2010 General Meeting of SIRGAS and Second IAG-PAIGH-SIRGAS School on Reference Systems November 8 – 12, 2010, Lima, Peru

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SIRGAS (Sistema de Referencia Geocéntrico para las Américas) is the geocentric reference system for Latin America and the Caribbean, including a gravity field-related vertical reference system. It is the Sub-commission 1.3b (Regional Reference Frame for South and Central America) of the International Association of Geodesy (IAG) and a Working Group of the Cartographic Commission of the Pan American Institute for Geography and History (PAIGH). Activities, advances, and new challenges of SIRGAS are reported, discussed, and re-oriented (if necessary) in the SIRGAS yearly meetings, which have been realized since 1993. The SIRGAS 2010 General Meeting was carried out together with the 42 Meeting of the PAIGH Directing Council in November 11 and 12 in Lima, Peru. In the three days prior to the SIRGAS Meeting (November 8 - 10), the Second IAG-PAIGH-SIRGAS School on Reference Systems took place. This report summarizes these two events.

Participants of the SIRGAS 2010 General Meeting and Second IAG-IPGH-SIRGAS School on Reference Frames

Second IAG-PAIGH-SIRGAS School on Reference Systems

SIRGAS is the basis for all projects on the generation and use of geo-referenced data in national as well as international levels in Latin America. Besides to provide the reference frame for the

development of practical applications such as engineering, digital administration of geographical data, geospatial data infrastructures, etc., SIRGAS is also the platform for a wide range of scientific applications such as monitoring Earth crust deformations, sea level variations, atmospheric studies, etc. The maintenance and use of SIRGAS as the reference frame in the countries of the region is oriented and supported by different capacity building activities, which provide fundamental concepts about the appropriate generation and application of reference geodetic data. These activities may be divided into two classes: The first one focuses on the establishment of SIRGAS Analysis Centres operated by Latin American institutions. It includes theoretical and computational education concerned with the analysis of GNSS data following IAG standards, conventions, and methods.

The second activity is mainly oriented to the users of SIRGAS as a reference frame and comprises a theoretical course denominated IAG-PAIGH-SIRGAS School on Reference Systems. The first school took place in Bogotá (Colombia) from 13 to 17 July, 2009 with 120 participants representing 12 countries of Latin America and the Caribbean. The Second School was carried out from 8 to 10 November 2010 in Lima hosted by the Instituto Geográfico Nacional of Peru. This school was attended by 112 participants representing 13 countries. It included five topics:

- Types of coordinates, their definitions, relations and transformations;
- Geodetic reference systems and frames (ICRS/ICRF, ITRS/ITRF, regional and national densifications of ITRF);
- Determination of precise coordinates (station positions and velocities) using GNSS techniques, including network adjustment and alignment to ITRF;
- Vertical reference systems (geometrical and physical heights, reference surfaces, unification of heights systems);
- Definition, realization, and use of SIRGAS in practice and science.

The third IAG-PAIGH-SIRGAS School on Reference Systems will be carried out together with the SIRGAS 2011 General Meeting in Heredia, Costa Rica.

SIRGAS 2010 General Meeting

The SIRGAS 2010 General Meeting was held in November 11 and 12 in Lima. It was attended by 89 participants and also hosted by the Instituto Geográfico Nacional of Peru. In 37 oral presentations and 13 posters, the following SIRGAS issues were presented:

- Enlargement/densification and analysis of the continuously operating network SIRGAS-CON;
- The SIRGAS reference frame and the impacts caused by the recent earthquakes occurred in Latin America and the Caribbean;
- Studies of the atmosphere (ionosphere and troposphere) based on the SIRGAS infrastructure;
- Achievements related to the use of GNSS data in real time in the SIRGAS area;
- National reports about the SIRGAS activities in the Latin American and Caribbean countries;
- SIRGAS vertical reference system;
- Contribution of SIRGAS to GGOS (Global Geodetic Observing System).

Presentations and extended abstracts of the contributions are available at the SIRGAS web site (www.sirgas.org).

Complementary to the scientific and technical contributions, the following reports were presented:

Report of SIRGAS President
- Main activities during the last year;
- Changes in the Executive Committee (new National Representatives);
- Participation of SIRGAS in international working groups and meetings.

Report of SIRGAS Vice-President
- Availability and distribution of the SIRGAS products;
- SIRGAS in the Internet, maintenance of the SIRGAS web site;
- Use of the SIRGAS products.

