Nordic Journal of Surveying and Real Estate Research 4:2 (2007) 59–69
submitted on 29 October, 2006
revised on 3 September, 2007
accepted on 3 September, 2007

Absolute Gravity Measurements and Gravity Networks in South America

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Abstract*. The main task of Commission Project CP2.7 is to establish a new Absolute Gravity Network in South America with a medium distance between the stations on the order of 1,000 m, with the re-observation of the existent absolute gravity stations to assure internal consistency in precision, reference system, method of measurement, etc.*

This paper presents the state of the art of all the existent information regarding Absolute Gravity Measurements in South America.

Some stations have already been occupied in Brazil and Uruguay. Besides, a budget was approved for the reoccupation of absolute gravity stations in Argentina. Furthermore, eleven new stations have been measured in Chile with the micro-g FG5 Nº 206 and the definition of sites for new absolute gravity determinations has been already performed.

On the other side, a strong effort was carried out in several countries in order to improve the distribution of gravity information in South America.

These activities are intended to organize gravity measurements in the continent and will provide the necessary information for the height system in association with the geoid determination.

The greatest effort at the moment pertains to the coordination of collecting, validating, and bringing consistency to existing data sets from among the many participating groups (countries and/or organizations).

Keywords. *Gravity Measurements, Gravity Networks, Altimetric Networks, South America*

1 Introduction

A gravity reference network was established in South America and adjusted by the Canadian Geological Survey in 1992 (Torge et al., 1994). Most of the stations of that old network are destroyed. In many countries, new reference networks have been established recently like in Chile, Paraguay, Argentina, Ecuador.

It is necessary and urgent to tie the networks together and carry out an adjustment. On the other hand, many gaps of gravity data have been filled in

the last few years in different countries. In spite of that, other gaps still exist, in particular in the mountains and forests.

Many activities were encouraged in the frame of Commission Project CP2.7: Gravity in South America. A brief description of some activities has been included in the report of Commission II: Gravity Field.

Besides, the project is intended to validate fundamental gravity networks from different countries in order to establish a single and common gravity network for South America.

It will contribute to the "Geoid in South America Project" by obtaining and maintaining files with gravity data necessary for the geoid computation.

Furthermore, another objective of the project is to encourage and eventually support local organizations in different countries to increase the gravity data coverage, in particular, airborne surveys as well as to organize and encourage the organization of workshops, symposia or seminars on gravity in South America.

The objectives and actions regarding gravity measurements in South America were discussed and approved in the first meeting of the project that took place on September 9th, 2004, at Buenos Aires, during the XXII Scientific Assembly of the Argentine Association of Geodesy and Geophysics.

2 Absolute gravity stations

South American Gravity Project (SAGP, Green and Fairhead, 1991) was the first great effort in collecting and validating gravity data in South America. In 1991, the Anglo Brazilian Gravity Project (ABGP) started some new efforts to fill the gaps in Brazil.

The activities of ABGP were extended to other countries in the continent as South America Gravity Studies (SAGS). Due to these projects, a total of more than 2,400,000 land, marine, airborne and sea bottom gravity data points were acquired (Fig. 1).

They are not only part of gravity networks but also gravity measurements, mainly from oil and mining companies, universities, geological surveys, etc.

They are very useful for many purposes, like geoid modeling or geological interpretation, but not appropriate enough for others.

Many important areas remain to be surveyed and efforts are being envisaged to do airborne gravity where traditional terrestrial surveys are extremely difficult to execute, as in the Amazonas forest and the Andean mountains.

2.1 The IFE Project

The Institut für Erdmessung (IfE), University of Hannover, Germany, performed a large-scale gravity control survey between 1988 and 1991 in South America, in cooperation with university institutes and state agencies of the countries involved and supported by "Deutsche Forschungsgemeinschaft" (DGF) and "Instituto Panamericano de Geografía e Historia" (IPGH). This control system covers a large part of South America by establishing 22 absolute gravity stations with additional local eccentric stations (Fig. 2). The regional and local selection of the

stations was handled by the counterparts in the respective country, following the criteria given by the IfE gravimetry group, and taking local aspects of logistics and microseismics into account.

