Modernizing the Brazilian Active Control Network

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BIOGRAPHY

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ABSTRACT

The Brazilian Network for Continuous Monitoring of GPS – RBMC, since its foundation in December of 1996, has been playing an essential role for the maintenance and user access of the fundamental geodetic frame in the country,. It provides users with a direct link to the Brazilian Geodetic System - SGB. Its role has become more relevant with the increasing use of space navigation technology in the country. Recently, Brazil adopted a new geodetic system, SIRGAS2000, in February 2005, fully compatible with GNSS technology. The paper provides an overview of the recent modernization phases the RBMC network has undergone highlighting its future steps. From its current post-mission mode, the RBMC will evolve into a real-time network, providing real-time data and real-time correction to users. The network enhanced with modern GPS receivers and the addition of atomic clocks will be used to compute WADGPS-type corrections to be transmitted, in real time, to users in Brazil and surrounding areas. It is estimated that users will be able to

achieve a horizontal accuracy around 0.5 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 in a more rapid and transparent way for 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. In addition to this, a post-mission Precise Point Positioning (PPP) service will be provided based on the one currently provided by the Geodetic Survey Division of NRCan (CSRS-PPP). The modernization of the RBMC 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. The Geodetic Survey Division of NRCan is also participating in this modernization effort under the same project.

INTRODUCTION

The Brazilian Network for Continuous Monitoring of GPS – RBMC (Fortes et al., 1998; IBGE, 2005a) plays the role of the Brazilian active geodetic network. It is the core geodetic framework of the country. It allows users to be precisely connected to the Brazilian Geodetic System – SGB. Observations are collected by a network of 24 stations (a 25th station is currently in test). These observations are daily files that are made available to users, via IBGE's web site, within one day, and after their quality has been tested. This availability depends on the type of connection between the stations and the central storage facility, located in Rio. Most stations communicate with the central facility via the internet or by phone, allowing automatic data transfer. One station communicates via e-mail, a manual, sub-optimal scheme. The stations that composed today's RBMC have been implemented in a stepwise manner since December of 1996. Several institutions and organizations have been collaborating with IBGE either providing the location to have the equipment installed or by providing both receiver and installation. For that reason, not all stations are occupied by the same type of receiver. Figure 1 shows the spatial distribution of RBMC stations around the country. Table 1 indicates the type of communication and receiver used in each station. All stations use dual-frequency receivers and choke-ring antennas.

Two RBMC stations, the ones in Brasilia and Fortaleza, are part of the International GNSS Service - IGS global network (IGS, 2005a). The remaining ones compose the IGS densification network in South America. These data are processed on a weekly basis by the IGS Regional Network Associate Analysis Center for the continent – IGS RNAAC SIR (Seemueller and Drewes, 2004). A few geodetic organizations in South America, among them IBGE, will take over the responsibility of being a regional analysis centre. This fact ascertains the Brazilian geodetic reference framework to be part of the global frame in a consistent and permanent way, allowing its continuous monitoring and update.

RBMC observations are made available to both national and international communities via IBGE's web site, at http://www.ibge.gov.br/home/geociencias/geodesia/rbmc/rbmc.shtm.

The Brazilian data has contributed to several studies, papers and reports. Currently, about 3500 daily observation files are downloaded each month (see Figure 2). This high demand is related to the increasing use of GPS for positioning applications in general, as well as in support of global and regional geodynamics.

Table 1 – Receiver and communication types (TL stands for Trimble, Lei for Leica and Ash for Ashtech)

Station	Receiver	Communication
SMAR	TL4000 SSi	Internet
POAL	TL4000 SSi	Internet
PARA	TL4000 SSi	Internet
NEIA	TL4000 SSi	Internet
UBAT	TL4000 SSi	Internet
RIOD	TL4000 SSi	Internet
VARG	Ash Z-FX	Internet
VICO	TL4000 SSi	Internet
UBER	Ash Z-FX	Internet
GVAL	Ash Z-FX	Internet
MCLA	Ash Z-FX	Internet
BRAZ	TL4000 SSi	Internet
CUIB	TL4000 SSi	Internet
BOMJ	TL4000 SSi	Dial-up
SALV	TL4000 SSi	Dial-up
RECF	TL4000 SSi	Internet
CRAT	TL4000 SSi	Internet
BRFT	Lei GSX1200	Internet
IMPZ	TL4000 SSi	e-mail
BELE	TL4000 SSi	Internet
MAPA	TL4000 SSi	Internet
NAUS	TL NetRS	Internet
POVE	TL4000 SSi	Internet
PPTE	TL NetRS	Internet
POLI	Lei GSX1200	Internet

