Proceedings of the International Symposium on Global Navigation Satellite Systems, Space-Based and Ground-Based Augmentation Systems and Applications

Berlin, 11-14 November 2008

Berlin Senate Department for Urban Development

SIRGAS: BASIS FOR GEOSCIENCES, GEODATA, AND NAVIGATION IN LATIN AMERICA

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Proceedings of the International Symposium on Global Navigation Satellite Systems, Space-based and Ground-based Augmentation Systems and Applications. Berlin, 11-14 November. Berlin Senate Department for Urban Development. P. 37 - 39., 2009

SIRGAS (Sistema de Referencia Geocéntrico para las Américas) deals with definition, realization, and maintenance of the 3D geocentric reference system for South and Central America, including a gravity field-related vertical reference system. This objective comprises:

i) Determination and maintenance of a geocentric reference frame (a set of stations with high-precise geocentric coordinates [X, Y, Z] and their variation with time [Vx, Vy, Vz]), as a regional densification of the global ITRF;

ii) Establishment of the geocentric datum defined by the origin, orientation and scale of SIRGAS (i.e. IERS) in the member countries;

iii) Definition and realization of a unified vertical reference system composed by consistent physical and geometrical heights, as well as, their variations with time, i.e. [h, V_h, H, V_H, N, V_N].

From the practical point of view, SIRGAS is the backbone for all projects based on the generation and use of geo referenced data in a national as well in an international level in Latin America. Besides to provide the reference coordinates for the development of practical applications such as engineering projects, digital administration of geographical data, geospatial data infrastructures, etc., SIRGAS is also the platform for a wide range of scientific applications such as the monitoring of cortical deformations, vertical movements, sea level variations, atmospheric studies, etc.

The organizational structure of SIRGAS (Figure 1) is based on an Executive Committee, composed by a national representative of each member country, which approves the official SIRGAS policies and recommendations and promotes their adoption between the national bodies responsible for the local geodetic reference systems. The scientific activities are coordinated by the working groups in close cooperation with the SIRGAS Scientific Council and representatives of IAG (International Association of Geodesy) and PAIGH (Pan-American Institute for Geography and History). At the moment, there are three working groups (WG), which have been created following the main objectives of SIRGAS, i.e.

i) SIRGAS-WGI is responsible for the maintenance and permanent improvement of the reference system realization;

ii) SIRGAS-WGII is in charge of promoting and assisting the SIRGAS realization (densification) in the member countries;

iii) SIRGAS-WGIII deals with the definition and realization of a unified vertical reference system for the region.

The interaction between the administrative and scientific bodies is coordinated by the SIRGAS Steering Council, which also takes care of the administrative issues.

