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Multi-GNSS through Global Collaboration

GNSS-NavAer NETWORK FOR SUPPORTING IONOSPHERIC STUDIES IN BRAZIL

Abstract

The main aim of the project is related with the effects of ionospheric irregularities, specially scintillation (IS) for air navigation at the Brazilian region. Considering that the use of GNSS for aerial navigation constitutes a worldwide tendency in present days and, in the future, it will be the main technology adopted for determination of airplanes positioning in all flight phases. The application of this kind of technology has numerous benefits such as considerably reduced need of ground equipment installation, optimization of aerial space with routes, and reduction in flight duration and its consequent fuel saving, to mention a few. It can be highlighted GBAS, which uses GNSS systems, transmitting the corrections to improve the accuracy in determining the aircrafts position aiming at guiding it for a precise landing. However, GNSS signals, as well as those ones of any other satellite positioning system, suffer strong influences from ionospheric layer, with introduction of errors that might affect accuracy, integrity, availability and continuity requirements postulated by ICAO. The ionospheric layer presents distinct behaviors according to location (mainly with latitude variation), hour of the day, period of the year and solar activity cycle. The ionosphere over the Brazilian territory, especially on the region of Equatorial Ionization Anomaly (EIA), presents singular features in comparison with other parts of the planet, due to concentration of anomalies occurring there, making satellite positioning systems performance worse when compared to regions such as United States and Europe, for instance. Thus, the application of technologies based on GNSS in aviation over Brazilian territory demands a deep evaluation of ionospheric effects. For example, in the United State, the GBAS system expects ionospheric gradient of the order of 425 mm/km, for the worst case. In Brazil it can be very worse. Therefore, a better understanding of all factors affecting the ionosphere in Brazil have to be reached. For doing that, we are expanding the up to now deployed network for monitoring the ionosphere, such as CIGALA/CALIBRA/GNSS-SP network, together with improvements in the ISMR Query Tool developed for supporting search in the huge data base. An integration with other LISN network is under development. Therefore, a more deeply understanding of the ionosphere will be feasible of being realized. Several studies have already been carried out in Brazil. For instance, it was computed a great number of ionospheric gradients for all available GNSS stations in Brazil since 2000. A tool was developed for prediction of ionospheric amplitude scintillation, via the S4 parameters available in the data base, using neural network. It was also developed a new algorithm to mitigate the IS effects in the PPP, among others. Short details of the project and part of the results are presented below.

GNSS-NavAer Aims and Characteristics

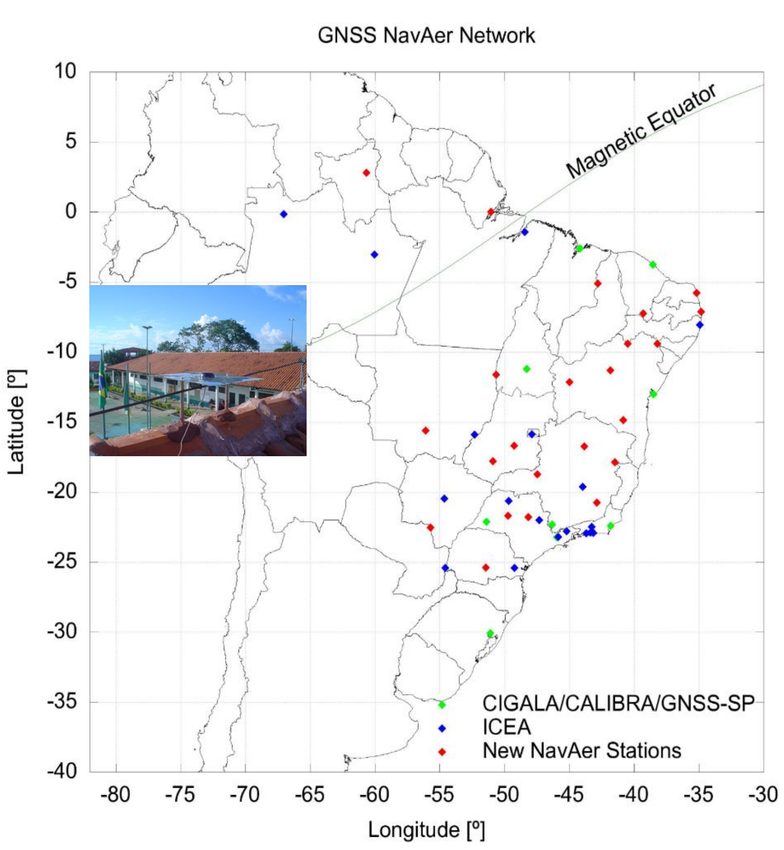
General Objective:

The INCT (acronym in Portuguese for National Institute of Science and Technology) GNSS-NavAer mission is to graduate human resources to develop researchers and to transfer knowledge to the society, in the area of atmosphere monitoring, especially with the aspects related to the TEC and IS in the GNSS signal, aiming to apply them in the air navigation with reliability and safety, in the Brazilian territory.