Figure 3 shows the results of data quality performed with TEQC. It shows the multipath level at both L1 and L2 pseudoranges (mp1 and mp2).

In February 2005 Brazil adopted a new geodetic geocentric reference frame, SIRGAS2000 (IBGE, 2005b). SIRGAS2000 is a densification of the ITRF2000, realized by means of a two-week long GPS campaign covering the whole of the Americas. SIRGAS2000 is realized in Brazil by most of the current RBMC stations**.**

In September 2004, an international collaboration was established 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). PIGN (PIGN, 2005) project activities include technical issues, study on the impacts resulting from the adoption of the new geodetic reference 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. Specifically Demo Project 7 will initiate the implementation of real-time and post-mission correction services in Brazil. Both services will provide corrections to facilitate user connection to SIRGAS 2000 for positioning and navigation applications. Since the corrections will be implicitly attached to SIRGAS2000, their application by the users will result in SIRGAS2000 coordinates. Users will then be directly attached to SIRGAS2000 in their positioning and navigation applications. The Geodetic Survey Division of Natural Resources Canada will contribute expertise in the development and operation of a Wide DGPS Service (CDGPS, 2005a).

RBMC MODERNIZATION

In its current stage, the inter-station distances between RBMC stations vary from over 200 km in the Southeast, to more than 1,000 km, in the Amazon region. This disparity is mostly due to economics and demographics, with more stations where there is more economical activity and population density. But with land regularization growing in importance, there is the desire to enhance network coverage. Also, we have to remember that ionosphere being so active over Brazil; the final quality of satellite positioning can only increase with additional stations. Five stations have been installed in the Amazon in the past year, including the reactivation of Manaus station (NAUS). The installation of these stations, as well as the ones in Belém (BELE) and Macapá (MACA), is the result of cooperation with SIVAM, the System for the Vigilance of the Amazon. But additional stations are still desirable.

Besides the RBMC, another active network operates in Brazil. This network, known as RIBaC, is maintained by the National Institute for Land Reform – INCRA. It is a L1-based network aimed at providing support to land reform activities. It is composed of 31 continuously operating GPS stations distributed in the Brazilian territory. Being equipped with single frequency receivers 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 at the level of tens parts per million (Fortes, 2002). IBGE has signed an agreement with INCRA towards integrating both networks. Under this agreement, as many as 65 state-of-the-art dual frequency GPS receivers are expected to be purchased to replace the majority of receivers currently used in both RBMC and RIBaC.

With this receiver replacement RIBaC stations will have dual frequency receivers, as well as RBMC will have its "old" Trimble 4000SSi replaced by modern receivers. Both networks will be equipped with receivers with good GPS signal tracking performance, especially with respect to L2, as Brazil is located under the Equatorial Anomaly where occurrence of scintillations is very common (Camargo et al, 2000; Fortes, 2002). Finally, both networks will be equipped 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, as described in next section. The objective of direct connection from the receiver to the internet is to avoid the use of a computer at the ACP sites, since we have noticed that most problems encountered at the stations are caused by the computer, not by the receiver.

The new receivers will have to satisfy a number of specifications, such as having at least 12 L1 and 12 L2 channels to track carrier phase and C/A (L1) e P (L2) codes, having low carrier phase and code noises, having IP network port for direct connection to LAN/Internet, being remotely controlled and provide real time data transfer through the Internet, being capable of storing observations on the its memory simultaneously to the data transfer through the Internet to the network Control Center, being slaved to an external atomic standard and being upgradeable to L2C and L5 signals.

