Chapter 94

Accessing the New SIRGAS2000 Reference Frame through a Modernized Brazilian Active Control Network

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Abstract. Since the beginning of its establishment, in December of 1996, the Brazilian Network for Continuous Monitoring of GPS - RBMC has been playing the role as the fundamental geodetic frame in the country, providing users with a direct connection to the Brazilian Geodetic System - SGB. This role has become more relevant with the adoption of the new geodetic system, SIRGAS2000, as of February 25, 2005. In this paper, the current RBMC status is presented, as well as the expansion and modernization plans for its structure, functionality and services to be provided to users. RBMC currently works in post-mission mode, where users are able to freely download from the Internet data collected by each of its 19 stations 24 hours after the observations are collected. The modernization plans specify, in a first step, the network expansion with six additional stations in the Amazon region, including the reactivation of Manaus station, and the connection of all stations to the Internet, to support real time transfer of 1 Hz data to the control center, in Rio de Janeiro. When available at the control center, the data will support WADGPS (Wide Area Differential GPS) corrections to be transmitted, in real time, to users in Brazil and surrounding areas. This new service is under development based on a cooperation signed at the end of 2004 with the University of New Brunswick, supported by the Canadian International Development Agency and the Brazilian Cooperation Agency. It is estimated that users will be able to achieve a horizontal accuracy around 0.5 m (1-σ) in static and kinematic positioning. The expected accuracy for dual frequency receiver users is even better. The availability of the WADGPS service – at no cost - will allow users to tie to the new SIRGAS2000 system in a more rapid and transparent way in positioning and navigation applications. It should be emphasized that support to post-mission static positioning will continue to be provided to users interested in higher accuracy levels.

Keywords. RBMC, real time, SIRGAS2000

1 Introduction

The Brazilian Network for Continuous Monitoring of GPS – RBMC (Fortes et al., 1998; IBGE, 2005a) is an active geodetic network which constitutes the main geodetic framework of the country, providing users with the possibility of precise linking to the Brazilian Geodetic System - SGB. This role is even more relevant at the current moment, when the new geodetic system SIRGAS2000 (Drewes et al., 2005) has been officially adopted in Brazil as of February 25, 2005 (IBGE, 2005b), considering that this new system is mainly realized in the country throughout the RBMC stations. In this paper, the current RBMC status is presented, as well as the expansion and modernization plans for its structure, functionality and services provided to users.

2 Current RBMC Status

The Brazilian Institute of Geography and Statistics - IBGE started to establish RBMC at the end of 1996, when the Curitiba/PR and Presidente Prudente/SP stations were installed with the support of the National Fund for the Environment – FNMA and of the Politechnic School of the University of São Paulo -EPUSP. Nowadays, the network is composed of 19 continuous operating GPS stations (Fig. 1), distributed across the national territory, being automatically monitored and remotely controlled by the control center localized in Rio de Janeiro. Among these 19 stations, the ones in Brasilia and Fortaleza are part of the International GNSS Service - IGS global network (IGS, 2005a), whereas the remaining ones compose the IGS

Fig. 1 RBMC stations in operation, in test, and being established

densification network in South America and surroundings, whose data is processed on a weekly basis by the IGS Regional Network Associate Analysis Center for the continent – IGS RNAAC SIR (Seemueller and Drewes, 2004). These characteristics include the Brazilian geodetic reference framework in the global structures in a consistent way, which guarantees its continuous monitoring and update.

Each RBMC station is equipped with a dual frequency GPS receiver and a chokering antenna. At the end of each 24 hour observing session, the collected data are automatically transferred to a local computer. Few minutes later, the computer server at the control center downloads data from the local computer to Rio de Janeiro, through a dial-up connection or using the Internet. After being transferred, data is checked and made freely available at the site http://www.ibge.gov.br/home/geociencias/geodesia/rbmc/rbmc.shtm in general within 24 hours after the observation date.

During its almost ten years of operation, the network has been largely used by the national and international communities, as demonstrated by many projects and published papers carried out based on the RBMC. Currently around 3500 daily observation files are downloaded each month (Fig. 2). This high demand is related to the increasing use of GPS for positioning applications in general. Among these applications, the following can be listed:

- Support to GPS relative positioning in general;
- Topographic and cadastral systematic mapping;

