



Monitoring crustal deformation and the Ionosphere by GPS in the Caribbean

Report on the project

Monitoring crustal deformation and the ionosphere by GPS in the Caribbean

sponsored by the **International Union of Geodesy and Geophysics (IUGG)** through
the **International Association of Seismology and Physics of the Earth's Interior (IASPEI)**
the **International Association of Geodesy (IAG)**
the **International Association of Geomagnetism and Aeronomy (IAGA)**

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Introduction

The main objective of this project is to invite the Caribbean countries to participate actively in geodetic and geophysical initiatives going on in the Central and South American region, in order to enable the use of the acquired data for practice and science in their countries, and to promote geosciences. This includes capacity building activities providing the basis for profound education and sustainable development as well as the establishment of international and interdisciplinary contacts to participate in research projects at regional and global scales.

The planned work for 2012-2013 approved by IUGG concentrated on the education in fundamental topics about monitoring crustal deformation and the ionosphere. This included a school on the performance of GNSS observations, data analysis and appropriate use of results, as well as the participation of colleagues from Caribbean countries in recent meetings related with these topics in the region. All the proposed activities were carried out; and in the following the corresponding details are presented.

Developed activities and results

Starting contacts and implementing a directory of colleagues working in Geodesy and Geophysics in the Caribbean Region (October 2012). Under the umbrella of the IAG sub-commission 1.3b (*SIRGAS: Geocentric Reference System for the Americas*), some Caribbean colleagues were invited to the SIRGAS 2012 Meeting held in October 2012 in Concepción, Chile. The main purposes of this invitation were:

- to demonstrate how international scientific meetings are structured;
- to motivate their regular participation in similar meetings;
- to evaluate the feasibility of organising a meeting of this type in a Caribbean country;
- to estimate how many participants from Caribbean countries could attend this meeting;
- to identify main inconveniences in the realization of such meeting.

The SIRGAS 2012 meeting in Concepción was attended by 135 participants from 17 countries, among those from the Caribbean: Colombia, Costa Rica, Guatemala, Guyana, Honduras, Mexico, Panama, and Venezuela. The main conclusions in Concepción regarding this project were:

- To have a training course on precise processing of GNSS data in Costa Rica in December 2012, hosted by the *Universidad Nacional*.
- To plan a school on geodetic reference systems, crustal deformation and ionosphere monitoring to be carried out in Guyana in April 2013, approximately. The meeting should be hosted by the Geology Mines Commission.



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Attendees to the SIRGAS 2012 General Meeting. Concepción, Chile. October 29-31, 2013.

Training course on precise processing of GNSS data (December 2012). Thanks to the support of the *Escuela de Topografía, Cartografía y Geodesia* of the *Universidad Nacional* of Costa Rica (ETCG-UNA), the *Deutsches Geodätisches Forschungsinstitut* (DGFI), Munich, Germany, and the *University of Bern* (Switzerland), it was possible to develop a capacity building activity concentrated on the precise analysis of GNSS data using the Bernese GPS Software 5.0. This course took five days, eight hours per day, and it was attended by 15 participants. It included

- determination of high-precise station positions;
- analysis of time series of station positions;
- estimation of station position changes with time (the so-called station velocities);
- modelling of station position discontinuities;
- computation of atmospheric parameters (ionosphere and neutral atmosphere) based on GNSS observations.

The main result regarding this project is the installation of the first GNSS Processing Centre in Central America. ETCG-UNA started in January 2013 computing weekly solutions for a GNSS network of about 50 stations. These weekly solutions were regularly evaluated by the SIRGAS Combination Centres and, during the last SIRGAS Meeting, it was decided to declare ETCG-UNA as an official SIRGAS Processing Centre from January 2014, since it satisfies all the requirements of a high-level processing centre. With this, the weekly solutions delivered by ETCG-UNA will be integrated in the official SIRGAS products and the colleagues in Costa Rica are now able to model crustal deformations caused by seismic events and to estimate atmospheric parameters based on GNSS observations.



Participants in the training course on precise processing of GNSS data. Heredia, Costa Rica. December 3-7, 2012.