Figure 4 presents the anticipated configuration for the network, with the stations to be modernized being shown as triangles. The chosen stations satisfy three major criteria:

- 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.

RBMC-BASED SERVICES

The ultimate goal is to have a real-time network, capable of not only making the observations available, but also generating products. In this way, there will be an increase in the assortment of applications that can be supported by the network, most notably those which require real-time information. Those applications also include navigation, either air, maritime or terrestrial. For this purposes the operation of RBMC will support:

- the use of remote and automatic stations, the active control points (ACP);
- an increase in the observation sampling rate from the current 15 seconds to 1 second;
- atomic clocks collocated with some of the ACPs to provide a time frequency of sufficient stability and accuracy to serve as time reference for the RT clock corrections;
- the real time data transfer from ACPs to the master control center (MACS), located in Rio de Janeiro;
- the real-time computation of WADGPS-type corrections, including real-time orbits, at the MACS;
- the real-time access to the WADGPS corrections by users in Brazil, and surrounding areas, either via the Internet or satellite link;
- the collaboration with international organizations such as the IGS Real Time Working Group.

The real-time service intends to provide accuracies of 1 meter (95%) horizontal to single-frequency users and 0.3 meter (95%) to dual-frequency users (CDGPS, 2005b; Rho et al., 2005). ACP data will also remain available for higher accuracy post-processing applications.

The scheme shown in Figure 5 illustrates the modernized RBMC data flow. GPS data will be remotely collected by the ACPs and automatically transmitted to the central processing facility (or Master Active Control Station (MACS)) via the Internet. Routers will be deployed in such a way that there will be redundancy in the data flow, i.e., data from ACPs will flow through more then one router, avoiding interruption of data in the event of a router failure. As soon as the data flow is received by the MACS, it will be used for the computation of the corrections, stored and distributed to those interested in real-time data. The corrections will be transmitted to users either by the Internet or via a communication satellite

Figure 6 shows schematically the minimum infrastructure needed for the real-time MACS at IBGE headquarters to host a RT correction service. While the main software required to implement the wide area, real-time correction service will be provided by GSD, IBGE will need to modify its current infrastructure in order to ensure reliable delivery of real-time data and the processing capacity required to generate the corrections. Two workstations will handle the real-time processing while two Linux servers will host the UDP-Relay, Data Translator, Data Archiver and RT service monitoring. A Time Server, synchronized to GPS time, will provide the time signal for the IBGE RT LAN and external atomic frequency standards located at several ACP's will provide the stable and accurate time reference needed for the RT clock corrections. Routers, at both the MACS and ACPs, have the duty of providing internet firewall security for the ACP GPS receivers.

In addition to the real-time service, a post-mission Precise Point Positioning (PPP) service will also be mad offered to users. A precise point positioning service provides an efficient means of positioning in a well defined reference frame such as the ITRF or SIRGAS. The PPP approach is based on the use of precise GPS orbit and clock corrections and data from a single GPS receiver (Tétreault et al., 2005).

The PPP service developed at NRCan that will be provided to IBGE consists of two parts. A processing engine and a web interface module. The GPS processing engine will require the addition of an ITRF to SIRGAS transformation module to be operational in Brazil. The web interface, which consists in a suite of cgi perl scripts specific to NRCan web environment, will be adapted to IBGE and the Brazilian environment.

PILOT TEST

A pilot phase will be carried out in 2007/2008 in order to test the functionality of the RBMC. Figure 7 shows the stations that been selected for the pilot phase on the basis of having the best and most reliable Internet connections. In the pilot project, the real-time corrections will be transmitted to users using a combination of radio and Internet (NTRIP), using a modified RTCA message.

The prototype RT service based on the 6 ACP network depicted in Figure 7 and a MACS as configured in Figure 6 and located at an IBGE Rio facility will be sufficient to train IBGE personnel in all aspects of the service operation. It will also provide the necessary correction stream needed for targeted demonstration projects in partnership with Brazilian stakeholders. The prototype RT correction service should only require, besides possibly more ACP's and a more robust correction distribution mechanism, the addition of back-up power, redundant equipment and continuous monitoring in order to become a high-availability, production service for Brazil. The 6-station network prototype will likely not provide the required geometric coverage needed for ionospheric corrections of sufficient quality to ensure 1m 2D rms single-frequency positioning. It should, however, support sub-metre (~30cm) 2D rms double-frequency positioning as long as the open Internet can provide the RT data on time for the computation of corrections.