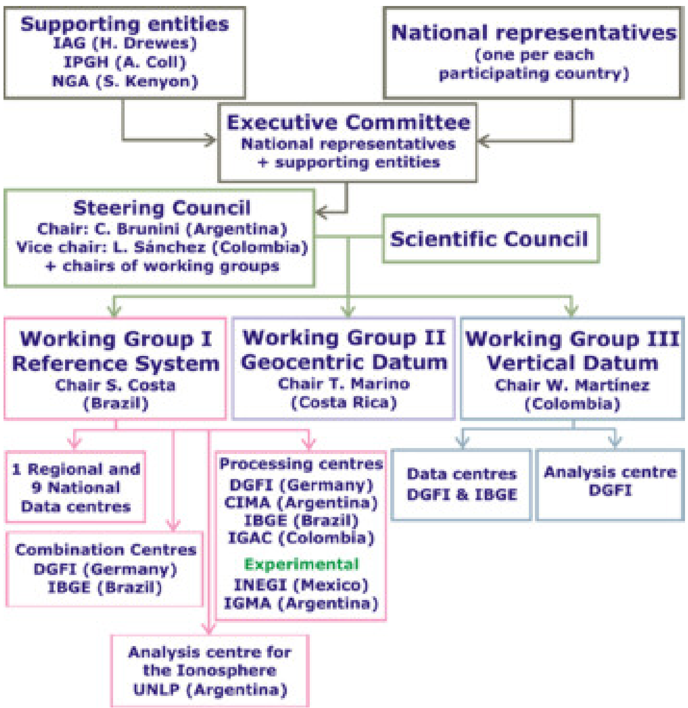

***Fig. 1**. Organizational Structure of SIRGAS.*

The SIRGAS Reference Frame

SIRGAS is identical with the International Terrestrial Reference System (ITRS) defined and maintained by the IERS (International Earth Rotation and Reference Systems Service). Its realization is a regional densification, by means of a continental network, of the global International Terrestrial Reference Frame (ITRF). Consequently, the local reference frames of the member countries are national densifications of the continental network (Table 1). The SIRGAS reference coordinates are associated with a specific (reference) epoch. Their variation with time is taken into account by discrete station velocities or by a continuous velocity model, which comprises tectonic plate movements and crustal deformations. Realizations or densifications of SIRGAS related to different reference epochs materialize the same reference system and, after reducing their coordinates to the same epoch, are compatible at the mm-level.

Table 1. *SIRGAS densifications in Latin America (Status September 2008)*

Country	ITRF/SIRGAS Densification	No. passive/ continuous stations
Argentina	SIRGAS95, epoch 1995.4	139 / 21
Bolivia	SIRGAS95, epoch 1995.4	125 / 8
Brazil	SIRGAS2000, epoch 2000.4	1903 / 55
Chile	SIRGAS2000, epoch 2002.2	269 / 13
Colombia	SIRGAS95, epoch 1995.4	70 / 35
Costa Rica	ITRF2000, epoch 2005.8	34 / 1
Ecuador	SIRGAS95, epoch 1995.4	135 / 3
French Guyana	ITRF93, epoch 1995.0	7 / 1
Mexico	ITRF92, epoch 1988.0	0 / 17
Panama	ITRF2000, epoch 2000.0	20 / 3
Peru	SIRGAS95, epoch 1995.4	47 / 1
Uruguay	SIRGAS95, epoch 1995.4	17 / 3
Venezuela	SIRGAS95, epoch 1995.4	156 / 4

SIRGAS was initially realized by two GPS campaigns, one in 1995 (SIRGAS95) with 58 stations, and one in 2000 (SIRGAS2000) with 184 stations. Today, SIRGAS is realized by the SIRGAS Continuously Operating Network (SIRGAS-CON), which is composed by around 170 permanently operating GNSS sites, 50 of them belonging to the global IGS network (Figure 2). The operational performance of SIRGAS-CON is based on the contribution of more than 50 Latin American organizations, which install and operate the permanent stations and voluntarily provide the tracking data for the weekly processing of the network.

Since more and more Latin American countries are qualifying their national reference frames by installing GNSS continuously operating stations and these stations shall be consistently integrated into the continental reference frame, the SIRGAS-CON network comprises two hierarchy levels:

i) One core network (SIRGAS-CON-C), densification of ITRF in Latin America, with a good continental coverage and stabile site locations to ensure high long-term stability of the reference frame;

ii) Many densification sub-networks (SIRGAS-CON-D), which should correspond to the national reference frames realized by continuously operating stations. At the moment, 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. The main objective in this aspect is that each country processes its own permanent stations. Since at present there are not enough Local Processing Centres, the SIRGAS-CON-D stations have been allocated to the operating centres until new ones are functional.

