Recovery of the South American Gravity Network Efforts on Paraguay and Chile

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Abstract

The Polytechnic School of the University of São Paulo – EPUSP- and the Brazilian Institute of Geography and Statistics - IBGE - are developing efforts for more than one decade to improve the distribution of gravity data in Brazil. Recently, the iniciatives were extended to Paraguay and Chile that, through their Military Geographic Institutes, IGM and DISERGEMIL, respectivelly, concentrated efforts to also create a gravimetric infrastructure directed to the densification work. In this sense, several surveys were done aiming to re-establish the Reference Gravity Network in those countries, most of it already destroyed, and to contribute to the re-establishment of the South-American Gravity Network itself. This paper focus on the main details inherents to the methodology used. Those iniciatives have the support of the Universtity of Leeds, through GETECH, as well as NIMA.

Summary

La Escuela Politecnica de la Universidad de São Paulo – USP y el Instituto Brasileño de Geografía y Estatística – IBGE, están desarollando esfuerzos hace más de 10 años para promover la distribuición de datos de gravidad en el Brasil. Recentimente esas iniciativas fueron conducidas en Paraguay y Chile, a través de sus Institutos geográficos militares, DISERGEMIL y IGM, respectivamiente, concentrando esfuezos para criar una infraestructura de gravidad direccionada a los trabajos de densificación. En este contexto vários levantamientos fueron realizados para recuperar la Red de Referencia de Gravidad en eses paíces, cuja mayor parte está destruída y contribuir para el restabelecimiento de una Red de Referencía Suramericano. Este trabajo técnico muestra los principales detalles sobre la metodología usada. Las iniciativas fueron patrocinadas pela Universidad de Leeds através del GETECH y por el NIMA.

Introduction

For more than one decade, a technical scientific cooperation agreement between IBGE and EPUSP allows many efforts to be done. Among them, there are those related to a better knowledge of the South American geoidal surface, with emphasis on the gravimetric measurements in areas with lack of geodetic informations.

In 1991, gravity surveys were initiated in a systematic way in remote areas of Brazil. The activities mainly envisaged the acquisition and treatment of gravimetric data, making them consistent to generate a homogeneous geoidal model for Brazil and South America. However, as the work was being done, it was necessary to expand the areas, what meant to have informations of the neighbour countries.

Support and Procedures

The main aspects that motivate these surveys are related to the interests and purposes of IAG (International Association of Geodesy), SIRGAS (South American Geocentric Reference System), NIMA (National Imagery and Mapping Agency) and GETECH (Geophysical Exploration Technology of the University of Leeds). In the case of IAG, there was always a great interest in supporting the activities related to the improvement of the geoidal heights knowledge. For this, in 1987, the International Commission of the Geoid (ICG) was created and was revitalized in 2001 as the International Commission of Gravity and Geoid (IGGC). Through it, a Sub-Commission of the Geoid for South America, established in 1994, had also its interests extended to include gravity in 2001.

Meanwhile, the SIRGAS project created a working group aiming to broaden the horizontal referential studies to the vertical referential. In this way, the choice of a height system is essential and the computation of compatible geoidal heights (quasi-geoidal) is fundamental. NIMA and GETECH have been offering a great support to the viabilization of measurements and data processing.

To obtain a consistent geoidal model, a homogeneous distribution of gravity stations in the area of interest is very important. In the case of the South American continent, it was noticed the existence of many gravity gaps and also the necessity of making available, evaluate and consolidate the existent data in several countries. It was also clear the need of performing gravity surveys in some countries through joint missions envolving a team composed of technitians from Brazil and from the country to be surveyed. The presence of the Brazilian members was necessary, at

least in the initial stage, to allow that a homogeneous procedure was followed in the surveys. The gravity meters in use by IBGE, loaned by NIMA, took part in the joint campaigns.

In parallel with the surveys, a process of training happened to enable each country technicians to proceed the gravimetric densification by themselves and to guarantee the continuity of the project on the same pattern of quality and homogeneity.

All gravity profiles were measured in less than 48 hours, observing a rigid control of drift and anomalies. Special attention was given to the basic stations established, most of all with four gravity meters, double occupation and adopting the mean of a minimum of three values with a maximum standard deviation of 0,05 mGal.

Besides gravity measurements, the vertical component was determined in order to reduce the anomalies to the mean sea level. In a first moment, it was chosen to make use of the spirit levelling network of each country and obtain the horizontal coordinates through GPS. With the developing of the works to regions where no height control was availabele, the vertical coordinate was given by GPS reduced by EGM96 until the degree and order 72.

As the informations collected and organized will be used in future versions of the South American geoidal model. For this, are being used software that perform the integration of the Stokes formula through direct numerical methods and fast Fourier transform.