The following criteria will be considered for the selection of demonstration projects and partners:

- Demonstrate all the features and capability of the services (note that the performance in Brazil may differ especially for single frequency data processing which requires the use of ionospheric models or corrections).
- Continued use of the service beyond the demonstration phase.
- Address issues of concern to the overall project such as land reform, environmental management and natural resources development.

Possible performance issues with a 6 ACP prototype network have been identified and must be addressed:

- Data distribution via the open internet may not always deliver sufficient 1Hz data on time for GPS•C computations.
- Ionospheric corrections needed for single frequency positioning may be of poor quality.
- No level of corrections availability can be guaranteed during the demonstration phase due to lack of redundancy and back-up power of prototype service.

CONCLUDING REMARKS

The growing use of space technology in Brazil has led to the enhancement plans for the current geodetic infra-structure of the country. These plans include a modern active network delivering not only data files for post-mission positioning but also WADGPS-type corrections to be made available to users all around the country, 24/7. The RBMC network 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. Modernizations steps include new receivers; adding value with the land reform network RIBaC to use some of their stations as part of the fundamental active network; fully automatic ACPs, being some of them collocated with atomic frequency standards; the generation of correction at the MACS; transmission of corrections through various media to users. These developments are taking place under a collaborative effort with the University of New Brunswick and with the Geodetic Survey Division of Natural Resources Canada under the National Geospatial Framework Project, supported by CIDA. The Land Reform institute (INCRA) will contribute a total of 65 new geodetic receivers.

The application of 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. For higher post-processed accuracies, a new post-mission PPP service, in addition to the current ACP data files, will also be available.

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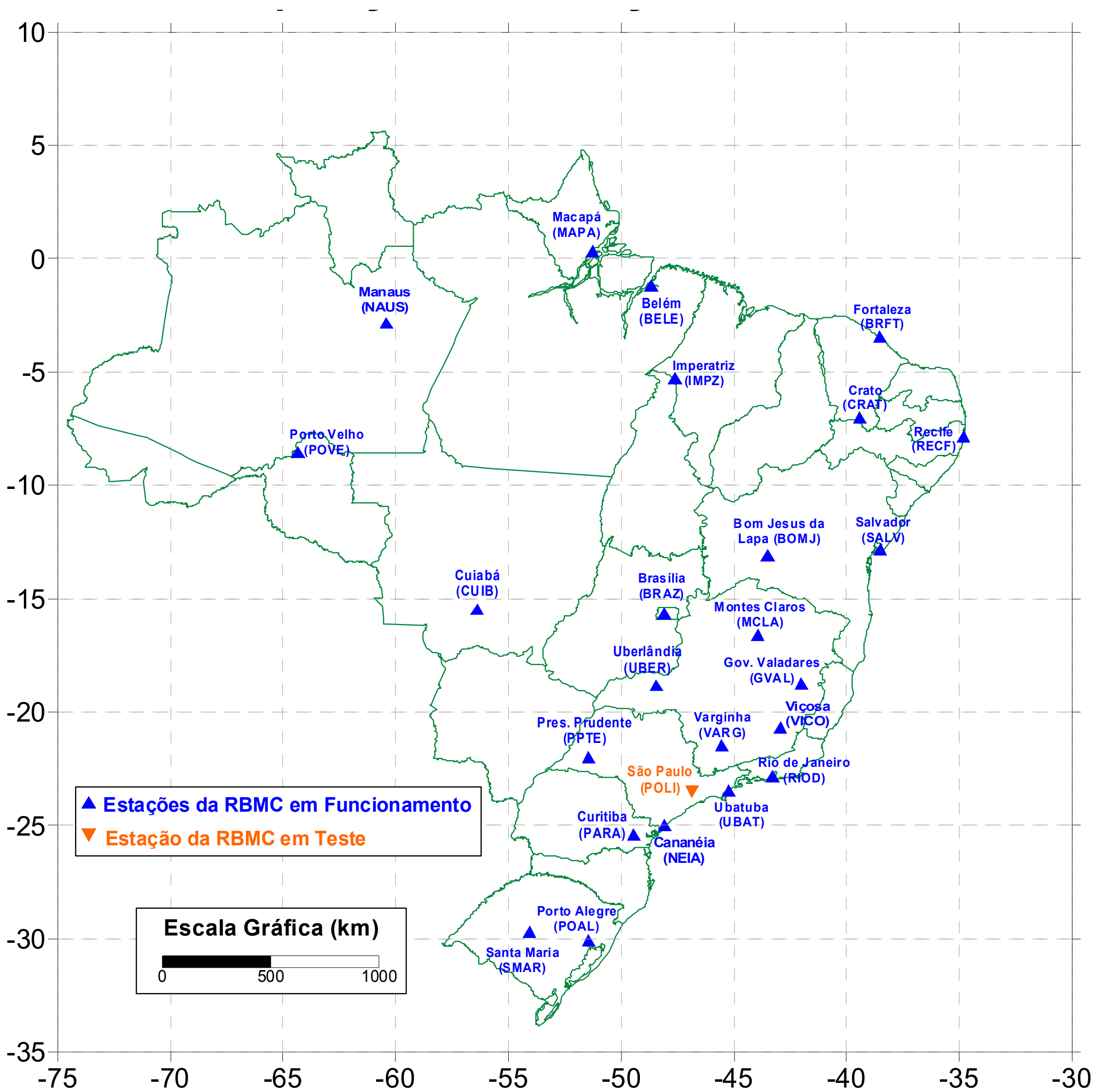