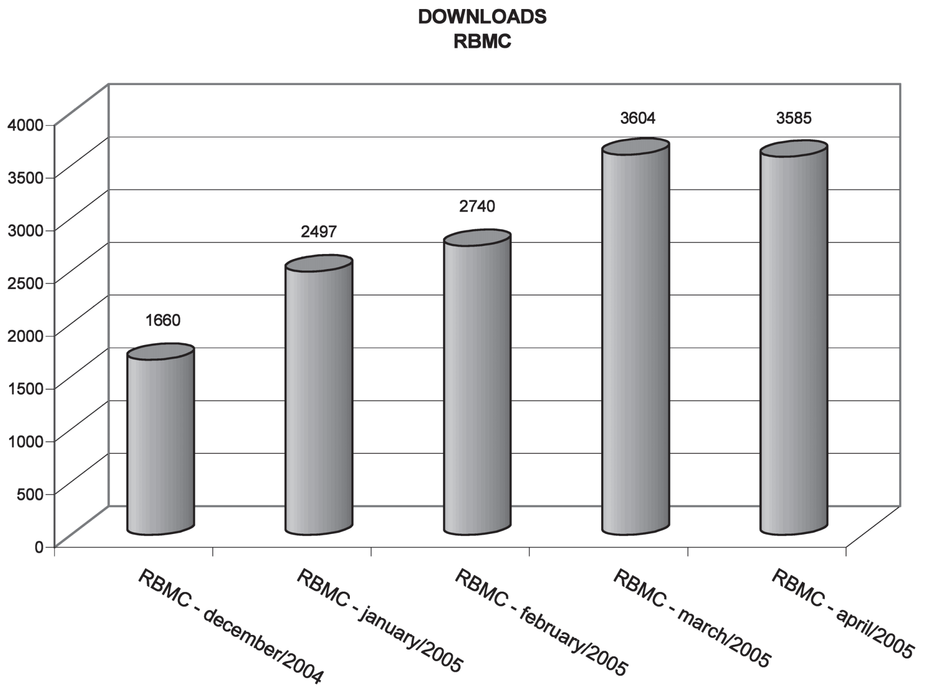

Fig. 2 Number of RBMC daily observation files downloaded from the Internet each month from December 2004 to April 2005

- Area delimitation (political-administrative, environmental, etc.);
- Land use (land reform, precise agriculture, etc.);
- Navigation (currently in post-mission mode);
- Ionosphere modeling;
- Support to climatology and meteorology;
- Fleet control and management;
- Integration into global geodetic networks;
- Regional and global Geodynamics.

3 RBMC Structure Expansion and Modernization Plans

As it can be seen in Fig. 1, the RBMC inter-station distances vary from over 200 km in the Southeast, to more than 1000 km, in the Amazon region, where due to regional characteristics the network is sparser. Increasing the density of network points becomes a necessity. In its current configuration, RBMC supports GPS positioning applications using long baselines, requiring longer observation sessions to generate adequate results, due to the spatial decorrelation of the positioning residual errors, especially those caused by the ionosphere. A denser RBMC will provide users with stations closer to their area of interest, allowing them to achieve their desired accuracy faster. Five stations are expected to be installed in the Amazon, including the reactivation of the Manaus station (Fig. 1). The installation of these stations, as well as of the Belém and Macapá stations, is result of cooperation with SIVAM project (System for the Vigilance of the Amazon), in order to improve the coverage of the network in the region.

It must be emphasized the understandings being established with the National Institute for Land Reform – INCRA, towards integrating their Network of Community GPS Base Stations – RIBaC to RBMC. RIBaC was established to support land surveys directly or indirectly carried out by INCRA. It is currently composed of 31 continuously operating GPS stations distributed in the Brazilian territory. RIBaC stations are equipped with single frequency receivers, which significantly restricts the coverage area of each station, especially in Brazil, where error gradients caused by the ionosphere on GPS signals can easily reach values around tens of parts per million, (Fortes, 2002). The RIBaC stations must also have their coordinates tied to SGB through RBMC. Based on the afore mentioned understandings, around 30 to 40 last generation dual frequency GPS receivers are expected to be purchased in order to replace the majority of receivers currently used in both RBMC and RIBaC. This receiver replacement has the following objectives:

- To equip RIBaC stations with dual frequency receivers;
- To equip RBMC and RIBaC stations with receivers with good GPS signals tracking performance, especially with respect to L2, as Brazil is located under the Equatorial Anomaly where occurrence of scintillations is very common (Fortes, 2002);
- To equip both networks with receivers capable of real time operation, at 1 Hz, directly connected to the Internet, without the need of a local computer, in order to support real time applications described in next section.