Specific Objectives:

- To expand the GNSS infrastructure for ionospheric monitoring in Brazil;
- To research the ionospheric dynamics over the Brazilian territory, mainly the TEC and scintillation effects which are typical from the low latitudes;
- To investigate about Ionospheric threat model suitable for GBAS operation in the Brazilian airspace;
- To develop or improve GNSS positioning technics for air navigation using the new GNSS signals; and
- To improve GNSS receivers performances under ionospheric scintillation in the equatorial ionization anomaly region.

GNSS-NavAer Network Distribution and Station Tefé at Amazon



- The stations distribution will guarantee a significant sampling of data representing the real conditions of the ionosphere and scintillation occurrence in Brazil;
- This figure shows the existing (CIGALA/CALIBRA/GNSS-SP and ICEA) stations and the planned ones;
- Most of the receivers are PolaRx5S from Septentrio;
- It provides several parameters for ionospheric studies, like S4, SigmaPhi, TEC and others.

Acknowledgment and Team

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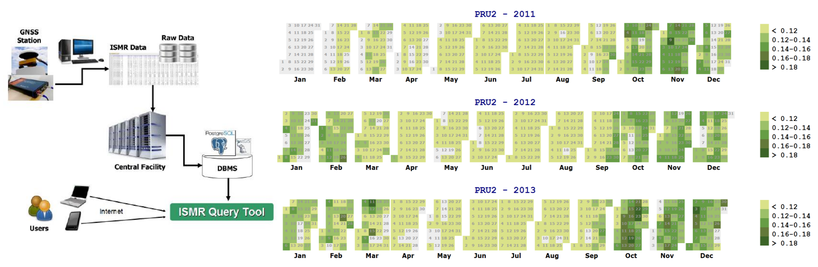
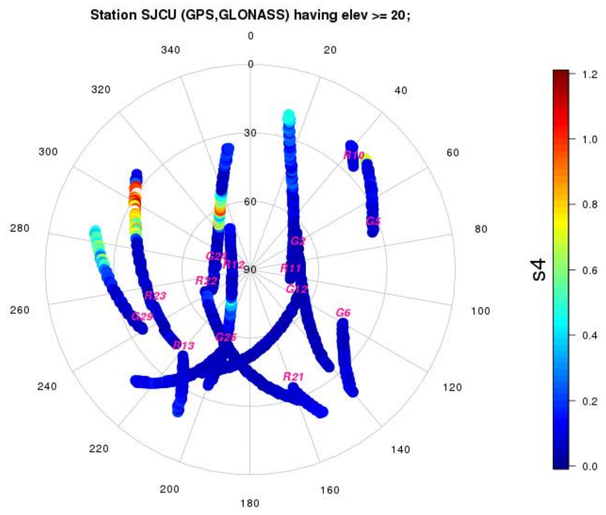
Data Provision via ISMR Query Tool

- Historical scintillation monitoring data (since 2011) was made available to the community via the ISMR Query Tool online software, available at http://is-cigala-calibra.fct.unesp.br;
- Datasets from each station are integrated and organized for retrieval process optimization. The aim is to promote teaching, research, dissemination and awareness on topics in the project context;
- Researchers from different parts of the world can preview and have access to the data (as well as analysis resources available in the ISMR Query Tool) after free registration;
- More than 35,000 queries to the database were performed in the last five years;
- Users can use ISMR Query Tool data visualization and data mining capabilities to interact with data;
- Different visualization tools are available, such as standard xy plots, calendar views, skyplots and IPP maps;
- Researchers can also download monitoring data (ISMR format) to work locally.