Figure 1 - RBMC stations in operation, in test, and being established

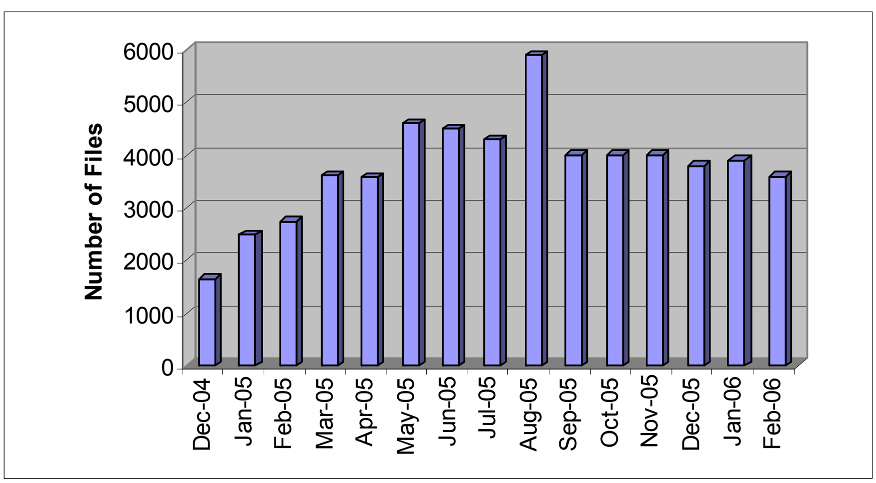

Figure 2 - Number of monthly RBMC observation files downloaded from December 2004 to February 2006

