ADVANCING GEODESY IN LATIN AMERICA AND THE CARIBBEAN

Geodetic Reference Frame for the Americas

SIRGAS (an acronym of the Spanish term for 'Geocentric Reference System for the Americas') is an international organisation under the umbrella of the International Association of Geodesy (IAG) and the Pan-American Institute of Geography and History (PAIGH). Its main objective is the definition, realisation and maintenance of a state-of-the-art geodetic reference frame in Latin America and the Caribbean. This reference frame must support both highly demanding scientific studies and the development of a Spatial Data Infrastructure for the Americas. More than 50 institutions from 19 countries, including the national mapping agencies of Latin America, are committed to SIRGAS in a voluntary partnership.

Due to the complexity of the scientific and technological concepts – digital signal processing, celestial mechanics, relativity theory and a great many others – that make Global Navigation Satellite Systems (GNSS) possible, it is easy to forget the fact that positioning theory is based on one of the oldest and simplest mathematical formulas: Pythagoras' Theorem. Receiver coordinates are computed by solving a triangle whose vertices are the Earth's geocentre, the GNSS receiver, and the GNSS satellite (Figure 1). The unknown receiver coordinates are embedded in the length of the side that links the receiver to the geocentre; the lengths of the other two sides are either known – the distance between the satellite and the geocentre – or measured by the GNSS receiver – the distance between the satellite and the receiver. In order to apply Pythagoras' theorem, the receiver coordinates must be computed in the same reference frame as the satellite coordinates.

The precise GNSS orbits delivered by the International GNSS Service (IGS) refer to the International Terrestrial Reference Frame (ITRF). Hence, GNSS users interested in the accuracy of their results must compute their coordinates in the ITRF. The use of a different reference frame does not ensure compatibility between the three sides of the abovementioned triangle, and might significantly reduce the accuracy of the computed coordinates.

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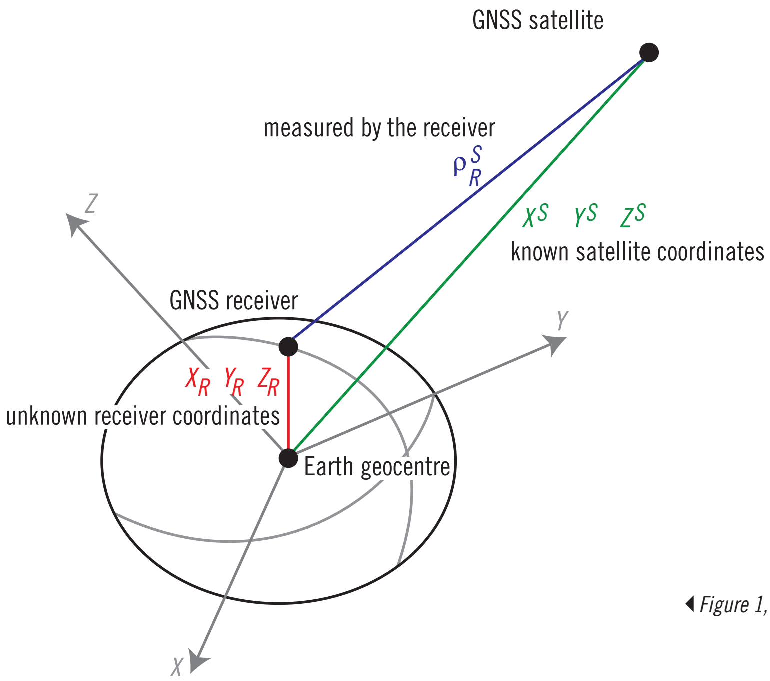

Figure 1, Principle of GNSS positioning.

SIRGAS is the densification of the ITRF in Latin America and the Caribbean. Its use was recommended to all the American and Caribbean countries at the United Nations Cartographic Conference for the Americas which held in New York, USA, from 22 to 26 January 2001. At present, SIRGAS has been officially adopted by 14 countries in the region.

THE MAJOR CHALLENGE

Within the main SIRGAS objective of defining, realising and maintaining the reference frame in Latin America and the Caribbean, the biggest challenge lies within the 'maintenance' aspect. Modern geodesy demands reference coordinates established with an accuracy of a few millimetres while, at the same time, these reference coordinates must be materialised on the ground by means of geodetic marks. These markers are continuously moving due to a variety of geodynamic processes, ranging from the rather smooth continental drift to the sudden jumps produced by earthquakes or seasonal changes caused by hydrological or atmospheric variability. These natural processes change the marker coordinates in different ways: continental drift or crustal deformation occurs with an almost constant velocity, from millimetres to centimetres, per year (Figure 2); variations of hydrologic and atmospheric masses loading the ground produce coordinate changes up to several centimetres with a seasonal periodicity (Figure 3); while intense earthquakes can suddenly change the coordinates from centimetres to metres (Figure 4).

