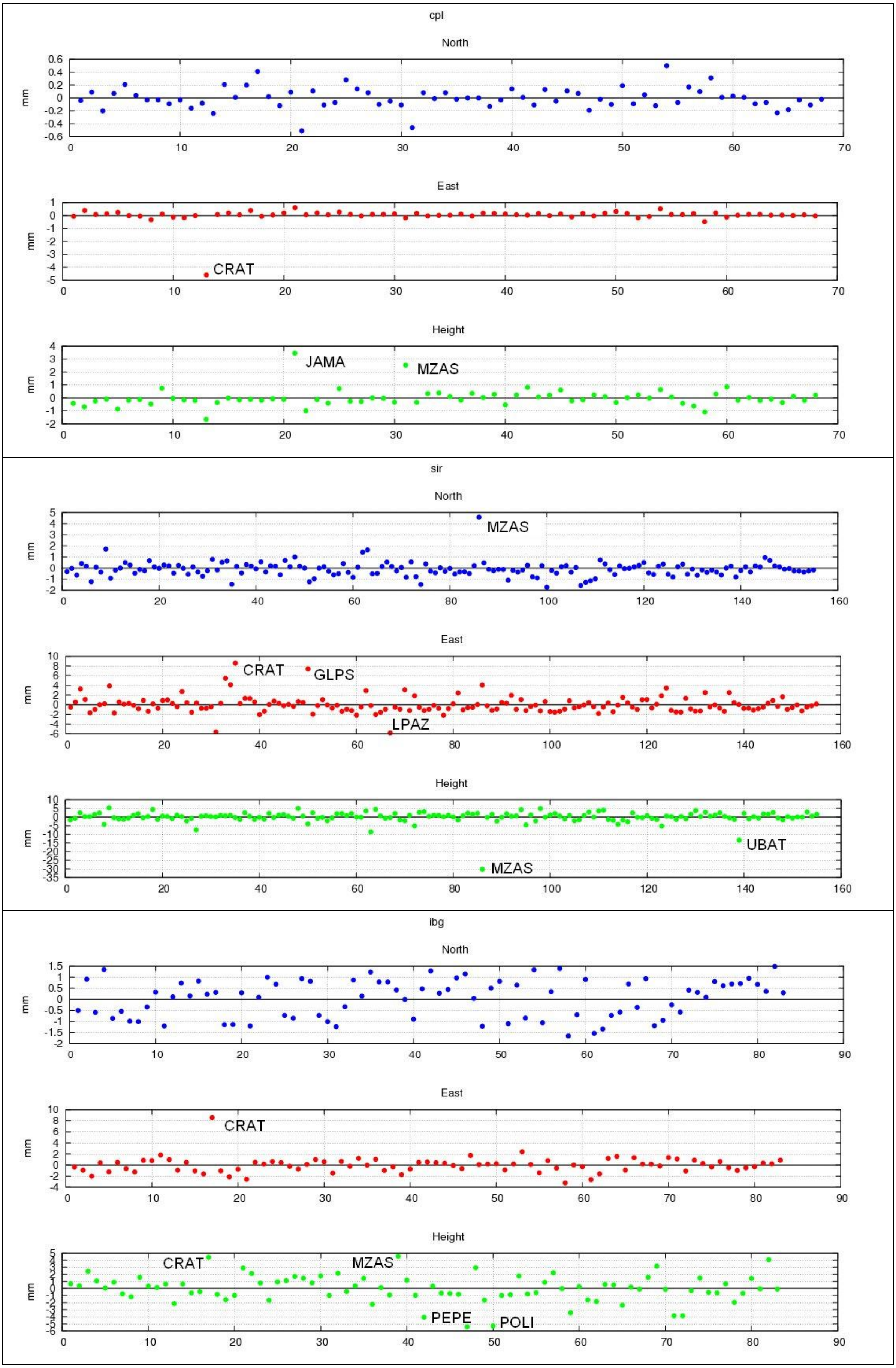
Table 6 presents the transformation parameters estimated between IGS05(epoch 2007,4) and each sub-network combination, in order to check the external fit of each sub-network results. As can be seen, rotation and scale are meaningless in these results, translations values are bigger in IBG solution, RMS of transformation confirm the good agreement of these solutions with IGS05.

SIRGAS-CON Combined Solution Results

The SIRGAS-CON sub-network combination solution was estimated using the same methodology for weekly combination, as described in the SIRGAS-CON combination strategy. The MVC matrix of each processing center was scaled with the value of variance factor presented on Table 2. The main aspects of final combination are:

Alignment method: Minimal constraint conditions on fiducial stations by No Net Translation (NNT) conditions
Reference Frame: ITRF2005/IGS05
Reference epoch (the middle of the time interval):2007-06-06, 00:00:00(2007.4)
Fiducial stations: BRAZ, CHPI, CONZ, CRO1, LPGS, MANA, MDO1, OHI2, SANT, SCUB and UNSA

The residuals of station repeatability obtained in the final solution are presented on Figure 7. Some interesting cases can be seen in this Figure, for example station CRAT presents big residuals with different signals in the solutions CPL and IBG, the same happens with station MZAS, where solution SIR, doesn't agree with residuals of solutions CPL and IBG. The residuals RMS of critical stations are presented on Figure 8.


cpl
North
East
CRAT
Height
JAMA
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sir
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ibg
North
East
CRAT
Height
CRAT
MZAS
PEPE
POLI
mm