Field Surveys

Any field survey must be preceeded by a stage directed to the mission planning, where both the technical and operational aspects must be observed and the teams performance in the surveys must be highligthed.
The equipments used were basically the same in Chile and Paraguay:

Lacoste & Romberg gravity meters G model
GPS Trimble 4000 SSI – used on the base stations
GPS Trimble Geoexplorer II – for the densification stations
GPS Garmin II Plus – for navigation
Level – connection between bench marks and GPS stations
Maps, charts and geodetic stations descriptions

Each survey team was composed by representatives of the country surveyed and Brazilians. These technicians had to work through more than ten hours daily on a Toyota´s jeeps with a production of about ten stations by day. The gravity basic stations were spaced 100 km maximum apart and established on cities or small villages, always when possible. The choice of the locations considered their stability and lasting, usually a monument or an important building (church, school, governmental). In the other hand, the gravimetric densification had its stations spaced from five to eight km apart. All the measurement process for each station took around 30 minutes and the starting and closing stations belonged to the reference gravity network.

Activities in Paraguay

The first step was taken in 1999 aiming a joint work between Brazil and Paraguay through a visit of representatives from the University of São Paulo and IBGE to Assunción, where meetings were held in the Direccion del Servicio Geografico Militar, DISERGEMIL, counting with a representative from NIMA.

This contact made possible a preliminary knowledge of the Paraguayan gravimetric network and, consequently, enabled the elaboration of a detailed plan of the country main needs. It was verified lack of gravity stations in Paraguay to where the surveys could be referred. All the basic stations established in the past were destroyed, even the IGSN71 in Assunción. With this situation, it was necessary to initiate a conection to the Brazilian Gravimetric Network and also with one of its absolute gravity station. These ties were done by car demanding the measurement of many profiles during several days, in a total of 5,000 km.

The first field campaign in July 2000 was directed to the measurement of a Reference Gravity Network at the eastern and part of western regions. With this, were chosen and surveyed 35 basic stations in 17 days. The team was composed by two Brazilians and three Paraguayans technicians, involving two vehicles from DISERGEMIL.

In November of the same year, a second campaign for densification took 27 days. This time the work was done by 5 Paraguayans and 4 Brazilians technicians, organized in 4 teams, distributed in two vehicles from IBGE and two from DISERGEMIL. The Eastern region took priority with the measurement of 591 gravity stations.

A third stage took place in July 2001 and lasted 15 days. The work was done in Paraguayan Chaco with three Brazilians technicians and two local representatives, resulting in the determination of 10 basic and 86 densification stations. With the end of this stage, the Reference Gravity Network of the country was pratically completed.

The Paraguayan Chaco is a very atypical region. There is almost no infrastructure and no availability of water in most of its extension. Additional care had to be taken and other will have to be observed during the next steps. There is no doubt that the densification in this area will be the main challenge in Paraguay.

During the months of October and November 2001, in 22 days of work, the fourth campaign was concluded. A total of 645 gravity stations were measured in the southern center region by 5 Paraguayans and 4 Brazilians technicians, with 3 brazilians and one paraguayans vehicles.

A total of 81 days of work in the Paraguayan territory provided a basic gravity network of reference with 47 stations and 1321 densification stations. This result can be seen in the map presented in fig….

It is estimated that about 60 days would be yet necessary to complete the initial plans. It is also planned a conection with the Argentinean network aiming a future adjustment of all South American Gravity Network of Reference.

Activities in Chile

A meeting held at the IGM in Santiago in February 2001 determined the beginning of the works in Chile. At that moment, were estimated the existent surveys and the areas with gaps that needed gravity informations. Low temperatures, snow, rough routes in the Andes were the main challenges that had to be surpassed.

The first field survey happened in the middle of September of that year. Around 30 days of work envolving six Chileans and two Brazilians technicians and three Chileans trainees. Five Toyota Hilux vehicles, from IGM were used.

In this campaign 10 basic gravity stations were established between the latitudes 30ºS and 35ºS. The densification surveys that followed the work determined 553 gravity stations. Three gravity meters from IGM were used by three teams.

The data computation revealed some inconsistencies in the gravity meters used. It was concluded that there was some problem in the scale factor of the equipments. As a consequence, a calibration of the meters along the four absolute stations throughout Chile was necessary. This work was performed in July 2001 and lasted seven days. The team was composed by a Brazilian and two Chileans engineers. The course was done by commercial airplanes and rented vehicles. The results of calibration were significant as they allowed a good convergence on the computation of a reference network. However, one of the absolute stations, located in the southern part of Chile, in Punta Arenas, didn´t offered reading condition to the gravity meters, due to a great instability ocurred on those days. During all the work frequently was noticed some difficulty in keeping the stability of the readings due probably by tectonic instability.