School on Reference Systems, Crustal Deformation and Ionosphere Monitoring (October 2013). As mentioned above, it was initially planned to have this school in Guyana in April 2013. However, three



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weeks before the starting date, it was realised that only 21 persons had registered, being most of them from Guyana. In order to take a maximum advantage of this activity, it was decided to postpone the school and to have it together with the SIRGAS 2013 Meeting in October 2013 in Panama City. At this point, a divulgation campaign about the school was started using mainly the Internet and electronic mail. Due to the positive reaction from the Caribbean countries, the *School on Reference Systems, Crustal Deformation and Ionosphere Monitoring* was held from October 21 to 23, 2013 in Panama City and it was hosted by the *Instituto Geográfico Nacional Tommy Guardia*. In the three following days, from October 24 to 26, the SIRGAS 2013 Meeting was carried out in such a way, that the school attendees could also participate in the SIRGAS meeting. The main topics treated during the school were:

- Types of coordinates, their definitions, relations and transformations.
- Geodetic reference systems and frames (celestial and terrestrial reference systems and frames, regional reference frames, SIRGAS, vertical reference frames).
- Installation and maintenance of observation instruments (in particular of GNSS), real-time data dissemination (via Internet), and data archiving and management.
- Coordinates determination from GNSS (observation equations, uncertainties in GNSS positioning, controlling errors in GNSS positioning, adjustment of GNSS networks).
- Crustal deformation observation and modelling (geodynamic processes, plate tectonics, intra- and inter-plate crustal deformation, monitoring deformations by GPS)
- Ionosphere modelling and analysis (structure of the atmosphere, models of the ionosphere, observation techniques, analysis of the ionosphere).

The school was attended by 145 participants from 28 countries, among those from the Caribbean: Barbados, Colombia, Costa Rica, Dominican Republic, Guatemala, Honduras, Jamaica, Mexico, Monserrat-UK, Nicaragua, Panama, Puerto Rico, St. Lucia, Suriname, Trinidad and Tobago, Turks and Caicos Islands, USA, and Venezuela. The main results of the school regarding this project are

- The purpose of the Dominican Republic, Puerto Rico, Suriname, Trinidad and Tobago, Jamaica, St. Lucia and Turks and Caicos Islands to join the IAG activities developed by SIRGAS. Representatives of these countries started the necessary contacts to be integrated in different working and research groups.
- Trinidad and Tobago and Dominican Republic are interested in hosting a similar school in order to disseminate these topics to those people who were not able to come to Panama.
- Dominican Republic, Guyana, Nicaragua and Puerto Rico are now integrating their geodetic reference stations into the continental reference frame.
- The willingness of the Dominican Republic to install a high-level GNSS processing centre.
- It should be mentioned that Colombia and Venezuela participate actively in SIRGAS since 1993; Costa Rica, Guatemala, Honduras, Mexico, Nicaragua and Panama joined SIRGAS in 2003, and Guyana joined SIRGAS in 2011.

SIRGAS 2013 General Meeting (October 2013). Immediately after the School on Reference Systems, Crustal Deformation and Ionosphere Monitoring, the SIRGAS2013 Meeting was held. This allowed the Caribbean countries the presentation of the current status of their geodetic/geophysical infrastructure during the meeting. Presentations about the infrastructure in Colombia, Costa Rica, Dominican Republic, Guatemala, Honduras, Jamaica, Mexico, Nicaragua, Panama, Puerto Rico, St. Lucia, and Venezuela were given. These presentations are available at www.sirgas.org. After the conclusions of the SIRGAS2013 meeting (also available at www.sirgas.org), the main result of this



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activity is the decision to hold the SIRGAS General Meeting 2015 in the Dominican Republic. This will allow the further integration of the Caribbean countries in IUGG initiatives.



Participants in the School on Reference Systems, Crustal Deformation and Ionosphere Monitoring and the SIRGAS2013 General Meeting. Panama City, Panama. October 21-26, 2013.

Financial issues

IUGG granted an amount of 16000 US dollars for this project. These resources were invested to support the travel of some Caribbean colleagues to Panama. However, applicants of travel support were requested to find additional resources to cover a complementary part of the costs (flight ticket, daily expenses or accommodation). In this way, it was guaranteed that attendees were really interested in the school and the so-called *scientific tourism* was avoided. In addition to the IUGG resources, it was possible to get economical support from the IAG and from the Pan-American Institute of Geography and History (PAIGH), also for travel grants. The following table summarizes the travel expenses for the different activities carried out in the frame of this project. Organisational and logistic expenses are not included because they were covered by the hosting institutions, namely *Universidad de Concepción* and *Instituto Geográfico Militar* of Chile for the SIRGAS2012 General Meeting, *Universidad Nacional* for the training course on Precise Processing of GNSS data, and *Instituto Geográfico Nacional Tommy Guardia* for the School on Reference Systems, Crustal Deformation and Ionosphere Monitoring, and the SIRGAS2013 General Meeting. From the 16000 US dollars granted by IUGG to this project, 9030 USD were invested during 2013. The remaining resources (6790 USD) are foreseen to support the attendance of Caribbean colleagues to the meeting in the Dominican Republic in 2015.