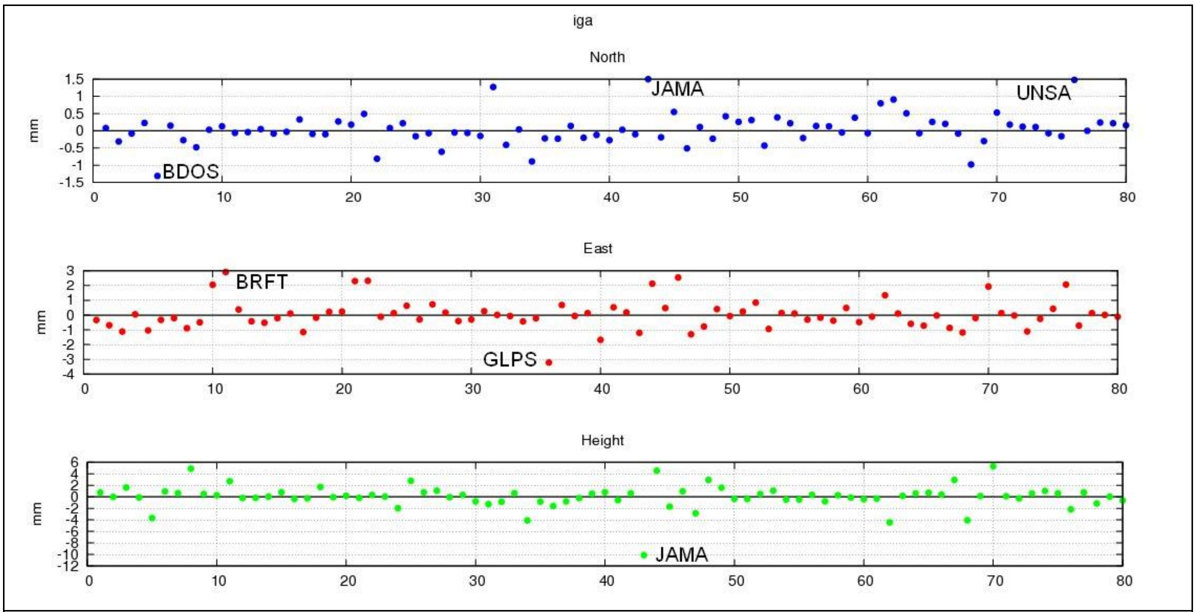


Figure 7: The residuals of station repeatability obtained in the final combination

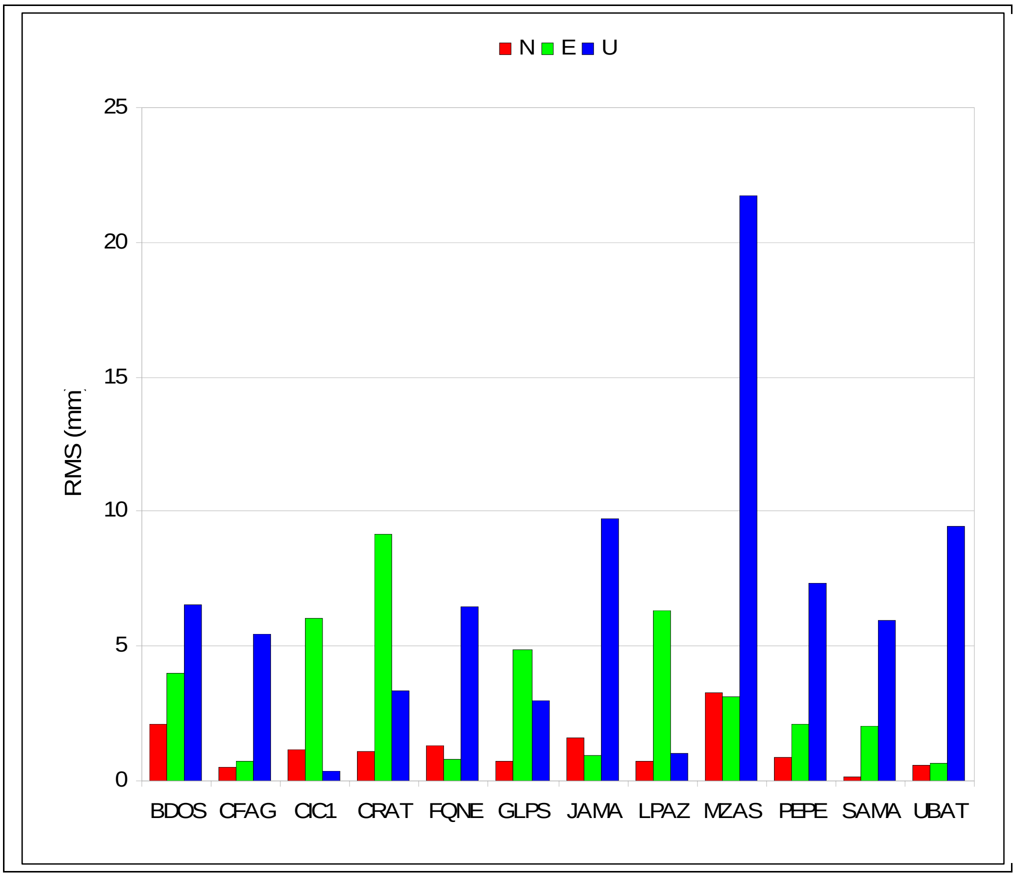


Figure 8: Higher RMS of residuals of station repeatability in the final combination.

The transformation parameters between sub-network solutions and the final combination (minimum constraint solution) are presented in Table 7. The transformation RMS of 1 mm indicates a good internal agreement between solutions.

Table 7: Transformation parameters between sub-network solutions to the final combination.