These changes must be continuously monitored and the reference coordinates must be permanently updated in order to keep their accuracy within modern geodesy's acceptable range of just a few millimetres. The major challenge currently faced by SIRGAS is the definition of a strategy to cope with coordinate changes that are not constant over time (e.g. seasonal changes due to load processes or jumps caused by earthquakes).

THE SIRGAS ENGINE

SIRGAS is realised and maintained through a complex engine that encompasses: i) a continent-wide Continuously Observing Network (CON) of GNSS stations (SIRGAS-CON); ii) data centres; iii) processing centres; and iv) combination centres. GNSS data are produced, archived and processed according to international standards and specifications, particularly those issued by the IGS and the International Earth Rotation and Reference Systems Service (IERS).

SIRGAS-CON is presently composed of 280 GNSS stations distributed throughout Latin America, the Caribbean and surrounding regions (Figure 5). These stations are installed and maintained by national organisations, in some cases in an international collaboration framework, under the co-ordination of SIRGAS. Seventy of these stations are also part of the IGS network and provide the link to the ITRF. In the last decade, the network has grown at an average rate of 25 stations per year while station performance has continuously improved too: today, 127 stations are GPS+GLONASS-capable and 52 stations are real-time-capable.

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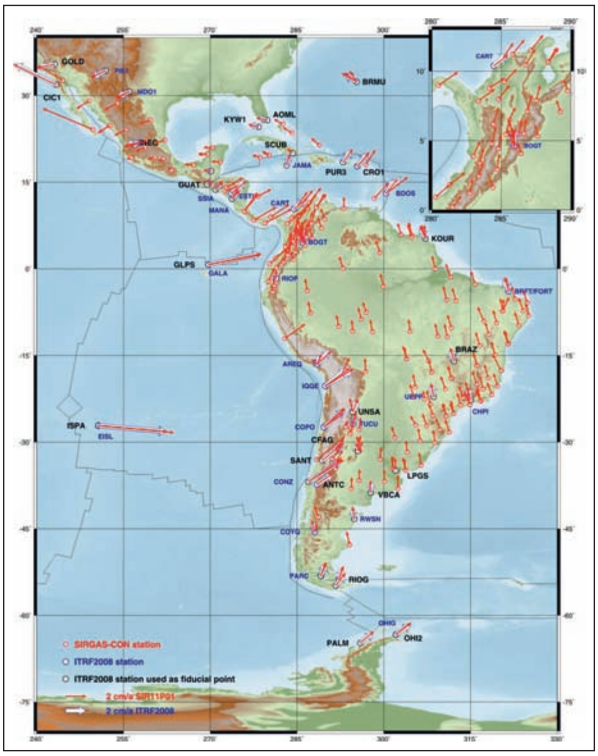
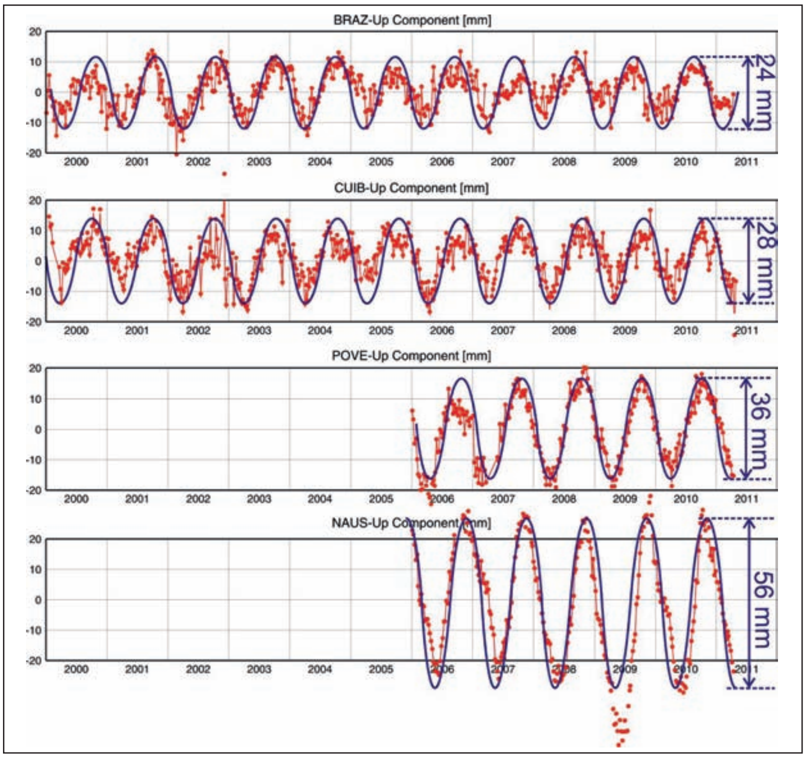
One global and nine regional data centres archive the data produced by the network, which are processed, on a weekly basis, by 10 processing centres. To accomplish this task, SIRGAS-CON is clustered in one core network and several densification sub-networks. Each sub-network is independently computed by three processing centres operated by different Latin American institutions (CIMA-Argentina, IGN-Argentina, IBGE-Brazil, IGM-Chile, IGAC-Colombia, IGM-Ecuador, INEGI-Mexico, SGM-Uruguay, LUZ-Venezuela) and by the Deutsches Geodätisches Forschungsinstitut (DGFI). The weekly solutions computed for every sub-network are integrated in a continental solution by two combination centres: IBGE (Brazil) and DGFI (Germany). SIRGAS promotes the installation of (at least) one processing centre in each country, ensuring the development and sustainability of in-country capabilities to manage modern reference frames at the national level. Moreover, SIRGAS encourages and supports the installation of experimental processing centres, which are candidates to become SIRGAS processing centres. During a specified probation period, they align their processing strategies with those required by SIRGAS and demonstrate their capacity for timely and regular delivery of weekly solutions. Afterwards, they may be appointed as official processing centres. In January 2013, the first SIRGAS Experimental Processing Centre in Central America started activities at the Universidad Nacional of Costa Rica.

