THE SPATIAL REFERENCE FOR GEOMATICS IN THE AMERICAS

Claudio Brunini  
SIRGAS President  
UNLP - CONICET  
Argentina

Laura Sánchez  
SIRGAS Vice-President  
DGFI - Germany

Hermann Drewes  
IAG Representative  
DGFI - Germany

William Martínez  
SIRGAS WGII President  
IGAC - Colombia

María Virginia Mackern  
SIRGAS - WGI President  
UN Cuyo - LUJAM  
Argentina

Roberto Luz  
SIRGAS WGIII President  
IBGE - Brazil

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SIRGAS stands for Geocentric Reference System for the Americas

✓ IAG Sub Commission 1.3b: Reference Frames / Regional Reference Frames / South and Central America
✓ Working Group of the PAIGH Cartography Commission

- SIRGAS as a reference system is defined as identical with the International Terrestrial Reference System (ITRS)

- SIRGAS as a reference frame is a regional densification of the International Terrestrial reference Frame (ITRF)

(a) The International Terrestrial Reference System (ITRS)

(a) The International Terrestrial Reference Frame (ITRF) visualized as a distributed set of ground control stations (represented by red points)

http://www.kartografie.nl
The science for measuring changes in the Earth System

The science of accurately measure and understand three fundamental properties of Earth: its geometric shape, its orientation in space, and its gravity field; and the changes of these properties with time (Precise Geodetic Infrastructure: National Requirements for a Shared Resource. NAP, 2010)
• SIRGAS was created during the International Conference for the Definition of a South American Geocentric Datum, held from October 4 to 7, **1993**, in **Asunción**, Paraguay.

• The development of SIRGAS “Project” comprised the activities needed to the adoption on the continent of a reference network of accuracy compatible with the techniques of satellite positioning, especially those associated with the Global Positioning System (GPS).
THE FIRST CAMPAIGN: 1995

- Measurements from 00:00 (UT), may 26 to 24:00 (UT) June 04.

- 57 stations

- 30 institutions

- 11 countries

- 3 processing centres

"An extremely well executed project", Wolfgang Torge, XXI IUGG General Assembly, Boulder.
• Measurements from 00:00 (UT), May 10 to 24:00 (UT), May 19.

• 184 stations

• 25 countries

• The SIRGAS 95 campaign stations were re-occupied as well as national tide gauges and international connecting points

Table 1. Distribution and types of stations in the countries

<table>
<thead>
<tr>
<th>Country (Island)</th>
<th>SIRGAS 1995</th>
<th>New Site</th>
<th>Tide Gauge</th>
<th>Total No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Argentina</td>
<td>10</td>
<td>7</td>
<td>3</td>
<td>20</td>
</tr>
<tr>
<td>Bermuda</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Bolivia</td>
<td>6</td>
<td>3</td>
<td>-</td>
<td>9</td>
</tr>
<tr>
<td>Brazil</td>
<td>11</td>
<td>5</td>
<td>5</td>
<td>21</td>
</tr>
<tr>
<td>Canada</td>
<td>-</td>
<td>10</td>
<td>3</td>
<td>13</td>
</tr>
<tr>
<td>Chile</td>
<td>7</td>
<td>8</td>
<td>5</td>
<td>20</td>
</tr>
<tr>
<td>Colombia</td>
<td>5</td>
<td>2</td>
<td>1</td>
<td>8</td>
</tr>
<tr>
<td>Ecuador</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td>Fr. Guiana</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>Guatemala</td>
<td>-</td>
<td>3</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Guyana</td>
<td>-</td>
<td>2</td>
<td>-</td>
<td>2</td>
</tr>
<tr>
<td>Honduras</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>Jamaica</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>Mexico</td>
<td>-</td>
<td>13</td>
<td>2</td>
<td>15</td>
</tr>
<tr>
<td>Nicaragua</td>
<td>-</td>
<td>2</td>
<td>-</td>
<td>2</td>
</tr>
<tr>
<td>Paraguay</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>Puerto Rico</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>Saint Croix</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Peru</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td>10</td>
</tr>
<tr>
<td>Trinidad&amp;Tobago</td>
<td>-</td>
<td>2</td>
<td>-</td>
<td>2</td>
</tr>
<tr>
<td>Uruguay</td>
<td>2</td>
<td>4</td>
<td>2</td>
<td>8</td>
</tr>
<tr>
<td>USA</td>
<td>-</td>
<td>12</td>
<td>12</td>
<td>24</td>
</tr>
<tr>
<td>Venezuela</td>
<td>5</td>
<td>3</td>
<td>3</td>
<td>11</td>
</tr>
<tr>
<td>Antarctica</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>Sum</td>
<td>56</td>
<td>85</td>
<td>43</td>
<td>184</td>
</tr>
</tbody>
</table>
After 2000, SIRGAS begun its realization by a network of continuously operating GNSS stations with precisely known positions (referred to an specific reference epoch) and their changes with time (station velocities). This SIRGAS Continuously Operating Network (SIRGAS-CON) is currently composed by about 250 permanently operating GNSS sites, 48 of them belonging to the global IGS network.