SOL		RMS(m)	TX(m)	TY(m)	TZ(m)	ROT_X(")	ROT_Y(")	ROT_Z(")	SCL(ppm)
1	CPL	0,00054	0,0005	-0,0009	0,0004	0,0000	0,0000	0,0000	-0,00001
2	SIR	0,00226	0,0011	-0,0023	-0,0005	0,0000	0,0000	0,0000	0,00005
3	IBG	0,00147	-0,0015	-0,0014	-0,0061	0,0001	0,0001	0,0000	-0,00043
4	IGA	0,00134	0,0006	-0,0024	-0,0006	0,0001	0,0000	0,0000	-0,00017
	MEAN	0,00140	0,0002	-0,0018	-0,0017	0,0001	0,0000	0,0000	-0,0001
	STD.DEV	0,00070	0,0011	0,0007	0,0030	0,0001	0,0001	0,0000	0,0002

Table 8 presents the transformation parameters estimated between the final combination and IGS05 solution propagated to epoch 2007.4, in order to check the external fit of combination. As can be seen, rotation and scale are meaningless in these results, translations values as well as, RMS of transformation confirm the good agreement of this solution with IGS05.

Table 8: Transformation parameters between IGS05(epoch 2007,4) and the final combination.

RMS (mm)	TX (mm) / σ ±	TY (mm) / σ ±	TZ (mm) / σ ±	ROT_X / σ ± (")	ROT_Y / σ ± (")	ROT_Z / σ ± (")	SCL / σ ± (ppm)
4.4	2.0 / 2.5	2.0 / 1.7	-3.4 / 2.0	0.00014 /0.00007	- 0.00004 /0.00006	0.00009 /0.00010	0.0006 /0.0003

Final Considerations

A total of 156 stations were available for the final solution of four processing centers. The results were satisfactory even considering the problems related to antenna/receiver identifications as well as related to antenna height.

Some organization needs to be done for all processing centers to use the same identification for receiver/antenna as well as antenna height. It’s suggested to make available a station information file and Ocean loading file. File updates are in the responsibility of the network coordinator. Radome codes need to be supplied.

More IGS stations should be included in the solutions of processing centers, this is the case of IBGE, in order to have the redundancy of five or more IGS stations in different sub-networks.

Add more redundant solutions for as many stations as possible, especially those in the SIRGAS-CON network. Many SIRGAS-CON stations are only in one regional solution and therefore have no independent quality control checks

ANEX A

Name	SIR	IBG	IGA	INE	CPL	#Solutions	#Centers	Receiver	Antenna Radome		Antenna Height (m)
RIOP	25	21	19		21	86	4	TRIMBLE 4000SSI	TRM29659.00	NONE	0.0729
PUR3	25		20	24	26	95	4	ASHTECH Z-XII3	ASH700829.3		0.0000
									ASH700829.3	SNOW	
MANA	64		64	29	55	212	4	TRIMBLE 4000SSI	TRM29659.00		0.0000
									TRM29659.00	UNAV	
BRFT	69	67	64		63	263	4	LEICA GRX1200PRO	LEIAT504		0.0083
									LEIAT504	NONE	
BOGT	67	66	64		65	262	4	ASHTECH UZ-12	ASH701945G_M	NONE	0.0610
UNSA	67	67	67		66	267	4	ASHTECH Z-XII3	AOAD/M_T		0.0460
									AOAD/M_T	NONE	
SCUB	69		69	33	67	238	4	ASHTECH Z-XII3	ASH700936C_M	SNOW	0.0460
									ASH700936C_M		
KOUR	69	69	69		68	275	4	ASHTECH UZ-12	ASH701945C_M		0.0450
								JPS LEGACY	ASH701945C_M	NONE	
BRAZ	71	71	69		68	279	4	TRIMBLE 4000SSI	AOAD/M_T		0.0080
								TRIMBLE NETRS	TRM41249.00	NONE	
GUAT	69		68	34	69	240	4	TRIMBLE 4000SSI	TRM29659.00		0.0000
									TRM29659.00	UNAV	
GLPS	71	70	71		69	281	4	ASHTECH Z-XII3	ASH701945B_M		0.0083
									ASH701945B_M	SCIT	
CHPI	71	70	71		70	282	4	ASHTECH UZ-12	ASH701945C_M		0.0792
									ASH701945C_M	NONE	
AREQ	71	71	71		70	283	4	ASHTECH UZ-12	AOAD/M_T	JPLA	0.0610
AUTF	6	14			8	28	3	ASHTECH Z-XII3	ASH700936D_M		0.0000
RIOG	22	21			22	65	3	ASHTECH Z-XII3	ASH700936C_M		0.0350
									ASH700936C_M	SNOW	
PDES	27	23			26	76	3	LEICA RS500	LEIAT504	LEIS	0.0000
LHCL	41	35			29	105	3	TRIMBLE NETRS	ASH700936D_M	SNOW	0.0000
PARA	32	32			32	96	3	TRIMBLE 4000SSI	TRM29659.00		0.1550
									TRM29659.00	NONE	
JAMA	34		34		35	103	3	ASHTECH UZ-12	AOAD/M_TA_NGS	SNOW	0.0000
COPO	36	33			36	105	3	ASHTECH Z-XII3	ASH700936D_M	SNOW	0.0000
UNSJ	40	44			38	122	3	ASHTECH Z-XII3	TRM41249.00	NONE	0.0000
RIO2	33	38			39	110	3	ASHTECH Z-XII3	ASH700936C_M	SNOW	0.0350
ANTC	43	41			39	123	3	ASHTECH Z-XII3	ASH700936D_M	SNOW	0.0000
MZAS	40	41			40	121	3	TRIMBLE NETRS	TRM41249.00	NONE	0.0000
MPLA	46	40			40	126	3	LEICA MC1000	LEIAT504	LEIS	0.0000
POLI	49	58			40	147	3	LEICA GRX1200	LEIAX1202	NONE	0.0500
SSIA	43		42		41	126	3	TRIMBLE 4000SSI	TRM29659.00	UNAV	0.0000
								TRIMBLE NETRS			
ONRJ	45	44			41	130	3	TRIMBLE NETRS	TRM41249.00	NONE	0.0080