Report of the SIRGAS Working Groups

- SIRGAS-WGI (Reference System): New experimental processing centres, new multi year solution for the SIRGAS-CON network, atmospheric studies based on the SIRGAS infrastructure (SIRGAS-ION), coming activities;
- SIRGAS-WGII (Geocentric Datum): New national densifications of SIRGAS, Second IAG-PAIGH-SIRGAS School on Reference Systems, SIRGAS Real Time, coming activities;
- SIRGAS-GTIII (Vertical Datum): Towards geopotential numbers computation in a continental level, realization of the reference surface, coming activities.

The main conclusions and recommendations of the SIRGAS 2010 General Meeting are:

1. The present realization of SIRGAS is a network of more than 230 continuously operating stations covering Latin America and The Caribbean. The weekly analysis of this so-called SIRGAS-CON network is based on the combination of individual solutions including different clusters of stations and guarantying that each station is calculated by three processing centres. At present, there are seven SIRGAS official processing centres (CIMA Argentina, DGFI Germany, IBGE Brazil, IGAC Colombia, IGM Ecuador, LGFS/LUZ Venezuela, SGM Uruguay) and two experimental processing centres (IGN-Argentina, INEGI-Mexico). The evaluation of the individual solutions confirmed that all Processing Centres (official and experimental) satisfy the administrative and quality processing requirements defined in the SIRGAS guidelines. Their weekly solutions are at the same accuracy level with respect to each other and with respect to final weekly combinations. As a main conclusion, it was recommended that IGN-Argentina and INEGI-Mexico become official processing centres as soon as possible.

2. The combination of the individual solutions delivered by the SIRGAS processing centres is carried out by the SIRGAS combination centres (IBGE-Brazil, DGFI-Germany). After the SIRGAS 2009 General Meeting, the SIRGAS-WGI outlined a conventional strategy to define the geodetic datum within the SIRGAS-CON weekly combinations. This strategy is based on constraining the coordinates of selected ITRF stations to their positions calculated within the IGS weekly combinations (igs*yy*P*wwww*.snx). The applied constraint corresponds to a weight inversely proportional to the internal variance of the GPS measurements. This procedure replaces the use of epoch station positions plus linear velocities as reference coordinates. It is applied by both SIRGAS combination centres since January 2010 and their results are practically identical. Until now, the final SIRGAS weekly coordinates are the combinations computed by DGFI as IGS Regional Associate Analysis Centre for SIRGAS (IGS RNAAC SIR). The IBGE combinations provide redundancy and backup. After the evaluation carried out within the SIRGAS 2010 General Meeting, it was concluded that the IBGE combinations can also be made available to users as the final SIRGAS weekly coordinates.

3. The main SIRGAS-CON products (i.e. loosely constrained weekly solutions for the IGS polyhedron and weekly positions aligned to the ITRF) present a precision (internal consistency) of about ±0,9 mm in horizontal and ±2,5 mm in vertical positions, while the accuracy with respect to the ITRF (external consistency) is about ±1,7 mm for the horizontal and ±3,7 mm for the vertical component.

4. A new multi-annual solution, identified as SIR10P01, for the SIRGAS-CON network was released in July 2010. It encompasses all the weekly solutions provided by the SIRGAS analysis centres from January 2, 2000 (GPS week 1043) to June 5, 2010 (GPS week 1586) and refers to the ITRF2008 at epoch 2005,0. Positions and velocities for 183 SIRGAS-CON stations are included. Its precision was estimated to be ~±0,5 mm (horizontal) and ~±0,9 mm (vertical) for the station positions at the reference epoch, and ~±0,2 mm/a (horizontal) and ~±0,4 mm/a (vertical) for the linear velocities. A loosely constrained version of this solution was delivered as SIRGAS contribution to the IAG SC1.3 Working Group on Regional Dense Velocity Fields.

5. The availability of horizontal velocities in those regions which are not covered by SIRGAS-CON stations is strongly improved through the new Velocity Model for South America and the Caribbean (VEMOS 2009), which represents the continuous present-day deformation of the Earth crust in the SIRGAS region. It is based on nearly 500 velocity stations observed in 13 GPS projects. The overall precision of the point velocities is better than ±1 mm/a in South-North and about ±1,5 mm/a in West-East direction.