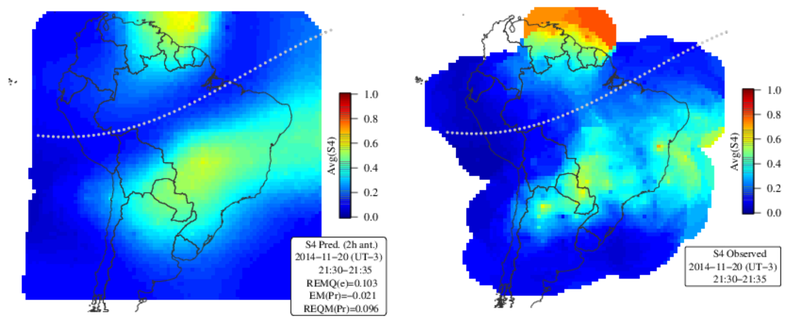
Example of skyplot of SJCU station during scintillation (nightime of 2014-10-03, 20:00-23:00 LT)



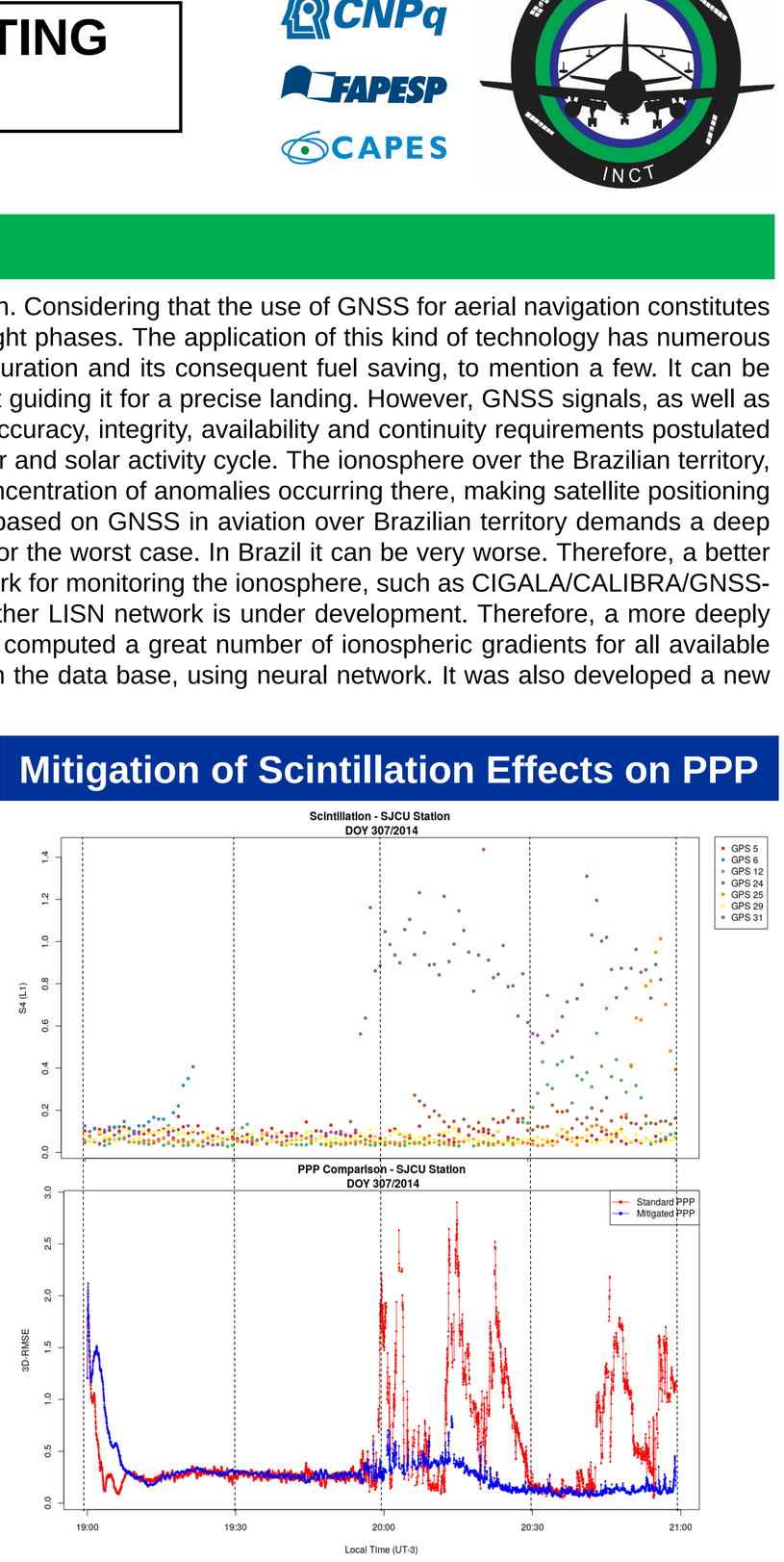
IS Statistics From the NavAer Network

- Integrated databases (CIGALA, CALIBRA, LISN, ICEA and NavAer) networks monitoring data (60s sample) result in more than 2,000,000,000 (two trillion) of samples;