Name	SIR	IBG	IGA	INE	CPL	#Solutions	#Centers	Receiver	Antenna Radome	Antenna Height (m)
PARC	57	42			43	142	3	ASHTECH Z-XII3	ASH700936D_M	0.0000
								TRIMBLE NETRS	ASH700936D_M SNOW	
POAL	51	47			45	143	3	TRIMBLE 4000SSI	TRM29659.00	0.0075
									TRM29659.00 NONE	
								TRIMBLE NETR5	TRM55971.00 NONE	
									TRM29659.00 NONE	
PMB1	38	63			52	153	3	TRIMBLE NETRS	TRM41249.00 NONE	0.0000
BOMJ	55	51			52	158	3	TRIMBLE 4000SSI	TRM29659.00	0.0080
									TRM29659.00 NONE	
								TRIMBLE NETR5	TRM55971.00 NONE	
CRAT	58	56			53	167	3	TRIMBLE 4000SSI	TRM29659.00	0.0070
									TRM29659.00 NONE	
								TRIMBLE NETR5	TRM55971.00 NONE	
SRZN	40	66			54	160	3	TRIMBLE NETRS	TRM41249.00 NONE	0.0000
SRNW	42	67			55	164	3	TRIMBLE NETRS	TRM41249.00 NONE	0.0000
BELE	61	57			55	173	3	TRIMBLE 4000SSI	AOAD/M_T	0.0075
									AOAD/M_T NONE	
								TRIMBLE NETRS	TRM41249.00 NONE	
IMPZ	62	57			56	175	3	TRIMBLE 4000SSI	TRM29659.00	0.0080
									TRM29659.00 NONE	0.0070
								TRIMBLE NETR5	TRM55971.00 NONE	0.0080
POVE	61	59			57	177	3	TRIMBLE 4000SSI	TRIMBLE 4000SSI	0.0075
									TRM29659.00 NONE	
								TRIMBLE NETR5		
UBAT	62	62			58	182	3	TRIMBLE 4000SSI	TRM29659.00	0.0000
									TRM29659.00 NONE	
VBCA	52	41			59	152	3	LEICA SR9500	LEIAT303	1.0707
									LEIAT303 NONE	
VICO	63	62			61	186	3	TRIMBLE 4000SSI	TRM29659.00	0.0160
									TRM29659.00 NONE	
								TRIMBLE NETR5	TRM55971.00 NONE	0.0080
MECO	66	67			64	197	3	TRIMBLE NETRS	TRM41249.00 TZGD	0.5350
NAUS	67	65			64	196	3	TRIMBLE NETRS	TRM41249.00	0.0080
									TRM41249.00 NONE	
RECF	67	66			64	197	3	TRIMBLE 4000SSI	TRM29659.00	0.0700
									TRM29659.00 NONE	
								TRIMBLE NETR5	TRM55971.00 NONE	0.0710
MAPA	69	65			64	198	3	TRIMBLE 4000SSI	TRM29659.00	0.0880
									TRM29659.00 NONE	
								TRIMBLE NETRS		
OHI2	66	66			65	197	3	AOA SNR-8000 ACT	AOAD/M_T	-0.0080
									AOAD/M_T DOME	
								JPS E_GGD		

Name	SIR	IBG	IGA	INE	CPL	#Solutions	#Centers	Receiver	Antenna	Radome	Antenna Height (m)
UCOR	70	67			65	202	3	TRIMBLE 4000SSE	TRM14532.00		0.0000
									TRM14532.00	NONE	
NEIA	67	67			66	200	3	TRIMBLE 4000SSI	TRM29659.00		0.0000
									TRM29659.00	NONE	
SMAR	70	70			67	207	3	TRIMBLE 4000SSI	TRM29659.00		0.0080
									TRM29659.00	NONE	
								TRIMBLE NETRS	TRM41249.00	NONE	
TUCU	70	70			67	207	3	TRIMBLE NETRS	ASH700936C_M	SNOW	0.0000
								ASHTECH Z-XII3	ASH700936D_M	SNOW	
UBER	70	70			67	207	3	ASHTECH UZ-12	ASH700700.B		0.0400
									ASH700700.B	NONE	
OHI2	66	66			65	197	3	AOA SNR-8000 ACT	AOAD/M_T		-0.0080
UNRO	71	66			67	204	3	ASHTECH Z-XII3	ASH700700.B		0.0000
									ASH700700.B	NONE	0.0000
									TRM41249.00	NONE	
CFAG	71	71			67	209	3	ASHTECH Z-XII3	ASH700936D_M		
									ASH700936D_M	NONE	
RWSN	68	67			68	203	3	ASHTECH UZ-12	ASH700936D_M		0.0000
									ASH700936D_M	NONE	
LPGS	70	70			69	209	3	AOA BENCHMARK AC	AOAD/M_T		0.0460
								AOA BENCHMARK ACT	AOAD/M_T	NONE	
GVAL	71	71			69	211	3	ASHTECH UZ-12	ASH700700.B		0.0500
									ASH700700.B	NONE	
MCLA	71	71			69	211	3	ASHTECH UZ-12	ASH700700.B		0.0600
									ASH700700.B	NONE	
VARG	71	71			69	211	3	ASHTECH UZ-12	ASH700700.B		0.0650
									ASH700700.B	NONE	
CRO1	69		71		70	210	3	ASHTECH UZ-12	ASH701945G_M		0.0814
									ASH701945G_M	JPLA	
IGM1	71	69			70	210	3	ASHTECH UZ-12	ASH700936C_M		0.0000
									ASH700936C_M	SNOW	
								TRIMBLE NETRS	ASH700936D_M	SNOW	
CONZ	71	71			70	212	3	TPS E_GGD	TPSCR3_GGD		0.0574
									TPSCR3_GGD	CONE	
CUIB	71	71			70	212	3	TRIMBLE 4000SSI	TRM29659.00		0.0080
									TRM29659.00	NONE	
								TRIMBLE NETRS	TRM41249.00	NONE	
MZAC	71	71			70	212	3	ASHTECH Z-XII3	ASH701933C_M	SNOW	0.0000
PPTE	71	71			70	212	3	TRIMBLE NETRS	TRM41249.00		0.0025
									TRM41249.00	NONE	
RIOD	71	71			70	212	3	TRIMBLE 4000SSI	TRM29659.00		0.0080
									TRM29659.00	NONE	
								TRIMBLE NETRS	TRM41249.00	NONE	