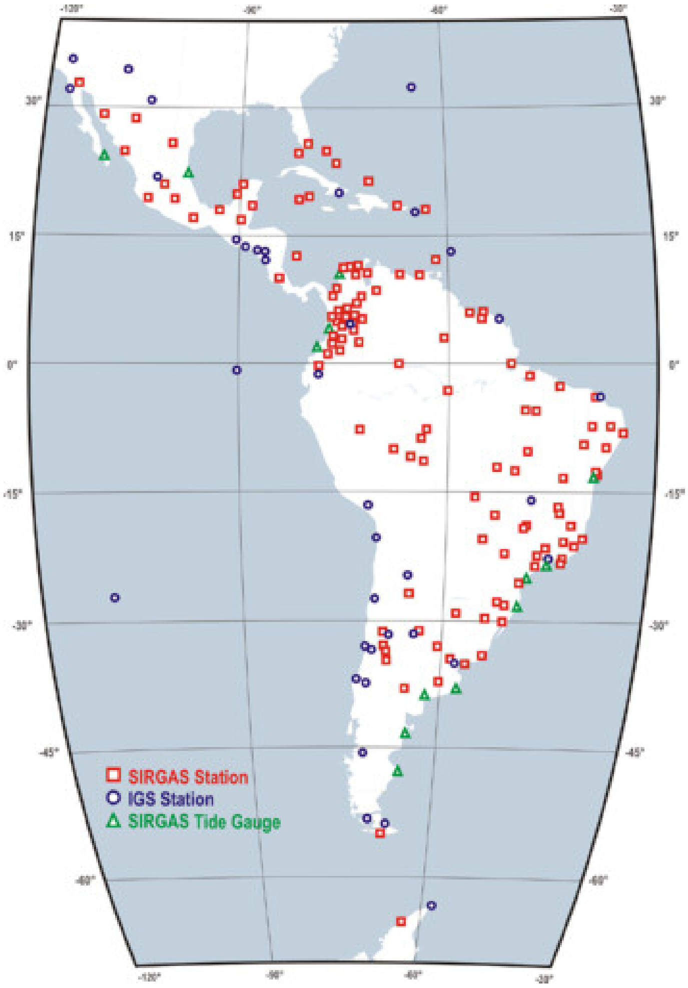

Fig. 2*. SIRGAS Continuously Operating Network (SIRGAS-CON). Status September, 2008.*

The SIRGAS-CON-C network is processed by the IGS Regional Network Associate Analysis Centre for SIRGAS (IGS-RNAAC-SIR), which at present operates at the Deutsches Geodätisches Forschungsinstitut (DGFI) in Munich, Germany. The SIRGAS-CON-D sub-networks are computed by the SIRGAS Local Processing Centres installed in Latin America. At present, they are: Instituto Brasileiro de Geografia e Estatistica, Brazil (IBGE), Instituto Geográfico Agustín Codazzi, Colombia (IGAC), and Instituto de Geodesia y Geodinámica de la Universidad Nacional del Cuyo, Argentina (IGG-CIMA). These processing centres deliver loosely constrained weekly solutions for the SIRGAS-CON-D densification sub-networks, which are combined with the SIRGAS-CON-C core network to get homogeneous accuracies for station positions and velocities in a continental level. The main products of SIRGAS-CON (SIRGAS-CON-C + SIRGAS-CON-D stations) are:

i) Loosely constrained weekly station coordinates in SINEX format for the IGS polyhedron solutions;

ii) Constrained weekly coordinates for practical applications in Latin America;

iii) Multi-annual solutions (coordinates + velocities) for practical and scientific applications requiring time depending positioning.

The SIRGAS Ionospheric Analysis

The ionosphere over the Central and South American areas presents a particularly complex behaviour because the free electron distribution is strongly affected by the Equatorial Anomaly and the distortion of the geomagnetic field (with respect to its dipolar approximation). The high-quality dual-frequency GNSS observations provided by the SIRGAS-CON network constitute an invaluable source of information for continuously monitoring this complex phenomenon. In order to exploit this unique opportunity, SIRGAS promotes the establishment of analysis centres devoted to that kind of studies. In this context, since July 2005 the Universidad Nacional de La Plata, Argentina, computes hourly maps of vertical total electron content (vTEC) for the SIRGAS region. Twenty four maps per day, presented in graphical and numerical formats (grids of 1°×1° in latitude and longitude) and daily movies are available through the SIRGAS web page (www.sirgas.org). They are computed using the La Plata Ionospheric Model, which implements a thin-layer ionospheric approximation particularly tailored for the SIRGAS region.