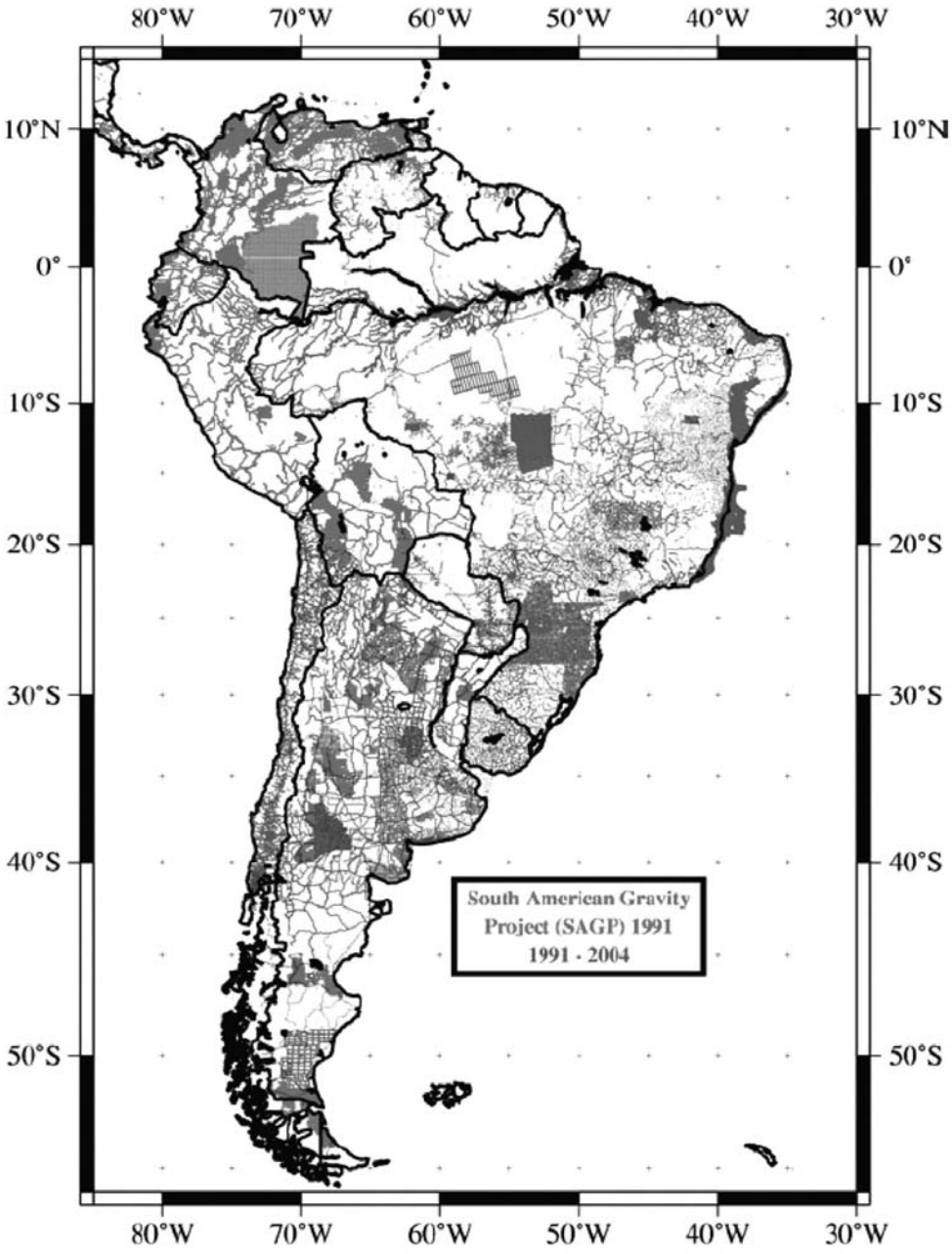

***Fig. 1**: Gravity Data in South America.*

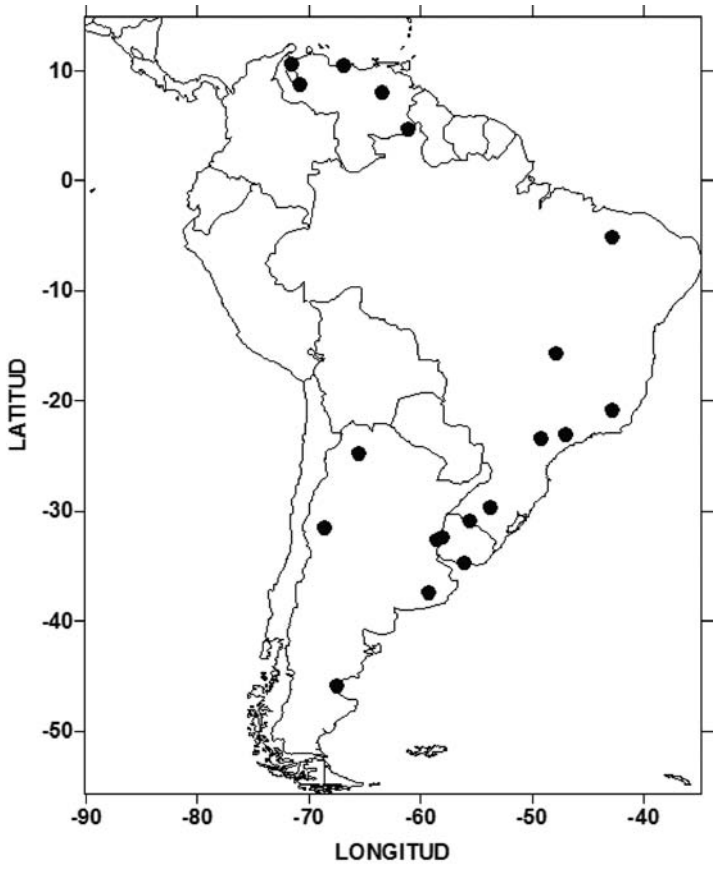

***Fig. 2**: IFE Absolute Gravity Program.*

After a first observation campaign in Venezuela in 1988 (6 stations), a project in Brazil (7 stations), Uruguay (2 stations) and Argentina (3 stations) has been performed in 1989. A final campaign in 1991 concentrated on Argentina (3 new stations) and Uruguay (1 new station, 1 reoccupied).

Three gravity stations (Sta. Helena, Brasilia, Tandil) are part of the International Absolute Gravity Base Station Network (IAGBN). In addition, the stations serve as absolute gravity control for geodynamic networks in the Central and Venezuelan Andes and they improve existing national gravity networks (Torge et al., 1994).

The JILAG-3 absolute gravimeter (Faller et al., 1983) of IfE was employed in the South America Absolute Gravity Program in combination with relative-type LaCoste – Romberg gravimeters. 1,500 to 3,000 drops have been performed per station according to local microseismic conditions. The standard deviation for one drop varied between ±0.3 and ±1.7 μms^{-2}. The standard deviation of the adjusted gravity values are between ±0.01 and ±0.05 μms^{-2}.

Local connections to the existing national gravity networks indicated that the absolute level of the IGSN71 based networks is correct within a few 0.1 μms^{-2}, but may be locally biased of up to 0.4 to 0.5 μms^{-2}.

2.2 New Absolute Gravity Stations