July 2007
149 stations
54 IGS

May 2012
250 stations
72 GLONASS
48 IGS
• National reference frames in Latin America are part of SIRGAS-CON.

• The core network (SIRGAS-CON-C) is the primary densification of ITRF in Latin America.

• Densification sub-networks (SIRGAS-CON-D) provide accessibility to the reference frame at local levels.

• Today, there are three SIRGAS-CON-D sub-networks, but in the future, there shall be given so many SIRGAS-CON-D sub-networks as countries in the region.
DATA PROCESSING AND ANALYSIS

2007

SIRGAS-CON
NETWORK

1 DATA CENTRE
(DGFI as IGS-RNAAC-SIR)

1 ANALYSIS CENTRE
(DGFI as IGS-RNAAC-SIR)

Weekly loosely constrained solutions for combination (IGS multiannual solutions)

Weekly coordinates adjusted to ITRF
Multiannual solutions (positions + velocities)

2012

SIRGAS-GTI

Red Continental SIRGAS-CON-C

1 Centro Regional de Datos (DGFI)

Centros Nacionales de Datos (entidades encargadas de los marcos de referencia)

1 Centro de Procesamiento (DGFI como IGS-RNAAC-SIR)

8 Centros Locales de Procesamiento
CEPGE, CIMA, CPAGS-LUZ, IBGE, IGAC, IGN-Ar, INEGI, SGM-Uy

2 Centros de Combinación
(DGFI, IBGE)

Soluciones finales para el marco de referencia SIRGAS-CON

Soluciones semanales semilibres para el poliedro global del IGS y soluciones multiannual

- Coordenadas semanales ajustadas al ITRF
- Soluciones multiannual (posiciones y velocidades)
9 processing centres

- CEPGE-Ec
- CIMA-Ar
- CPAGS-Ve
- IBGE-Br
- IGAC-Co
- SGM-Uy
- IGN-Ar
- INEGI-Mx

2 combination centres

- IBGE-Br
- DGFI-De

- Each station is processed by 3 centres
- 2 independent combinations
- Weekly coordinates:
  \[ \sigma = \pm 1,7 \text{ mm in N-E} \]
  \[ \sigma = \pm 3,7 \text{ mm in h} \]
INTERNATIONAL ASSOCIATION OF GEODESY (IAG)

Pan American Institute of Geography and History (PAIGH)

Argentina
Bolivia
Brazil
Canada
Chile
Colombia
Costa Rica
Ecuador
El Salvador
Guatemala
Guyana
Honduras
Mexico
Nicaragua
Panama
Paraguay
Peru
Uruguay
Venezuela
SIR11P01 horizontal velocities

SIR11P01 vertical velocities
VELOCITY MODELS

Reference Frame
SIRGAS95 (ITRF94, $t_s=1995.4$)
SIRGAS2000 (ITRF2000, $t_o=2000.4$)

Transformation $t_o \rightarrow t_i$, $t_k$

$X'(t_i) = X(t_o) + \Delta T + R \cdot X(t_i - t_o) + \frac{dX}{dt}(t_i - t_o)$

Coordinates related to the reference frame $X(t_o)$

Processing of the new coordinates $X'(t_i)$, referred to $t_k$

Transformation $t_i \rightarrow t_k$, $t_o$

$X'(t_k) = X(t_i) - \Delta T - R \cdot X'(t_k - t_o) - \frac{dX'}{dt}(t_i - t_o)$

Model VEMOS2009 referred to ITRF2005
(Drewes and Heidbach 2009)

The new SIRGAS vertical reference system is based on a geometrical component that corresponds to ellipsoidal heights referred to the SIRGAS datum, and a physical component that is given in terms of geopotential quantities ($W_0$ as a reference level and geopotential numbers as primary coordinates). Its realization should:

i) Refer to a unified global reference level $W_0$,

ii) Be given by proper physical heights (derived from spirit levelling in combination with gravity reductions), and

iii) Be associated to a specific reference epoch, i.e. it should consider the coordinate and referential changes with time.

The respective reference surface (geoid or quasi-geoid) shall be determined in a common analysis over the whole continent.
Evolution of the ionospheric model:

3-D representation of TEC and 4D of EC.

Applications for the projects:
• Augmentation Solution for the Caribbean, Central and South America (SACCSA) for ICAO.
• Low Ionosphere Sensor network;
• International Reference Ionosphere.