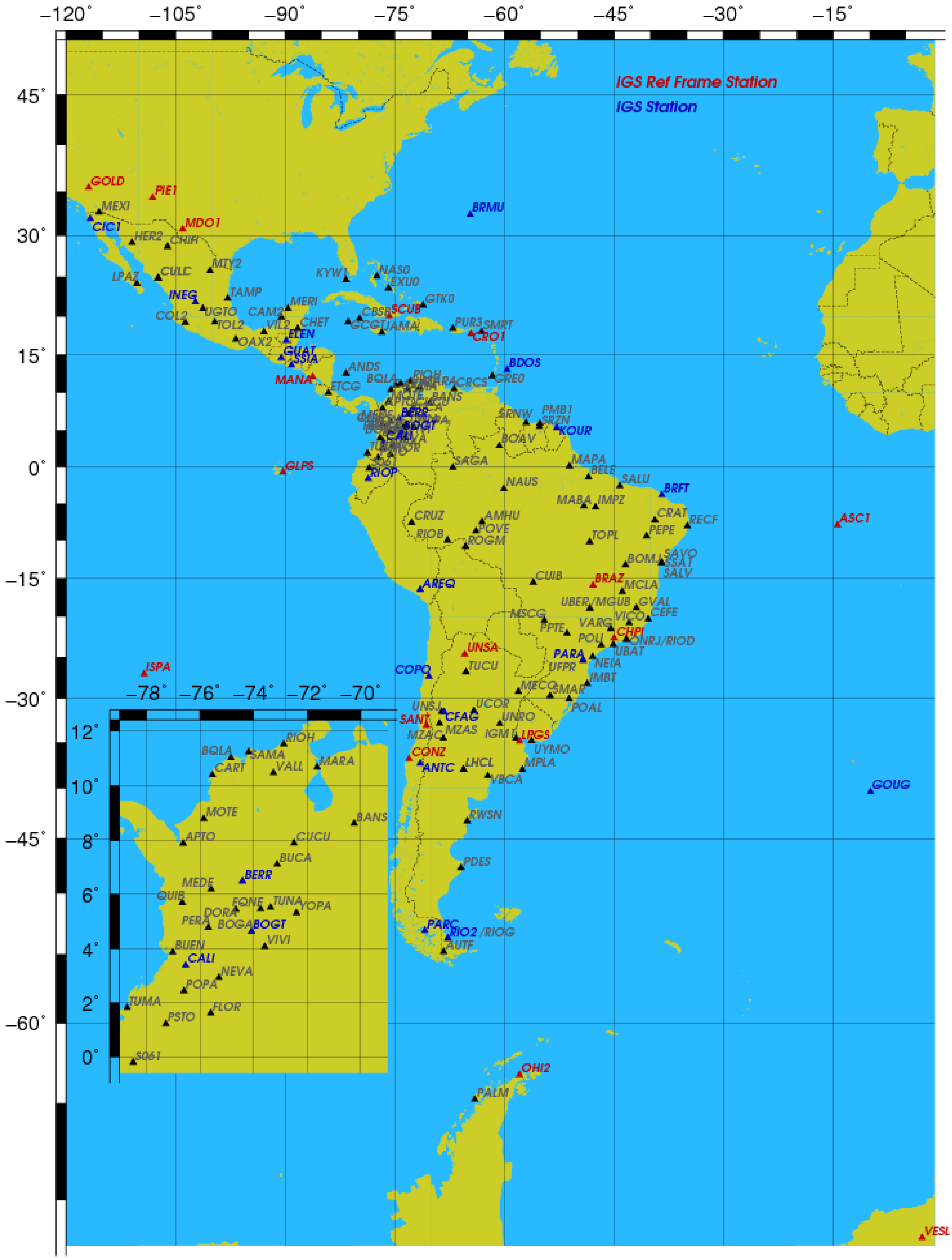
Name	SIR	IBG	IGA	INE	CPL	#Solutions	#Centers	Receiver	Antenna Radome	Antenna Height (m)
SANT	71	71			70	212	3	ASHTECH Z-XII3	AOAD/M_T	0.0614
									AOAD/M_T JPLA	
PIE1	30		52	18		100	3	ASHTECH UZ-12	ASH701945E_M NONE	0.0610
CULI	40		41	34		115	3	TRIMBLE 5700	TRM41249.00	0.0827
									TRM41249.00 NONE	
BANS	50	59	39			148	3	TRIMBLE 5700	TRM29659.00	0.0000
									TRM29659.00 NONE	
CRCS	54	69	46			169	3	TRIMBLE 5700	TRM29659.00	0.0160
									TRM29659.00 NONE	
YOPA	56	7	56			119	3	LEICA GRX1200	LEIAT504 LEIS	0.0000
MDO1	56		70	34		160	3	ROGUE SNR-8000	AOAD/M_T JPLA	0.0610
VIL2	58		71	34		163	3	TRIMBLE 5700	TRM41249.00	0.0707
									TRM41249.00 NONE	
CIC1	59		61	25		145	3	ROGUE SNR-8000	AOAD/M_T NONE	0.0793
TAMP	59		70	34		163	3	TRIMBLE 5700	TRM41249.00	0.0947
OHI2	66	66			65	197	3	AOA SNR-8000 ACT	AOAD/M_T	-0.0080
									AOAD/M_T DOME	
								JPS E_GGD		
MEDE	61	4	60			125	3	LEICA GRX1200	LEIAT504 LEIS	0.0000
								ASHTECH UZ-12	ASH701945E_M SNOW	
BRMU	67		67	31		165	3	TRIMBLE 5700	TRM29659.00	0.0000
									TRM29659.00 UNAV	
POPA	69	7	69			145	3	LEICA GRX1200	LEIAT504 LEIS	0.0000
S061	70	37	53			160	3	ASHTECH Z-XII3	ASH700936B_M SNOW	0.0000
TOL2	70		70	34		174	3	TRIMBLE 5700	TRM41249.00	0.0947
									TRM41249.00 NONE	
INEG	70		71	34		175	3	TRIMBLE 4700	TRM29659.00	0.0705
									TRM29659.00 NONE	
NEVA	71	8	71			150	3	LEICA GRX1200	LEIAT504 LEIS	0.0000
MARA	71	56	52			179	3	LEICA SR9500	LEIAT303	0.0450
									LEIAT303 NONE	
LPAZ	71		70	34		175	3	TRIMBLE 5700	TRM41249.00	0.0817
									TRM41249.00 NONE	
MERI	71		70	34		175	3	TRIMBLE 5700	TRM41249.00	0.0817
									TRM41249.00 NONE	
CAM2	71		71	34		176	3	TRIMBLE 5700	TRM41249.00	0.0807
									TRM41249.00 NONE	
CHET	71		71	34		176	3	TRIMBLE 5700	TRM41249.00	0.0898
									TRM41249.00 NONE	
COL2	71		71	34		176	3	TRIMBLE 5700	TRM41249.00	0.1067
									TRM41249.00 NON	
HER2	71		71	34		176	3	TRIMBLE 5700	TRM41249.00	0.1767
									TRM41249.00 NONE	