High precision gravity combined with GPS geodesy offers increasing potentialities for the study of time variations of the earth gravity field and crustal deformations related with geodynamic, tectonic or volcanic processes. (Bonvalot et al., 2003 a). During summer 2002, the first experience of simultaneous absolute gravity and GPS measurement in North and Central Chile was carried out with the aim to set up a repetition network of precise reference stations.

The measurements have been performed with the FG5 absolute gravity meter Nº 206 from Institut de Recherche pour le Développement, France (IRD). The sites were selected to ensure precise and safe data acquisition and mid- to long-term stability of the stations. Special care was attempted to get measurements on existing sites where other geodetic / gravity observations are available (permanent GPS, DORIS, VLBI, SLR, absolute or superconducting gravity).

For other sites, differential GPS observations have been done simultaneously with the gravity measurements.

Scintrex CG-3M relative gravity measurements have been taken for earth-tide recording and vertical gravity gradient determinations. A total number of 11 absolute gravity stations have been established in Northern and Central/Southern Chile. A preliminary processing confirms that an accuracy of 1 to 3 μGal is achieved for these absolute gravity networks (Bonvalot et al., 2003 b, Comte and Bonvalot, 2002).

3 National Gravity Networks

In Argentina, the national gravity network coincides with the national levelling network. It consists of 370 levelling lines composed of 16,320 benchmarks, including 225 nodes (Fig. 3).