“Contribution to the Study of the Global Climatic Change and the Meteorological Prediction and the Space Weather: Argentina, Brazil, Colombia, Ecuador, Mexico, Venezuela and Uruguay” under the guidance of Virginia Mackern (approved PAIGH in 2010)
• Increasing number of stations that generate observations and corrections in real Time: installation of new casters and sharing of experiences that demonstrate the potential of the method, specially in Brazil, Uruguay, Argentina and Venezuela.

• At the beginning of 2011, the project “Evaluation of potential applications of NTRIP in SIRGAS” was presented to PAIGH with the participation of Uruguay, Argentina and Venezuela.
NEW GLONASS AND MoNoLin

SIRGAS Resolution 03, August 10, 2011:

- To establish the project SIRGAS-GLONASS ascribed to the WG-I.

- To study the appropriate processing strategies for obtaining the best possible accuracies based on GLONASS positioning as a tool for the realization of the SIRGAS reference frame and to define the feasibility of its routine analysis in the same way as GPS.

SIRGAS Resolution 04, August 10, 2011:

- To establish the project SIRGAS-MoNoLin ascribed to the WGI and WGII.

- To define the most appropriate strategy to include the non linear movements of the reference stations in the determination of their coordinates and, in consequence, to improve the kinematic representation of the reference frames that they integrate.
- Specialized courses for the establishment of the SIRGAS analysis centres
  - Instituto Geográfico Militar de Ecuador, December 2008 and February 2011. CEPGE-IGM
  - Servicio Geográfico Militar del Uruguay, March 2009

- SIRGAS Schools on Reference Systems
  - First: Bogotá, July 2009, IGAC, 120 participants, 12 countries.
  - Second: Lima, November 2010, IGN, 122 participants, 13 countries.
  - Third: Heredia, August 2011, ETCG, 116 participants, 18 countries

- SIRGAS Chapter in Advanced Course of Satellite Positioning: AECID
  - Universidad Politécnica de Madrid, November 2009
  - Montevideo, May 2010
  - Universidad Politécnica de Madrid, November 2010
Adapted from: http://cast.uark.edu/home/research/geomatics.html
SIRGAS data are...

- The most basic theme in the SDI’s of the Americas
- The basis for spatial data standardization
- The space-time link among data sets and information
- The common language for data sharing, interoperability and compatibility

http://www.fgdc.gov/library/whitepapers-reports/
As the contribution of geodetic science and techniques to the family of Earth sciences by sharing data, providing services and generating information that combined with those provided by different sources lead to a better comprehension of Earth.
• Working on a SIRGAS basis, implies the use of the ITRF

• World Geodetic System WGS84 was adjusted to ITRF and, nowadays they are equivalent.

• The practical use of SIRGAS involves a referencing to the International Terrestrial Reference Frame (ITRF).

• SIRGAS, ITRF and WGS84 are equivalent

http://www.dgfi.badw.de/index.php?id=2
At present, member countries are implementing strategies to adopt the last version: ITRF08. GPS broadcasted information is compatible with it.
• A georeferencing process must be adequately linked to SIRGAS. It means, the use of continuous and/or passive stations in order to get accurate positions for engineering, surveying, among others.

• The use of VEMOS 2009 to refer the survey to a national reference frame in a space-time context. Constant velocities and deformation models can not reflect the effect of earthquakes (leaps) on stations coordinates. Linear velocities in these cases are useless. So...

• The use of the last set of coordinates released by SIRGAS is recommended (http://www.sirgas.org/index.php?id=153&L=2)

• Coordinates of control points in former national local datums can be transformed to SIRGAS, but accuracies will be low. Instead, points must be measured using SIRGAS base stations.
Satellite imagery is normally referred to ITRF (WGS84). In consequence, it is recommended that local ground control be made linked to SIRGAS.

Maps elaborated using a former national datum should be transformed to SIRGAS. The inverse process decreases the accuracy and quality of results. SIRGAS countries have computed national transformation parameters. Even so, in the most of cases, global transformation parameters are valid for mapping purposes.

GNSS measurements do not eliminate the electro-optical surveys. They are complementary processes: GNSS establishes the datum, and EDM’s gets detailed information, mainly in places where satellite signals are not available and/or no practical.

Field measured positions, after a survey like traverses or GNSS accurate positioning have their own accuracies. They cannot be “mixed” with a cartographic product assuming full compatibility. Usually, errors in a map are, by far, greater than those of control points.

Plane (projected) coordinates of control points can be assumed with the same accuracy than original geocentric Cartesian or geographic coordinates. This is valid if the SIRGAS frame is used for both data sets. This process is called conversion; different than transformation, which implies a shift between reference frames.

Natural features must be avoided as reference for parcel delimitations. Instead, SIRGAS coordinates are recommended. Even if they change with time, areas normally keep their dimension.
Thank you very much