- Research is being conducted aiming to provide observed and predicted scintillation maps. A model base on Artificial Neural Network (ANN) is under operationalization tests;



Mitigation of Scintillation Effects on PPP



- During strong scintillation, the performance of high precise positioning methods, such as PPP and RTK, can be harshly deteriorated (if not properly modeled);
- The effects on the signal tracking and in the GNSS observables, such as losses of lock, cycle slips and range degradation, lead to decreases in the positioning accuracy;
- Research on mitigation field aims to model the scintillation effects and recover the accuracy of the given GNSS positioning method to its expected level;
- Recent research on mitigation applied to PPP reached improvements up to 80% in the positioning accuracy during strong scintillation in relation to the standard PPP.

Ionospheric Parameters for GBAS Threat Models

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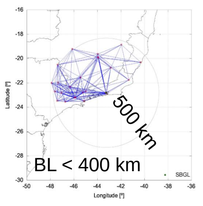
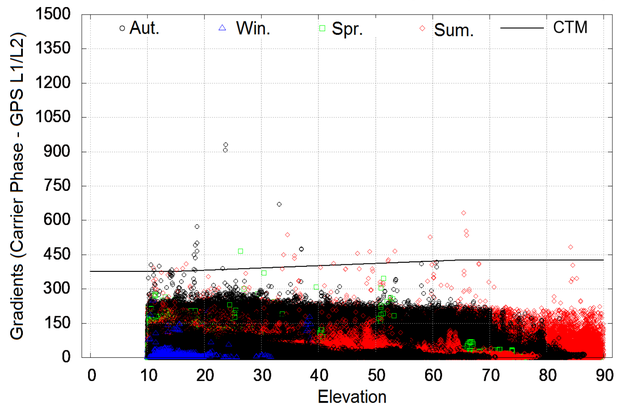


Rio de Janeiro International Airport (SBGL/GIG)



- 307 days between the years 2000 and 2006;
- Data: GPS (L1/L2 and L1/L5), GLONASS (L1/L2) and Galileo (L1/L5); and
- Gradients from carrier phase and smoothed pseudorange to find the time windows feasible of using GBAS.

Time and Elevation Window Exceptions (L1/L2), Carrier Phase

Brazilian International Airports	Seasons			
	Autumn	Winter	Spring	Summer
Sao Paulo (SBGR/GRU)	22h-05h UT	-	22h-05h UT	22h-05h UT
Rio de Janeiro (SBGL/GIG)	elev 10°- 37°	-	23h-24h UT	21h-24h UT
Brasilia (SBBR/BSB)	22h-04h UT	-	22h-02h UT	22h-03h UT
Porto Alegre (SBPA/POA)	-	-	-	-
Recife (SBRF/REC)	-	-	-	21h-24h UT

- From these results and others, the Brazilian authorities decided not to certify the GBAS deployed at Rio de Janeiro International Airport. New strategies will have to take place.

Authors:

João F. Galera Monico (1), Milton H. Shimabukuro (2), Paulo O. Camargo (1), Bruno C. Vani (3), and Vinícius A. Stuani Pereira (4)
(1) Sao Paulo State University (UNESP) – Department of Cartography, Presidente Prudente, SP, Brazil. {galera.monico; paulo.camargo}@unesp.br
(2) Sao Paulo State University (UNESP) – Department of Mathematics and Computer Science, Presidente Prudente, SP, Brazil. milton.h.shimabukuro@unesp.br
(3) Federal Institute of Education, Science and Technology of Sao Paulo (IFSP) – Presidente Epitacio, SP, Brazil. brunovani22@gmail.com
(4) Sao Paulo State University (UNESP) – Graduate Program in Cartographic Sciences, Presidente Prudente, SP, Brazil. vi_stuani@hotmail.com