Name	SIR	IBG	IGA	INE	CPL	#Solutions	#Centers	Receiver	Antenna	Radome	Antenna Height (m)
MEXI	71		71	34		176	3	TRIMBLE 5700	TRM41249.00		0.0837
									TRM41249.00	NONE	
MTY2	71		71	34		176	3	TRIMBLE 5700	TRM41249.00		0.0857
									TRM41249.00	NONE	0.0860
AX2	71		71	34		176	3	TRIMBLE 5700	TRM41249.00		0.1317
									TRM41249.00	NONE	
PALM	71				70	141	2	ASHTECH Z-XII3	ASH700936D_M	SCIS	0.0794
QUIB	1		1			2	2	TPS GB-1000	TPSCR4	CONE	0.0000
AMHU	2	1				3	2	NETR5	TRM55971.00	NONE	0.0080
TOPL	3	1				4	2	TRIMBLE NETRS	TRM41249.00	NONE	0.0080
MGUB	4	2				6	2	TRIMBLE NETR5	TRM55971.00	NONE	0.0080
MSCG	4	2				6	2	TRIMBLE NETR5	TRM55971.00	NONE	0.0000
PEPE	4	2				6	2	TRIMBLE NETRS	TRM41249.00	NONE	0.0080
ROGM	4	2				6	2	TRIMBLE NETR5	TRM55971.00	NONE	0.0080
PSTO	8		10			18	2	LEICA GRX1200	LEIAT504	LEIS	0.0000
UYMO	14	12				26	2	LEICA GRX1200PRO	LEIAX1202GG	NONE	0.0000
ELEN	14		9			23	2	TRIMBLE 4700	TRM29659.00	UNAV	0.0000
APTO	14		13			27	2	ASHTECH UZ-12	ASH701945E_M	SNOW	0.0000
EXU0	14		19			33	2	TRIMBLE NETRS	TRM41249.00	NONE	0.1310
GTK0	14		23			37	2	TRIMBLE NETRS	TRM41249.00	NONE	0.0000
GRE0	14		24			38	2	TRIMBLE NETRS	TRM41249.00	NONE	0.0000
NAS0	14		24			38	2	TRIMBLE NETRS	TRM41249.00	NONE	0.0000
SMRT	14		24			38	2	TRIMBLE NETRS	TRM41249.00	NONE	0.0000
BOAV	17	19				36	2	TRIMBLE NETR5	TRM55971.00	NONE	0.0080
BQLA	17		15			32	2	ASHTECH UZ-12	ASH701945E_M	SNOW	0.0000
FQNE	18		16			34	2	LEICA GX1220	LEIAT504	LEIS	0.0000
CULC	19		13			32	2	TRIMBLE 5700	TRM41249.00	NONE	0.0927
SAGA	21	21				42	2	TRIMBLE NETRS	TRM41249.00	NONE	0.0100
IMBT	22	24				46	2	TRIMBLE NETR5	TRM55971.00	NONE	0.0080
MABA	22	24				46	2	TRIMBLE NETR5	TRM55971.00	NONE	0.0080
CRUZ	23	23				46	2	TRIMBLE NETR5	TRM55971.00	NONE	0.0080
UFPR	23	23				46	2	TRIMBLE NETR5	TRM55971.00	NONE	0.1000
RIOB	23	24				47	2	TRIMBLE NETRS	TRM41249.00	NONE	0.0080
SALU	23	24				47	2	TRIMBLE NETR5	TRM55971.00	NONE	0.0080
SAVO	23	24				47	2	TRIMBLE NETR5	TRM55971.00	NONE	0.0010
SSA1	23	24				47	2	TRIMBLE 4000SSI	TRM29659.00	NONE	0.0000
CEFE	23	25				48	2	TRIMBLE NETR5	TRM55971.00	NONE	0.0000
UGTO	25		24			49	2	TRIMBLE 5700	TRM41249.00	NONE	0.0677
CBSB	27		23			50	2	TRIMBLE NETRS	TRM41249.00	NONE	0.0000
GCGT	27		23			50	2	TRIMBLE NETRS	TRM41249.00	NONE	0.0000
BERR	36		35			71	2	TPS GB-1000	TPSCR4	CONE	0.0000
ANDS	40		39			79	2	LEICA GRX1200	LEIAT504	LEIS	0.0000
MOTE	48		48			96	2	LEICA GRX1200	LEIAT504	LEIS	0.0000

