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Abstract

The Brazilian Network for Continuous Monitoring of GNSS – RBMC is a national network of continuously operating reference GNSS stations. Since its establishment in December of 1996, it has been playing an essential role for the maintenance and user access of the fundamental geodetic frame in the country.

In order to provide better services for RBMC, the Brazilian Institute of Geography and Statistics – IBGE and the National Institute of Colonization and Land Reform – INCRA are both partners involved in the National Geospatial Framework Project – PIGN. This paper provides an overview of the recent modernization phases the RBMC network has undergone highlighting its future steps.

These steps involve the installation of new equipment, provide real time data from a group of “core” stations and compute real-time DGPS corrections, based on CDGPS (The real-time Canada-Wide DGPS Service) (The Real-Time Canada-Wide DGPS Service. <http://www.cdgps.com/> 2009a).

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In addition to this, a post-mission Precise Point Positioning (PPP) service has been established based on the current Geodetic Survey Division of NRCan (CSRS-PPP) service. This service is operational since April 2009 and is in large use in the country.

All activities mentioned before are 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. The Geodetic Survey Division of NRCan is also participating in this modernization effort under the same project.

This infrastructure of 66 GNSS stations, the real time, post processing services and the potentiality of providing Wide Area DGPS corrections in the future show that the RBMC system is comparable to those available in USA and Europe.

121.1 Introduction

In operation for more than 1 decade, the Brazilian Network for Continuous Monitoring of GNSS – RBMC (Fortes et al. 1998, 2006a), is an active geodetic network, constituting the main geodetic framework of the country. It provides Brazilian users with a precise link to the Brazilian Geodetic System – SGB, SIRGAS2000 (IBGE 2009b), fully compatible with GNSS technology. The purpose of RBMC is to provide data, without any cost, for several post-processing applications. In this respect, it is important to mention that RBMC represents a substantial economical, technological and scientific effort of several Brazilian federal, state and academic institutions (in close collaboration with some Canadian agencies) to build and maintain a modern geo-spatial infrastructure.

A law of 2001 requiring all rural properties to be referred to the Brazilian geodetic system intensified the use of RBMC reference data. In order to provide better services for RBMC, the Brazilian Institute of Geography and Statistics – IBGE, and the National Institute of Colonization and Land Reform – INCRA, became partners involved in the National Geospatial Framework Project – PIGN (PIGN 2009).

This paper provides an overview of the recent modernization phases of the RBMC network and the future steps. The first step was the acquisition of new equipment and network expansion providing a better national coverage and new characteristics of operation. The RBMC increased from 24 stations by the end of 2006 to 66 stations at the beginning of 2009. The modern GNSS receivers allow for remote control and real time transfer of observations over the Internet. Data is available on two websites, INCRA (2009)

providing hourly and IBGE (2009a) providing daily files with different sampling rates.

In 2008, a Networked Transport of RTCM via Internet Protocol (NTRIP) caster was put in operation, providing real-time data of 26 stations. This new service called RBMC-IP is open for all users since May 2009, through a login and password. A challenge for the future is to compute Wide Area Differential GPS (WADGPS)-corrections to be transmitted, in real time, to users in Brazil and surrounding areas. For this purpose some receivers are working already with an external frequency standard. It is estimated that users will be able to achieve a horizontal accuracy between 0.5 and 1 m (1σ) in static and kinematic positioning and better for dual frequency users. The availability of the WADGPS service will allow users to tie to the new SIRGAS2000 system for positioning and navigation applications in a more rapid and transparent way. It should be emphasized that support to post-mission static positioning will continue to be provided to users interested in higher accuracy levels.

In addition to the RBMC services, a post-mission Precise Point Positioning (PPP) (IBGE 2009c) is in operation since April 2009. The IBGE-PPP service is based on the Geodetic Survey Division of NRCan (CSRS-PPP) service (CSRS-PPP 2009b). Millimeter precision is achieved after 6 h of data for double frequency receivers, and sub-meter precision is achieved for single frequency receivers after 2 h of data.

121.2 Network Expansion

After 3 years working on the expansion plan of RBMC \RIBac, the number of stations increased from 24 to 66 in 2009. The goal is provide a larger national coverage

with additional capabilities, for example, real time data and an adequate infrastructure for collecting data from GPS and GLONASS, foreseeing the possibility of collecting GALILEO data in the future.

Each RBMC station is equipped with a double frequency GPS receiver. At the end of each 24 h observing session, the collected data is automatically transferred to a server at the control center in Rio de Janeiro, through the Internet connection (cable or satellite). After transferred, data is checked and made freely available at the site <ftp://geofp.ibge.gov.br/RBMC/> within 24 h after the observation date.