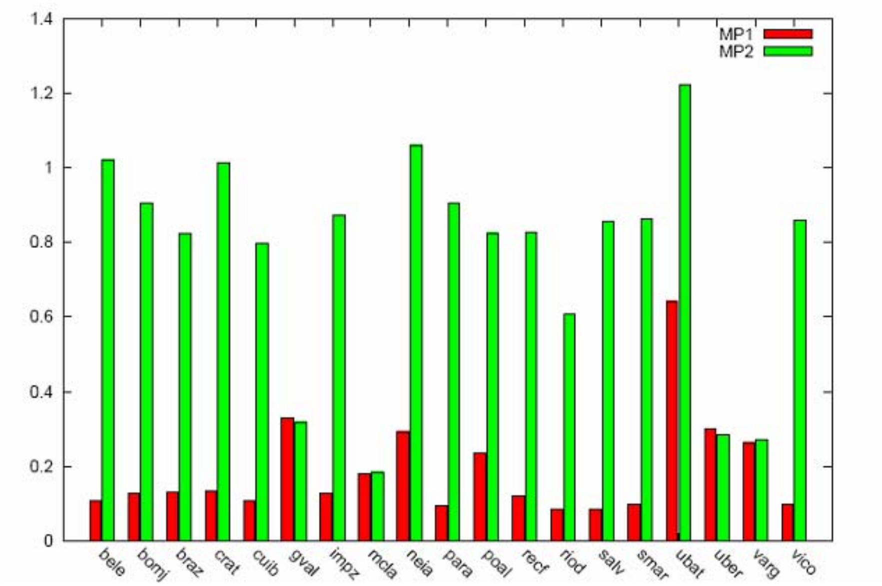

Figure 3 – Mean RMS L1 and L2 pseudoranges multipath values as given by TEQC (values in metres)

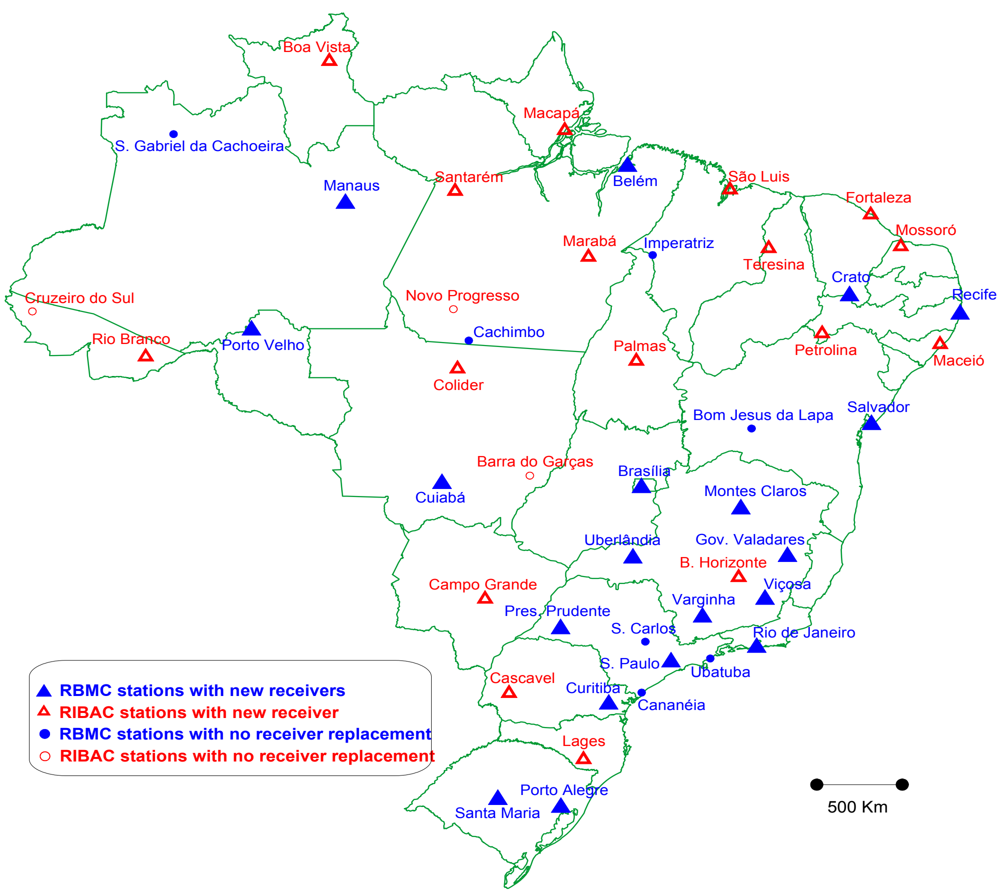

Figure 4- Active geodetic network resulting from the integration of RBMC and RIBaC. Stations represented as triangles will have real time capability, whereas the remaining ones will continue to work in post-mission mode