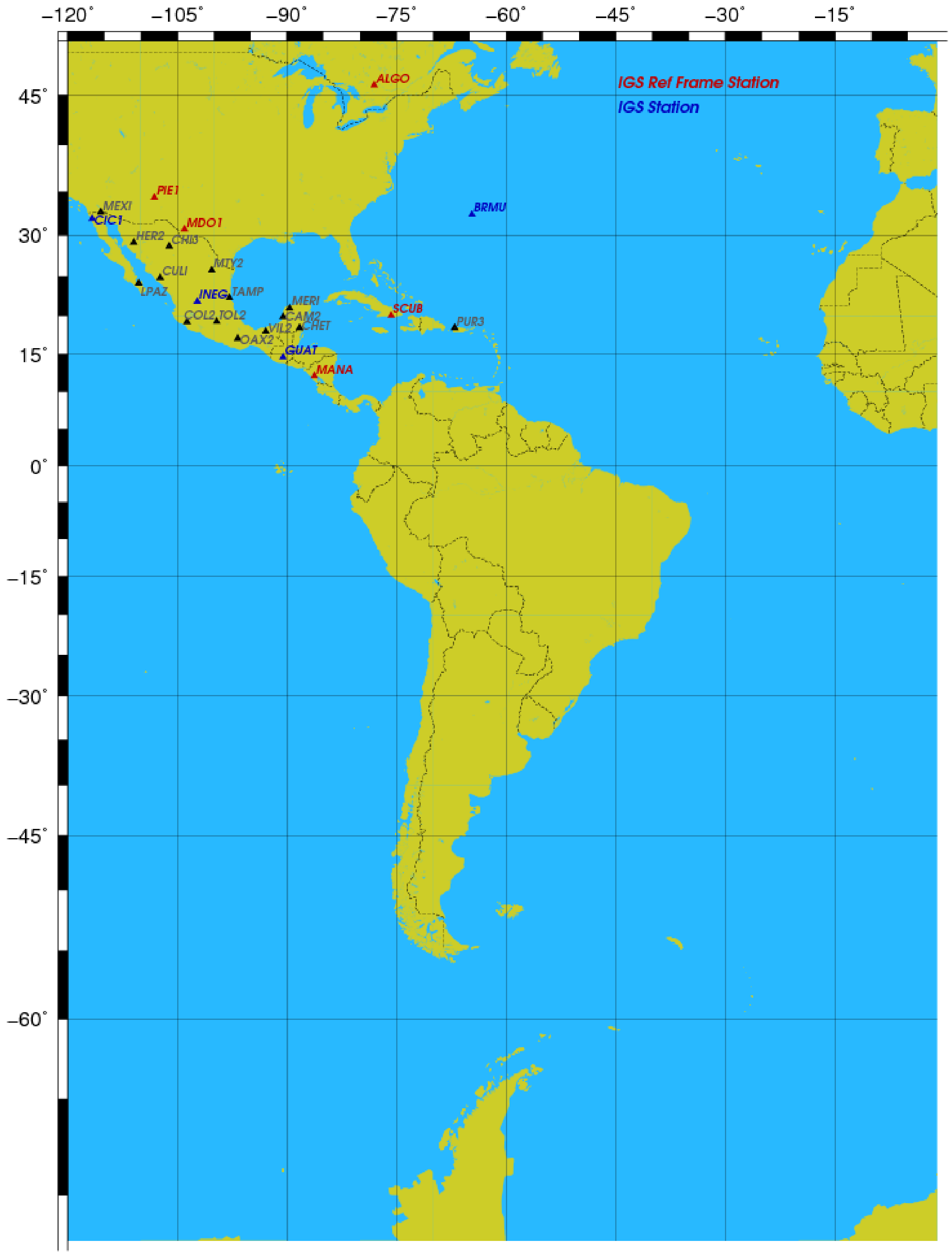
Name	SIR	IBG	IGA	INE	CPL	#Solutions	#Centers	Receiver	Antenna Radome	Antenna Height (m)
FLOR	52		53			105	2	TPS GB-1000	TPSCR4 CONE	0.0000
RIOH	53		50			103	2	TPS GB-1000	TPSCR4 CONE	0.0000
KYW1	54		36			90	2	ASHTECH Z-XII3	ASH700829.3 SNOW	0.0000
TUMA	56		56			112	2	TPS GB-1000	TPSCR4 CONE	0.0000
GOLD	58		70			128	2	ASHTECH Z-XII3	AOAD/M_T NONE	0.0254
CHIH	60		70			130	2	TRIMBLE 5700	TRM41249.00	0.1807
									TRM41249.00 NONE	
ETCG	61		17			78	2	TRIMBLE 5700	TRM41249.00	0.3240
									TRM41249.00 NONE	
BUCA	65		64			129	2	LEICA GRX1200	LEIAT504 LEIS	0.0000
VALL	65		64			129	2	TPS LEGACY	TPSCR4	0.0000
									TPSCR4 CONE	
VIVI	65		67			132	2	LEICA GRX1200	LEIAT504 LEIS	0.0000
CART	66		64			130	2	LEICA CRS1000	LEIAT504	0.0006
									LEIAT504 LEIS	
PERA	67		67			134	2	TPS LEGACY	TPSCR4 CONE	0.0000
DORA	67		68			135	2	TPS GB-1000	TPSCR4 CONE	0.0000
CALI	68		66			134	2	TPS LEGACY	TPSCR4	0.0000
									TPSCR4 CONE	
BDOS	69		71			140	2	ASHTECH UZ-12	ASH700936E_C SNOW	0.0000
BOGA	71		71			142	2	LEICA GRX1200	LEIAT504	1.3720
									LEIAT504 NONE	
BUEN	71		71			142	2	TPS GB-1000	TPSCR4 CONE	0.0000
CUCU	71		71			142	2	TPS LEGACY	TPSCR4	0.0000
									TPSCR4 CONE	
SAMA	71		71			142	2	TPS GB-1000	TPSCR4 CONE	0.0000
TUNA	71		71			142	2	TPS GB-1000	TPSCR4 CONE	0.0000
ASC1	2					2	1	AOA BENCHMARK ACT	AOAD/M_T NONE	0.0677
MIA3	9					9	1	ASHTECH Z-XII3	ASH700829.3 SNOW	0.0000
GOUG	36					36	1	TRIMBLE 4000SSI	TRM29659.00 TCWD	0.0030
ISPA	36					36	1	ASHTECH UZ-12	ASH701945E_M SCIT	0.0083
VESL	54					54	1	TRIMBLE 4000SSI	TRM29659.00 TCWD	-0.0112
								TPS GB-1000		
MZAE		33				33	1	TRIMBLE NETRS	TRM29659.00 SCIS	0.0000
ALGO				34		34	1	AOA BENCHMARK ACT	AOAD/M_T NONE	0.1000
CHI3				34		34	1	TRIMBLE 5700	TRM41249.00 NONE	0.1810