After all these years of operation, the network has been largely used by the national and international community, as it is demonstrated by many projects

and published papers, as in Fortes et al. (2006a, 2007). An important national project example is related to land formalization and regularization, under the responsibility of INCRA.

The cooperation between IBGE and INCRA continues with the installation of more 30 stations that will be concentrated in the central and northern part of country. By the end of this year, 10 additional stations will be installed, extending the present network configuration from 66 to 76 stations. The data collected at new stations are released after a period of evaluation, when the official SIRGAS2000 coordinates are computed and data delivered is analysed. Figure 121.1 shows the distribution of the station's network and Table 121.1 shows the current (August 2009) receivers being used.

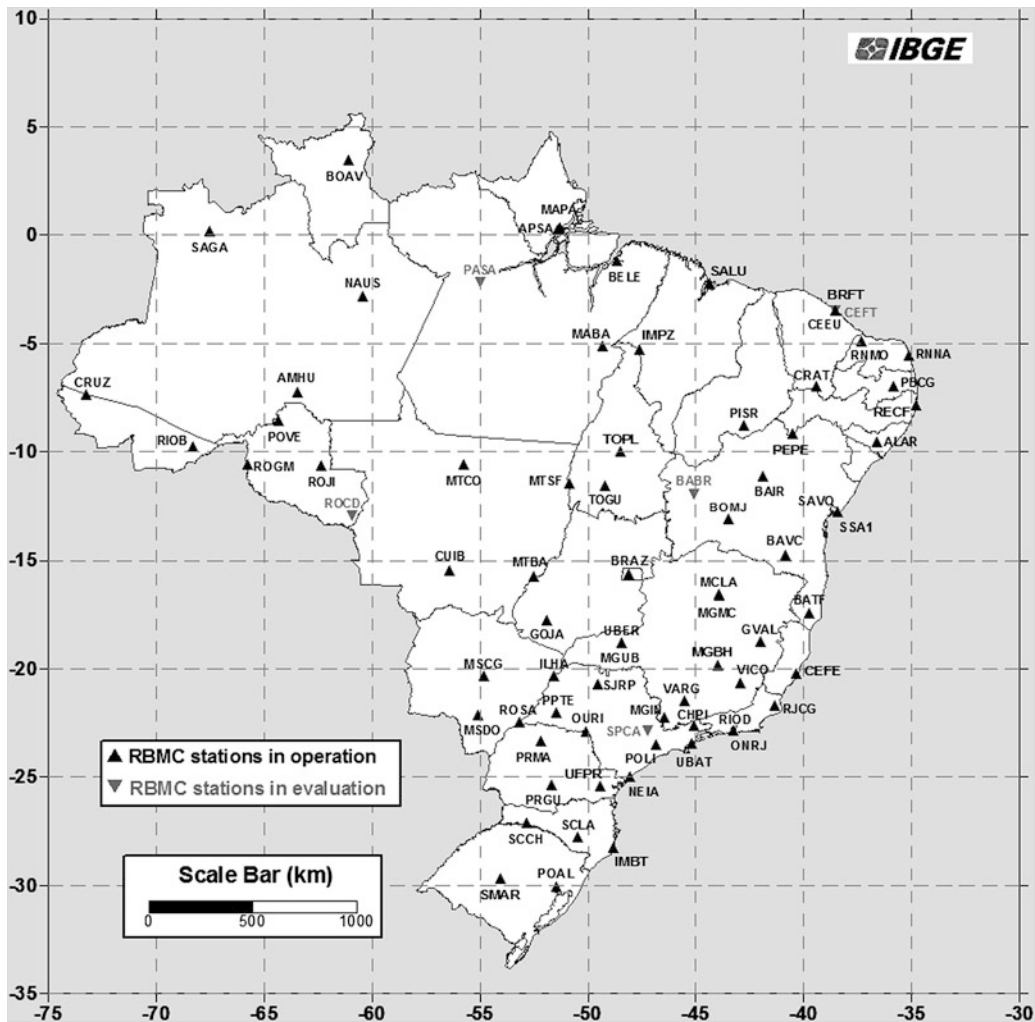


Fig. 121.1 RBMC status in August 2009

Table 121.1 Type and number of receivers in operation

Receiver type	No. of receivers	
	Mar/07	Aug/09
NetRS	2	15
NetR5	0	40
Trimble 4000SSi	17	3
Leica GSX1200	1	2
Ashtech ZFX	4	4
Ashtech UZ-12	0	1
Total no. of receivers	24	66

RBMC corresponds to the Brazilian contribution to many international initiatives, such as SIRGAS (2009), IGS (2009a), Real-Time IGS IGS (2009b), NTRIP and others related to world climate monitoring.