Following a request from IGM, a calibration line was planned and measured with four stations and a height difference of approximately 3,000 m between the Andes and Pacific Ocean. Always when possible this line will be measured in order to assure that its stations have the appropriate consistency to the calibration of the gravity meters.

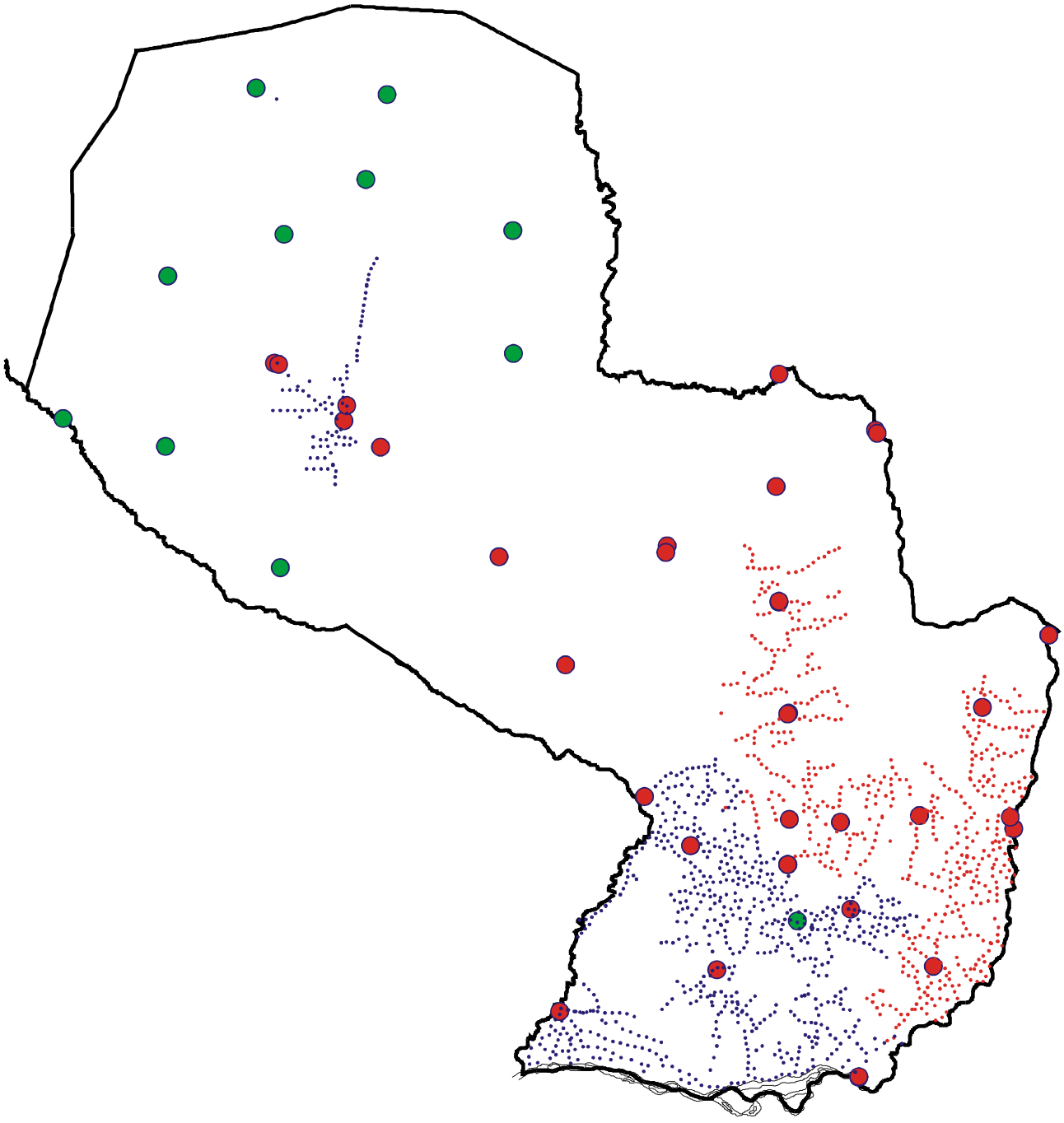
Solved the question of the gravity meters scale factors, the second field campaign, in September 2001, could be proceeded. This time, the area was located between the latitudes 33ºS and 43ºS with the prioritization of the establishment of a reference network with more than 20 stations. The team was formed by two Brazilians and three Chileans crossing more than 6,000 Km in 16 days of work with a IGM vehicle.

