**SIRGAS: the core geodetic infrastructure in Latin America and the Caribbean**

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**SIRGAS reference frame**

The primary objective of SIRGAS (Sistema de Referencia Geocéntrico para las Américas) is the determination and maintenance of a reliable reference frame in Latin America and the Caribbean as a densification of the ITRF and as a regionalisation of the ITRF. The SIRGAS reference frame is currently composed of 418 continuously operating GNSS stations (Fig. 1). It comprises two hierarchy levels: a core network (SIRGAS-C) providing the primary link to the global ITRF, and national reference networks (SIRGAS-N) improving the geographical density of the reference stations to ensure the accessibility to the reference frame at national and local levels. Given that most of the existing ITRF stations in South America are affected by strong seismic activity in this region, further stations located in Europe, Africa, Oceania and North America are included in SIRGAS to increase the availability of fiducial points.

![Fig. 1 SIRGAS reference frame (as of July 2017).](Image)

**Routine processing of the SIRGAS reference frame**

The SIRGAS-C network is processed by DFG-TUM (Germany) as IGS RINAC SIRGAS (IGS RINAC SIRGAS Regional Network Associate Analysis Centre for SIRGAS). The SIRGAS-N networks are computed by the SIRGAS local analysis centres, which are operated by GEOP (Ecuador), CPNGD-UNA (Costa Rica), CPAGS (Venezuela), IVBGE (Brazil), IGAC (Colombia), IGM (Chile), IGMC (Argentina), IIGE (Mexico), and SGM (Uruguay). The SIRGAS analysis centres follow unified standards for the computation of loosely constrained weekly solutions for the station positions. These standards are generally based on the conventions outlined by the IERS and the GNSS-see specifications defined by the IGS, with the exception that in the SIRGAS solutions the satellite orbits and clocks as well as the Earth orientation parameters (EOP) are fixed to the final weekly IGS products, and positions for all stations are constrained to ±1 m. The individual solutions are combined by the SIRGAS combination centre operated by the DFG-TUM and the IBGE.

**Surface deformation modelling within SIRGAS**

Based on GNSS measurements gained after the strong earthquakes (in 2010 in Chile and Mexico, a new continental crustal deformation model for the SIRGAS region was computed. It is based on a multi-year velocity solution for a network of 456 continuously operating GNSS stations and covering a five years period from March 14, 2010 to April 11, 2015. This deformation model, called VEMOS2015 (Velocity Model for SIRGAS 2015), is computed using the least square collocation (LSC) approach with empirically determined covariance functions. The results make evident that the tectonic structure in South America has to be redefined: the area between the latitudes 35°S and 40°N is no longer considered as a stable part of the South American plate, whereas it is now obvious that there is a large and extended crustal deformation zone (Fig. 3). Combined with the other reference frames, this information provides a constraint on measurements before the 2010 earthquakes (like the TRF2000 network) and those conducted after the 2010 earthquakes in the Pacific region. The deformation caused by these earthquakes and highlight the necessity of updating accordingly reference frames and deformation models in the affected regions. At present, an updated deformation model based on GPS data gained from January 2014 to January 2017 is being computed.

**Geocentric datum realisation in the weekly SIRGAS solutions**

Due to the strong seismic activity in Latin America, the fiducial points used for the geodetic datum realisation often present discontinuities and they are no longer suitable as reference stations. In addition, the weekly solutions suffer from the convention that the geodetic reference frames model only linear station position changes, so that the geocentricity of the SIRGAS network is lost when seasonal or abrupt episodic variations occur. Thus one of the present SIRGAS objectives is to design a new strategy for the geocentric realisation of the SIRGAS reference frame. The basic idea is to extend the global network beyond the SIRGAS region including GRACE and SLR stations to perform a multi-technique combination and to define the transformation from the SLR/VRB optimally to the regional network. To initiate the empirical experiments, the existing regional SIRGAS network was extended by globally distributed co-location and all available GNSS core stations (Fig. 4). Based on this network configuration, different processing strategies are being evaluated. As an example, Fig. 5 shows the difference between the SIRGAS weekly positions and those obtained within the global network using GNSS observations with orbit and EOP determination for the first week of June 2014. The computation of the regional reference frame within a global network may change its station positions some millimetres. In the case of SIRGAS, it seems the network “moves” to the north about 3 mm.

**Modelling seasonal displacements at SIRGAS stations**

As an example, SIRGAS stations present strong seasonal motions, an investigation is being conducted to model these movements using vertical load values as additional parameters in the accumulation of the weekly SIRGAS normal equations (NEQ). The proposed model relates the response of the Earth’s crust (as measured by GNSS) to the vertical load inferred from GRACE. Although gravity changes over the surface are due to atmospheric, non-tidal ocean and hydrological mass variations, in the SIRGAS region the hydrological contribution holds the main role of the overall contributions. Our method is based on a numerical solution of the semi-stationary equation for an elastic medium (i.e. the Earth’s crust) characterized by an elastic parameter. The elastic parameter relies on the combination of Poisson’s ratio and Young’s modulus. The empirical experiments combine (a) the NEQ calculated on a weekly basis as the SIRGAS reference frame along five years, with (b) monthly grids of equivalent water height (EWH) derived from GRACE for the same time span. The solution of the combined NEQ leads to the common adjustment of seven parameters per GNSS station: namely, three position coordinates at a certain epoch, three constant velocity coordinates, and one elastic parameter. The vertical positions predicted with this method are compared with the SIRGAS weekly positions within ±3 mm at the one sigma level. Some examples are shown in Fig. 6.