MAPS OF SUB-NETWORKS

SIR : a complete set of stations processed by Deutsches Geodätisches Forschungsinstitut-DGFI

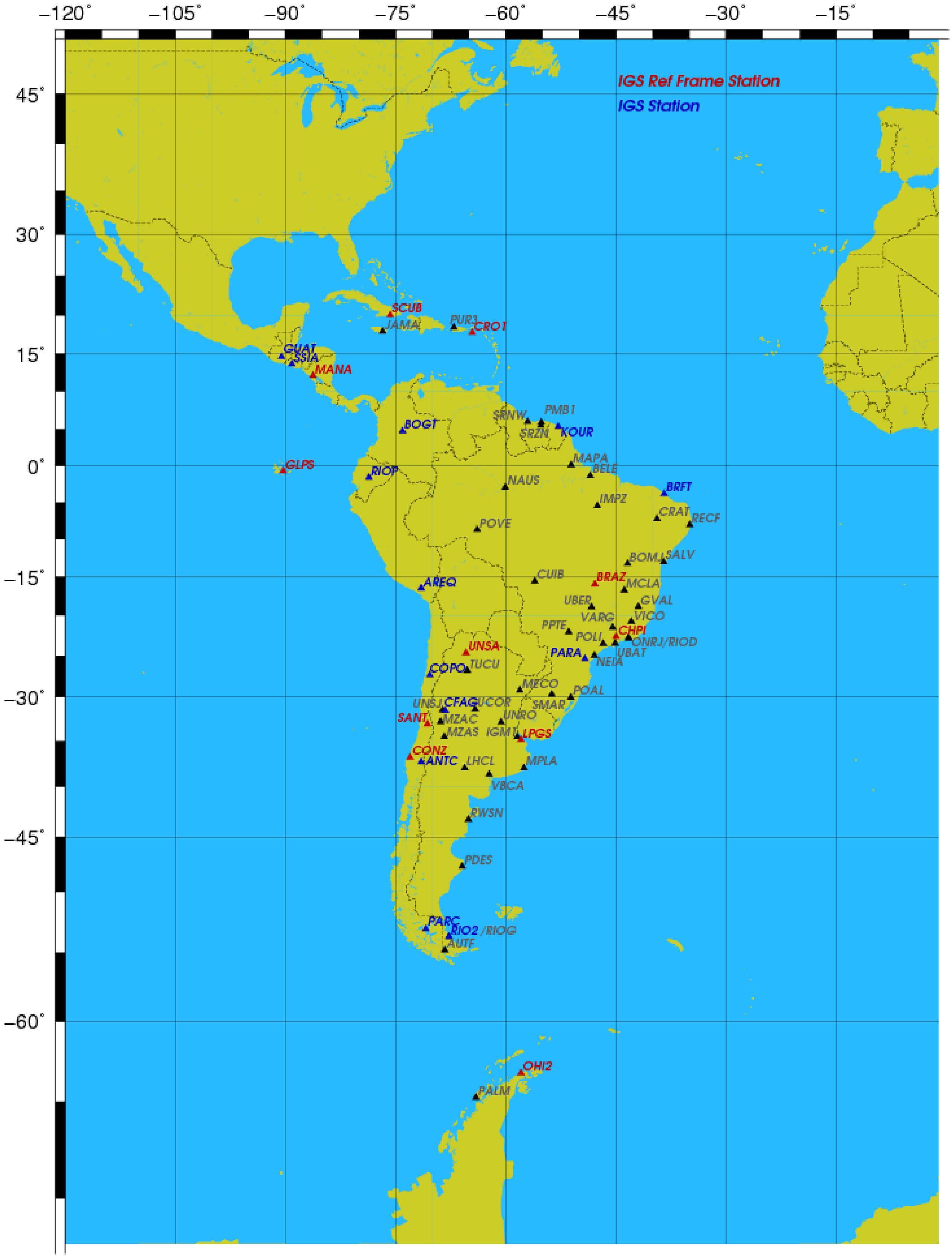


INE - a complete set of stations processed by Instituto Nacional de Estadística, Geografía y Información - INEGI



IBG - a complete set of stations processed by Instituto Brasileiro de Geografia e Estatística - IBGE

CPL- a complete set of stations processed by LA PLATA



IGA - a complete set of stations processed by Instituto Geográfico Agustin Codazi- IGAC