Concluding, 31 basic gravity stations of reference and more than 550 densification stations were determined in a total of 52 days of work.

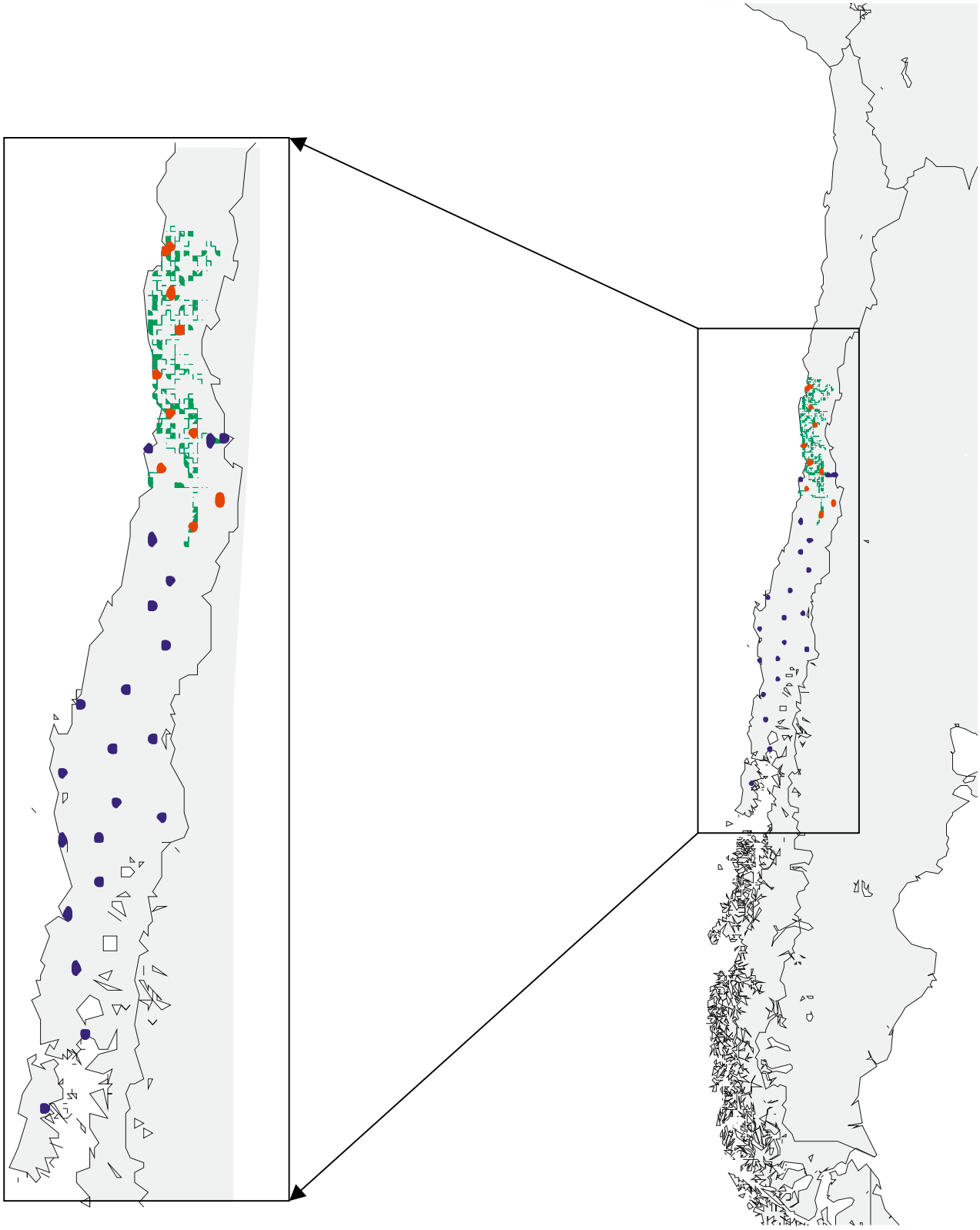
New joint campaigns are planned in Chile aiming to cover the remaining gaps. Meanwhile, efforts are being made in order to perform airborne gravity surveys in the Andean region.

Results

Results in Paraguay



Results in Chile



Conclusions

A more consistent South American geoidal model is expected as one of the results of those efforts in the continent. Other parallel aims are being reached as the establishment of consistent and homogeneous systematic procedures for gravity surveys there. The creation of conditions to make feasible, through geopotential numbers, the integration of the vertical networks of the countries involved in the surveys is also pursued. Finally, these initiatives are showing the great benefits that are obtained from joint efforts and coordinated work with a common objetive.

Acknowledgement

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