Conclusions and Outlook

Almost all the countries in the Caribbean region are developing countries according to UNO and ICSU categories. The accomplished activities provided a significant outreach in all related fields of geosciences and practice; especially in those disciplines covered by IUGG, IASPEI, IAG, and IAGA. The new knowledge transferred by means of the School in Panama and the Training Course in Costa Rica contributes to the sustainable development of geosciences in the region and it is expected that the participants become more engaged in geodetic and geophysical activities. The Caribbean area is underrepresented in IUGG and its Associations, as well as in active participation in Earth science



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projects. This project enhanced the visibility of IUGG and encouraged the colleagues to raise funds from their governments and private companies to extend the existing observational infrastructure and to support data processing at a high-level. The improvement of the coverage of the area by additional GNSS observation stations will allow to increase the precision of the existing continuous (aseismic) crustal deformation model of the Caribbean, and future seismic events can better be modelled. The mapping of the ionosphere will significantly be improved in the Caribbean. As an immediate task, SIRGAS will support, as far as possible, all requirements of the Caribbean countries related to their integration in international geodetic and geophysical initiatives. These follow-on actions will provide a better coverage of the region in terms of observatories, data delivery, analysis and interpretation. This will have an effect not only on the scientific knowledge but also on the sustainable development in practical applications (navigation, surveying, engineering, etc.).

Summary of amounts according to the developed activities.

Activity	Detail	Amount	Source
Starting contacts and implementing a directory with colleagues working in Geodesy and Geophysics in the Caribbean Region, activity developed in the frame of the SIRGAS2012 Meeting (Concepción, Chile, Oct. 2012)	Travel awards for young scientists in GNSS processing.	3,200 USD	International Association of Geodesy
	Flight tickets for representatives of Costa Rica, Colombia, Guatemala, Honduras, Panama	6,200 USD	Pan-American Institute of Geography and History
	Travel award for Guyana	1,000 USD	SIRGAS
	Complementary travel expenses of participants with travel grant	6,000 USD	National geodetic and geophysical agencies
Training course on precise processing of GNSS data in Costa Rica (December 2012)	Travel expenses of the lecturer (flight from Munich, Germany, stay of five days in Heredia)	3,000 USD	Universidad Nacional of Costa Rica
School on Reference Systems, Crustal Deformation and Ionosphere Monitoring and the SIRGAS2013 General Meeting (October 2013)	Travel awards for young scientists, GNSS processing centres representatives, and real time positioning services.	4,000 USD	International Association of Geodesy
		2,180 USD	International Union of Geodesy and Geophysics
		4,800 USD	Pan-American Institute of Geography and History
	Travel awards for representatives of Venezuela, Costa Rica, Guatemala, Dominican Republic, Nicaragua, Colombia, Jamaica.	6,850 USD	International Union of Geodesy and Geophysics
	Travel expenses of the lecturers	2,000 USD	CONICET, Argentina
		3,500 USD	DGFI, Germany
	Complementary travel expenses for participants with travel grant	8,000 USD	National geodetic and geophysical agencies
Total		50,730 USD	

Summary of amounts according founding organisations.

Organisation	Amount	Comments
International Union of Geodesy and Geophysics	9,030 USD	Founds of the project <i>Monitoring crustal deformation and the ionosphere by GPS in the Caribbean</i>
International Association of Geodesy	7,200 USD	Travel awards for young scientists
Pan-American Institute for Geography and History	11,000 USD	Flight tickets
National geodetic and geophysical agencies	14,000 USD	Complementary travel costs for grant beneficiaries
Others (SIRGAS; Universidad Nacional of Costa Rica; CONICET, Argentina; DGFI, Germany)	9,500 USD	Training course in Costa Rica; travel awards; travel costs of lecturers in Panama School (paid by their home institutions)
Total	50,730 USD	



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Resources assigned to the project *Monitoring crustal deformation and the ionosphere by GPS in the Caribbean*

Amount granted by IUGG to the project	16,000 USD	Money was transferred to the IAG General Secretariat account; 12,067 Euros were received.
Resources invested in 2013	9,030 USD	This corresponds to 56,43% of the total resources assigned by IUGG. Travel grant receipts are archived at the IAG General Secretariat.
Remaining resources approved by IUGG to this project to be used for the meeting in the Dominican Republic (2015)	6,790 USD	This corresponds to 43,57% of the total resources assigned by IUGG.