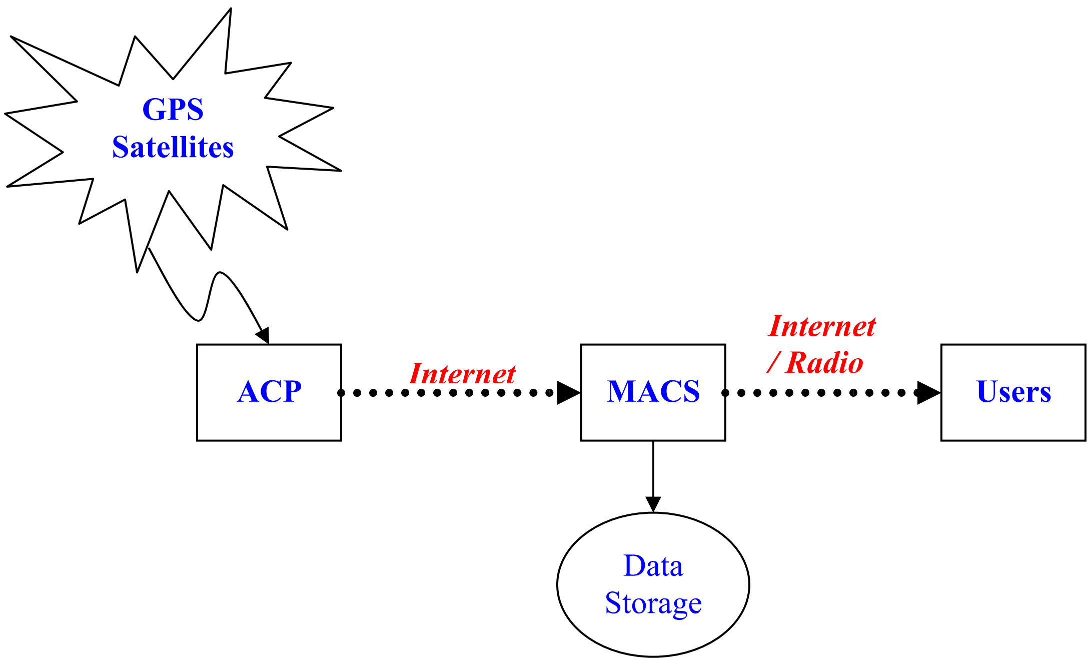

Figure 5 – Modernized RBMC data flow

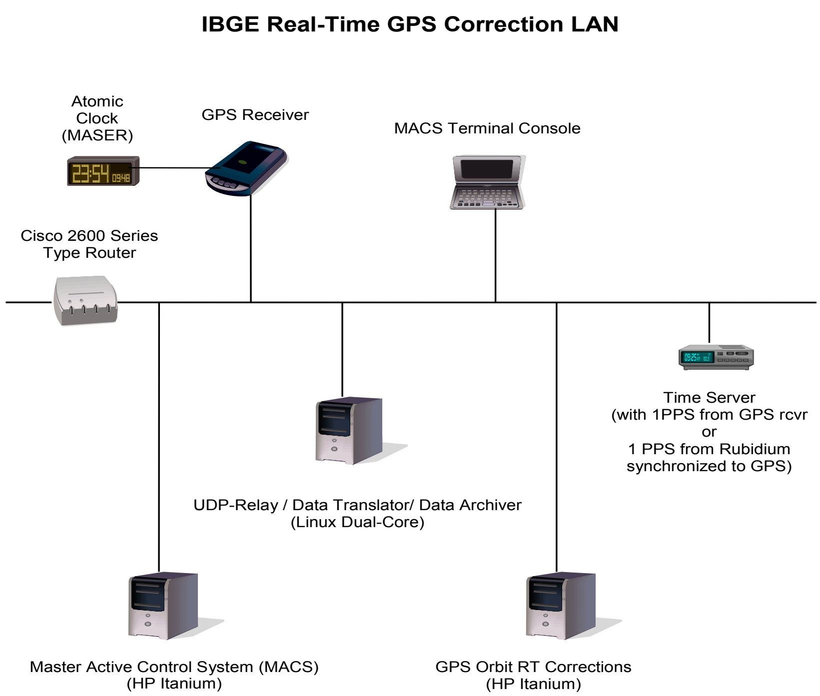

Figure 6 – MACS configuration for IBGE RT correction service