SIRGAS AND THE COMMUNITY

Two kinds of solutions are delivered to the community by SIRGAS, both of which realise the ITRF: i) weekly station positions referred to the corresponding weekly solution of the IGS network, and ii) multi-year solutions referred to the ITRF, including station position at a reference epoch and linear coordinate changes, i.e. velocities.
A new multi-year solution is computed by the DGFI annually. The latest one, named SIR11P01 (Figure 2), comprises all weekly solutions from January 2000 to April 2011. It includes 229 stations and realises the ITRF2008 at the reference epoch 2005.0. The precision of the coordinates at the reference epoch was estimated to be ± 0.5mm for the horizontal components and ± 0.9mm for the vertical, while the precision of the constant station velocities was estimated to be ± 0.4mm/a.
Public and private-sector users alike can freely access the SIRGAS-CON solutions through the SIRGAS website, where they can find guidelines for the proper application of such products.



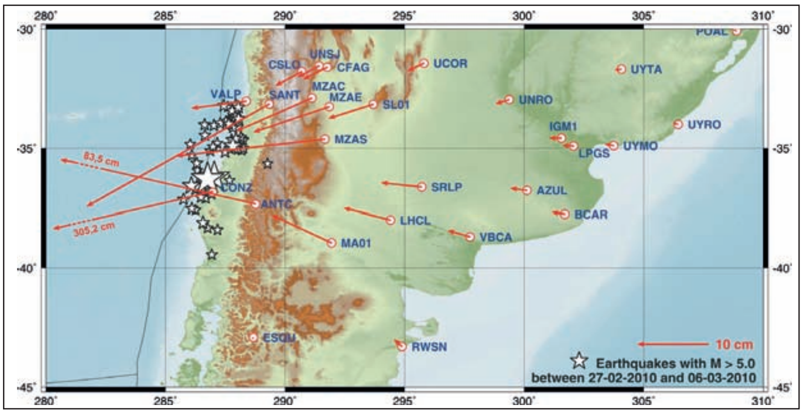
▲ *Figure 2, Mean yearly displacements of the SIRGAS reference stations.*



▲ *Figure 3, Station height variations in Brasilia and Manaus (Brazil).*

SIRGAS ORGANISATION

SIRGAS is a non-profit organisation based on the voluntary partnership of more than 50 organisations in 19 countries, including the national cartographic and other governmental agencies committed to the production of land information, as well as universities and research institutions. SIRGAS activities are mostly supported by these organisations which provide their human and material resources to carry out the working plans. ▶