The network maintenance and operation improved in the last 4 years with only 6% of outages per month and consequently the number of users increased more than 50% per month due to service credibility.

121.3 Real Time Differential GPS Corrections Service

In May of 2009 the IBGE NTRIP caster was officially opened to Brazilian users, with 26 mount points (stations) installed in the main cities of the country where wireless internet is available. For a better control of the network traffic we are limiting the number of registered users to access stream data from three mount points in a maximum period of 3 months. For the Universities or Research Institutions all mount points are available without restrictions. This new service is called RBMC-IP and more information can be found at: <http://www.ibge.gov.br/home/geociencias/geodesia/rbmc/ntrip/>.

At present, Brazil contributed with five new IGS stations (POVE, SALU, SAVO, RECF and UFPR) and eight RTIGS stations (POVE, SALU, SAVO, RECF, UFPR, CEEU, BRAZ and ONRJ) with GNSS receivers belonging to a subset of RBMC-IP network. Other nine stations (POVE, SALU, SAVO, RECF, UFPR, ONRJ, NAUS, CEEU and BRAZ) contribute to the IGS-IP network providing data in real time as well.

In a second step the real-time Wide Area Corrections service of the RBMC, corresponding to PIGN Demonstration Project #7, is under development together with the Geodetic Survey Division of NRCan

which is transferring its experience from the CDGPS – Canadian Differential GPS service. The availability of the WADGPS service will allow users to tie to the new SIRGAS2000 system in a more rapid and transparent way.

Besides the group of real-time stations, the *Master Active Control System* (MACS), is the “heart” of the system. The hardware at the MACS are composed of:

- Two HP-UX servers (running RTAP – Real Time Application)
- Two Linux servers (storing and data management)
- Time server with GPS receiver providing GPS time to the HP-UX servers

The following parts of the system’s implementation are already concluded:

1. Connect a subset of receivers to the atomic clock. At least two stations can satisfy this requirement, CEEU (located in Fortaleza) is connected to a Hydrogen Maser and ONRJ (located in Rio de Janeiro) is connected to a Caesium clock that belongs to the Brazilian Time Service at the National Observatory
2. Operate a group of stations streaming data on real-time
3. Installation of Linux and HP-UX servers responsible for the data management and computation of corrections
4. Installation and configuration of software for data format conversion, scan and management, and the computation of corrections

The real-time GPS data is transmitted using UDP/IP over Internet to the Linux server, which then re-broadcasts this data using multicast UDP/IP over the internal IBGE network. The multicast data is received by the two HP-UX servers and processed to produce GPS corrections.

The following steps will be completed until the end of this year:

1. The installation and configuration of a NTP time server, to slave the MACS server’s (CPU responsible for the DGPS corrections computation to the GPS time).
2. Near real time orbit computations.
3. Evaluation of ION grid corrections generated with Brazilian data.
4. The transmission of corrections to the users, through internet.

The resulting configuration for this system is shown in Fig. 121.2.

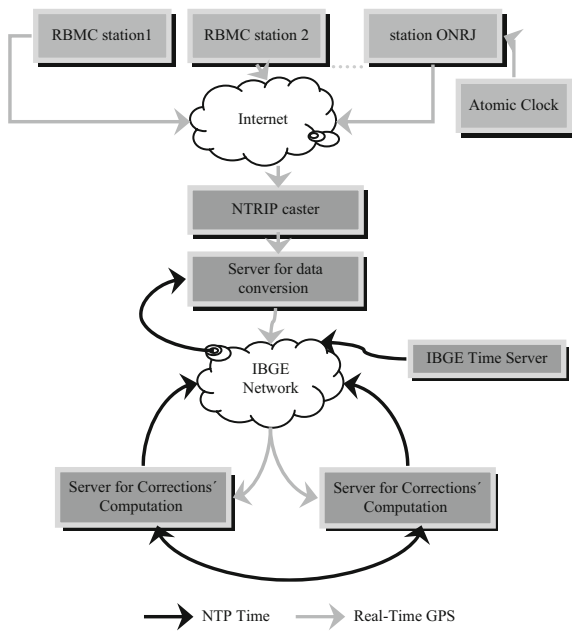


Fig. 121.2 Configuration of real-time wide area corrections of the RBMC

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) (Rho et al. 2003).