Most of the gravity values in the network were originally referred to the Potsdam frame but today they have been converted to IGSN71 through the application of a shift of –14.93 mGal to the measured values. This conversion formula has been tested on more than 800 points that have measurements in both systems, the mean difference being 0.2 mGal ± 0.3 mGal. Apart from the reported measuring methodology and instrumentation, this fact leads us in principle to assume an accuracy for the gravity measurements of at least 0.5 mGal.

The Brazilian gravity network consists of about 6,000 stations and was partially adjusted to 9 absolute gravity stations in 2001. The network extends for 40 degrees in the latitudinal direction with a maximal difference of about 1900 mGal. (Piña and Sousa, 2001). It is connected to Argentina, Bolivia, Venezuela and Uruguay.

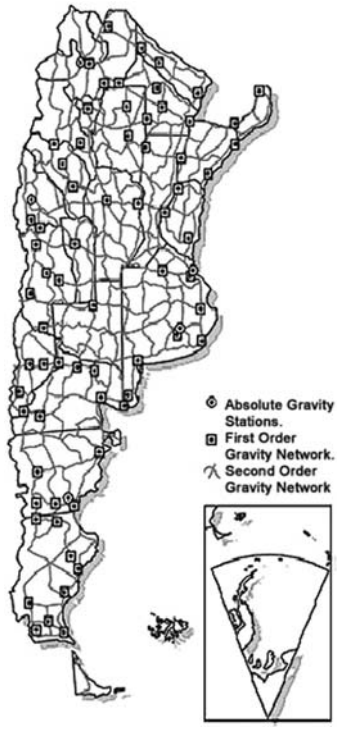

***Fig. 3**: Argentina First Order Levelling and Gravity Network.*

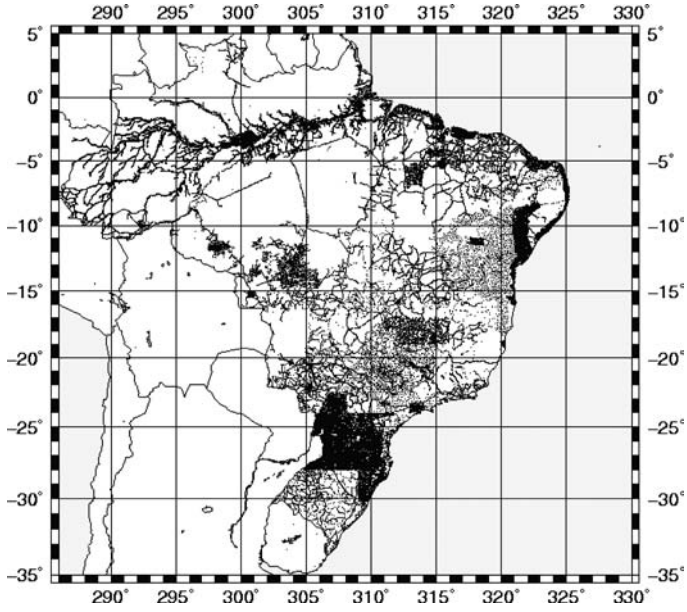

***Fig. 4:** Brazil gravity data.*

In Chile, a joint work was developed with Brazil, with the support of National Geospatial Agency (NGA) and Geophysical Technology (GETECH) (Blitzkow et al., 2002). During 2001, 31 basic gravity stations of reference and more than 550 densification stations were determined in a total of 52 days of work (Fig. 5). Efforts are being made in order to perform airborne gravity surveys in the Andean region.

A joint work was also developed between Brazil and Paraguay and between Brazil and Ecuador, with the support of NGA and GETECH (Blitzkow et al., 2002). In Paraguay, noa gravity stations could be found to where the surveys could be referred. All the basic stations established in the past had been destroyed, even the IGSN71 in Asunción, the capital city. Given this situation it was necessary to initiate a connection to the Brazilian gravity network and also with one of its absolute gravity stations.

A total of 81 days of work in Paraguayan territory provided a basic gravity network of reference with 47 stations and 1,321 densification stations (Fig. 6).

Also planned is a connection with the Argentinian network aiming at a future adjustment of all South American Gravity stations of reference.