In order to achieve the above objectives, the new receivers have to satisfy the following specifications:

- At least 12 L1 and 12 L2 channels to track carrier phase and C/A (L1) e P (L1 e L2) codes;
- Low carrier phase and code noises (few decimeters for codes and ≤ 0.01 cycle for carrier phase);
- Chokering or equivalent antenna for multipath mitigation;
- Observation rates up to 1 Hz;
- L2-tracking technique with good performance under high ionospheric activities (e.g., semi-codeless or equivalent);
- IP network port for connecting the receiver to LAN/Internet with no local computer interface;
- Possibility of remote controlling the receiver and real time transferring of observations through the Internet;
- Possibility of storing observations on the receiver memory at the same time as transferring them through the Internet to the network Control Center;
- Enough memory to store 30 days of observations at 1 Hz;
- External oscillator port;
- Possibility of L2C signals tracking or upgradeability to that.

Fig. 3 presents the intended configuration for the resulting network, with the stations to be modernized being shown. The selection of these stations satisfied the following priorities:

- Availability of local connection to the Internet, with good stability and quality (i.e., broad band);
- Existence of long time dual frequency data series collected at the station;
- Existence of stable monuments.

4 Plans for Modernization of RBMC's Functionality and Services to Users

Until today, RBMC has provided support to applications that rely on post-processing data, mostly in relative mode. A modernization of RBMC's functionality is being proposed in order to increase the range of applications, most notably those which require real-time information. Those applications include navigation, either air, maritime or terrestrial. The new functionality planned for a modernized RBMC involves:

- Real-time transmission of the data collected by each station to the Control Center in Rio de Janeiro;
- Reduction of the current 15-second observation interval to 1 second.
- Real-time computation of WADGPS-type corrections at the Control Center.
- Real-time availability of the corrections to users, at no via the Internet or satellite link.

The WADGPS corrections are those for the satellite and clock orbits and for the delay provoked by signal propagation through the ionosphere and troposphere. Since the RBMC stations have highly accurate coordinates the data collected can be used to quantify the actual errors and to predict the corrections to be transmitted to users.

This new service is being developed in cooperation with the University of New Brunswick under the National Geospatial Framework Project (PIGN), a technology transfer project sponsored by the Canadian International Development Agency (CIDA) with the support of the Brazilian Cooperation Agency (ABC). The PIGN (PIGN, 2005) has a main object to