6. Although the reliability of the estimated positions and velocities of the SIRGAS reference stations as well as its compatibility through time are guaranteed, it is necessary to give special care to the reference frame deformations caused by seismic events. It is well known that the western part of the SIRGAS region, i.e. the plate boundary zone between the Pacific, Cocos, and Nazca plates in the west and the North American, Caribbean, and South American plates in the east, is an extremely active seismic area. The frequent occurrence of earthquakes causes episodic station movements, which influence the long-term stability of the SIRGAS reference frame. For instance, the recent earthquake in Chile on 2010-02-27 moved 23 reference stations between 1 cm and 3 m to the west. The earthquake in Mexicali, Mexico (on 2010-04-04) caused a jump of 24 cm in the south-east direction of the station MEXI. To mitigate the impact of seismic events in the use of SIRGAS, it is necessary:

   - To improve the national reference frames by installing more continuously operating GNSS stations in order to precisely monitor eventual deformations;
   - The reference networks composed by non-continuously operating stations must be replaced as far as possible by continuously operating stations. If this is not possible, they have to be re-measured immediately after a strong seism;
   - The transformation between the pre-seismic and the post-seismic frame realizations must be based on a deformation model derived from discrete (weekly) station positions. Usual network transformations (e.g. similarity or affine) cannot be applied;
   - In stations not observed continuously, the post-seismic coordinate changes can be interpolated from the deformation model;
   - In precise positioning, users have to apply epoch (weekly or monthly) positions as reference coordinates instead of those derived from a reference epoch and (a sequence of) velocities.

7. Until now, the SIRGAS Analysis Centres process GPS data only. Since the number of GLONASS stations is increasing in the SIRGAS region, the SIRGAS-WGI initiates the routine processing of GLONASS observations on a weekly basis. All GLONASS stations will be analysed as an individual network, loosely constrained solutions of which will be combined with the similar solutions generated for the other SIRGAS-CON sub-networks.

8. The national reference frames of El Salvador and Bolivia were integrated into SIRGAS. The frame SIRGAS-ES2007.8 (SIRGAS El Salvador 2007.8) is composed by 35 stations observed in a GPS-campaign in 2007. Adjusted station positions refer to the IGS05, epoch 2007.8, and the datum definition is given by constraining the weekly coordinates of the SIRGAS-CON network at the observation epoch. The reference frame of Bolivia (Referencia Geodésico Nacional, MARGEN) comprises 17 GPS stations, 8 of those continuously observing. The final coordinates are given in IGS05, epoch 2010.2. The analysis of both networks was carried out by DGFI using the Bernese Software.

9. The activities of the SIRGAS-WGII, in charge of supporting national initiatives oriented to the densification and use of SIRGAS in the Latin American and Caribbean countries, are concentrating on the incorporation of the continuously operating GNSS reference stations of Guatemala, Costa Rica, and Dominican Republic into SIRGAS.

10. The SIRGAS Real Time (SIRGAS-RT) project was established in the SIRGAS 2008 General Meeting (May 2008). Its main objective is to evaluate the possibility of providing near real time corrections for GNSS positioning based on the SIRGAS-CON stations. After two years, Argentina, Brazil, Uruguay, and Venezuela, who are applying the NTRIP tool, show significant advances in its use, and the SIRGAS-WGII will continue promoting the development of similar studies in other SIRGAS countries. The planned activities include a capacitation course of two weeks to provide expertise in the implementation and adequate use of the protocol NTRIP in the SIRGAS countries. This course will be supported by the Agencia Española de Cooperación Internacional together with the Instituto Geográfico Nacional de España.

11. The routine production of vTEC maps for South America by the Universidad Nacional de la Plata (Argentina) as SIRGAS Ionosphere Analysis Centre provides control and improvement for different kind of projects such as the International Reference Ionosphere (IRI) over South

America, positioning with single-frequency GPS receivers, and the feasibility of computing ionosphere corrections for a satellite based augmentation system (SBAS) for the region.

12. Regarding the definition and realization of a unified vertical reference system for SIRGAS, it has to be mentioned that the Latin American countries continue preparing the levelling data to be processed in a continent-wide adjustment. The SIRGAS-WGIII analyses at present geopotential numbers of Colombia, Venezuela, Brazil, Ecuador, Uruguay, Argentina, and Chile. Bolivia, Peru, and Paraguay will provide the corresponding data in the next future.

Thanks to a kind invitation of the Escuela de Topografía, Catastro y Geodesia of the Universidad Nacional, the SIRGAS 2011 General Meeting will be held in August 2010 in Heredia, Costa Rica. Prior to the meeting, the third IAG-IPGH-SIRGAS School on Reference Systems will also take place.

SIRGAS deeply acknowledges the financial support given by IAG, PAIGH, and IUGG (International Union of Geodesy and Geophysics) for facilitating the attendance to the SIRGAS Meeting of many SIRGAS colleagues. In total 15 participants received grants for travel costs and daily expenses.