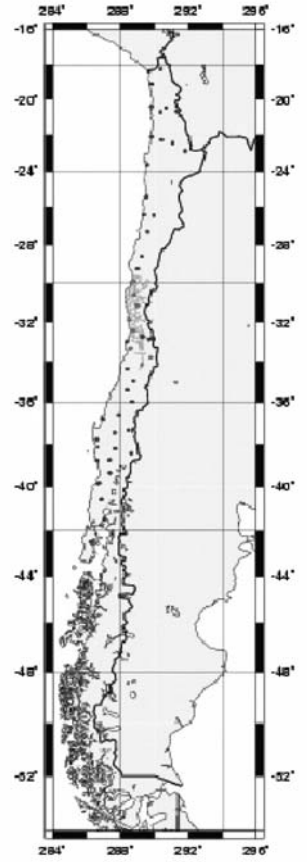

Fig. 5*: Fundamental Gravity Network in Chile.*

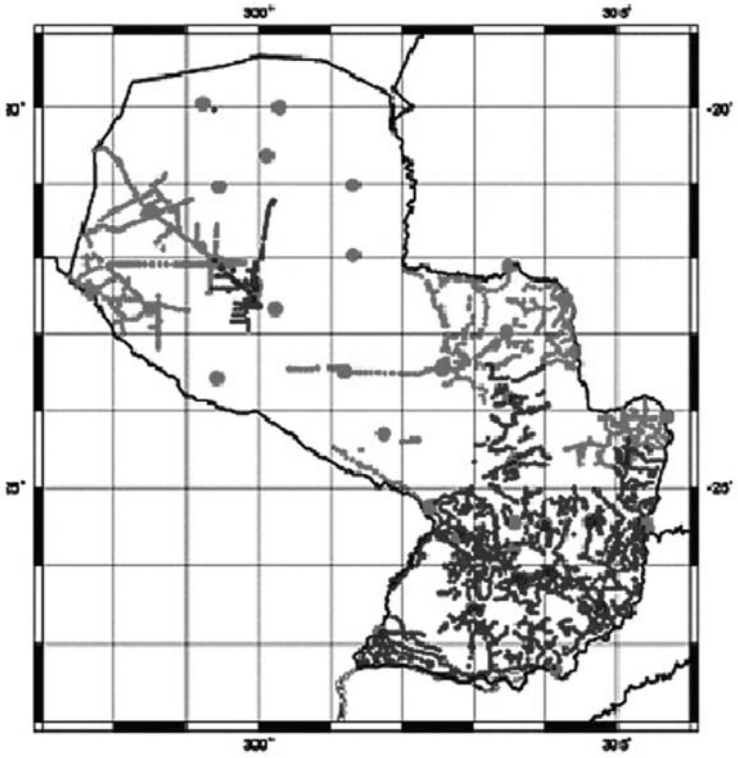

***Fig. 6**: Fundamental Gravity Network in Paraguay.*

On the other side, the work in Ecuador provided a basic gravity network of reference with 36 stations and several hundreds of densification stations (Rosero, 2005) (Fig. 7).

In Colombia, the order 0 network consists of six absolute gravity stations from the IfE Project, three of them on the territory of Venezuela. The order 1 network is formed of 40 relative gravity stations and linked to Panama, Venezuela, Brazil, Peru and Ecuador. The order 2 network coincides with the leveling network and consists of about 12,000 relative gravity stations (Fig. 8).

The national gravity network of Venezuela was measured in 1982 and is composed of 20 reference stations referred to IGSN71. There are many densification stations for prospecting purposes. About 200,000 registers from the oil company PDVSA were used to make a geoid model (Cuevas et al., 2003; Hoyer et al., 2002).

In Uruguay, the national gravity network was observed between 1967 and 1983 and was evaluated in a common adjustment of all relative and absolute measurements available. A total of 5,447 relative gravity measurements were introduced, with four absolute gravity stations serving as scale for the network (Fig. 9).