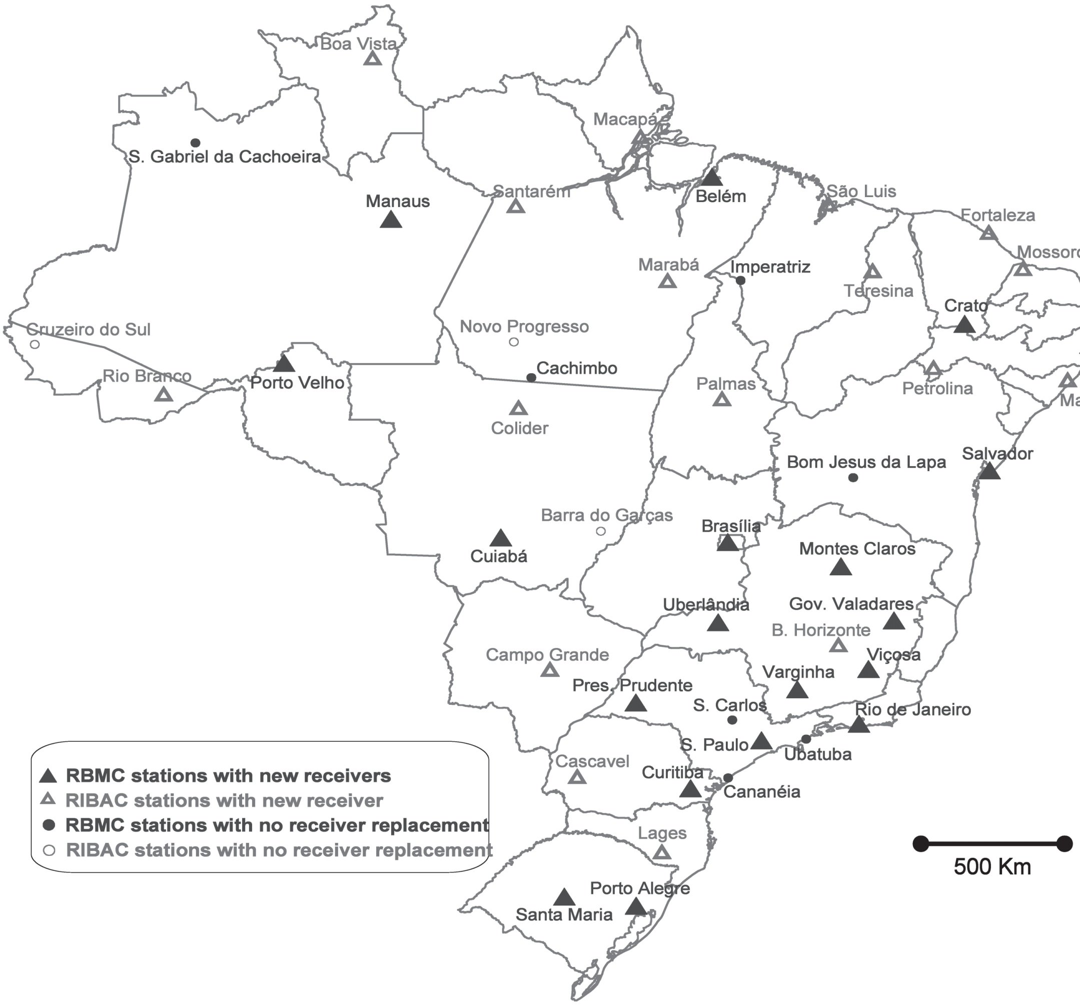

Fig. 3 Active geodetic network resulting from the integration of RBMC and RIBaC. The stations represented as triangles will have real time capability, whereas the remaining ones will continue to work in post-mission mode

collaborate and assist in Brazilian efforts towards the adoption of a geocentric coordinate system (SIRGAS2000) compatible with modern satellite positioning technology. Project activities include technical issues, study on the impacts resulting from the adoption of the new system and communication with user community. The modernization of the RBMC corresponds to PIGN Demonstration Project #7. This Demo Project aims at providing the background for the implementation of a modern reference structure that facilitates the connection to the Brazilian geodetic system by users. Since the corrections will be implicitly attached to SIRGAS2000, their application by the users will result in SIRGAS2000 coordinates. Users will be directly attached to SIRGAS2000 in their positioning and navigation applications. The participation of the Geodetic Survey Division of Natural Resources Canada is being discussed considering the expertise this institution holds from the development of the Canada-Wide DGPS Service – CDGPS (CDGPS, 2005a).

It is expected that users will be capable of performing (real-time) static and kinematic positioning at the 1 m 95% confidence level (0.5 m DRMS). For dual-frequency users, these figures drop to 0.3 m at 95% confidence level (less than 0.2 DRMS) (CDGPS, 2005b; Rho et al., 2005).

The real-time functionality of RBMC will allow an even closer collaboration with the IGS within the IGS Real Time Working Group (IGS, 2005b).

5 Conclusions

The development of global navigation satellite system (GNSS) positioning technology has set up new standards to national geodetic infrastructure via active networks such as RBMC. RBMC has been the fundamental geodetic infrastructure in Brazil since its inception in 1996, providing accurate connection to the Brazilian Geodetic System, in post-processing mode. In an attempt to follow the technological evolution, IBGE is proposing the expansion and modernization of the geodetic infrastructure, functionality and services provided to users. With these purposes in mind, the densification of the network in the Amazon region is being planned with the establishment of five new stations. In addition, an on-going understanding with INCRA may result in the purchase of 30 to 40 new generation dual-frequency GPS receivers, to be used in RBMC and also in the network maintained by INCRA in support of land reform activities. The resulting infrastructure will provide capabilities for real-time services, by means of computation of WADGPS-type corrections and consequent transmission of these corrections to users in Brazil, and possibly in neighboring regions. The modernization of the RBMC is being carried out under the National Geospatial Framework Project, supported by CIDA.

The application of the WADGPS corrections will allow users to be attached to SIRGAS2000 in a direct and clear way in positioning and navigation applications. It is believed that users will be capable of real-time static and kinematic positioning with a 2D accuracy of 0.5 m (DRMS) or better, depending on the type of receiver used. The current post-processing service will still be offered, allowing users to reach the highest accuracy possible.

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EPUSP - Escola Politécnica da Universidade de São Paulo
DSG - Diretoria do Serviço Geográfico do Exército, 4ª DL, Manaus
FNMA - Fundo Nacional do Meio Ambiente
IME - Instituto Militar de Engenharia
INPE - Instituto Nacional de Pesquisas Espaciai, Cuiabá e Euzébio
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UFPE - Universidade Federal de Pernambuco
UFPR - Universidade Federal do Paraná
UFRGS - Universidade Federal do Rio Grande do Sul
UFSM - Universidade Federal de Santa Maria
UFV - Universidade Federal de Viçosa
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URCA - Fundação Universidade Regional do Cariri

7 In Memoriam

This paper is dedicated to the memory of Eng. Kátia Duarte Pereira. Kátia was responsible for the operation of the RBMC since its establishment. Kátia passed away, prematurely, in April 2005.

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