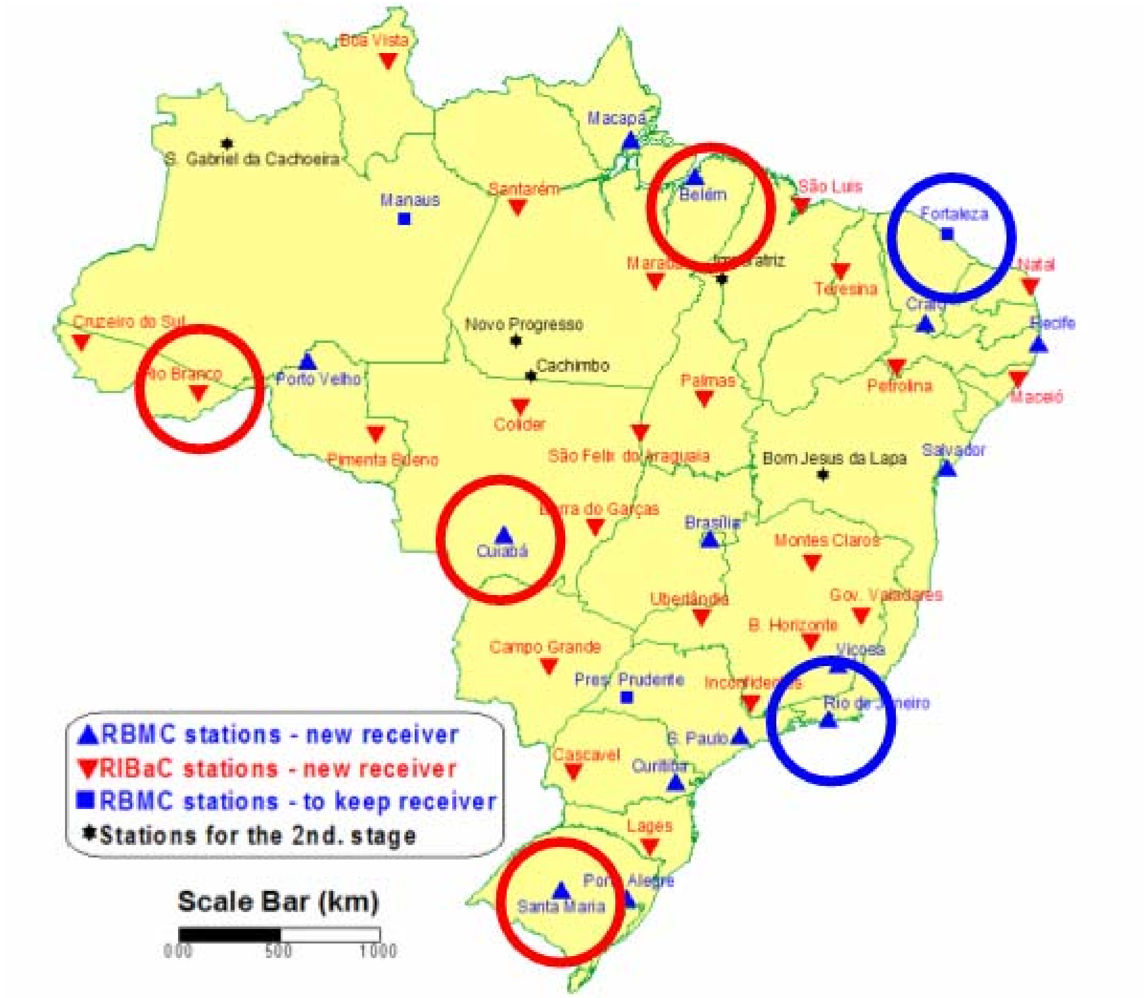

Figure 7 – Pilot project network configuration (circled stations). Circles in blue indicate where atomic clocks will be collocated.