121.4 IBGE-PPP Service

The IBGE Precise Point Positioning (IBGE-PPP) is an on-line service for GPS data-processing. It allows the GPS users to get coordinates of good precision in the Geocentric Reference System for the Americas (SIRGAS2000) and the International Terrestrial Reference Frame (ITRF).

In GPS positioning, the term Precise Point Positioning usually refers to the computation of a single station using carrier phase observation, obtained from dual-frequency receivers, together with IGS products.

The IBGE-PPP service processes data collected in either static or kinematic modes, from single or dual frequency receivers. Only data collected after February 25, 2005, are accepted, this being the time of official adoption of the SIRGAS2000 frame in Brazil.

The following information is required by the service:

1. GPS data in RINEX or Hatanaka format, preferably compressed using Winzip, Gzip or Tar-Gzip.
2. Antenna type used to collect the data, following the IGS identification scheme, and the value of the antenna height in meters referred to the antenna reference plane (ARP).

Besides the user supplied RINEX files, the IBGE-PPP service uses other information for the processing, such as: orbit and clock (satellite) information from IGS (final and rapid), IGS antenna phase centre corrections for satellite and receiver antennas, transformation parameters between ITRF and SIRGAS2000 frames, FES04 ocean loading model parameters, velocity model VEMOS and the geoidal undulation model – MAPGEO2004.

The results are informed through a compressed archive containing five files, as following: readme, summary report, coordinate series for kinematic mode, Google Earth file (kml), and the complete report. This positioning service makes use of CSRS-PPP developed by the Geodetic Survey Division of Natural Resources of Canada (NRCan) and can be accessed through the following webpage: <http://www.ibge.gov.br/home/geociencias/geodesia/ppp/>.

121.5 Accuracy of IBGE-PPP

After 2 h of data from double frequency receivers, the horizontal coordinates have an accuracy better than 4 cm and height better than 6 cm. After 6 h of data the accuracy stabilizes on 2 and 4 cm level, respectively. These results confirm the good quality of service. Figure 121.3 shows the positioning accuracy using a double frequency receiver in the static mode during 24 h of data.

After 2 h of data from single frequency receivers, the horizontal coordinates have an accuracy better than 30 cm and height better than 70 cm. After 6 h of data the accuracy stabilizes on the 15 and 40 cm level, respectively. Figure 121.4 shows the positioning accuracy using a single frequency receiver in the static mode during 24 h of data.

121.6 Final Considerations

The new structure, after full implementation, will have as main characteristics:

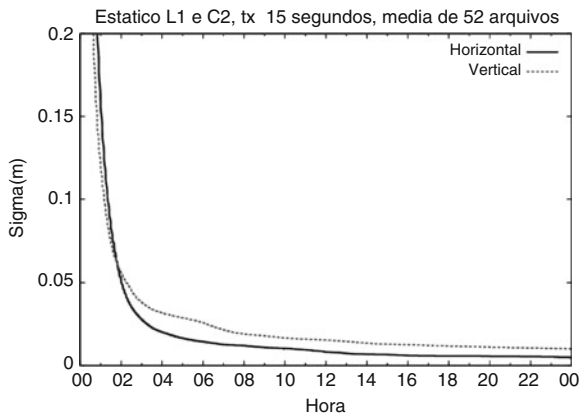


Fig. 121.3 Accuracy in static mode with double frequency receivers

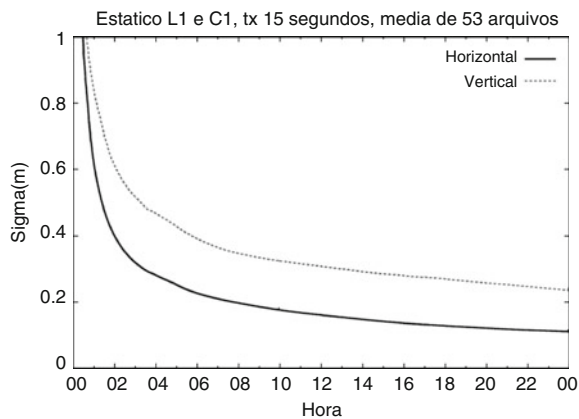


Fig. 121.4 Accuracy in static mode with single frequency receivers

- Provide 1-Hz real time data to IBGE NTRIP caster, located in Rio de Janeiro
- Generate real-time WADGPS corrections (orbit, clocks and ionosphere)
- Make corrections available to users in Brazil (and surrounding areas) through Internet
- Offer a Precise Point Positioning (PPP) service (IBGE-PPP) to users
- Collaborate with international GNSS networks such as IGS and RTIGS

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