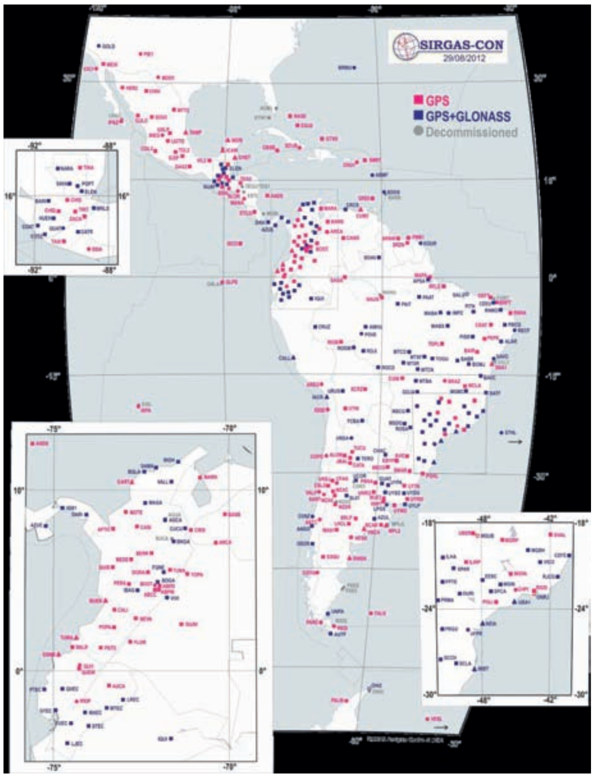
▲ *Figure 4, Station displacements caused by the earthquake of February 2010 in Chile.*

SIRGAS is integrated in the IAG as the Sub-Commission 1.3b, 'Reference System for Latin America', and in the PAIGH as the 'SIRGAS Working Group' of its Commission of Cartography. The interaction with the IAG guarantees guidance in the advances of geodesy and provides the Latin American community with all the benefits offered by the IAG's various components. The relationship with PAIGH facilitates knowledge of each country's needs regarding the use of reference frames by non-geodesist experts. The administrative issues of SIRGAS are managed by an Executive Committee, which depends on the Directing Council, the main body of the organisation. This Council is comprises one representative of each member country, one of IAG and one of PAIGH. It outlines the policies to be followed within SIRGAS. The technical activities are co-ordinated by three working groups: I) 'Reference System' devoted to the analysis and maintenance of the reference network; II) 'SIRGAS at national level' in charge of promoting and supporting the adoption of SIRGAS in the different countries; and III) 'Vertical Datum' (not considered in this article) dedicated to the unification of the existing height systems.

SUMMARY

SIRGAS is the regional densification of the ITRF in Latin America and the Caribbean. It provides the reference frame for practical applications such as cadastre and land management. In addition, it is the unique reference frame in the region capable of supporting climate-change studies (sea-level rise, water cycle, etc.) and natural disaster monitoring (seismicity, volcanic activity, etc.).

Presently, the main activities SIRGAS is involved in are: installing more continuously operating GNSS stations to monitor frame deformations; establishing a deformation model (derived from measured station positions) to transform between pre- and post-seismic frame realisations; and accounting for seasonal and other non-linear movements of the station positions.



▲ *Figure 5, The SIRGAS Continuously Observing Network (SIRGAS-CON).*

ACKNOWLEDGEMENTS

SIRGAS's achievements are possible thanks to the efforts of many people in more than 50 institutions. Special thanks are given to Hermann Drewes, Virginia Mackern, William Martínez and Roberto Luz. The support provided by IAG and PAIGH is greatly appreciated. ◀

FURTHER READING

Up-to-date and detailed information about SIRGAS can be obtained from the organisation's website (www.sirgas.org).

The following papers recently published in S. Kenyon, M.C. Pacino, U. Marti (Eds.), 'Geodesy for Planet Earth', IAG Symposia, Vol. 136, Springer 2012, are also recommended:

- Brunini, C., L. Sánchez, H. Drewes, S. Costa, V. Mackern, W. Martínez, W. Seemüller, A. da Silva: Improved Analysis Strategy and Accessibility of the SIRGAS Reference Frame, 3-10.
- Costa, S.M.A., A.L. Silva, J.A. Vaz: Report on the SIRGAS-CON Combined Solution by IBGE Analysis Center, 853-858.
- Drewes, H., O. Heidbach: The 2009 Horizontal Velocity Field for South America and the Caribbean, 657-664.
- Sánchez, L., W. Seemüller, M. Seitz: Combination of the Weekly Solutions Delivered by the SIRGAS Processing Centres for the SIRGAS-CON Reference Frame, 845-852.
- Seemüller, W., M. Seitz, L. Sánchez, H. Drewes: The New Multi-year Position and Velocity Solution SIR09P01 of the IGS Regional Network Associate Analysis Centre (IGS RNAAC SIR), 877-884.