SIRGAS maps of vTEC are being applied for different kind of studies such as validation of the International Reference Ionosphere (IRI) over the South America, improvement of positioning with single-frequency GPS receivers, and the feasibility of computing ionospheric corrections for a satellite based augmentation system (SBAS) for the region. This study was promoted by the International Civil Aviation Organization (ICAO) in the framework of its so-called "Solución de Aumentación para el Caribe, Centro y Sur América" (SACCSA) project.

The SIRGAS Vertical Reference System

The vertical datums presently used in Latin America refer to different realizations of the mean sea level and to different epochs. They do not take care of variations of the heights and of the reference level with time. In most of the countries, the vertical networks were processed without applying corresponding gravity reductions to the levelled heights. These datums present big discrepancies between neighbouring countries, they do not permit data exchange neither at continental nor at global scale, and they are not able to support practical height determination using GNSS techniques. Therefore, a main challenge for SIRGAS today is to integrate a gravity field-related vertical component, which consistently supports the determination of physical heights from terrestrial levelling as well as from satellite positioning in combination with (quasi)geoid models.

The new vertical reference system for SIRGAS is based on two components: a geometrical one, which is given by ellipsoidal heights referred to SIRGAS, and a physical one, defined by geopotential numbers (or physical heights) associated to a unique global W_0 value. Both components, the geometrical and the physical one, shall also consider the variation of the coordinates with time. The geometrical component is achieved by adopting and using SIRGAS as the official reference frame in Latin America. The realization of the physical component implies primarily i) a continental adjustment of geopotential numbers referred to one and the same W_0 value, and ii) the determination of a unified high resolution (quasi)geoid model for the region. Regarding the first task, the South American countries have been requested to check their first order levelling networks, to check the existing gravity data, and to calculate geopotential numbers. Since the vertical networks were measured stepwise during different periods, the estimation of the height variation with time is required to reduce the observed level differences to the same epoch. The second task, the (quasi)geoid computation, must be performed in a common way by all countries using a global gravity model derived from satellite-only observations (i.e. from the gravity satellite missions) as a reference gravity field, and terrestrial (aerial and marine) gravity measurements to determine the high frequency component.

The unification of the classical height datums into the new system is feasible through the estimation of potential differences (called datum discrepancies) between their individual reference levels and the global W_0 value. This estimation is based on the combination of ellipsoidal heights (derived from space techniques), geopotential numbers (derived from levelling and gravity reductions) and the solution of the boundary value problem, i.e. the (quasi)geoid determination. In order to get reliable datum discrepancies, they are being determined in four different approaches: At the references points (tide gauges) of the classical height systems (Figure 3), in the marine areas close to the tide gauges, at the SIRGAS reference stations, and at connection points between classical height systems. The final datum discrepancies shall be given by a combined adjustment of the observation equation systems generated in each approach.

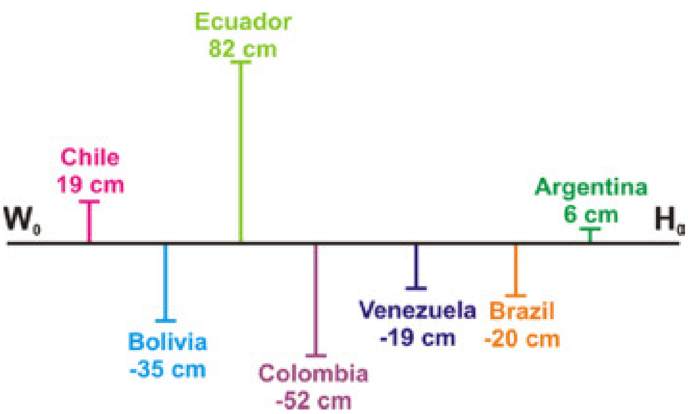

Fig. 3. *Preliminary vertical datum discrepancies at the reference tide gauges in South America.*

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