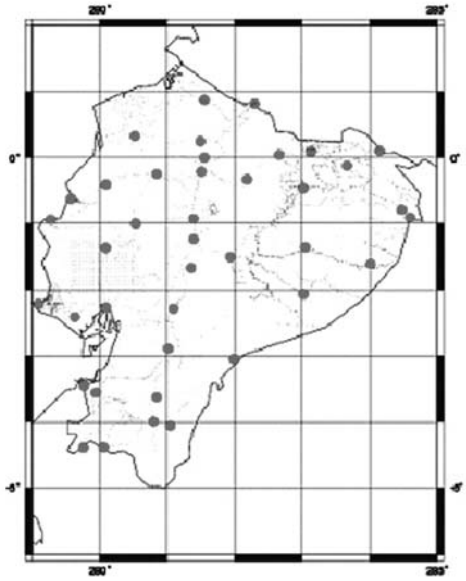

***Fig. 7: F**undamental Gravity Network in Ecuador.*

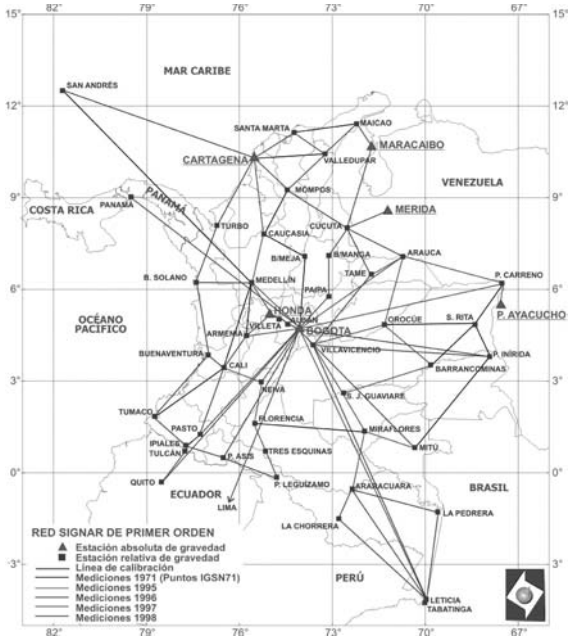

***Fig. 8: F**undamental Gravity Network in Colombia.*

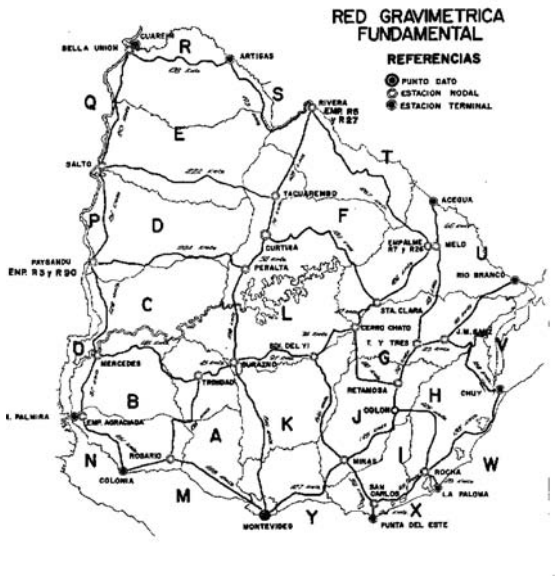

Fig. 9: *Fundamental Gravity Network in Uruguay.*

4 Conclusions and possibilities

Gravity in South America (GSAP) is a project of IAG Commission 2 and strongly linked to other international projects. Two IAG projects should be quoted among them: The SIRGAS project, and more specifically group 3 of the SIRGAS project, devoted to vertical reference frames in America, and the Geoid in South America Project (GSAP). Besides, the updated gravity data will play an important role in geophysical investigations.

The main objectives of GSAP are:

- To re-measure the existent absolute gravity stations and to encourage new measurements.
- To validate the fundamental gravity networks of different countries in order to establish a single and common gravity network for South America.
- To adjust national gravity networks and to link them.
- To contribute to the GSAP by obtaining and maintaining files with gravity data necessary for the geoid computation.
- To contribute to the SIRGAS project by supplying reliable gravity data to calculate geopotential numbers.
- To encourage and eventually support local organizations in different countries to increase the gravity data coverage, in particular, airborne surveys.
- To organize and/or encourage the organization of workshops, symposia or seminars on gravity in South America.

Successful work is possible only through the assistance of South American organizations and colleagues. It is important to point out the long history of real and strong cooperation among the groups, which is really useful everywhere, but vital in South America. Furthermore, most countries have their own national projects, which contribute to the international ones.

Under the umbrella of GSAP, the coordination of isolated efforts is taking place.

After these efforts, a new Absolute Gravity Network is expected for the continent with internal consistency in precision, reference system and method of measurement.

Acknowledgements. I want to express my gratitude and deepest appreciation to all countries, cooperating institutions and persons who are supporting the success of the project.

This presentation was partially supported by *Agencia Nacional de Promoción Científica y Técnica de Argentina* (ANPCyT – PICT 7-15163).

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